IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF DELAWARE

SENKO ADVANCED COMPONENTS, INC., Plaintiff, vs. **US CONEC, LTD.**, Defendant.	)	C.A. No. 23-83-JPM

AMENDED AND SUPPLEMENTAL COMPLAINT

Plaintiff Senko Advanced Components, Inc. ("Senko" or "Plaintiff") makes this Amended and Supplemental Complaint, including a demand for a jury trial, against Defendant US Conec, Ltd. ("US Conec" or "Defendant") and alleges as follows:

NATURE OF THE ACTION

1. This action seeks past and ongoing money damages and permanent injunctive relief for the Defendant's acts of making, using, selling, offering for sale, and/or importing its accused MDC and MMC fiber optic connector and adapter products that infringe Senko's rights in twelve issued U.S. patents.

THE PARTIES

2. Plaintiff Senko is incorporated under the laws of the State of Massachusetts, and its principal place of business is located at 2 Cabot Road, Suite 103, Hudson, Massachusetts 01749.

3. Upon information and belief, Defendant US Conec, Ltd. is a corporation organized and existing under the laws of the State of Delaware, and its principal place of business is located at 1138 25th St SE, Hickory, North Carolina 28602.

JURISDICTION AND VENUE

4. This action arises under the United States patent laws, 35 U.S.C. § 101, *et seq.*, including 35 U.S.C. § 271, *et seq*. This Court has subject matter jurisdiction under 28 U.S.C. § 1331 and § 1338(a).

5. This Court has personal jurisdiction over US Conec because, upon information and belief, US Conec is incorporated under the laws of the State of Delaware and therefore resides in Delaware. On information and belief, Defendant also regularly conducts business in this judicial district related to the products at issue in this action. On information and belief, Defendant uses, offers for sale and/or sells its products at issue in this action within this District or otherwise places such products within the stream of commerce with the expectation that they would be used in this District.

6. Venue is proper in this judicial district pursuant to 28 U.S.C. § 1400(b) because US Conec is, upon information and belief, incorporated under the laws of the State of Delaware and is legally deemed to reside in Delaware.

INTRODUCTION

7. The parties are competitors in the markets for various types of passive fiber optic connection components. Traditional customers for the parties' competing products are vendors who provide fiber optic equipment and solutions to data centers, communication network providers, and other owners of fiber optic networks. Fiber optic communications require a high degree of accuracy at each connection point for robust, consistent, and high-speed transmission of data.

8. As demand for bandwidth has increased, networks increasingly use fiber optic systems instead of traditional copper-electrical systems because of fiber's capacity for higher speed and reduced maintenance. For example, networks rely on fiber optic components to connect the switches and servers that underlie high-speed computer and communication systems. In some fiber optic facilities, for example data centers, millions of connection components of the type sold by the parties are used to connect the optical fibers.

9. Fiber optic cables hold one or more fibers that run between two points in a data center or communication network. It is challenging to directly connect (*e.g.*, fuse) one optical fiber to another, so cables are terminated with standard connectors that are configured to plug into corresponding adapters to make optical connections.

10. Most optical connectors in use today retain the ends of fibers in high-precision ferrules. The ferrules, in turn, are mounted in a housing or plug frame that attaches to the cable. Optical connector housings include precise alignment and retention features that correspond to complementary features of the adapter. Since optical fibers are often less than the diameter of a human hair, these alignment and retention features have very strict tolerances to ensure the fibers line up in the adapter. For ease of use, fiber optic connectors can be equipped with extraction mechanisms that enable them to be disconnected from the adapter after initial mating.

11. Two types of ferrules are common: cylindrical single-fiber ferrules and rectangular multi-fiber ferrules. The industry frequently calls multi-fiber ferrules "MT" ferrules. Various fiber optic connectors have been developed around both types of ferrules.

12. For many years, fiber optic networks have employed "small form factor" ("SFF") single-fiber ferrule connectors and adapters. In the United States, the most common type of SFF single-fiber ferrule connector is an LC Connector, which comprises a 1.25 mm-diameter ferrule

in a square connector housing with an integrated upper latch hook for securing the connector to a mating adapter. Two individual LC connectors are frequently assembled together in a side-by-side configuration to make an LC duplex connector.

13. The most common multi-fiber ferrule connector in the United States is called an MPO connector. In an MPO connector, there is a single MT ferrule that carries a plurality of optical fibers. This MPO connector has a rectangular housing and a spring-loaded sleeve and latching mechanism.

14. Conventional LC and MPO connector and adapter components have met the industry's needs for many years. But within a fiber optic network installment, space can be at a premium. Optoelectronic transceivers have also advanced, creating a need for smaller fiber optic connection components that can accommodate more fiber connections in the same transceiver footprint.

15. To meet the industry's desire for density, Senko has spent years developing a new generation of connectors and adapters with smaller footprints than the conventional components described above. These efforts have yielded three all-new connection systems, which the industry now calls "VSFF," *i.e.*, very small form factor. Senko offers two "duplex" VSFF connector platforms that utilize two 1.25-mm single-fiber ferrules in each plug and one "multi-fiber" VSFF connector platform that utilizes an MT ferrule in a plug.

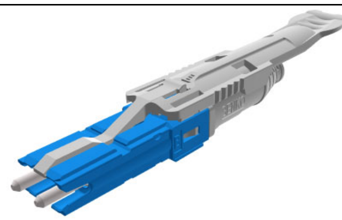
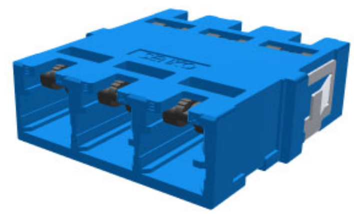
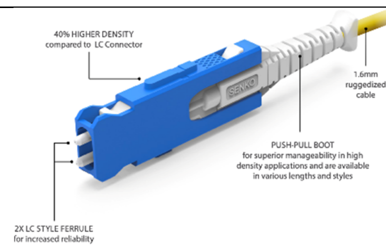
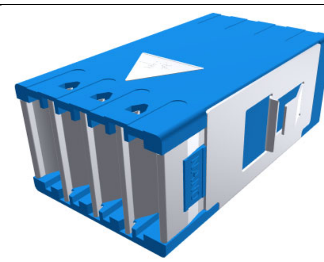
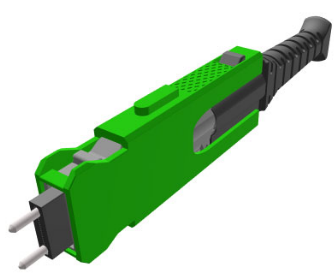
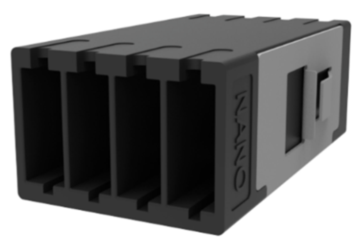
16. Senko's first VSFF product was a duplex connector platform called "CS". The CS platform includes duplex connectors and corresponding adapters. The CS connector has a 40% smaller size than the conventional duplex LC connector.

17. After the CS connector, Senko released another VSFF duplex connector platform, called "SN". The SN connectors and adapters allow for even greater density than CS. Compared

with conventional LC components, the SN components allow for about three-times the fiber connection density.

18. Most recently, Senko has begun marketing its SN-MT platform, which includes a connector and corresponding adapters. The SN-MT connector has a similar mating interface to the SN connector but uses a multi-fiber ferrule instead of two single-fiber ferrules. The SN-MT connector allows for about 2.7-times as many multi-fiber ferrules to be connected in a given footprint than the conventional MPO connector.

19. Shown below is a chart with representative samples of Senko's CS, SN, and SN-MT connectors and their corresponding adapters:

Product platform	Connector	Adapter
CS		
SN		
SN-MT		

20. To achieve these improvements in fiber optic connection density while still meeting industry expectations for accuracy, robustness, and ease of use, Senko made significant research and development investments. Its research and development led to important innovations that underlie Senko's three VSFF product platforms. For example, Senko developed new low-profile push-pull latch interfaces that enable simple, accessible insertion and extraction of a VSFF connector within a small footprint. Senko also developed new ways to integrate the high-precision alignment features of connectors and adapters to save space. Additionally, Senko innovated new ways of enabling connector polarity reversal within the limited size available for VSFF connectors. Recognizing the importance of these innovations to the next generation of fiber optic network equipment, Senko consistently sought patent protection for its VSFF inventions. Seven of the resulting patents are the subject of this lawsuit.

21. In addition to the VSFF products described above, Senko has numerous other products that relate to different fiber optic connectivity solutions. Senko understands and values intellectual property rights that are intended to protect its products and innovation. Senko has over 200 U.S. patents that cover various features and improvements in the field of fiber optic connectivity. Over 70 of Senko's patents pertain to VSFF interconnect systems.

22. US Conec is also marketing two VSFF product lines in direct competition with Senko's patented VSFF products and in violation of the asserted patents. US Conec's products in these two product lines are referred to herein as the "Infringing Products."[1]

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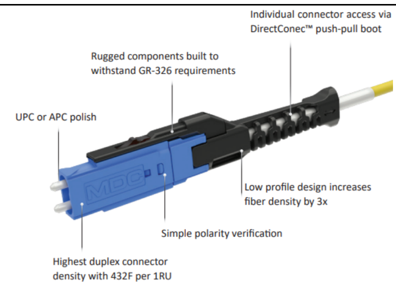
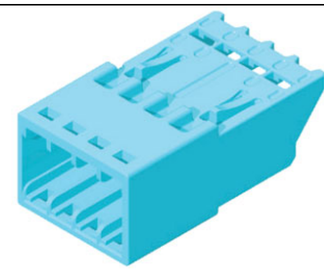
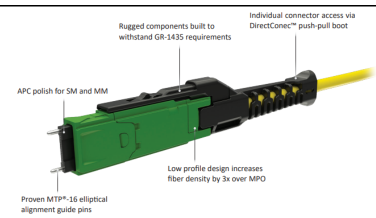
[1] A list of specific "Infringing Products" currently known to Senko is provided below. *See infra* ¶ 69. Senko reserves the right to revise, amend, or supplement the list of Infringing Products as the case progresses.

23. The first US Conec VSFF product line is called MDC, which, upon information and belief, includes a VSFF duplex connector and various mating adapters. The MDC connector marketed by US Conec has a similar size to Senko's SN connector.

24. The second US Conec VSFF product line is called MMC, which upon information and belief, includes a multi-fiber connector and various mating adapters. The MMC connector marketed by US Conec has a similar size to Senko's SN-MT connector.

25. Below is a chart depicting representative Infringing Products that, based on information and belief, US Conec is selling or offering for sale, in direct competition with Senko's patented VSFF products:

Product Platform	Connector	Adapter
MDC		
MMC		

26. None of US Conec's VSFF products is cross-compatible with any of Senko's VSFF products. For example, it is not possible to make a direct optical connection between an SN connector and an MDC connector or an SN-MT connector and an MMC connector.

Likewise, it is not possible to properly mate an SN connector to an MDC adapter, or vice versa, or to properly mate an SN-MT connector to an MMC adapter, or vice versa.

27. The above-described Senko and US Conec fiber optic connectivity products are generally not sold at retail to consumers. They are instead sold most often in bulk quantities to suppliers that specify these components in bids to supply equipment to a fiber optic network installation. Together with a lack of cross-compatibility between the parties' respective connector and adapters, this often leads to the "single-winner" bidding aspect of the competition for sales between companies such as Senko and US Conec.

28. These market factors generally mean that for every bid in which a given network installation chooses to buy US Conec's infringing connectors and adapters, Senko is shut out completely from making that sale–and often future sales–to that end customer and its vendors.

29. On information and belief, US Conec has successfully offered its Infringing Products in direct competition with Senko as part of bidding on at least two recent large-scale fiber optic network projects. When US Conec's Infringing Products are chosen for such installations over Senko's patented products, Senko is effectively shut out from being a supplier.

30. If US Conec is allowed to continue marketing and promoting its infringing MDC and MMC connector and adapter products, then Senko will continue to suffer irreparable harm, including loss of sales, market share, profit, and goodwill. This impacts both Senko's sale of the CS, SN, and SN-MT product platforms and also its potential participation in more lucrative sales of entire data center installations and communication networks. In short, Senko's VSFF innovation, its current market success, and its accompanying patent rights are deeply threatened by US Conec's infringement.

31. To eliminate further infringement and to recover appropriate legal and equitable remedies for past and ongoing infringement, Senko brings this action for patent infringement.

THE SENKO ASSERTED PATENTS

32. Senko has over 200 issued U.S. patents and is actively seeking additional protection for its innovative products and product features relating to fiber optic connectivity solutions. While Senko put US Conec on notice of infringement of several additional patents and claims before bringing this suit, the claims in this Complaint are for infringement of U.S. Patent Nos. 11,307,369; 11,333,836; 11,340,413; 11,415,760; 10,191,230; 11,181,701; 11,061,190; 11,391,895; 11,435,535; 11,585,989; 11,774,685; and 11,809,006 (collectively, the "Asserted Patents"). Senko does not waive, and expressly reserves, all rights and claims for relief against US Conec and others with regard to its patent rights beyond those set forth in this Amended and Supplemental Complaint.

THE '369 PATENT

33. U.S. Patent No. 11,307,369 (the "'369 Patent") is entitled "ULTRA - SMALL FORM FACTOR OPTICAL CONNECTORS USED AS PART OF A RECONFIGURABLE OUTER HOUSING." The '369 Patent was duly and legally issued on April 19, 2022, by the United States Patent and Trademark Office. A copy of the '369 Patent is attached to this Amended and Supplemental Complaint as **Exhibit A** and incorporated herein by reference.

34. Senko is the owner and assignee of the '369 Patent and possesses all rights of recovery under the '369 Patent.

35. The '369 Patent has not expired and is in full force and effect.

36. The '369 Patent claims are valid and enforceable.

37. The '369 Patent relates generally to certain claimed latching and unlatching features in a very small form fiber optic connector.

THE '836 PATENT

38. U.S. Patent No. 11,333,836 (the "'836 Patent") is entitled "ADAPTER FOR OPTICAL CONNECTORS." The '836 Patent was duly and legally issued on May 17, 2022, by the United States Patent and Trademark Office. A copy of the '836 Patent is attached to this Amended and Supplemental Complaint as **Exhibit B** and incorporated herein by reference.

39. Senko is the owner and assignee of the '836 Patent and possesses all rights of recovery under the '836 Patent.

40. The '836 Patent has not expired and is in full force and effect.

41. The '836 Patent claims are valid and enforceable.

42. The '836 Patent relates generally to a partition-free adapter for aligning and latching with multiple VSFF connectors.

THE '413 PATENT

43. U.S. Patent No. 11,340,413 (the "'413 Patent") is entitled "ULTRA - SMALL FORM FACTOR OPTICAL CONNECTORS USED AS PART OF A RECONFIGURABLE OUTER HOUSING." The '413 Patent was duly and legally issued on May 24, 2022, by the United States Patent and Trademark Office. A copy of the '413 Patent is attached to this Amended and Supplemental Complaint as **Exhibit C** and incorporated herein by reference.

44. Senko is the owner and assignee of the '413 Patent and possesses all rights of recovery under the '413 Patent.

45. The '413 Patent has not expired and is in full force and effect.

46. The '413 Patent claims are valid and enforceable.

47. The '413 Patent relates to a multi-fiber VSFF optical connector with a polarity key that is integrated with a pullback extraction mechanism.

THE '760 PATENT

48. U.S. Patent No. 11,415,760 (the "'760 Patent") is entitled "NARROW WIDTH ADAPTERS AND CONNECTORS WITH PULL TAB RELEASE." The '760 Patent was duly and legally issued on August 16, 2022, by the United States Patent and Trademark Office. A copy of the '760 Patent is attached to this Amended and Supplemental Complaint as **Exhibit D** and incorporated herein by reference.

49. Senko is the owner and assignee of the '760 Patent and possesses all rights of recovery under the '760 Patent.

50. The '760 Patent has not expired and is in full force and effect.

51. The '760 Patent claims are valid and enforceable.

52. The '760 Patent relates generally to a multi-fiber VSFF connector with a low-profile sliding interface between the connector housing and pullback remote release mechanism.

THE '230 PATENT

53. U.S. Patent No. 10,191,230 (the "'230 Patent") is entitled "OPTICAL CONNECTORS WITH REVERSIBLE POLARITY." The '230 Patent was duly and legally issued on January 29, 2019, by the United States Patent and Trademark Office. A copy of the '230 Patent is attached to this Amended and Supplemental Complaint as **Exhibit E** and incorporated herein by reference.

54. The '230 Patent was the subject of *Ex Parte* Reexamination Request No. 90/014,456, filed on February 19, 2020 ("2020 *Ex Parte* Reexamination").

55. The *Ex Parte* Reexamination resulted in issuance of *Ex Parte* Reexamination Certificate No. 10,191,230 C1 (the "'230 Reexamination Certificate") on November 16, 2020. The '230 Reexamination Certificate is attached to this Complaint as Exhibit F.

56. The '230 Reexamination Certificate amends claims 1, 9, 15, 19, and 23 of the '230 Patent and adds new claims 26-34.

57. Senko is the owner and assignee of the '230 Patent and '230 Reexamination Certificate and possesses all rights of recovery under the '230 Patent and '230 Reexamination Certificate.

58. The '230 Patent, as amended by the '230 Reexamination Certificate, has not expired and is in full force and effect.

59. The '230 Patent claims, as amended by the '230 Reexamination Certificate, are valid and enforceable.

60. The '230 Patent and the '230 Reexamination Certificate generally relate to duplex VSFF connectors with upper and lower couplings that facilitate polarity reversal.

THE '701 PATENT

61. U.S. Patent No. 11,181,701 (the "'701 Patent") is entitled "OPTICAL CONNECTORS WITH REVERSIBLE POLARITY AND METHOD OF USE." The '701 Patent was duly and legally issued on November 23, 2021, by the United States Patent and Trademark Office. A copy of the '701 Patent is attached to this Amended and Supplemental Complaint as **Exhibit G** and incorporated herein by reference.

62. Senko is the owner and assignee of the '701 Patent and possesses all rights of recovery under the '701 Patent.

63. The '701 Patent has not expired and is in full force and effect.

64. The '701 Patent claims are valid and enforceable.

65. The '701 Patent generally relates to duplex VSFF connectors with removable latch elements that facilitate polarity reversal.

THE '190 PATENT

66. U.S. Patent No. 11,061,190 (the "'190 Patent") is entitled "SMALL FORM FACTOR FIBER OPTIC CONNECTOR WITH MULTI – PURPOSE BOOT ASSEMBLY." The '190 Patent was duly and legally issued on July 13, 2021, by the United States Patent and Trademark Office. A copy of the '190 Patent is attached to this Amended and Supplemental Complaint as **Exhibit H** and incorporated herein by reference.

67. Senko is the owner and assignee of the '190 Patent and possesses all rights of recovery under the '190 Patent.

68. The '190 Patent has not expired and is in full force and effect.

69. The '190 Patent claims are valid and enforceable.

70. The '190 Patent generally relates to a duplex VSFF connector with a rotatable boot that can both (i) rotate to reverse the polarity of the connector and (ii) be pulled back to release the connector from an adapter.

THE '895 PATENT

71. U.S. Patent No. 11,391,895 (the "'895 Patent") is entitled "OPTICAL FIBER CONNECTOR WITH CHANGEABLE POLARITY." The '895 Patent was duly and legally issued on July 19, 2022, by the United States Patent and Trademark Office. A copy of the '895 Patent is attached to this Amended and Supplemental Complaint as **Exhibit I** and incorporated herein by reference.

72. Senko is the owner and assignee of the '895 Patent and possesses all rights of recovery under the '895 Patent.

73. The '895 Patent has not expired and is in full force and effect.

74. The '895 Patent claims are valid and enforceable.

75. The '895 Patent generally relates to a fiber optic connector with top and bottom grooves that can selectively accept the tongue of a polarity change element in order to locate a key portion of the polarity change element on a connector housing for changing polarity.

THE '535 PATENT

76. U.S. Patent No. 11,435,535 (the "'535 Patent") is entitled "BEHIND THE WALL OPTICAL CONNECTOR WITH REDUCED COMPONENTS." The '535 Patent was duly and legally issued on September 6, 2022, by the United States Patent and Trademark Office. A copy of the '535 Patent is attached to this Amended and Supplemental Complaint as **Exhibit J** and incorporated herein by reference.

77. Senko is the owner and assignee of the '535 Patent and possesses all rights of recovery under the '535 Patent.

78. The '535 Patent has not expired and is in full force and effect.

79. The '535 Patent claims are valid and enforceable.

80. The '535 Patent generally relates to a VSFF duplex adapter with behind-the-wall ports and non-behind-the-wall ports.

THE '989 PATENT

81. U.S. Patent No. 11,585,989 (the "'989 Patent") is entitled "SMALL FORM FACTOR FIBER OPTIC CONNECTOR WITH MULTI-PURPOSE BOOT." The '989 Patent was duly and legally issued on February 21, 2023, by the United States Patent and Trademark

Office. A copy of the '989 Patent is attached to this Amended and Supplemental Complaint as **Exhibit K** and incorporated herein by reference.

82. Senko is the owner and assignee of the '989 Patent and possesses all rights of recovery under the '989 Patent.

83. The '989 Patent has not expired and is in full force and effect.

84. The '989 Patent claims are valid and enforceable.

85. The '989 Patent generally relates to a duplex VSFF connector with a rotatable boot that can both (i) rotate to reverse the polarity of the connector and (ii) be pulled back to release the connector from an adapter.

THE '685 PATENT

86. U.S. Patent No. 11,774,685 (the "'685 Patent") is entitled "ADAPTER FOR OPTICAL CONNECTORS." The '685 Patent was duly and legally issued on October 3, 2023, by the United States Patent and Trademark Office. A copy of the '685 Patent is attached to this Amended and Supplemental Complaint as **Exhibit L** and incorporated herein by reference.

87. Senko is the owner and assignee of the '685 Patent and possesses all rights of recovery under the '685 Patent.

88. The '685 Patent has not expired and is in full force and effect.

89. The '685 Patent claims are valid and enforceable.

90. The '685 Patent generally relates to a partition-free adapter for aligning and latching with multiple VSFF connectors.

THE '006 PATENT

91. U.S. Patent No. 11,809,006 (the "'006 Patent") is entitled "ULTRA-SMALL FORM FACTOR OPTICAL CONNECTORS USED AS PART OF A RECONFIGURABLE

OUTER HOUSING." The '006 Patent was duly and legally issued on November 7, 2023, by the United States Patent and Trademark Office. A copy of the '006 Patent is attached to this Amended and Supplemental Complaint as **Exhibit M** and incorporated herein by reference.

92. Senko is the owner and assignee of the '006 Patent and possesses all rights of recovery under the '006 Patent.

93. The '006 Patent has not expired and is in full force and effect.

94. The '006 Patent claims are valid and enforceable.

95. The '006 Patent generally relates to VSFF connectors with top-mounted push-pull latch release mechanisms.

DEFENDANT'S ACCUSED PRODUCTS

96. US Conec's infringement of Senko's patent rights by making, using, offering for sale, selling and/or importing connector and adapter products in both the MDC and MMC platforms has been and is continuous and ongoing. The currently known US Conec connector and adapter Infringing Products include:

- MDC UPC Connector
- MDC APC Connector
- MMC Connector
- MMC Adapter
- MDC 2-Port Adapter Aligned Key MDC/MDC
- MDC 3-Port Adapter MDC/MDC Jr.
- MDC 4-Port Adapter MDC/MDC Jr.
- MDC 4-Port Adapter Aligned Key MDC/MDC
- MDC 4-Port Adapter Opposed Key – MDC/MDC

DEFENDANT'S KNOWLEDGE OF SENKO'S PATENT RIGHTS

97. Senko complies with the marking requirements of 35 U.S.C. § 287 at least through the websites and other materials related to its products under the Asserted Patents. Senko's marking includes a virtual patent marking page, located at https://www.senko.com/corporate/#patents, which associates its CS and SN product platforms with some of the Asserted Patents, among others.

98. At least as of January 26, 2022, US Conec has known that Senko is a competing manufacturer of fiber optic connectors and adapters, and at least as of that same date US Conec has known about Senko's products and its corresponding patents as well.

99. On information and belief, US Conec directed the attorneys who filed the 2020 *Ex Parte* Reexamination.

100. On information and belief, US Conec paid at least part of the fees of the attorneys who filed the 2020 *Ex Parte* Reexamination.

101. On information and belief, the same attorneys that filed the 2020 *Ex Parte* Reexamination are also counsel of record for US Conec in the prosecution of its own patent applications currently pending before the USPTO.

102. On information and belief, US Conec had knowledge of the '230 Patent at least as early as February 19, 2020.

103. Beginning in early 2022, Senko sent multiple letters to US Conec to provide notice of Senko's Asserted Patents, among several other Senko patents. Senko sent the first notice letter on January 26, 2022, which notified US Conec of the '230 Patent, the '836 Patent (which at the time was an allowed patent application), and the '369 Patent (which at the time was an allowed patent application), among others. The January 26, 2022 correspondence included

claim charts providing examples that explained how Defendant's products infringed, including how Defendant's MDC and the MMC connectors infringed the '369 Patent; how Defendant's MDC connectors infringed the '230 Patent; and how Defendant's MDC adapter and MMC adapter infringed the '836 Patent. On information and belief, a reasonable investigation of Senko's notice of infringement would have also made Defendant aware of other Asserted Patents around this time after receiving the January 26, 2022 correspondence that were related to the Asserted Patents or were also owned by Senko. On information and belief, US Conec subsequently became aware of other Asserted Patents on their issue date. Defendant thus had knowledge of certain of the Asserted Patents at least as of January 26, 2022, the date of Senko's first notice letter. On information and belief, after receiving such notice, Defendant continued to make, use, offer for sale, and/or sell infringing products and/or continued to import into the United States its infringing products. *See, e.g.*, https://www.usconec.com/featured-products/mdc-connectors; https://www.usconec.com/featured-products/mmc-connector.

104. Throughout 2022, Senko gave further actual pre-suit notice of its claims of infringement to US Conec on other Asserted Patents as well. As another example, at least as early as October 5, 2022, Senko sent claim charts to Defendant providing examples that explain how its products infringe the following patents: the '190 Patent, the '701 Patent, the '413 Patent, and the '760 Patent[2]. On information and belief, after receiving such notice, Defendant continued to make, use, offer for sale, and/or sell infringing products and/or continued to import into the United States its infringing products.

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[2] The correspondence and claim charts were sent to US Conec on June 2, 2022. At one point in time, US Conec disputed that it received the package on June 2, 2022, but US Conec has not disputed that it received the package on October 5, 2022, when Senko resent it. Discovery in this matter should clarify this timing issue.

105. On January 24, 2023, Senko filed a Complaint for Patent Infringement, alleging that US Conec infringes the following Senko patents: the '369 Patent, the '836 Patent, the '413 Patent, the '760 Patent, the '230 Patent, the '701 Patent, and the '190 Patent. On information and belief, despite receiving such notice, Defendant continued to make, use, offer for sale, and/or sell infringing products and/or continued to import into the United States its infringing products.

106. On December 28, 2023, Senko sent correspondence to Defendant notifying it that Senko planned to amend and supplement its Complaint to add infringement counts for the following patents: the '006 Patent, the '685 Patent, the '895 Patent, the '989 Patent, and the '535 Patent. On January 10, 2024, Senko sent correspondence to Defendant that included a draft Amended and Supplemental Complaint and claim charts providing examples that explained how Defendant's products infringed each of these patents – as well as U.S. Patent No. 11,806,831.[3]

107. Despite having been made aware of its infringement of some Asserted Patents before this action was commenced (and having been made aware of its infringement of Senko's later-issued Asserted Patents before the filing of this Amended and Supplemental Complaint), US Conec continues its infringement through its sales and marketing of MDC and MMC connectors and adapters, unabated. On information and belief, US Conec's alleged infringement of the Asserted Patents, with prior knowledge of Senko's claims, is willful.

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[3] On January 15, 2024, US Conec responded to Senko's January 10, 2024 correspondence and stated the following: "As for Senko's proposed infringement claim for U.S. Patent No. 11,806,831, we do not believe Senko has adequate basis for the claim and, if that claim is pressed, US Conec reserves its right to seek dismissal." Senko has not included the '831 Patent, which claims a method of manufacture, in this Amended and Supplemental Complaint (although it was included in the draft provided to US Conec), believes that US Conec infringes the '831 Patent as set forth in the January 10, 2024 claim chart, believes that further discovery will confirm this, and Senko reserves the right to seek to add the '831 Patent to this lawsuit at an appropriate time prior to trial in accordance with the pretrial schedule adopted by the Court.

108. On information and belief, US Conec has not made any attempt to redesign, modify, or withdraw any of its Infringing Products in response to Senko's infringement notices and demands.

109. Defendant knows and at all relevant times has known of its infringement of the Asserted Patents, or at the very least has been willfully blind to its infringement of the Asserted Patents.

110. Upon information and belief, such infringement has been, and will continue to be, willful, and upon further belief, Defendant lacks any reasonable invalidity or non-infringement defense making this case exceptional and entitling Senko to increased damages and reasonable attorneys' fees pursuant to 35 U.S.C. §§ 284 and 285.

CLAIMS FOR RELIEF

111. Senko's averments of infringement against US Conec that follow in Counts One – Twelve and as further illustrated in the corresponding infringement charts are exemplary of, and without prejudice to Senko's ultimate infringement contentions. The Claim Charts attached and incorporated by reference in this Amended and Supplemental Complaint as **Exhibits N--Y** have individual claim elements of a representative claim mapped to an Accused Product and shall be considered a separate averment within the meaning of the Federal Rules of Civil Procedure, for which an element-by-element response is expected in conformity with Rule 8(b) of the Federal Rules of Civil Procedure. In providing these averments, Senko does not convey or imply any particular claim constructions or purport to describe the precise scope of the claims. Senko's claim constructions, as necessary, regarding any particularized meaning of the claim terms for the Asserted Patents' claims will be provided in accordance with the Court's scheduling order and any applicable local rules or standards.

COUNT ONE
(INFRINGEMENT OF U.S. PATENT NO. 11,307,369)

112. Senko repeats, re-alleges, and incorporates by reference the averments of paragraphs 1-111 of this Amended and Supplemental Complaint as though fully set forth herein.

113. Defendant US Conec, without license or authorization to do so, has directly infringed one or more claims of the '369 Patent, currently infringes, and will continue to infringe, literally or under the doctrine of equivalents, one or more claims the '369 Patent by making, using, offering for sale and/or selling its MDC and MMC fiber optic connectivity products within this District and elsewhere in the United States, and/or importing into the United States its MDC and MMC fiber optic connectivity products, in violation of 35 U.S.C. § 271(a).

114. Defendant's accused fiber optic connectivity products directly infringe the '369 Patent. For example, US Conec's Accused Products infringe at least claims 1-20 and 22-39 of the '369 Patent. By way of further illustrative infringement, Senko provides an exemplary claim chart for claim 23 of the '369 patent. *See* **Exhibit N** (claim chart), attached and incorporated by reference.

115. Defendant's past and continuing infringement of the '369 Patent by its sales and offers for sale of the Accused Products are causing economic harm to Senko, for which Senko is entitled to damages for past infringement up to and including the date of judgment in an amount to be determined by the Court but in no event less than a reasonable royalty.

116. Defendant's infringement of Senko's rights in the 369 Patent has caused, is causing, and will continue to cause irreparable harm to Senko for which there is no adequate remedy at law, and such irreparable harm will continue unless US Conec is enjoined by this Court.

COUNT TWO
(INFRINGEMENT OF U.S. PATENT NO. 11,333,836)

117. Senko repeats, re-alleges, and incorporates by reference the averments of paragraphs 1-116 of this Amended and Supplemental Complaint as though fully set forth herein.

118. Defendant US Conec, without license or authorization to do so, has infringed one or more claims of the '836 Patent, currently infringes, and will continue to infringe, literally or under the doctrine of equivalents, one or more claims the '836 Patent by making, using, offering for sale and/or selling its fiber optic adapter products within this District and elsewhere in the United States and/or importing into the United States its fiber optic adapter products, in violation of 35 U.S.C. § 271(a).

119. Defendant's accused fiber optic adapter products directly infringe the '836 Patent. For example, US Conec's Accused Products infringe at least claims 3-5 of the '836 Patent. By way of further illustrative infringement, Senko provides an exemplary claim chart for claim 3 of the '836 patent. *See* **Exhibit O** (claim chart), attached and incorporated by reference.

120. Defendant's past and continuing infringement of the '836 Patent by its sales and offers for sale of the Accused Products are causing economic harm to Senko, for which Senko is entitled to damages for past infringement up to and including the date of judgment in an amount to be determined by the Court but in no event less than a reasonable royalty.

121. Defendant's infringement of Senko's rights in the '836 Patent has caused, is causing, and will continue to cause irreparable harm to Senko for which there is no adequate remedy at law, and such irreparable harm will continue unless US Conec is enjoined by this Court.

COUNT THREE
(INFRINGEMENT OF U.S. PATENT NO. 11,340,413)

122. Senko repeats, re-alleges, and incorporates by reference the averments of paragraphs 1-121 of this Amended and Supplemental Complaint as though fully set forth herein.

123. Defendant US Conec, without license or authorization to do so, has infringed one or more claims of the '413 Patent, currently infringes, and will continue to infringe, literally or under the doctrine of equivalents, one or more claims the '413 Patent by making, using, offering for sale and/or selling its fiber optic adapter and connector products within this District and elsewhere in the United States and/or importing into the United States its fiber optic adapter and connector products, in violation of 35 U.S.C. § 271(a).

124. Defendant's accused fiber optic connectivity products, both adapters and connectors, directly and indirectly infringe the '413 Patent. For example, US Conec's Accused Products infringe at least claims 1-8, 10, 13-18, and 20-28 of the '413 Patent. By way of further illustrative infringement, Senko provides an exemplary claim chart for claim 1 of the '413 patent. *See* **Exhibit P** (claim chart), attached and incorporated herein by reference.

125. Defendant's past and continuing infringement of the '413 Patent by its sales and offers for sale of the Accused Products are causing economic harm to Senko, for which Senko is entitled to damages for past infringement up to and including the date of judgment in an amount to be determined by the Court but in no event less than a reasonable royalty.

126. Defendant's infringement of Senko's rights in the '413 Patent has caused, is causing, and will continue to cause irreparable harm to Senko for which there is no adequate remedy at law, and such irreparable harm will continue unless US Conec is enjoined by this Court.

COUNT FOUR
(INFRINGEMENT OF U.S. PATENT NO. 11,415,760)

127. Senko repeats, re-alleges, and incorporates by reference the averments of paragraphs 1-126 of this Amended and Supplemental Complaint as though fully set forth herein.

128. Defendant US Conec, without license or authorization to do so, has infringed one or more claims of the '760 Patent, currently infringes, and will continue to infringe, literally or under the doctrine of equivalents, one or more claims the '760 Patent by making, using, offering for sale and/or selling its fiber optic adapter and connector products within this District and elsewhere in the United States and/or importing into the United States its fiber optic adapter and connector products, in violation of 35 U.S.C. § 271(a).

129. Defendant's accused fiber optic connectivity products directly infringe the '760 Patent. For example, US Conec's Accused Products infringe at least claims 1-4, 9-12, 13, and 15-17 of the '760 Patent. By way of further illustrative infringement, Senko provides an exemplary claim chart for claim 1 of the '760 patent. *See* **Exhibit Q** (claim chart), attached and incorporated herein by reference.

130. Defendant's past and continuing infringement of the '760 Patent by its sales and offers for sale of the Accused Products are causing economic harm to Senko, for which Senko is entitled to damages for past infringement up to and including the date of judgment in an amount to be determined by the Court but in no event less than a reasonable royalty.

131. Defendant's infringement of Senko's rights in the '760 Patent has caused, is causing, and will continue to cause irreparable harm to Senko for which there is no adequate remedy at law, and such irreparable harm will continue unless US Conec is enjoined by this Court.

COUNT FIVE
(INFRINGEMENT OF U.S. PATENT NO. 10,191,230)

132. Senko repeats, re-alleges, and incorporates by reference the averments of paragraphs 1-131 of this Amended and Supplemental Complaint as though fully set forth herein.

133. Defendant US Conec, without license or authorization to do so, has infringed one or more claims of the '230 Patent, currently infringes, and will continue to infringe, literally or under the doctrine of equivalents, one or more claims the '230 Patent by making, using, offering for sale and/or selling its fiber optic connectivity products with polarity change features within this District and elsewhere in the United States and/or importing into the United States its fiber optic connectivity products with polarity change features, in violation of 35 U.S.C. § 271(a).

134. Defendant's accused fiber optic connectivity products with polarity change features directly infringe the '230 Patent. For example, US Conec's Accused Products infringe at least claims 1, 6, 9, 11, and 26-34 of the '230 Patent. By way of further illustrative infringement, Senko provides an exemplary claim chart for claim 1 of the '230 patent, as amended by the '230 Reexamination Certificate. *See* **Exhibit R** (claim chart), attached and incorporated herein by reference.

135. Defendant's past and continuing infringement of the '230 Patent by its sales and offers for sale of the Accused Products are causing economic harm to Senko, for which Senko is entitled to damages for past infringement up to and including the date of judgment in an amount to be determined by the Court but in no event less than a reasonable royalty.

136. Defendant's infringement of Senko's rights in the '230 Patent has caused, is causing, and will continue to cause irreparable harm to Senko for which there is no adequate remedy at law, and such irreparable harm will continue unless US Conec is enjoined by this Court.

COUNT SIX
(INFRINGEMENT OF U.S. PATENT NO. 11,181,701)

137. Senko repeats, re-alleges, and incorporates by reference the averments of paragraphs 1-136 of this Amended and Supplemental Complaint as though fully set forth here.

138. Defendant US Conec, without license or authorization to do so, has infringed one or more claims of the '701 Patent, currently infringes, and will continue to infringe, literally or under the doctrine of equivalents, one or more claims the '701 Patent by making, using, offering for sale and/or selling its fiber optic connectivity products with polarity change features within this District and elsewhere in the United States and/or importing into the United States its fiber optic connectivity products with polarity change features, in violation of 35 U.S.C. § 271(a).

139. Defendant's accused fiber optic connectivity products with polarity change features directly infringe the '701 Patent. For example, US Conec's Accused Products infringe at least claims 1-53 of the '701 Patent. By way of further illustrative infringement, Senko provides an exemplary claim chart for claim 1 of the '701 patent. *See* **Exhibit S** (claim chart), attached and incorporated by reference.

140. Defendant's past and continuing infringement of the '701 Patent by its sales and offers for sale of the Accused Products are causing economic harm to Senko, for which Senko is entitled to damages for past infringement up to and including the date of judgment in an amount to be determined by the Court but in no event less than a reasonable royalty.

141. Defendant's infringement of Senko's rights in the '701 Patent has caused, is causing, and will continue to cause irreparable harm to Senko for which there is no adequate remedy at law, and such irreparable harm will continue unless US Conec is enjoined by this Court.

COUNT SEVEN
(INFRINGEMENT OF U.S. PATENT NO. 11,061,190)

142. Senko repeats, re-alleges, and incorporates by reference the averments of paragraphs 1-141 of this Amended and Supplemental Complaint as though fully set forth herein.

143. Defendant US Conec, without license or authorization to do so, has infringed one or more claims of the '190 Patent, currently infringes, and will continue to infringe, literally or under the doctrine of equivalents, one or more claims the '190 Patent by making, using, offering for sale and/or selling its fiber optic connectivity products with polarity change features within this District and elsewhere in the United States and/or importing into the United States its fiber optic connectivity products with polarity change features, in violation of 35 U.S.C. § 271(a).

144. Defendant's accused fiber optic connectivity products with polarity change features directly infringe the '190 Patent. For example, US Conec's Accused Products infringe at least claims 1-3 and 6-20 of the '190 Patent. By way of further illustrative infringement, Senko provides an exemplary claim chart for claim 1 of the '190 patent. *See* **Exhibit T** (claim chart), attached and incorporated by reference.

145. Defendant's past and continuing infringement of the '190 Patent by its sales and offers for sale of the Accused Products are causing economic harm to Senko, for which Senko is entitled to damages for past infringement up to and including the date of judgment in an amount to be determined by the Court but in no event less than a reasonable royalty.

146. Defendant's infringement of Senko's rights in the '190 Patent has caused, is causing, and will continue to cause irreparable harm to Senko for which there is no adequate remedy at law, and such irreparable harm will continue unless US Conec is enjoined by this Court.

COUNT EIGHT
(INFRINGEMENT OF U.S. PATENT NO. 11,391,895)

147. Senko repeats, re-alleges, and incorporates by reference the averments of paragraphs 1-146 of this Amended and Supplemental Complaint as though fully set forth herein.

148. Defendant US Conec, without license or authorization to do so, has infringed one or more claims of the '895 Patent, currently infringes, and will continue to infringe, literally or under the doctrine of equivalents, one or more claims the '895 Patent by making, using, offering for sale and/or selling its MDC connectors with polarity change features within this District and elsewhere in the United States and/or importing into the United States its MDC connectors with polarity change features , in violation of 35 U.S.C. § 271(a).

149. Defendant's accused MDC connectors with polarity change features directly infringe the '895 Patent. For example, US Conec's Accused Products infringe at least claims 1-25 of the '895 Patent. By way of further illustrative infringement, Senko provides an exemplary claim chart for claim 1 of the '895 patent. *See* **Exhibit U** (claim chart), attached and incorporated by reference.

150. Defendant's past and continuing infringement of the '895 Patent by its sales and offers for sale of the Accused Products are causing economic harm to Senko, for which Senko is entitled to damages for past infringement up to and including the date of judgment in an amount to be determined by the Court but in no event less than a reasonable royalty.

151. Defendant's infringement of Senko's rights in the '895 Patent has caused, is causing, and will continue to cause irreparable harm to Senko for which there is no adequate remedy at law, and such irreparable harm will continue unless US Conec is enjoined by this Court.

COUNT NINE
(INFRINGEMENT OF U.S. PATENT NO. 11,435,535)

152. Senko repeats, re-alleges, and incorporates by reference the averments of paragraphs 1-151 of this Amended and Supplemental Complaint as though fully set forth herein.

153. Defendant US Conec, without license or authorization to do so, has infringed one or more claims of the '535 Patent, currently infringes, and will continue to infringe, literally or under the doctrine of equivalents, one or more claims the '535 Patent by making, using, offering for sale and/or selling its MDC/MDC Jr. Adapters within this District and elsewhere in the United States and/or importing into the United States its MDC/MDC Jr. Adapters, in violation of 35 U.S.C. § 271(a).

154. Defendant's accused MDC/MDC Jr. Adapters directly infringe the '535 Patent. For example, US Conec's Accused Products infringe at least claims 1-19 of the '535 Patent. By way of further illustrative infringement, Senko provides an exemplary claim chart for claim 1 of the '535 patent. *See* **Exhibit V** (claim chart), attached and incorporated by reference.

155. Defendant's past and continuing infringement of the '535 Patent by its sales and offers for sale of the Accused Products are causing economic harm to Senko, for which Senko is entitled to damages for past infringement up to and including the date of judgment in an amount to be determined by the Court but in no event less than a reasonable royalty.

156. Defendant's infringement of Senko's rights in the '535 Patent has caused, is causing, and will continue to cause irreparable harm to Senko for which there is no adequate remedy at law, and such irreparable harm will continue unless US Conec is enjoined by this Court.

COUNT TEN
(INFRINGEMENT OF U.S. PATENT NO. 11,585,989)

157. Senko repeats, re-alleges, and incorporates by reference the averments of paragraphs 1-156 of this Amended and Supplemental Complaint as though fully set forth herein.

158. Defendant US Conec, without license or authorization to do so, has infringed one or more claims of the '989 Patent, currently infringes, and will continue to infringe, literally or under the doctrine of equivalents, one or more claims the '989 Patent by making, using, offering for sale and/or selling its MDC connector products with polarity change features within this District and elsewhere in the United States and/or importing into the United States its MDC connector products with polarity change features , in violation of 35 U.S.C. § 271(a).

159. Defendant's accused MDC connector products with polarity change features directly infringe the '989 Patent. For example, US Conec's Accused Products infringe at least claims 1-3 and 5-20 of the '989 Patent. By way of further illustrative infringement, Senko provides an exemplary claim chart for claim 1 of the '989 patent. *See* **Exhibit W** (claim chart), attached and incorporated by reference.

160. Defendant's past and continuing infringement of the '989 Patent by its sales and offers for sale of the Accused Products are causing economic harm to Senko, for which Senko is entitled to damages for past infringement up to and including the date of judgment in an amount to be determined by the Court but in no event less than a reasonable royalty.

161. Defendant's infringement of Senko's rights in the '989 Patent has caused, is causing, and will continue to cause irreparable harm to Senko for which there is no adequate remedy at law, and such irreparable harm will continue unless US Conec is enjoined by this Court.

COUNT ELEVEN
(INFRINGEMENT OF U.S. PATENT NO. 11,774,685)

162. Senko repeats, re-alleges, and incorporates by reference the averments of paragraphs 1-161 of this Amended and Supplemental Complaint as though fully set forth herein.

163. Defendant US Conec, without license or authorization to do so, has infringed one or more claims of the '685 Patent, currently infringes, and will continue to infringe, literally or under the doctrine of equivalents, one or more claims the '685 Patent by making, using, offering for sale and/or selling its MDC and MMC adapter products within this District and elsewhere in the United States and/or importing into the United States its MDC and MMC adapter products, in violation of 35 U.S.C. § 271(a).

164. Defendant's accused MDC and MMC adapter products directly infringe the '685 Patent. For example, US Conec's Accused Products infringe at least claims 1-18 of the '685 Patent. By way of further illustrative infringement, Senko provides an exemplary claim chart for claim 1 of the '685 patent. *See* **Exhibit X** (claim chart), attached and incorporated by reference.

165. Defendant's past and continuing infringement of the '685 Patent by its sales and offers for sale of the Accused Products are causing economic harm to Senko, for which Senko is entitled to damages for past infringement up to and including the date of judgment in an amount to be determined by the Court but in no event less than a reasonable royalty.

166. Defendant's infringement of Senko's rights in the '685 Patent has caused, is causing, and will continue to cause irreparable harm to Senko for which there is no adequate remedy at law, and such irreparable harm will continue unless US Conec is enjoined by this Court.

COUNT TWELVE
(INFRINGEMENT OF U.S. PATENT NO. 11,809,006)

167. Senko repeats, re-alleges, and incorporates by reference the averments of paragraphs 1-166 of this Amended and Supplemental Complaint as though fully set forth herein.

168. Defendant US Conec, without license or authorization to do so, has infringed one or more claims of the '006 Patent, currently infringes, and will continue to infringe, literally or under the doctrine of equivalents, one or more claims the '006 Patent by making, using, offering for sale and/or selling its MDC and MMC fiber optic connectivity products within this District and elsewhere in the United States and/or importing into the United States its MDC and MMC fiber optic connectivity products , in violation of 35 U.S.C. § 271(a).

169. Defendant's accused MDC and MMC fiber optic connectivity products directly infringe the '006 Patent. For example, US Conec's Accused Products infringe at least claims 1-31 of the '006 Patent. By way of further illustrative infringement, Senko provides an exemplary claim chart for claim 1 of the '006 patent. *See* **Exhibit Y** (claim chart), attached and incorporated by reference.

170. Defendant's past and continuing infringement of the '006 Patent by its sales and offers for sale of the Accused Products are causing economic harm to Senko, for which Senko is entitled to damages for past infringement up to and including the date of judgment in an amount to be determined by the Court but in no event less than a reasonable royalty.

171. Defendant's infringement of Senko's rights in the '006 Patent has caused, is causing, and will continue to cause irreparable harm to Senko for which there is no adequate remedy at law, and such irreparable harm will continue unless US Conec is enjoined by this Court.

PRAYER FOR RELIEF

WHEREFORE, Senko respectfully requests that the Court find in its favor and against the Defendant US Conec, and that the Court grant Senko the following relief:

a. A judgment in favor of Senko that US Conec has infringed one or more claims of the following Asserted Patents of Senko: U.S. Patent Nos. 11,307,369; 11,333,836; 11,340,413; 11,415,760; 10,191,230; 11,181,701; 11,061,190; 11,391,895; 11,435,535; 11,585,989; 11,774,685; and 11,809,006;

b. A permanent injunction pursuant to 35 U.S.C. § 283, enjoining US Conec and each of its officers, directors, agents, servants, affiliates, employees, divisions, branches, subsidiaries, parents, and all others acting in active concert therewith from continued acts of infringement, including, but not limited to, directly infringing or inducing the infringement of, or contributing to the infringement of the Asserted Patents, or such other equitable relief the Court determines is warranted;

c. An accounting of and an award to Senko of damages adequate to compensate Senko for US Conec's acts of infringement, including lost profits and/or a reasonable royalty, and also including supplemental damages for any post-verdict infringement up until entry of final judgment with an accounting as needed, together with pre-judgment and post-judgment interest pursuant to 35 U.S.C. § 284;

d. Finding US Conec's infringement to be willful and an award to Senko of enhanced damages in an amount up to treble the amount of compensatory damages as justified under 35 U.S.C. § 284 for US Conec's willful infringement;

e. A declaration that this is an exceptional case, including, an award to Senko of its costs, expenses, and reasonable attorneys' fees under 35 U.S.C. § 285 and all other applicable statutes and rules in common law as may apply;

f. An award to Senko of its costs pursuant to 35 U.S.C. § 284 and/or Fed. R. Civ. P. 54(d); and

g. An award of any such further relief that the Court deems just and proper.

Dated: February 1, 2024

YOUNG CONAWAY STARGATT
& TAYLOR, LLP

/s/ Robert M. Vrana

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Index of Exhibits to Complaint

EXHIBIT NO.	DESCRIPTION
A	US PATENT NO. 11,307,369
B	US PATENT NO. 11,333,836
C	US PATENT NO. 11,340,413
D	US PATENT NO. 11,415,760
E	US PATENT NO. 10,191,230
F	US PATENT EX PARTE REEXAMINATION CERTIFICATE NO. 10,191,230 C1
G	US PATENT NO. 11,181,701
H	US PATENT NO. 11,061,190
I	US PATENT NO. 11,391,895
J	US PATENT NO. 11,435,535
K	US PATENT NO. 11,585,989
L	US PATENT NO. 11,774,685
M	US PATENT NO. 11,809,006
N	CLAIM CHART FOR 369 PATENT
O	CLAIM CHART FOR 836 PATENT
P	CLAIM CHART FOR 413 PATENT
Q	CLAIM CHART FOR 760 PATENT
R	CLAIM CHART FOR 230 PATENT
S	CLAIM CHART FOR 701 PATENT
T	CLAIM CHART FOR 190 PATENT
U	CLAIM CHART FOR 895 PATENT
V	CLAIM CHART FOR 535 PATENT
W	CLAIM CHART FOR 989 PATENT
X	CLAIM CHART FOR 685 PATENT
Y	CLAIM CHART FOR 006 PATENT

EXHIBIT A

US011307369B2

(12) United States Patent
Takano et al.

(10) Patent No.: US 11,307,369 B2
(45) Date of Patent: Apr. 19, 2022

(54) **ULTRA-SMALL FORM FACTOR OPTICAL CONNECTORS USED AS PART OF A RECONFIGURABLE OUTER HOUSING**

(71) Applicant: **Senko Advanced Components, Inc.**, Marlborough, MA (US)

(72) Inventors: **Kazuyoshi Takano**, Tokyo (JP); **Jimmy Jun-Fu Chang**, Worcester, MA (US)

(73) Assignee: **Senko Advanced Components, Inc.**, Marlborough (MA)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **17/370,057**

(22) Filed: **Jul. 8, 2021**

(65) **Prior Publication Data**

US 2021/0373262 A1 Dec. 2, 2021

Related U.S. Application Data

(63) Continuation of application No. 17/327,197, filed on May 21, 2021, which is a continuation of application (Continued)

(51) **Int. Cl.**
G02B 6/42 (2006.01)
G02B 6/38 (2006.01)

(52) **U.S. Cl.**
CPC .... ***G02B 6/4292*** (2013.01); ***G02B 6/387*** (2013.01); ***G02B 6/3825*** (2013.01); (Continued)

(58) **Field of Classification Search**
None
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

681,132 A 8/1901 Norton
3,721,945 A 3/1973 Hults
(Continued)

FOREIGN PATENT DOCUMENTS

CA 2495693 A1 4/2004
CA 2495693 A1 4/2004
(Continued)

OTHER PUBLICATIONS

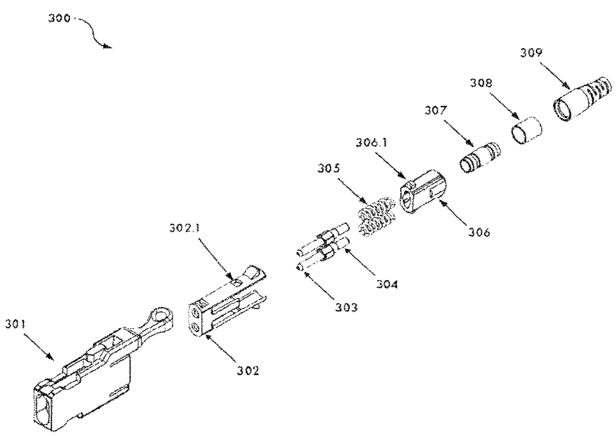
International Search Report and Written Opinion; Application No. PCT/US2018/042202, dated Dec. 7, 2018, pp. 17.
(Continued)

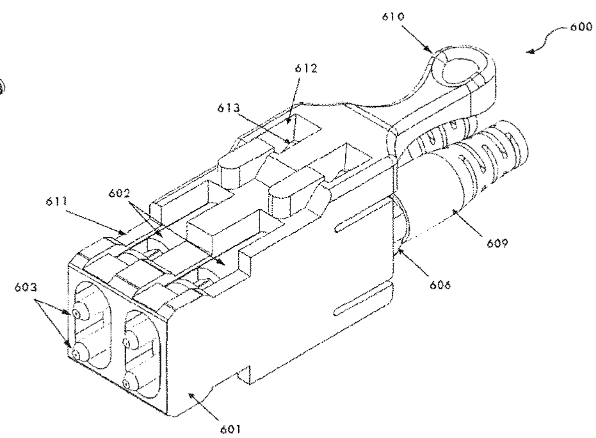
Primary Examiner — Tina M Wong

(57) **ABSTRACT**

An optical connector holding one or more optical ferrule assembly is provided. The optical connector includes an outer body, an inner front body accommodating the one or more optical ferrule assembly, ferrule springs for urging the optical ferrules towards a mating receptacle, and a back body for supporting the ferrule springs. The outer body and the inner front body are configured such that four optical ferrule assembly are accommodated in a small form-factor pluggable (SFP) transceiver footprint or eight optical ferrule assembly are accommodated in a quad small form-factor pluggable (QSFP) transceiver footprint. A receptacle can hold one or more connector inner bodies forming a single boot for all the optical fibers of the inner bodies.

40 Claims, 82 Drawing Sheets





Related U.S. Application Data

No. 17/090,855, filed on Nov. 5, 2020, which is a continuation of application No. 16/414,546, filed on May 16, 2019, now Pat. No. 10,859,778, which is a continuation of application No. 16/388,053, filed on Apr. 18, 2019, now Pat. No. 11,169,338, which is a continuation of application No. 16/035,691, filed on Jul. 15, 2018, now Pat. No. 10,281,668.

(60) Provisional application No. 62/588,276, filed on Nov. 17, 2017, provisional application No. 62/549,655, filed on Aug. 24, 2017, provisional application No. 62/532,710, filed on Jul. 14, 2017.

(52) **U.S. Cl.**
CPC ***G02B 6/3893*** (2013.01); *G02B 6/3873* (2013.01); *G02B 6/3878* (2013.01); *G02B 6/4228* (2013.01)

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,150,790 A 4/1979 Potter
4,240,695 A 12/1980 Evans
4,327,964 A 5/1982 Haesley et al.
4,478,473 A 10/1984 Frear
4,762,388 A 8/1988 Tanaka et al.
4,764,129 A 8/1988 Jones et al.
4,840,451 A 6/1989 Sampson et al.
4,872,736 A 10/1989 Myers et al.
4,979,792 A 12/1990 Weber
5,026,138 A 6/1991 Boudreau
5,031,981 A 7/1991 Peterson
5,011,025 A 8/1991 Haitmanek
5,041,025 A 8/1991 Haitmanek
5,073,045 A 12/1991 Abendschein
D323,143 S 1/1992 Ohkura et al.
5,101,463 A 3/1992 Cubukciyan
5,146,813 A 9/1992 Stanfill, Jr.
5,159,652 A 10/1992 Grassin D'Alphonse
5,212,752 A 5/1993 Stephenson et al.
5,265,181 A 11/1993 Chang
5,289,554 A 2/1994 Cubukciyan et al.
5,315,679 A 5/1994 Baldwin
5,317,663 A 5/1994 Beard et al.
5,321,784 A 6/1994 Cubukciyan et al.
5,335,301 A 8/1994 Newman et al.
5,348,487 A 9/1994 Marazzi et al.
5,418,875 A 5/1995 Nakano
5,444,806 A 8/1995 de Marchi et al.
5,481,634 A 4/1996 Anderson et al.
5,506,922 A 4/1996 Grois et al.
5,521,997 A 5/1996 Rovenolt et al.
5,570,445 A 10/1996 Chou et al.
5,588,079 A 12/1996 Tanabe et al.
5,602,951 A 2/1997 Shiota
5,684,903 A 11/1997 Kyomasu et al.
5,687,268 A 11/1997 Stephenson et al.
5,781,681 A 7/1998 Manning
5,845,036 A 12/1998 De Marchi
5,862,282 A 1/1999 Matsuura
5,915,987 A 6/1999 Reed
5,930,426 A 7/1999 Harting
5,937,130 A 8/1999 Amberg et al.
5,953,473 A 9/1999 Shimotsu
5,956,444 A 9/1999 Duda et al.
5,971,626 A 10/1999 Knodell et al.
6,041,155 A 3/2000 Anderson et al.
6,049,040 A 4/2000 Biles et al.
6,095,862 A 8/2000 Doye
6,134,370 A 10/2000 Childers et al.
6,178,283 B1 1/2001 Weigel
RE37,080 E 3/2001 Stephenson et al.
6,206,577 B1 3/2001 Hall, III et al.
6,206,581 B1 3/2001 Driscoll et al.
6,227,717 B1 5/2001 Ott et al.
6,238,104 B1 5/2001 Yamakawa et al.
6,240,228 B1 5/2001 Chen
6,247,849 B1 6/2001 Liu
6,250,817 B1 6/2001 Lampert et al.
6,276,840 B1 8/2001 Weiss
6,318,903 B1 11/2001 Andrews
6,364,537 B1 4/2002 Maynard
6,379,052 B1 4/2002 de Jong
6,422,759 B1 7/2002 Kevern
6,450,695 B1 9/2002 Matsumoto
6,461,054 B1 10/2002 Iwase
6,471,412 B1 10/2002 Belenkiy et al.
6,478,472 B1 11/2002 Anderson et al.
6,485,194 B1 11/2002 Shirakawa
6,527,450 B1 3/2003 Miyachi
6,530,696 B1 3/2003 Ueda
6,551,117 B2 4/2003 Poplawski et al.
6,565,262 B2 5/2003 Childers
6,572,276 B1 6/2003 Theis
6,579,014 B2 6/2003 Melton et al.
6,585,194 B1 7/2003 Brushwood
6,634,796 B2 10/2003 de Jong
6,634,801 B1 10/2003 Waldron et al.
6,648,520 B2 11/2003 McDonald et al.
6,668,113 B2 12/2003 Togami
6,682,228 B2 1/2004 Ralhnam et al.
6,685,362 B2 2/2004 Burkholder et al.
6,695,486 B1 2/2004 Falkenberg
6,811,321 B1 11/2004 Schmalzigaug et al.
6,817,272 B2 11/2004 Holland
6,854,894 B1 2/2005 Yunker et al.
6,869,227 B2 3/2005 Del Grosso
6,872,039 B2 3/2005 Baus et al.
6,935,789 B2 8/2005 Gross, III et al.
7,036,993 B2 5/2006 Luther
7,052,186 B1 5/2006 Bates
7,077,576 B2 7/2006 Luther
7,090,407 B2 8/2006 Melton et al.
7,091,421 B2 8/2006 Kukita et al.
7,111,990 B2 9/2006 Melton et al.
7,113,679 B2 9/2006 Melton et al.
D533,504 S 12/2006 Lee
D534,124 S 12/2006 Taguchi
7,150,567 B1 12/2006 Luther et al.
7,153,041 B2 12/2006 Mine et al.
7,198,409 B2 4/2007 Smith et al.
7,207,724 B2 4/2007 Gurreri
D543,146 S 5/2007 Chen et al.
7,258,493 B2 8/2007 Milette
7,261,472 B2 8/2007 Suzuki et al.
7,264,402 B2 9/2007 Theuerkorn
7,281,859 B2 10/2007 Mudd et al.
7,284,912 B2 10/2007 Suzuki et al.
D558,675 S 1/2008 Chien et al.
7,315,682 B1 1/2008 En Lin et al.
7,325,976 B2 2/2008 Gurreri et al.
7,325,980 B2 2/2008 Pepe
7,329,137 B2 2/2008 Martin et al.
7,347,634 B2 3/2008 Gunther et al.
7,354,291 B2 4/2008 Caveney et al.
7,331,718 B2 5/2008 Yazaki et al.
7,371,082 B2 5/2008 Zimmel et al.
7,387,447 B2 6/2008 Mudd et al.
7,390,203 B2 6/2008 Murano et al.
D572,661 S 7/2008 En Lin et al.
7,431,604 B2 10/2008 Waters et al.
7,463,803 B2 12/2008 Cody et al.
7,465,180 B2 12/2008 Kusuda et al.
7,473,124 B1 1/2009 Briant
7,510,335 B1 3/2009 Su et al.
7,513,695 B1 4/2009 Lin et al.
7,534,128 B2 5/2009 Caveney et al.
7,540,666 B2 6/2009 Luther
7,561,775 B2 7/2009 Lin et al.
7,588,373 B1 9/2009 Sato
7,591,595 B2 9/2009 Lue et al.
7,594,766 B1 9/2009 Sasser et al.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,641,398	B2	1/2010	O'Riorden et al.	
7,695,199	B2	4/2010	Teo et al.	
7,699,533	B2	4/2010	Milette	
7,712,970	B1	5/2010	Lee	
7,717,625	B2	5/2010	Margolin	
7,824,113	B2	11/2010	Wong et al.	
7,837,395	B2	11/2010	Lin et al.	
D641,708	S	7/2011	Tammauchi	
8,083,450	B1	12/2011	Smith et al.	
8,152,385	B2	4/2012	de Jong	
8,186,890	B2	5/2012	Lu	
8,192,091	B2	6/2012	Hsu et al.	
8,202,009	B2	6/2012	Lin et al.	
8,221,007	B2	7/2012	Peterhans	
8,251,733	B2	8/2012	Wu	
8,267,595	B2	9/2012	Lin et al.	
8,270,796	B2	9/2012	Nhep	
8,408,815	B2	4/2013	Lin et al.	
8,414,196	B2	4/2013	Lu	
8,465,317	B2	6/2013	Gniadek et al.	
8,534,928	B2	9/2013	Cooke	
8,550,728	B2	10/2013	Takahashi	
8,556,645	B2	10/2013	Crain	
8,559,781	B2	10/2013	Childers	
8,622,634	B2	1/2014	Arnold	
8,636,424	B2	1/2014	Kuffel et al.	
8,651,749	B2	2/2014	Clovis et al.	
8,676,022	B2	3/2014	Jones	
8,678,670	B2	3/2014	Takahashi	
8,727,638	B2	5/2014	Lee	
8,757,894	B2	6/2014	Katoh	
8,764,308	B2	7/2014	Irwin	
8,770,863	B2	7/2014	Cooke et al.	
8,869,661	B2	10/2014	Opstad	
9,052,474	B2	6/2015	Jiang	
9,063,296	B2	6/2015	Dong	
9,250,399	B2	2/2016	Margolin et al.	
9,250,402	B2	2/2016	Ishii et al.	
9,310,569	B2	4/2016	Lee	
9,366,829	B2	6/2016	Czosnowski	
9,411,110	B2	8/2016	Barnette, Jr. et al.	
9,448,370	B2	9/2016	Xue et al.	
9,465,172	B2	10/2016	Shih	
9,494,744	B2	11/2016	de Jong	
9,548,557	B2	1/2017	Liu	
9,551,842	B2	1/2017	Theuerkorn	
9,557,495	B2	1/2017	Raven et al.	
9,568,686	B2	2/2017	Fewkes et al.	
9,581,768	B1	2/2017	Baca et al.	
9,599,778	B2	3/2017	Wong et al.	
9,658,409	B2	5/2017	Gniadek	
9,678,283	B1	6/2017	Chang et al.	
9,684,130	B2	6/2017	Veatch et al.	
9,684,136	B2	6/2017	Cline et al.	
9,684,313	B2	6/2017	Chajec	
9,709,753	B1	8/2017	Chang et al.	
9,778,425	B2	10/2017	Nguyen	
9,829,644	B2	11/2017	Nguyen	
9,829,645	B2	11/2017	Good	
9,829,653	B1	11/2017	Nishiguchi	
9,869,825	B2	1/2018	Bailey et al.	
9,880,361	B2	1/2018	Childers	
9,946,035	B2	4/2018	Gustafson	
9,971,103	B2	5/2018	de Jong et al.	
9,989,711	B2	6/2018	Ott et al.	
10,031,296	B2	7/2018	Good	
10,067,301	B2	9/2018	Murray	
10,107,972	B1	10/2018	Gniadek et al.	
10,114,180	B2	10/2018	Suzic	
10,146,011	B2	12/2018	Nhep	
10,281,668	B2	5/2019	Takano et al.	
10,281,669	B2	5/2019	Takano et al.	
10,859,778	B2 *	12/2020	Takano	G02B 6/4292
11,181,701	B2 *	11/2021	Wong	G02B 6/3821
2002/0168148	A1	11/2002	Gilliland	
2002/0172467	A1	11/2002	Anderson et al.	
2002/0191919	A1	12/2002	Nolan	
2003/0053787	A1	3/2003	Lee	
2003/0063862	A1	4/2003	Fillion	
2003/0157825	A1	8/2003	Kane	
2004/0052473	A1	3/2004	Seo	
2004/0109646	A1	6/2004	Anderson	
2004/0161958	A1	6/2004	Togami et al.	
2004/0136657	A1	7/2004	Ngo	
2004/0141693	A1	7/2004	Szilagvi et al.	
2004/0234209	A1	11/2004	Cox et al.	
2004/0247252	A1	12/2004	Ehrenreich	
2005/0036744	A1	2/2005	Caveney et al.	
2005/0111796	A1	5/2005	Matasek et al.	
2005/0135755	A1	6/2005	Kiani et al.	
2005/0141817	A1	6/2005	Yazaki et al.	
2006/0013539	A1	1/2006	Thaler	
2006/0076061	A1	4/2006	Bush	
2006/0089049	A1	4/2006	Sedor	
2006/0127025	A1	6/2006	Haberman	
2006/0153503	A1	7/2006	Suzuki	
2006/0160429	A1	7/2006	Dawiedczyk et al.	
2006/0193562	A1	8/2006	Theuerkorn	
2006/0269194	A1	11/2006	Luther et al.	
2006/0274411	A1	12/2006	Yamauchi	
2007/0025665	A1	2/2007	Dean	
2007/0028409	A1	2/2007	Yamada	
2007/0079854	A1	4/2007	You	
2007/0098329	A1	6/2007	Shimoji et al.	
2007/0149028	A1	6/2007	Yu et al.	
2007/0149062	A1	6/2007	Long et al.	
2007/0230874	A1	10/2007	Lin	
2007/0232115	A1	10/2007	Burke et al.	
2007/0243749	A1	10/2007	Wu	
2008/0008430	A1	1/2008	Kewitsch	
2008/0013896	A1	1/2008	Salzberg et al.	
2008/0044137	A1	2/2008	Luther et al.	
2008/0056647	A1	3/2008	Margolin et al.	
2008/0064334	A1	3/2008	Hamadi	
2008/0069501	A1	3/2008	Mudd et al.	
2008/0101757	A1	5/2008	Lin et al.	
2008/0226237	A1	9/2008	O'Rioreden et al.	
2008/0267566	A1	10/2008	En Lin	
2009/0028507	A1	1/2009	Jones et al.	
2009/0047818	A1	2/2009	Irwin et al.	
2009/0092360	A1	4/2009	Lin et al.	
2009/0176401	A1	7/2009	Gu	
2009/0196555	A1	8/2009	Lin et al.	
2009/0214162	A1	8/2009	O'Riorden et al.	
2009/0220197	A1	9/2009	Gniadek	
2009/0220200	A1	9/2009	Wong et al.	
2009/0222457	A1	9/2009	Gallant	
2009/0290839	A1	11/2009	En Lin	
2009/0290938	A1	11/2009	Asaoka	
2010/0034502	A1	2/2010	Lu et al.	
2010/0054668	A1	3/2010	Nelson	
2010/0061069	A1	3/2010	Cole	
2010/0092136	A1	4/2010	Nhep	
2010/0220961	A1	9/2010	de Jong et al.	
2010/0247041	A1	9/2010	Szilagyi	
2010/0284656	A1	11/2010	Morra	
2010/0322561	A1	12/2010	Lin et al.	
2011/0044588	A1	2/2011	Larson et al.	
2011/0058773	A1	3/2011	Peterhans	
2011/0131801	A1	6/2011	Nelson et al.	
2011/0155810	A1	6/2011	Taniguichi	
2011/0177710	A1	7/2011	Tobey	
2011/0239220	A1	9/2011	Gibson	
2012/0099822	A1	4/2012	Kuffel et al.	
2012/0155810	A1	6/2012	Nakagawa	
2012/0189260	A1	7/2012	Kowalczyk et al.	
2012/0237177	A1	9/2012	Minota	
2012/0269485	A1	10/2012	Haley et al.	
2012/0301080	A1	11/2012	Gniadek	
2012/0308183	A1	12/2012	Irwin	
2012/0328248	A1	12/2012	Larson	
2013/0019423	A1	1/2013	Srutkowski	
2013/0071067	A1	3/2013	Lin	
2013/0089995	A1	4/2013	Gniadek et al.	

(56) **References Cited**

U.S. PATENT DOCUMENTS

2013/0094816 A1 4/2013 Lin et al.
2013/0101258 A1 4/2013 Hikosaka
2013/0121653 A1 5/2013 Shitama et al.
2013/0170797 A1 7/2013 Ott
2013/0183012 A1 7/2013 Lopez et al.
2013/0216185 A1 8/2013 Klavuhn
2013/0259429 A1 10/2013 Czosnowski et al.
2013/0308915 A1 11/2013 Buff
2013/0322825 A1* 12/2013 Cooke G02B 6/3831 385/59
2014/0016901 A1 1/2014 Lambourn et al.
2014/0023322 A1 1/2014 Gniadek
2014/0050446 A1 2/2014 Chang
2014/0056562 A1 2/2014 Limbert
2014/0133808 A1 5/2014 Hill et al.
2014/0169727 A1 6/2014 Veatch et al.
2014/0219621 A1 8/2014 Barnette, Jr. et al.
2014/0226946 A1 8/2014 Cooke et al.
2014/0241644 A1 8/2014 Kang
2014/0241678 A1 8/2014 Bringuier et al.
2014/0241688 A1 8/2014 Isenhour et al.
2014/0334780 A1 11/2014 Nguyen et al.
2014/0348477 A1 11/2014 Chang
2015/0003788 A1 1/2015 Chen
2015/0111417 A1 4/2015 Vanderwoud
2015/0177463 A1 6/2015 Lee
2015/0198766 A1 7/2015 Takahashi
2015/0212282 A1 7/2015 Lin
2015/0241644 A1 8/2015 Lee
2015/0301294 A1 10/2015 Chang et al.
2015/0331201 A1 11/2015 Takano et al.
2015/0355417 A1 12/2015 Takano et al.
2015/0370021 A1 12/2015 Chan
2015/0378113 A1 12/2015 Good et al.
2016/0131849 A1 5/2016 Takano et al.
2016/0139343 A1 5/2016 Dean, Jr. et al.
2016/0161681 A1 6/2016 Banal, Jr. et al.
2016/0172852 A1 6/2016 Tamura
2016/0178852 A1 6/2016 Takano
2016/0195682 A1 6/2016 Takano
2016/0291262 A1 6/2016 Chang et al.
2016/0231512 A1 8/2016 Seki
2016/0259135 A1 9/2016 Gniadek et al.
2016/0266326 A1 9/2016 Gniadek
2016/0320572 A1 11/2016 Gniadek
2016/0349458 A1 12/2016 Murray
2016/0370545 A1 12/2016 Jiang
2017/0003458 A1 1/2017 Gniadek
2017/0205587 A1 7/2017 Chang et al.
2017/0205590 A1 7/2017 Bailey
2017/0205591 A1 7/2017 Takano et al.
2017/0212313 A1 7/2017 Elenabaas
2017/0212316 A1 7/2017 Takano
2017/0254961 A1 9/2017 Kamada et al.
2017/0276275 A1 9/2017 Beemer et al.
2017/0276887 A1 9/2017 Allen
2017/0277059 A1 9/2017 Miura et al.
2017/0343740 A1* 11/2017 Nguyen G02B 6/4246
2018/0128988 A1 5/2018 Chang
2018/0156988 A1 6/2018 Gniadek
2018/0172923 A1 6/2018 Bauco
2018/0252872 A1 9/2018 Chen
2018/0341069 A1 11/2018 Takano
2019/0064447 A1 2/2019 Chang et al.
2019/0204513 A1 7/2019 Davidson et al.

FOREIGN PATENT DOCUMENTS

CN 2836038 Y 11/2006
CN 2836038 Y 11/2006
CN 201383588 Y 1/2010
CN 201383588 Y 1/2010
CN 2026500189 U 12/2013
CN 106997078 8/2017
DE 19507669 A1 9/1996
DE 202006011910 U1 3/2007
DE 102006019335 U1 10/2007
EP 1074868 A1 2/2001
EP 1074868 A1 7/2001
EP 1211537 A2 6/2002
EP 1211537 A3 6/2002
EP 1245980 A1 10/2002
EP 1566674 A2 8/2005
GB 2111240 A 6/1983
JP 2000089059 A 3/2000
JP 03752331 B2 3/2006
JP 2009229545 A 10/2009
JP 2009276493 A 11/2009
JP 04377820 B2 12/2009
JP 2011027876 A 2/2011
JP 2012053375 A 3/2012
KR 20040028409 A 4/2006
KR 2009005382 A 1/2009
KR 200905382 U 6/2009
KR 1371686 B1 3/2014
TW 200821653 A 5/2008
WO 200179904 A2 10/2001
WO WO2001079904 A2 10/2001
WO 2004027485 A1 4/2004
WO WO2006007120 A1 1/2006
WO 2008112986 A1 9/2008
WO 2009135787 A1 11/2009
WO 2010024851 A2 3/2010
WO 2012136702 A1 10/2012
WO 2012162385 A1 11/2012
WO WO2012162385 A1 11/2012
WO 2014028527 A1 2/2014
WO 2014182351 A1 11/2014
WO WO2015103783 A1 7/2015
WO 2015191024 A1 12/2015
WO 2016019993 A1 2/2016
WO 2016148741 A1 9/2016
WO WO2019126333 A1 6/2019

OTHER PUBLICATIONS

International Search Report and Written Opinion, Application No. PCT/US2019/013861, dated Apr. 8, 2019, pp. 15.
Fiber Optic Connectors Tutorial, 2018, pp. 20.
Fiber Optic Glossary, Feb. 29, 2016, pp. 93.
"Fiber Optic Interconnect Solutions, Tactical Fiber Optical Connectors, Cables and Termini" 2006, Glenair, Inc., Glendale, California, www.mps-electronics.de, pp. 232.
"Fiber Optic Products Catalog" Nov. 2007, Tyco Electronics Corporation, Harrisburg, Pennsylvania, www.ampnetconnect.com, pp. 204.
"Fiber Optic Connectors and Assemblies Catalog" 2009, Huber & Suhner Fiver Optics, Herisau, Switzerland, www.hubersuhner.com, pp. 104.
PCT/US2018/062406 International Search Report dated Mar. 18, 2019.
PCT/US2018/062406 The written Opinion dated Mar. 18, 2019.
PCT/US2018/062405 International Search Report dated Apr. 3, 2019.
PCT/US2018/062405 The written Opinion dated Apr. 3, 2019.
PCT/IB2018/056133 Written Opinion dated Jan. 3, 2019.
PCY/IB/056133 Search Report dated Jan. 3, 2019.
Final Office Action, U.S. Appl. No. 16/035,691, dated Feb. 11, 2019, pp. 8.
Non-Final Office Action, U.S. Appl. No. 16/035,695, dated Sep. 28, 2018, pp. 7.
International Search Report and Written Opinion, Application No. PCT/US/2018/042202, pp. 17, dated Dec. 7, 2018.
International Search Report and Written Opinion, Application No. PCT/US19/24718, dated Jun. 26, 2019, pp. 7.
ISR for PCT/US2019/013861, dated Apr. 8, 2019, 3 pages.
WO for PCT/US2019/013861, dated Apr. 8, 2019, 11 pages.
International Search Report and Written Opinion for Application No. PCT/US2018/62406 dated Mar. 18, 2019, 12, pages, United States.

(56) **References Cited**

OTHER PUBLICATIONS

International Search Report and Written Opinion for Application No. PCT/US2019/40700 dated Sep. 27, 2019, 12, pages, United States.
International Search Report and Written Opinion for Application No. PCT/US2019/50895 dated Jan. 6, 2020, 12, pages, United States.
International Search Report and Written Opinion for Application No. PCT/US2019/50909 dated Dec. 17, 2019, 11, pages, United States.
International Search Report and Written Opinion for Application No. PCT/US2019/56564 dated Jan. 14, 2020, 14, pages, United States.
International Search Report and Written Opinion, Application No. PCT/US19/46397, dated Nov. 12, 2019, pp. 6.
International Search Report; PCT/US2018/042202 filed Jul. 16, 2018; Applicant: Senko Advanced Components, Inc.
International Preliminary Report on Patentability for PCT/US2019/022940 dated Oct. 1, 2020, 11 pages.
Extended European Search Report and Written Opinion, Application No. 18832246.5, dated Mar. 15, 2021, pp. 6.

* cited by examiner

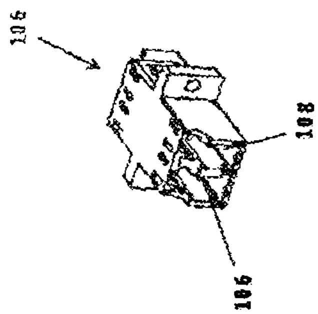


FIG. 1B
(Prior Art)

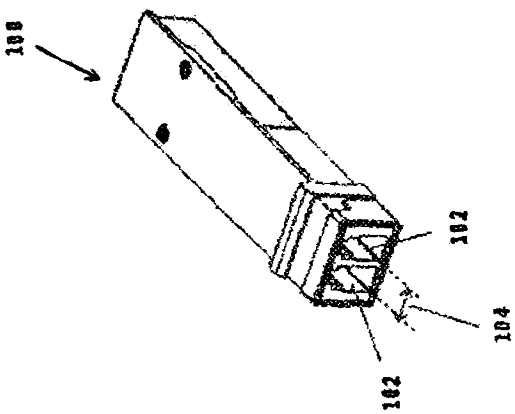


FIG. 1A
(Prior Art)

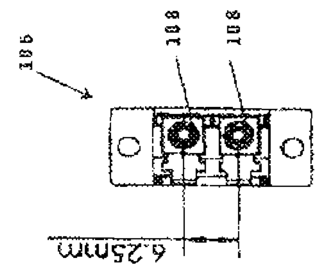


FIG. 1D
(Prior Art)

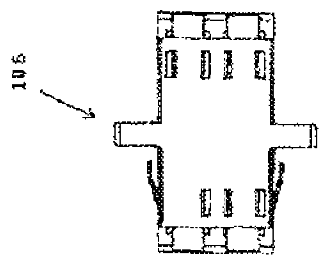


FIG. 1C
(Prior Art)

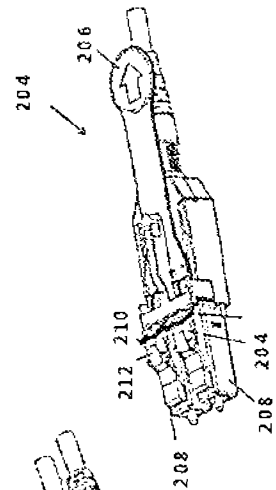


FIG. 2B
(Prior Art)

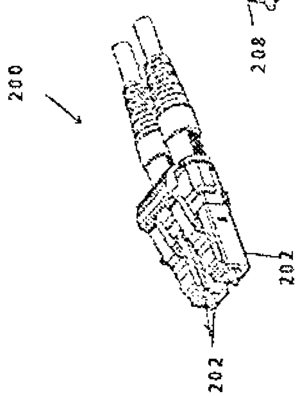


FIG. 2A
(Prior Art)

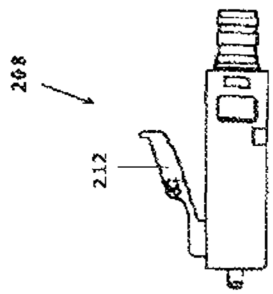


FIG. 2D
(Prior Art)

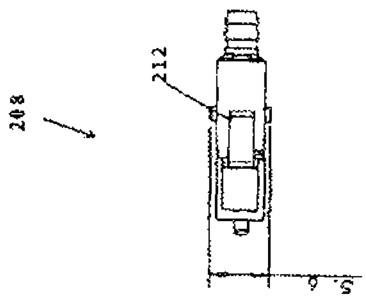


FIG. 2C
(Prior Art)

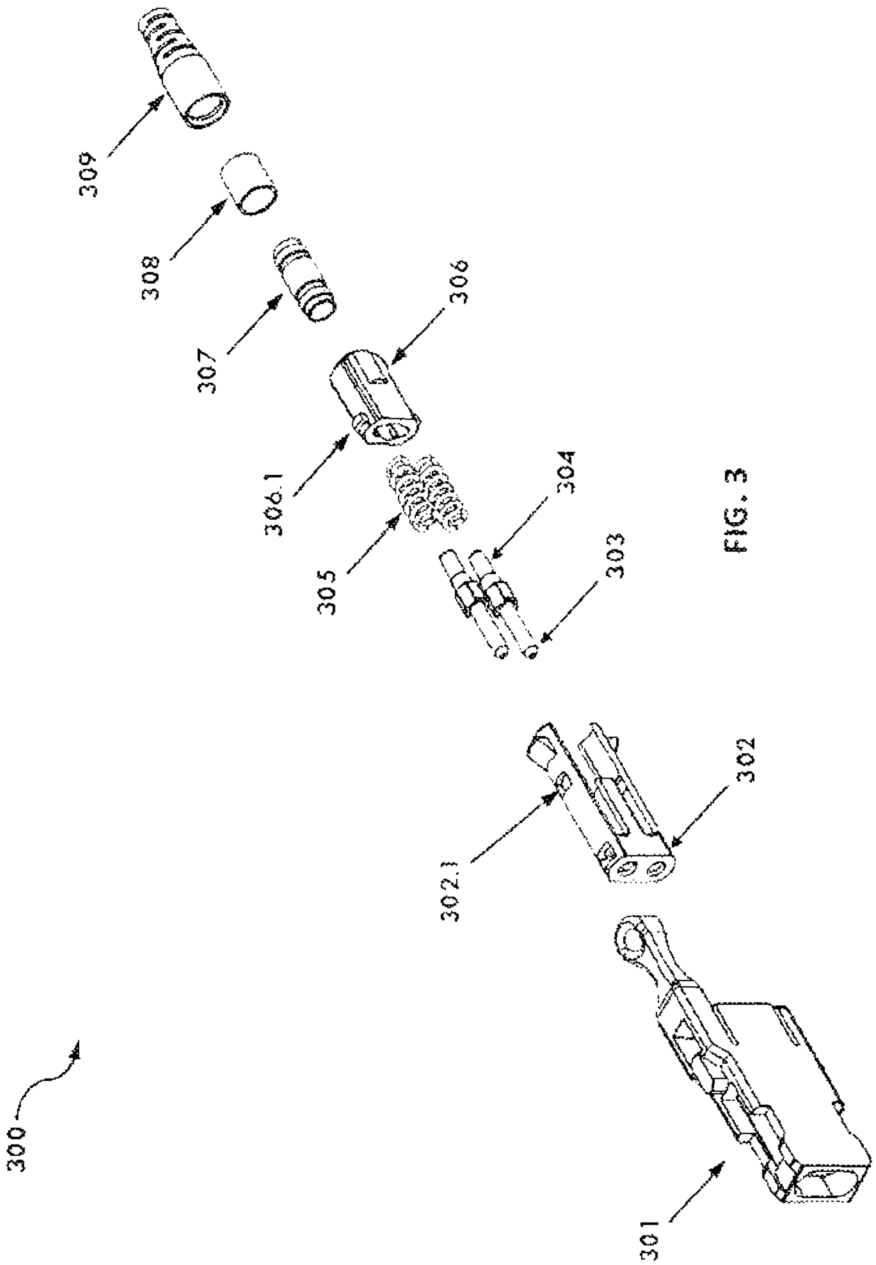


FIG. 3

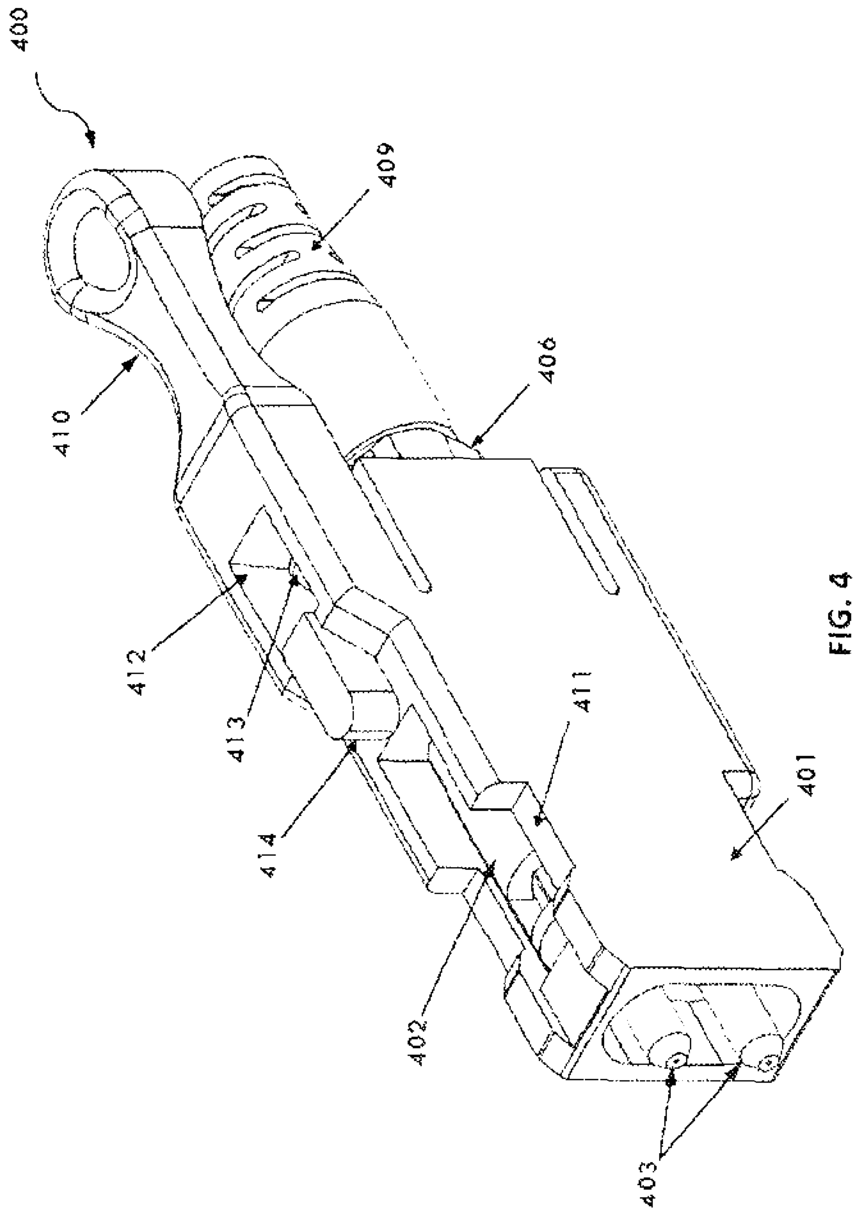


FIG. 4

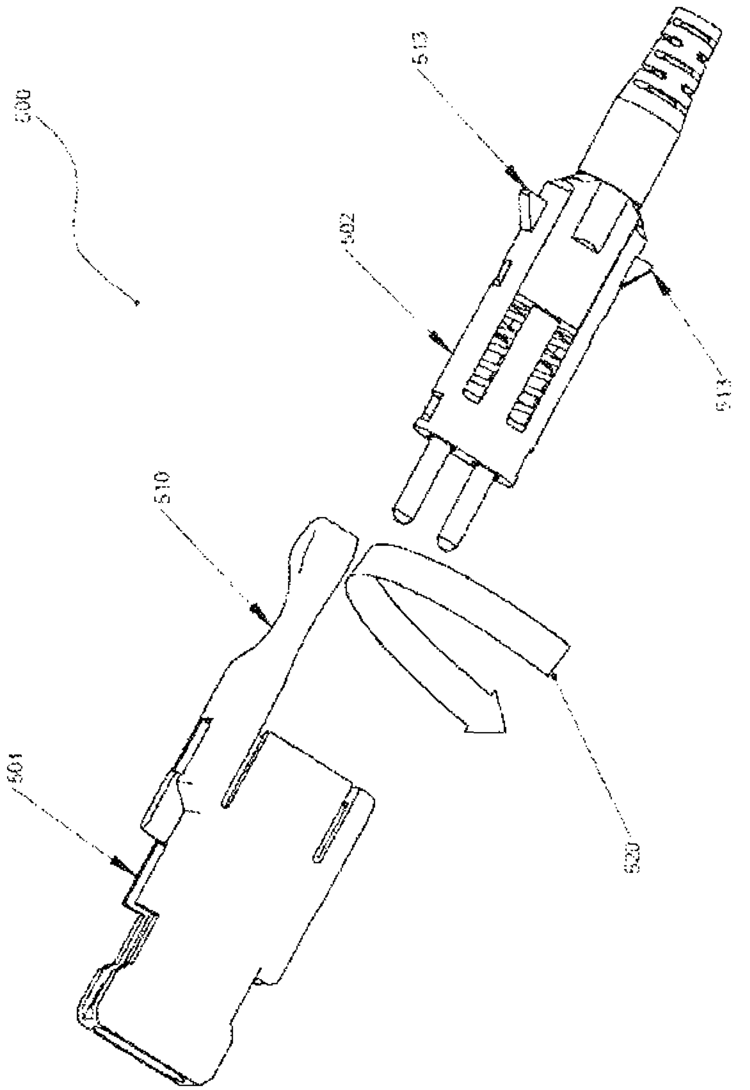


FIG. 5

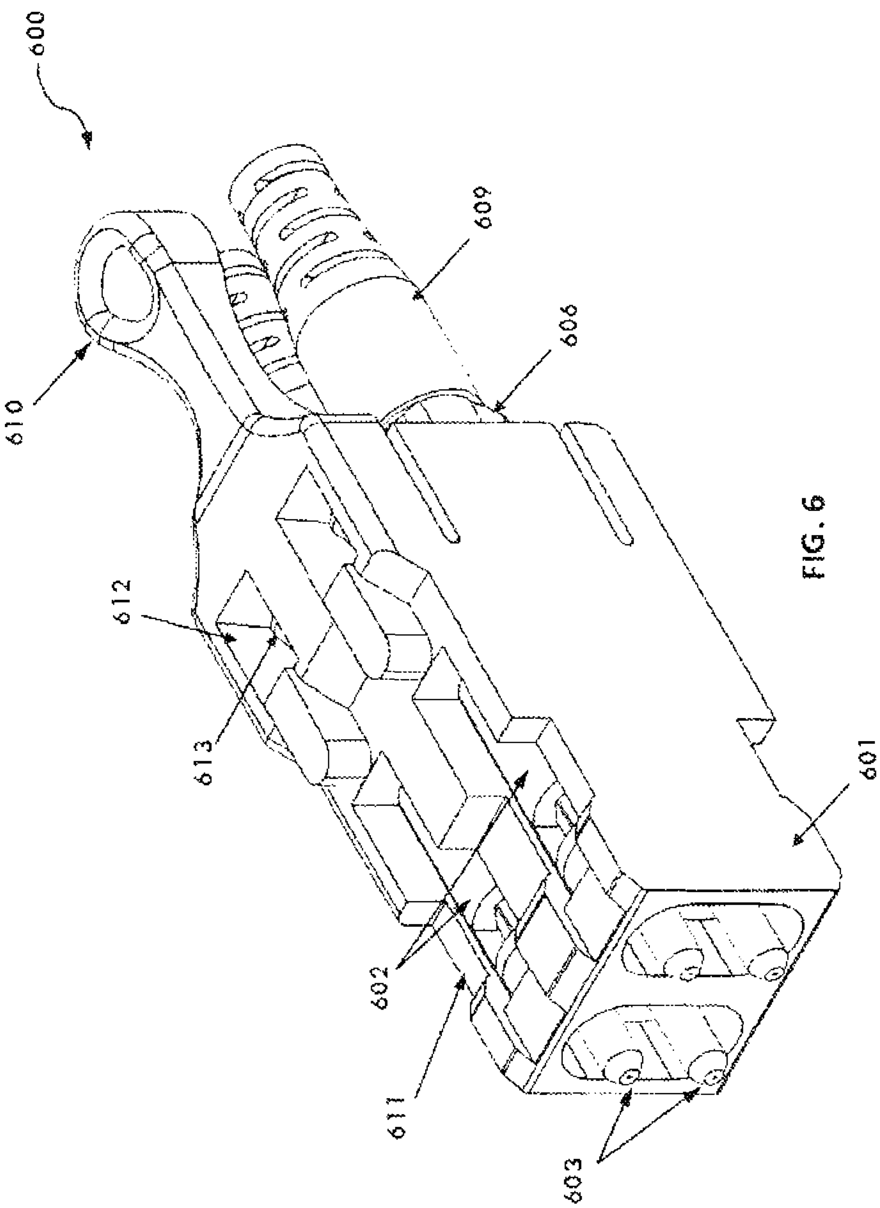


FIG. 6

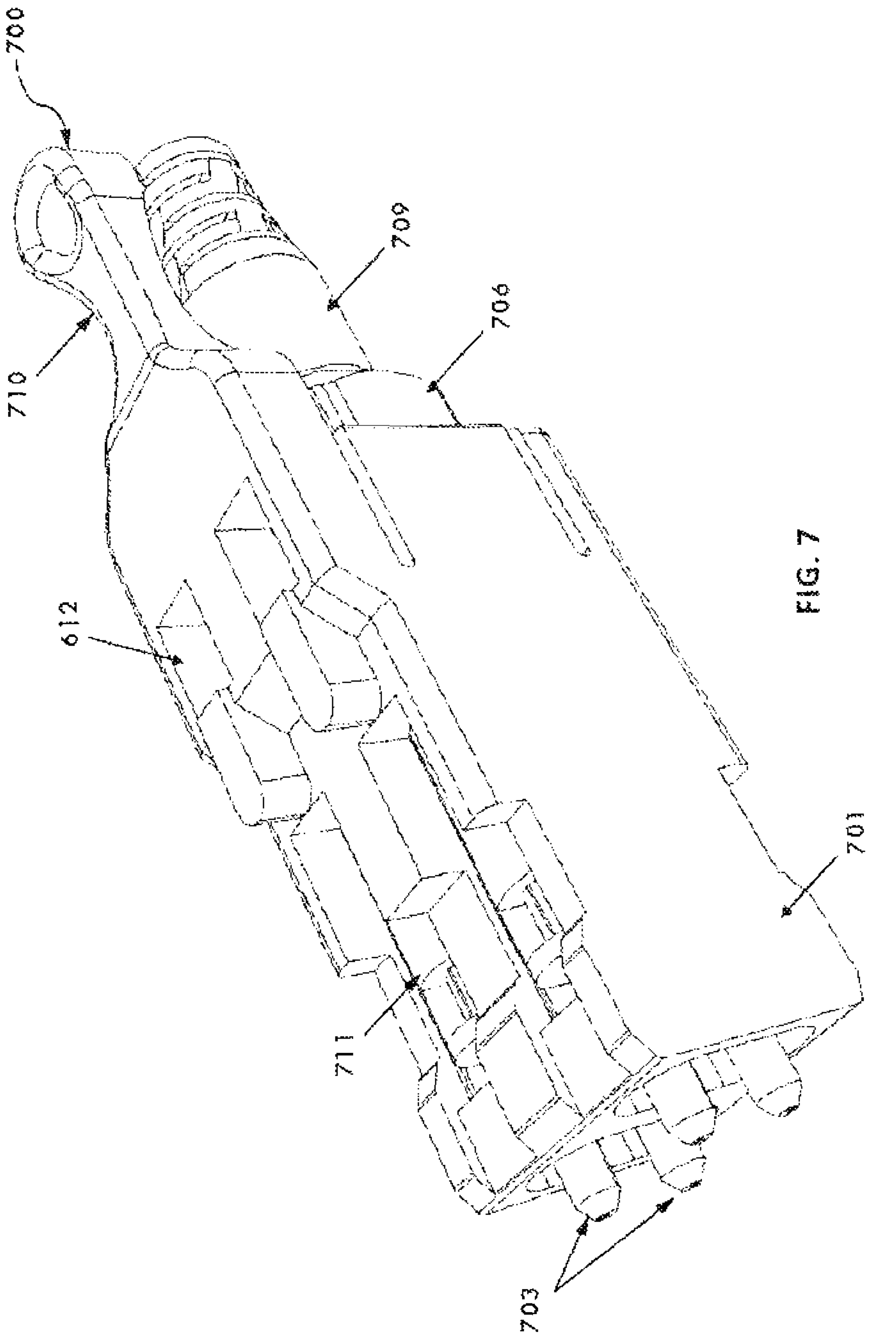


FIG. 7

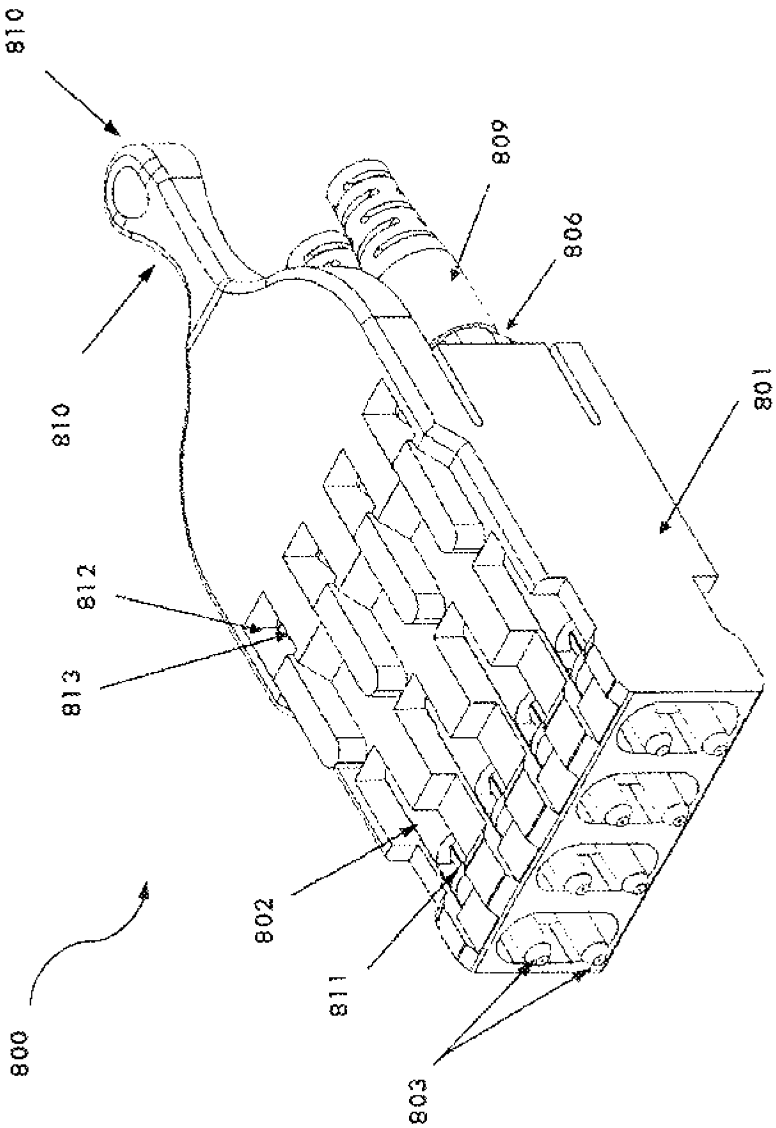


FIG. 8

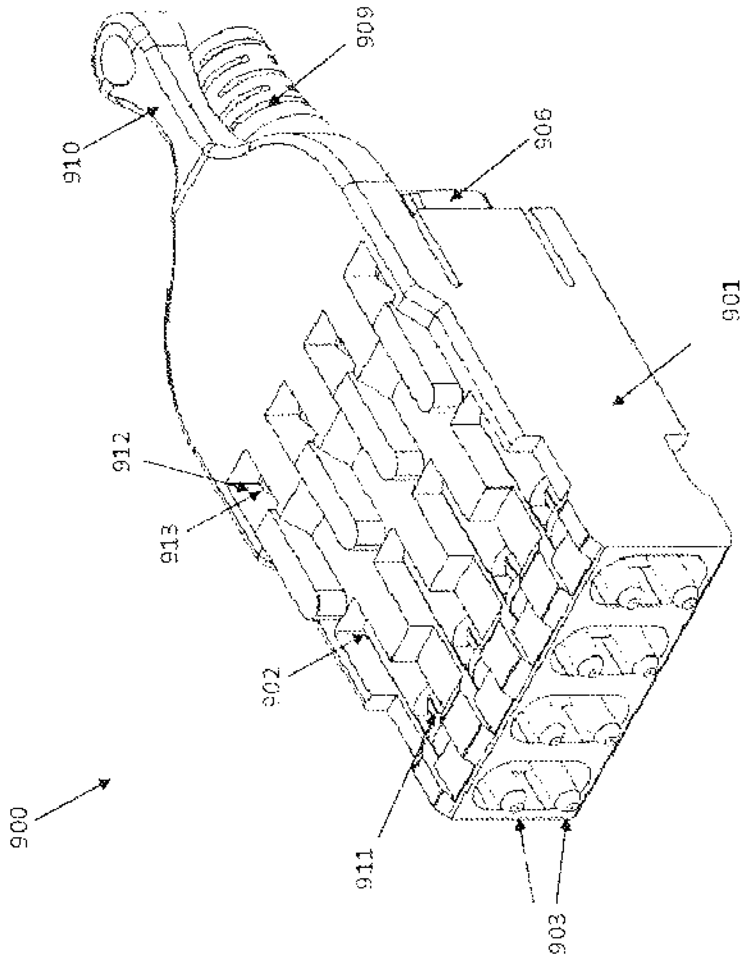


FIG. 9

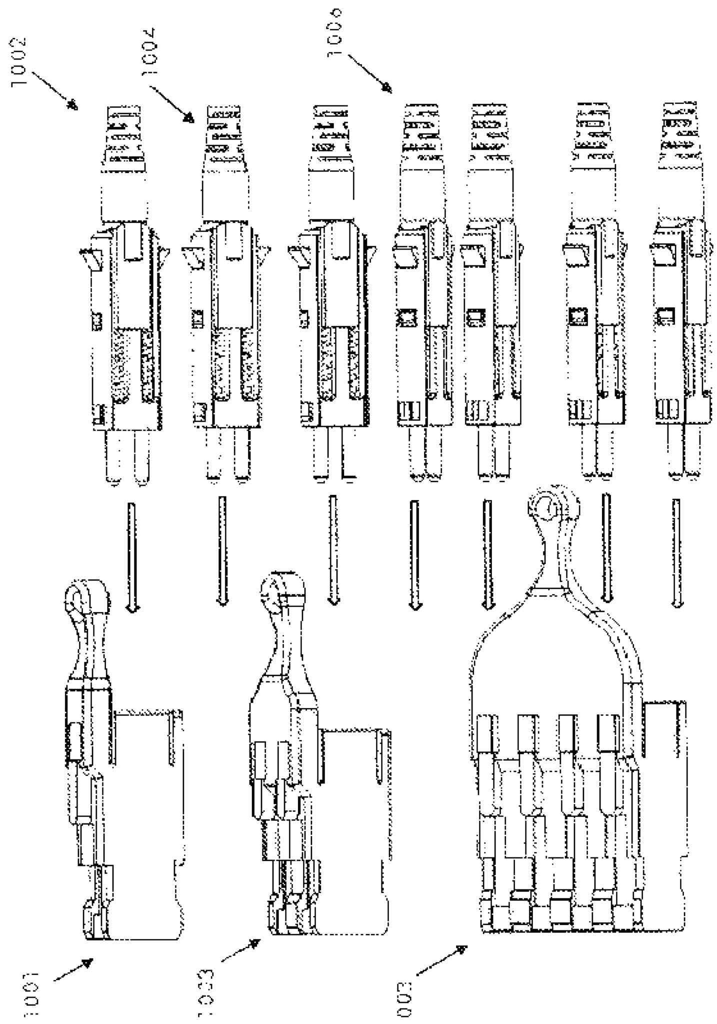


FIG. 10

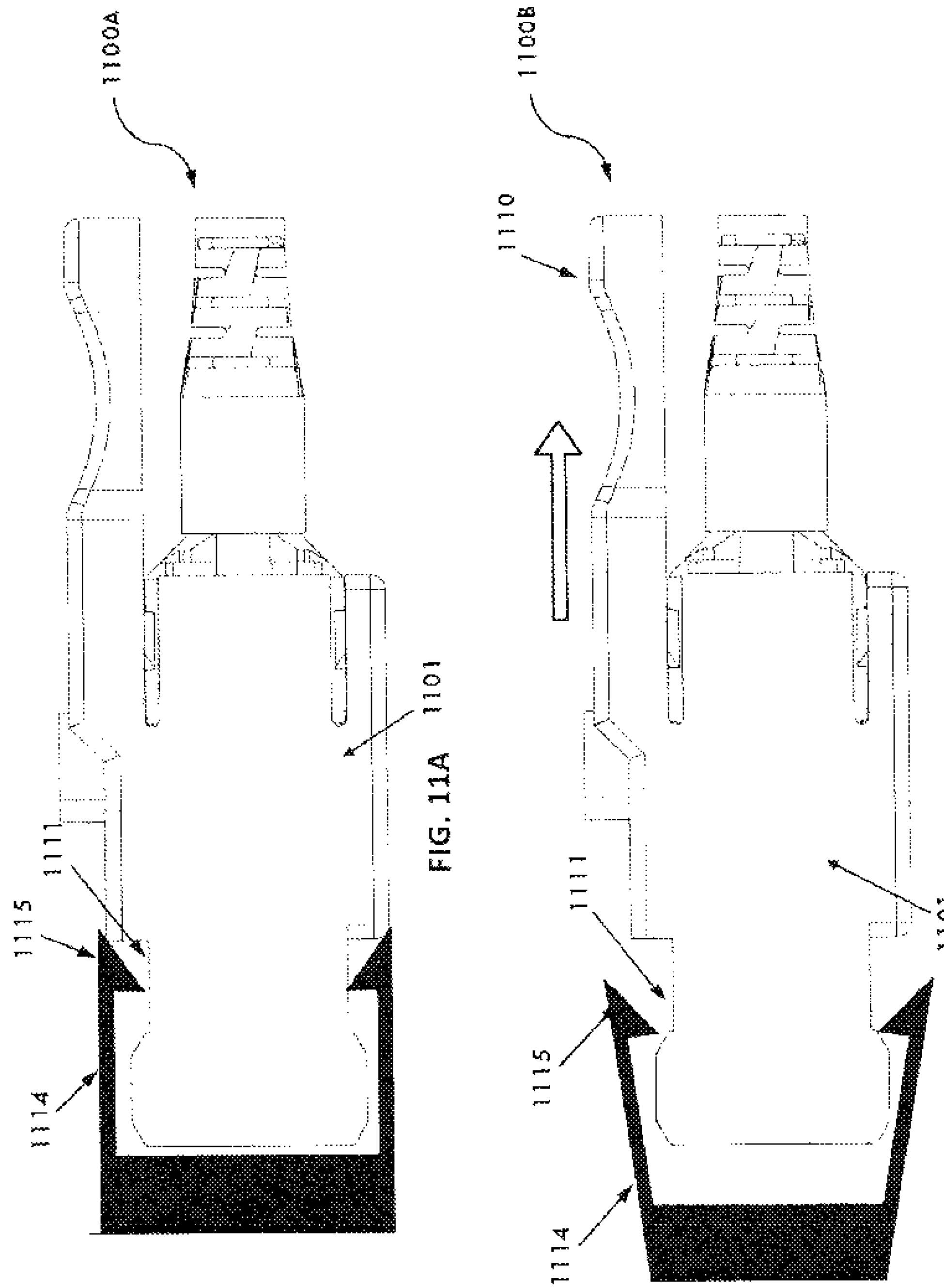


FIG. 11A

FIG. 11B

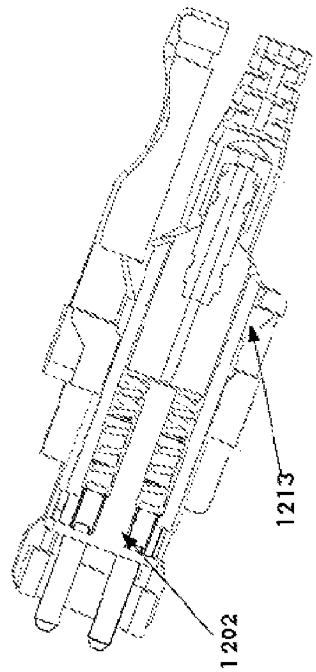


FIG. 12B

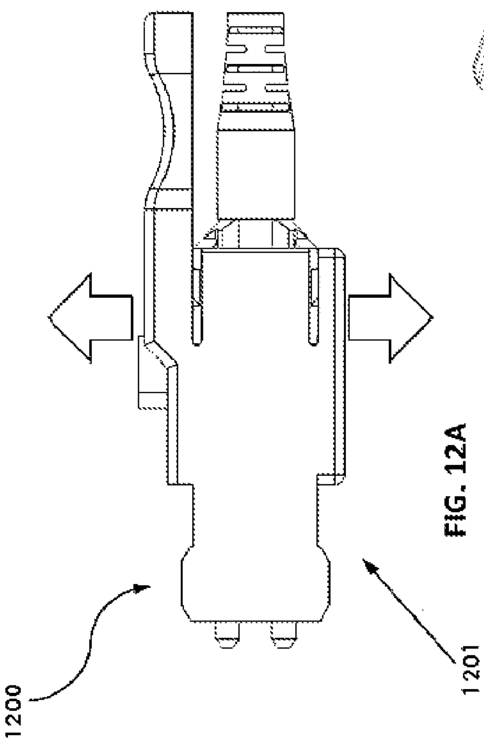


FIG. 12A

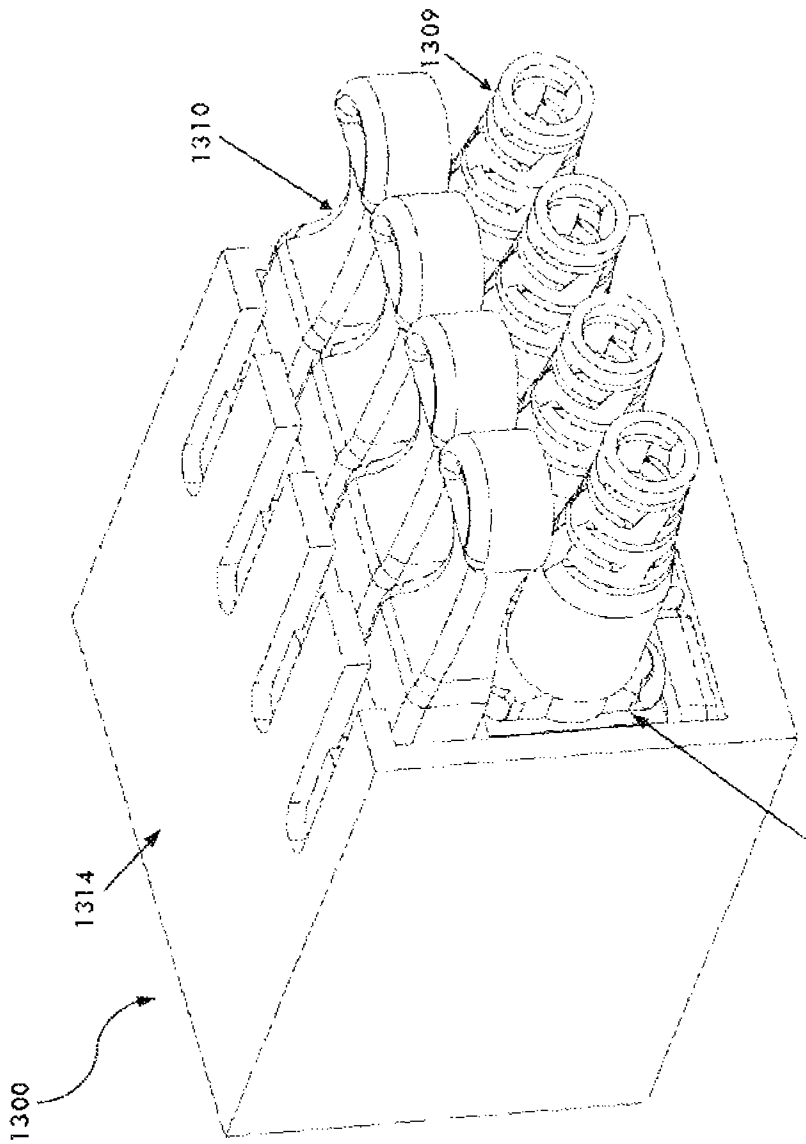


FIG. 13

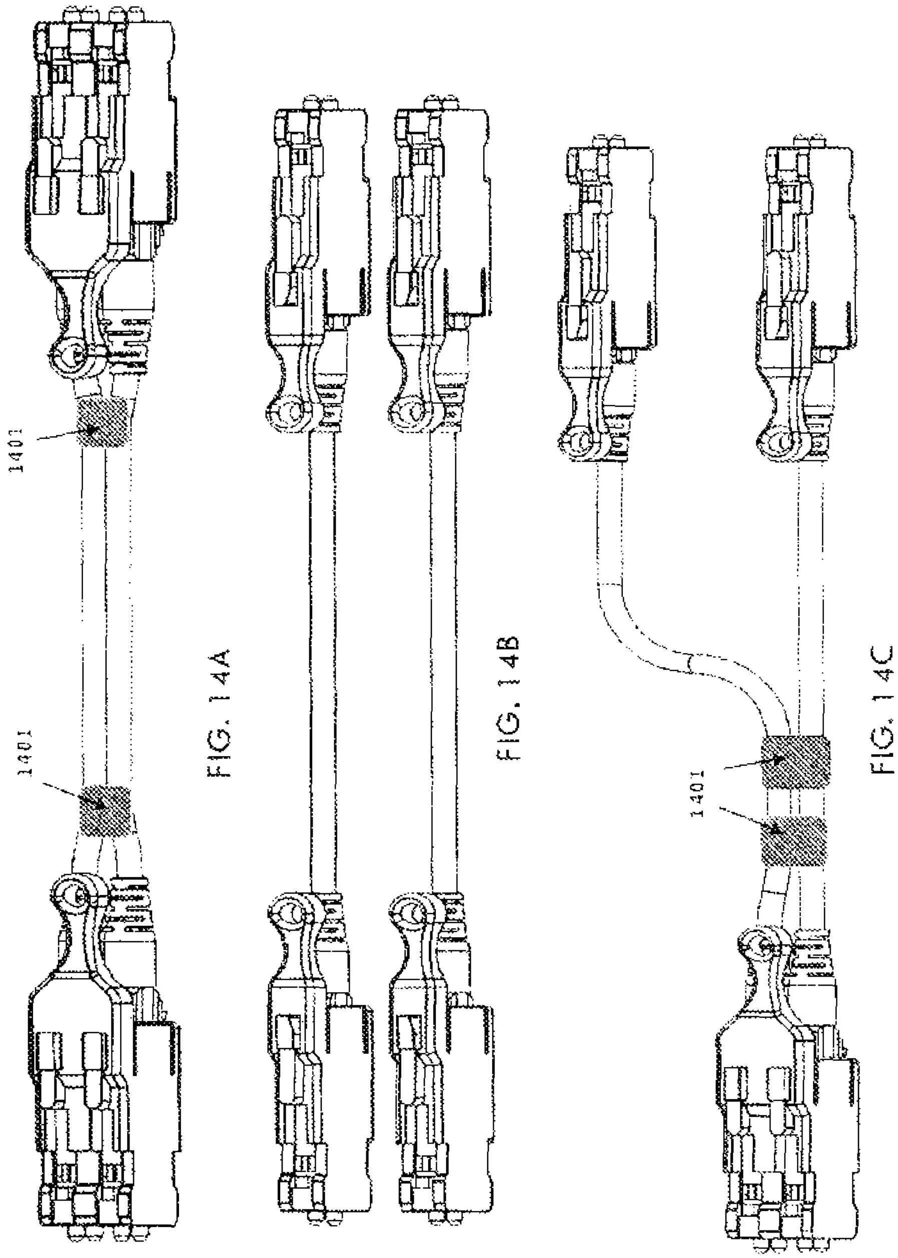


FIG. 14A

FIG. 14B

FIG. 14C

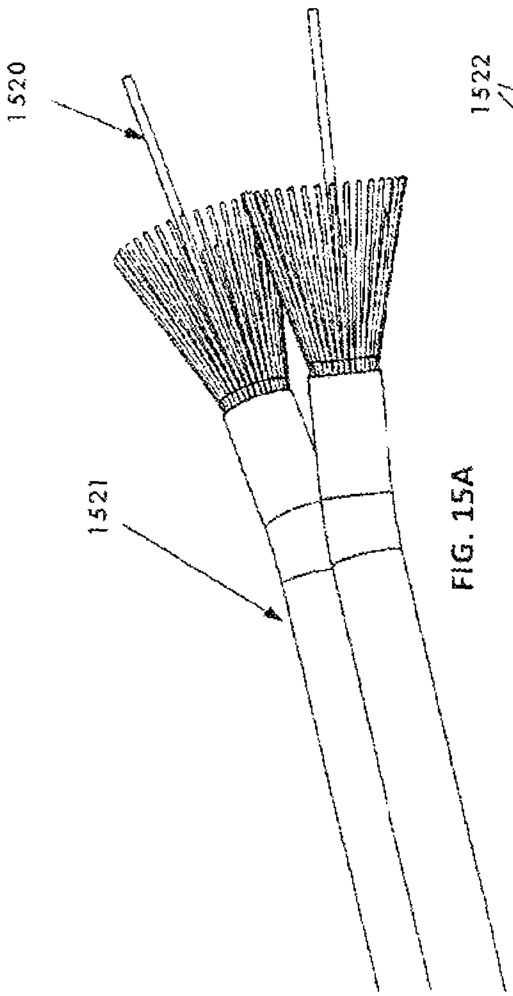


FIG. 15A

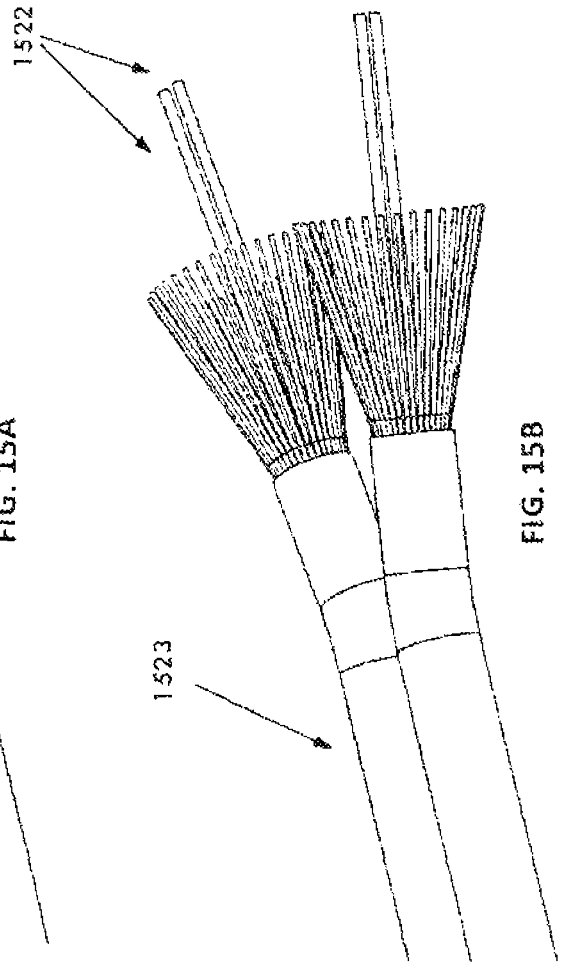
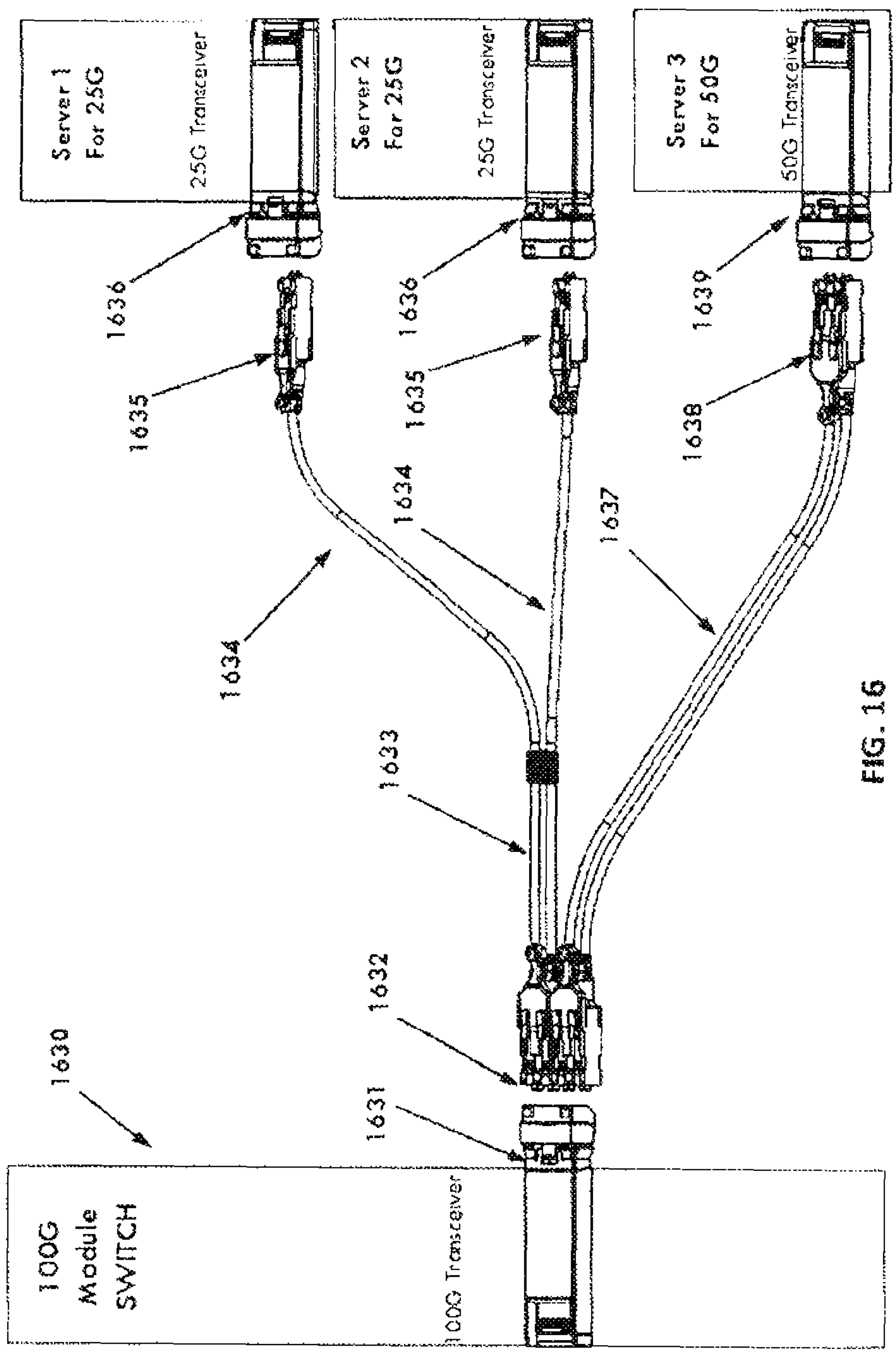


FIG. 15B


Server 1
For 25G
25G Transceiver
Server 2
For 25G
25G Transceiver
Server 3
For 50G
50G Transceiver
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1637
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1632
1631
1630
100G
Module
SWITCH
100G Transceiver

FIG. 16

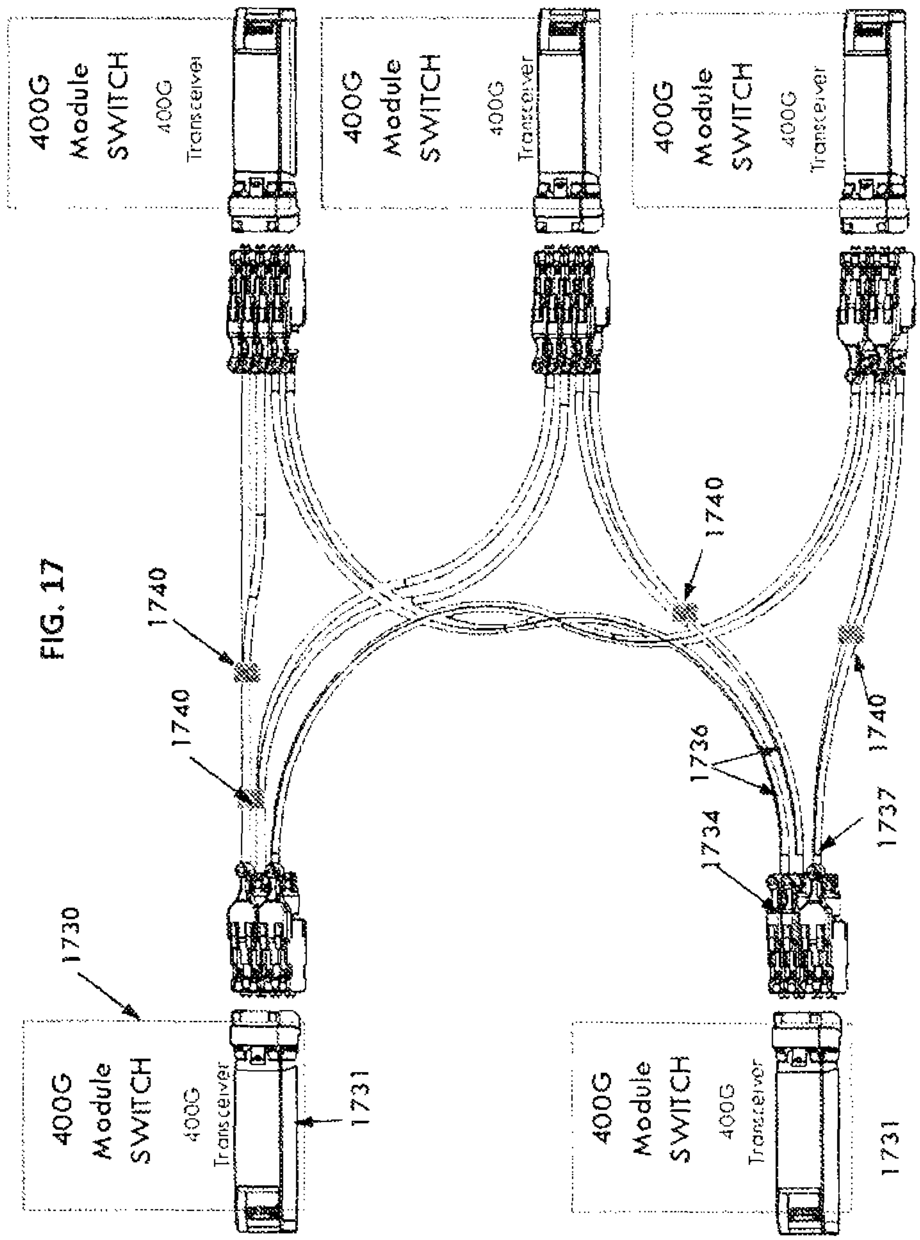
400G Module SWITCH
400G Transceiver
400G Module SWITCH
400G Transceiver
400G Module SWITCH
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FIG. 17

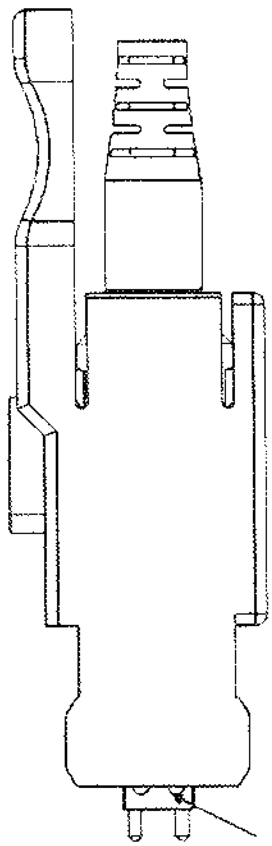

FIG. 18A

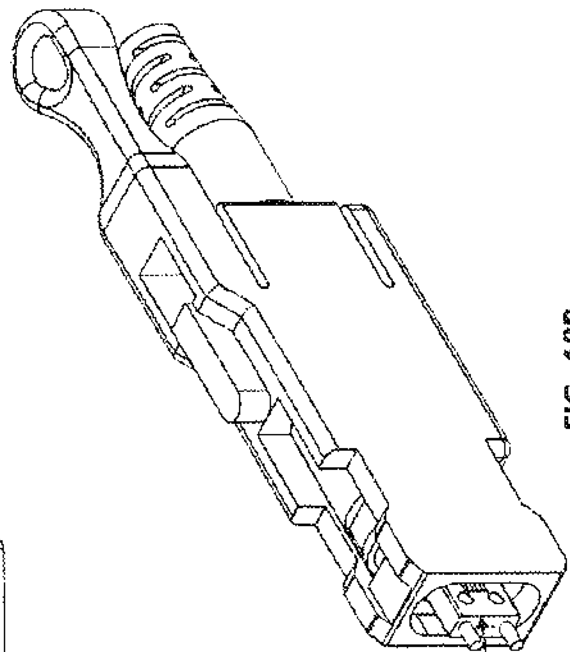

FIG. 18B

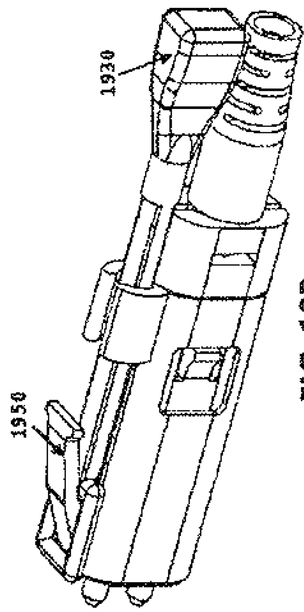

FIG. 19B

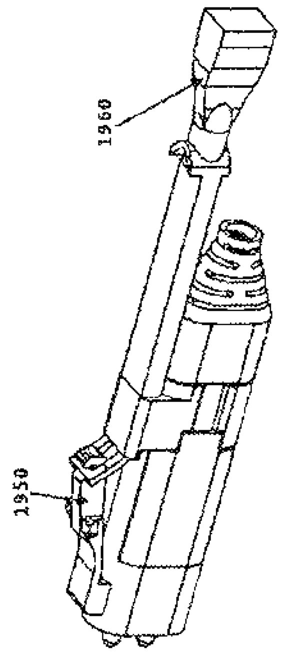

FIG. 19D

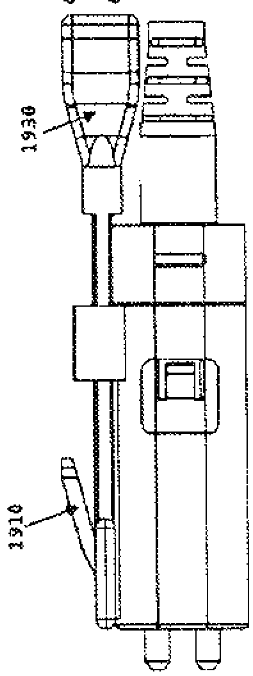

FIG. 19A

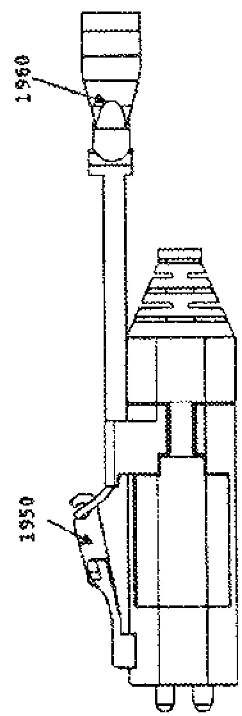

FIG. 19C

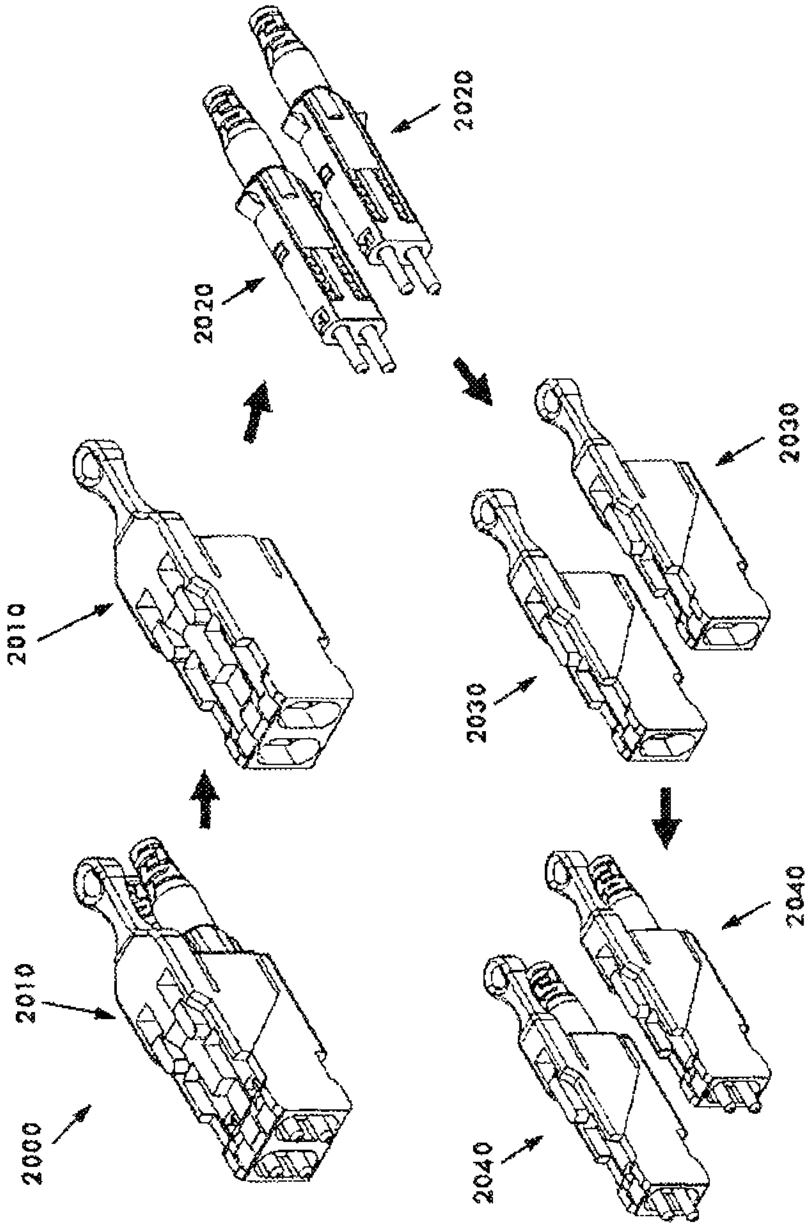

FIG. 20

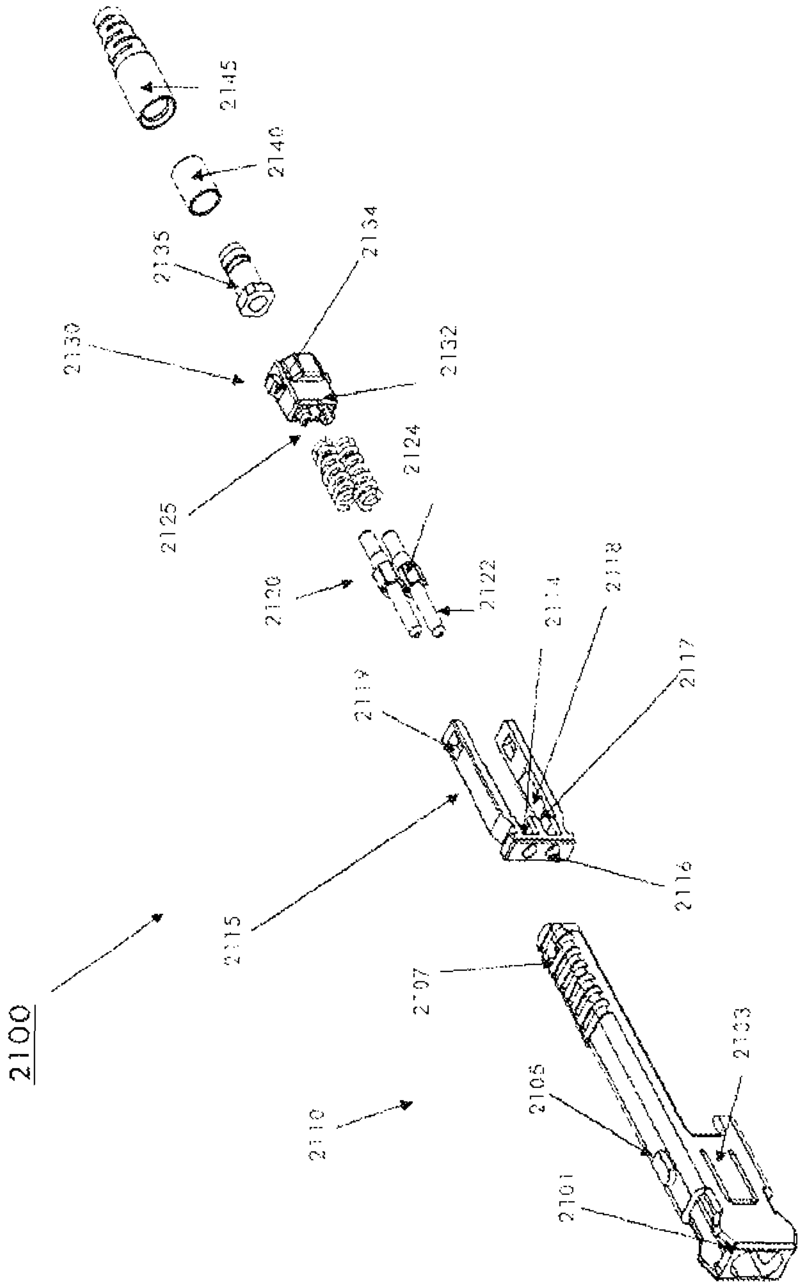
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FIG. 21A

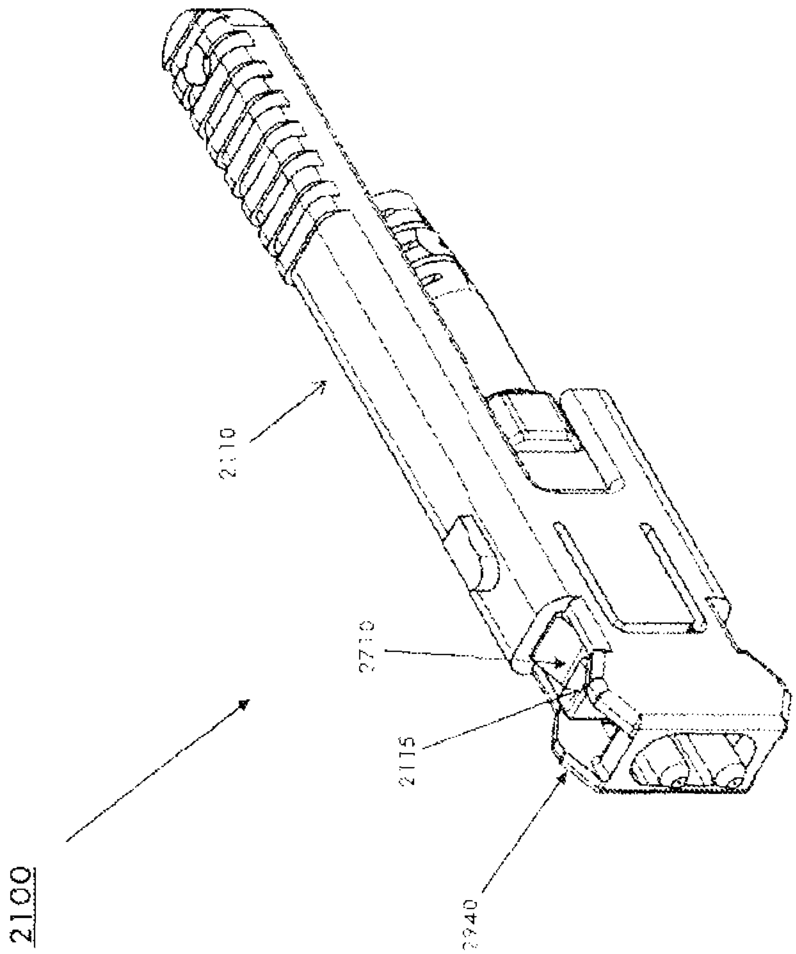

FIG. 21B

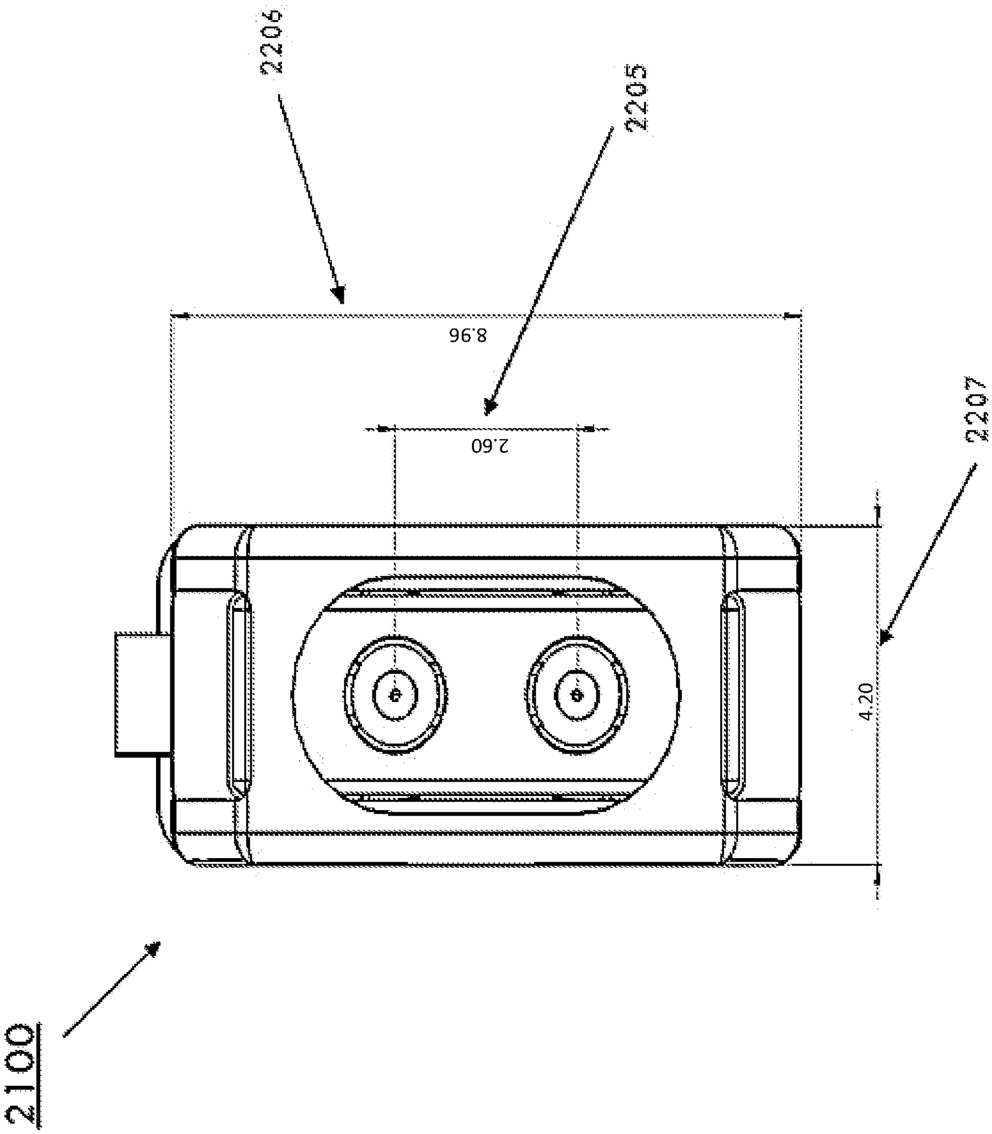

FIG. 22

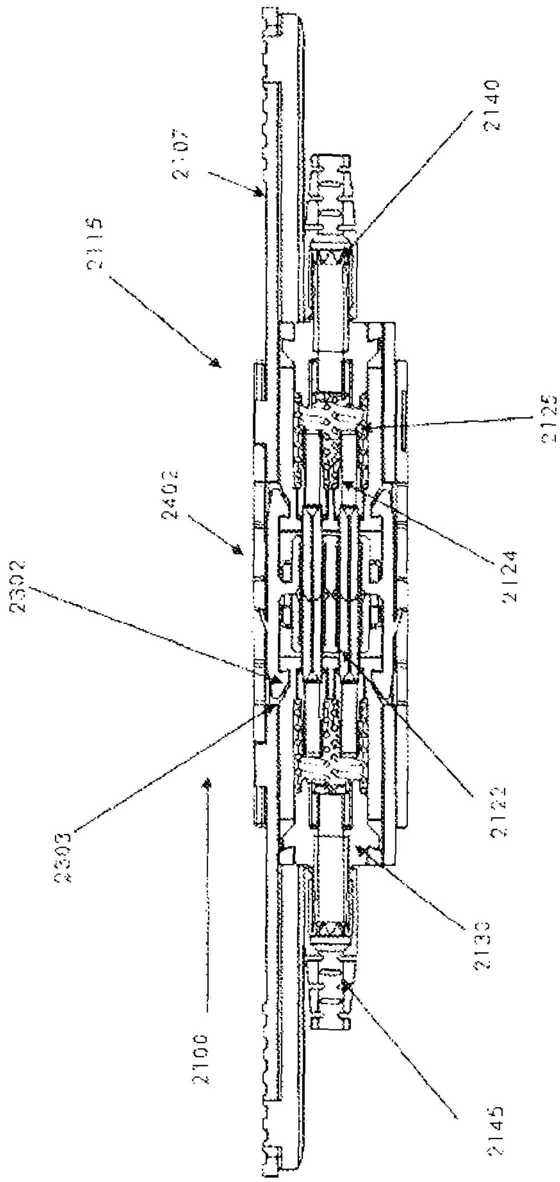

FIG. 23A

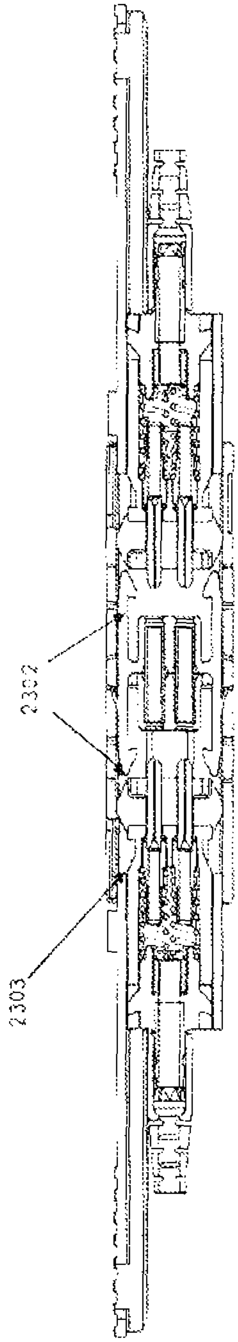

FIG. 23B

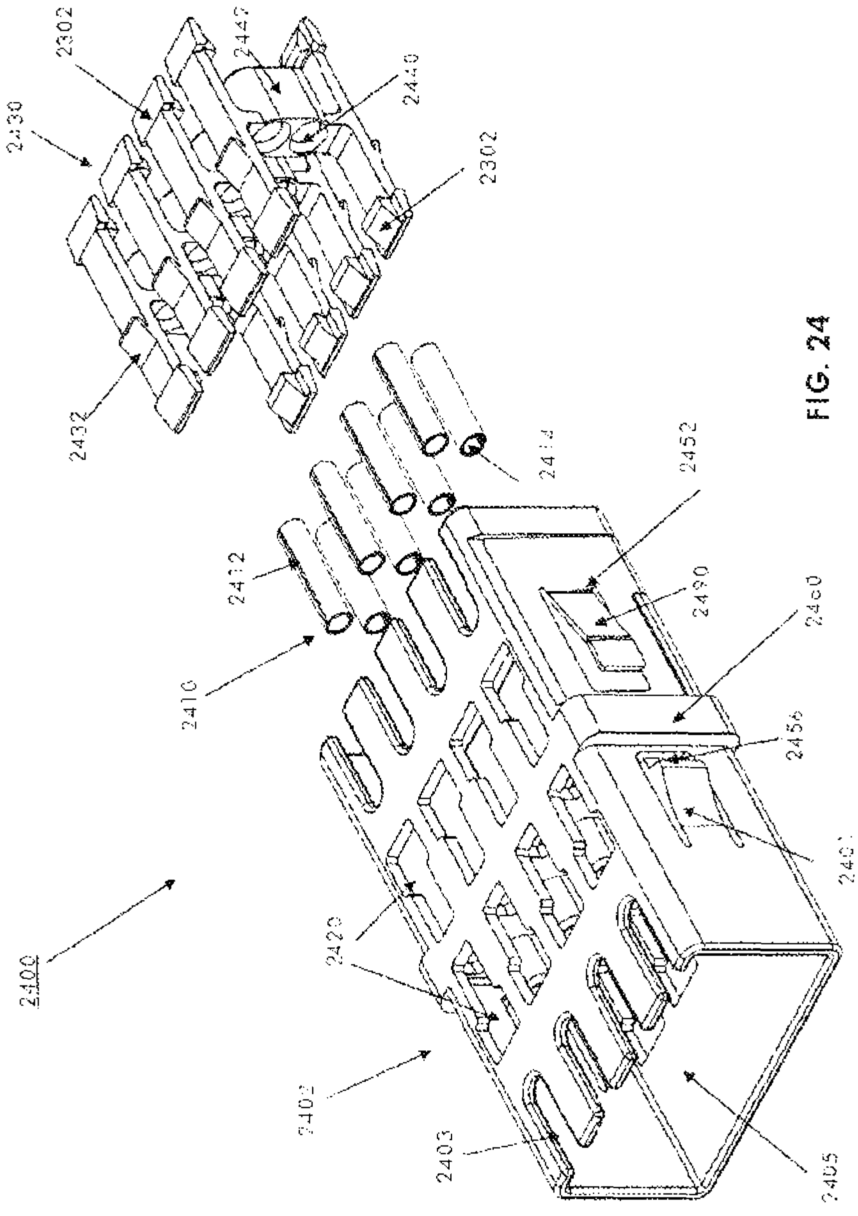

FIG. 24

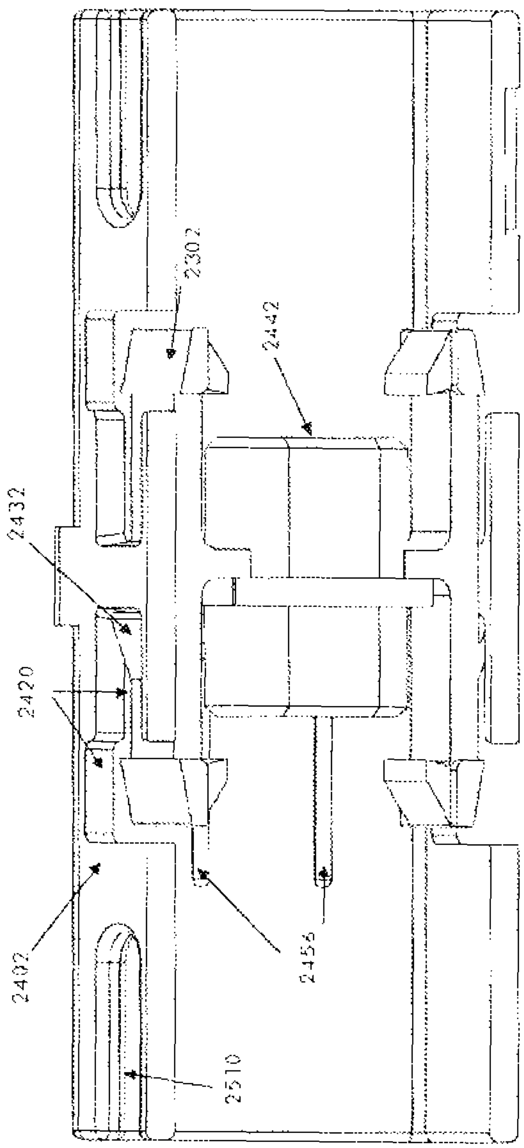

FIG. 25A

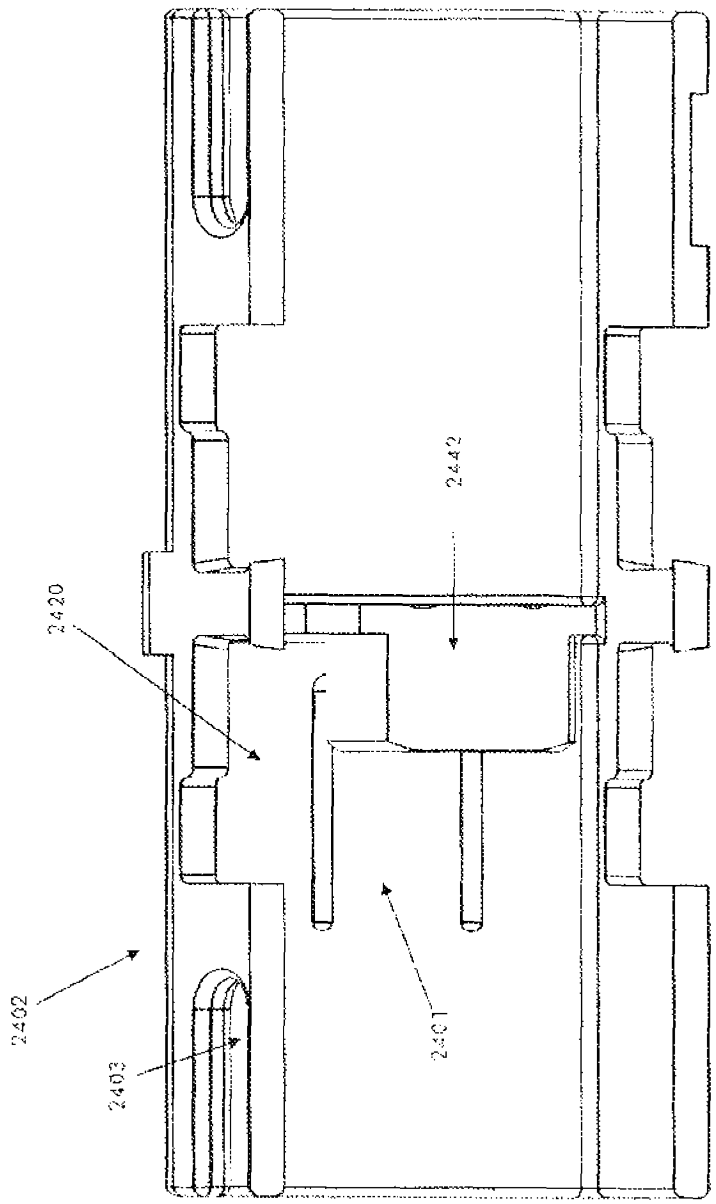

FIG. 25B

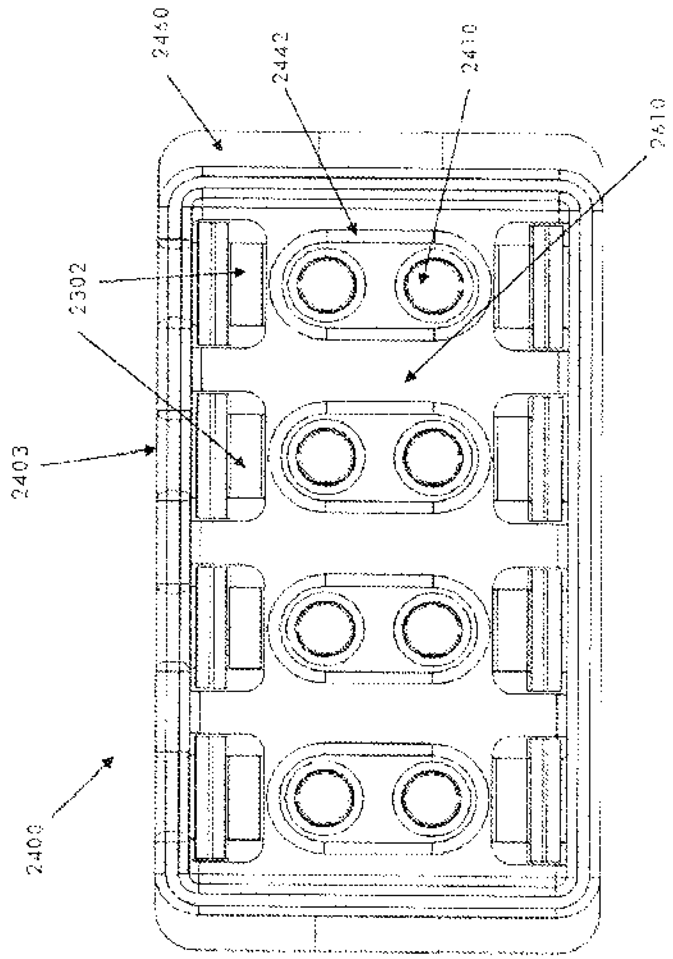

FIG. 26

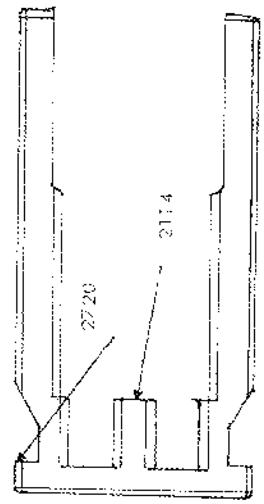

FIG. 27B

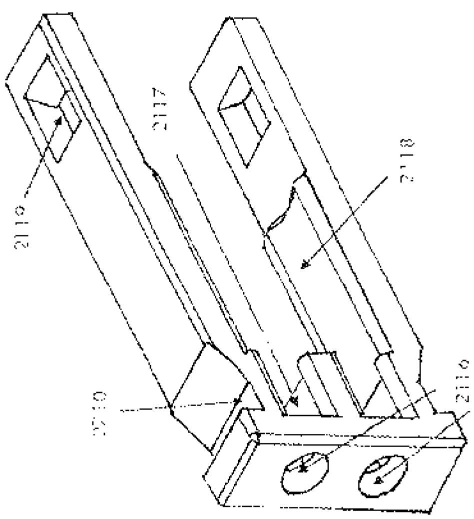

FIG. 27A

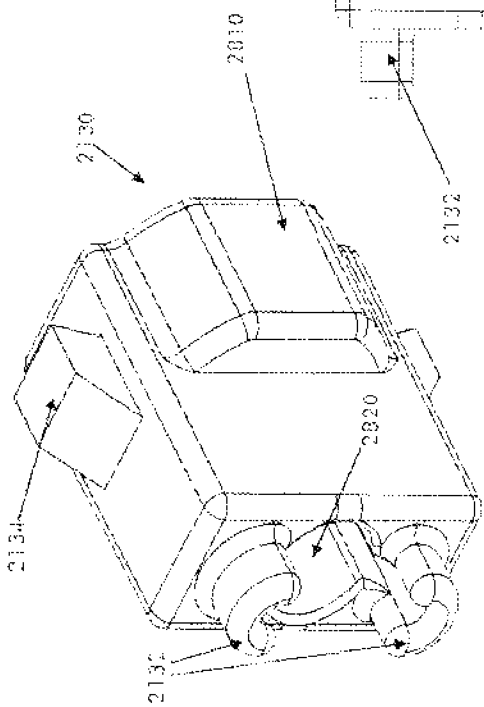

FIG. 28A

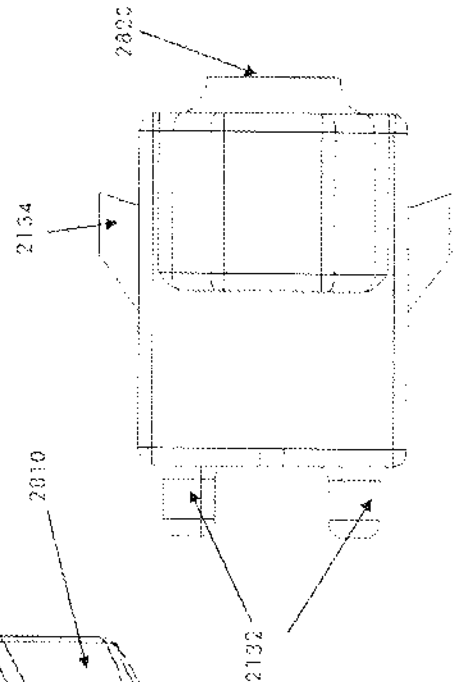

FIG. 28B

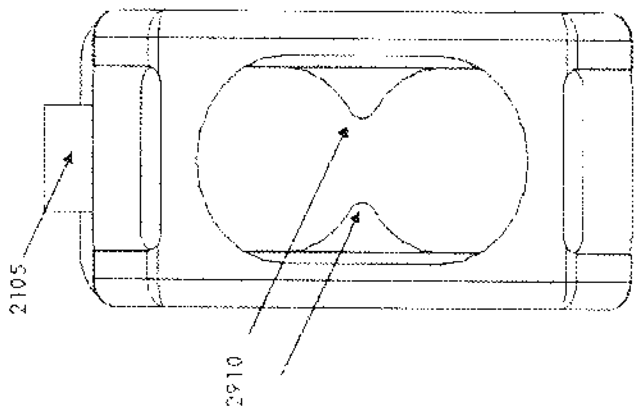

FIG. 29B

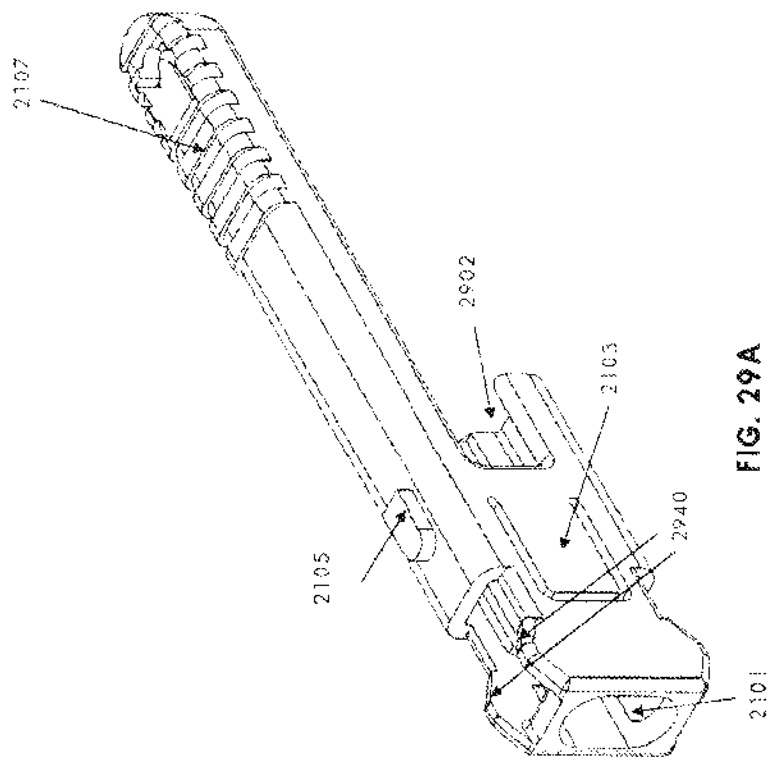

FIG. 29A

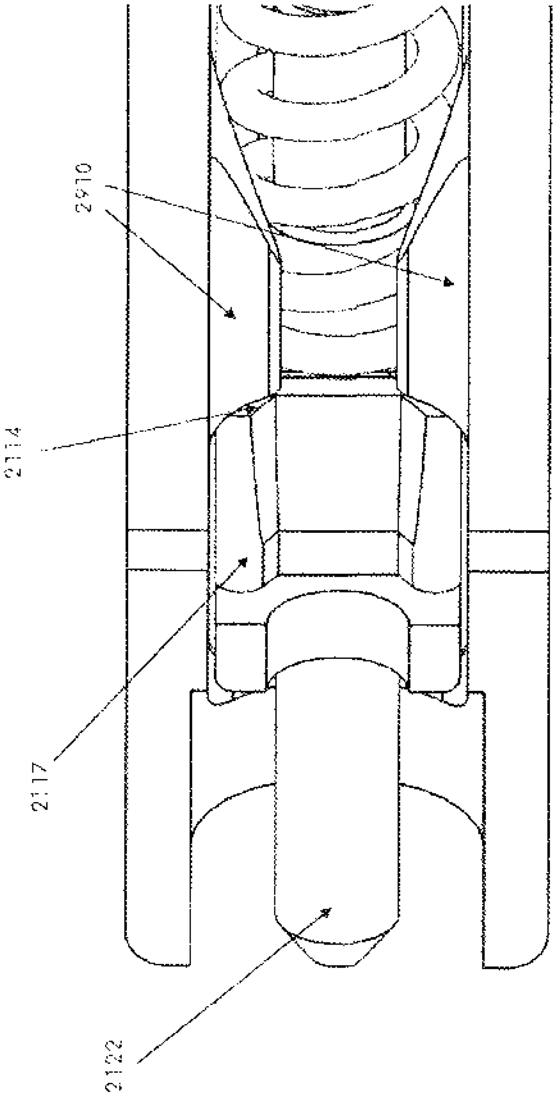

FIG. 29C

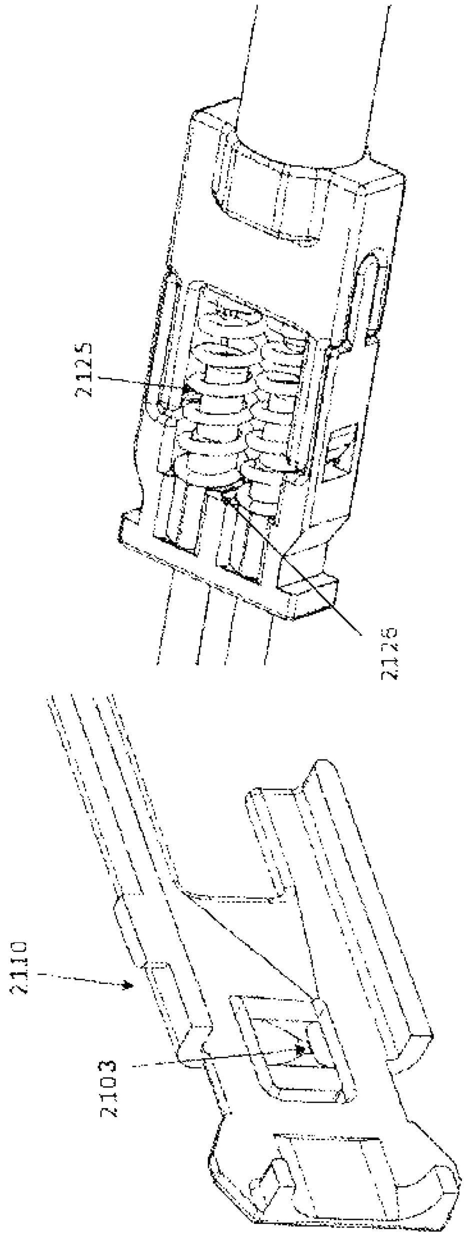

FIG. 29D

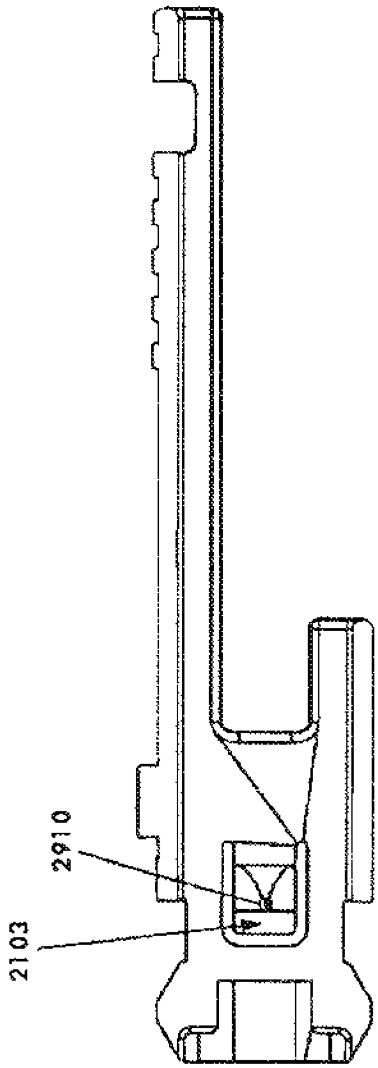

FIG. 29E

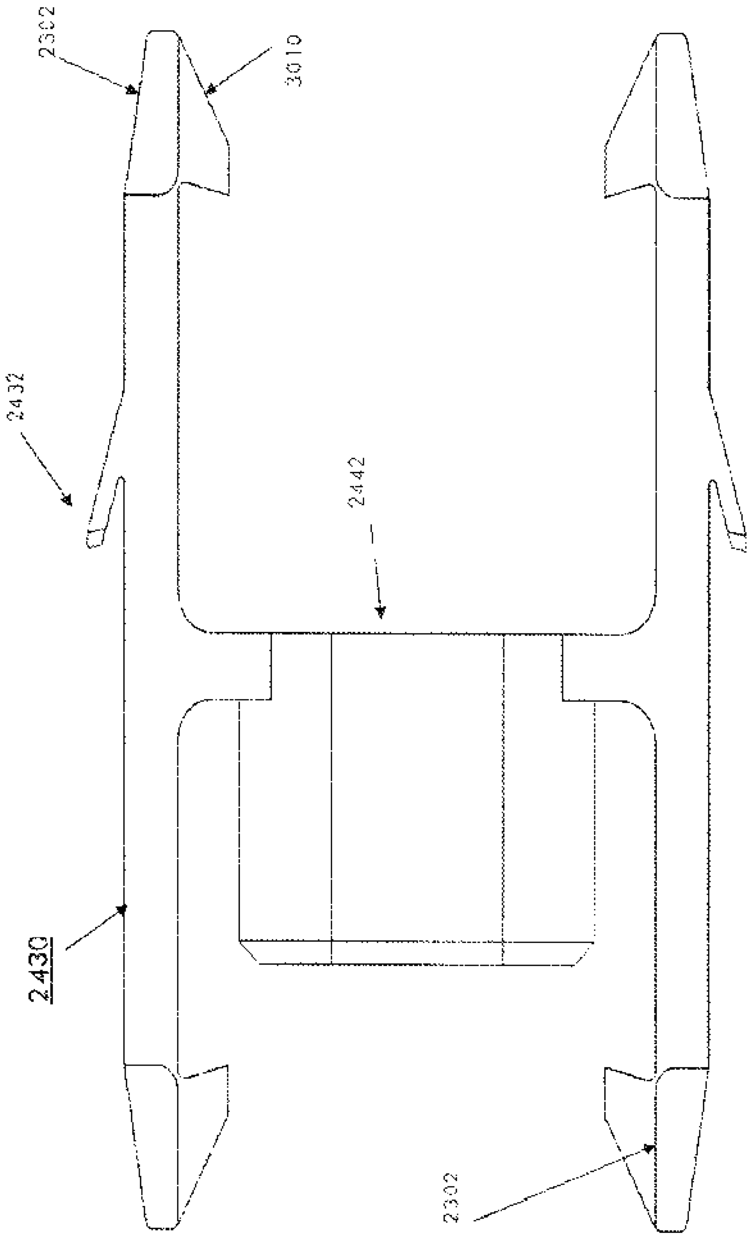

FIG. 30

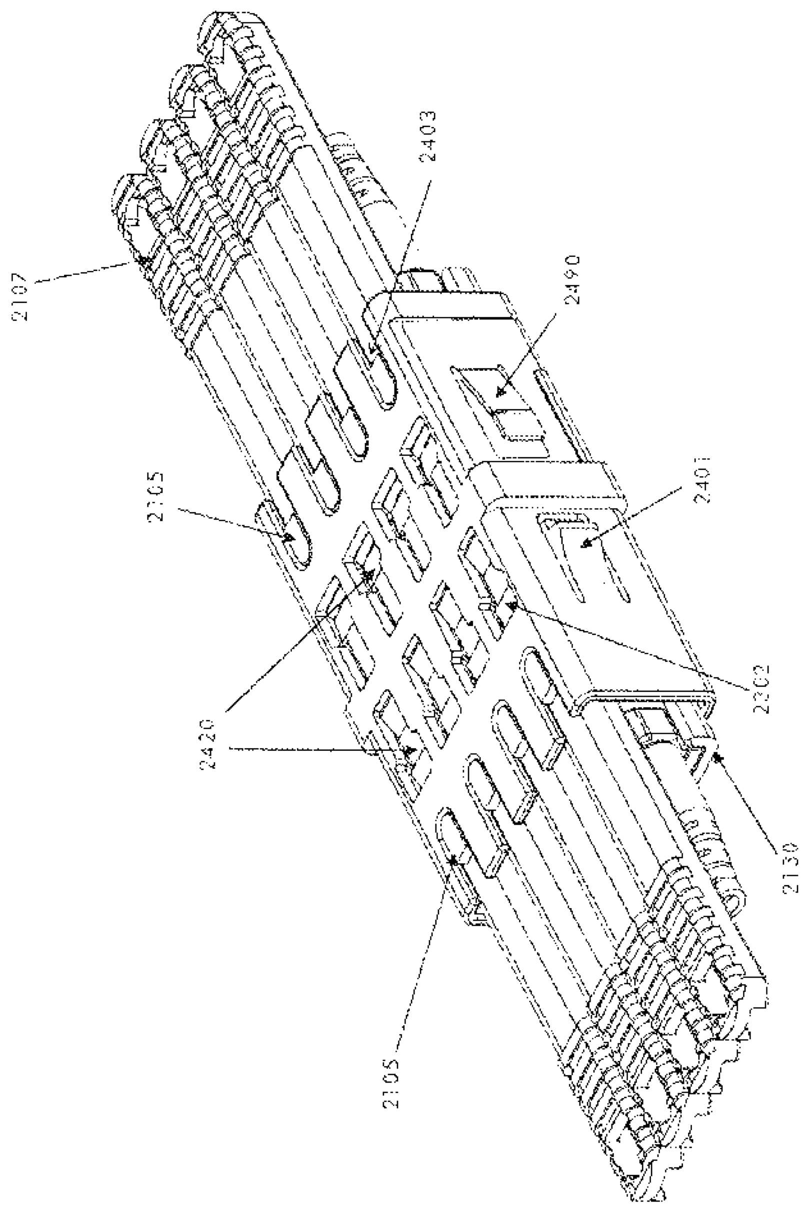

FIG. 31

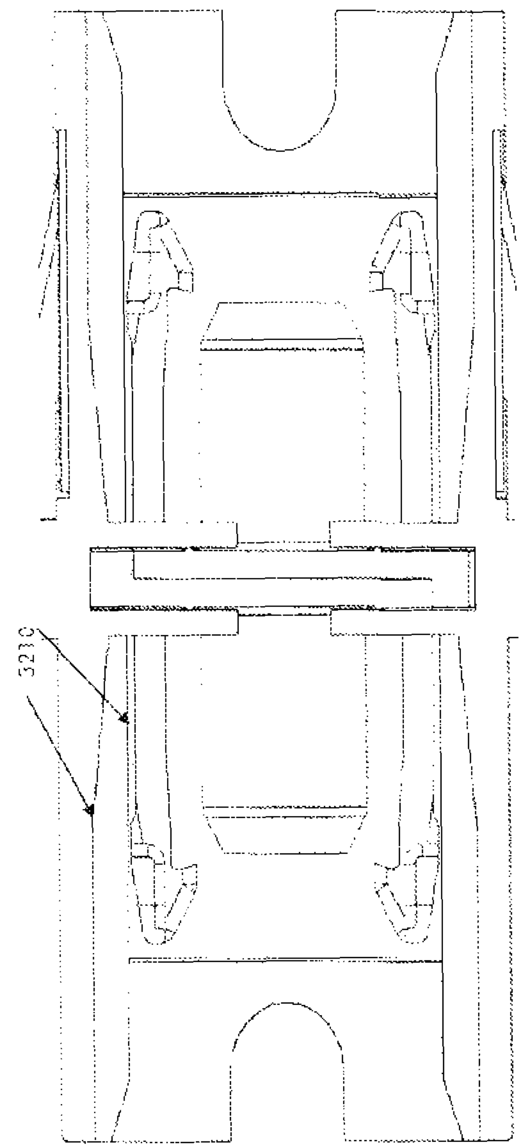

FIG. 32A

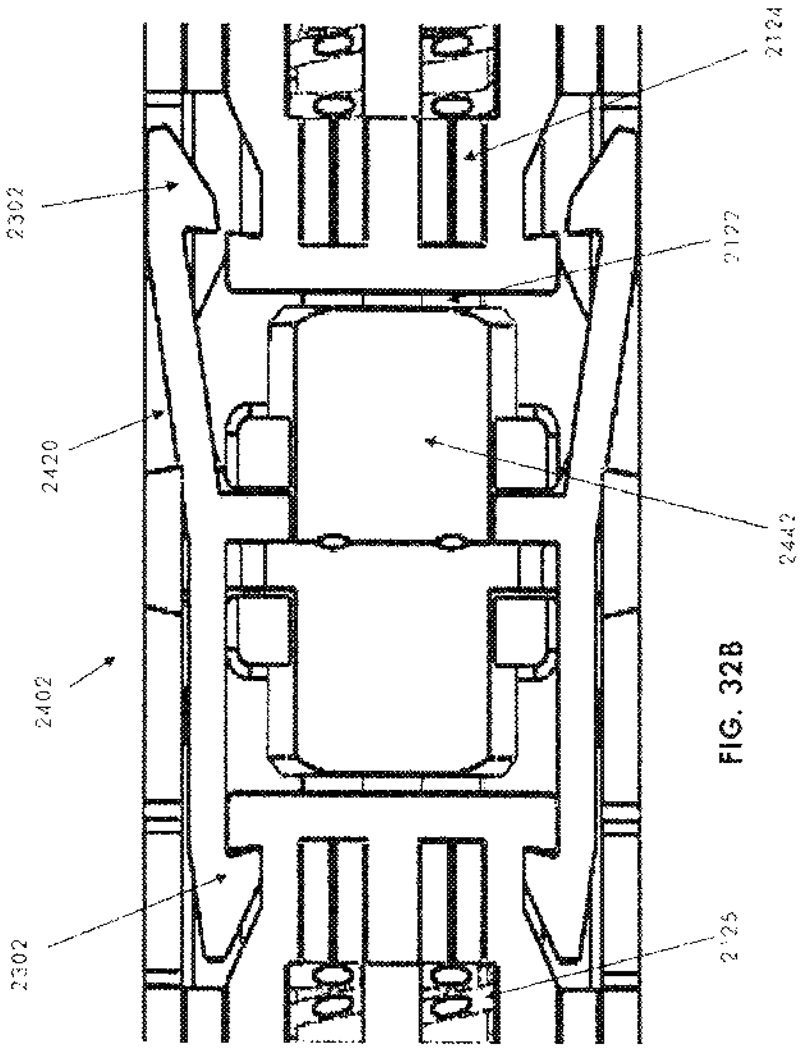

FIG. 32B

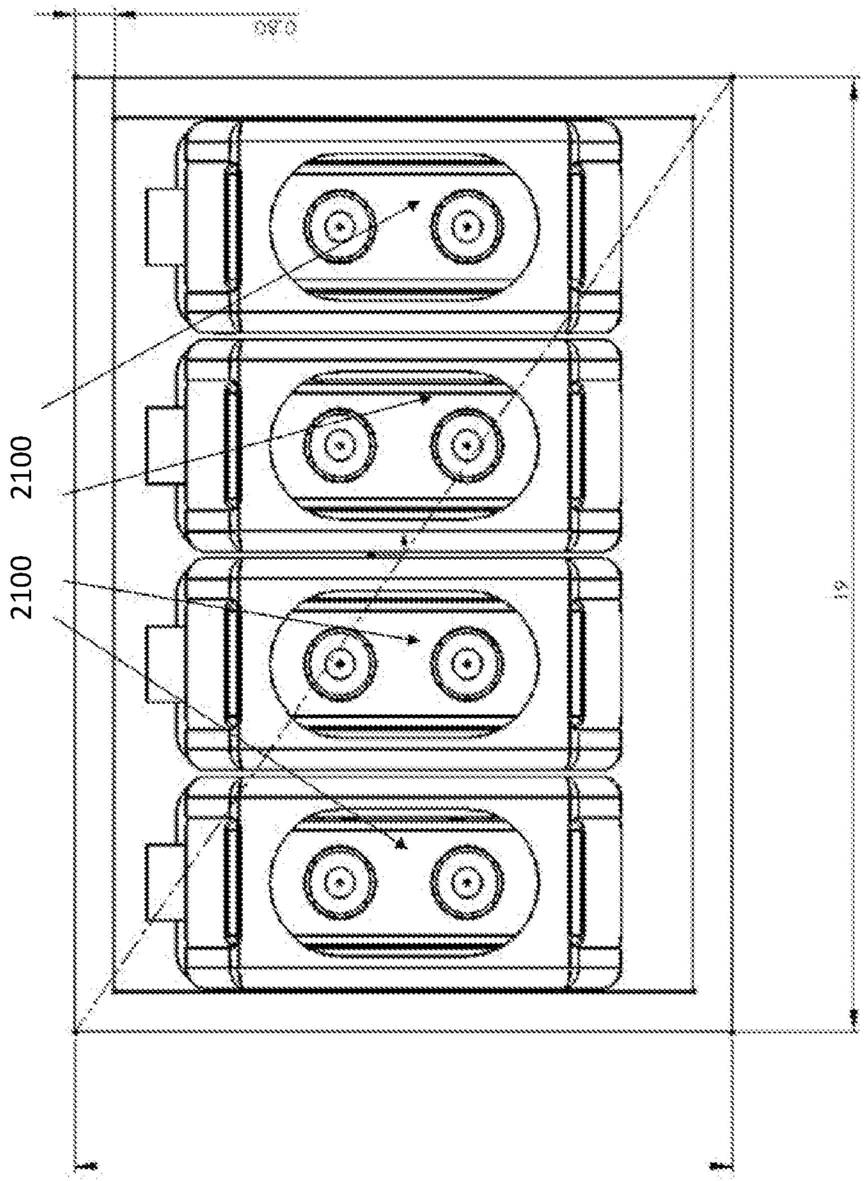

FIG. 33A

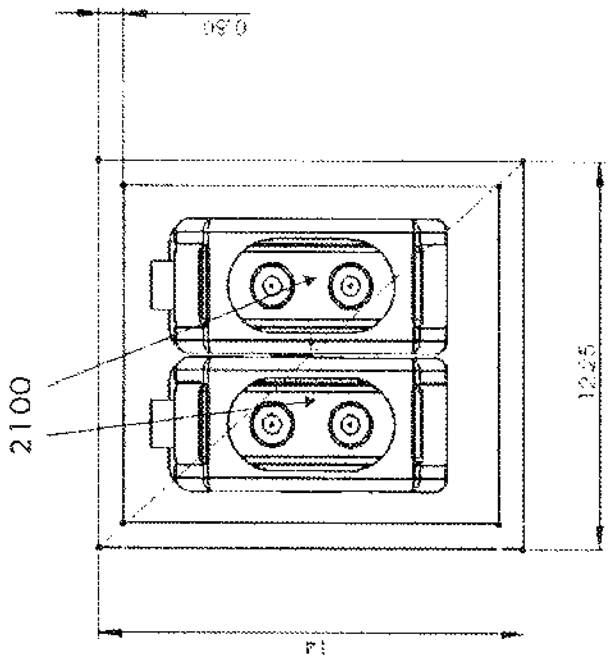

FIG. 33B

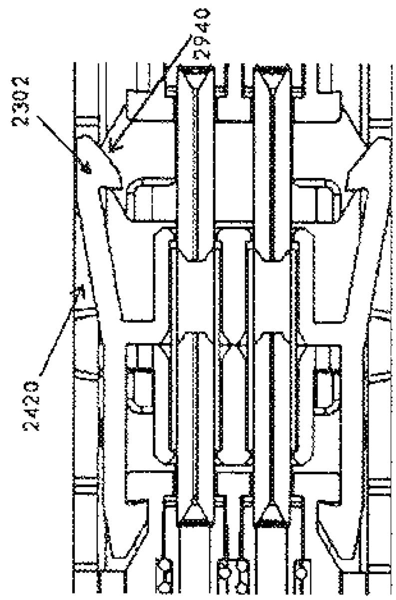

FIG. 34B

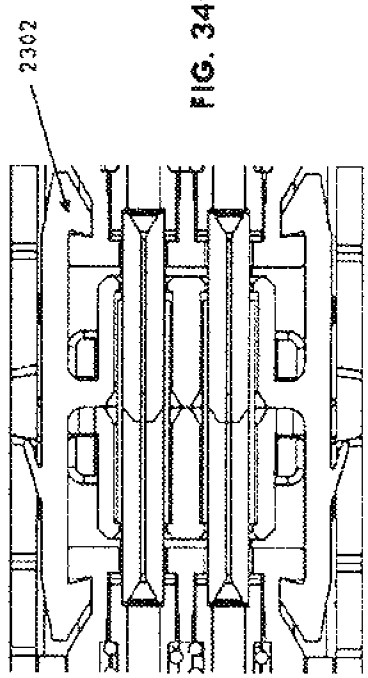

FIG. 34C

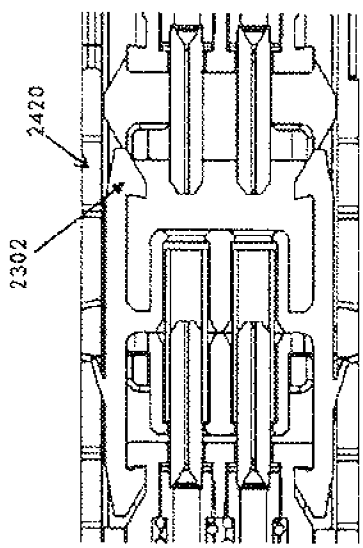

FIG. 34A

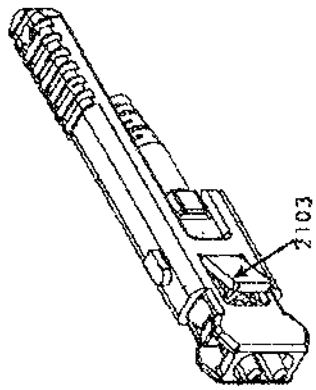

FIG. 35B

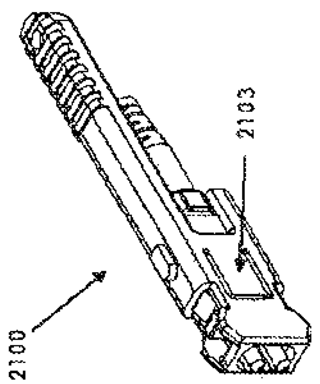

FIG. 35A

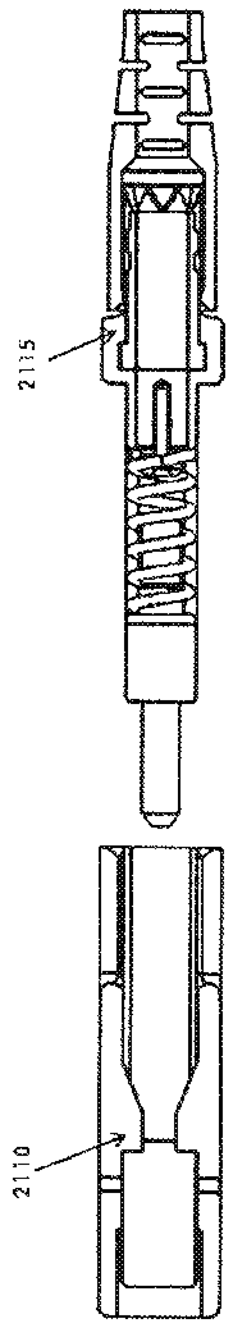

FIG. 35C

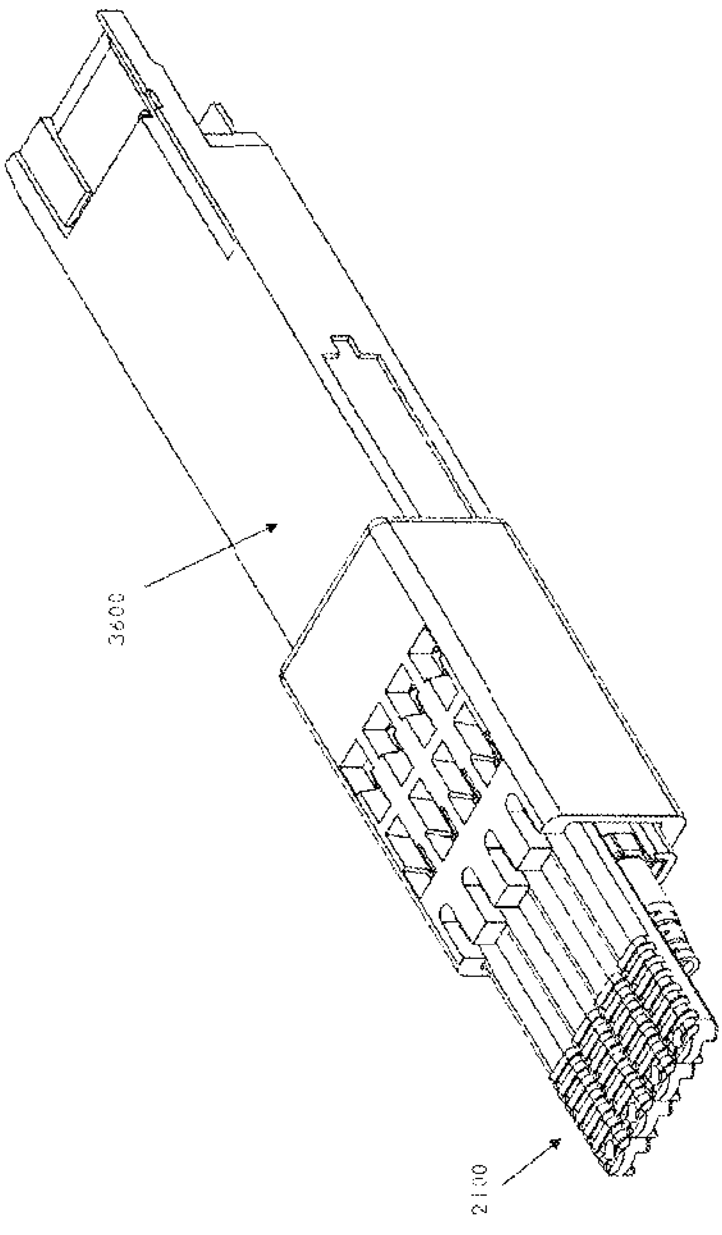

FIG. 36A

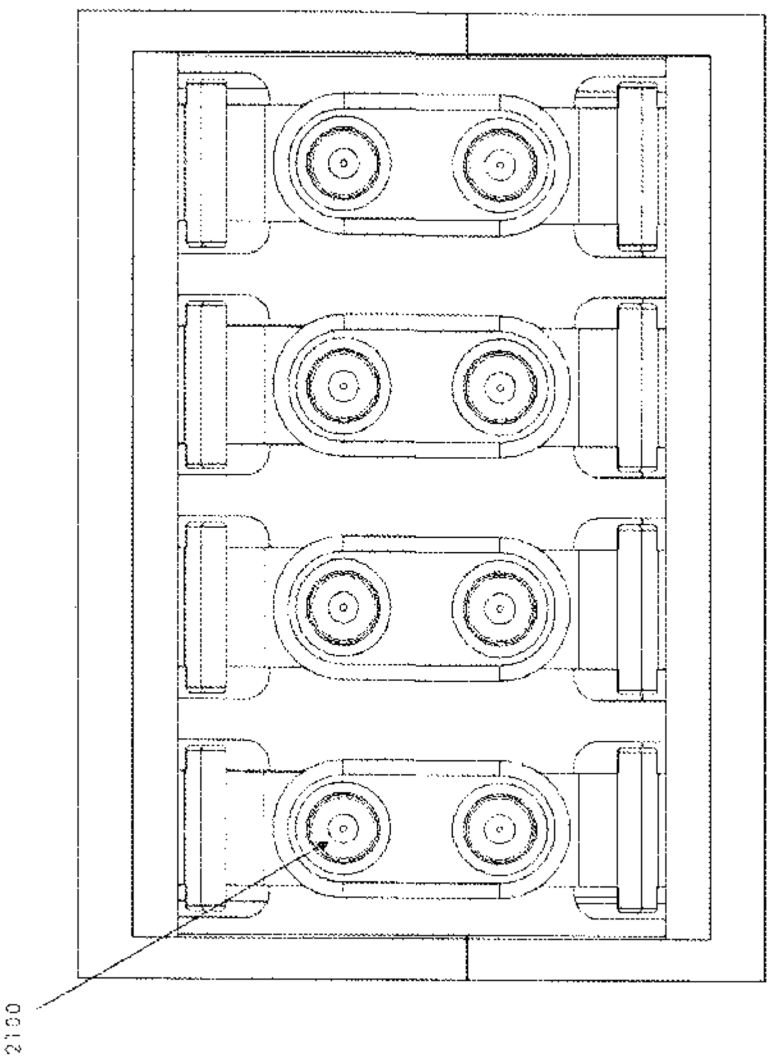

FIG. 36B

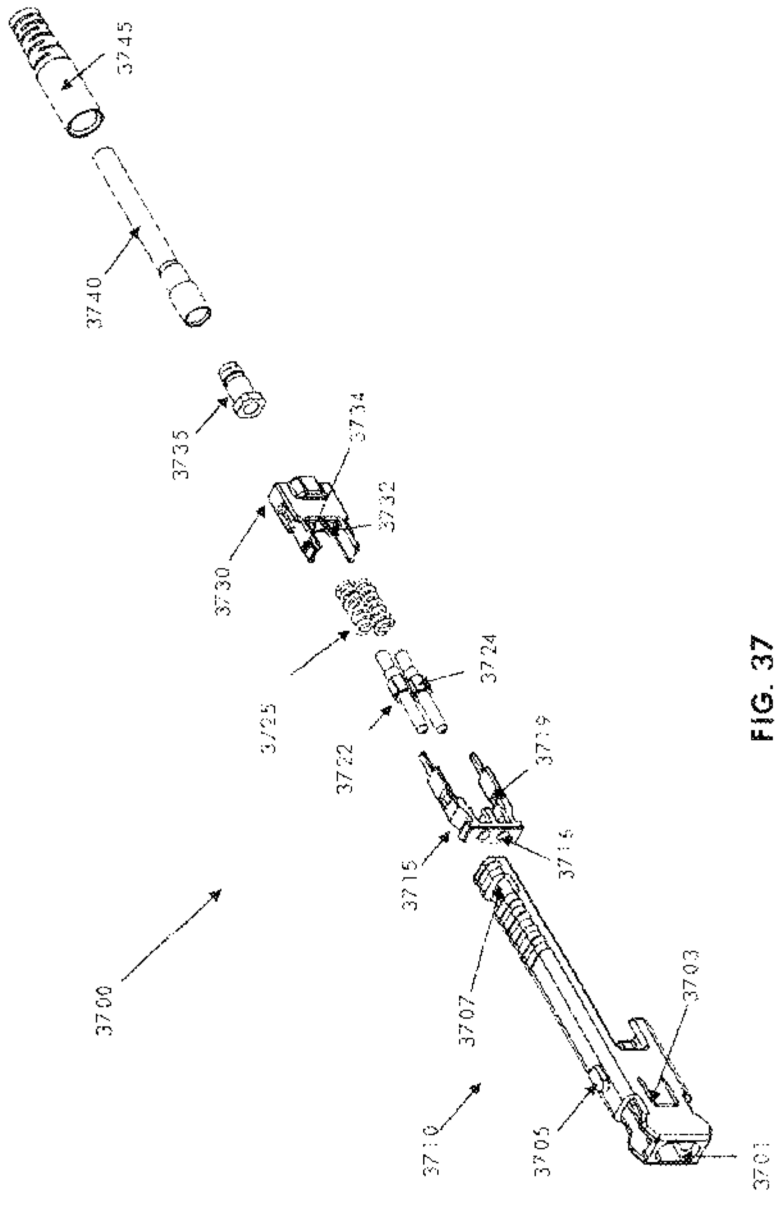
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FIG. 37

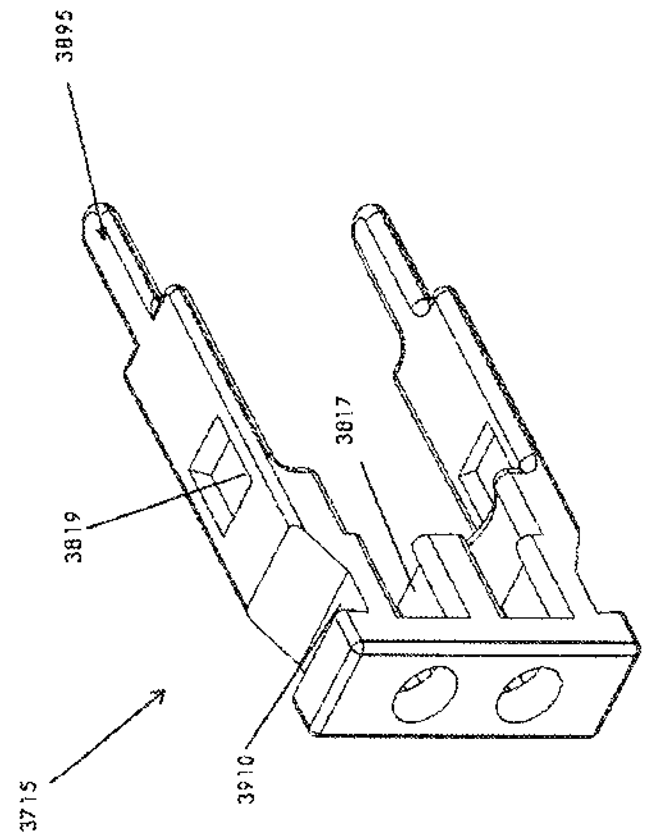


FIG. 38

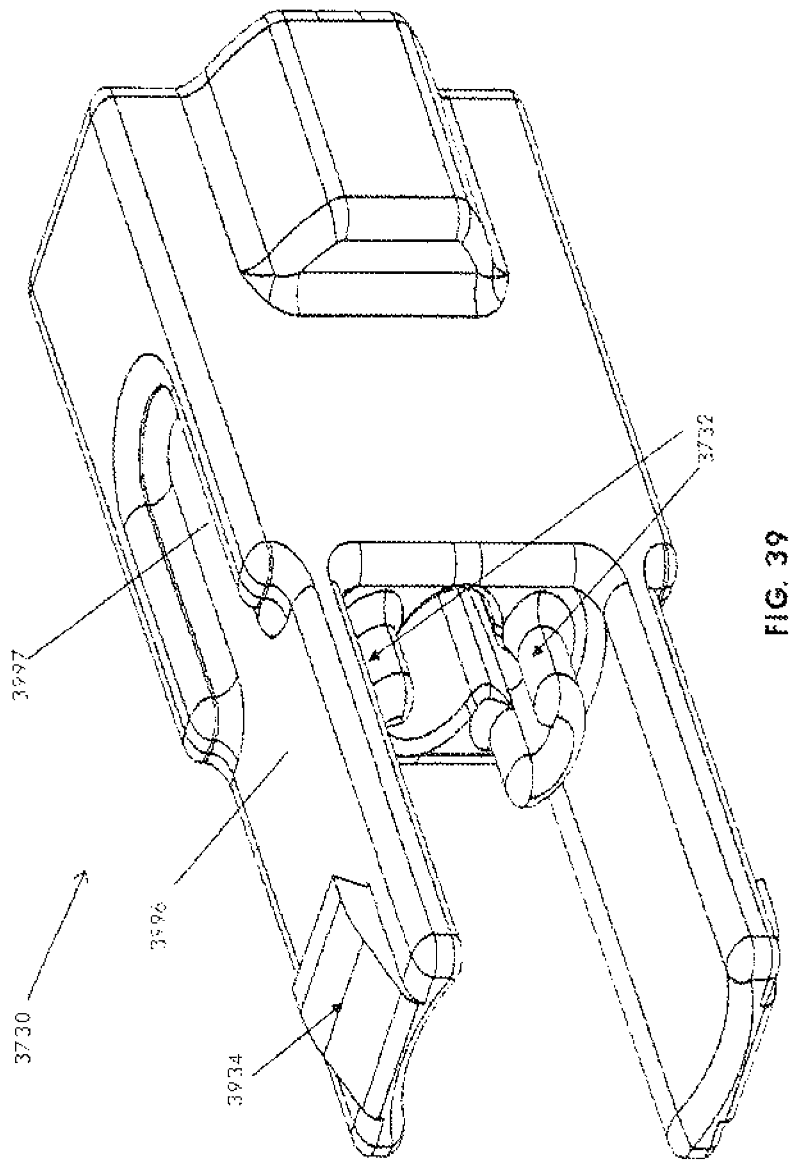


FIG. 39

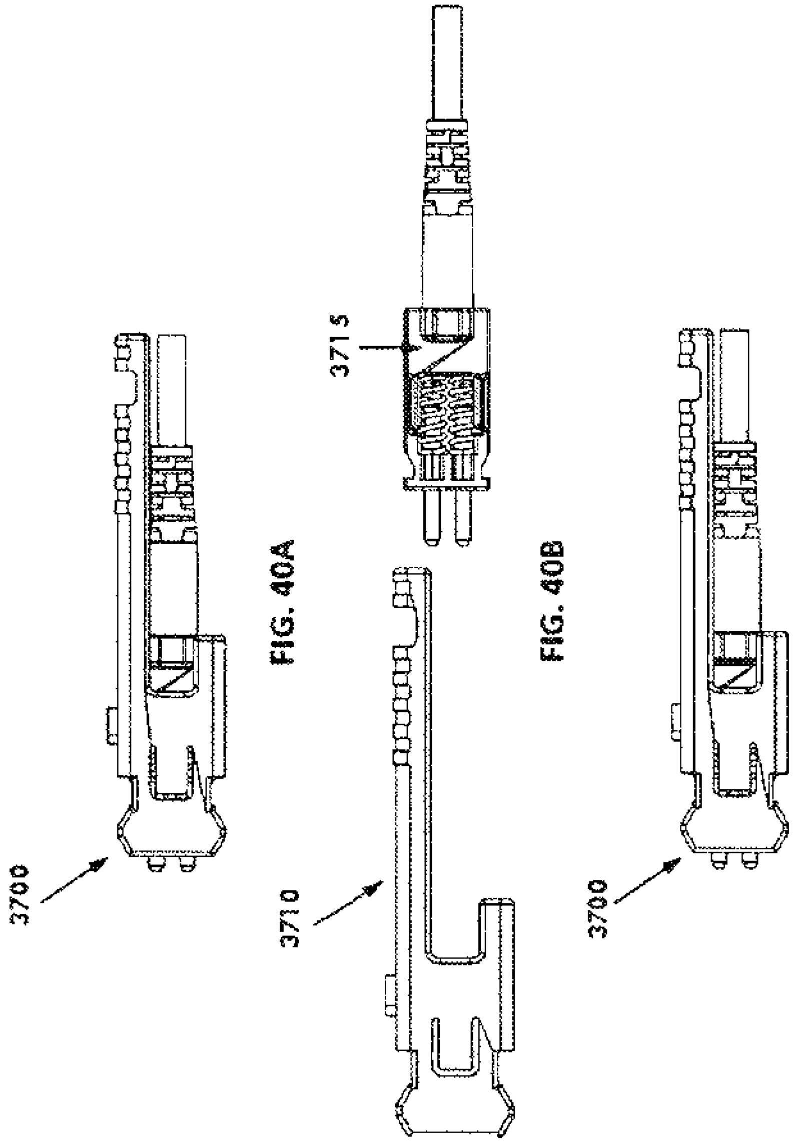


FIG. 40A

FIG. 40B

FIG. 40C

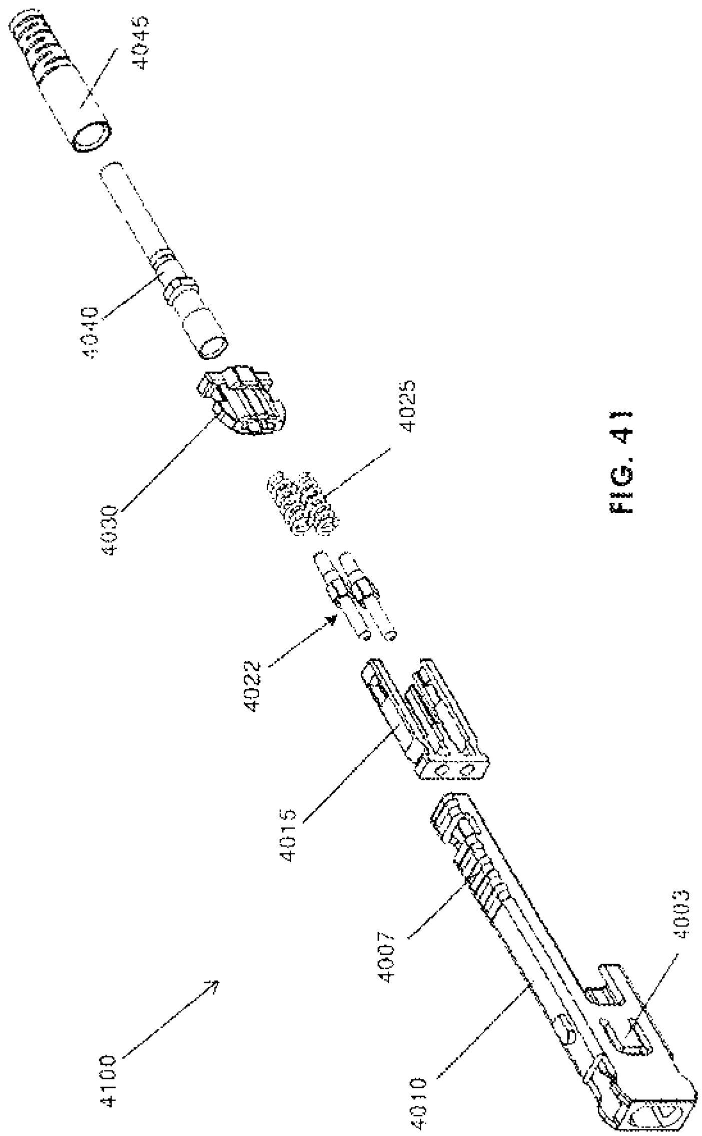


FIG. 41

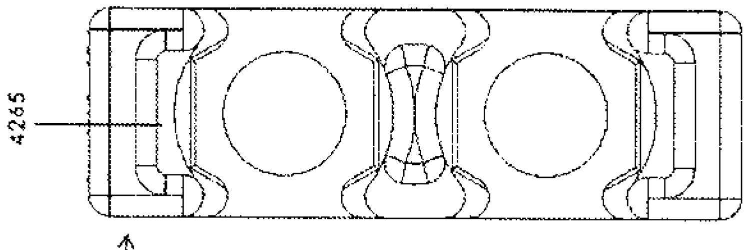


FIG. 42B

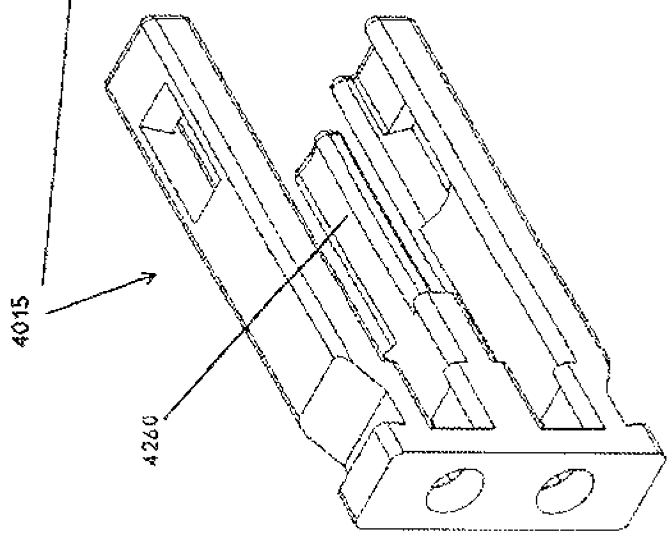


FIG. 42A

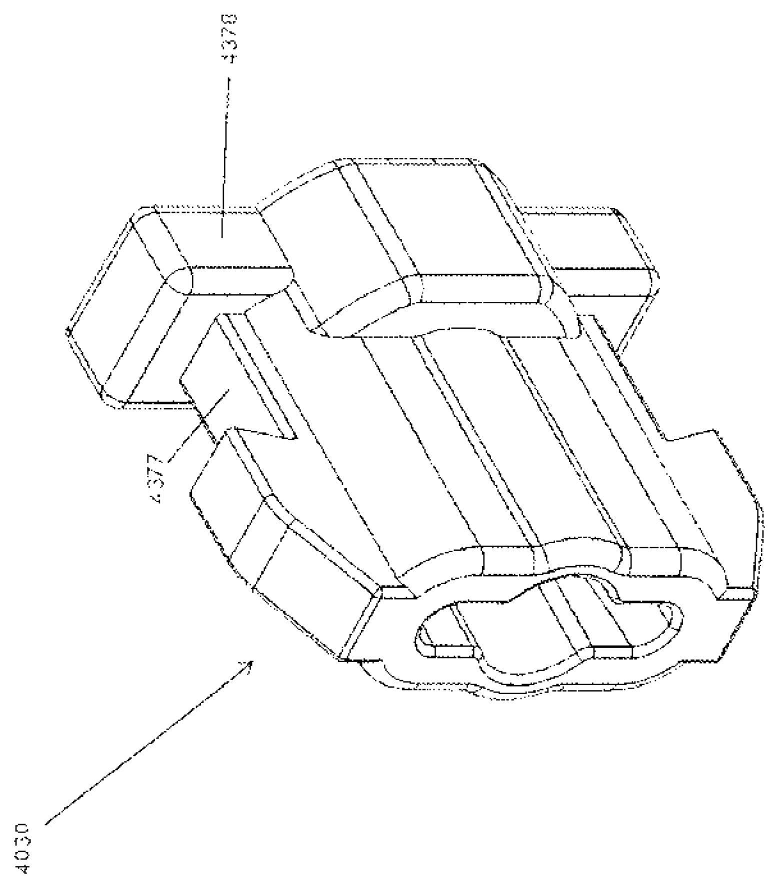


FIG. 43

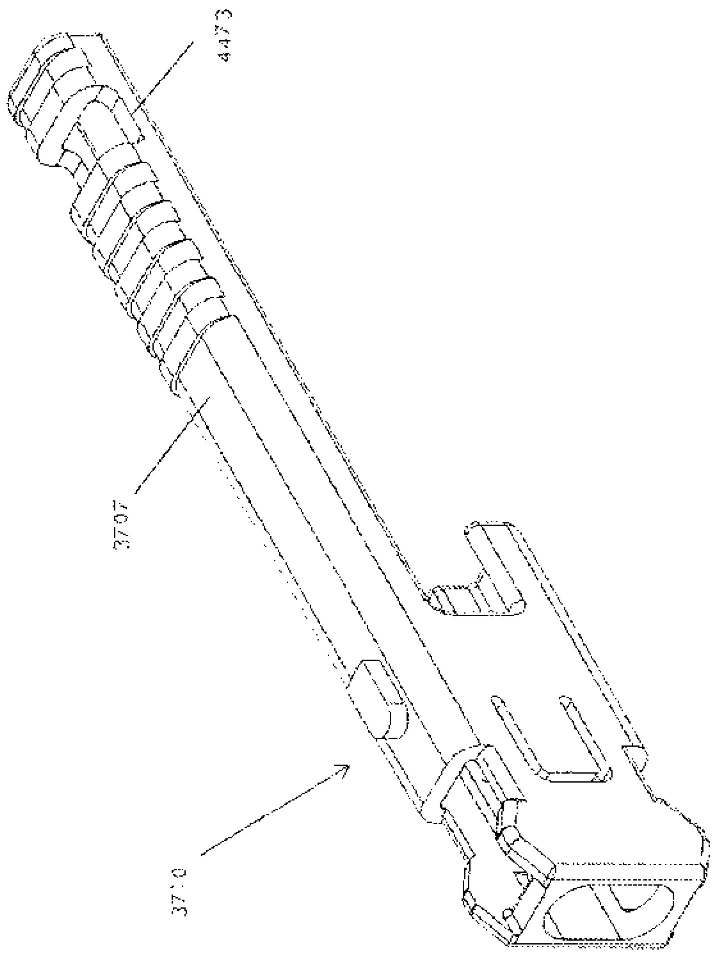


FIG. 44A

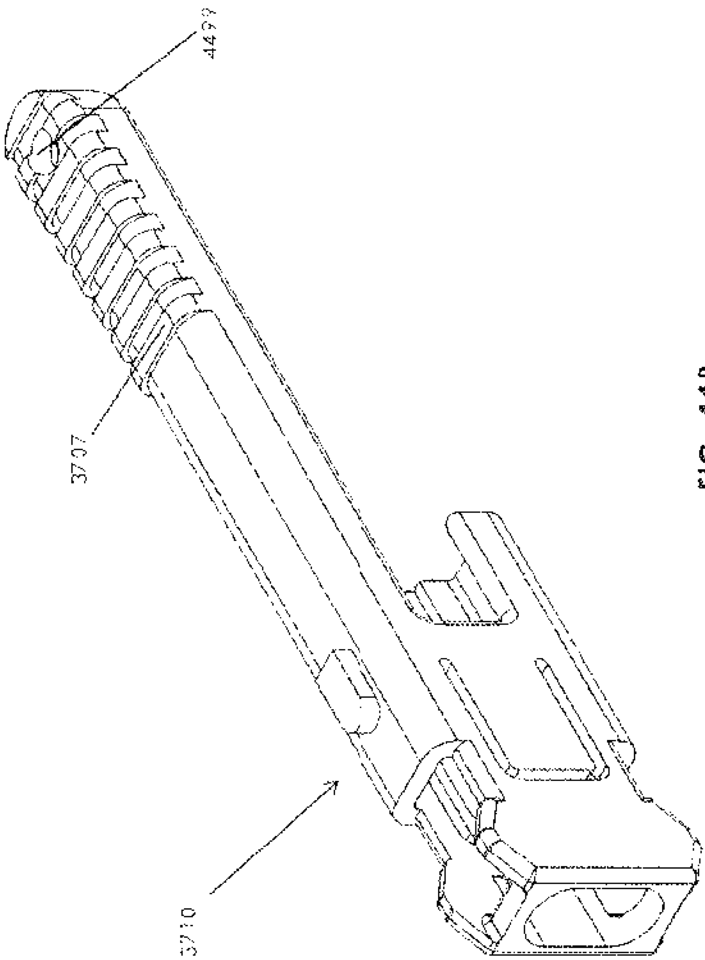


FIG. 44B

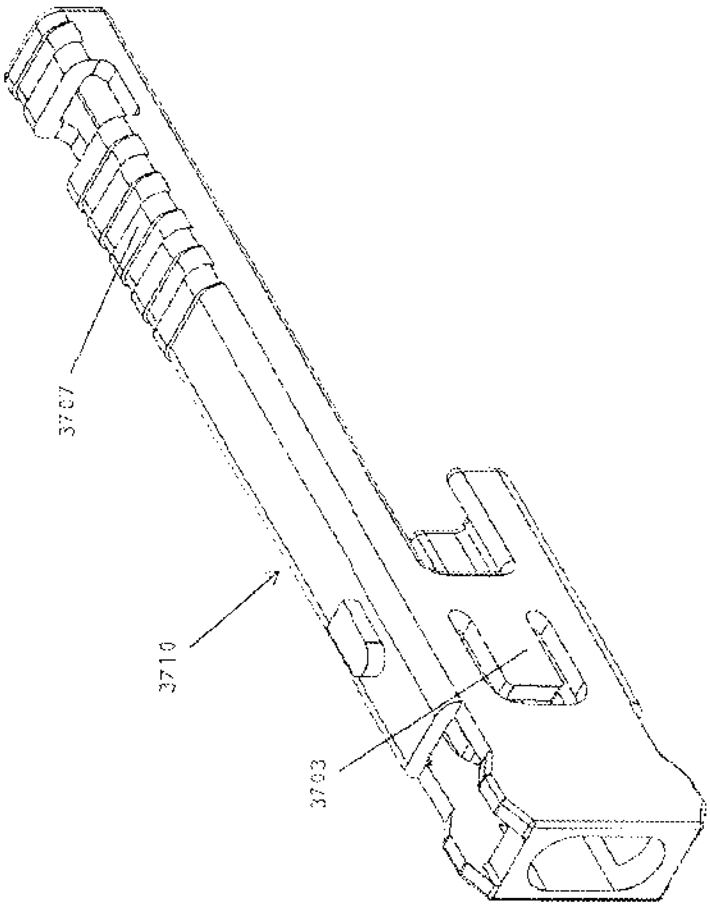


FIG. 44C

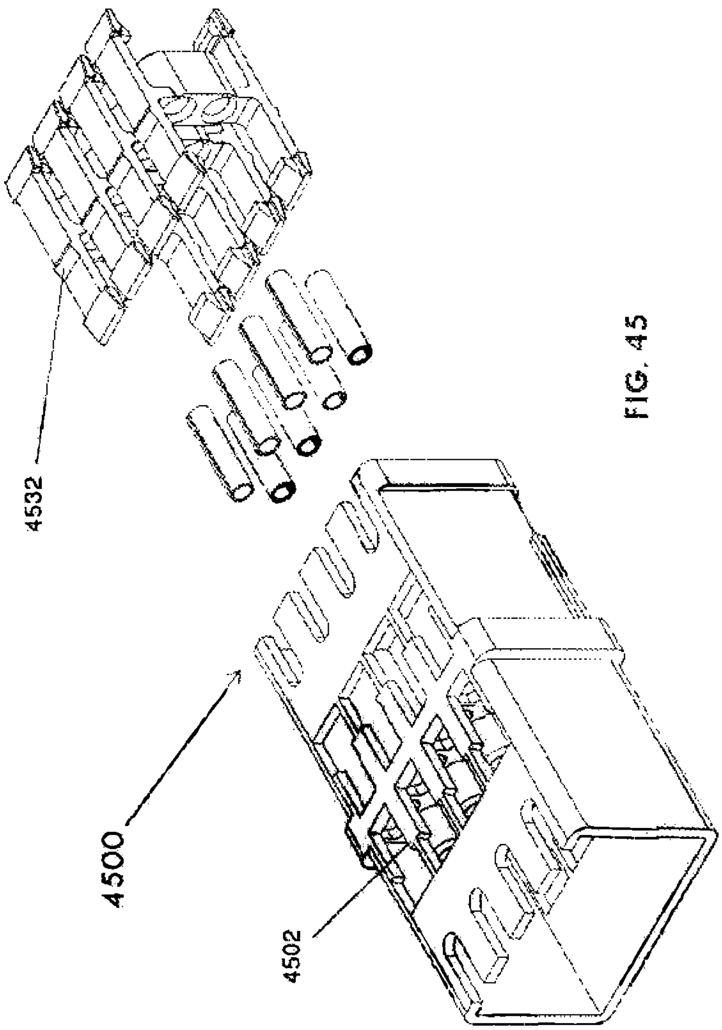


FIG. 45

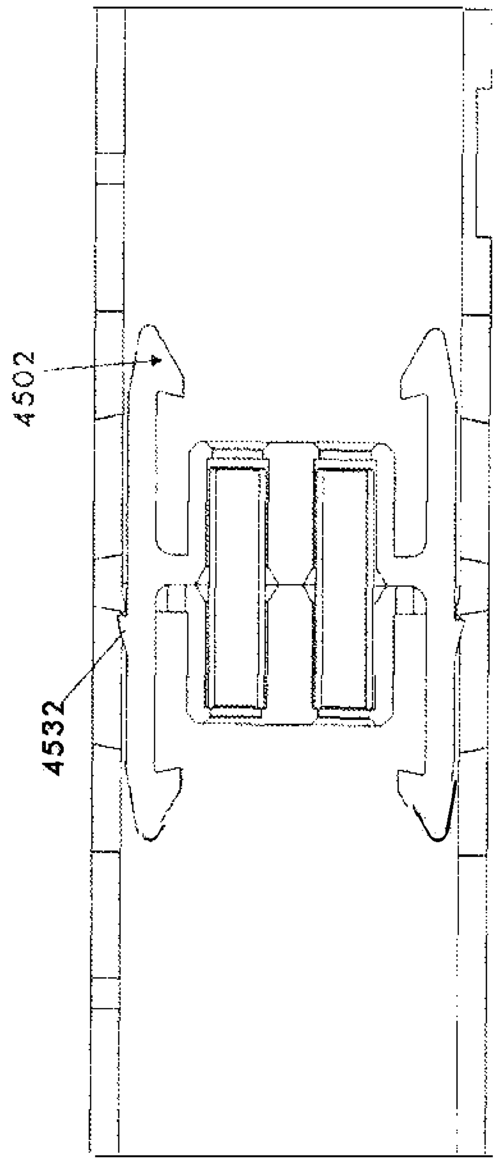


FIG. 46

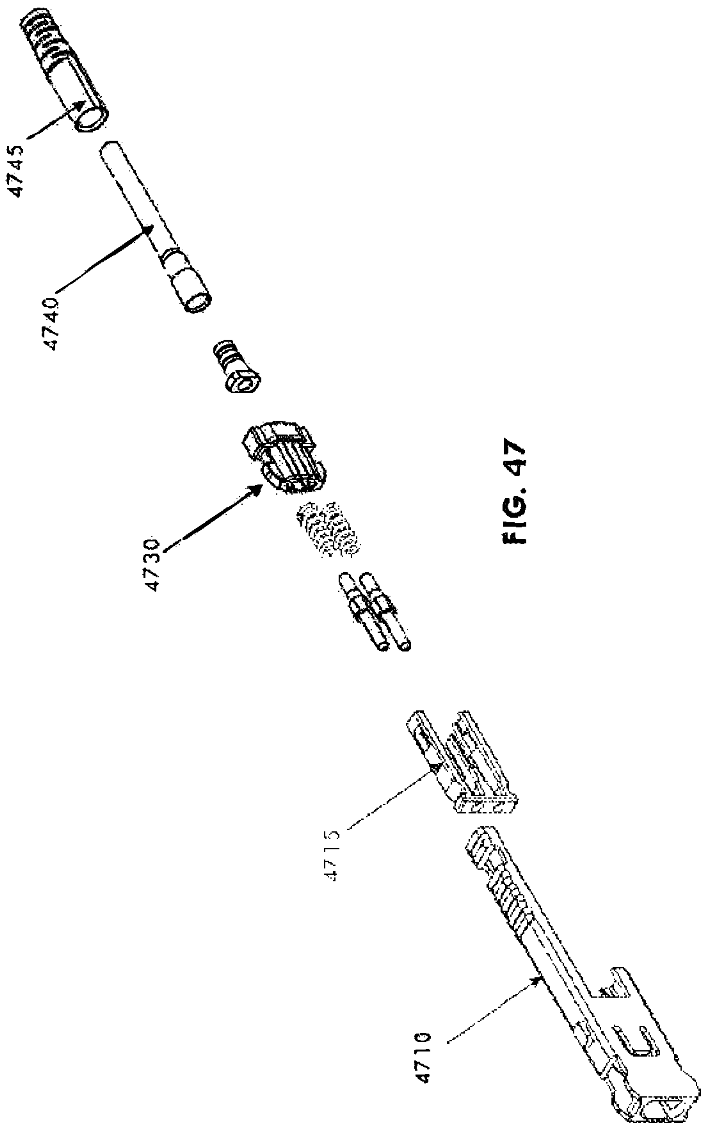


FIG. 47

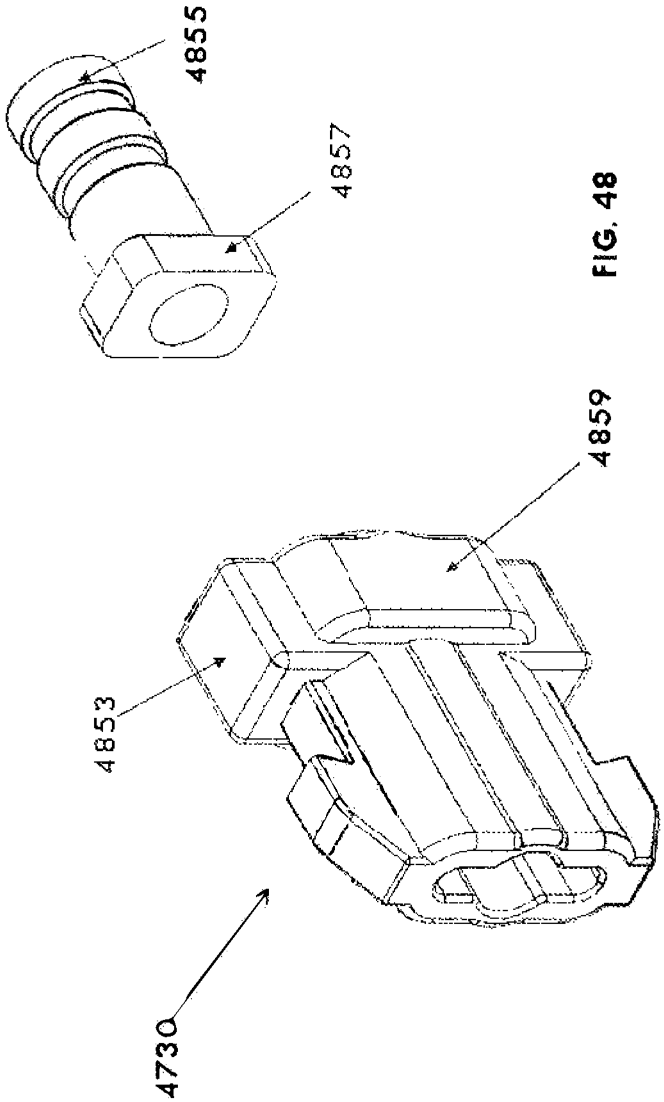


FIG. 48

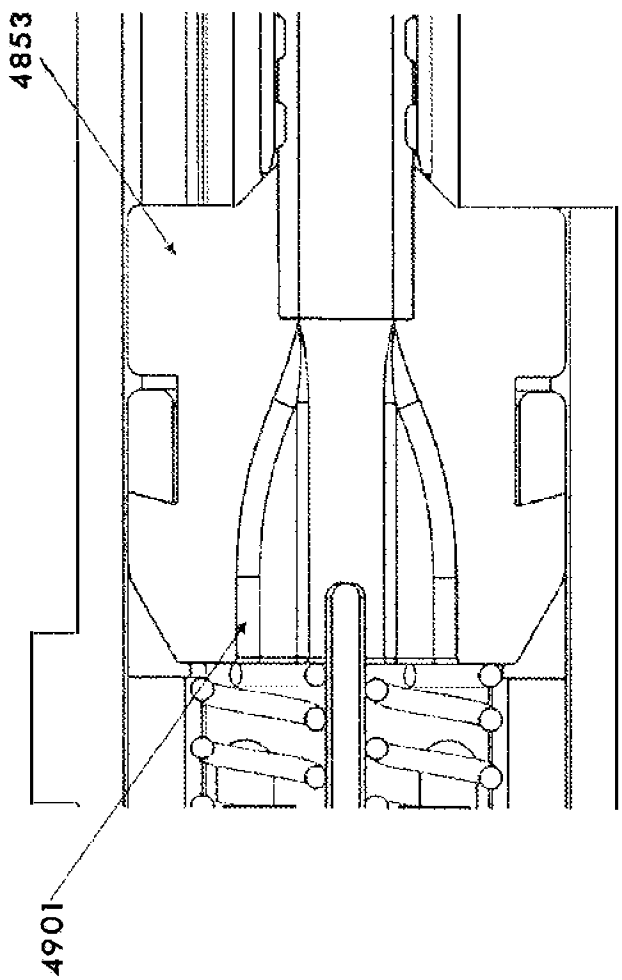


FIG. 49

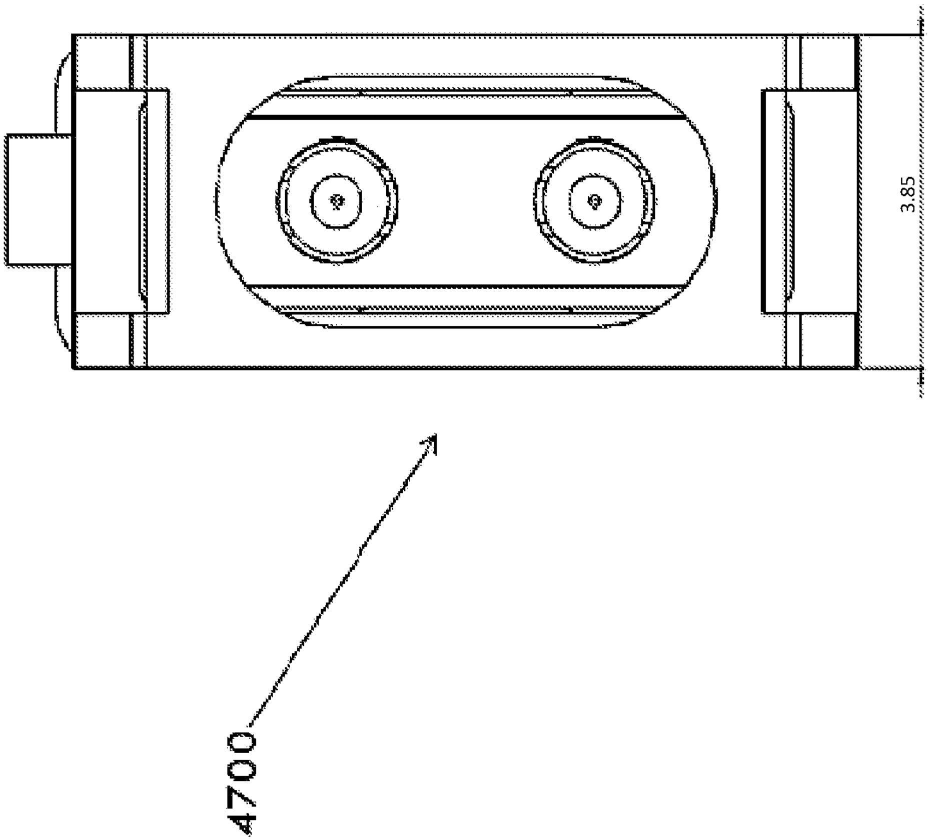


FIG. 50

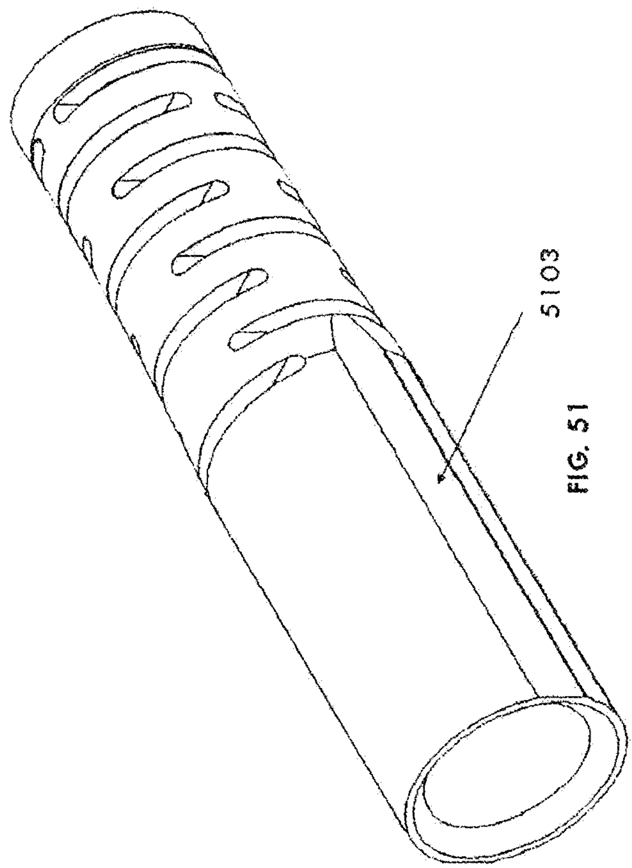


FIG. 51

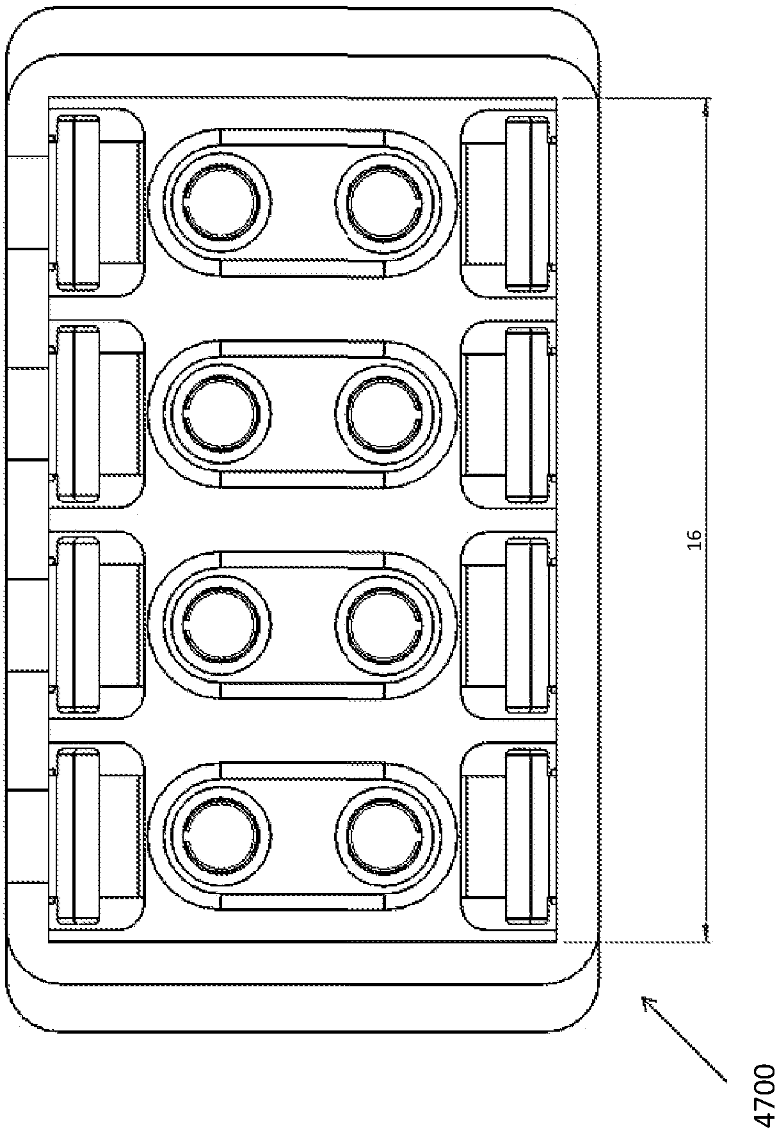


FIG. 52

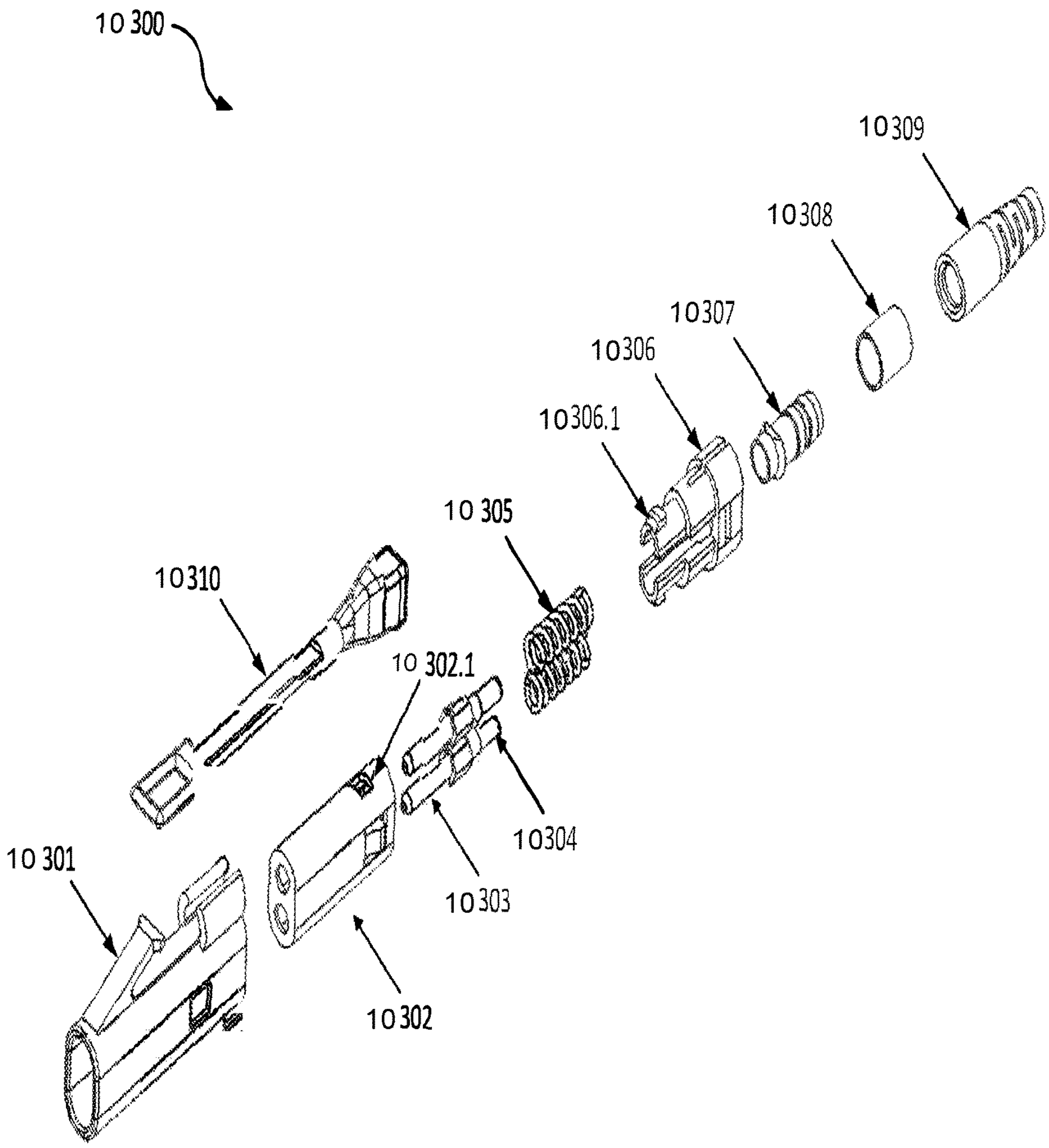

10 300
10309
10308
10307
10306
10306.1
10 305
10310
10 302.1
10304
10 301
10303
10302

FIG. 53

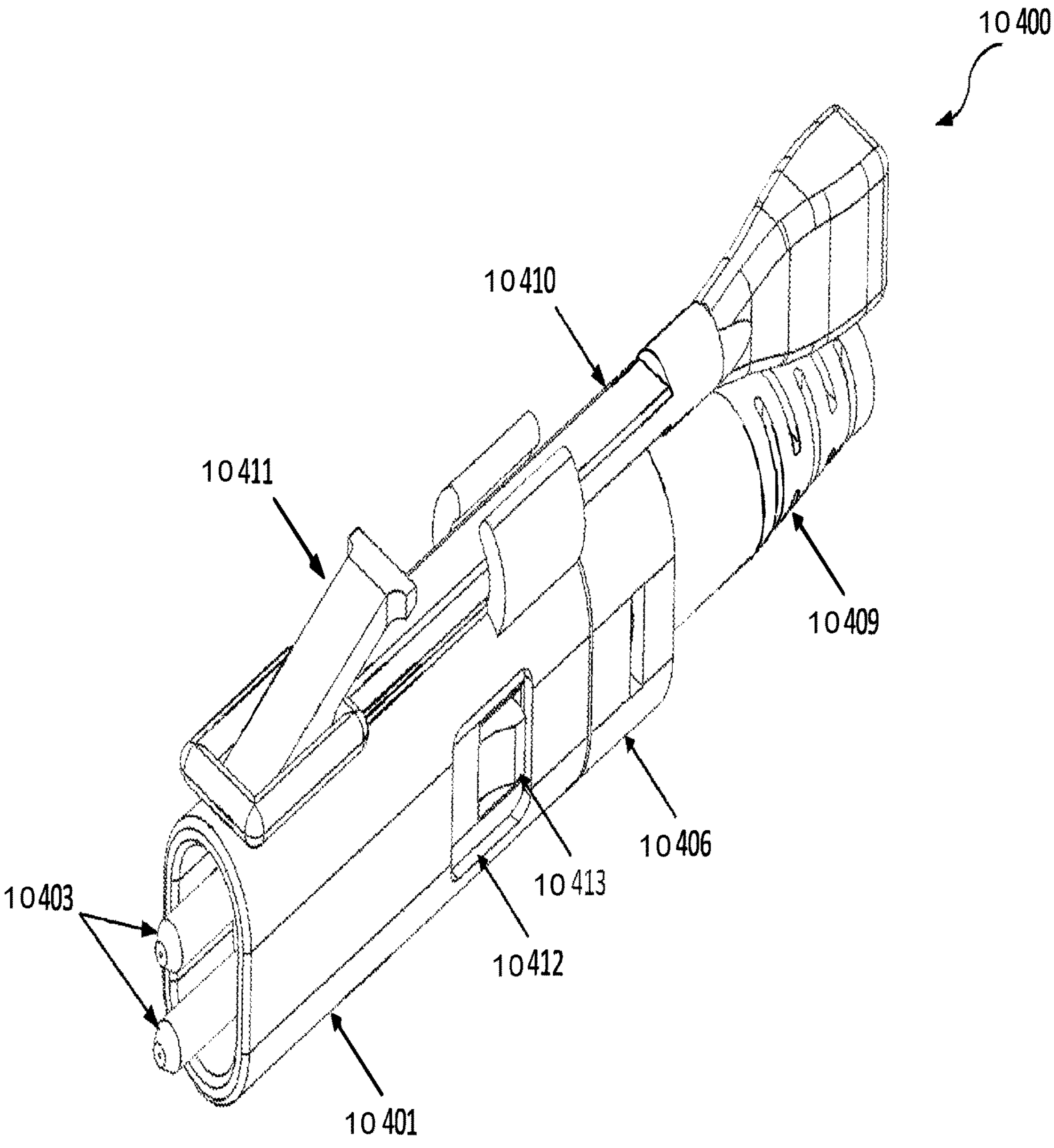


FIG. 54

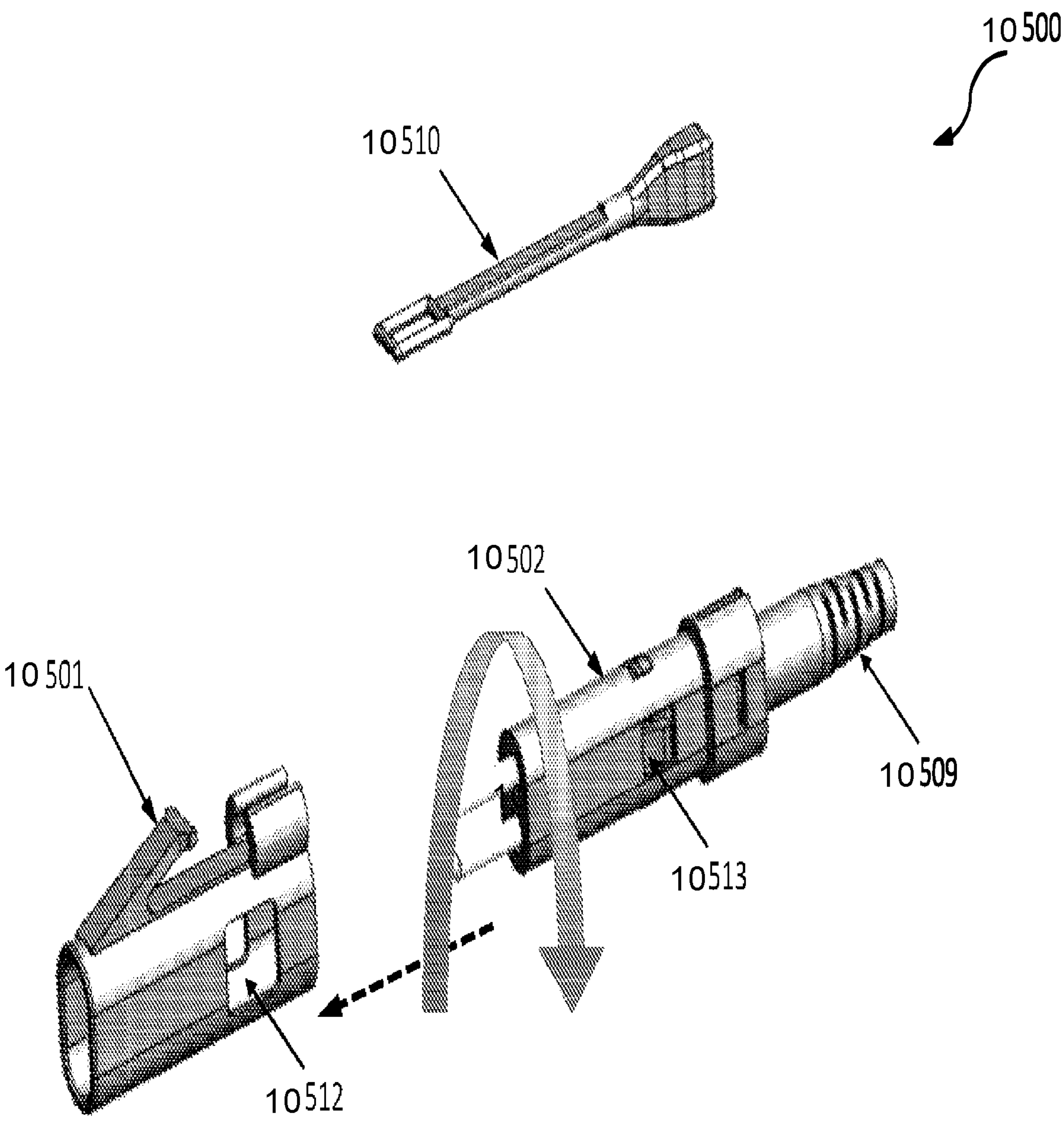


FIG. 55

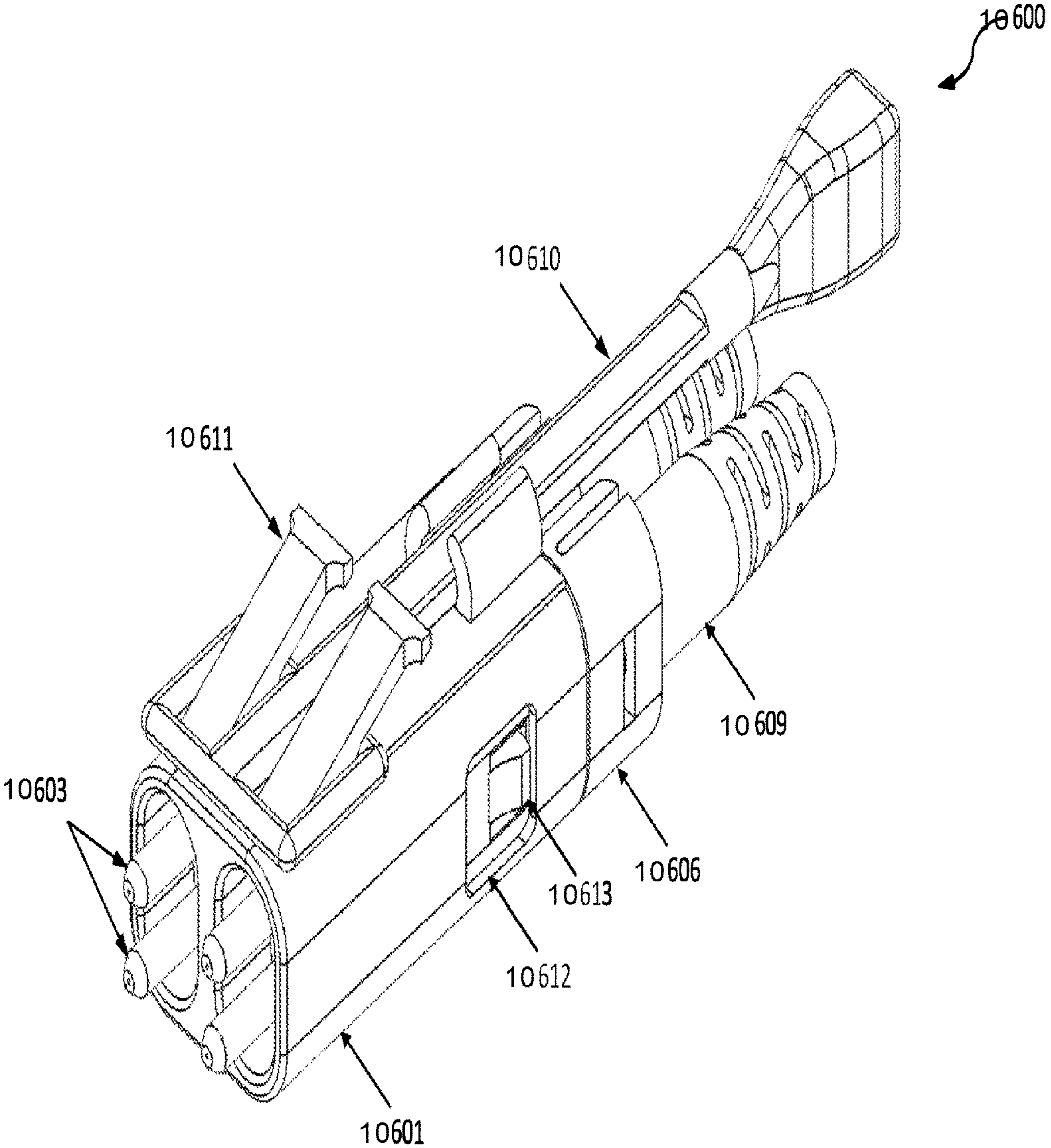


FIG. 56

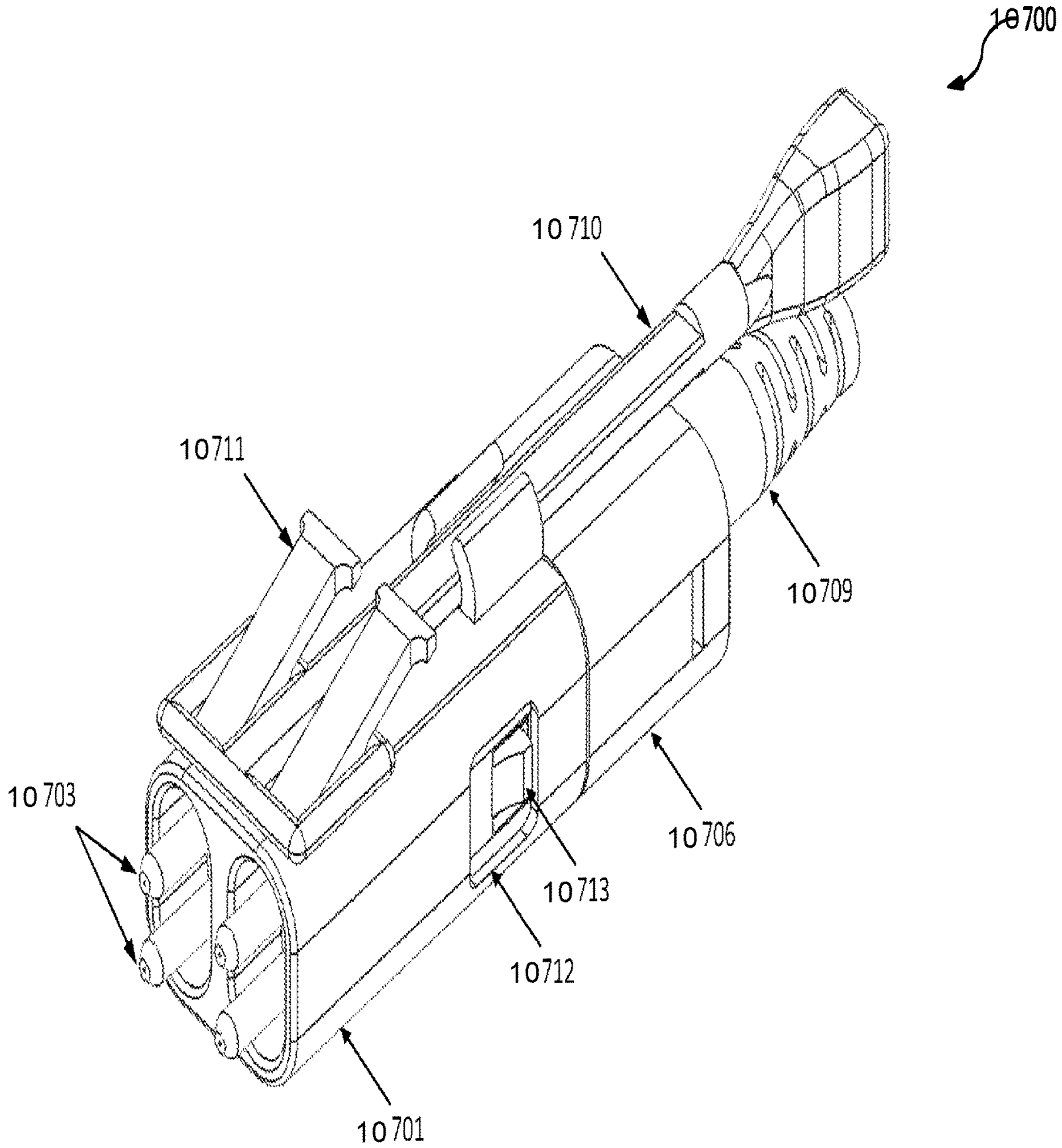


FIG. 57

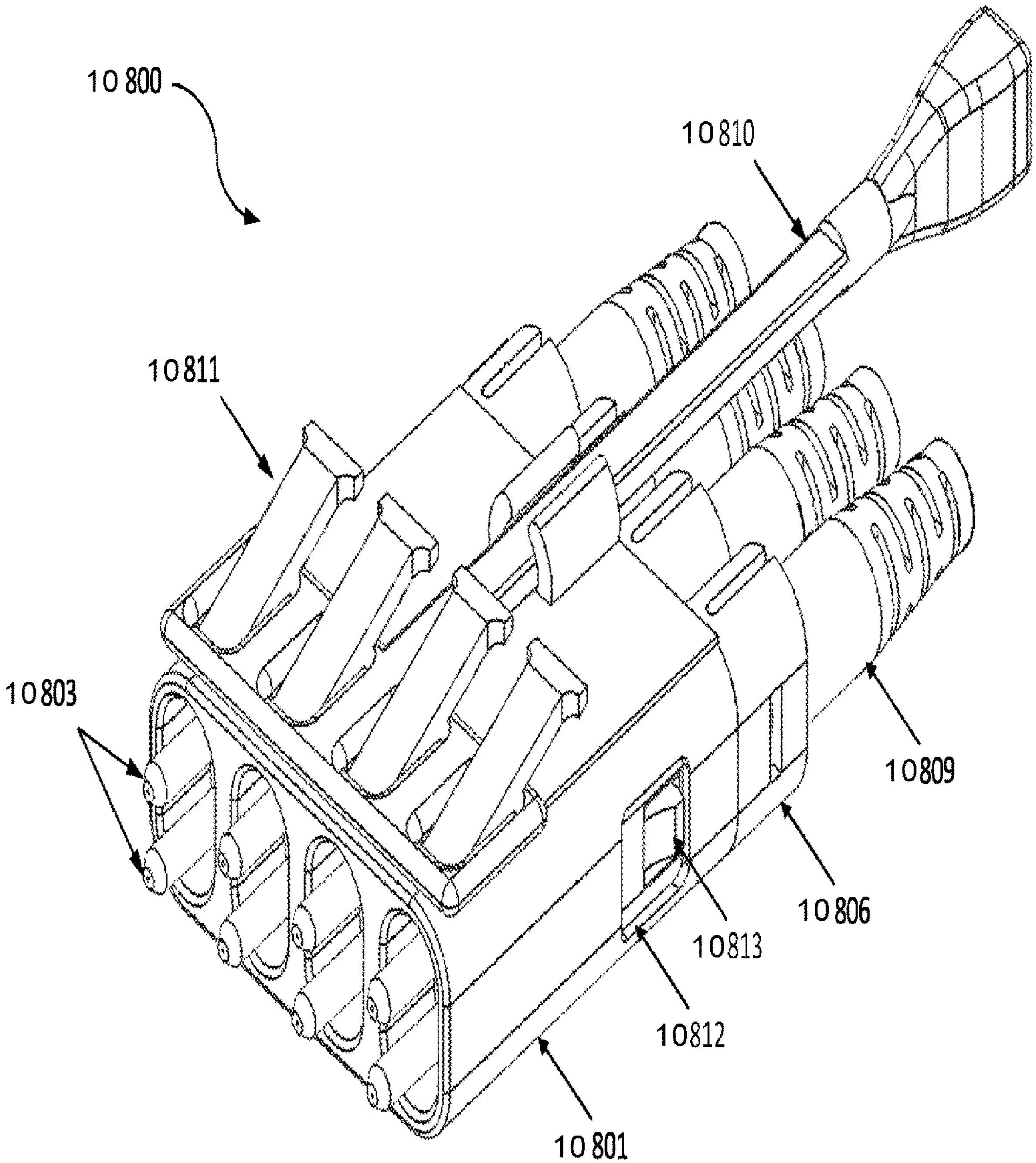


FIG. 58

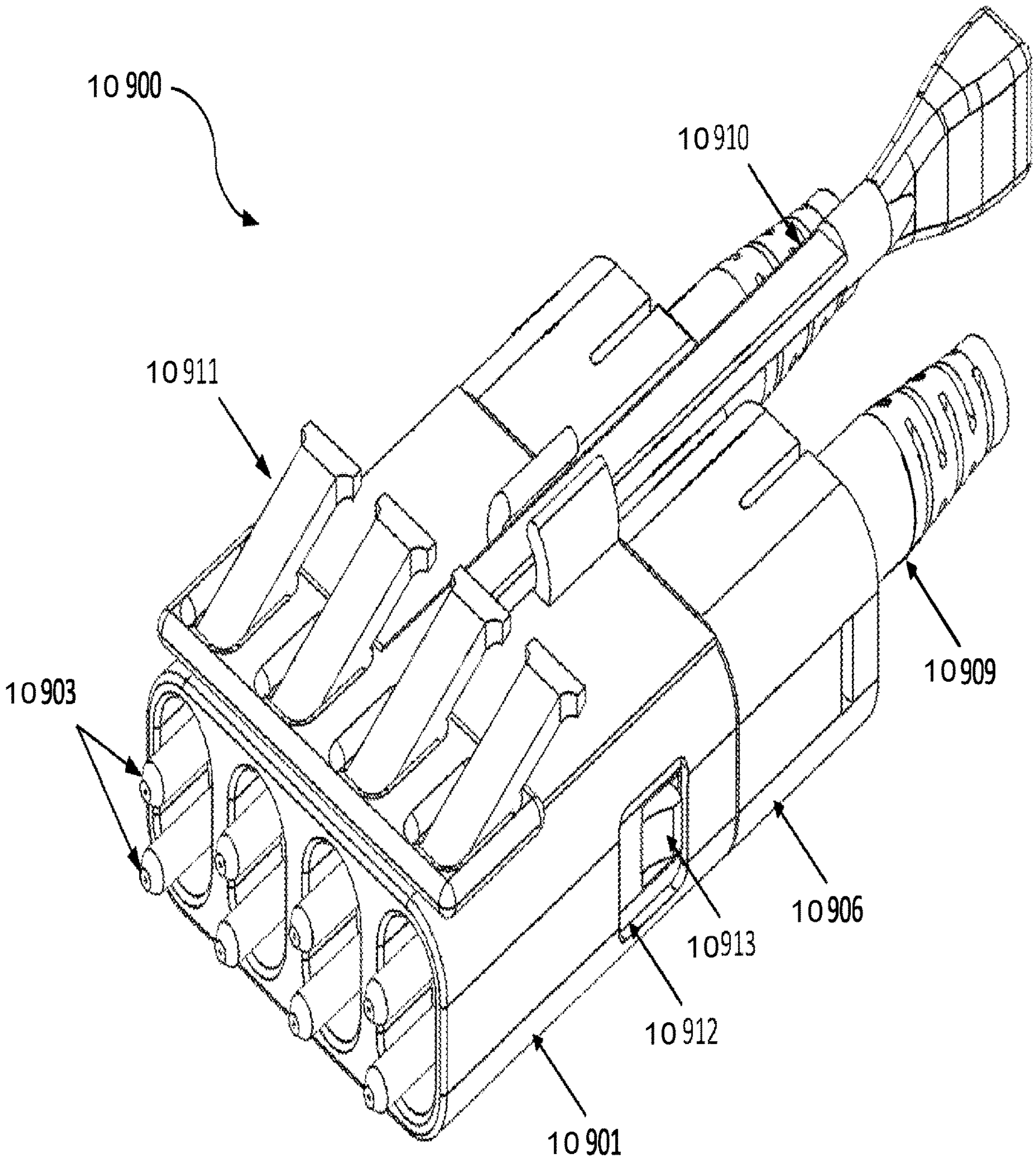


FIG. 59

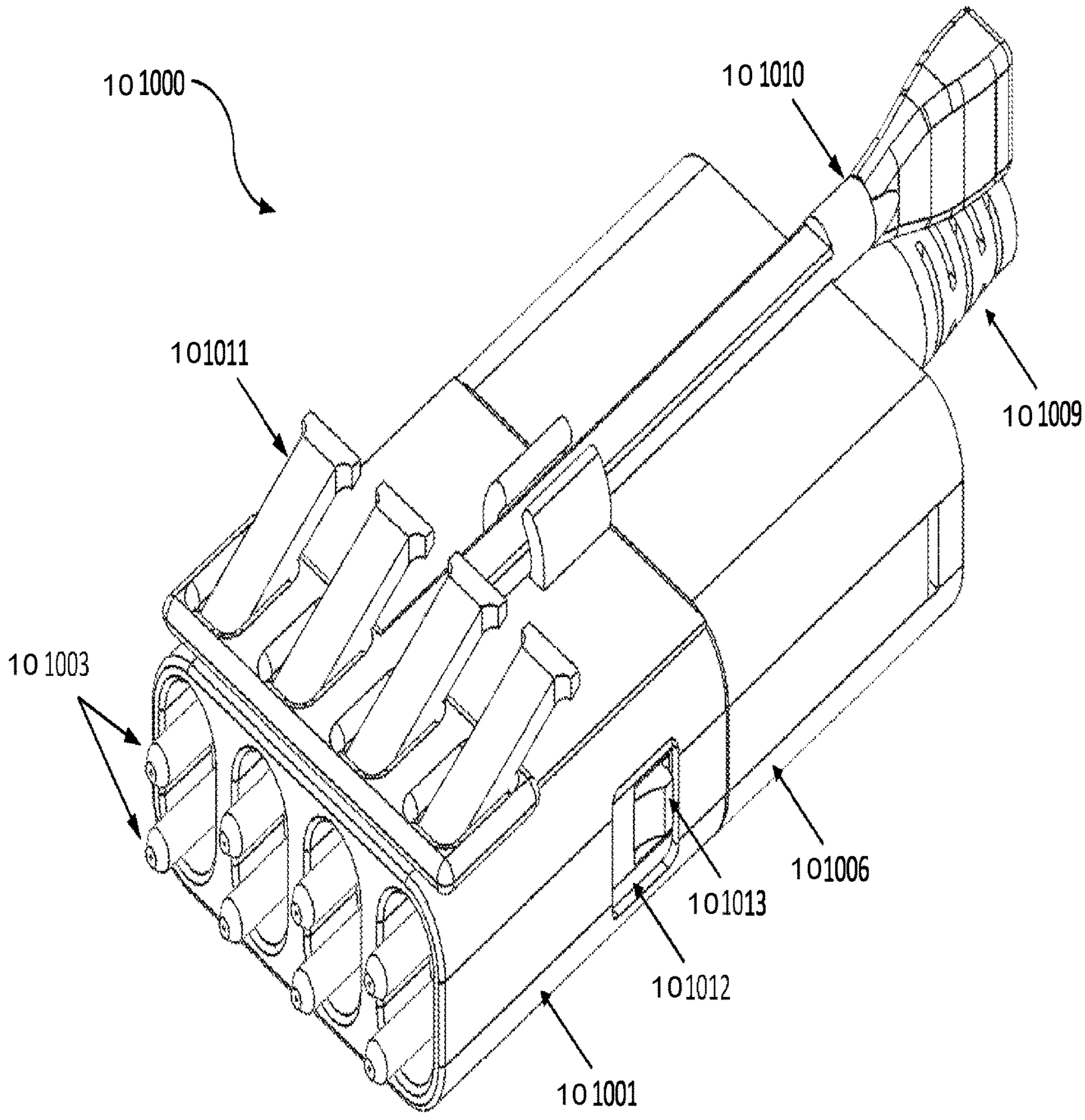

101000
101010
101011
101009
101003
101006
101013
101012
101001

FIG. 60

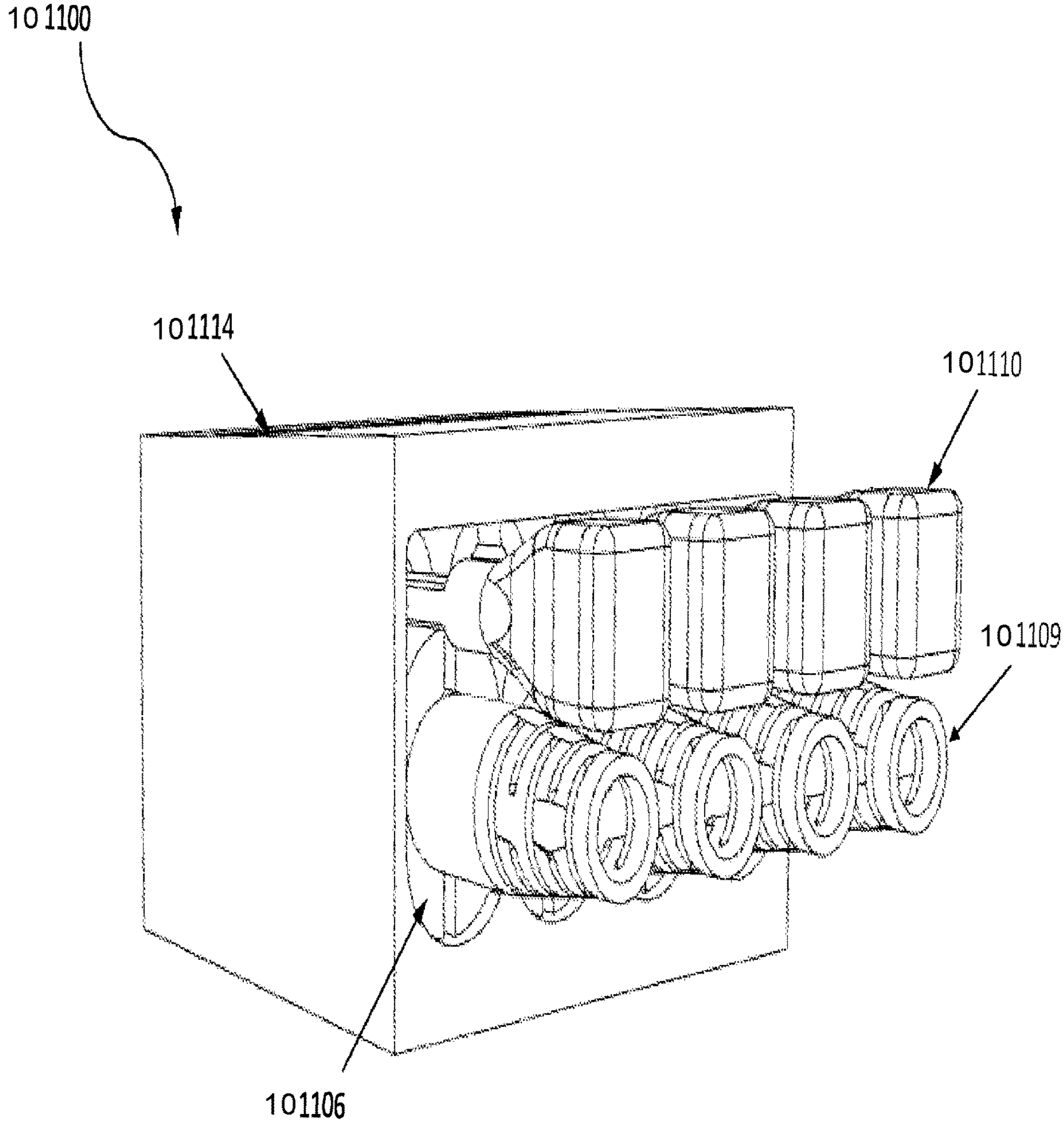


FIG. 61

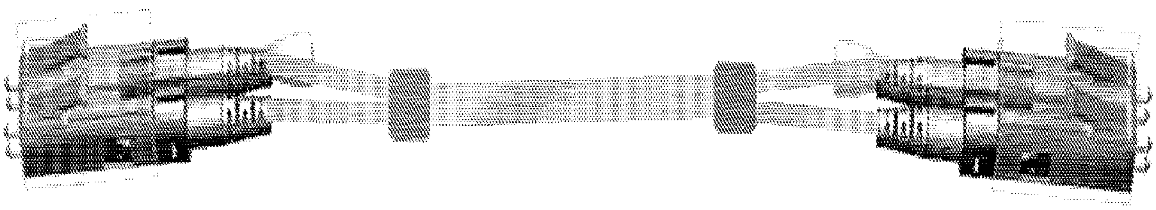


FIG. 62A

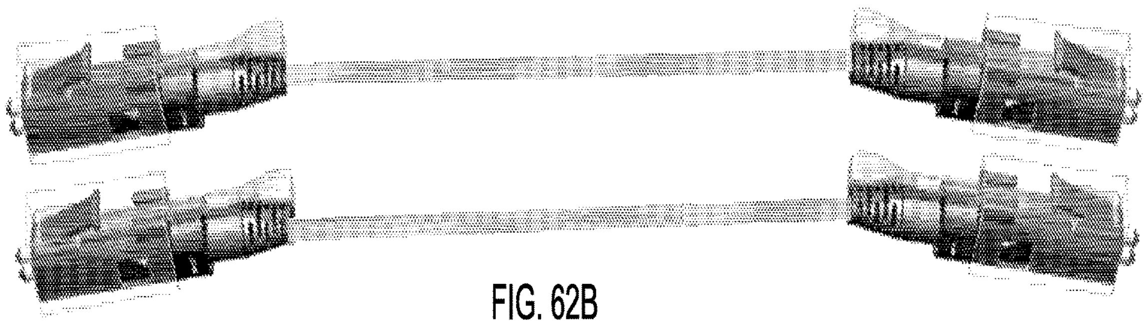


FIG. 62B

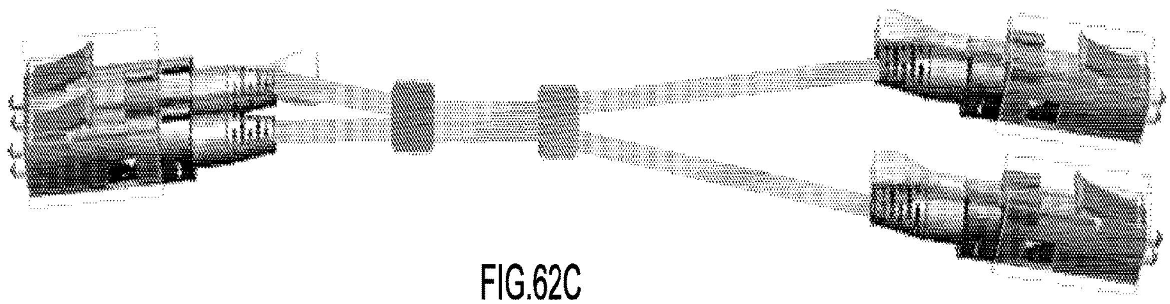


FIG.62C

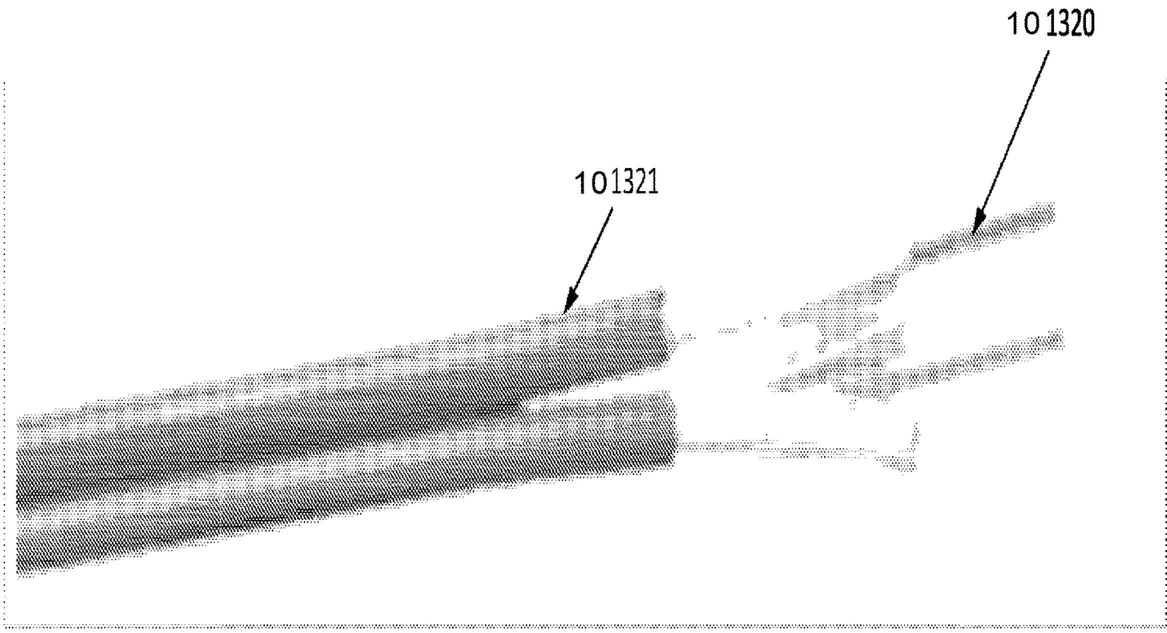


FIG. 63A

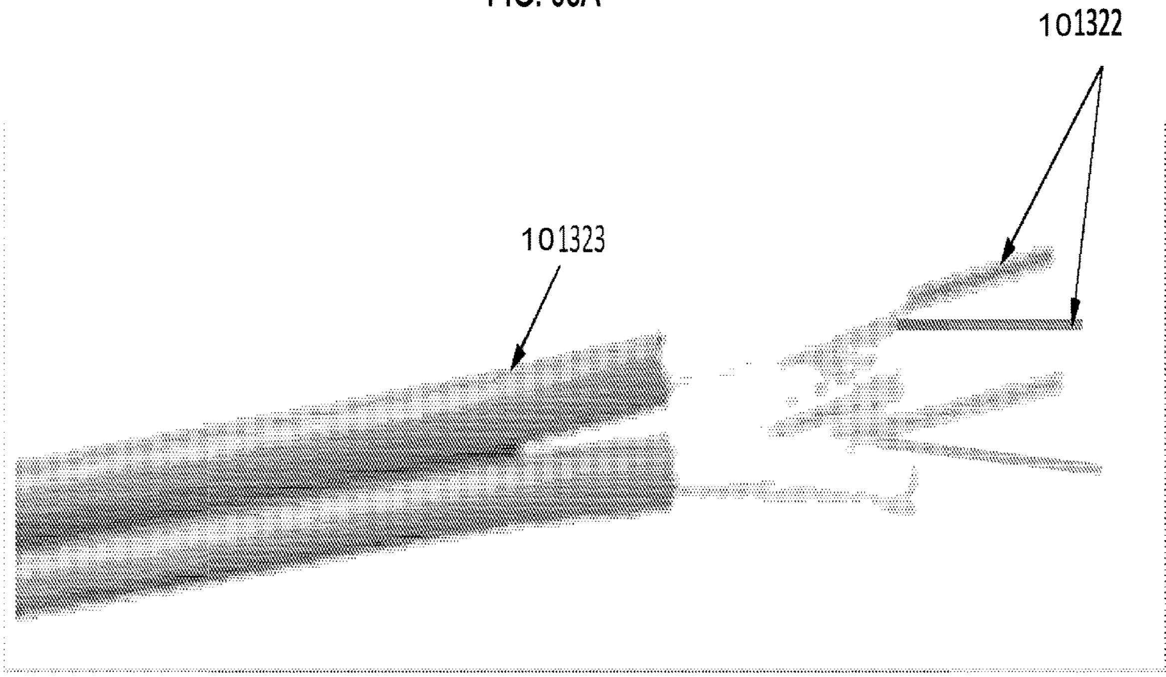


FIG. 63B

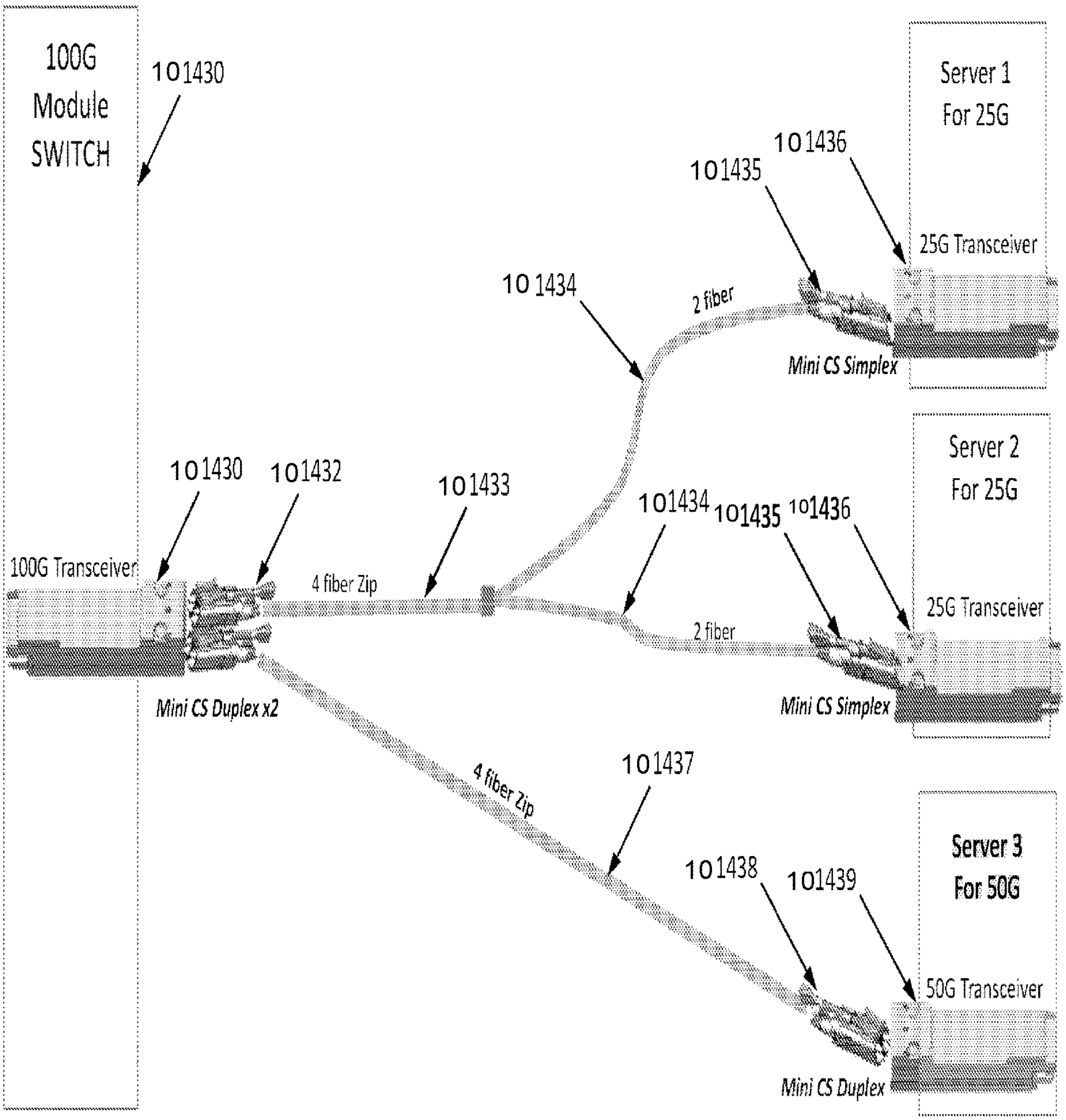

100G Module SWITCH
101430
Server 1 For 25G
101436
101435
25G Transceiver
101434
2 fiber
Mini CS Simplex
Server 2 For 25G
101430
101432
101433
101434
101435
101436
100G Transceiver
4 fiber Zip
25G Transceiver
2 fiber
Mini CS Duplex x2
Mini CS Simplex
101437
4 fiber Zip
Server 3 For 50G
101438
101439
50G Transceiver
Mini CS Duplex

FIG. 64

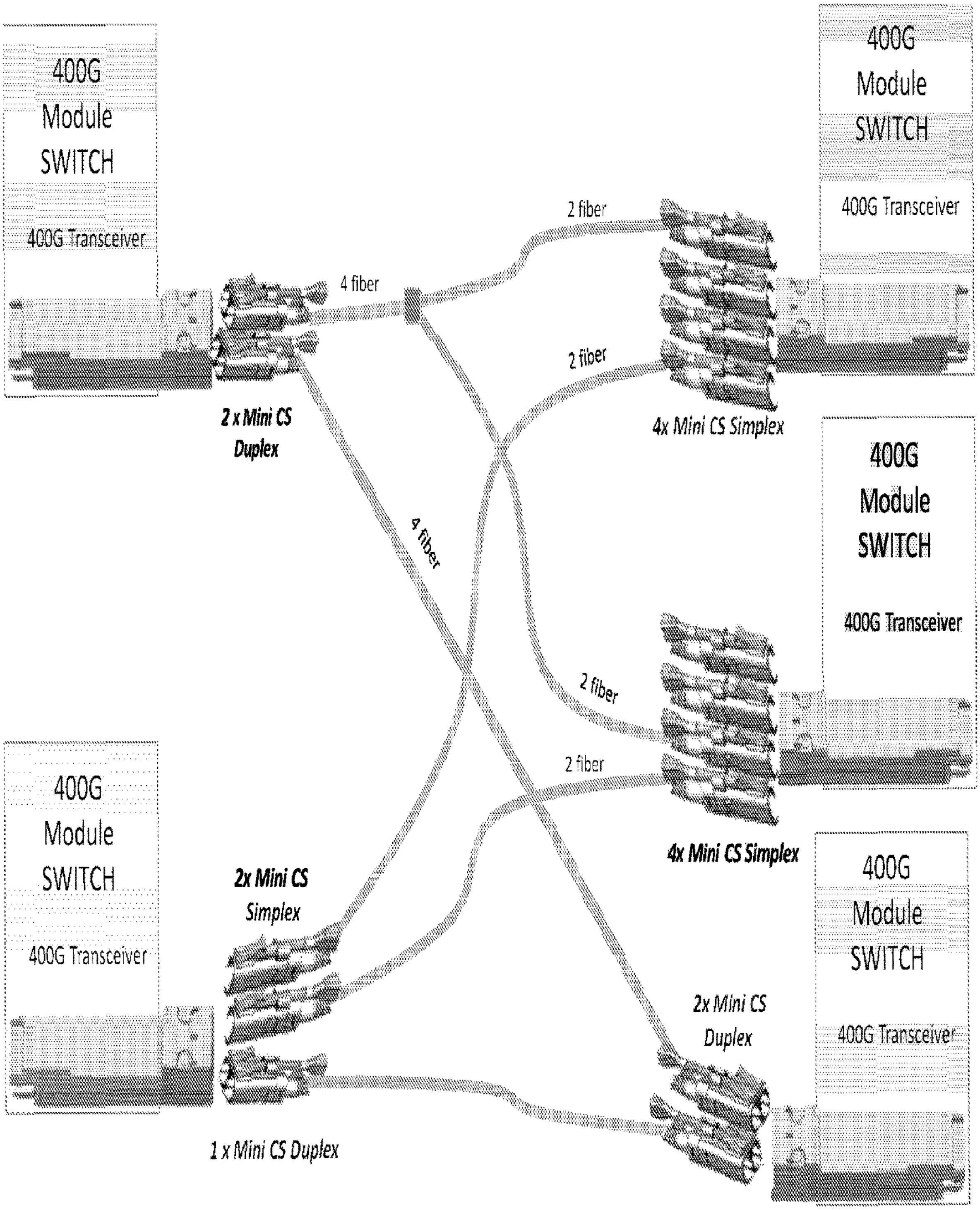

400G
Module
SWITCH
400G Transceiver
400G
Module
SWITCH
400G Transceiver
2 fiber
4 fiber
2 fiber
2 x Mini CS
Duplex
4x Mini CS Simplex
400G
Module
SWITCH
400G Transceiver
4 fiber
2 fiber
2 fiber
400G
Module
SWITCH
400G Transceiver
2x Mini CS
Simplex
4x Mini CS Simplex
400G
Module
SWITCH
400G Transceiver
2x Mini CS
Duplex
1 x Mini CS Duplex

FIG. 65

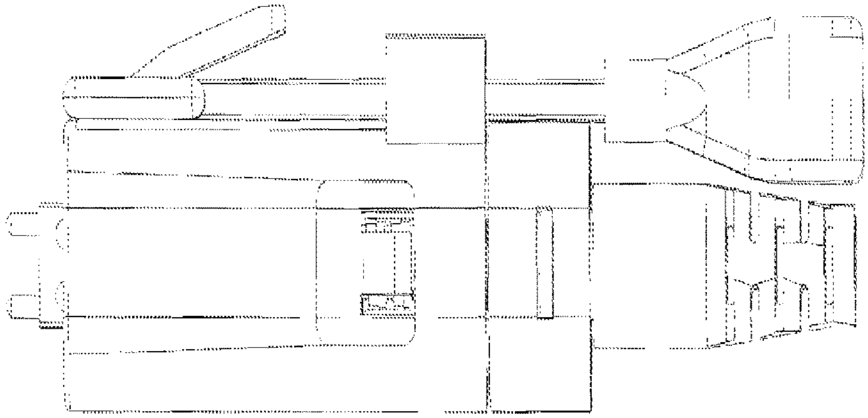


FIG. 66A

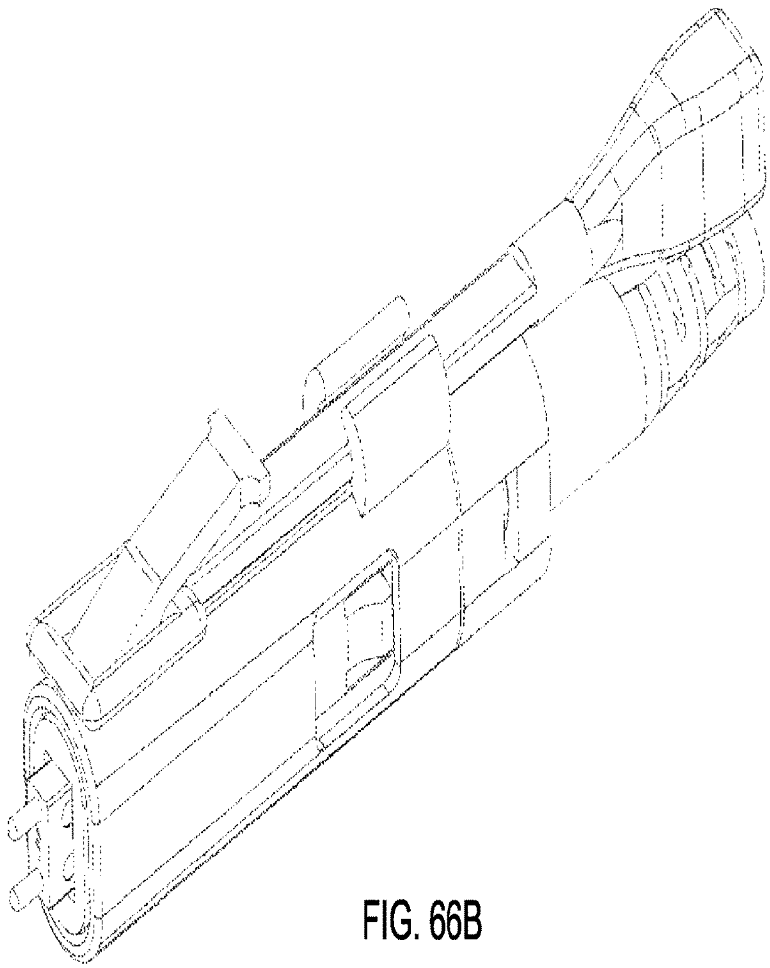


FIG. 66B

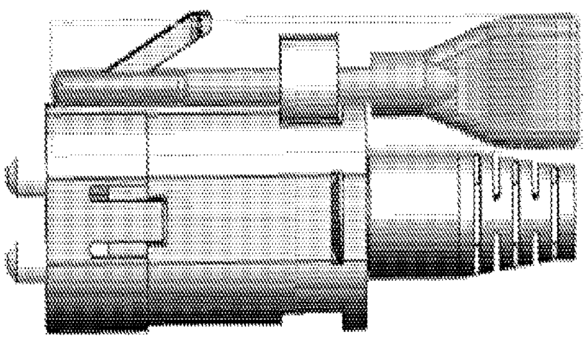


FIG. 67A

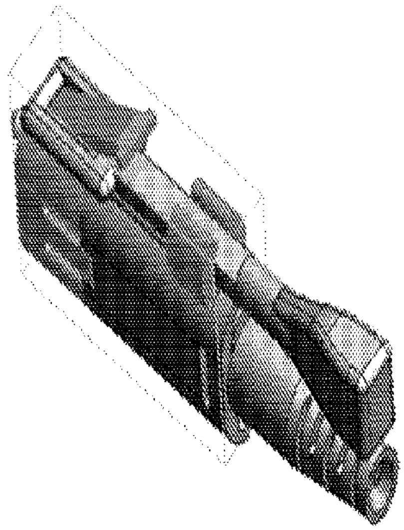


FIG. 67B

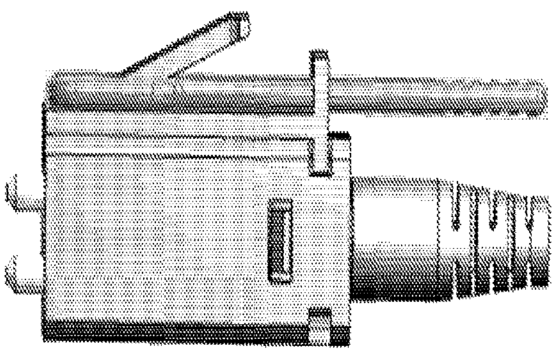


FIG. 67C

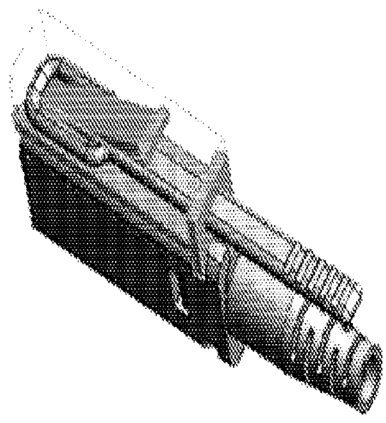


FIG. 67D

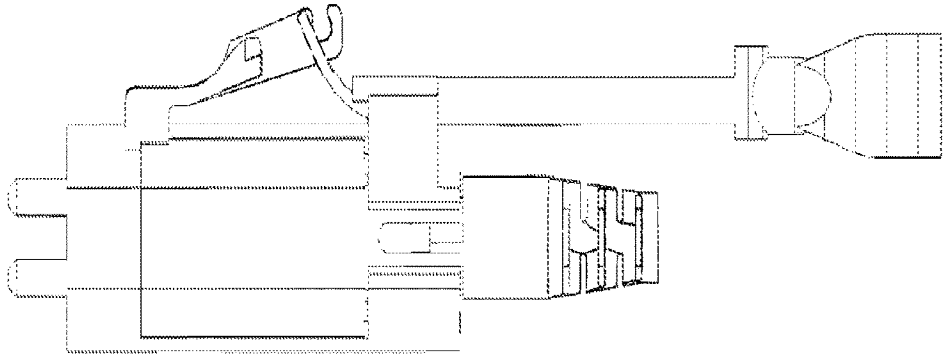


FIG. 68A

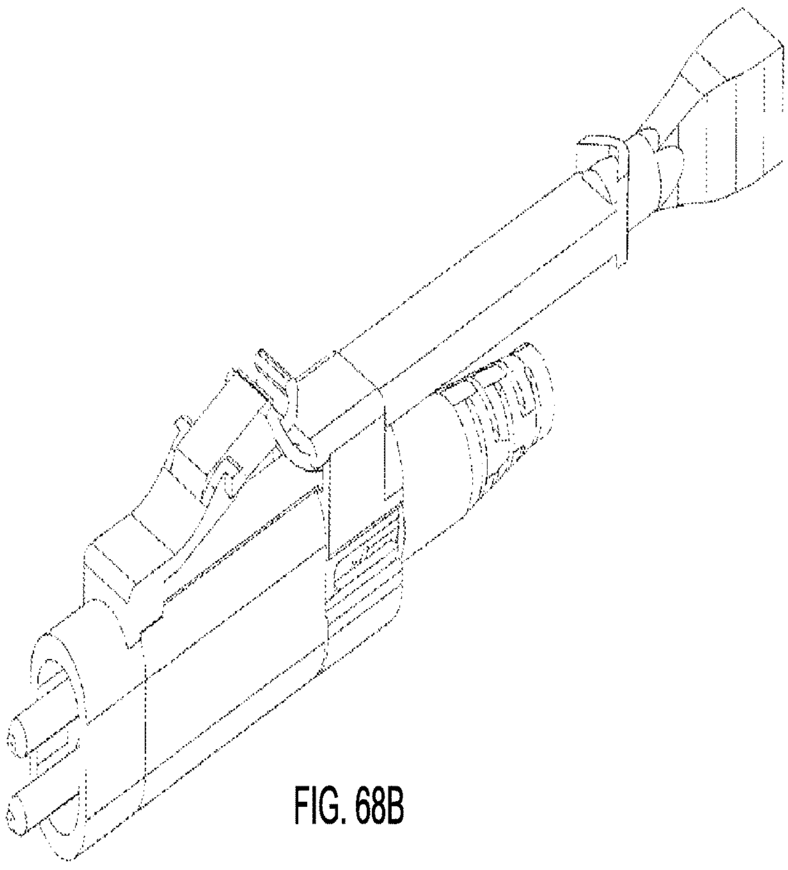


FIG. 68B

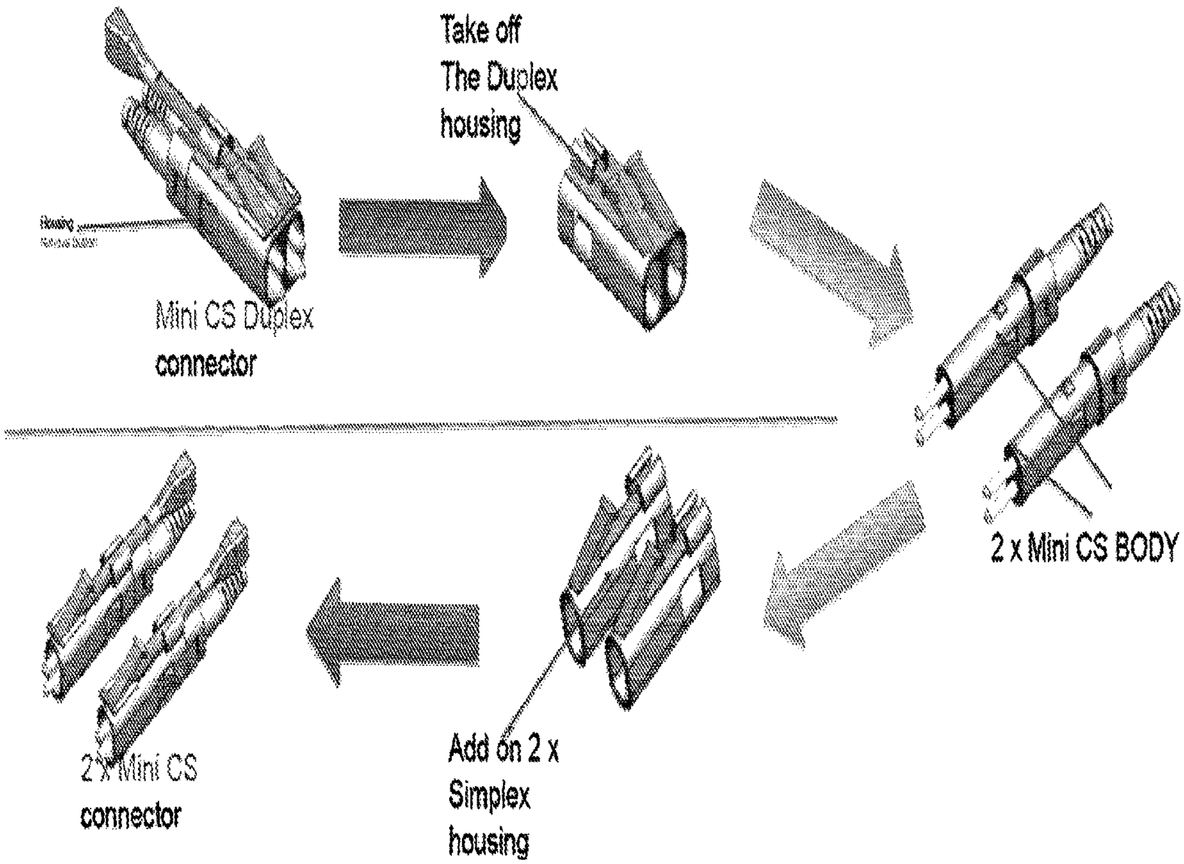

Take off
The Duplex
housing
Mini CS Duplex
connector
2 x Mini CS BODY
Add on 2 x
Simplex
housing
2 x Mini CS
connector

FIG. 69

ULTRA-SMALL FORM FACTOR OPTICAL CONNECTORS USED AS PART OF A RECONFIGURABLE OUTER HOUSING

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority as continuation of U.S. patent application Ser. No. 17/327,197 filed on May 21, 1921 entitled "ULTRA-SMALL FORM FACTOR OPTICAL CONNECTORS USED AS PART OF A RECONFIGURABLE OUTER HOUSING" which is a continuation of Ser. No. 17/090,855 filed Nov. 5, 1920 entitled "ULTRA-SMALL FORM FACTOR OPTICAL CONNECTORS USED AS A PART OF A RECONFIGURABLE OUTER HOUSING" which is a continuation of U.S. patent application Ser. No. 16/414,546 filed May 16, 2019 entitled "ULTRA-SMALL FORM FACTOR OPTICAL CONNECTORS USED AS PART OF A RECONFIGURABLE OUTER HOUSING" which is a continuation of U.S. patent application Ser. No. 16/388,053 filed Apr. 18, 2019 entitled "Ultra-Small Form Factor Optical Connectors", which is a continuation of U.S. patent application Ser. No. 16/035,691, filed Jul. 15, 2018 entitled "Ultra-Small Form Factor Optical Connectors" now U.S. Pat. No. 10,281,668 granted May 7, 2019, which claims priority to the following: U.S. Provisional Patent Application Ser. Nos. 62/532,710 filed Jul. 14, 2017, 62/549,655 filed Aug. 24, 2017, and 62/588,276 filed Nov. 17, 2017, all the disclosures of which are incorporated by reference herein.

FIELD OF THE INVENTION

The present disclosure relates generally to ultra-small form factor optical connectors and related connections within adapters and optical transceivers.

BACKGROUND

The prevalence of the Internet has led to unprecedented growth in communication networks. Consumer demand for service and increased competition has caused network providers to continuously find ways to improve quality of service while reducing cost.

Certain solutions have included deployment of high-density interconnect panels. High-density interconnect panels may be designed to consolidate the increasing volume of interconnections necessary to support the fast-growing networks into a compacted form factor, thereby increasing quality of service and decreasing costs such as floor space and support overhead. However, room for improvement in the area of data centers, specifically as it relates to fiber optic connections, still exists. For example, manufacturers of connectors and adapters are always looking to reduce the size of the devices, while increasing ease of deployment, robustness, and modifiability after deployment. In particular, more optical connectors may need to be accommodated in the same footprint previously used for a smaller number of connectors in order to provide backward compatibility with existing data center equipment. For example, one current footprint is known as the small form-factor pluggable transceiver footprint (SFP). This footprint currently accommodates two LC-type ferrule optical connections. However, it may be desirable to accommodate four optical connections (two duplex connections of transmit/receive) within the same footprint. Another current footprint is the quad small form-factor pluggable (QSFP) transceiver footprint. This

footprint currently accommodates four LC-type ferrule optical connections. However, it may be desirable to accommodate eight optical connections of LC-type ferrules (four duplex connections of transmit/receive) within the same footprint.

In communication networks, such as data centers and switching networks, numerous interconnections between mating connectors may be compacted into high-density panels. Panel and connector producers may optimize for such high densities by shrinking the connector size and/or the spacing between adjacent connectors on the panel. While both approaches may be effective to increase the panel connector density, shrinking the connector size and/or spacing may also increase the support cost and diminish the quality of service.

In a high-density panel configuration, adjacent connectors and cable assemblies may obstruct access to the individual release mechanisms. Such physical obstructions may impede the ability of an operator to minimize the stresses applied to the cables and the connectors. For example, these stresses may be applied when the user reaches into a dense group of connectors and pushes aside surrounding optical fibers and connectors to access an individual connector release mechanism with his/her thumb and forefinger. Overstressing the cables and connectors may produce latent defects, compromise the integrity and/or reliability of the terminations, and potentially cause serious disruptions to network performance.

While an operator may attempt to use a tool, such as a screwdriver, to reach into a dense group of connectors and activate a release mechanism, adjacent cables and connectors may obstruct the operator's line of sight, making it difficult to guide the tool to the release mechanism without pushing aside the adjacent cables. Moreover, even when the operator has a clear line of sight, guiding the tool to the release mechanism may be a time-consuming process. Thus, using a tool may not be effective at reducing support time and increasing the quality of service.

SUMMARY OF THE INVENTION

An optical connector holding two or more LC-type optical ferrules is provided. The optical connector includes an outer body, an inner front body accommodating the two or more LC-type optical ferrules, ferrule springs for urging the optical ferrules towards a mating receptacle, and a back body for supporting the ferrule springs. The outer body and the inner front body are configured such that four LC-type optical ferrules are accommodated in a small form-factor pluggable (SFP) transceiver footprint or eight LC-type optical ferrules are accommodated in a quad small form-factor pluggable (QSFP) transceiver footprint. A mating receptacle (transceiver or adapter) includes a receptacle hook and a housing with an opening that accommodates the receptacle hook in a flexed position as the optical connector makes connection with the mating receptacle by introducing the receptacle hook into an optical receptacle hook recess.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**A is a perspective view of a prior art standard 6.25 mm pitch LC connector SFP;

FIG. **1**B is a perspective view of a prior art standard 6.25 mm pitch LC adapter;

FIG. **1**C is a top view of the prior art adapter of FIG. **1**B;

FIG. **1**D is a front view of the prior art adapter of FIG. **1**B, showing the 6.25 mm pitch;

FIG. **2**A is a perspective view of a prior art LC duplex connector;

FIG. **2**B is a perspective view of a prior art LC duplex connector with a remote release pull tab;

FIG. **2**C is a top view of a prior art LC connector used in the embodiments shown in FIGS. **2**A and **2**B;

FIG. **2**D is a side view of the prior art LC connector of FIG. **2**C;

FIG. **3** is an exploded view of one embodiment of a connector;

FIG. **4** is a perspective view of one embodiment of a connector;

FIG. **5** is a perspective view of one embodiment of a connector with the outer housing removed from the front body.

FIG. **6** is a perspective view of one embodiment of a duplex connector;

FIG. **7** is a perspective view of another embodiment of a duplex connector;

FIG. **8** is a perspective view of one embodiment of a quad connector;

FIG. **9** is another perspective view of one embodiment of a quad connector;

FIG. **10** shows various embodiments of adapter types;

FIG. **11**A is a side view of a connector connected to an adapter;

FIG. **11**B is a side view of a connector being removed from an adapter;

FIG. **12**A is a side view of the outer housing of a connector being removed;

FIG. **12**B is a perspective view of a transparent outer housing of a connector showing the front body;

FIG. **13** is a perspective view of one embodiment of a quad connector inserted into a corresponding adapter;

FIGS. **14**A-C are illustrative examples of cable management using various embodiments of connectors;

FIG. **15**A-B are illustrative examples of cable management using multiple fiber strands per jacket;

FIG. **16** is an illustrative example of using a cable management system using multiple fiber strands per jacket.

FIG. **17** is another illustrative example of using a cable management system using multiple fiber strands per jacket.

FIGS. **18**A-B are various views of one embodiment of a MT connector.

FIGS. **19**A-D are illustrative examples of possible alternative connector designs.

FIG. **20** shows moving two connectors from a duplex connector to two simplex connectors.

FIG. **21**A is an exploded view of a micro optical connector according to an embodiment.

FIG. **21**B is a perspective view of the assembled micro optical connector of FIG. **21**A.

FIG. **22** is a front view of the micro optical connector of FIG. **21**B showing overall connector dimensions and ferrule pitch.

FIG. **23**A is a cross-sectional view of the micro optical connector of FIG. **21**B latched into the adapter of FIG. **24**.

FIG. **23**B is a cross-sectional view of the micro optical connectors of FIG. **21**B unlatched from the adapter of FIG. **24**.

FIG. **24** is an exploded view of an adapter for the micro optical connectors of FIG. **21**B.

FIG. **25**A is a cross-sectional view of the adapter of FIG. **24**, assembled.

FIG. **25**B is a cross-sectional side view of the adapter housing of FIG. **24**.

FIG. **26** is a front view of the assembled adapter of FIG. **24**.

FIG. **27**A is an isometric view of the front body of the micro optical connector of FIG. **21**A.

FIG. **27**B is a right side view of the front body of FIG. **27**A.

FIG. **28**A is an isometric view of the back body of the micro optical connector of FIG. **21**A.

FIG. **28**B is a side view of the back body of FIG. **28**A.

FIG. **29**A is an isometric view of the outer housing of the micro optical connector of FIG. **21**A.

FIG. **29**B is a front view of the outer housing of FIG. **29**A.

FIG. **29**C is a cross-sectional view of the outer housing of FIG. **29**A showing the top of an orientation protrusion.

FIG. **29**D is an inner view of the outer housing of FIG. **29**A;

FIG. **29**E is an inner view of the outer housing of FIG. **29**A.

FIG. **30** is a side view of an adapter hook of the adapter of FIG. **24**.

FIG. **31** is an isometric view of the adapter of FIG. **24** assembled with the micro optical connectors of FIG. **21**B.

FIG. **32**A is cross-sectional view of a prior art connector showing a latch gap.

FIG. **32**B is a cross-sectional view of the micro optical connector of FIG. **21**B latched (left) and unlatched (right) within the adapter of FIG. **24**, assembled.

FIG. **33**A depicts the micro optical connector of FIG. **21**B in a QSFP footprint, depicting dimensions in millimeters.

FIG. **33**B depicts the micro optical connectors of FIG. **21**B in an SFP footprint, depicting dimensions in millimeters.

FIG. **34**A-**34**C depicts adapter hooks interacting with the micro optical connectors of FIG. **21**B before (FIG. **34**A), during (FIG. **34**B), and after (FIG. **34**C) latching.

FIG. **35**A-FIG. **35**C depicts the micro optical connector of FIG. **21**B side flap operation before (FIG. **35**A), during (FIG. **35**B), and after (FIG. **35**C) latching.

FIG. **36**A depicts plural micro optical connectors in a transceiver.

FIG. **36**B is a front view of the transceiver of FIG. **36**A.

FIG. **37** is an exploded view of a micro optical connector according to a further embodiment.

FIG. **38** is an isometric view of a front body of the micro optical connector of FIG. **37**.

FIG. **39** is an isometric view of a back body of the micro optical connector of FIG. **37**.

FIGS. **40**A, **40**B, and **40**C depict a technique for reversing polarity of the optical connector of FIG. **37**.

FIG. **41** is an exploded view of a micro optical connector according to a further embodiment.

FIG. **42**A is an isometric view of the front body of the micro optical connector of FIG. **41**.

FIG. **42**B is a side view of the front body of FIG. **42**A.

FIG. **43** is an isometric view of the back body of the micro optical connector of FIG. **41**.

FIGS. **44**A, **44**B, and **44**C are isometric views of the outer housings that may be used with any of the micro optical connectors of FIGS. **21**A, **37**, and **41**.

FIG. **45** is an exploded view of an adapter according to a further embodiment.

FIG. **46** is a cross-section of the adapter of FIG. **45**, assembled.

FIG. **47** is an exploded view of a connector according to another embodiment.

FIG. **48** is an isometric view of the back body and the back post of the connector of FIG. **47**.

FIG. **49** is a cross-section of the back post of FIG. **47** assembled with optical fibers.

FIG. **50** is a front view of the connector of FIG. **47**.

FIG. **51** is an isometric view of the boot of the connector of FIG. **47**.

FIG. **52** is a front view of the adapter of FIG. **45**.

FIG. **53** is a exploded view of one embodiment of a connector;

FIG. **54** is a perspective view of one embodiment of a connector;

FIG. **55** is a perspective view of one embodiment of a connector with the outer housing removed from the front body

FIG. **56** is a perspective view of one embodiment of a duplex connector;

FIG. **57** is a perspective view of another embodiment of a duplex connector;

FIG. **58** is a perspective of one embodiment of a quad connector;

FIG. **59** is a perspective of another embodiment of a quad connector;

FIG. **60** is a perspective of another embodiment of a quad connector;

FIG. **61** is a perspective of one embodiment of a quad connector inserted into a corresponding adapter;

FIGS. **62**A-C are illustrative examples of cable management using various embodiments of connectors;

FIG. **63**A-B are illustrative examples of cable management using multiple fiber strands per jacket;

FIG. **64** is an illustrative example of using a cable management system using multiple fiber strands per jacket.

FIG. **65** is another illustrative example of using a cable management system using multiple fiber strands per jacket;

FIG. **66**A-B are various views of one embodiment of a MT connector.

FIGS. **67** A-D are illustrative examples of possible alternative connector designs.

FIGS. **68**A-B are illustrative examples of additional possible alternative connector designs.

FIG. **69** is an illustrative example of a method of switching modes of operation of one or more connectors.

DETAILED DESCRIPTION

This disclosure is not limited to the particular systems, devices and methods described, as these may vary. The terminology used in the description is for the purpose of describing the particular versions or embodiments only, and is not intended to limit the scope.

As used in this document, the singular forms "a," "an," and "the" include plural references unless the context clearly dictates otherwise. Unless defined otherwise, all technical and scientific terms used herein have the same meanings as commonly understood by one of ordinary skill in the art. Nothing in this disclosure is to be construed as an admission that the embodiments described in this disclosure are not entitled to antedate such disclosure by virtue of prior invention. As used in this document, the term "comprising" means "including, but not limited to."

The following terms shall have, for the purposes of this application, the respective meanings set forth below.

A connector, as used herein, refers to a device and/or components thereof that connects a first module or cable to a second module or cable. The connector may be configured for fiber optic transmission or electrical signal transmission. The connector may be any suitable type now known or later developed, such as, for example, a ferrule connector (FC), a fiber distributed data interface (FDDI) connector, an LC connector, a mechanical transfer (MT) connector, a square connector (SC) connector, a CS connector, or a straight tip (ST) connector. The connector may generally be defined by a connector housing body. In some embodiments, the housing body may incorporate any or all of the components described herein.

A "fiber optic cable" or an "optical cable" refers to a cable containing one or more optical fibers for conducting optical signals in beams of light. The optical fibers can be constructed from any suitable transparent material, including glass, fiberglass, and plastic. The cable can include a jacket or sheathing material surrounding the optical fibers. In addition, the cable can be connected to a connector on one end or on both ends of the cable.

Various embodiments described herein generally provide a remote release mechanism such that a user can remove cable assembly connectors that are closely spaced together on a high density panel without damaging surrounding connectors, accidentally disconnecting surrounding connectors, disrupting transmissions through surrounding connectors, and/or the like. Various embodiments also provide narrow-pitch LC duplex connectors and narrow-width multi-fiber connectors, for use, for example, with future narrow-pitch LC SFPs and future narrow width SFPs. The remote release mechanisms allow use of the narrow-pitch LC duplex connectors and narrow-width multi-fiber connectors in dense arrays of narrow-pitch LC SFPs and narrow-width multi-fiber SFPs.

FIG. **1**A shows a perspective view of a prior art standard 6.25 mm pitch LC connector SFP **100**. The SFP **100** is configured to receive a duplex connector and provides two receptacles **102**, each for receiving a respective LC connector. The pitch **104** is defined as the axis-to-axis distance between the central longitudinal axes of each of the two receptacles **102**. FIG. **1**B shows a perspective view of a prior art standard 6.25 mm pitch LC adapter **106**. The adapter **106** is also configured to receive a duplex connector, and provides two receptacles **108**, each for receiving a respective LC connector. FIG. **1**C is a top view of the adapter **106** of FIG. **1**B. The pitch of the adapter **106** is defined similarly to that of the SFP **100**, as the axis-to-axis distance between the central longitudinal axes of each of the two receptacles **108**, as illustrated in FIG. **1**D, which shows a front view of the adapter **106**.

FIG. **2**A shows a prior art LC duplex connector **200** that may be used with the conventional SFP **100** and the conventional adapter **106**. The LC duplex connector **200** includes two conventional LC connectors **202**. FIG. **2**B shows another prior art LC duplex connector **204** having a remote release pull tab **206**, and including two conventional LC connectors **208**. As shown, the remote release pull tab includes two prongs **210**, each configured to couple to the extending member **212** of a respective LC connector **208**. FIGS. **2**C and **2**D show top and side views, respectively, of the conventional LC connector **208**, having a width of 5.6 mm, and further showing the extending member **212**.

As discussed herein, current connectors may be improved by various means, such as, for example, reducing the footprint, increasing the structural strength, enabling polarity changes, etc. Various embodiments disclosed herein offer improvements over the current state of the art, as will be further discussed below.

In some embodiments, as shown in FIG. **3**, a connector **300** may comprise various components. Referring to FIG. **3**, an illustrative embodiment of a connector **300** is shown in an exploded view to display detail. In some embodiments, and as discussed further herein, a connector **300** may have an outer housing **301**, a front body **302**, one or more ferrules **303**, one or more ferrule flanges **304**, one or more springs **305**, a back body **306**, a back post **307**, a crimp ring **308**, and a boot **309**. In some embodiments, the back body **306** may comprise one or more protrusions **306.1** which may interlock with a window/cutout **302.1** in the front body **302**. This may allow for the back body **306** and the front body **302** to be securely fastened together around the ferrule(s) **303**, ferrule flange(s) **304**, and the spring(s) **305**. The elements of FIG. **3** are configured such that two optical connectors having four LC-type optical ferrules may be accommodated in a small form-factor pluggable (SFP) transceiver footprint or at least two optical connectors having a total of eight LC-type optical ferrules may be accommodated in a quad small form-factor pluggable (QSFP) transceiver footprint.

Referring now to FIG. **4**, an embodiment is shown wherein the connector **400** is assembled. In some embodiments, the assembled connector may have an outer housing **401**, a front body **402** positioned within the outer housing, one or more ferrules **403**, one or more ferrule flanges (not shown), one or more springs (not shown), a back body **406**, a back post (not shown), a crimp ring (not shown), a boot **409**, and a push-pull tab **410**. In some embodiments, the connector may have one or more latching mechanisms made up of a window **412** on the outer housing **401** near the push-pull tab **410** and a protrusion **413** on the front body. The latching mechanism made up of the window **412** and protrusion **413** securely attaches the outer housing **401** to the front body **402**. In a further embodiment, the outer housing **401** may have a recess **411** to receive a locking tab or locking mechanism from an adapter (depicted in FIG. **13**, below). The recess **411** of the outer housing **401** is used to interlock with an adapter (depicted in FIG. **13**, below) or transceiver receptacle to secure the connector into the adapter. As would be understood by one skilled in the art, the push-pull tab **410** enables removal of the connector from a receptacle without requiring additional tools. Alternatively, the push-pull tab may be eliminated and the connector removed manually. In one or more further embodiments, the outer housing **401** may also have a key **414**. The key **414** may keep the connector in a given orientation when inserted into a receptacle such as an adapter or transceiver.

FIG. **5** depicts a procedure for changing the polarity of the optical connectors of the present disclosure. As shown in FIG. **5**, in some embodiments, the latching mechanism of the connector **500** may be made up of two main parts: a window (not visible) and one or more protrusions **513**. As illustrated in FIG. **5**, the outer housing **501** can slide on to or be removed from the front body **502** by disengaging the latching mechanisms formed by the protrusion **513** exiting through the window, whereby it contacts a rear wall of the window (refer to FIG. **4** for an illustrated example of the outer housing being attached to the front body via the latching mechanism). In some embodiments, the push-pull tab **510** may be permanently attached to the outer housing **501**, as shown.

The front body **502** may be removed from the outer housing **501**, rotated 180° as indicated by arrow **520**, and re-inserted into the outer housing. This allows for a change in the polarity of the front body **502**, as shown by the arrow diagram in FIG. **5**, and therefore the ferrules can switch quickly and easily without unnecessarily risking the delicate fiber cables and ferrules.

In some embodiments, it may be beneficial to connect two or more connectors together to increase structural integrity, reduce the overall footprint, and cut manufacturing costs.

Accordingly, as shown in FIG. **6**, a connector **600** may in some embodiments, utilize an outer housing **601** that is capable of holding two front bodies **602**. Various other embodiments are disclosed herein, and it should be noted that the embodiments disclosed herein are all non-limiting examples shown for explanatory purposes only.

Accordingly, although the embodiment shown in FIG. **6** utilizes a duplex outer housing **601**, additional or alternative embodiments may exist with more capacity, for example, six or eight optical connectors within a single outer housing. As shown in FIG. **6**, in some embodiments, the outer housing **601** may accept two front bodies **602**, each with two separate ferrules **603**. As shown, the front body(s) **602** may securely fasten to the outer housing **601** via the latching mechanism **612** and **613**. In additional embodiments, the push-pull tab **610** may be modified, as shown, such that a single tab can be used to free the two or more connectors from an adapter. As illustrated in FIG. **6**, the uni-body push-pull tab **610** and the outer housing **601** may have two windows **612** with which to receive multiple protrusions **613** of the front body(s) **602**. As discussed herein the recesses **611** of the outer housing **601** are used to secure the connectors to an adapter (depicted in FIG. **13** below). In one or more further embodiments, the connectors may have individual back bodies **606** and boots **609** (i.e., one back body/boot per front body) as shown.

Alternatively, in some embodiments, such as that shown in FIG. **7**, the connector **700** may have a single boot **709** and a duplex (i.e., uni-body) back body **706** instead of individual back bodies (e.g., such as shown in FIG. **6**). In some embodiments, the duplex back body **706** may have different dimensions than that of the individual back bodies of FIG. **6**, such as, for example, they may be longer to accommodate the need for routing the fiber after it exits the boot **709**. As with other embodiments discussed herein, the connector shown in FIG. **7** may also include an outer housing (e.g., duplex outer housing) **701**, one or more ferrules **703**, at least one latching mechanism formed by the protrusion (not shown) exiting through one or more windows **712**, and a push-pull tab **710**.

As stated, it may be beneficial to connect two or more connectors together to increase structural integrity, reduce the overall footprint, and cut manufacturing costs. Accordingly, similar to FIG. **6**, FIG. **8** shows a connector **800** that may, in some embodiments, utilize an outer housing **801** that is capable of holding multiple (e.g., four) front bodies **802**.

As shown in FIG. **8**, some embodiments may have an outer housing **801** able to accept up to four front bodies **802**, each with one or more ferrules **803**. As shown, each front body **802** may securely fasten to the outer housing **801** via the latching mechanism **812** and **813**. In additional embodiments, the push-pull tab **810** may be modified such that a single tab can be used to remove the up to four connectors from an adapter. As illustrated in FIG. **8**, the push-pull tab **810** may include four recesses **811**, which as discussed herein are used to secure the connector to a receptacle such as an adapter (shown in FIG. **13**, below) or the front receptacle portion of a transceiver. In one or more further embodiments, the connectors may have individual back bodies **806** and boots **809** (i.e., one back body/boot per front body) as shown.

Similar to FIG. **8**, FIG. **9** shows an embodiment where the outer housing **901** is able to accept up to four front bodies **902**, each with one or more ferrules **903**. As shown, each front body **902** may securely fasten to the outer housing **901** via the latching mechanism **912** and **913**. In additional embodiments, the push-pull tab **910** may be modified such that a single tab can be used to remove the up to four CS connectors from an adapter. As illustrated in FIG. **9**, the push-pull tab **910** may include four recesses **911**, which as discussed herein are used to secure the connector to an adapter (shown in FIG. **13**, below) or the optical receptacle portion of a transceiver. The FIG. **9** embodiment may utilize a single back body **906** and a single boot **909**. In one or more further embodiments, the connectors may have individual back bodies **906** and boots **909** (i.e., one back body/boot for all four front bodies) as shown.

In another aspect, the present disclosure provides method for reconfiguring optical cables in which the outer housings of the connectors may be removed and the remaining portion of the assembled connector is inserted into a housing having a larger or smaller capacity.

For example, the outer housings of plural two-ferrule capacity housings may be removed and the connector inner body and associated components inserted into a second outer housing that has either a four-ferrule or eight-ferrule capacity. Alternatively, an outer housing with a four-ferrule capacity may be removed and the inner bodies and associated components are inserted into two second outer housings, each of the two second housings having a two-ferrule capacity. Similarly, an outer housing with an eight-ferrule capacity may be removed and replaced by two four-ferrule capacity housing or a four-ferrule capacity and two two-ferrule capacity housings. In this manner, cables may be flexibly reconfigured to match the capacity of a mating optical-electrical component such as a transceiver. This aspect of the present disclosure is demonstrated in connection with FIG. **10**.

Referring now to FIG. **10**, various embodiments may exist such as a single housing **1001** which receives a single connector **1002**. Additional embodiments may also exist, such as a duplex housing **1003** which receives two connectors **1004** and/or a quad housing **1005** which may receive up to four connectors **1006**. It should be understood by one skilled in the art that various other embodiments may exist that are not explicitly shown. For example, a housing with the capacity for 5, 6, 7, 8, 9, 10 or more connectors may be utilized for various embodiments disclosed herein. As shown below, it is desirable to have flexible housing configurations so that connectors may be grouped and ungrouped between optical and optoelectronic components such as adapters and transceivers.

Alternatively, in some embodiments the connector may utilize one or more duplex back bodies with a single boot, similar to that shown in FIG. **7**. Thus, similar to FIG. **7**, an embodiment may allow for a further reduced footprint, less cabling, and easier maintenance of the connector. Accordingly, one or more embodiments may have an outer housing that may accept up to four front bodies, each with one or more ferrules. In some embodiments, each front body may securely fasten to the outer housing via a latching mechanism. In additional embodiments, the push-pull tab may be modified such that a single tab can be used to free the up to four front bodies from an adapter. The push-pull tab may include four openings with which to receive multiple locking tabs of the outer housing. As discussed herein the locking tabs of the outer housing are used to secure the connectors to an adapter (shown in FIG. **13**) or the optical receptacle portion of a transceiver.

In further embodiments, the connector may utilize a single uni-body back body with a single boot (i.e., as shown in FIG. **9**). Thus, an embodiment may allow for a further reduced foot print, less cabling, and easier maintenance of the connector. Accordingly, one or more embodiments may

have an outer housing that may accept up to four front bodies, each with one or more ferrules. Each front body may securely fasten to the outer housing via the latching mechanism as discussed herein. In additional embodiments, the push-pull tab may be modified such that a single tab can be used to remove up to four connectors from an adapter. The push-pull tab may include four openings with which to receive multiple locking tabs of the outer housing. As discussed herein the locking tabs of the outer housing are used to secure the connectors to an adapter.

The optical connectors of the present disclosure are all configured to be received in a receptacle. As used herein, the term "receptacle" relates generically to a housing that receives an optical connector. A receptacle includes both optical adapters, that is, components that mate two or more optical connectors, and transceivers, which include an optical receptacle to hold connectors that are to communicate with an optoelectronic component (e.g., a component that converts optical signals to electrical signals). As shown in FIG. **11**A, in one embodiment **1100**A, the outer housing **1101** may comprise one or more recesses **1111**. As discussed and shown herein, the one or more recesses may allow for a receptacle **1114** to securely connect to the connector **1100**A. Accordingly, in some embodiments, the receptacle **1114** may have a receptacle hook **1115**, which is flexible and can secure the connector **1100**A into the receptacle via latching onto the wall of the recess **1111**, as shown. This latching takes place when the outer housing **1101** is pushed forward into the receptacle. The sloped portions of the outer housing **1101** allow the receptacle hook **1115** to slide up and over the front of the outer housing thereby securing the connector **1100**A into the receptacle.

Additionally or alternatively, in some embodiments, such as that shown in FIG. **11**B, a connector **1100**B may be removed from a receptacle **1114** by pulling the connector away from the adapter as indicated by the directional arrow. In some embodiments, the force may be applied by a user via the push-pull tab **1110**. Alternatively, when a push-pull tab is not present, the connector may still be manually removed from a receptacle. As shown in FIG. **11**B, as the connector **1100**B is removed from the receptacle **1114**, the flexible receptacle hooks **1115** separate and slide up the slope of the end of the connector and allow for removal of the connector from the receptacle.

Referring now to FIGS. **12**A and **12**B, as discussed herein and previously shown in FIG. **5**, the front body **1202** can be removed from the outer housing **1201**. In some embodiments, a portion of the outer body **1201** can be flexibly extended away from the front body **1202** as shown by the arrows in FIG. **12**A. As discussed herein, in some embodiments, the front body **1202** may comprise a protrusion **1213** which interlocks with a window (not shown) on the outer housing **1201**. Accordingly, when force is applied to the outer housing **1201** in a manner that removes the one or more protrusions **1213** from the one or more windows (not shown, see FIG. **4**), the front body **1202** may be removed from the outer housing.

Referring now to FIG. **13**, an embodiment **1300** is shown in which the connector (not shown in its entirety) is inserted into a receptacle such as adapter **1314**. In this specific non-limiting example, the connector is similar to that shown in FIG. **8** (i.e., comprising four front bodies each with their own back body **1306** and boot **1309**). However, unlike FIG. **8**, the embodiment shown here utilizes four individual push-pull tabs **1310** instead of a duplex push-pull tab system which manipulates two latching tabs per push-pull tab to allow the connector to be removed from the adapter **1314**.

Various benefits and details have been discussed herein with regard to the connectors and their modular ability (e.g., to include multiple connectors into a single housing). In addition to the reduced footprint, structural improvements, and cost reduction, various embodiments herein may also be beneficial with regard to reducing the burden of cabling in a data center environment. Illustrative embodiments shown in FIGS. **14**A through **14**C depict cable configurations that may be used to reduce the complexity of optical cables in a compact environment. Note that any of the optical connectors described in this disclosure may be used in these embodiments, including the optical connectors of FIGS. **21**B, **37**, and **41**, to be discussed in detail below. FIG. **14**A shows two duplex cables similar to the cable shown in FIG. **6**. In some embodiments, one or more detachable clips **1401** may be attached to two or more zip cables to prevent the zip cables from detaching. This allows for two or more cables to be bundled and reduce the risk of entanglement with additional cables. FIG. **14**B is an illustrative example of how easily an embodiment can separate into two individual connectors by unbinding the cables and thus quickly and easily creating two independent fiber optic channels that can move and be connected independently. FIG. **14**C shows an embodiment in which a duplex connector like that of FIGS. **6** and **14**A is connected to two separate individual connectors. Through the variable housing configurations depicted above in FIG. **10**, the cable of FIG. **14**A can be reconfigured as the cables of either **14**B or FIG. **14**C.

In addition to binding existing fiber cables, some embodiments herein may utilize a new four fiber zip cable. Referring now to FIG. **15**A, a conventional zip cable (i.e., one with a single fiber strand **1520** per jacket **1521**) is shown in comparison with an embodiment in which two fibers **1522** per jacket **1523** are utilized. It should be understood that this is merely a non-limiting example. In some embodiments, multiple fibers may be included per jacket, such as, for example, four fibers per jacket in order to utilize the single boot **909** and uni-body rear body **906** of the connector shown in FIG. **9**.

A specific example using multi-strand cables is shown in FIG. **16** for illustrative purposes only. It should be understood that numerous alternatives and modifications are possible, such as, for example, that shown in FIGS. **18**A-**18**B and FIGS. **19**A-**19**D. As shown, a switch (e.g., 100G switch) **1630** is shown with a transceiver (e.g., 100G transceiver) **1631**. The transceiver **1631** has a receptacle to receive duplex connectors **1632**. From each of the two duplex connectors **1632**, a four fiber cable **1633** extends to connect to various other connectors and transceivers. In some embodiments, as discussed herein, a clip (e.g., detachable clip) **1640** may connect two or more cables (e.g., **1633**) to ensure the zip cables do not come apart. As shown, one four fiber cable **1633** is split into two two-fiber cables **1634**, which are then each attached to a single simplex connector **1635** and placed into a transceiver (e.g., 25G transceiver) **1636**. As further shown, one of the four fiber cables **1637** is connected to a single duplex connector **1638**, which is then inserted into another transceiver (e.g., 50G transceiver) **1639**.

An additional or alternative embodiment is shown in FIG. **17**. As shown, one or more switches (e.g., 400G switches) **1730** and **1732** are shown each with a transceiver (e.g., 400G transceiver) **1731** and **1733**. The first transceiver **1731** has a receptacle that is receiving two simplex (single) connectors **1734** and one duplex (dual) connector **1735**. From each of the two simplex connectors **1734**, a two fiber cable **1736** extends to connect to various other connectors and transceivers. Similar to FIGS. **14** and **16**, some embodiments may have a clip (e.g., detachable clip) **1740** that may connect two or more cables (e.g., **1736**, **1738**, etc.) to ensure the zip cables do not come apart. From the duplex connector **1735** a four-fiber cable **1737** is split into two two-fiber cables **1738**, which are then each attached to a single simplex connector each and placed into a transceiver (e.g., 400G transceiver).

Accordingly, embodiments described herein allow for improvements over the current state of the art. By way of specific example, connectors generally have three types of fixed cables. Moreover, some cables may be bifurcated. As such, the cable cannot be split once installed and the polarity of the cables cannot be changed. Alternatively, the embodiments discussed herein may allow a user to change from a four-way to a 2-Duplex, to a 4-simplex connector, etc. (e.g., FIG. **20**). Moreover, as discussed herein, the individual connectors can be split into individual connectors anytime, even after deployment. Additionally, the polarity can be changed within the connectors easily in a manner that does not risk damage to the one or more ferrules and fibers, as discussed above. It should also be noted that the depicted connectors are used herein merely for illustrative purposes, and that various other connectors may be used in any embodiment (e.g., an MT connector, such as that shown in FIGS. **18**A-**18**B, and the optical connectors of FIGS. **21**, **37**, and **41**).

FIGS. **18**A-**18**B depict an optical connector including an MT ferrule **1810** in a housing that is substantially similar to the housing **301** of FIG. **3**. As with the embodiment of FIG. **3**, the various features of the connector are configured such that two optical connectors having two MT-type optical ferrules may be accommodated in a small form-factor pluggable (SFP) transceiver footprint or at least four optical connectors having a total of four MT-type optical ferrules may be accommodated in a quad small form-factor pluggable (QSFP) transceiver footprint.

FIGS. **19**A-**19**D show alternative embodiments of the optical connectors of FIG. **3** in which the push-pull tabs are not integrated with the optical connector housing. As seen in FIGS. **19**A-**19**B, a push-pull tab **1930** is a separable element from a connector housing. The push-pull tab **1930** actuates a latch **1910** for inserting and extracting the connector from an adapter or transceiver. An alternative latching mechanism is depicted in FIGS. **19**C-**19**D. Latch **1950** includes a notch that is actuated by push-pull tab **1960**.

FIG. **20** depicts the disassembly of a four-connector housing (two duplex connectors in a single housing) into two duplex connectors. This may be performed in changing, for example, a connector as shown in FIG. **14**A to a connector as shown in FIG. **14**C. In FIG. **20**, an optical connector **2000** is depicted including a housing **2010** that houses two duplex connectors (four optical fibers). The housing **2010** is removed, leaving the two duplex connectors **2020**. Two housings **2030** are then provided and two individual duplex connectors **2040** are then created from the initial single housing connector **2000**. This reconfigurable housing simplifies cable management, for example, when optical cables are interconnected between lower-speed transceivers and higher-speed transceivers as seen in FIG. **16**.

FIG. **21**A depicts an embodiment of an optical connector **2100**, shown in exploded view while **21**B depicts the optical connector **2100** in an assembled view. Optical connector **2100** may include an outer housing **2110**, a front body **2115**, one or more ferrules **2122**, one or more ferrule flanges **2124**, one or more springs **2125**, a back body **2130**, a back post **2135**, a crimp ring **2140**, and a boot **2145**. The outer housing

2110 may include a longitudinal bore for accommodating the front body **2115** and a ferrule assembly **2120**, a connector alignment key **2105** used during interconnection, a connector flap **2103** and an optional pull tab **2107** to facilitate removal of the connector **2100** when connected in a dense array of optical connectors. Optionally, the ferrules may be LC-type ferrules having an outer diameter of 1.25 mm.

In prior art optical connectors, an inner enclosed housing was used in place of open front body **2115**. Front body **2115** includes top and bottom portions but no sidewalls, termed "open sidewalls" in this embodiment. By using front body **2115**, space occupied by the prior art inner housing sidewalls becomes available to increase the density of optical connectors within a given footprint, an advantage over prior art connectors. It was determined that the outer housing **2110**, combined with the front body **2115**, provided sufficient mechanical strength and ferrule protection, advantageously providing the space for additional optical connectors. Removal of sidewalls increases available space by 1-2 millimeters.

Note that, in this embodiment, the outer housing is configured to hold two optical ferrules **2122**. Typically, two optical ferrules may be used in a "transmit" and "receive" pairing of optical fibers, called a duplex connector. However, the outer housing may be configured to hold more or fewer optical ferrules including a single optical ferrule, multiples of single optical ferrules, or multiple pairs of optical ferrules, depending upon the application. Further, the front body **2115** may be removed from the outer housing **2110** and the front body placed in a larger outer housing with other front bodies to form a larger optical connector in a manner to be discussed in more detail below. In particular, two front bodies may be used with a four-ferrule outer housing or four front bodies may be used with an eight-ferrule outer housing.

Turning to FIGS. **29**A and **29**B, isometric and front views of the outer housing **2110** are shown. As seen in the front view of FIG. **29**B and the cross-sectional view of FIG. **29**C, connector orientation protrusions **2910** are provided within the interior of the outer housing **2110**. Connector protrusion **2910** is further seen in the inner view of the housing, FIG. **29**E. When the front body is inserted within the longitudinal bore **2101** of outer housing **2110**, the outer housing connector flap **2103** locks the outer housing **2110** to the front body **2115** in the following manner. As the front body **2115** is inserted into the outer housing **2110**, the outer housing locking surface **2114**, best seen in FIG. **27**C, engages the connector orientation protrusion **2910**, seen in an inside view of the outer housing in FIG. **29**D, labelled as "Flap A", flexing the connector flap **2103** outwardly from the outer housing body **2110**, depicted in the inset of FIG. **29**C. The flap protrusion mating location is indicated as "mating place B" in FIG. **29**D. Once the locking surface **2114** passes beyond the orientation protrusion, the connector flap returns to its original position (FIG. **29**A), and the protrusion **2910** engages locking surface **2114** and any withdrawal of the front body assembly from the outer housing **2110** is prevented as the proximal end face of the connector flap **2103** is stopped by protrusion **2910**.

FIGS. **35**A-**35**C depict the sequence of operations to remove an assembled front body from the outer housing in order to reverse polarity or to aggregate plural connectors in a multi-connector housing. To separate the front body from the outer housing, the connector flap **2103** is flexed outward using a finger or a tool, as depicted in FIG. **35**B. Flexing the connector flap **2103** outwardly causes the protrusion **2910** to disengage from the front body's outer housing locking surface **2114**, permitting the front body/ferrule assembly **2115** to be removed from the outer housing. This may be performed when it is desired to reverse the polarity of the connector (to be discussed below) or when desiring to aggregate plural connectors into a larger connector housing as discussed above. The separated components are depicted in FIG. **35**C, that is, front body **2115** with the ferrule assembled therein and outer housing **2110**.

In some embodiments, the back body **2130** may comprise one or more protrusions or hooks **2134**, best seen in FIGS. **28**A and **28**B, which may interlock with a back body hook window/cutout **2119** in the front body **2115**. This may allow for the back body **2130** and the front body **2115** to be securely fastened together around the ferrule(s) **2122**, ferrule flange(s) **2124**, and the spring(s) **2125**. The back body **2130** includes a cable bore **2820**, spring guides **2132**, and side protrusions **2810**.

During assembly, the ferrule flanges **2124** fit into ferrule flange alignment slots **2117** (see FIGS. **27**A and **27**B) adjacent the ferrule openings **2116** of the front body **2115**, compressing the springs **2125** (preload) which are positioned along front body spring holders **2118**. The ends of the springs **2125** are secured on spring guides **2132** (FIGS. **28**A, **28**B) of back body **2130** by spring tension. As seen in the assembled cross-sectional views of FIGS. **23**A and **23**B, the springs **2125** are positioned to urge the ferrules **2122** into contact with mating connectors or transceiver optics, ensuring minimum insertion loss. As further seen in FIGS. **27**A and **27**B, the front body includes a receptacle hook recess **2710** with a receptacle hook retainer surface **2720** the receiver a receptacle hook when mating with an adapter or with a transceiver receptacle, as shown in further detail below.

Further reductions in connector size may be obtained by reducing the size of springs **2125**, see FIG. **21**. By using a maximum spring outer diameter of 2.5 mm, the pitch of the ferrules, that is to say, the spacing between adjacent ferrules, may be reduced to 2.6 mm when coupled with the removal of inner housing walls and walls separating adjacent ferrules. This advantage is best seen in FIG. **22** which depicts the front of connector **2100** showing overall connector dimensions and ferrule pitch. The connector size 4.2×8.96×30.85 mm (excluding optional pull tab **2107** and connector alignment key **2105**) with a ferrule pitch of 2.6 mm.

As best seen in FIG. **21**B, the outer housing **2110** and the front body **2115** together provide a receptacle hook ramp **2940** (on the outer housing) used to guide a receptacle hook into a receptacle hook recess **2170** (in the front body **2115**), also shown in FIGS. **27**A and **27**B (receptacle hook recess **2710** and receptacle hook retainer surface **2720**). The receptacle hook, to be discussed in more detail below, may be from an adapter or a transceiver to secure the optical connector **2100** thereto.

The optical connectors **2100** may be used in a variety of connection environments. In some applications, the optical connectors **2100** will mate with other optical connectors. Typically, this mating will occur with a receptacle such as an adapter or optical transceiver receptacle. An exemplary adapter **2400** depicted in FIG. **24** in an exploded view and depicted in FIG. **31** having four mating pairs of optical connectors **2100** latched therein. In other applications, as when an optical signal is to be converted to an electrical signal, the micro optical connectors **2100** will mate with an optical receptacle in a transceiver **3600** as shown in FIG. **36**. Typically, transceiver **3600** may be found in a data center, switching center, or any other location where optical signals are to be converted to electrical signals. Transceivers are often a part of another electrical device such as a switch or a server, as is known in the art. Although much of the connection operation of this embodiment will be described with respect to an adapter, **2400**, it is understood that substantially similar mechanical retention mechanisms are positioned within the receptacle of transceiver **3600** so that any description of connector retention in adapter **2400** applies in a substantially similar way to retention of an optical connector within transceiver **3600**. An example of a transceiver optical receptacle is depicted in FIG. **36**B (holding optical connectors **2100**); as seen in FIG. **36**B, the connection environment is substantially similar to one-half of an adapter **2400**.

Turning to FIG. **24**, further size reductions in the overall optical assembly of connectors plus adapter or connectors plus transceiver may be obtained through various connection mechanisms to be described with respect to the adapter **2400** but also apply to optical connection features within the front end of transceiver **3600**. The adapter **2400** includes an adapter housing **2402** having an adapter alignment assembly **2430** positioned therein. The adapter alignment assembly **2430** includes alignment sleeves **2410** positioned within alignment sleeve openings **2440** of alignment sleeve holders **2442**. The adapter alignment assembly further includes receptacle hooks **2302** that will grip optical connectors **2100** through front body connector hook recess **2710** of FIG. **21**B. As seen in FIG. **30**, receptacle hooks **2302** include an inner surface **3110**. The adapter housing **2402** further includes connector alignment slots **2403** that mate with connector alignment key **2105** of FIG. **21**A. The connectors **2100** are received through connector opening **2405** of the adapter housing **2402** which also includes flex tab **2401**, cutout **2456**, mount plate **2452** and panel hook **2490**. To assemble the adapter alignment assembly **2430** in the adapter housing **2402**, adapter housing hooks **2432** are provided. Adapter housing hooks **2432** are received in housing adapter hook openings.

It should be understood that above description of connection mechanisms with respect to adapter **2400** may be applied in a substantially similar way with respect to the receptacle of transceiver **3600**. Particularly, the receptacle of transceiver **3600** may include a receptacle housing having a receptacle alignment assembly positioned therein. The receptacle alignment assembly includes alignment sleeves positioned within alignment sleeve openings of alignment sleeve holders. The receptacle alignment assembly further includes receptacle hooks that will grip optical connectors **2100** through front body connector hook recess **2710** of FIG. **21**B. As seen in FIG. **30**, receptacle hooks **2302** include an inner surface **3110**. The receptacle housing further includes connector alignment slots that mate with connector alignment key of FIG. **21**A. The connectors **2100** are received through connector opening of the receptacle housing which also includes flex tab, cutout, mount plate and panel hook. To assemble the receptacle alignment assembly in the receptacle housing, receptacle housing hooks are provided. Receptacle housing hooks are received in housing receptacle hook openings.

To further reduce the size of optical connectors and associated mating components, the adapter housing **2402** includes receptacle hook openings **2420**, seen in FIGS. **25**A and **25**B. Receptacle hook openings **2420** accommodate the clearance required by receptacle hooks **2302** when they flex upwards prior to latching with connectors **2100**. The interaction of the receptacle hooks **2302**, having slanted inner surfaces **3110**, with the receptacle hook openings **2420** is best seen in FIGS. **32**B and **34**A-C. Prior to latching (FIG. **34**A), the receptacle hook **2302** is in an unflexed condition within the receptacle (adapter or transceiver). As the connector **2100** is inserted into the adapter housing **2402** or the transceiver, the receptacle ramp **2490** pushes against the receptacle hook inner surfaces **3110**, flexing receptacle hook **2302** into the receptacle hook opening **2420**. Without providing the opening, additional clearance would need to be provided to accommodate the flexing of the receptacle hook **2302**. This additional required clearance is depicted in the prior art connector/adapter of FIG. **32**A. As seen in FIG. **32**A, a connector latch gap **3210** must be provided in the prior art to accommodate the prior art connector hooks, increasing the overall footprint of the prior art connector/adapter assembly. By providing receptacle hook openings **2420** in the present disclosure, approximately 2.25 mm of valuable footprint real estate is obtained which may be used to increase connector density.

Another improvement in adapter size is obtained by removing prior art adapter walls between adjacent connectors. This is best seen in the front view of an assembled adapter **2400** shown in FIG. **26**. As seen, pairs of ferrule alignment sleeves **2410** are separated only by connector gap **2610** with a 4.35 mm pitch between adjacent connectors. The adapter size is 19.0×10.71×32.5 mm (excluding the adapter flange **2460**). Also seen in FIG. **26** is the connector alignment slot **2403**, alignment sleeve holder **2442**, and a front view of receptacle hooks **2302**.

FIG. **31** depicts an assembled adapter **2400** with four pairs of mating connectors **2100** latched therein. Note that in the latched position, receptacle hooks **2302** do not extend into receptacle hook openings **2420**. This is further visible in the cross-sectional view of an assembled adapter **2400** of FIG. **25**A. Connector alignment keys **2105** are positioned within connector alignment slots **2403**. As seen in the cross-sectional view of FIG. **23**A, the push-pull tab **2017** may extend beyond the connector boot **2145** providing clearance to easily grip the tab and remove a connector. Also seen in FIG. **31** is adapter flex tab **2401** and panel hook **2490** for interaction with racks or other equipment.

Through the various features described above, the density of optical connectors **2100** that may be provided in the standard transceiver footprint connector spaces may be doubled. For example, in a small form factor pluggable (SFP) footprint of 14×12.25 mm, two connectors **2100** having four LC-type ferrules **2122** of 1.25 mm outer diameter may be accommodated as seen in FIG. **33**B. Similarly, in a quad small form factor pluggable (QSFP) footprint of 13.5×19 mm, four connectors **2100** having a total of eight LC-type ferrules **2122** may be accommodated as seen in FIG. **33**A. Further, by providing the connectors in transmit and receive pairs, greater flexibility in optical routing is obtained, as demonstrated by previous FIGS. **16** and **17**.

Turning to FIG. **37**, another embodiment of an optical connector is depicted. In this embodiment, the last two digits of each element correspond to the similar elements in the optical connector of FIG. **21**A et seq. In FIG. **37**, connector **3700** may include an outer housing **3710**, a front body **3715**, one or more ferrules **3722**, one or more ferrule flanges **3724**, one or more springs **3725**, a back body **3730**, a back post **3735**, a crimp ring **3740** (depicted with an optional heat shrink tube extending therefrom), and a boot **3745**. The outer housing **3710** may include a longitudinal bore **3701** for accommodating the front body **3715** and ferrules **3722**, a connector alignment key **3705** used during interconnection, a connector flap **3703** and an optional pull tab **3707** to facilitate removal of the connector **3700** when connected in a dense array of optical connectors. Optionally, the ferrules may be LC-type ferrules having an outer diameter of 1.25 mm.

In FIG. **38** an isometric view of the front body **3715** is depicted. In this embodiment, the back body hook cutout **3819** has been moved forward, advantageously strengthening the assembled connector in side load environments. An alignment tab **3895** is provided for mating with a receiving recess on the back body. The receptacle hook recess **3910** operates in a substantially similar manner to the recess of FIG. **21**A, described above. A ferrule flange alignment slot **3817** is also provided.

In FIG. **39**, the back body **3730** is depicted, showing alignment tab recess **3997** for receiving alignment tab **3895**. The front body hook **3934**, for interconnecting in back body hook cutout **3819**, extends outwardly from the main portion of the back body through extended hook arm **3996**. Through the extended hook arm **3996** and the alignment tab **3895**, breakage during side loads is reduced as the load is redistributed more evenly across the entire connector, reducing stress on the backpost.

As seen in FIGS. **40**A-**40**C, the assembled front body **3715** may be removed from the outer housing **3710**, rotated 180° as indicated by the arrow (FIG. **40**B), and re-inserted into the outer housing (FIG. **40**C). This allows for a change in the polarity of the front body **3715**, and therefore the ferrules can switch quickly and easily without unnecessarily risking the delicate fiber cables and ferrules. As described previously with respect to FIGS. **35**A-**35**C, connector flap **3703** is flexed outward to release the front body from the outer housing.

Turning to FIG. **41**, another embodiment of an optical connector is depicted. In this embodiment, the last two digits of each element correspond to the similar elements in the micro optical connectors of FIG. **21**A and FIG. **37**. In FIG. **41**, connector **4100** may include an outer housing **4110**, a front body **4115**, one or more ferrules **4122**, one or more springs **4125**, a back body **4130**, a crimp ring **4140**, and a boot **4145**. The outer housing **4110** may include a connector flap **4103** and an optional pull tab **4107** to facilitate removal of the connector **4100** when connected in a dense array of optical connectors. Optionally, the ferrules may be LC-type ferrules having an outer diameter of 1.25 mm.

As seen in FIG. **42**A, the front body **4015** in this embodiment includes a middle wall **4260** interposed between the ferrules and springs when the front body is assembled. This middle wall reduces the possibility of the springs becoming entangled with each other, binding the connector and breaking the optical fibers. The front body **4015** also includes an alignment cut out guide **4625**, seen in the side view of FIG. **42**B. The alignment cut out guides the back body **4030** into the front body **4015** during assembly of the connecter, and also further reduces the side load that leads to connector breakage or disconnection of the front body and the back body **4030**.

Back body **4030**, depicted in an enlarged view in FIG. **43**, includes an alignment guide **4377** that fits into the alignment cut out guide **4265** of FIG. **42**B. The wall structure **4378** also stops the front body to prevent over-compressing the springs and provides strength under a side load.

Various modifications to the outer housing, depicted in FIGS. **44**A-**44**C, may be used with any of the optical connectors depicted in FIGS. **21**, **37**, and **41** or earlier embodiments. In FIG. **44**A, the push-pull tab **3707** may include a release recess **4473**. Release recess **4473** permits insertion of a tool or fingernail to remove the connector from an adapter or transceiver, without disturbing adjacent connectors. Similarly, FIG. **44**B depicts a release hole **4499** in push-pull tab **3707** to permit insertion of an extraction tool to remove the connector from an adapter or transceiver. FIG. **44**C shows a modified connector flap **3703** with an increased cutout size of 1 mm to make it easier to insert a tool or a finger to flex the flap **3703** and remove the front body assembly when making a polarity change or aggregating the front body with other front bodies in a larger outer housing.

Another embodiment of an adapter/transceiver receptacle is depicted in FIG. **45**. Unlabeled elements are substantially similar to elements depicted in FIG. **24**. In this FIG., adapter housing hooks **4532** can be seen along with receptacle hooks **4502**. Turning to the cross-sectional view of the assembled adapter in FIG. **46**, the engagement of these elements may be seen.

Another embodiment of an optical connector **4700** is depicted in FIG. **47**. The optical connector of FIG. **47** includes outer housing **4710**, front body **4715**, ferrules **4722**, springs **4725**, back body **4730**, backpost **4735**, crimp ring **4740**, and boot **4745**. Here, the emphasis is on the back body, **4730**. A more detailed view of the back body **4730** is presented in FIG. **48**. In this embodiment, the backpost flange has a substantially rectangular shape in order to narrow the overall connector profile by approximately 0.5 mm. Back post overmolding **4859** accommodates the back post flange **4857** and reduces the potential for back post breakage. The back wall **4853** is extended in length to 3 mm from 1.5 mm to improve the sideload strength of the overall connector. The crimp ring positioning **4855** is inversed from earlier embodiments to improve holding of aramid fiber from an optical fiber cable, improving cable retention of the back post.

Many advantages are achieved by the backpost of FIG. **48**. In addition to increased connector strength, a longer fiber path **4901** is provided as shown in FIG. **49**. This longer fiber path, approximately 1.5 mm longer than in previous embodiments, allows for a gentler curve as the fibers are split from the fiber optic cable, improving insertion and return loss of the fibers. In FIG. **49**, the back wall **4853** can be seen as a portion of the back body **4730**.

In view of the various modifications of this embodiment, FIG. **50** depicts a connector **4700** front view showing overall reduced connector width of 3.85 mm. Such a size reduction permits **4** optical connectors (a total of 8 ferrules) to be accommodated in a transceiver or connector footprint of 16 mm (including tolerances). Thus, the connectors of the present invention may be used to connect 8 LC-ferrule-housed fibers in a QSFP footprint.

To further decrease the space required by the optical connectors, a side thickness reduction may be carried out on the boot of connector **4700**. Side thickness reduction **5103**, depicted in FIG. **51**, narrows the thickness of the boot on either side, reducing the space required by the boot to the 3.85 mm profile of connector **4700**. Thus four connectors will fit in the QSFP transceiver footprint. This footprint is shown in the adapter front view of FIG. **52**—as noted above, the front view of an adapter and that of a transceiver are substantially similar from the optical perspective. In FIG. **52**, the adapter inner wall is reduced from 17.4 mm to 16 mm. All of the modifications set forth in the FIG. **47** et seq. embodiment make it possible for the four connectors to fit in the profile of FIG. **52**.

In some embodiments, as shown in FIG. **53**, a connector **10300** may comprise various components. Referring to FIG. **53**, an illustrative embodiment of a connector **10300** is shown in an exploded view to display detail. In some embodiments, and as discussed further herein, a connector

10300 may have an outer housing **10301**, a front body **10302**, one or more ferrules **10303**, one or more ferrule flanges **10304**, one or more springs **10305**, a back body **10306**, a back post **10307**, a crimp ring **10308**, a boot **10309**, and a push-pull tab **10310**. In some embodiments, the back body **10306** may comprise one or more protrusions **10306.1** which may interlock with a window/cutout **10302.1** in the front body **10302**. This may allow for the back body **10306** and the front body **10302** to be securely fastened together around the ferrule(s) **10303**, ferrule flange(s) **10304**, and the spring(s) **10305**.

Referring now to FIG. **54**, an embodiment is shown wherein the connector **10400** is assembled. In some embodiments, the assembled connector may have an outer housing **10401**, a front body (not shown, see FIGS. **53** and **55**.), one or more ferrules **10403**, one or more ferrule flanges (not shown), one or more springs (not shown), a back body **10406**, a back post (not shown), a crimp ring (not shown), a boot **10409**, a push-pull tab **10410**, and one or more latching mechanisms made up of a window **10412** on the outer housing and a protrusion **10413** on the front body. The latching mechanism **10412** and **10413** securely attaches the outer housing **10401** to the front body. In a further embodiment, the push-pull tab **10410** may have an opening to receive a locking tab **10411**. The locking tab **10411** of the outer housing **10401** is used to interlock with an adapter (not shown) to secure the connector into the adapter. As would be understood by one skilled in the art, the push-pull tab **10410** enables easy manipulation of the locking tab **10411** to allow for removal of the connector from the adapter without requiring additional tools.

As shown in FIG. **55**, in some embodiments, the latching mechanism of the connector **10500** may be made up of two parts: a window **10512** and a protrusion **10513**. As illustrated in FIG. **55**, the outer housing **10501** can slide on to or be removed from the front body **10502** by disengaging the latching mechanisms formed by the protrusion **10513** exiting through the window **10512**, whereby it contacts a side wall of the window (refer to FIG. **54** for an illustrated example of the outer housing being attached to the front body via the latching mechanism). In some embodiments, the push-pull tab **10510** may also be detached from the outer housing **10501**, as shown.

In a further embodiment, the front body **10502** may be removed from the outer housing **10501**, rotated 180°, and re-inserted into the outer housing. This allows for a change in the polarity of the front body **10502**, as shown by the arrow diagram in FIG. **55**, and therefore the ferrules can switch quickly and easily without unnecessarily risking the delicate fiber cables and ferrules.

In some embodiments, it may be beneficial to connect two or more connectors together to increase structural integrity, reduce the overall footprint, and cut manufacturing costs. Accordingly, as shown in FIG. **56**, a connector **10600** may in some embodiments, utilize an outer housing **10601** that is capable of holding two front bodies (not shown). Various other embodiments are disclosed herein, and it should be noted that the embodiments disclosed herein are all non-limiting examples shown for explanatory purposes only.

Accordingly, although the embodiment shown in FIG. **56** utilizes a duplex outer housing **10601**, additional or alternative embodiments may exist with more capacity. As shown in FIG. **56**, in some embodiments, the outer housing **10601** may accept two front bodies (not shown), each with two separate ferrules **10603**. As shown, the front body (not shown) may securely fasten to the outer housing **10601** via the latching mechanism **10612** and **10613**. In additional

embodiments, the push-pull tab **10610** may be modified, as shown, such that a single tab can be used to free the two or more connectors from an adapter. As illustrated in FIG. **56**, the push-pull tab **10610** may include two openings with which to receive multiple locking tabs **10611** of the outer housing **10601**. As discussed herein the locking tabs **10611** of the outer housing **10601** are used to secure the connectors to an adapter (not shown). In one or more further embodiments, the connectors may have individual back bodies **10606** and boots **10609** (i.e., one back body/boot per front body) as shown.

Alternatively, in some embodiments, such as that shown in FIG. **57**, the connector **10700** may have a single boot **10709** and a duplex (i.e., uni-body) back body **10706** instead of individual back bodies (e.g., such as shown in FIG. **56**). In some embodiments, the duplex back body **10706** may have different dimensions than that of the individual back bodies of FIG. **56**, such as, for example, they may be longer to accommodate the need for routing the fiber after it exits the boot **10709**. As with other embodiments discussed herein, the connector shown in FIG. **57** may also include an outer housing (e.g., duplex outer housing) **10701**, one or more ferrules **10703**, at least one latching mechanism formed by the protrusion **10713** exiting through the window **10712**, and push-pull tab **10710**.

As stated, it may be beneficial to connect two or more connectors together to increase structural integrity, reduce the overall footprint, and cut manufacturing costs. Accordingly, similarly to FIG. **56**, FIG. **58** shows an connector **10800** that may, in some embodiments, utilize an outer housing **10801** that is capable of holding multiple (e.g., four) front bodies (not shown).

As shown in FIG. **58**, some embodiments may have an outer housing **10801** able to accept up to four front bodies, each with one or more ferrules **10803**. As shown, each front body (not shown) may securely fasten to the outer housing **10801** via the latching mechanism **10812** and **10813**. In additional embodiments, the push-pull tab **10810** may be modified, as shown, such that a single tab can be used to free the up to four connectors from an adapter. As illustrated in FIG. **58**, the push-pull tab **10810** may include four openings with which to receive multiple locking tabs **10811** of the outer housing **10801**. As discussed herein the locking tabs **10811** of the outer housing **10801** are used to secure the connectors to an adapter (not shown). In one or more further embodiments, the connectors may have individual back bodies **10806** and boots **10809** (i.e., one back body/boot per front body) as shown.

Alternatively, in some embodiments, such as that shown in FIG. **59**, the connector **10900** may utilize one or more duplex back bodies **10906** with a single boot **10909**, similar to that shown in FIG. **57**. Thus, similar to FIG. **57**, the embodiment shown in FIG. **59** may allow for a further reduced foot print, less cabling, and easier maintenance of the connector. Accordingly, one or more embodiments may have an outer housing **10901** may accept up to four front bodies, each with one or more ferrules **10903**. As shown, each front body (not shown) may securely fasten to the outer housing **10901** via the latching mechanism **10912** and **10913**. In additional embodiments, the push-pull tab **10910** may be modified, as shown, such that a single tab can be used to free the up to four front bodies from an adapter. As illustrated in FIG. **59**, the push-pull tab **10910** may include four openings with which to receive multiple locking tabs **10911** of the outer housing **10901**. As discussed herein the locking tabs **911** of the outer housing **10901** are used to secure the connectors to an adapter (not shown).

In further embodiments, such as that shown in FIG. **60**, the connector **101000** may utilize a single uni-body back body **101006** with a single boot **101009**. Thus, the embodiment shown in FIG. **59** may allow for a further reduced foot print, even less cabling, and easier maintenance of the connector. Accordingly, one or more embodiments may have an outer housing **101001** that may accept up to four front bodies, each with one or more ferrules **101003**. As shown, each front body (not shown) may securely fasten to the outer housing **101001** via the latching mechanism **101012** and **101013**. In additional embodiments, the push-pull tab **101010** may be modified, as shown, such that a single tab can be used to free up to four connectors from an adapter. As illustrated in FIG. **60**, the push-pull tab **101010** may include four openings with which to receive multiple locking tabs **101011** of the outer housing **101001**. As discussed herein the locking tabs **101011** of the outer housing **101001** are used to secure the connectors to an adapter (not shown).

Referring now to FIG. **61**, an embodiment **101100** is shown in which the connector (not shown in its entirety) is inserted into an adapter **101114**. In this specific non-limiting example, the connector is similar to that shown in FIG. **58** (i.e., comprising four front bodies each with their own back body **101106** and boot **101109**). However, unlike FIG. **58**, the embodiment shown here utilizes four individual push-pull tabs **101110** instead of a single push-pull tab which manipulates four latching tabs to allow the connector to be removed from the adapter **101114**.

Various benefits and details have been discussed herein with regard to the connectors and their modular ability (e.g., to include multiple connectors into a single unit). In addition to the reduced footprint, structural improvements, and cost reduction, various embodiments herein may also be beneficial with regard to reducing the burden of cabling in a data center environment. Illustrative embodiments shown in FIGS. **62**A through **62**C depict cable configurations that can be used to reduce the complexity of optical cables in a compact environment. FIG. **62**A shows two duplex cables similar to the cable shown in FIG. **56**. This allows for two or more cables to be bundled and reduce the risk of entanglement with additional cables. FIG. **62**B is an illustrative example, of how easily an embodiment can separate into two individual connectors by unbinding the cables and thus quickly and easily creating two independent fiber optic channels that can move independently. FIG. **62**C shows an embodiment in which a duplex connector like that of FIGS. **56** and **62**A is connected to two separate individual connectors.

In addition to binding existing fiber cables, some embodiments herein may utilize a new four fiber zip cable. Referring now to FIG. **63**A, a conventional zip cable (i.e., one with a single fiber strand **101320** per jacket **101321**) is shown in comparison with an embodiment where two fibers **101322** per jacket **101323** may be utilized. It should be understood that this is merely a non-limiting example. In some embodiments, multiple fibers may be included per jacket, such as, for example, four fibers per jacket in order to utilize the single boot **101009** and uni-body read body **101006** of the connector shown in FIG. **60**.

A specific example using multi-strand cables is shown in FIG. **64** for illustrative purposes only. It should be understood that numerous alternatives and modifications are possible, such as, for example, that shown in FIG. **66**A-**66**B, FIGS. **67**A-**67**D, and **68**A-**68**B. As shown, a switch (e.g., 100G switch) **101430** is shown with a transceiver (e.g., 100G transceiver) **101431**. The transceiver **101431** has an adapter to receive two mini duplex connectors **101432**. From each of the two duplex connectors **1432**, a four fiber cable **101433** extends to connect to various other connectors and transceivers. As shown, one four fiber cable **101433** is split into two two-fiber cables **101434**, which are then attached to a single simplex connector **101435** and placed into a transceiver (e.g., 25G transceiver) **101436**. As further shown, one of the four fiber cables **101437** is connected to a single mini duplex connector **101438**, which is then inserted into another transceiver (e.g., 50G transceiver) **101439**.

Accordingly, embodiments described herein allow for improvements over the current state of the art. By way of specific example, ROX connectors generally have three types of fixed cables: ROX 1, ROX 2, and ROX 4. Moreover, ROX cables are bifurcated. As such, the cable cannot be split once installed and the polarity of the cables cannot be changed. Alternatively, the embodiments discussed herein may allow a user to change from a four way to a 2-Duplex, to a 4-simplex connector, etc. (e.g., FIG. **69**). Moreover, as discussed herein, the individual connectors can be split into individual connectors anytime, even after deployment. Additionally, as discussed herein, the polarity can be changed within the connectors in an easy manner that does not risk damage to the one or more ferrules. It should also be noted, as discussed herein that connectors are used herein merely for simplicity purposes, and that various other connectors may be used in any embodiment (e.g., an MT connector, such as that shown in FIG. **66**A-**66**B).

In the above detailed description, reference is made to the accompanying drawings, which form a part hereof. In the drawings, similar symbols typically identify similar components, unless context dictates otherwise. The illustrative embodiments described in the detailed description, drawings, and claims are not meant to be limiting. Other embodiments may be used, and other changes may be made, without departing from the spirit or scope of the subject matter presented herein. It will be readily understood that the aspects of the present disclosure, as generally described herein, and illustrated in the Figures, can be arranged, substituted, combined, separated, and designed in a wide variety of different configurations, all of which are explicitly contemplated herein.

The present disclosure is not to be limited in terms of the particular embodiments described in this application, which are intended as illustrations of various aspects. Many modifications and variations can be made without departing from its spirit and scope, as will be apparent to those skilled in the art. Functionally equivalent methods and apparatuses within the scope of the disclosure, in addition to those enumerated herein, will be apparent to those skilled in the art from the foregoing descriptions. Such modifications and variations are intended to fall within the scope of the appended claims. The present disclosure is to be limited only by the terms of the appended claims, along with the full scope of equivalents to which such claims are entitled. It is to be understood that this disclosure is not limited to particular methods, reagents, compounds, compositions or biological systems, which can, of course, vary. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to be limiting.

With respect to the use of substantially any plural and/or singular terms herein, those having skill in the art can translate from the plural to the singular and/or from the singular to the plural as is appropriate to the context and/or application. The various singular/plural permutations may be expressly set forth herein for sake of clarity.

It will be understood by those within the art that, in general, terms used herein, and especially in the appended claims (for example, bodies of the appended claims) are generally intended as "open" terms (for example, the term "including" should be interpreted as "including but not limited to," the term "having" should be interpreted as "having at least," the term "includes" should be interpreted as "includes but is not limited to," et cetera). While various compositions, methods, and devices are described in terms of "comprising" various components or steps (interpreted as meaning "including, but not limited to"), the compositions, methods, and devices can also "consist essentially of" or "consist of" the various components and steps, and such terminology should be interpreted as defining essentially closed-member groups. It will be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present. For example, as an aid to understanding, the following appended claims may contain usage of the introductory phrases "at least one" and "one or more" to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles "a" or "an" limits any particular claim containing such introduced claim recitation to embodiments containing only one such recitation, even when the same claim includes the introductory phrases "one or more" or "at least one" and indefinite articles such as "a" or "an" (for example, "a" and/or "an" should be interpreted to mean "at least one" or "one or more"); the same holds true for the use of definite articles used to introduce claim recitations. In addition, even if a specific number of an introduced claim recitation is explicitly recited, those skilled in the art will recognize that such recitation should be interpreted to mean at least the recited number (for example, the bare recitation of "two recitations," without other modifiers, means at least two recitations, or two or more recitations). Furthermore, in those instances where a convention analogous to "at least one of A, B, and C, et cetera" is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (for example, "a system having at least one of A, B, and C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, et cetera). In those instances where a convention analogous to "at least one of A, B, or C, et cetera" is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (for example, "a system having at least one of A, B, or C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, et cetera). It will be further understood by those within the art that virtually any disjunctive word and/or phrase presenting two or more alternative terms, whether in the description, claims, or drawings, should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms. For example, the phrase "A or B" will be understood to include the possibilities of "A" or "B" or "A and B."

In addition, where features or aspects of the disclosure are described in terms of Markush groups, those skilled in the art will recognize that the disclosure is also thereby described in terms of any individual member or subgroup of members of the Markush group.

As will be understood by one skilled in the art, for any and all purposes, such as in terms of providing a written description, all ranges disclosed herein also encompass any and all possible subranges and combinations of subranges thereof. Any listed range can be easily recognized as sufficiently describing and enabling the same range being broken down into at least equal halves, thirds, quarters, fifths, tenths, et cetera As a non-limiting example, each range discussed herein can be readily broken down into a lower third, middle third and upper third, et cetera As will also be understood by one skilled in the art all language such as "up to," "at least," and the like include the number recited and refer to ranges which can be subsequently broken down into subranges as discussed above. Finally, as will be understood by one skilled in the art, a range includes each individual member. Thus, for example, a group having 1-3 cells refers to groups having 1, 2, or 3 cells. Similarly, a group having 1-5 cells refers to groups having 1, 2, 3, 4, or 5 cells, and so forth.

Various of the above-disclosed and other features and functions, or alternatives thereof, may be combined into many other different systems or applications. Various presently unforeseen or unanticipated alternatives, modifications, variations or improvements therein may be subsequently made by those skilled in the art, each of which is also intended to be encompassed by the disclosed embodiments.

The invention claimed is:

1. An optical fiber connector comprising:

first and second optical fiber ferrules;

a connector housing having a front end portion and a rear end portion spaced apart along a longitudinal axis, the connector housing comprising a top portion and a bottom portion spaced apart along a transverse axis perpendicular to the longitudinal axis, the connector housing holding the first and second optical fiber ferrules such that the first and second optical fiber ferrules are exposed through the front end portion for making an optical connection and the first and second optical fiber ferrules are spaced apart from one another along the transverse axis,

a depressible latch above the top portion of the connector housing; and

an elongate arm connected to the connector housing above the top portion and configured to be pulled to actuate the depressible latch;

wherein the connector housing comprises a guide connecting the elongate arm to the optical fiber connector.

2. The optical fiber connector as set forth in claim **1**, wherein the guide defines a groove extending along the longitudinal axis.

3. The optical fiber connector as set forth in claim **2**, wherein the elongate arm is slidably received in the groove.

4. The optical fiber connector as set forth in claim **1**, wherein the elongate arm comprises a front end portion and a rear end portion spaced apart along the longitudinal axis.

5. The optical fiber connector as set forth in claim **4**, wherein the front end portion of the elongate arm defines an opening.

6. The optical fiber connector as set forth in claim **5**, wherein the depressible latch is received in the opening.

7. The optical fiber connector as set forth in claim **6**, wherein the depressible latch has a front end portion and rear end portion spaced apart along the longitudinal axis and wherein the depressible latch extends upward along the transverse axis as the depressible latch extends along the longitudinal axis from the front end portion to the rear end portion of the depressible latch.

8. The optical fiber connector as set forth in claim **7**, wherein the rear end portion of the depressible latch is spaced apart above the top portion of the connector housing along the transverse axis.

9. The optical fiber connector as set forth in claim **8**, wherein the front end portion of the elongate arm includes an edge defining a front end of the opening.

10. The optical fiber connector as set forth in claim **9**, wherein the depressible latch has an upper surface, the edge opposing the upper surface.

11. The optical fiber connector as set forth in claim **1**, wherein the connector housing includes a front body and a back body.

12. The optical fiber connector as set forth in claim **11**, further comprising a single cable boot extending rearward from the back body.

13. The optical fiber connector as set forth in claim **1**, further comprising a single cable boot extending rearward from the connector housing.

14. The optical fiber connector as set forth in claim **10**, wherein the elongate arm is configured to be pulled rearward along the longitudinal axis with respect to the connector housing whereby the edge slides longitudinally along the upper surface to depress the depressible latch.

15. The optical fiber connector as set forth in claim **14**, wherein the guide defines a groove extending along the longitudinal axis.

16. The optical fiber connector as set forth in claim **15**, wherein the elongate arm is slidably received in the groove.

17. The optical fiber connector as set forth in claim **15**, wherein the connector housing includes a front body and a back body.

18. The optical fiber connector as set forth in claim **17**, wherein the front body includes a recess and the back body includes a protrusion received in the recess to connect the back body to the front body.

19. The optical fiber connector as set forth in claim **18**, further comprising a single cable boot extending rearward from the connector housing.

20. An optical fiber connector comprising:

first and second optical fiber ferrules;

a connector housing having a front end portion and a rear end portion spaced apart along a longitudinal axis, the connector housing comprising a top portion and a bottom portion spaced apart along a transverse axis perpendicular to the longitudinal axis, the connector housing holding the first and second optical fiber ferrules such that the first and second optical fiber ferrules are exposed through the front end portion for making an optical connection and the first and second optical fiber ferrules are spaced apart from one another along the transverse axis,

a depressible latch above the top portion of the connector housing; and

an elongate arm connected to the connector housing above the top portion and configured to be pulled to actuate the depressible latch;

wherein the elongate arm comprises a front end portion and a rear end portion spaced apart along the longitudinal axis;

wherein the front end portion of the elongate arm defines an opening;

wherein the depressible latch is received in the opening;

wherein the depressible latch has a front end portion and rear end portion spaced apart along the longitudinal axis and wherein the depressible latch extends upward along the transverse axis as the depressible latch extends along the longitudinal axis from the front end portion to the rear end portion of the depressible latch;

wherein the rear end portion of the depressible latch is spaced apart above the top portion of the connector housing along the transverse axis;

wherein the front end portion of the elongate arm includes an edge defining a front end of the opening;

wherein the depressible latch has an upper surface, the edge opposing the upper surface;

wherein the elongate arm is configured to be pulled rearward along the longitudinal axis with respect to the connector housing whereby the edge slides longitudinally along the upper surface to depress the depressible latch.

21. An optical fiber connector comprising:

first and second optical fiber ferrules;

a connector housing having a front end portion and a rear end portion spaced apart along a longitudinal axis, the connector housing comprising a top portion and a bottom portion spaced apart along a transverse axis perpendicular to the longitudinal axis, the connector housing holding the first and second optical fiber ferrules such that the first and second optical fiber ferrules are exposed through the front end portion for making an optical connection and the first and second optical fiber ferrules are spaced apart from one another along the transverse axis,

a depressible latch above the top portion of the connector housing; and

an elongate arm connected to the connector housing above the top portion and configured to be pulled to actuate the depressible latch;

wherein the elongate arm comprises a front end portion and a rear end portion spaced apart along the longitudinal axis;

the optical fiber connector further comprising a push/pull tab extending from the rear end portion of the elongate arm.

22. An optical fiber connector comprising:

first and second optical fiber ferrules;

a connector housing having a front end portion and a rear end portion spaced apart along a longitudinal axis, the connector housing comprising a top portion and a bottom portion spaced apart along a transverse axis perpendicular to the longitudinal axis, the connector housing holding the first and second optical fiber ferrules such that the first and second optical fiber ferrules are exposed through the front end portion for making an optical connection and the first and second optical fiber ferrules are spaced apart from one another along the transverse axis,

a depressible latch above the top portion of the connector housing; and

an elongate arm connected to the connector housing above the top portion and configured to be pulled to actuate the depressible latch;

wherein the connector housing includes a front body and a back body;

wherein the front body includes a recess and the back body includes a protrusion received in the recess to connect the back body to the front body.

23. An optical fiber connector comprising:

a multi-fiber ferrule configured to terminate a plurality of optical fibers;

a connector housing having a front end portion and a rear end portion spaced apart along a longitudinal axis, the connector housing comprising a top portion and a bottom portion spaced apart along a transverse axis perpendicular to the longitudinal axis, the connector housing being configured to hold the multi-fiber ferrule such that the multi-fiber ferrule is exposed through the front end portion for making an optical connection and the plurality of optical fibers are spaced apart from one another in a row extending parallel to the transverse axis,

a depressible latch above the top portion of the connector housing; and

an elongate arm connected to the connector housing above the top portion and configured to be pulled to actuate the depressible latch;

wherein the connector housing comprises a guide connecting the elongate arm to the optical fiber connector.

24. The optical fiber connector as set forth in claim **23**, wherein the guide defines a groove extending along the longitudinal axis.

25. The optical fiber connector as set forth in claim **24**, wherein the elongate arm is slidably received in the groove.

26. The optical fiber connector as set forth in claim **23**, wherein the elongate arm comprises a front end portion and a rear end portion spaced apart along the longitudinal axis.

27. The optical fiber connector as set forth in claim **26**, wherein the front end portion of the elongate arm defines an opening.

28. The optical fiber connector as set forth in claim **27**, wherein the depressible latch is received in the opening.

29. The optical fiber connector as set forth in claim **28**, wherein the depressible latch has a front end portion and rear end portion spaced apart along the longitudinal axis and wherein the depressible latch extends upward along the transverse axis as the depressible latch extends along the longitudinal axis from the front end portion to the rear end portion of the depressible latch.

30. The optical fiber connector as set forth in claim **29**, wherein the rear end portion of the depressible latch is spaced apart above the top portion of the connector housing along the transverse axis.

31. The optical fiber connector as set forth in claim **30**, wherein the front end portion of the elongate arm includes an edge defining a front end of the opening.

32. The optical fiber connector as set forth in claim **31**, wherein the depressible latch has an upper surface, the edge opposing the upper surface.

33. The optical fiber connector as set forth in claim **32**, wherein the elongate arm is configured to be pulled rearward along the longitudinal axis with respect to the connector housing whereby the edge slides longitudinally along the upper surface to depress the depressible latch.

34. The optical fiber connector as set forth in claim **33**, wherein the guide defines a groove extending along the longitudinal axis.

35. The optical fiber connector as set forth in claim **34**, wherein the elongate arm is slidably received in the groove.

36. The optical fiber connector as set forth in claim **34**, wherein the connector housing includes a front body and a back body.

37. The optical fiber connector as set forth in claim **36**, wherein the front body includes a recess and the back body includes a protrusion received in the recess to connect the back body to the front body.

38. The optical fiber connector as set forth in claim **37**, further comprising a single cable boot extending rearward from the connector housing.

39. An optical fiber connector comprising:

a multi-fiber ferrule configured to terminate a plurality of optical fibers;

a connector housing having a front end portion and a rear end portion spaced apart along a longitudinal axis, the connector housing comprising a top portion and a bottom portion spaced apart along a transverse axis perpendicular to the longitudinal axis, the connector housing being configured to hold the multi-fiber ferrule such that the multi-fiber ferrule is exposed through the front end portion for making an optical connection and the plurality of optical fibers are spaced apart from one another in a row extending parallel to the transverse axis,

a depressible latch above the top portion of the connector housing; and

an elongate arm connected to the connector housing above the top portion and configured to be pulled to actuate the depressible latch;

wherein the elongate arm comprises a front end portion and a rear end portion spaced apart along the longitudinal axis;

wherein the front end portion of the elongate arm defines an opening;

wherein the depressible latch is received in the opening;

wherein the depressible latch has a front end portion and rear end portion spaced apart along the longitudinal axis and wherein the depressible latch extends upward along the transverse axis as the depressible latch extends along the longitudinal axis from the front end portion to the rear end portion of the depressible latch;

wherein the rear end portion of the depressible latch is spaced apart above the top portion of the connector housing along the transverse axis;

wherein the front end portion of the elongate arm includes an edge defining a front end of the opening;

wherein the depressible latch has an upper surface, the edge opposing the upper surface:

wherein the elongate arm is configured to be pulled rearward along the longitudinal axis with respect to the connector housing whereby the edge slides longitudinally along the upper surface to depress the depressible latch.

40. An optical fiber connector comprising:

a multi-fiber ferrule configured to terminate a plurality of optical fibers;

a connector housing having a front end portion and a rear end portion spaced apart along a longitudinal axis, the connector housing comprising a top portion and a bottom portion spaced apart along a transverse axis perpendicular to the longitudinal axis, the connector housing being configured to hold the multi-fiber ferrule such that the multi-fiber ferrule is exposed through the front end portion for making an optical connection and the plurality of optical fibers are spaced apart from one another in a row extending parallel to the transverse axis,

a depressible latch above the top portion of the connector housing; and

an elongate arm connected to the connector housing above the top portion and configured to be pulled to actuate the depressible latch;

wherein the elongate arm comprises a front end portion and a rear end portion spaced apart along the longitudinal axis;

further comprising a push/pull tab extending from the rear end portion of the elongate arm.

* * * * *

EXHIBIT B

US011333836B2

(12) **United States Patent**
Wong et al.

(10) **Patent No.: US 11,333,836 B2**
(45) **Date of Patent: May 17, 2022**

(54) **ADAPTER FOR OPTICAL CONNECTORS**

(71) Applicant: **Senko Advanced Components, Inc.**, Marlborough, MA (US)

(72) Inventors: **Kim Man Wong**, Kowloon (HK); **Jeffrey Gniadek**, Oxford, ME (US); **Kazuyoshi Takano**, Tokyo (JP); **Siu Kei Ma**, Kowloon (HK)

(73) Assignee: **Senko Advanced Components, Inc.**, Marlborough, MA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **17/375,856**

(22) Filed: **Jul. 14, 2021**

(65) **Prior Publication Data**

US 2021/0382245 A1 Dec. 9, 2021

Related U.S. Application Data

(63) Continuation of application No. 17/200,134, filed on Mar. 12, 2021, now Pat. No. 11,181,701, which is a continuation of application No. 16/297,607, filed on Mar. 9, 2019, now Pat. No. 10,976,505, which is a continuation of application No. PCT/US2018/016049, filed on Jan. 30, 2018.

(60) Provisional application No. 62/581,961, filed on Nov. 6, 2017, provisional application No. 62/546,920, filed on Aug. 17, 2017, provisional application No. 62/485,042, filed on Apr. 13, 2017, provisional application No. 62/463,898, filed on Feb. 27, 2017, provisional application No. 62/457,150, filed on Feb. 9, 2017, provisional application No. 62/452,147, filed on Jan. 30, 2017.

(51) **Int. Cl.**
G02B 6/38 (2006.01)

(52) **U.S. Cl.**
CPC ***G02B 6/3893*** (2013.01); ***G02B 6/3821*** (2013.01); ***G02B 6/3879*** (2013.01)

(58) **Field of Classification Search**
CPC ... G02B 6/3893; G02B 6/3821; G02B 6/3879
USPC 385/78
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2005/0135752 A1* 6/2005 Kiani G02B 6/3895
385/55

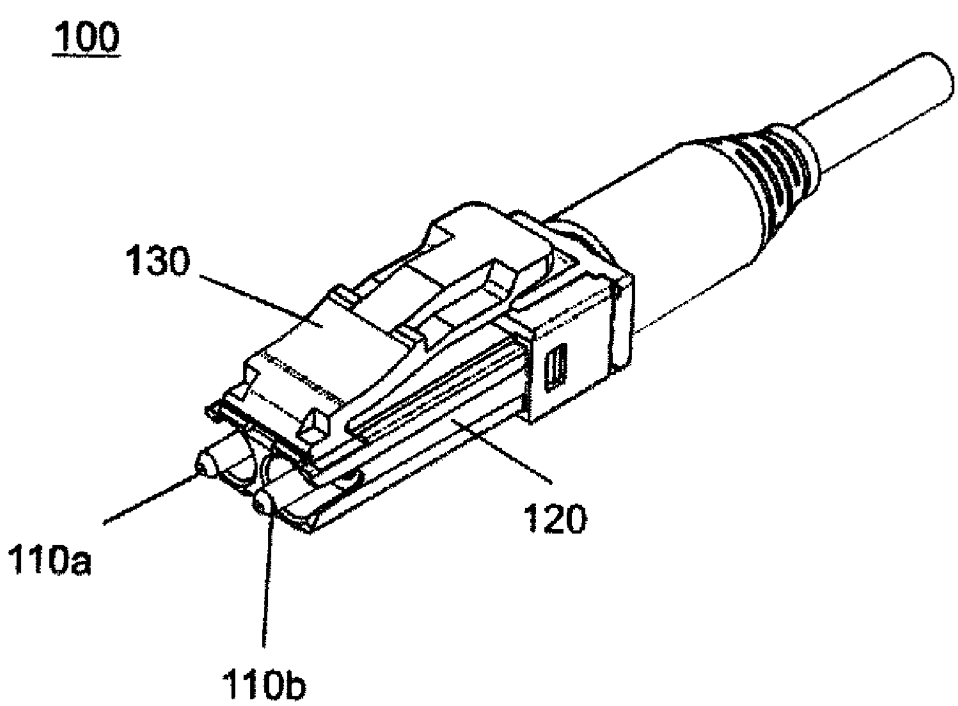
* cited by examiner

Primary Examiner — Jerry M Blevins

(57) **ABSTRACT**

An optical fiber connector assembly comprises at least one connector having a latching arm for coupling to an adapter, and a remote release tab having a protrusion configured to cooperate with the adapter to depress said latching arm when the remote release tab is pulled relative to the adapter. The optical fiber connector assembly may further be configured to allow reversing its polarity.

13 Claims, 28 Drawing Sheets



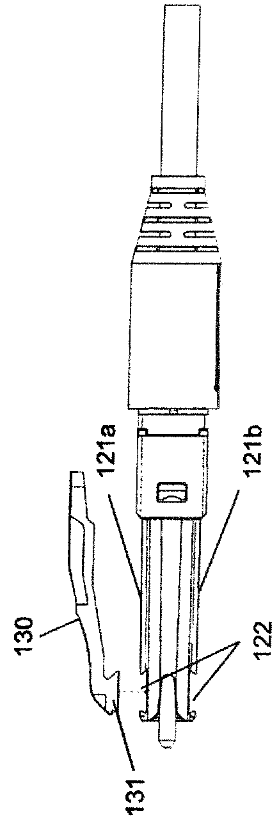


FIG. 1B

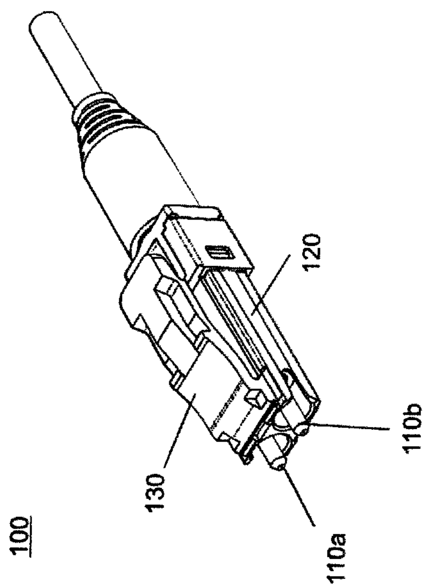


FIG. 1A

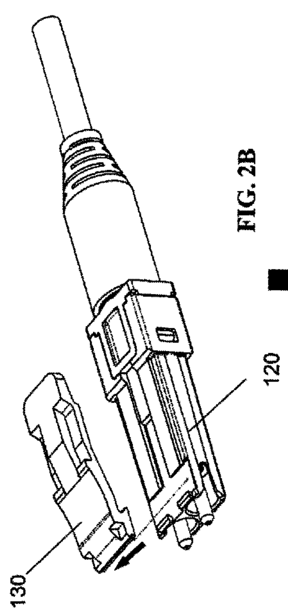


FIG. 2B

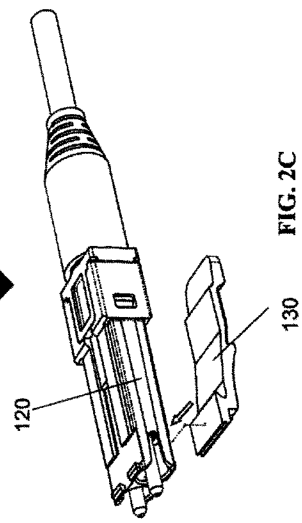


FIG. 2C

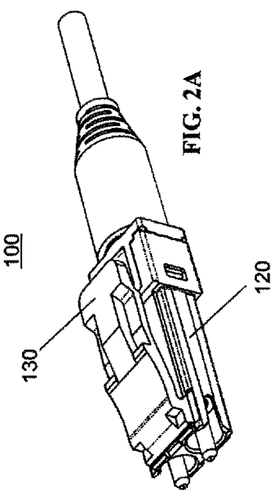


FIG. 2A

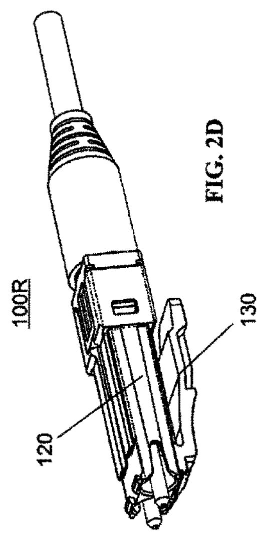


FIG. 2D

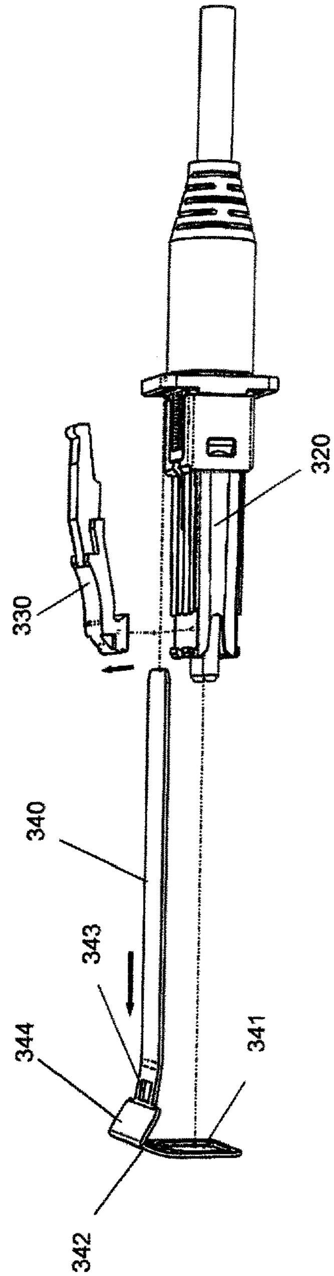


FIG. 3B

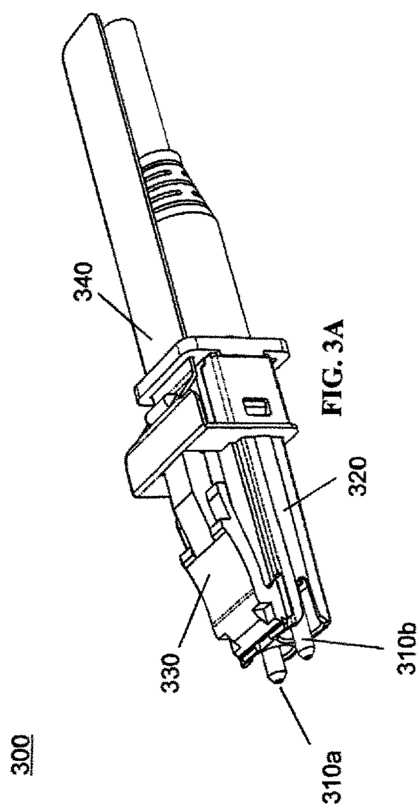


FIG. 3A

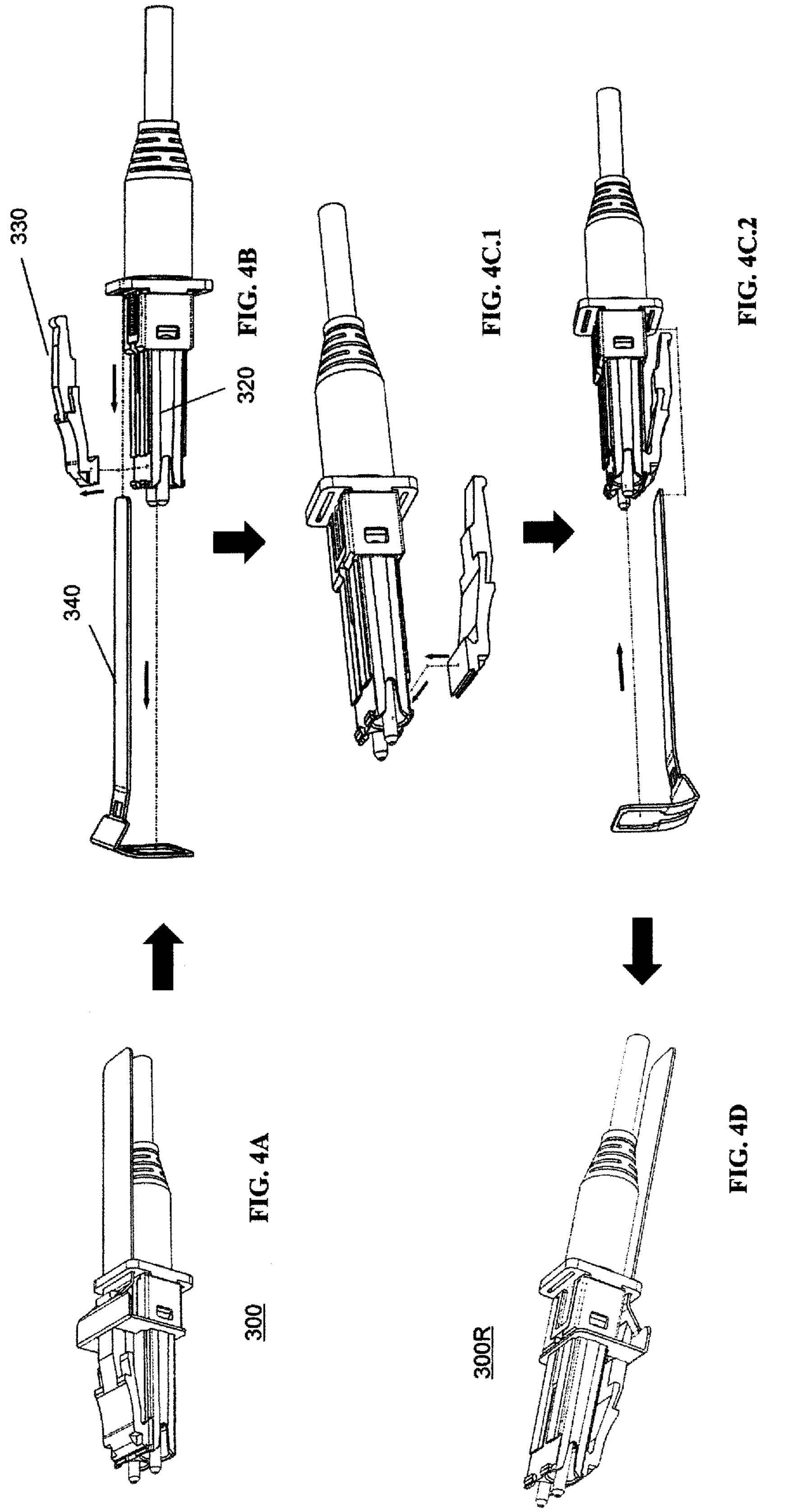


FIG. 4B

FIG. 4C.1

FIG. 4C.2

FIG. 4A

FIG. 4D

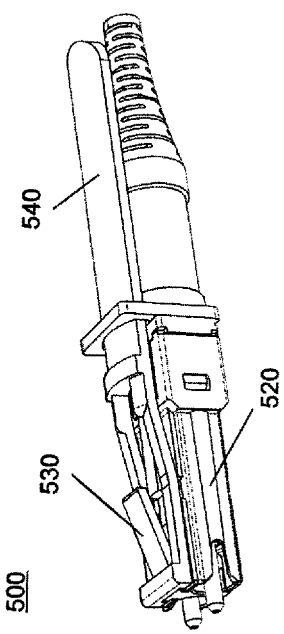


FIG. 5A

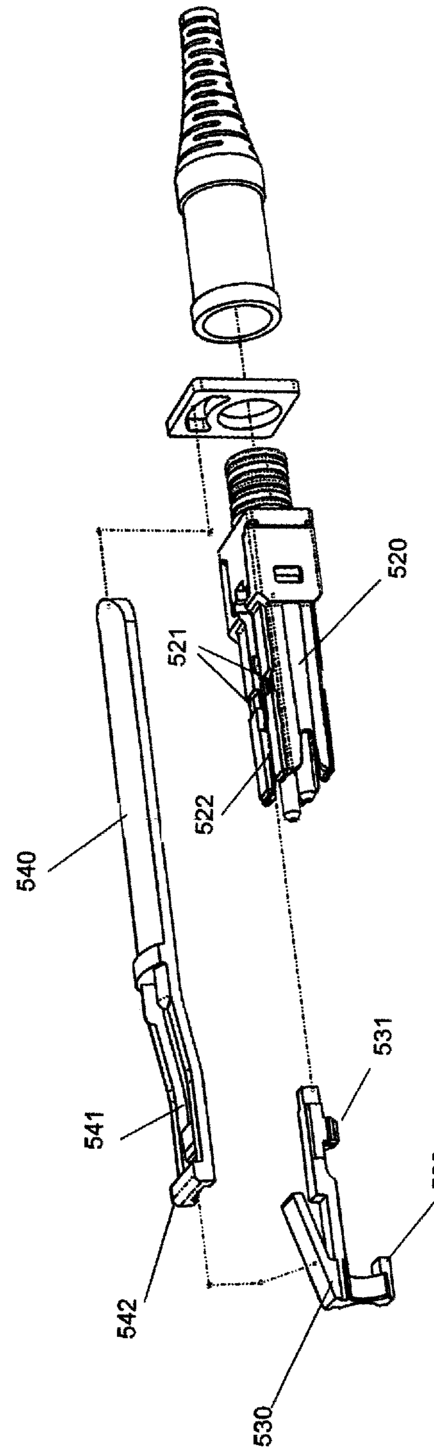


FIG. 5B

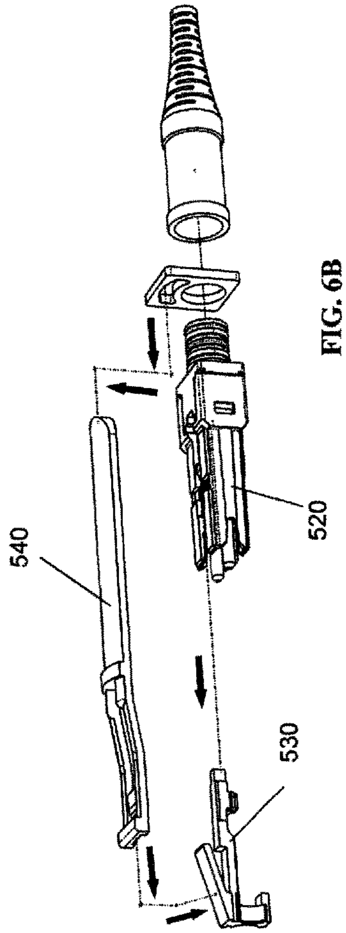


FIG. 6B

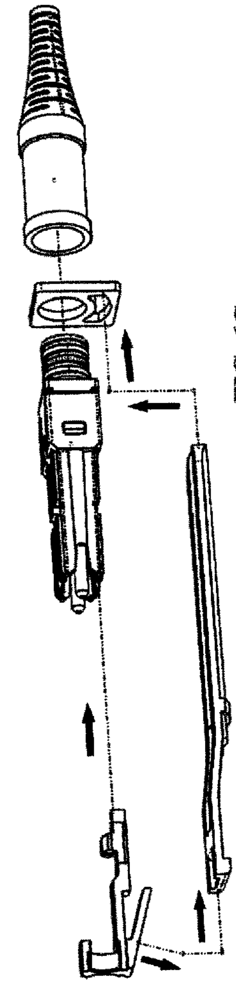


FIG. 6C

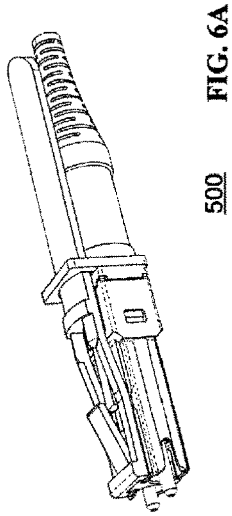


FIG. 6A

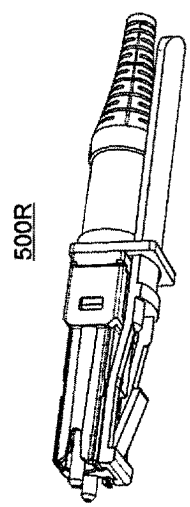


FIG. 6D

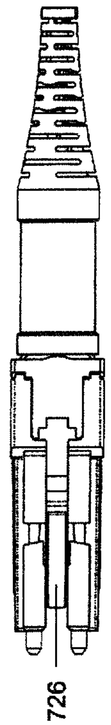


FIG. 7C

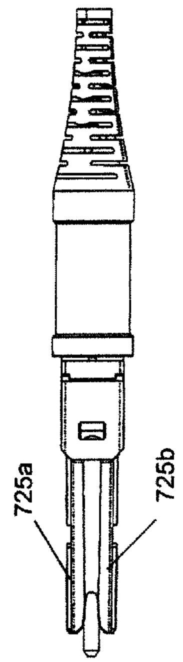


FIG. 7D

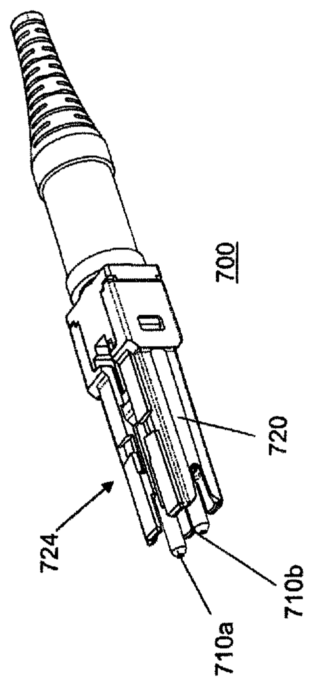


FIG. 7A

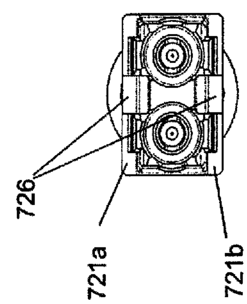


FIG. 7B

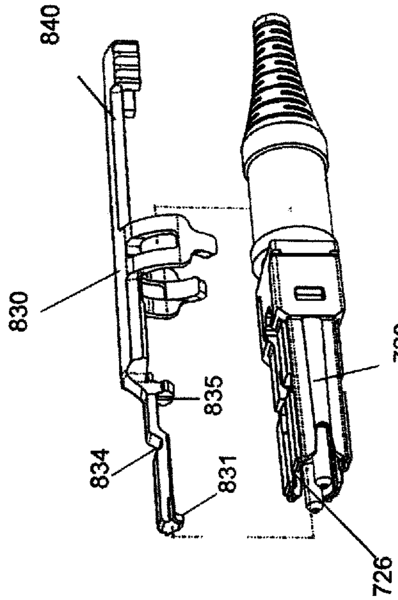


FIG. 8B.2

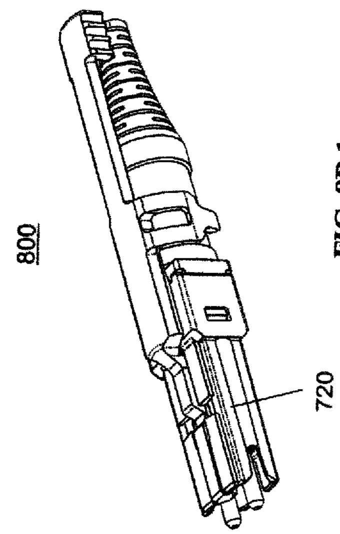


FIG. 8B.1

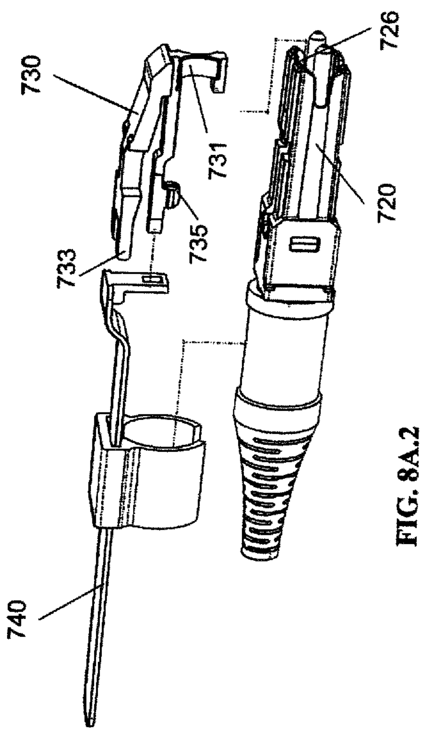


FIG. 8A.2

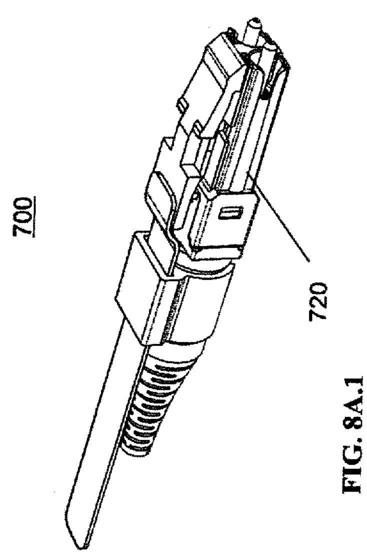


FIG. 8A.1

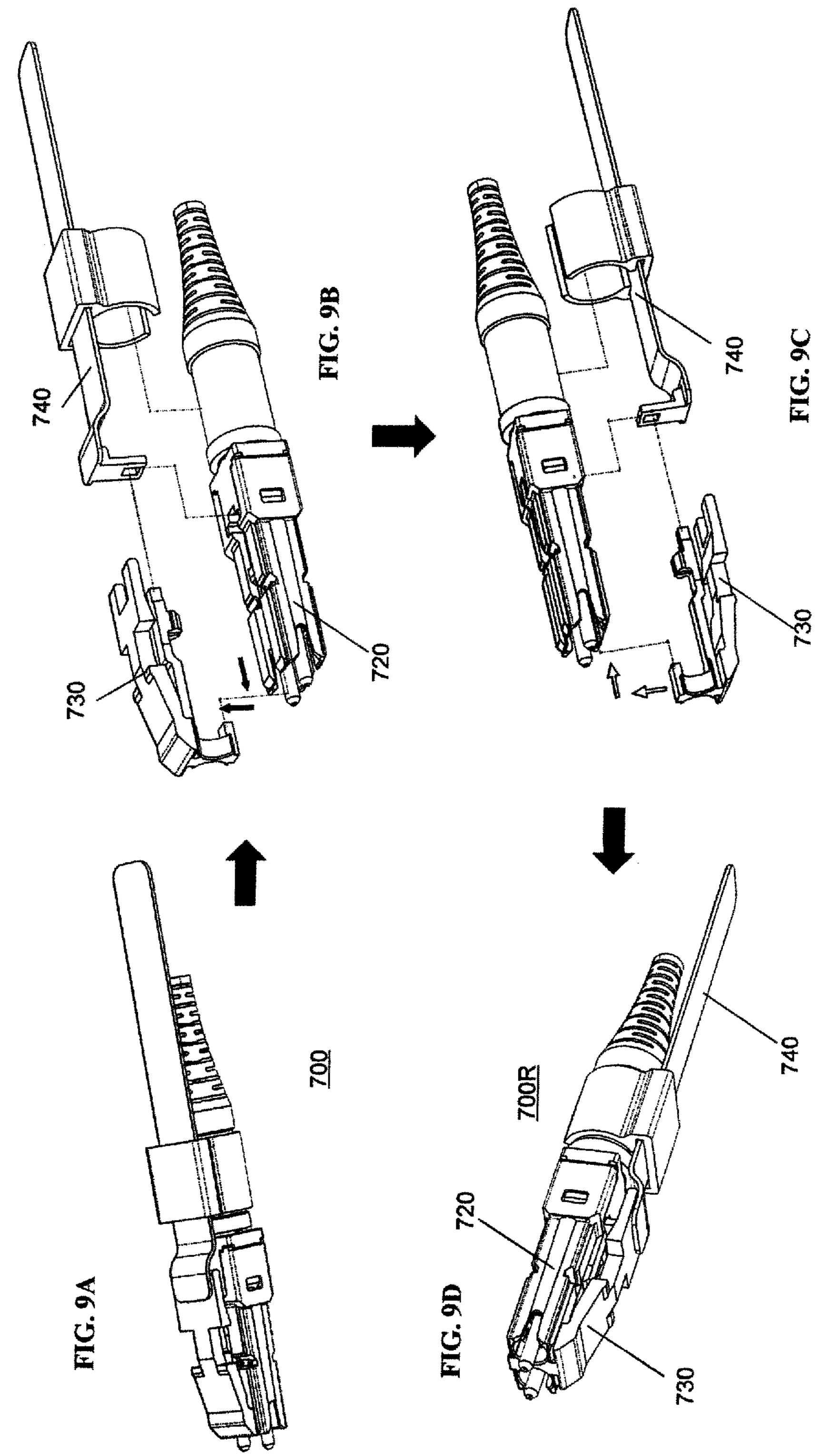


FIG. 9A

FIG. 9B

FIG. 9C

FIG. 9D

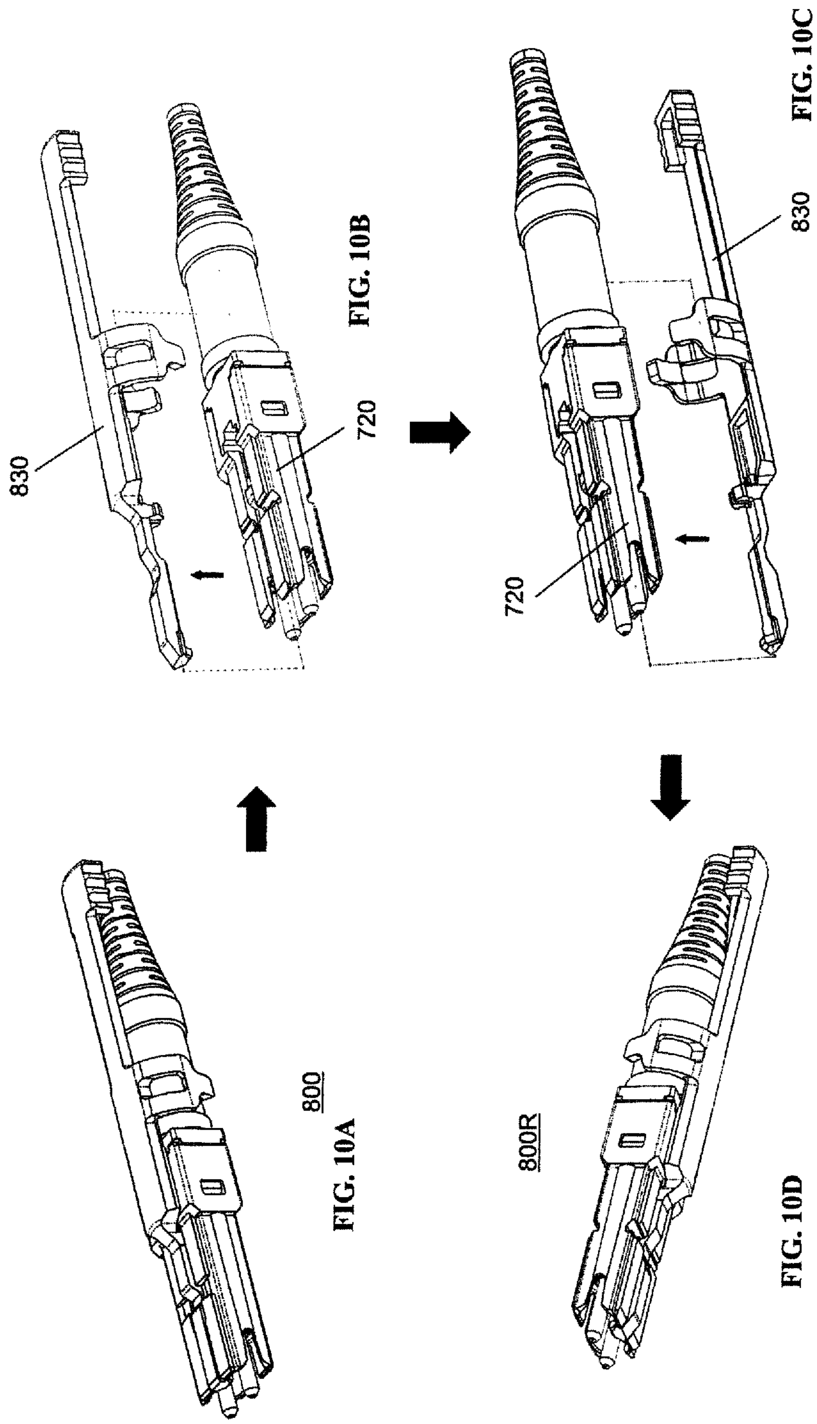


FIG. 10B

FIG. 10C

FIG. 10A

FIG. 10D

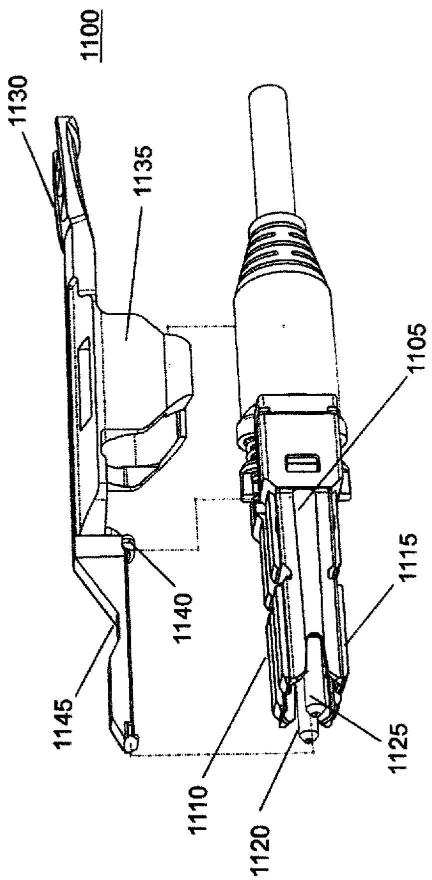


FIG. 11A

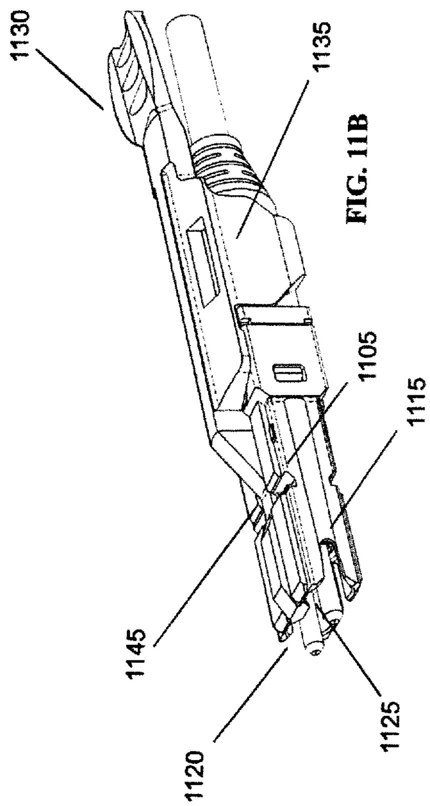


FIG. 11B

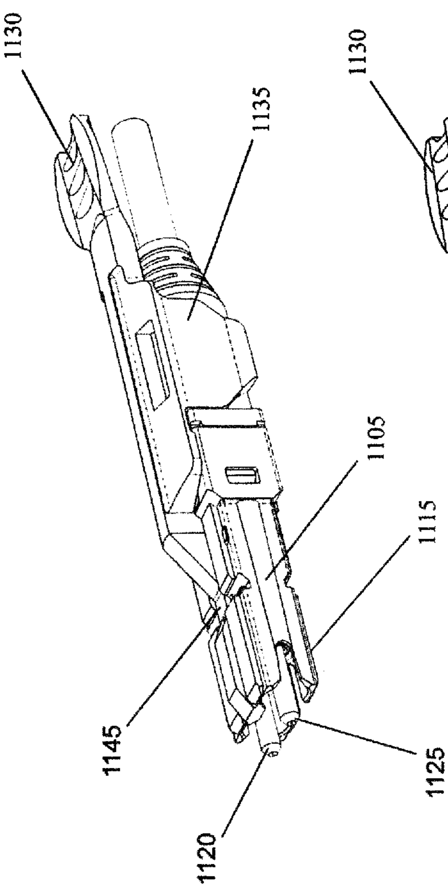


FIG. 12A

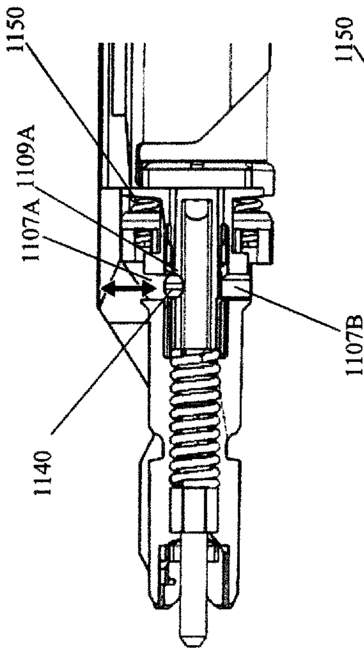


FIG. 12B

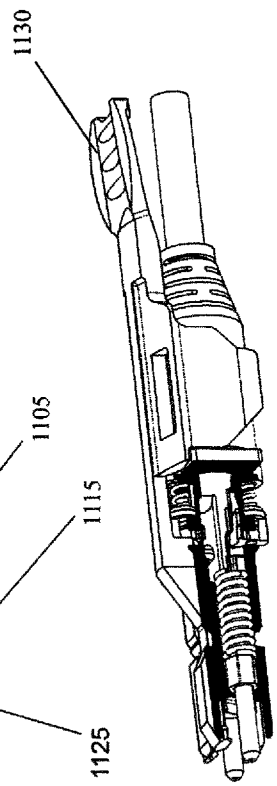


FIG. 12C

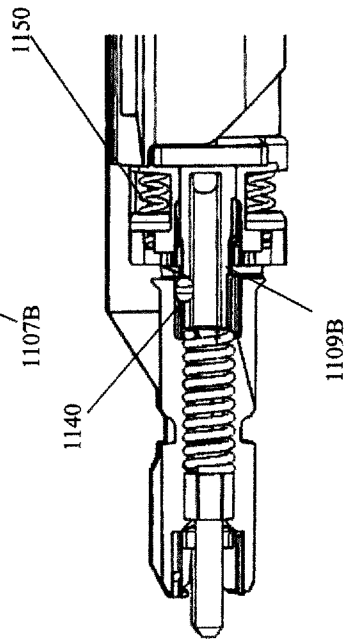


FIG. 12D

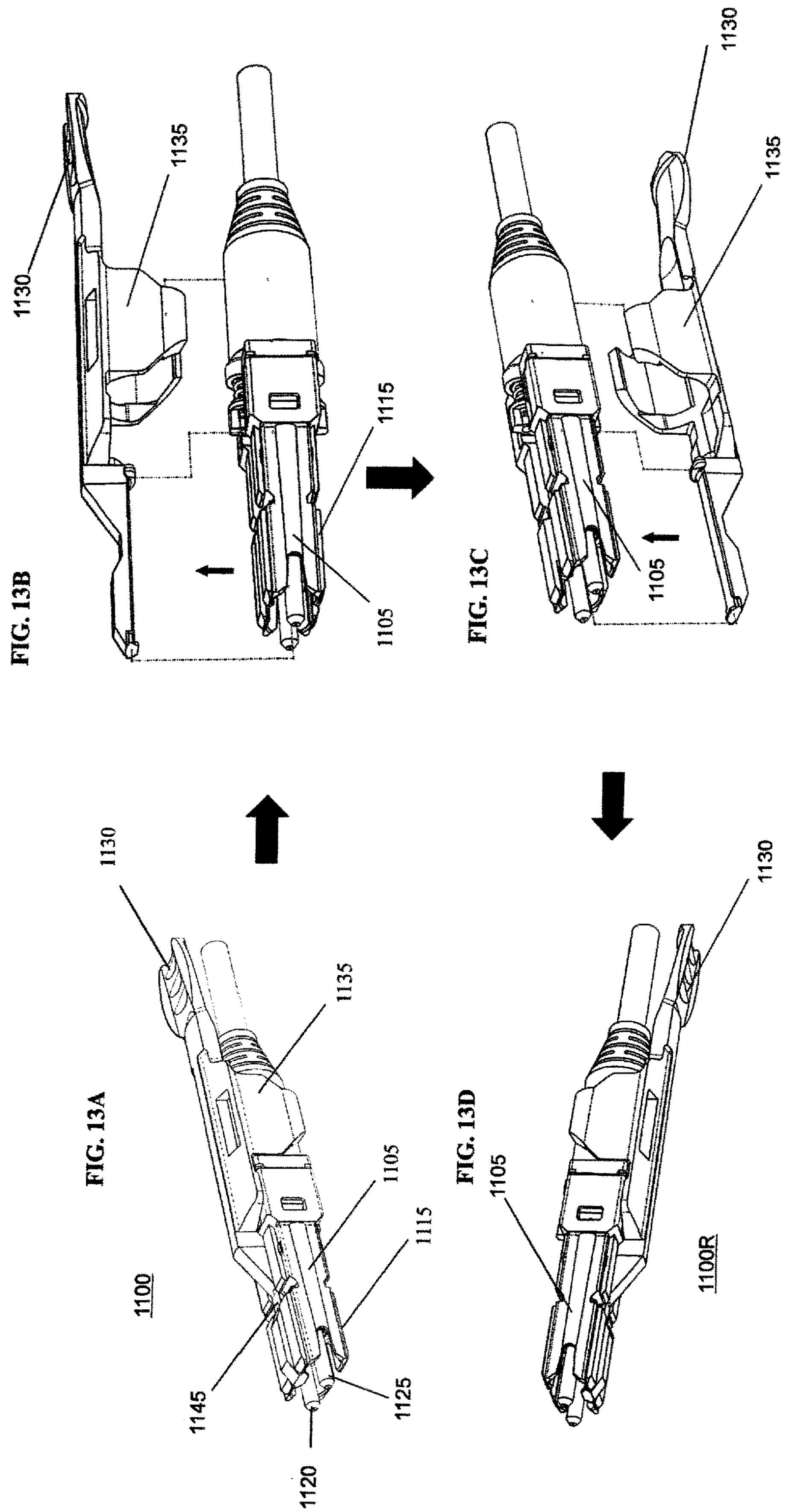


FIG. 13B
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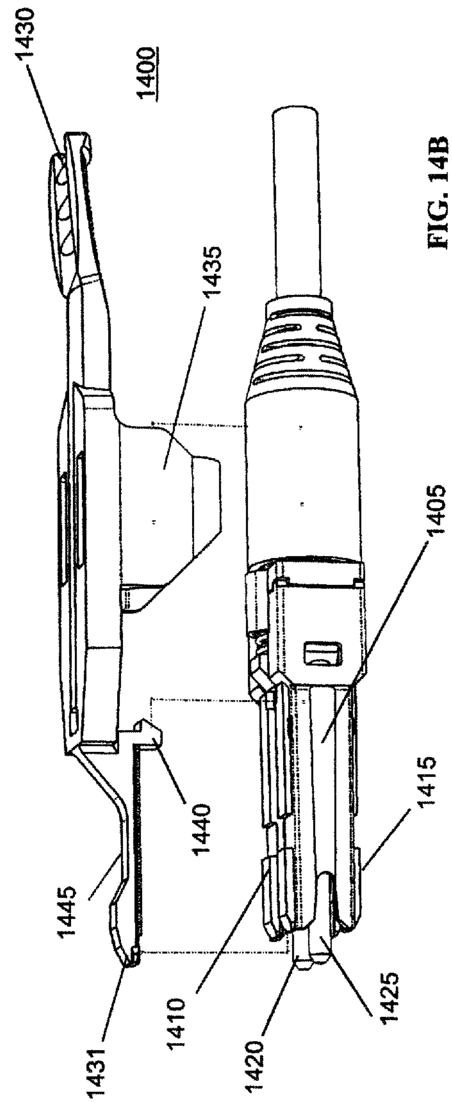

FIG. 14A

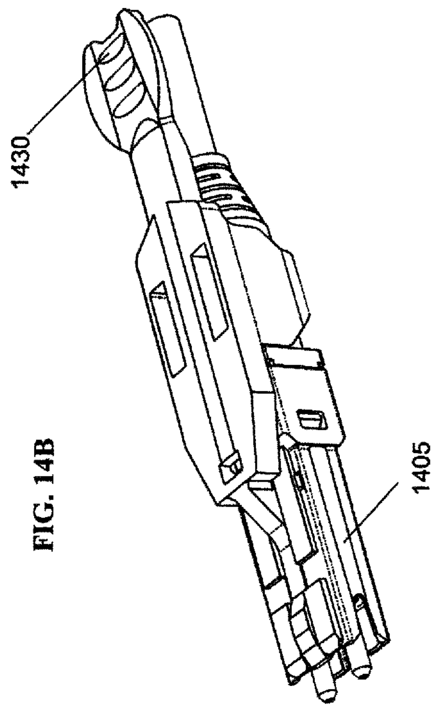

FIG. 14B

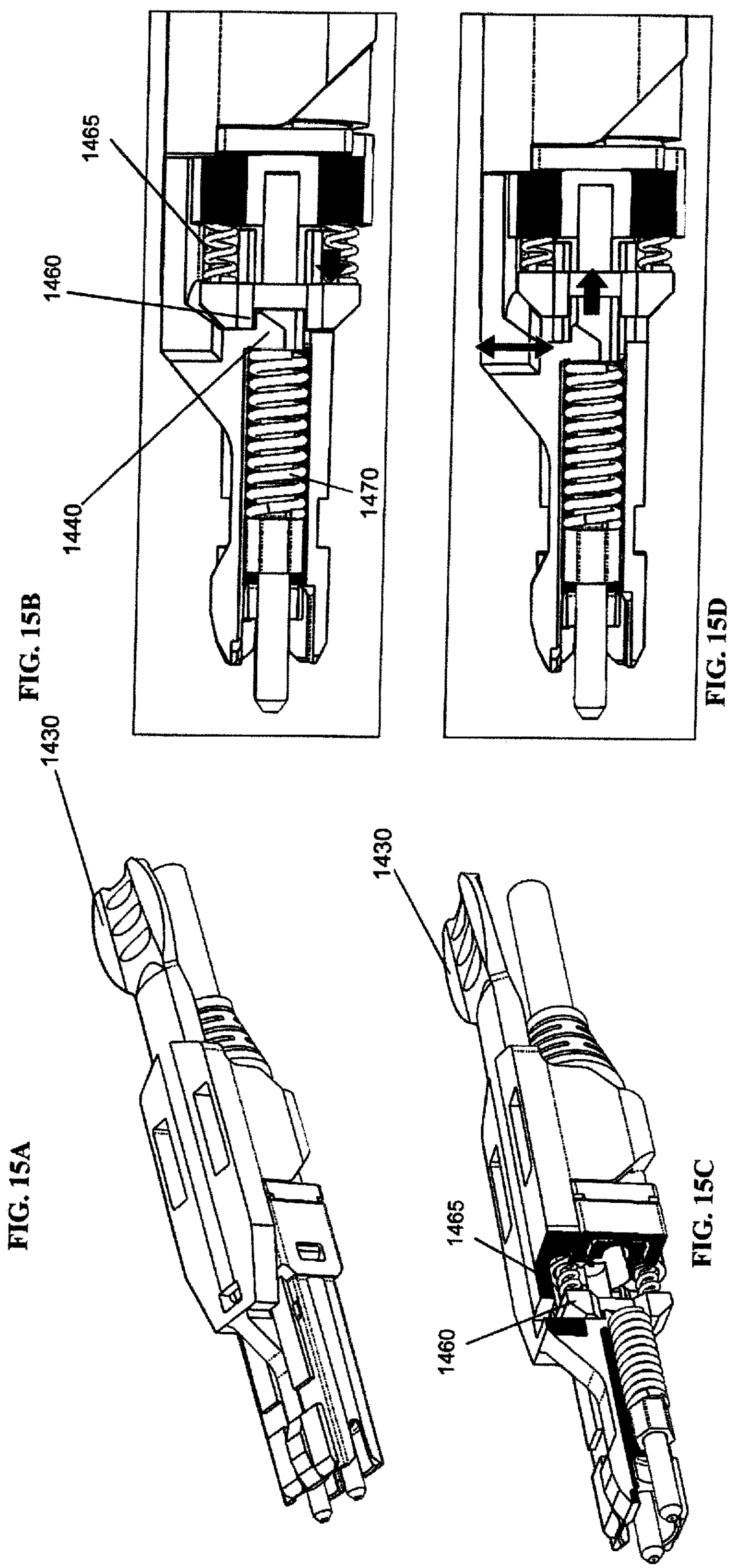

FIG. 15B

FIG. 15D

FIG. 15A

FIG. 15C

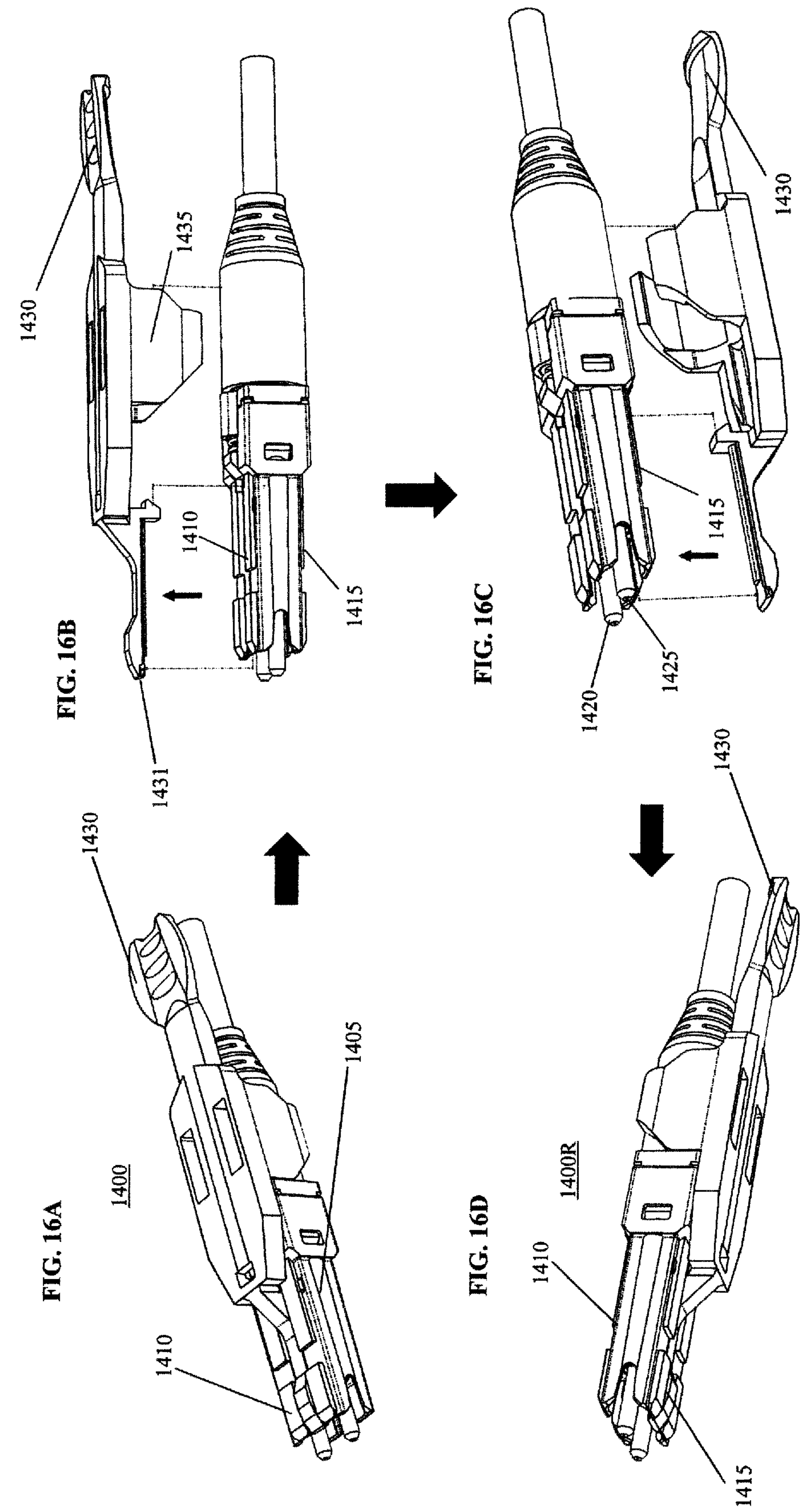
FIG. 16A
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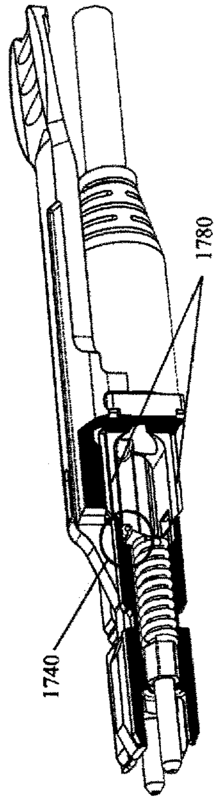


FIG 17B

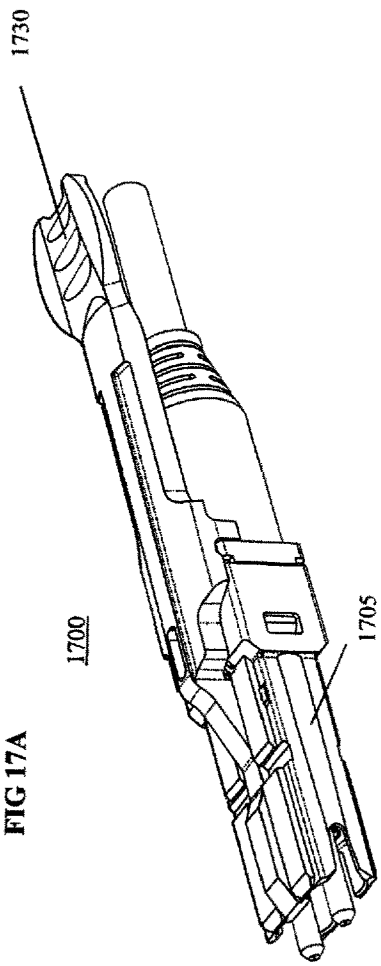


FIG 17A

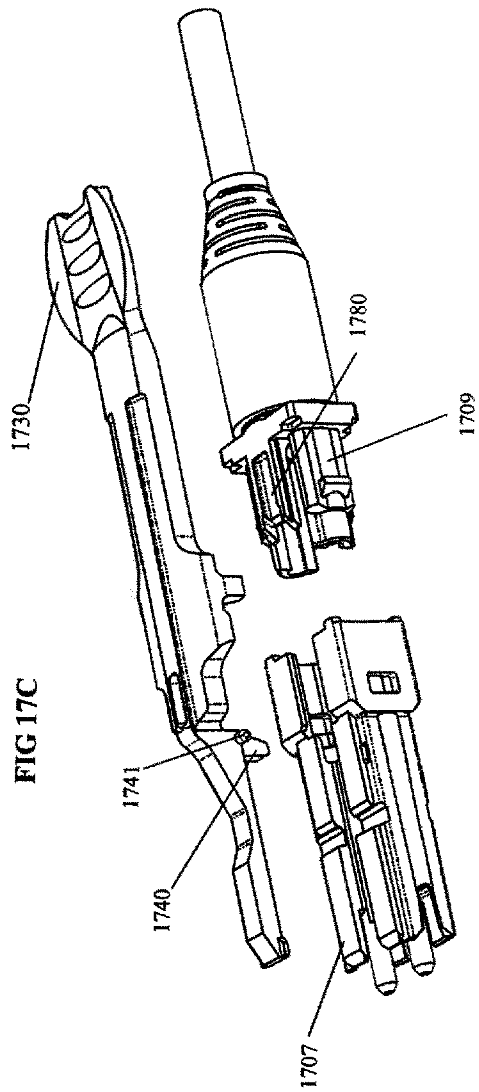


FIG 17C

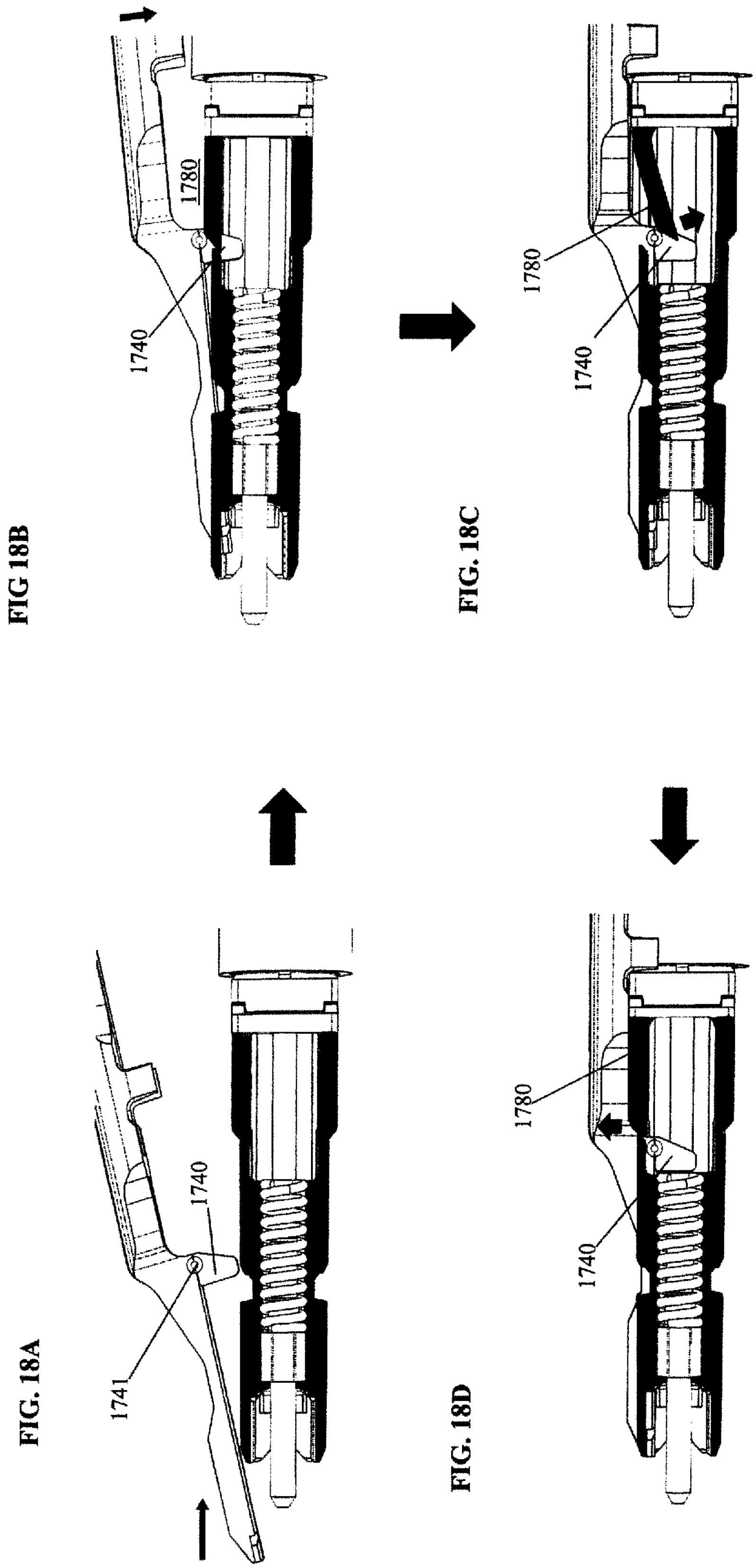


FIG 18B

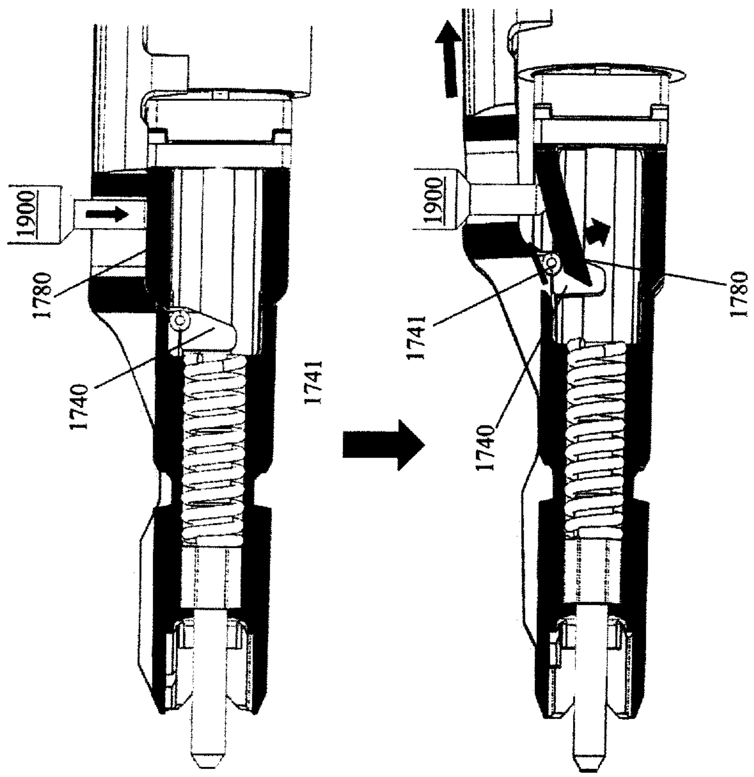
FIG. 18C

FIG. 18A

FIG. 18D

FIG. 19A

FIG. 19B



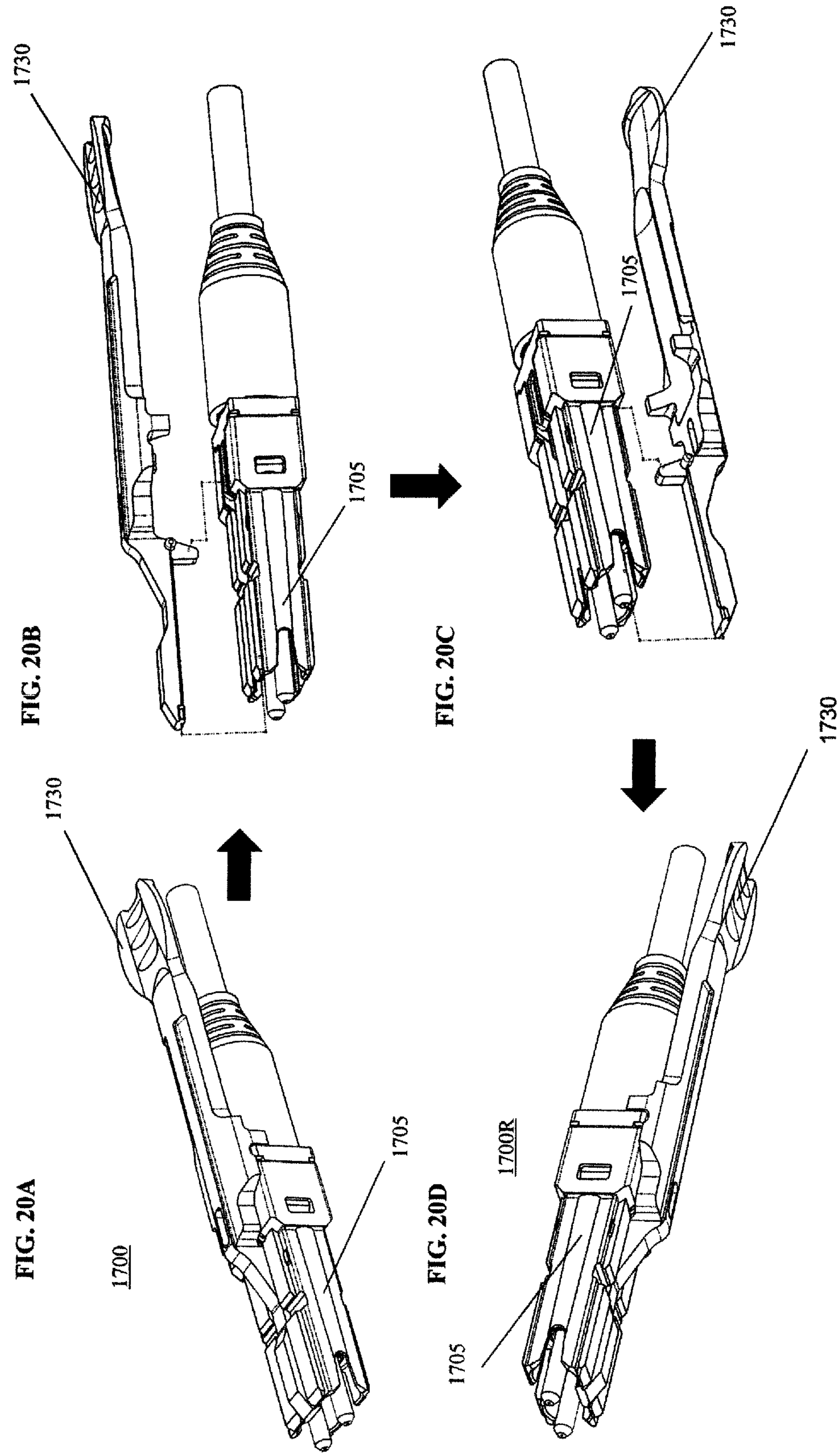


FIG. 20A

FIG. 20B

FIG. 20C

FIG. 20D

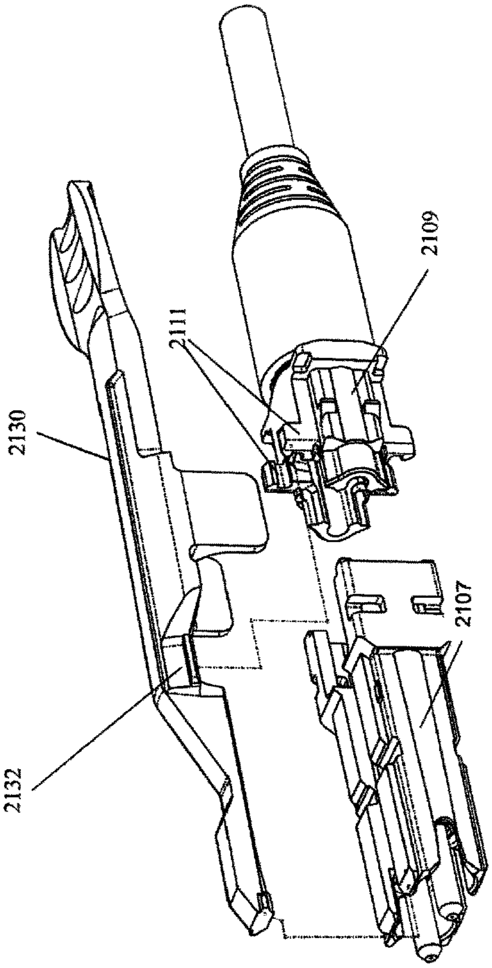


FIG. 21B

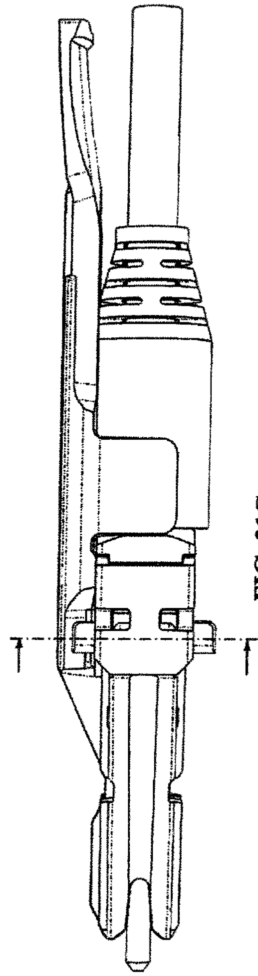


FIG. 21C

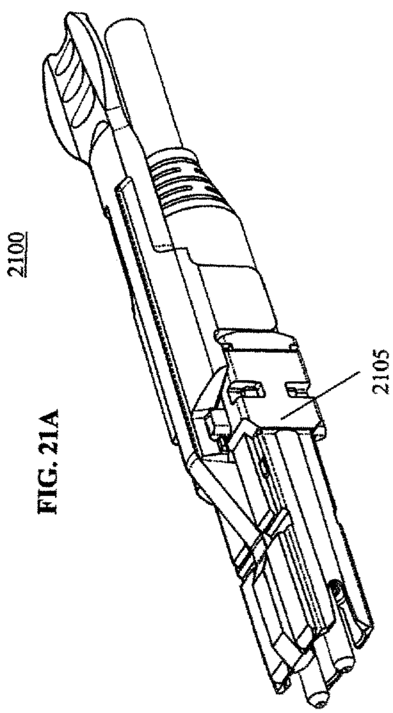


FIG. 21A

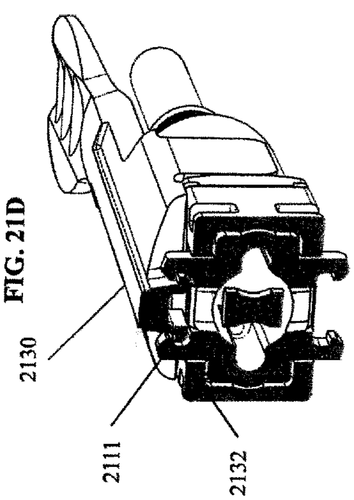


FIG. 21D

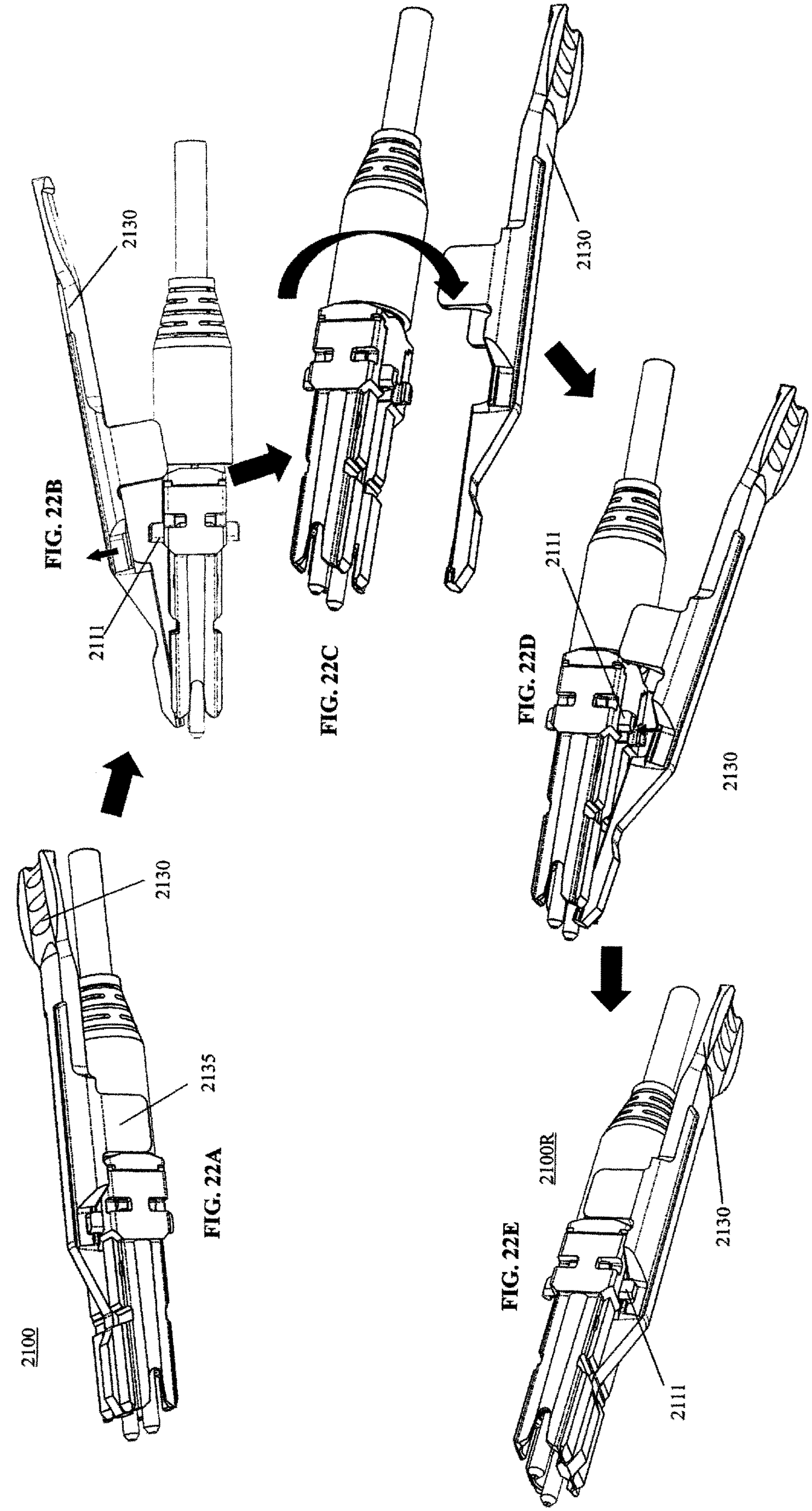


FIG. 22A

FIG. 22B

FIG. 22C

FIG. 22D

FIG. 22E

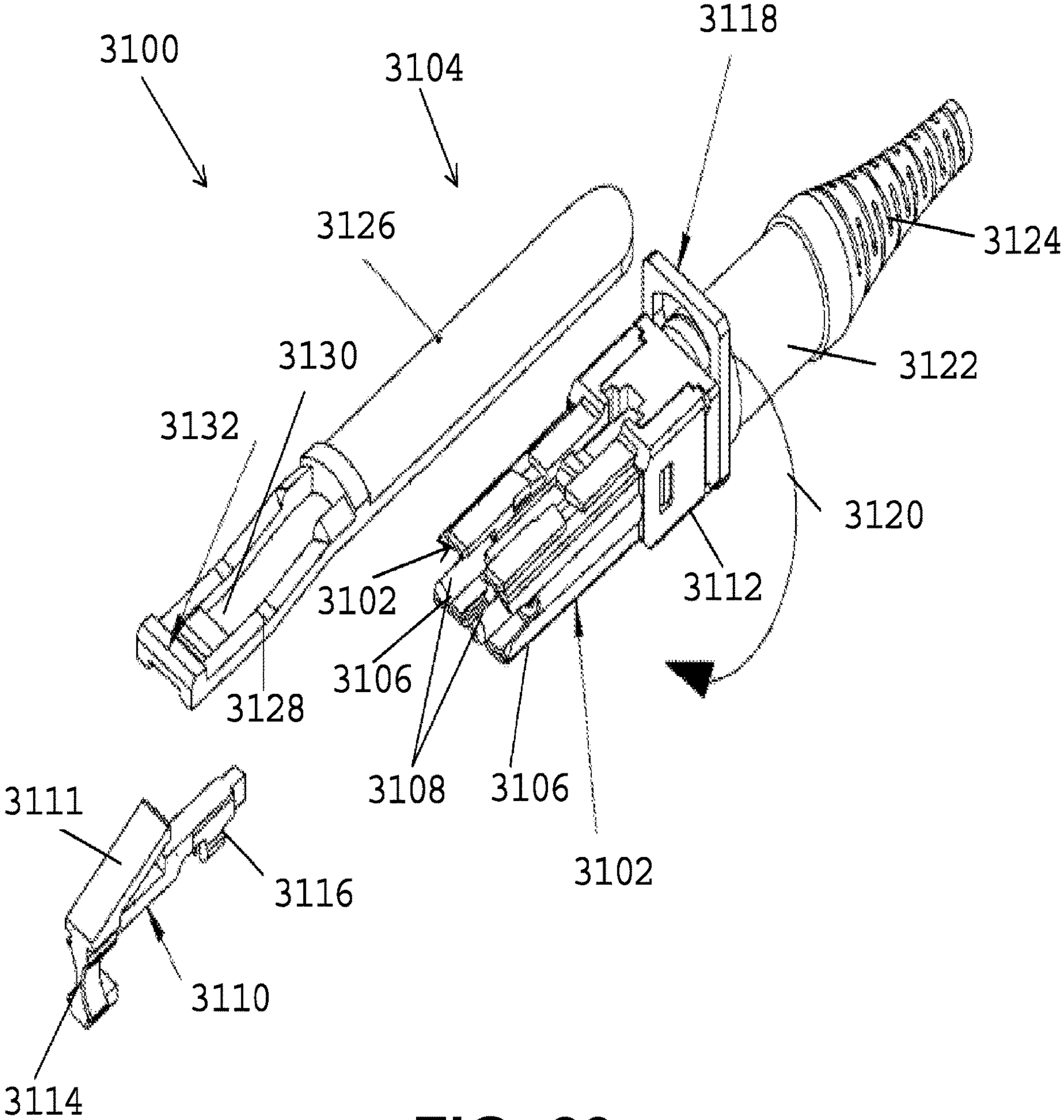

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FIG. 23

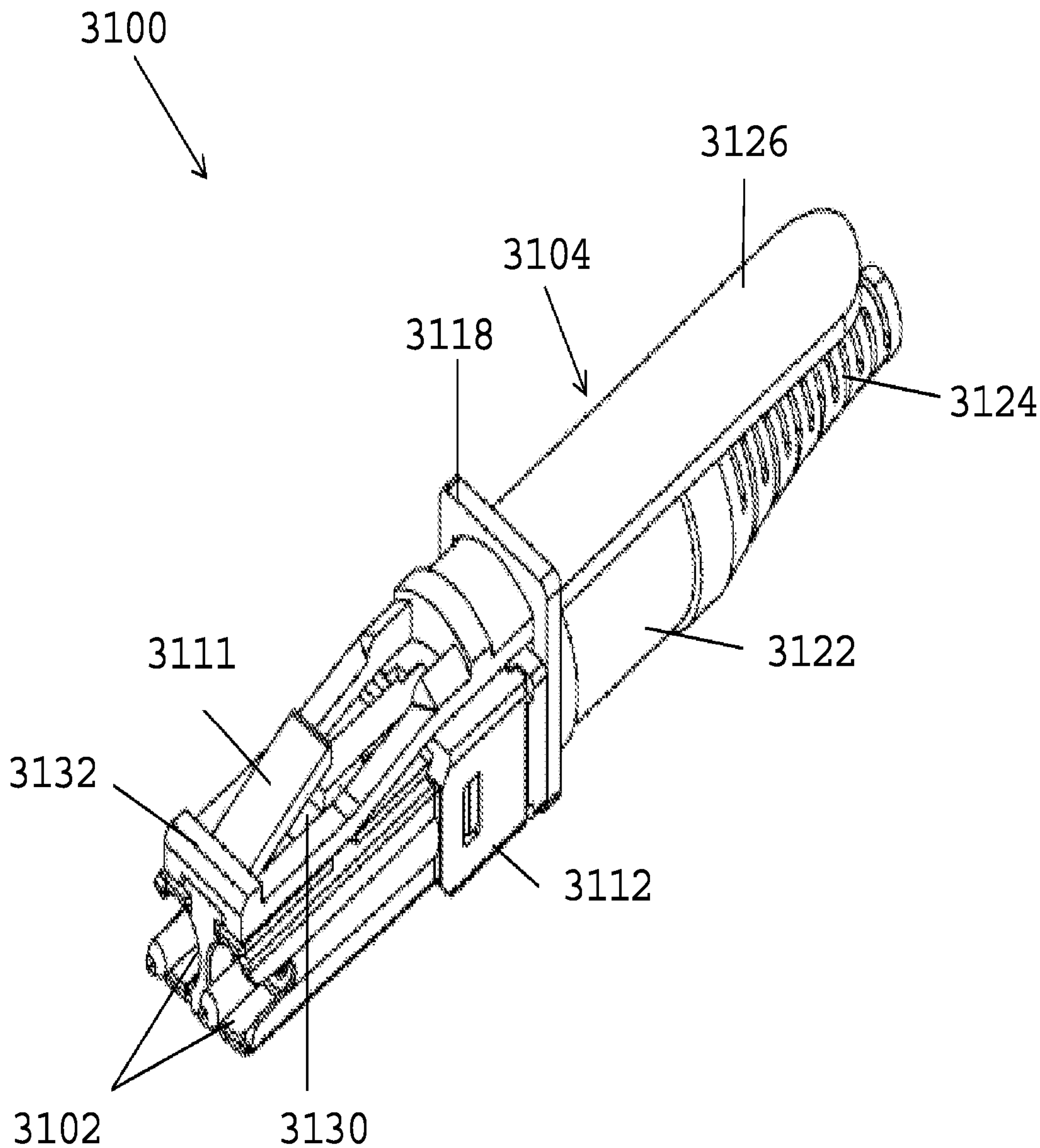

FIG. 24

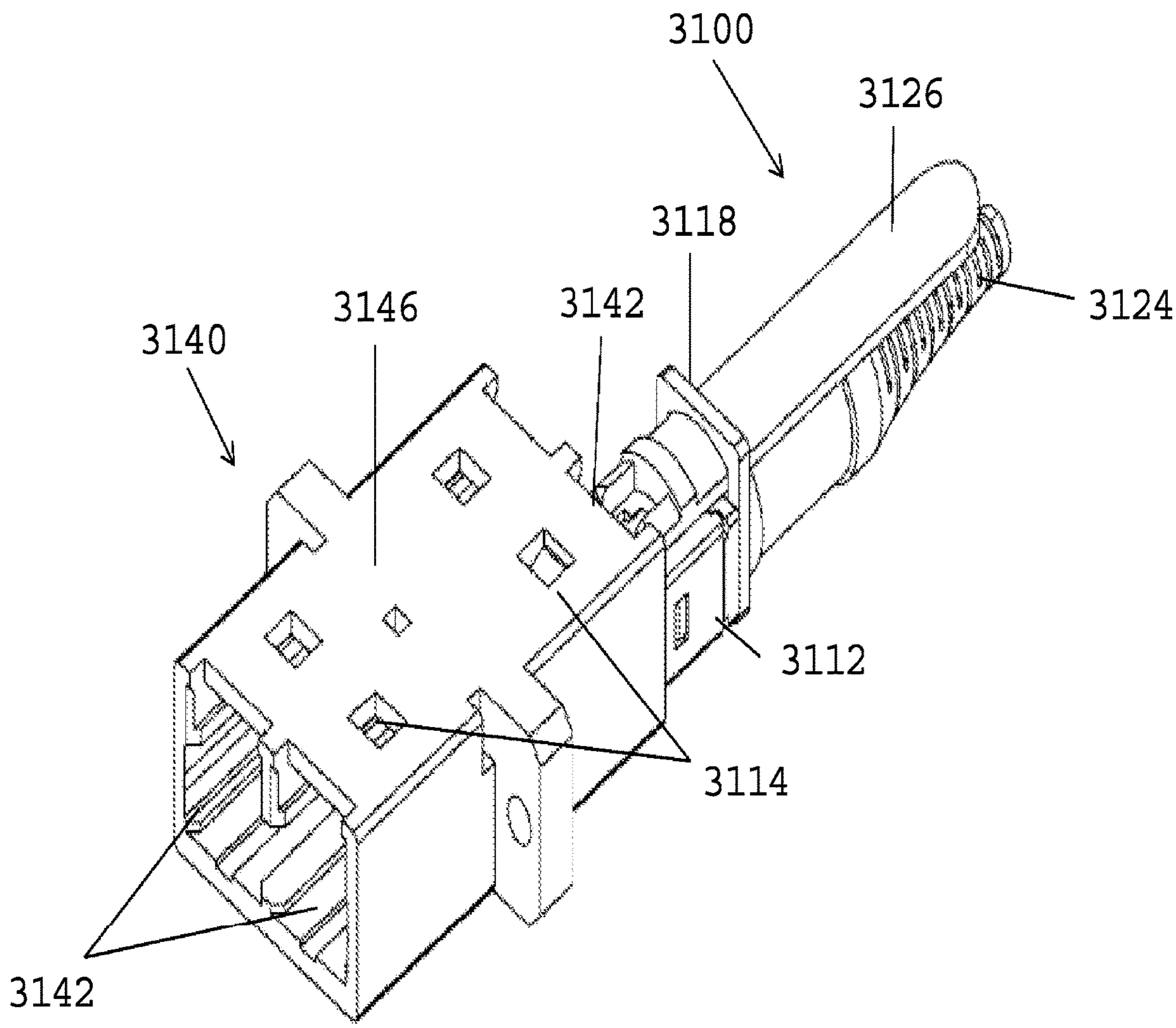

FIG. 25

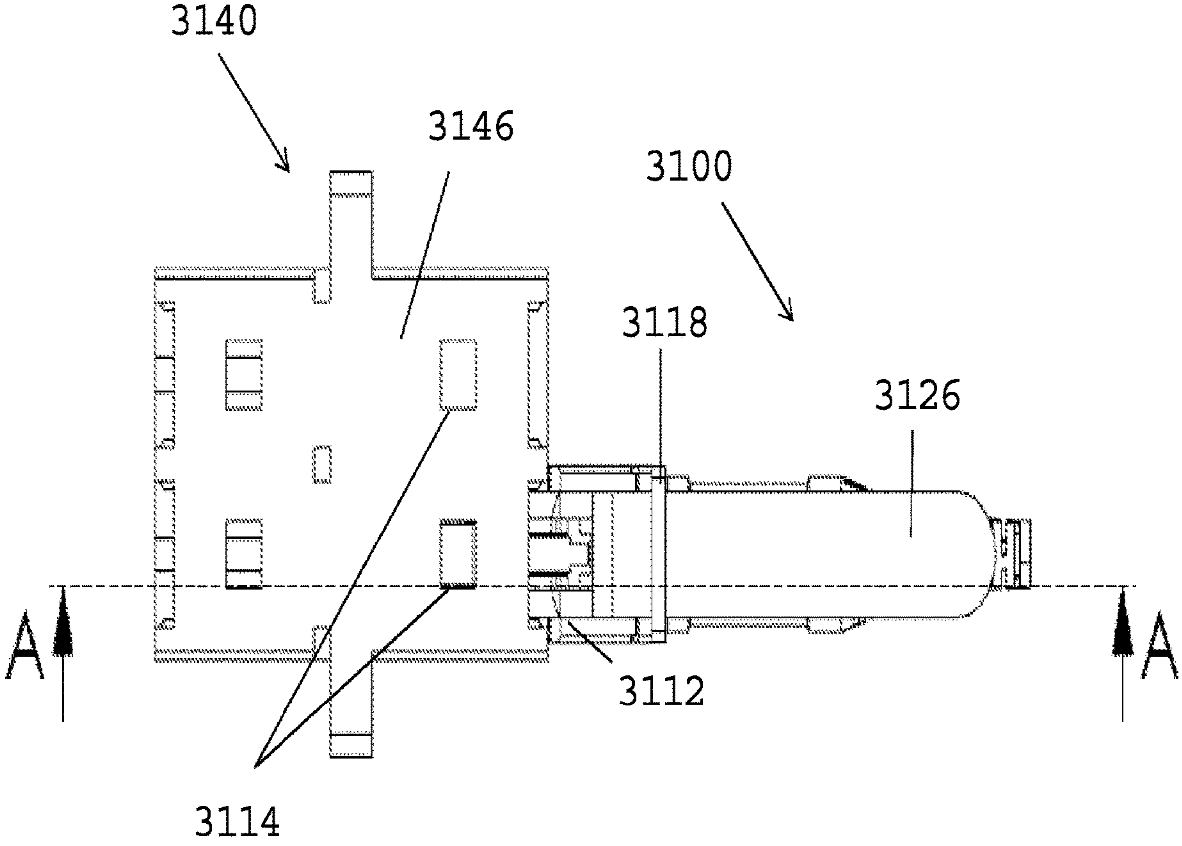

FIG. 26

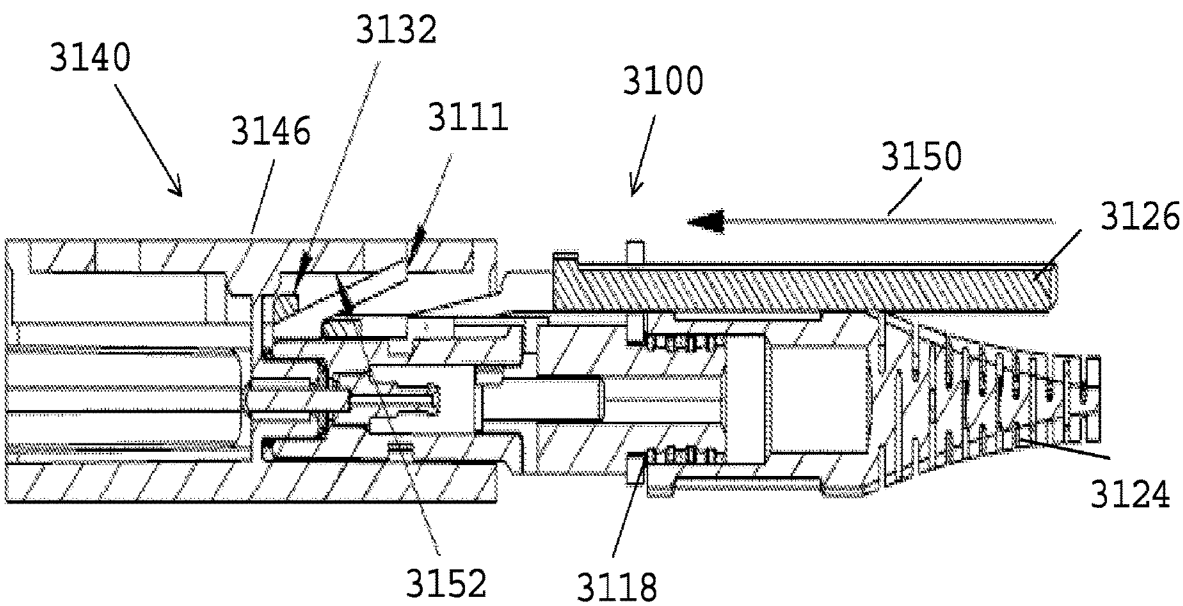

FIG. 27

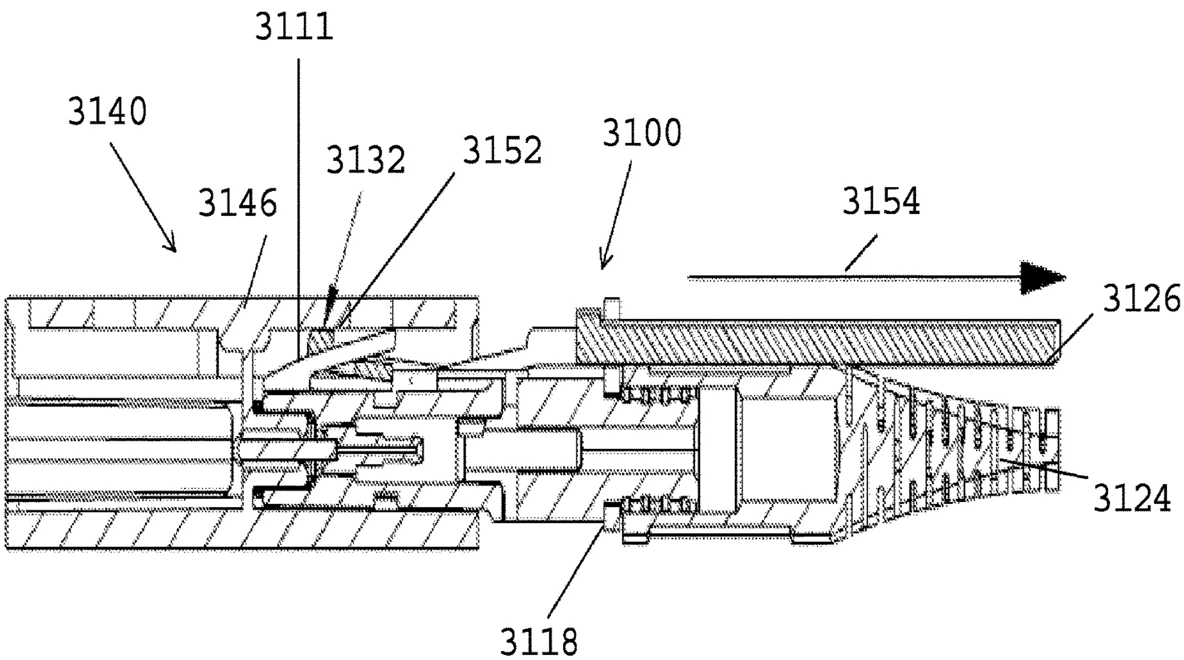

FIG. 28

ADAPTER FOR OPTICAL CONNECTORS

CROSS-REFERENCE TO RELATED PATENT APPLICATIONS

The present application is U.S. Non-Provisional patent application Ser. No. 17/200,134, filed on Mar. 12, 2021, titled Optical Connectors with Reversible Polarity, which is a continuation of U.S. Non-Provisional patent application Ser. No. 16/297,607, filed on Mar. 9, 2019, titled Optical Connectors with Reversible Polarity and Method of Use, which claims priority to PCT Application No. PCT/US2018/016049, filed Jan. 30, 2018, which claims priority to provisional applications: 62/452,147 filed Jan. 30, 2017, No. 62/457,150 filed Feb. 9, 2017, No. 62/463,898 filed Feb. 27, 2017, No. 62/463,901 filed Feb. 27, 2017, No. 62/485,042 filed Apr. 13, 2017, No. 62/546,920, filed Aug. 17, 2017, and No. 62/581,961 filed Nov. 6, 2017; all disclosures of the above are incorporated herein by reference in their entireties.

FIELD OF THE INVENTION

The present disclosure relates generally optical connectors with reversible polarity.

BACKGROUND

The prevalence of the Internet has led to unprecedented growth in communication networks. Consumer demand for service and increased competition has caused network providers to continuously find ways to improve quality of service while reducing cost.

Certain solutions have included deployment of high-density interconnect panels. High-density interconnect panels may be designed to consolidate the increasing volume of interconnections necessary to support the fast-growing networks into a compacted form factor, thereby increasing quality of service and decreasing costs such as floor space and support overhead. However, room for improvement in the area of data centers, specifically as it relates to fiber optic connections, still exists. For example, manufacturers of connectors are always looking to reduce the size of the devices, while increasing ease of deployment, robustness, and modifiability after deployment. In particular, more optical connectors may need to be accommodated in the same footprint previously used for a smaller number of connectors in order to provide backward compatibility with existing data center equipment. For example, one current footprint is known as the small form-factor pluggable footprint (SFP). This footprint currently accommodates two LC-type ferrule optical connections. However, it may be desirable to accommodate four optical connections (two duplex connections of transmit/receive) within the same footprint. Another current footprint is the quad small form-factor pluggable (QSFP) footprint. This footprint currently accommodates four LC-type ferrule optical connections. However, it may be desirable to accommodate eight optical connections of LC-type ferrules (four duplex connections of transmit/receive) within the same footprint.

In communication networks, such as data centers and switching networks, numerous interconnections between mating connectors may be compacted into high-density panels. Panel and connector producers may optimize for such high densities by shrinking the connector size and/or the spacing between adjacent connectors on the panel. While both approaches may be effective to increase the panel

connector density, shrinking the connector size and/or spacing may also increase the support cost and diminish the quality of service.

In a high-density panel configuration, adjacent connectors and cable assemblies may obstruct access to the individual release mechanisms. Such physical obstructions may impede the ability of an operator to minimize the stresses applied to the cables and the connectors. For example, these stresses may be applied when the user reaches into a dense group of connectors and pushes aside surrounding optical fibers and connectors to access an individual connector release mechanism with his/her thumb and forefinger. Overstressing the cables and connectors may produce latent defects, compromise the integrity and/or reliability of the terminations, and potentially cause serious disruptions to network performance.

Accordingly, there is a need for smaller fiber optic connectors that will meet the needs of future developments in smaller SFPs and are reconfigurable for flexible deployment.

SUMMARY OF THE INVENTION

In a first aspect, the present disclosure provides a reversible polarity fiber optic connector including at least first and second optical ferrules and a connector housing at least partially surrounding the first and second optical ferrules. The housing has a first exterior wall positioned above the first and second optical ferrules and a second exterior wall positioned beneath the first and second optical ferrules. A latch coupling is positioned on each of the first and second exterior walls of the housing. A removable latch may engage either the first or second exterior wall latch coupling on the connector housing. Positioning the removable latch on the first exterior wall yields a fiber optic connector with a first polarity and positioning the removable latch on the second exterior wall yields a fiber optic connector with a second, opposite polarity.

In another aspect, the present disclosure provides a reversible polarity fiber optic connector with exchangeable arms for changing connector type. Thus, a common connector body may be formed into different connector types. The connector includes at least first and second optical ferrules and a common connector housing at least partially surrounding the first and second optical ferrules. The housing has a first exterior wall positioned above the first and second optical ferrules and a second exterior wall positioned beneath the first and second optical ferrules. A coupling surface is positioned on each of the first and second exterior walls of the common connector housing. To create a connector, a removable arm engages either the first or second exterior wall coupling surface; the removable arm includes either a latch or a latch recess depending upon the type of optical connector to be formed. Further, positioning the removable arm on the first exterior wall of the connector housing yields a fiber optic connector with a first polarity and positioning the removable arm on the second exterior surface of the housing yields a fiber optic connector with a second, opposite polarity.

In another aspect, the present disclosure provides a reversible polarity fiber optic connector with a push-pull tab. The connector includes at least first and second optical ferrules and has a connector housing at least partially surrounding the first and second optical ferrules. A first exterior wall is positioned above the first and second optical ferrules and a second exterior wall is positioned beneath the first and second optical ferrules. A first aperture is in the first exterior wall of the housing and a second aperture is in the second exterior wall of the housing. A removable push-pull tab includes a protrusion for positioning within either of the first or second apertures in the first and second exterior walls, respectively, of the connector housing. Positioning the removable push-pull tab with its protrusion within the first aperture yields a fiber optic connector with a first polarity and positioning the removable push-pull tab with its protrusion within the second aperture yields a fiber optic connector with a second, opposite polarity.

In yet another aspect, the present disclosure provides a reversible polarity fiber optic connector including at least first and second optical ferrules and a connector housing at least partially surrounding the first and second optical ferrules. A first exterior wall is positioned above the first and second optical ferrules and a second exterior wall is positioned beneath the first and second optical ferrules. A removable push-pull tab is provided. A first push-pull tab retainer is positioned on the first exterior wall and a second push-pull tab retainer is positioned on the second exterior wall. Positioning the removable push-pull tab in the retainer on the first exterior wall of the connector housing yields a fiber optic connector with a first polarity and positioning the removable push-pull tab in the retainer on the second exterior wall of the housing yields a fiber optic connector with a second, opposite polarity.

According to one aspect of the present disclosure, there is provided an optical fiber connector assembly comprising at least one connector, a latch arm for coupling to an adapter, and a remote release tab having a protrusion configured to cooperate with the adapter to depress said latch arm when the remote release tab is pulled relative to the adapter.

In some embodiments, the remote release tab may be coupled to the latch arm. The remote release tab may further comprise a window configured to receive the latch arm. In some embodiments, the remote release tab may be configured such that the protrusion slides along the latch arm when the remote release tab is pulled relative to the adapter. In some embodiments, the remote release tab may further be configured such that the protrusion interacts with an inner portion of the adapter to receive a downward force needed to depress said latch arm. In some embodiments, the inner portion of the adapter may be a fixed portion. In some embodiments, the protrusion may have a wedge shape. In various embodiments, the remote release tab may be configured such that the protrusion pushes down the latch arm substantially simultaneously as sliding along an inner portion of the adapter.

In some embodiments, the optical fiber connector assembly may further comprise a boot, and the remote release tab may be configured to extend over the boot.

In some embodiments, the optical fiber connector assembly may comprise a guide configured to receive the remote release tab. In various embodiments, the guide may be further configured to rotate to allow reversing a polarity of the optical fiber connector assembly.

Some embodiments of the optical fiber connector assembly may comprise a housing configured to receive the at least one connector. Some embodiments of the connector assembly may further comprise a latch arm assembly including the latch arm. The latch arm assembly may have a first portion configured to couple to the at least one connector and a second portion configured to engage the housing. In some embodiments of the connector assembly, the latch arm may be coupled to the at least one connector. In other embodiments, the at least one connector may include the latch arm as an integral structure.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**A is a perspective view of one embodiment of a reversible polarity fiber optic connector according to some aspects of the present disclosure;

FIG. **1**B is a side view of the reversible polarity fiber optic connector of FIG. **3**A with the removable latch being removed from the connector housing;

FIG. **2**A is a perspective view of the reversible polarity fiber optic connector of FIG. **1**A;

FIG. **2**B is an exploded view of a step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. **2**A;

FIG. **2**C is an exploded view of a next step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. **2**A;

FIG. **2**D is a perspective view of the fiber optic connector of FIG. **1**A with its polarity reversed;

FIG. **3**A is a perspective view of an embodiment of a reversible polarity fiber optic connector with a pull tab according to aspects of the present disclosure;

FIG. **3**B is an exploded view of the reversible polarity fiber optic connector of FIG. **3**A;

FIG. **4**A is a perspective view of the polarity of the reversible polarity fiber optic connector of FIG. **3**A;

FIG. **4**B is an exploded view of a step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. **4**A;

FIG. **4**C.**1** is an exploded view of positioning the latch in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. **4**A;

FIG. **4**C.**2** is an exploded view of attaching the removed components of FIG. **4**B in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. **4**A;

FIG. **4**D is a perspective view of the reversible polarity fiber optic connector of FIG. **4**A with its polarity reversed;

FIG. **5**A is a perspective view of another embodiment of a reversible polarity fiber optic connector with a pull tab according to aspects of the present disclosure;

FIG. **5**B is an exploded view of the reversible polarity fiber optic connector of FIG. **5**A;

FIG. **6**A is a perspective view of the polarity of the fiber optic connector of FIG. **5**A;

FIG. **6**B is an exploded view of a step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. **5**A;

FIG. **6**C is an exploded view of a next step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. **6**A;

FIG. **6**D is a perspective view of the reversible polarity fiber optic connector of FIG. **6**A with its polarity reversed;

FIG. **7**A is a perspective view of a common connector housing of a reversible polarity fiber optic connector with exchangeable arms for changing connector type in an embodiment according to aspects of the present disclosure;

FIG. **7**B is the front view of the common connector housing of FIG. **7**A;

FIG. **7**C is the top view of the common connector housing of FIG. **7**A;

FIG. **7**D is the side view of the common connector housing of FIG. **7**A;

FIG. **8**A.**1** shows how the common connector housing of FIG. **7**A is used to create a latch-type connector;

FIG. **8**A.**2** is an exploded view of FIG. **8**A.**1**;

FIG. **8**B.**1** shows how the common connector housing of FIG. **7**A is used to create a recess-type connector;

FIG. **8**B.**2** is an exploded view of FIG. **8**B.**1**;

FIG. **9**A is a perspective view of FIG. **8**A.**1** of the polarity of the latch-type fiber optic connector of FIG. **8**A.**1**;

FIG. **9**B is an exploded view of a step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. **8**A.**1**;

FIG. **9**C is an exploded view of a next step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. **8**A.**1**;

FIG. **9**D is a perspective view of the reversible polarity fiber optic connector of FIG. **8**A.**1** with its polarity reversed;

FIG. **10**A is a perspective view of FIG. **8**B.**1** of the polarity of the recess-type fiber optic connector of FIG. **8**B.**1**;

FIG. **10**B is an exploded view of a step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. **8**B.**1**;

FIG. **10**C is an exploded view of a next step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. **8**B.**1**;

FIG. **10**D is a perspective view of the reversible polarity fiber optic connector of FIG. **8**B.**1** with its polarity reversed;

FIGS. **11**A and **11**B respectively depict exploded and perspective views of a reversible polarity optical connector according to a further embodiment of the disclosure;

FIGS. **12**A-**12**D depict the operation of the reversible polarity optical connector of FIGS. **11**A and **11**B;

FIGS. **13**A-**13**D depict the process for changing the polarity of the optical connector of FIGS. **11**A and **11**B;

FIGS. **14**A and **14**B respectively depict exploded and perspective views of a reversible polarity optical connector according to a further embodiment of the disclosure;

FIGS. **15**A-**15**D depict the operation of the reversible polarity optical connector of FIGS. **14**A and **14**B;

FIGS. **16**A-**16**D depict the process for changing the polarity of the optical connector of FIGS. **14**A and **14**B;

FIGS. **17**A-**17**C respectively depict perspective, partial cross-section, and exploded views of a reversible polarity optical connector according to a further embodiment of the disclosure;

FIGS. **18**A-**18**D depict the assembly of the push-pull tab to the connector body of the connector of FIGS. **17**A-**17**C;

FIGS. **19**A-**19**B depict the removal of the push-pull tab from the connector body using a tool;

FIGS. **20**A-**20**D depict the process for changing the polarity of the optical connector of FIGS. **17**A-**17**C;

FIGS. **21**A-**21**D depict the process of changing polarity of an optical connector according to an embodiment of the invention;

FIGS. **22**A-**22**E depict the process for changing the polarity of an optical connector according to an embodiment of the invention;

FIG. **23** is a perspective view of a partially disassembled optical fiber connector assembly having a remote release tab according to aspects of the present disclosure;

FIG. **24** is a perspective view of the optical fiber connector assembly of FIG. **23** according to aspects of the present disclosure;

FIG. **25** is a perspective view of the optical fiber connector assembly of FIG. **23** coupled to an adapter according to aspects of the present disclosure;

FIG. **26** is a top view of the optical fiber connector assembly and adapter of FIG. **25** according to aspects of the present disclosure;

FIG. **27** is a cross-sectional view of the optical fiber connector assembly and adapter of FIG. **26** along section A-A, showing the remote release tab in a forward position according to aspects of the present disclosure; and

FIG. **28** is a cross-sectional view of the optical fiber connector assembly and adapter of FIG. **26** along section A-A, showing the remote release tab in a rearward position according to aspects of the present disclosure.

DETAILED DESCRIPTION

This disclosure is not limited to the particular systems, devices and methods described, as these may vary. The terminology used in the description is for the purpose of describing the particular versions or embodiments only, and is not intended to limit the scope.

As used in this document, the singular forms "a," "an," and "the" include plural references unless the context clearly dictates otherwise. Unless defined otherwise, all technical and scientific terms used herein have the same meanings as commonly understood by one of ordinary skill in the art. Nothing in this disclosure is to be construed as an admission that the embodiments described in this disclosure are not entitled to antedate such disclosure by virtue of prior invention. As used in this document, the term "comprising" means "including, but not limited to."

The following terms shall have, for the purposes of this application, the respective meanings set forth below.

The connectors of the present disclosure may be configured for fiber optic transmission or electrical signal transmission. The connector may be any suitable type now known or later developed, such as, for example, a ferrule connector (FC), a fiber distributed data interface (FDDI) connector, an LC connector, a mechanical transfer (MT) connector, a square connector (SC) connector, an SC duplex connector, or a straight tip (ST) connector. The connector may generally be defined by a connector housing. In some embodiments, the housing may incorporate any or all of the components described herein.

Various embodiments described herein generally provide a remote release mechanism such that a user can remove cable assembly connectors that are closely spaced together without damaging surrounding connectors, accidentally disconnecting surrounding connectors, disrupting transmissions through surrounding connectors, and/or the like. Various embodiments also provide narrow pitch LC duplex connectors and narrow width multi-fiber connectors.

As discussed herein, current connectors may be improved by various means, such as, for example, reducing the footprint, increasing the structural strength, enabling polarity changes, etc. Various embodiments disclosed herein offer improvements over the current state of the art, as will be further discussed below.

In some embodiments, the fiber optic connector may be a narrow pitch duplex LC connector including two LC connectors. In some embodiments, such as that shown, the two LC connectors may comprise a single combined unit. In alternative embodiments, the LC connectors may be separate members, wherein an air gap exists between the two members, or wherein the two separate members are located adjacent and flush to each other (i.e., no air gap exists). In some embodiments, each of the LC connectors includes a respective ferrule and a respective extending member or modular arm. The connector may have a pitch of 4.8 mm, defined as the axis-to-axis distance between the central axes of the LC connectors. In other embodiments, the connector pitch may be less than that of the pitch of conventional connectors, for example less than 6.25 mm and less than about 5.25 mm. In some embodiments, the pitch may be about 4.8 mm or less.

In current designs, if a fiber optic connector, particularly a duplex connector, needs to have the ferrules rotated or swapped, for example, for exchanging transmit and receive optical fibers, it can be a time consuming and difficult process. Generally, if a duplex connector needs to be rotated, current systems require twisting the individual LC connector tips 180 degrees. However, this process also twists the fibers that enter the connector tip. Twisting the fiber at any stage of the connection can cause wear and/or damage to the delicate fibers. Thus, most systems involve an alternative solution, wherein the duplex connector is partially or completely disassembled in order to access the ferrules or fibers and manually relocate them within the duplex connector. However, swapping ferrules side to side is a delicate operation. In order to prevent damage to the internal fibers, great care must be taken. Thus, this operation usually requires specialized tools and preparation time to perform safely and accurately.

Therefore, embodiments as described herein, allow for easy, quick, and safe swapping of the left and right side ferrules in a connector. Thus, embodiments discussed herein allow for a change in polarity of the duplex connector without twisting the fibers or performing any complex disassembly of the duplex connector.

FIGS. **1**A and **1**B depict a fiber optic connector with reversible polarity according to one aspect of the present disclosure. As shown in FIG. **1**A, a reversible polarity fiber optic connector may include first and second optical ferrules **110***a* and **110***b* and a connector housing **120** at least partially surrounding the first and second optical ferrules. A removable latch **130** is depicted in FIG. **1**A in its assembled state and in FIG. **1**B removed from the connector housing **120**.

FIG. **1**B is a side view of the reversible polarity fiber optic connector of FIG. **1**A with the removable latch **130** being separated from the connector housing. As shown, the connector housing **120** may have a first exterior wall **121***a* positioned above the first and second optical ferrules and a second exterior wall **121***b* positioned beneath the first and second optical ferrules. A latch coupling **122** is positioned on each of the first and second exterior walls of the housing. The removable latch **130** may include a protrusion **131** for engaging the housing latch coupling **122**. In particular, the latch coupling **122** may include angled walls that interact with slanted edges of the protrusion **131** to prevent accidental disassembly of the latch **130**. Although the latch coupling **122** is depicted as a recess on the housing accommodating a latch protrusion, these elements may be reversed with the latch including a recess and the housing including a protrusion. Other mechanical coupling mechanisms may be used to interconnect the housing and the removable latch. For example, an embodiment may involve a coupling system wherein the removable latch is inserted into a recess in the connector housing and twisted (e.g., 90°, 180°, etc.) to secure the latch to the recess. Alternative coupling may use a more complex shape. For example, a u-shaped recess in the connector housing may engage a cooperatively-shaped projection in the latch that is inserted and fed through the u-shape until secure. It should thus be understood, that any system or method of coupling may be used to attach the removable latch to the connector housing, including various locations (e.g., sliding from the front, sides, back, bottom, top, etc.).

FIGS. **2**A-**2**D depict the process for changing the polarity of the fiber optic connector of FIG. **1**A from a first polarity, FIG. **2**A to a second, opposite polarity, FIG. **2**D. The removable latch **130** may be removed from the latch coupling on the first exterior wall of the connector housing, FIG. **2**B, positioned adjacent the second exterior wall on beneath the ferrules, FIG. **2**C, and then coupled with the latch coupling on the second exterior wall of the connector housing to yield a connector **100**R, FIG. **2**D, having the opposite polarity of connector **100**. In this manner, transmit and receive optical fibers may be reversed without necessitating any fiber twist or complex repositioning of the optical ferrules.

In typical embodiments, the latch of the connector housing is required to be flexible. Thus, when a latch and a connector housing (e.g., duplex connector) are built as one unified member (as is currently done), the fiber optic connector is built of a similar flexible or less rigid material. Building the connector housing out of a plastic or polymeric material, limits the amount of rigidity that it can have. Thus, as fiber optic connectors continue to reduce in size, the strength of the housing has been reduced. Therefore, it would be advantageous to build the connector housing out of a more robust material while still allowing the latch to remain flexible. In order to accomplish this, in some embodiments according to aspects of the present disclosure, the connector housing may be manufactured out of a very rigid or strong material (e.g., steel, graphene, carbon, metal alloys, or any material of suitable properties). Because the connector housing and the removable latch need only interlock with each other, the removable latch may still be made out of a more flexible material. Thus, the removable nature of the latch disclosed herein allow for a more robust and secure overall design when dealing with the shrinking footprint of fiber optic connectors.

FIG. **3**A is a perspective view of another embodiment of a reversible polarity fiber optic connector **300**. As shown, the reversible polarity fiber optic connector may further comprise a pull tab **340** for engaging a removable latch **330**. The pull tab **340** depresses the latch **330** as the tab is pulled in a direction away from the fiber optic ferrules.

FIG. **3**B is an exploded view of the reversible polarity fiber optic connector of FIG. **3**A. As shown, the pull tab **340** may comprise a first opening **341** and a second opening **344**. The first opening **341** is configured to allow the connector housing and the removable latch to pass through while the second opening is configured to accommodate the tip of the latch. The pull tab may further comprise a first deformable portion **342** and a second deformable portion **344**. In operation, the first deformable portion **342** cooperates with the second deformable portion **344** to depress the removable latch when the pull tab is pulled in a direction away from the ferrules.

FIGS. **4**A-**4**D depict the process for changing the polarity of the fiber optic connector **300** from a first polarity, FIG. **4**A to a second polarity **300**R, FIG. **4**D. The pull tab **340** may be disengaged from the connector housing **320** and the removable latch **330** on the first exterior wall of the connector housing, FIG. **2**B. The removable latch is then detached from the latch coupling on the first exterior wall of the connector housing, FIG. **4**C.**1**. Next, the removable latch is engaged with the latch coupling on the second exterior wall of the connector housing, beneath the ferrules, FIG. **4**C.**2**. Finally, the pull tab **340** is positioned surrounding the connector housing and engaging the removable latch tip, resulting in the assembled optical connector **300**R having polarity opposite to that of connector **300**, FIG. **4**D.

FIGS. **5**A and **5**B are a perspective view and exploded view, respectively, of another embodiment of a reversible polarity fiber optic connector **500**. The connector **500** includes a connector housing **520**, a latch **530**, and a pull tab **540**. On the first and second exterior walls of connector housing **520** are latch couplings that include a groove **522**. A recess **521** is also provided in the housing. The latch **530** includes a protrusion **531** that is received within groove **522**. The latch further includes a projection **532** that is received in the housing between the optical ferrules. The pull tab **540** includes an opening **541** for engaging the removable latch **530**. A front protrusion **542** is configured to depress the removable latch **530** when the pull tab is pulled in a direction away from the ferrule side of the optical connector.

FIGS. **6**A-**6**D depict the process for changing the polarity of the fiber optic connector **500** from a first polarity, FIG. **6**A to a second polarity, FIG. **6**D. The pull tab **540** is disengaged from the connector housing and the removable latch **530** on the first exterior wall of the connector housing, FIG. **6**B, and the removable latch is decoupled from the latch coupling on the first exterior wall of the connector housing. Then the removable latch may be coupled with the latch coupling on the second exterior wall of the connector housing, beneath the optical ferrules in FIG. **6**C, and the pull tab **540** is engaged with the connector housing and the removable latch on the second exterior wall of the connector housing to create reverse polarity connector **500**R, FIG. **6**D.

It is of interest within the optical connectivity industry to have multiple styles of optical connectors for multiple purposes and/or multiple implementation styles. Thus, in order to more easily provide flexibility, a solution is needed that allows for on-the-fly, in-the-field, or in manufacturing modification of the connector. The below embodiment provides a universal type fiber optic connector which has a unique housing design that allows for different latches or arms to be attached.

FIG. **7**A is a perspective view of a common connector housing **720** of a reversible polarity fiber optic connector **700** with exchangeable arms for changing connector type in an embodiment according to aspects of the present disclosure. As shown, the reversible polarity fiber optic connector may comprise first and second optical ferrules **710***a* and **710***b* and the common connector housing **720** at least partially surrounding the first and second optical ferrules.

FIGS. **7**B, **7**C and **7**D are the front view, top view and side view, respectively, of the common connector housing **720**. As shown, the common connector housing may have a first exterior wall **725***a* positioned above the first and second optical ferrules and a second exterior wall **725***b* positioned beneath the first and second optical ferrules. The connector housing **720** may further have a coupling surface **724** positioned on each of the first and second exterior walls and include a receiving track **726** in the coupling surface.

FIG. **8**A.**1** shows the common connector housing **720** used to create a latch-type connector **700** and FIG. **8**B.**1** shows the common connector housing **720** used to create a recess-type connector **800**. Both of connectors **700** and **800** include a removable arm **730** or **830** for engaging either of the first and second exterior wall coupling surfaces **724** on the connector housing, FIGS. **8**A.**2** and **8**B.**2** respectively. The removable arms **730** and **830** may each respectively include a projection **735** or **835** for engaging in the receiving track **726** of the coupling surface **724**, FIGS. **8**A.**2** and **8**B.**2** respectively. As with the previous embodiments, positioning the removable arm on the first exterior wall of the connector housing yields a fiber optic connector with a first polarity and positioning the removable arm on the second exterior surface of the housing yields a fiber optic connector with the opposite polarity.

Still referring to FIGS. **8**A.**2** and **8**B.**2** respectively the removable arms may include either a latch or a recess: removable arm **730** includes a latch **733** while removable arm **830** includes a recess **834**. Thus, a latch-type connector **700** is created through assembly of the removable latch arm to the common connector body **720** as shown in FIG. **8**A.**1** and a recess-type connector **800** is created through assembly of the removable recess arm to the common connector body **720** as shown in FIG. **8**B.**1**.

The fiber optic connector may further include a pull tab. When a removable arm with a latch **730** is positioned on the coupling surface of the common connector housing **720** to create a latch-type connector **700**, the pull tab **740** is a separate element from the removable arm, FIG. **8**A.**2**. When a removable arm includes a recess **830** is positioned on the coupling surface of the common connector housing **720** to create a recess-type connector **800**, the pull tab **840** is integrated with the removable arm, FIG. **8**B.**2**.

FIGS. **9**A-**9**D depict the process for changing the polarity of the latch-type fiber optic connector from a first polarity **700**, FIG. **9**A to a second polarity **700**R, FIG. **9**D. The sub-assembly of the removable arm **730** and the pull tab **740** may be decoupled from the coupling surface **724** of the first exterior wall of the connector housing, FIG. **9**B. Then the sub-assembly of the removable arm **730** and the pull tab **740** may be coupled with the coupling surface of the second exterior wall of the connector housing, FIG. **9**C, creating the opposite polarity connector **700**R.

FIGS. **10**A-**10**C depicts the process for changing the polarity of the recess-type fiber optic connector **800** from a first polarity, FIG. **10**A to a second polarity, FIG. **10**D. The removable arm **830** with a recess and a pull tab as an integral structure may be decoupled from the coupling surface **724** of the first exterior wall of the connector housing, FIG. **10**B. Then the removable arm may be coupled with the coupling surface **724** of the second exterior wall of the common connector housing **720**, FIG. **10**C to create opposite polarity optical connector **800**R, FIG. **10**D.

FIGS. **11**A and **11**B depict a further embodiment **1100** of the reversible polarity optical connectors of the present disclosure. In FIG. **11**A, a push-pull tab **1130** may interconnect with either a first exterior wall **1110** of housing **1105** or with a second exterior wall **1115** of housing **1105**. Ferrules **1120** and **1125** are at least partially surrounded by housing **1105** and may be LC connectors in an embodiment. As in previous embodiments, the push-pull tab may include a tab recess **1145**. Alternatively, push-pull tab **1130** may include a latch (not shown). Various features of the push-pull tab **1130** are provided to assist in affixing the push-pull tab to the first exterior wall **1110** or the second exterior wall **1115** of the housing **1105**. This includes push-pull tab clips **1135** that clip onto the optical connector, optionally in a boot region, and protrusion **1140** that fits within a first aperture, **1109**A, beneath the housing exterior wall **1110** or a second aperture, **1109**B, beneath housing exterior wall **1115** (to be discussed in more detail below), and projection **1131** for inserting into the housing between ferrules **1120** and **1125**. Each of these features is fully reversible such that the push-pull tab is easily removed and repositioned on the opposite exterior wall to change polarity of the connector.

As best seen in FIGS. **12**B and **12**D, push-pull tab protrusion **1140** may be inserted into first aperture **1109**A of housing **1105** through a first exterior housing aperture **1107**A. Alternatively, in the reverse-polarity configuration, the push-pull tab protrusion **1140** may be inserted into second housing aperture **1109**B through second exterior housing aperture **1107**B. When the push-pull tab **1130** is moved forward, the protrusion slides within the aperture **1109**A or **1109**B, as shown in FIG. **12**B. To maintain the push-pull tab in a forward-biased position, tab position spring **1150** is provided. During insertion or removal of the protrusion **1140**, tab position spring **1150** is compressed, depicted in FIG. **12**B. When the position spring **1150** is in its relaxed (uncompressed) position, FIGS. **12**C and **12**D, the protrusion **1140** is slid forward within the aperture **1109**A or **1109**B.

To change polarity of the optical connector **1100**, FIGS. **13**A-**13**D, the push-pull tab **1130** is removed by withdrawing the protrusion **1140** from the housing **1105** through exterior housing aperture **1107**A along with detaching clips **1135** and decoupling projection **1131**, thus releasing the push-pull tab from the first exterior housing wall **1110** (FIG. **13**B). The push-pull tab is moved toward second exterior housing wall **1115** and the protrusion **1140** is inserted into aperture **1109**B through exterior housing aperture **1107**B in FIG. **13**C. Projection **1131** is fitted between ferrules **1120** and **1125** and clips **1135** are affixed to the connector. The resultant connector **1100**R of **13**D is of opposite polarity to the connector **1100** of FIG. **13**A.

Various alternatives to the protrusion **1140** of optical connector **1100** may be used in the optical connectors of this disclosure. For example, the protrusion may be provided by the connector housing with receiving elements provided in the push-pull tab. Variations to the shape of the projection and apertures may be made without affecting the function of the reversible-polarity connector.

Another alternative embodiment is depicted in FIGS. **14**A and **14**B in which a hook-shaped protrusion **1440** is provided for engagement within the connector housing. As in the previous embodiment, the push-pull tab **1430** includes a tab recess **1445**, connector-attachment clips **1435** and projection **1431** for positioning between ferrules **1420** and **1425**. In FIG. **14**B, the push-pull tab **1430** is positioned on first exterior housing wall **1410** and has a first polarity. In this position, the hook-shaped protrusion **1440** engages a housing projection **1460**, held in a forward-biased position by push-pull tab position spring **1465**, as seen in FIGS. **15**B and **15**D. To release the protrusion **1440**, push-pull tab position spring **1465** is compressed in FIG. **15**C such that housing projection **1460** is retracted sufficiently to allow removal of protrusion **1440** through the housing **1405**, FIG. **15**D.

To change polarity of the optical connector **1400** from the first polarity of FIG. **16**A, the push-pull tab **1430** is removed by withdrawing the protrusion **1440** from the housing **1405** through the housing along with detaching clips **1435** and decoupling projection **1431**, thus releasing the push-pull tab from the first exterior housing wall **1110** (FIG. **16**B). The push-pull tab is moved toward second exterior housing wall **1415** and the protrusion **1440** is inserted into the housing **1405**. Projection **1431** is fitted between ferrules **1420** and **1425** and clips **1435** are affixed to the connector in FIG. **16**C. The resultant connector **1400**R of FIG. **16**D is of opposite polarity to the connector of FIG. **16**A.

Protrusions from a push-pull tab may be inserted into a housing via features other than a housing aperture. Such a connector is depicted in FIG. **17** and features a deformable housing region to allow entry of a push-pull tab protrusion during affixing of the push-pull tab to the connector housing. As seen in FIG. **17**A, the connector **1700** includes a connector housing **1705** which may optionally include a back body housing portion **1709** for connecting with a housing front portion **1707** (FIG. **17**C). The back body housing portion **1709** includes a deformable region **1780**, seen in the partial cross-section of FIG. **17**B and the perspective view of FIG. **17**C. The push-pull tab **1730** includes a protrusion **1740** with a projection **1741** extending therefrom.

Turning to FIG. **18**, to affix the push-pull tab to the connector housing, the protrusion **1740** penetrates the deformable region **1780** (FIG. **18**B) causing the deformable region to yield and accept entry of the protrusion **1740** into the housing. As the projection **1741** enters the housing as depicted in FIG. **18**C, the deformable region **1780** returns to its original position (FIG. **18**D), securing the push-pull tab **1730** to the connector housing.

Removal of the push-pull tab **1730** is depicted in FIGS. **19**A and **19**B. A removal tool **1900**, which may be shaped similar to a small screwdriver, depresses deformable region **1780**, allowing projection **1741** to slide along an edge of the deformable region **1780**, followed by the protrusion **1740**, releasing the push-pull tab **1730**.

To change polarity of the optical connector **1700** from the first polarity of FIG. **20**A, the push-pull tab **1730** is removed in FIG. **20**B by using the removal tool technique depicted in FIGS. **19**A and **19**B. The push-pull tab is moved toward the second exterior housing wall and the protrusion **1740** is inserted into the housing **1705** through the deformable region **1780** in FIG. **20**C. The resultant connector **1700**R of FIG. **20**D is of opposite polarity to the connector of FIG. **20**A.

In another aspect of the disclosure, a retaining member may be provided in the connector housing to retain a push-pull tab. As seen in FIGS. **21**A-**21**D, a connector **2100** having a housing **2105** is provided with a housing front portion **2107** and a back portion **2109**. FIG. **21**A depicts an assembled connector **2100** with housing **2105**. FIG. **21**B depicts an exploded view of connector **2100** of FIG. **21**A. Push-pull tab **2130** has a receiving surface **2132**, which during use of connector **2100** provides a surface over which retainer **2111** can slide across during tab movement. Extending from the housing back portion is a retainer **2111** which may include a pair of retaining clips, as shown, or any other structure configured to retain the push-pull tab **2130**. FIG. **21**C depicts connector **2100** showing a section view cut given by the arrows and broken line near the proximal end of connector **2100**. Optionally, when the retainer **2111** includes clips, the clips may be hook-shaped as seen in the cross-sectional view of FIG. **21**D. As shown in FIG. **21**D, receiving surface **2132** may be a recess with a protrusion along the edge that engages the hook-shaped edge of the clips.

FIG. **22**A through FIG. **22**E depicts the operation of polarity change for connector **2100** of FIG. **21**A-FIG. **21**D. FIG. **22**A depicts connector **2100** with pull-push tab clips **2135** (opposing side not shown) engaged around connector. To operate connector **2100**, user can move push-pull tab **2130** forward or toward front of connector or backward or toward rear of connector, and as describe in FIG. **21** above tab moves along connector receiving surface **2123**. This engages or releases connector **2100** from a receptacle as is known in the art. To change the polarity of connector **2100** from the polarity depicted in FIG. **22**A to the second, opposite polarity of FIG. **22**E, the retainer **2111** is removed from receiving surface **2132**. Referring to FIG. **21**B, lifting push-pull tab **2130** in direction of up-arrow, separates retainer **2111** from receiving surface. As shown in FIG. **22**C, push-pull tab clips separate from the connector as the retainer is removed. Continuing with FIG. **22**C, push-pull tab **2130** is moved to the opposite housing exterior wall in FIG. **22**C. FIG. **22**D depicts receiving surface **2132** engages with the retainer **2111**. In FIG. **21**E the assembled connector

2100R having the opposite polarity to the connector of FIG. **22**A is depicted, fully assembled. Retainer **2111** is in contact with receiving surface **2132**, and push-pull tab **2130** is secured to connector body, as shown in FIG. **22**E.

FIGS. **23-28**

The following terms shall have, for the purposes of this application, the respective meanings set forth below.

A connector, as used herein, refers to a device and/or components thereof that connects a first module or cable to a second module or cable. The connector may be configured for fiber optic transmission or electrical signal transmission. The connector may be any suitable type now known or later developed, for example, embodiments of multiple-fiber push-on/pull-off (MPO) connectors, such as the Senko mini MPO connector and the Senko MPO Plus connector. The connector may generally be defined by a connector housing body.

A “fiber optic cable” or an “optical cable” refers to a cable containing one or more optical fibers for conducting optical signals in beams of light. The optical fibers can be constructed from any suitable transparent material, including glass, fiberglass, and plastic. The cable can include a jacket or sheathing material surrounding the optical fibers. In addition, the cable can be connected to a connector on one end or on both ends of the cable.

Various embodiments provide single fiber and multi-fiber connectors having a remote release tab, also referred to as a pull tab or a push pull tab. Some embodiments may be configured to allow polarity changes.

The pull tab of a typical connector may interact solely with the profile of the connector latch arm to flex the latch arm downward the distance needed to allow the connector to become unlatched from within the adapter/coupler for removal. Alternatively, the pull tab of a connector may work to solely lift an adapter hook a required distance to allow the connector to become unlatched for removal.

Various embodiments of connectors disclosed herein include an outer main body with a unique un-latching system. Various embodiments described herein generally provide optical fiber connectors with remote release tabs configured to allow a user to easily remove or insert connectors into adapters or couplers, such as adapters disposed on a high density panel without damaging surrounding connectors, accidentally disconnecting surrounding connectors, disrupting transmissions through surrounding connectors, and/or the like.

Various embodiments of connectors disclosed herein include a remote release tab having a tip configured to interact with an inner portion of the top surface of an adapter or coupler to provide some of the downward force needed to unlatch the connector from the adapter or coupler. In some embodiments, the inner portion of the top surface of the adapter or coupler may be a fixed portion that does not move.

In some embodiments, the tip of the remote release tab may be a wedge shaped tip. The connector may have a latch arm and may be configured such that as the remote release tab is pulled back, the tip of the remote release tab slides upwards along the slope of the latch arm of the connector. At a certain distance of retraction of the remote release tab, the wedge shape comes in contact with an inner portion of the top surface of the adapter. Upon additional retraction of the remote release tab, the wedge shaped tip simultaneously begins to push down the connector latch arm while sliding along the inner portion of the top surface of the adapter. As the connector latch arm is depressed to a sufficient distance, it becomes unlatched from the adapter, and any additional pulling of the remote release tab results in removing the connector from the adapter.

Some embodiments, such as embodiments having multiple ferrules and embodiments having multiple fiber ferrule connectors, are further configured to allow reversing the polarity. For example, in some embodiments, a guide of the remote release tab may be configured to rotate about 180 degrees in order to reverse polarity.

FIG. **23** shows one embodiment of an optical fiber connector assembly **3100** having a plurality of connectors **3102** and a remote release tab **3104**. In this embodiment, the connector assembly **3100** has a plurality of connectors. In other embodiments, the connector assembly may have one or more connectors. Various embodiments may include connectors of different types than shown in FIG. **23**. Each connector **3102** has a respective connector housing **3106** and a respective ferrule **3108**.

The connector assembly **3100** further includes at least one flexible latch arm assembly **3110**. The latch arm assembly **3110** includes at least one flexible latch arm **3111**. The latch arm assembly **3110** is configured to couple to the connectors **3102**. In other embodiments, each of the connectors **3102** may include a respective latch arm. In some embodiments, the latch arm may be formed integrally with one or more connectors in the connector assembly.

The connector assembly **3100** further includes a housing **3112** configured to receive the connectors **3102**. The latch arm assembly **3110** includes a first portion **3114** configured to couple with the connectors **3102**, for example by coupling to the connector housings **3106**. The latch arm assembly **3110** also includes a second portion **3116** configured to be received by the housing **3112**. In other embodiments, the latch arm assembly **3110** may be configured differently than shown in FIG. **23** to allow coupling to the connector assembly **3100**.

The connector assembly **3100** further includes a guide **3118** configured to retain the remote release tab **3104**. The guide **3118** is further configured to be rotated about 180 degrees, as shown for example by the arrow **3120**, to reverse the polarity of the connector assembly **3100**. In one example, the guide **3118** may be coupled to at least one polarity key, and rotation of the guide allows changing the polarity key. In another example, the polarity key may rotate with the guide. In other embodiments, the connector assembly need not be configured to reverse the polarity, and the guide may merely be configured to receive the remote release tab. The connector assembly **3100** further includes a back post **3122** and a boot **3124**.

The remote release tab **3104** has a body **3126**. The body **3126** may extend over the boot **3124** to facilitate remotely releasing the connector assembly from an adapter. In various embodiments, the length of the remote release tab **3104** may be selected so as to extend beyond the boot **3124** of the connector assembly **3100**. For example, the length may be selected such that the handle of the remote release tab is located beyond the boot of the connector for easy access.

The body **3126** includes a coupling portion **3128** configured to couple to the connectors **3120**. For example, as shown in FIG. **23**, the coupling portion **3128** includes a window **3130** configured to receive at least a portion of the latch arm assembly **3110**. For example, the window **3130** may be configured to receive the flexible latch arm **3111** of the connectors **3102**.

The remote release tab **3104** further includes a protrusion **3132** at one end thereof. The protrusion **3132** is shaped as a wedge. In other embodiments, the protrusion **3132** may have different shapes and configurations. In various embodiments, the protrusion **3132** may be configured to slide along the latch arm **3111** of the latch arm assembly **3110** and further to interact with an adapter coupled to the connector assembly **3100**, as the remote release tab **3104** is pulled rearward, to decouple the connector assembly from the adapter, as described and illustrated further below in relation to FIGS. **27** and **28**.

In some embodiments, the remote release tab **3104** may be removable from the optical connector assembly **3100**. The remote release tab **3104** may also be re-installed by coupling to the connector assembly **3100**. For example, the guide **3118** may be configured to retain the remote release tab **3104**. The guide **3118** may further be configured to allow removing the remote release tab **3104** from the connector assembly **3100**.

In various embodiments, the remote release tab **3104** may have a single integral structure. In other embodiments, the remote release tab **3104** may comprise a plurality of pieces coupled together to form the remote release tab. For example, in some embodiments, the coupling portion **3128** and the protrusion **3132** may be formed integrally with the body **3126**. In other embodiments, the coupling portion **3128** or the protrusion **3132** may be separate pieces coupled to each other to form the remote release tab **3104**.

FIG. **24** shows a perspective view of the assembled connector assembly **3100**. As shown in FIG. **24**, the latch arm **3111** protrudes through the window **3130** of the remote release tab **3104**. The remote release tab **3104** is retained by the guide **3118** such that the protrusion **3132** is disposed at a front end of the connector assembly **3100** and may slide along the latch arm **3111** as the remote release tab **3104** is pulled rearward.

FIG. **25** shows the connector assembly **3100** coupled to an adapter **3140**. The adapter may have a plurality of channels **3142** configured to receive connectors, including for example the connector assembly **3100**. The adapter **3140** further comprises a plurality of openings **3144** configured to couple the connector assembly to the adapter. For example, the openings **3144** are configured to engage the latch arm **3111** of the connector assembly **3100** so as to retain the connector assembly **3100** within the adapter **3140**. As the remote release tab **3104** is pulled rearward, the protrusion **3132** of the remote release tab interacts with both the latch arm **3111** and the adapter **3140** to release the latch arm from an opening **3144**, thereby decoupling the connector assembly **3100** from the adapter. In one embodiment, the protrusion **3132** interacts with an inner portion of a top surface **3146** of the adapter **3140**.

FIG. **26** shows a top view of the adapter **3140** and the connector assembly **3100** of FIG. **25**. The latch arm assembly **3110** and the connectors **3102** are received through the channels **3142** of the adapter **3140**.

FIGS. **27** and **28** show a cross-sectional view of the adapter **3140** and the connector assembly **3100** of FIG. **26** along section A-A. FIG. **27** further illustrates the remote release tab **3104** in a forward position, as the connector assembly **3100** is pushed into the adapter **3140** in the direction of the arrow **3150**. As shown, the connector assembly **3100** is coupled to the adapter **3140** by the latch arm **3111** which engages the opening **3144** of the adapter **3140**. The opening **3144** is disposed in the top surface **3146** of the adapter **3140**. The protrusion **3132** of the remote release tab **3104** is disposed at a front end of the latch arm **3111**. The protrusion **3132** does not yet contact an inner portion **3152** of the top surface **3146**.

FIG. **28** further illustrates the remote release tab **3104** in a rearward position as it is being pulled in the direction of the arrow **3154** so as to pull the connector assembly **3100** out of the adapter **3140**. The protrusion **3132** of the remote release tab **3104** slides along the latch arm **3111** and contacts an inner portion **3152** of the top surface **3146** of the adapter **3140**. The protrusion **3132** continues to slide along the inner portion **3152** of the top surface **3146** as the remote release tab **3104** is pulled further. The protrusion **3132** simultaneously begins to push down the connector latch arm **3111** while sliding rearward along the inner portion **3152** of the top surface **3146** of the adapter **3140**. As the connector latch arm **3111** is depressed by the protrusion **3132**, the connector assembly **3100** becomes unlatched from the adapter **3140**, and any additional pulling of the remote release tab **3104** results in removing the connectors from the adapter.

In the above detailed description, reference is made to the accompanying drawings, which form a part hereof. In the drawings, similar symbols typically identify similar components, unless context dictates otherwise. The illustrative embodiments described in the detailed description, drawings, and claims are not meant to be limiting. Other embodiments may be used, and other changes may be made, without departing from the spirit or scope of the subject matter presented herein. It will be readily understood that the aspects of the present disclosure, as generally described herein, and illustrated in the Figures, can be arranged, substituted, combined, separated, and designed in a wide variety of different configurations, all of which are explicitly contemplated herein.

The present disclosure is not to be limited in terms of the particular embodiments described in this application, which are intended as illustrations of various aspects. Many modifications and variations can be made without departing from its spirit and scope, as will be apparent to those skilled in the art. Functionally equivalent methods and apparatuses within the scope of the disclosure, in addition to those enumerated herein, will be apparent to those skilled in the art from the foregoing descriptions. Such modifications and variations are intended to fall within the scope of the appended claims. The present disclosure is to be limited only by the terms of the appended claims, along with the full scope of equivalents to which such claims are entitled. It is to be understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to be limiting.

With respect to the use of substantially any plural and/or singular terms herein, those having skill in the art can translate from the plural to the singular and/or from the singular to the plural as is appropriate to the context and/or application. The various singular/plural permutations may be expressly set forth herein for sake of clarity.

It will be understood by those within the art that, in general, terms used herein, and especially in the appended claims (for example, bodies of the appended claims) are generally intended as "open" terms (for example, the term "including" should be interpreted as "including but not limited to," the term "having" should be interpreted as "having at least," the term "includes" should be interpreted as "includes but is not limited to," et cetera). While various compositions, methods, and devices are described in terms of "comprising" various components or steps (interpreted as meaning "including, but not limited to"), the compositions, methods, and devices can also "consist essentially of" or "consist of" the various components and steps, and such terminology should be interpreted as defining essentially closed-member groups. It will be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present. For example, as an aid to understanding, the following appended claims may contain usage of the introductory phrases "at least one" and "one or more" to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles "a" or "an" limits any particular claim containing such introduced claim recitation to embodiments containing only one such recitation, even when the same claim includes the introductory phrases "one or more" or "at least one" and indefinite articles such as "a" or "an" (for example, "a" and/or "an" should be interpreted to mean "at least one" or "one or more"); the same holds true for the use of definite articles used to introduce claim recitations. In addition, even if a specific number of an introduced claim recitation is explicitly recited, those skilled in the art will recognize that such recitation should be interpreted to mean at least the recited number (for example, the bare recitation of "two recitations," without other modifiers, means at least two recitations, or two or more recitations). Furthermore, in those instances where a convention analogous to "at least one of A, B, and C, et cetera" is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (for example, "a system having at least one of A, B, and C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, et cetera). In those instances where a convention analogous to "at least one of A, B, or C, et cetera" is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (for example, "a system having at least one of A, B, or C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, et cetera). It will be further understood by those within the art that virtually any disjunctive word and/or phrase presenting two or more alternative terms, whether in the description, claims, or drawings, should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms. For example, the phrase "A or B" will be understood to include the possibilities of "A" or "B" or "A and B."

In addition, where features or aspects of the disclosure are described in terms of Markush groups, those skilled in the art will recognize that the disclosure is also thereby described in terms of any individual member or subgroup of members of the Markush group.

As will be understood by one skilled in the art, for any and all purposes, such as in terms of providing a written description, all ranges disclosed herein also encompass any and all possible subranges and combinations of subranges thereof. Any listed range can be easily recognized as sufficiently describing and enabling the same range being broken down into at least equal halves, thirds, quarters, fifths, tenths, et cetera As a non-limiting example, each range discussed herein can be readily broken down into a lower third, middle third and upper third, et cetera As will also be understood by one skilled in the art all language such as "up to," "at least," and the like include the number recited and refer to ranges which can be subsequently broken down into subranges as discussed above. Finally, as will be understood by one skilled in the art, a range includes each individual member. Thus, for example, a group having 1-3 cells refers to groups having 1, 2, or 3 cells. Similarly, a group having 1-5 cells refers to groups having 1, 2, 3, 4, or 5 cells, and so forth.

Various of the above-disclosed and other features and functions, or alternatives thereof, may be combined into many other different systems or applications. Various presently unforeseen or unanticipated alternatives, modifications, variations or improvements therein may be subsequently made by those skilled in the art, each of which is also intended to be encompassed by the disclosed embodiments.

The invention claimed is:

1. An adapter for mating with optical fiber connectors, the adapter comprising:

an outer housing having a first end portion and a second end portion spaced apart along a longitudinal axis, the outer housing comprising a first side wall and a second side wall spaced apart along a lateral axis perpendicular to the longitudinal axis, the outer housing having a width extending along the lateral axis from the first side wall to the second side wall, the outer housing comprising a upper wall and a lower wall spaced apart along a transverse axis oriented perpendicular to the lateral axis and perpendicular to the longitudinal axis, each of the upper wall and the lower wall having an inner surface, the outer housing defining a plurality of channels spaced apart along the width, each of the channels being configured to receive an optical fiber connector, the plurality of channels including first and second channels; and

a first longitudinal rib formed on the inner surface of the upper wall at a location spaced apart along the width of the outer housing between the first side wall and the second side wall and a second rib formed on the inner surface of the lower wall at a location spaced apart along the width of the outer housing between the first side wall and the second side wall, the first and second ribs being aligned along the width of the outer housing, the first rib being spaced apart from the second rib along the transverse axis by a transverse gap,

wherein the first longitudinal rib and the second longitudinal rib are located between the first and second channels.

2. The adapter as set forth in claim **1**, wherein the upper wall comprises a first latch opening aligned with the first channel and a second latch opening aligned with the second channel, the first rib being spaced apart between the first latch opening and the second latch opening along the width.

3. The adapter as set forth in claim **2**, wherein the adapter is configured to receive a first one of the optical fiber connectors in the first channel and a second one of the optical fiber connectors in the second channel such that:

a flexible latch arm of the first optical fiber connector is latched with the first latch opening and a front section of a remote release of the first optical fiber connector is received in the first channel at a location spaced apart from the first latch opening along the longitudinal axis toward the second end portion of the outer housing; and

a flexible latch arm of the second optical fiber connector is latched with the second latch opening and a front section of a remote release of the second optical fiber connector is received in the first channel at a location spaced apart from the second latch opening along the longitudinal axis toward the second end portion of the outer housing.

4. The adapter as set forth claim **3**, wherein the first channel is configured to allow the front section of the remote release of the first optical fiber connector to slide along the flexible latch arm of the first optical fiber connector within the first channel toward the first end portion of the outer housing to depress the flexible latch arm of the first optical fiber connector and wherein the second channel is configured to allow the front section of the remote release of the second optical fiber connector to slide along the flexible latch arm of the second optical fiber connector within the second channel toward the first end portion of the outer housing to depress the flexible latch arm of the second optical fiber connector.

5. The adapter as set forth in claim **4**, wherein the upper wall is configured to unlatch from the flexible latch arm of the first optical fiber connector when the flexible latch arm of the first optical fiber connector is depressed and the upper wall is configured to unlatch from the flexible latch arm of the second optical fiber connector when the flexible latch arm of the second optical fiber connector is depressed.

6. The adapter as set forth in claim **2**, wherein the lower wall is free of latch openings.

7. The adapter as set forth in claim **2**, wherein the lower wall is configured to slidably engage each of the first and second optical fiber connectors without latching.

8. The adapter as set forth in claim **1**, wherein the first longitudinal rib has a first height along the transverse axis and the second longitudinal rib has a second height along the transverse axis, the first height being greater than the second height.

9. The adapter as set forth in claim **1**, wherein each of the first and second channels opens through the first end portion of the outer housing.

10. The adapter as set forth in claim **9**, further comprising a transverse wall extending between the upper wall and the lower wall at a location longitudinally spaced apart from the first end portion of the outer housing.

11. The adapter as set forth in claim **10**, wherein the transverse wall includes a socket in each of the first and second channels configured to receive a ferrule of one of the optical fiber connectors.

12. The adapter as set forth in claim **11**, wherein the socket in each of the first and second channels comprises a pair of cylindrical sockets in each of the first and second channels, each pair of sockets configured to receive a pair of cylindrical ferrules of one of the optical fiber connectors.

13. The adapter as set forth in claim **1**, wherein each of the optical fiber connectors is a multi-fiber connector comprising a multi-fiber ferrule.

* * * * *

EXHIBIT C

US011340413B2

(12) **United States Patent**
Takano et al.

(10) **Patent No.: US 11,340,413 B2**
(45) **Date of Patent: May 24, 2022**

(54) **ULTRA-SMALL FORM FACTOR OPTICAL CONNECTORS USED AS PART OF A RECONFIGURABLE OUTER HOUSING**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **17/327,197**

(22) Filed: **May 21, 2021**

(65) **Prior Publication Data**

US 2021/0311272 A1 Oct. 7, 2021

Related U.S. Application Data

(63) Continuation of application No. 17/090,855, filed on Nov. 5, 2020, which is a continuation of application (Continued)

(51) **Int. Cl.**
G02B 6/42 (2006.01)
G02B 6/38 (2006.01)

(52) **U.S. Cl.**
CPC .... ***G02B 6/4292*** (2013.01); ***G02B 6/387*** (2013.01); ***G02B 6/3825*** (2013.01); (Continued)

(58) **Field of Classification Search**
CPC G02B 6/42; G02B 6/38
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

681,132 A 8/1901 Norton
3,721,945 A 3/1973 Hults
(Continued)

FOREIGN PATENT DOCUMENTS

CA 2495693 A1 4/2004
CA 2495693 A1 4/2004
(Continued)

OTHER PUBLICATIONS

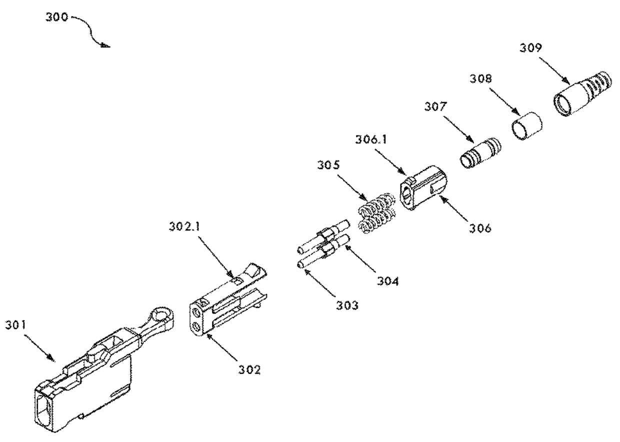
PCT/US2018/062406 International Search Report dated Mar. 18, 2019.
(Continued)

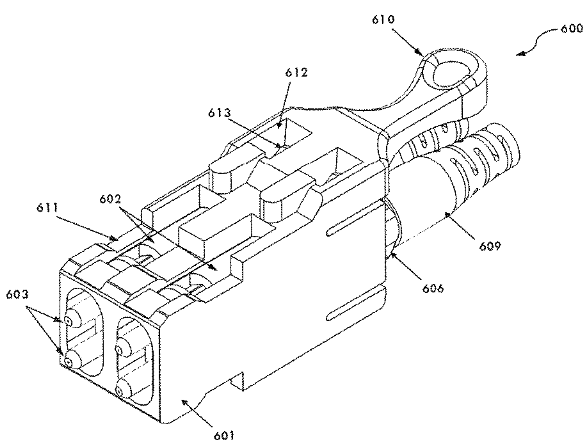
Primary Examiner — Tina M Wong

(57) **ABSTRACT**

An optical connector holding one or more optical ferrule assembly is provided. The optical connector includes an outer body, an inner front body accommodating the one or more optical ferrule assembly, ferrule springs for urging the optical ferrules towards a mating receptacle, and a back body for supporting the ferrule springs. The outer body and the inner front body are configured such that four optical ferrule assembly are accommodated in a small form-factor pluggable (SFP) transceiver footprint or eight optical ferrule assembly are accommodated in a quad small form-factor pluggable (QSFP) transceiver footprint. A receptacle can hold one or more connector inner bodies forming a single boot for all the optical fibers of the inner bodies.

28 Claims, 65 Drawing Sheets





Related U.S. Application Data

No. 16/414,546, filed on May 16, 2019, now Pat. No. 10,859,778, which is a continuation of application No. 16/388,053, filed on Apr. 18, 2019, now Pat. No. 11,169,338, which is a continuation of application No. 16/035,691, filed on Jul. 15, 2018, now Pat. No. 10,281,668.

(60) Provisional application No. 62/588,276, filed on Nov. 17, 2017, provisional application No. 62/549,655, filed on Aug. 24, 2017, provisional application No. 62/532,710, filed on Jul. 14, 2017.

(52) **U.S. Cl.**
CPC ***G02B 6/3893*** (2013.01); *G02B 6/3873* (2013.01); *G02B 6/3878* (2013.01); *G02B 6/4228* (2013.01)

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,150,790	A	4/1979	Potter
4,240,695	A	12/1980	Evans
4,327,964	A	5/1982	Haesley et al.
4,478,473	A	10/1984	Frear
4,762,388	A	8/1988	Tanaka et al.
4,764,129	A	8/1988	Jones et al.
4,840,451	A	6/1989	Sampson et al.
4,872,736	A	10/1989	Myers et al.
4,979,792	A	12/1990	Weber
5,026,138	A	6/1991	Boudreau
5,031,981	A	7/1991	Peterson
5,011,025	A	8/1991	Haitmanek
5,041,025	A	8/1991	Haitmanek
5,073,045	A	12/1991	Abendschein
D323,143	S	1/1992	Ohkura et al.
5,101,463	A	3/1992	Cubukciyan
5,146,813	A	9/1992	Stanfill, Jr.
5,159,652	A	10/1992	Grassin D'Alphonse
5,212,752	A	5/1993	Stephenson et al.
5,265,181	A	11/1993	Chang
5,289,554	A	2/1994	Cubukciyan et al.
5,315,679	A	5/1994	Baldwin
5,317,663	A	5/1994	Beard et al.
5,321,784	A	6/1994	Cubukciyan et al.
5,335,301	A	8/1994	Newman et al.
5,348,487	A	9/1994	Marazzi et al.
5,418,875	A	5/1995	Nakano
5,444,806	A	8/1995	de Marchi et al.
5,481,634	A	4/1996	Anderson et al.
5,506,922	A	4/1996	Grois et al.
5,521,997	A	5/1996	Rovenolt et al.
5,570,445	A	10/1996	Chou et al.
5,588,079	A	12/1996	Tanabe et al.
5,602,951	A	2/1997	Shiota
5,684,903	A	11/1997	Kyomasu et al.
5,687,268	A	11/1997	Stephenson et al.
5,781,681	A	7/1998	Manning
5,845,036	A	12/1998	De Marchi
5,862,282	A	1/1999	Matsuura
5,915,987	A	6/1999	Reed
5,930,426	A	7/1999	Harting
5,937,130	A	8/1999	Amberg et al.
5,953,473	A	9/1999	Shimotsu
5,956,444	A	9/1999	Duda et al.
5,971,626	A	10/1999	Knodell et al.
6,041,155	A	3/2000	Anderson et al.
6,049,040	A	4/2000	Biles et al.
6,095,862	A	8/2000	Doye
6,134,370	A	10/2000	Childers et al.
6,178,283	B1	1/2001	Weigel
RE37,080	E	3/2001	Stephenson et al.
6,206,577	B1	3/2001	Hall, III et al.
6,206,581	B1	3/2001	Driscoll et al.
6,227,717	B1	5/2001	Ott et al.
6,238,104	B1	5/2001	Yamakawa et al.
6,240,228	B1	5/2001	Chen
6,247,849	B1	6/2001	Liu
6,250,817	B1	6/2001	Lampert
6,276,840	B1	8/2001	Weiss
6,318,903	B1	11/2001	Andrews
6,364,537	B1	4/2002	Maynard
6,379,052	B1	4/2002	de Jong
6,422,759	B1	7/2002	Kevern
6,450,695	B1	9/2002	Matsumoto
6,461,054	B1	10/2002	Iwase
6,471,412	B1	10/2002	Belenkiy et al.
6,478,472	B1	11/2002	Anderson et al.
6,485,194	B1	11/2002	Shirakawa
6,527,450	B1	3/2003	Miyachi
6,530,696	B1	3/2003	Ueda
6,551,117	B2	4/2003	Poplawski et al.
6,565,262	B2	5/2003	Childers
6,572,276	B1	6/2003	Theis
6,579,014	B2	6/2003	Melton et al.
6,585,194	B1	7/2003	Brushwood
6,634,796	B2	10/2003	de Jong
6,634,801	B1	10/2003	Waldron et al.
6,648,520	B2	11/2003	McDonald et al.
6,668,113	B2	12/2003	Togami
6,682,228	B2	1/2004	Ralhnam et al.
6,685,362	B2	2/2004	Burkholder et al.
6,695,486	B1	2/2004	Falkenberg
6,811,321	B1	11/2004	Schmalzigaug et al.
6,817,272	B2	11/2004	Holland
6,854,894	B1	2/2005	Yunker et al.
6,869,227	B2	3/2005	Del Grosso
6,872,039	B2	3/2005	Baus et al.
6,935,789	B2	8/2005	Gross, III et al.
7,036,993	B2	5/2006	Luther
7,052,186	B1	5/2006	Bates
7,077,576	B2	7/2006	Luther
7,090,407	B2	8/2006	Melton et al.
7,091,421	B2	8/2006	Kukita et al.
7,111,990	B2	9/2006	Melton et al.
7,113,679	B2	9/2006	Melton et al.
D533,504	S	12/2006	Lee
D534,124	S	12/2006	Taguchi
7,150,567	B1	12/2006	Luther et al.
7,153,041	B2	12/2006	Mine et al.
7,198,409	B2	4/2007	Smith et al.
7,207,724	B2	4/2007	Gurreri
D543,146	S	5/2007	Chen et al.
7,258,493	B2	8/2007	Milette
7,264,402	B2	9/2007	Theuerkorn
7,281,859	B2	10/2007	Mudd et al.
D558,675	S	1/2008	Chien et al.
7,315,682	B1	1/2008	En Lin et al.
7,325,976	B2	2/2008	Gurreri et al.
7,325,980	B2	2/2008	Pepe
7,329,137	B2	2/2008	Martin et al.
7,354,291	B2	4/2008	Caveney et al.
7,331,718	B2	5/2008	Yazaki et al.
7,371,082	B2	5/2008	Zimmel et al.
7,387,447	B2	6/2008	Mudd et al.
7,390,203	B2	6/2008	Murano et al.
D572,661	S	7/2008	En Lin et al.
7,431,604	B2	10/2008	Waters et al.
7,463,803	B2	12/2008	Cody et al.
7,465,180	B2	12/2008	Kusuda et al.
7,473,124	B1	1/2009	Briant
7,510,335	B1	3/2009	Su et al.
7,513,695	B1	4/2009	Lin et al.
7,534,128	B2	5/2009	Caveney et al.
7,540,666	B2	6/2009	Luther
7,561,775	B2	7/2009	Lin et al.
7,588,373	B1	9/2009	Sato
7,591,595	B2	9/2009	Lue et al.
7,594,766	B1	9/2009	Sasser et al.
7,641,398	B2	1/2010	O'Riorden et al.
7,695,199	B2	4/2010	Teo et al.
7,699,533	B2	4/2010	Milette
7,712,970	B1	5/2010	Lee

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,717,625 B2 5/2010 Margolin
7,824,113 B2 11/2010 Wong et al.
7,837,395 B2 11/2010 Lin et al.
D641,708 S 7/2011 Tammauchi
8,083,450 B1 12/2011 Smith et al.
8,152,385 B2 4/2012 de Jong
8,186,890 B2 5/2012 Lu
8,192,091 B2 6/2012 Hsu et al.
8,202,009 B2 6/2012 Lin et al.
8,221,007 B2 7/2012 Peterhans
8,251,733 B2 8/2012 Wu
8,267,595 B2 9/2012 Lin et al.
8,270,796 B2 9/2012 Nhep
8,408,815 B2 4/2013 Lin et al.
8,414,196 B2 4/2013 Lu
8,465,317 B2 6/2013 Gniadek et al.
8,534,928 B2 9/2013 Cooke
8,550,728 B2 10/2013 Takahashi
8,556,645 B2 10/2013 Crain
8,559,781 B2 10/2013 Childers
8,622,634 B2 1/2014 Arnold
8,636,424 B2 1/2014 Kuffel et al.
8,651,749 B2 2/2014 Clovis et al.
8,676,022 B2 3/2014 Jones
8,678,670 B2 3/2014 Takahashi
8,727,638 B2 5/2014 Lee
8,757,894 B2 6/2014 Katoh
8,764,308 B2 7/2014 Irwin
8,770,863 B2 7/2014 Cooke et al.
8,869,661 B2 10/2014 Opstad
9,052,474 B2 6/2015 Jiang
9,063,296 B2 6/2015 Dong
9,250,402 B2 2/2016 Ishii et al.
9,310,569 B2 4/2016 Lee
9,366,829 B2 6/2016 Czosnowski
9,411,110 B2 8/2016 Barnette, Jr. et al.
9,448,370 B2 9/2016 Xue et al.
9,465,172 B2 10/2016 Shih
9,494,744 B2 11/2016 de Jong
9,548,557 B2 1/2017 Liu
9,551,842 B2 1/2017 Theuerkorn
9,557,495 B2 1/2017 Raven
9,568,686 B2 2/2017 Fewkes et al.
9,581,768 B1 2/2017 Baca et al.
9,599,778 B2 3/2017 Wong et al.
9,658,409 B2 5/2017 Gniadek
9,678,283 B1 6/2017 Chang et al.
9,684,130 B2 6/2017 Veatch et al.
9,684,136 B2 6/2017 Cline et al.
9,684,313 B2 6/2017 Chajec
9,709,753 B1 8/2017 Chang et al.
9,778,425 B2 10/2017 Nguyen
9,829,644 B2 11/2017 Nguyen
9,829,645 B2 11/2017 Good
9,829,653 B1 11/2017 Nishiguchi
9,869,825 B2 1/2018 Bailey et al.
9,880,361 B2 1/2018 Childers
9,946,035 B2 4/2018 Gustafson
9,971,103 B2 5/2018 de Jong et al.
9,989,711 B2 6/2018 Ott et al.
10,031,296 B2 7/2018 Good
10,067,301 B2 9/2018 Murray
10,107,972 B1 10/2018 Gniadek et al.
10,114,180 B2 10/2018 Suzic
10,146,011 B2 12/2018 Nhep
10,281,668 B2 5/2019 Takano et al.
10,281,669 B2 5/2019 Takano et al.
2002/0168148 A1 11/2002 Gilliland
2002/0172467 A1 11/2002 Anderson et al.
2002/0191919 A1 12/2002 Nolan
2003/0053787 A1 3/2003 Lee
2003/0063862 A1 4/2003 Fillion
2003/0157825 A1 8/2003 Kane
2004/0052473 A1 3/2004 Seo
2004/0109646 A1 6/2004 Anderson
2004/0161958 A1 6/2004 Togami et al.
2004/0136657 A1 7/2004 Ngo
2004/0141693 A1 7/2004 Szilagvi et al.
2004/0234209 A1 11/2004 Cox et al.
2004/0247252 A1 12/2004 Ehrenreich
2005/0036744 A1 2/2005 Caveney et al.
2005/0111796 A1 5/2005 Matasek et al.
2005/0141817 A1 6/2005 Yazaki et al.
2005/0281509 A1 12/2005 Cox et al.
2006/0013539 A1 1/2006 Thaler
2006/0076061 A1 4/2006 Bush
2006/0089049 A1 4/2006 Sedor
2006/0127025 A1 6/2006 Haberman
2006/0153503 A1 7/2006 Suzuki
2006/0160429 A1 7/2006 Dawiedczyk et al.
2006/0193562 A1 8/2006 Theuerkorn
2006/0269194 A1 11/2006 Luther et al.
2006/0274411 A1 12/2006 Yamauchi
2007/0025665 A1 2/2007 Dean
2007/0028409 A1 2/2007 Yamada
2007/0079854 A1 4/2007 You
2007/0098329 A1 6/2007 Shimoji et al.
2007/0149028 A1 6/2007 Yu et al.
2007/0149062 A1 6/2007 Long et al.
2007/0230874 A1 10/2007 Lin
2007/0232115 A1 10/2007 Burke et al.
2007/0243749 A1 10/2007 Wu
2008/0008430 A1 1/2008 Kewitsch
2008/0044137 A1 2/2008 Luther et al.
2008/0056647 A1 3/2008 Margolin et al.
2008/0064334 A1 3/2008 Hamadi
2008/0069501 A1 3/2008 Mudd et al.
2008/0101757 A1 5/2008 Lin et al.
2008/0226237 A1 9/2008 O'Rioreden et al.
2008/0267566 A1 10/2008 En Lin
2009/0028507 A1 1/2009 Jones et al.
2009/0047818 A1 2/2009 Irwin et al.
2009/0092360 A1 4/2009 Lin et al.
2009/0176401 A1 7/2009 Gu
2009/0196555 A1 8/2009 Lin et al.
2009/0214162 A1 8/2009 O'Riorden et al.
2009/0220197 A1 9/2009 Gniadek
2009/0220200 A1 9/2009 Wong et al.
2009/0222457 A1 9/2009 de Jong et al.
2009/0290839 A1 11/2009 Lin
2009/0290938 A1 11/2009 Asaoka
2010/0034502 A1 2/2010 Lu et al.
2010/0054668 A1 3/2010 Nelson
2010/0061069 A1 3/2010 Cole
2010/0092136 A1 4/2010 Nhep
2010/0220961 A1 9/2010 de Jong et al.
2010/0247041 A1 9/2010 Szilagyi
2010/0284656 A1 11/2010 Morra
2010/0322561 A1 12/2010 Lin et al.
2011/0044588 A1 2/2011 Larson
2011/0058773 A1 3/2011 Peterhans
2011/0131801 A1 6/2011 Nelson et al.
2011/0155810 A1 6/2011 Taniguichi
2011/0177710 A1 7/2011 Tobey
2011/0239220 A1 9/2011 Gibson
2012/0099822 A1 4/2012 Kuffel et al.
2012/0155810 A1 6/2012 Nakagawa
2012/0189260 A1 7/2012 Kowalczyk et al.
2012/0237177 A1 9/2012 Minota
2012/0269485 A1 10/2012 Haley et al.
2012/0301080 A1 11/2012 Gniadek
2012/0308183 A1 12/2012 Irwin
2012/0328248 A1 12/2012 Larson
2013/0019423 A1 1/2013 Srutkowski
2013/0071067 A1 3/2013 Lin
2013/0089995 A1 4/2013 Gniadek et al.
2013/0094816 A1 4/2013 Lin et al.
2013/0101258 A1 4/2013 Hikosaka
2013/0121653 A1 5/2013 Shitama et al.
2013/0170797 A1 7/2013 Ott
2013/0183012 A1 7/2013 Lopez et al.
2013/0216185 A1 8/2013 Klavuhn
2013/0259429 A1* 10/2013 Czosnowski G02B 6/3879
385/78

(56) **References Cited**

U.S. PATENT DOCUMENTS

2013/0308915	A1	11/2013	Buff	
2013/0322825	A1*	12/2013	Cooke	G02B 6/3831 385/59
2014/0016901	A1	1/2014	Lamboum et al.	
2014/0023322	A1	1/2014	Gniadek	
2014/0050446	A1	2/2014	Chang	
2014/0056562	A1	2/2014	Limbert	
2014/0133808	A1	5/2014	Hill et al.	
2014/0153877	A1	6/2014	Isenhour et al.	
2014/0169727	A1	6/2014	Veatch et al.	
2014/0219621	A1	8/2014	Barnette, Jr. et al.	
2014/0226946	A1	8/2014	Cooke et al.	
2014/0241644	A1	8/2014	Kang	
2014/0241678	A1	8/2014	Bringuier et al.	
2014/0241688	A1	8/2014	Isenhour et al.	
2014/0334780	A1	11/2014	Nguyen	
2014/0348477	A1	11/2014	Chang	
2015/0003788	A1	1/2015	Chen	
2015/0111417	A1	4/2015	Vanderwoud	
2015/0177463	A1	6/2015	Lee	
2015/0198766	A1	7/2015	Takahashi	
2015/0212282	A1	7/2015	Lin	
2015/0241644	A1	8/2015	Lee	
2015/0301294	A1	10/2015	Chang	
2015/0331201	A1	11/2015	Takano et al.	
2015/0355417	A1	12/2015	Takano et al.	
2015/0370021	A1	12/2015	Chan	
2015/0378113	A1	12/2015	Good et al.	
2016/0131849	A1	5/2016	Takano et al.	
2016/0139343	A1	5/2016	Dean, Jr. et al.	
2016/0161681	A1	6/2016	Banal, Jr. et al.	
2016/0172852	A1	6/2016	Tamura	
2016/0178852	A1	6/2016	Takano	
2016/0195682	A1	6/2016	Takano	
2016/0291262	A1	6/2016	Chang et al.	
2016/0231512	A1	8/2016	Seki	
2016/0259135	A1	9/2016	Gniadek	
2016/0266326	A1	9/2016	Gniadek	
2016/0320572	A1	11/2016	Gniadek	
2016/0349458	A1	12/2016	Murray	
2016/0370545	A1	12/2016	Jiang	
2017/0003458	A1	1/2017	Gniadek	
2017/0023746	A1*	1/2017	Good	G02B 6/3882
2017/0205587	A1	7/2017	Chang et al.	
2017/0205590	A1	7/2017	Bailey	
2017/0205591	A1	7/2017	Takano et al.	
2017/0212313	A1	7/2017	Elenabaas	
2017/0212316	A1	7/2017	Takano	
2017/0254961	A1	9/2017	Kamada et al.	
2017/0276275	A1	9/2017	Beemer et al.	
2017/0276887	A1	9/2017	Allen	
2017/0277059	A1	9/2017	Miura et al.	
2017/0343740	A1	11/2017	Nguyen	
2018/0128988	A1	5/2018	Chang	
2018/0156988	A1	6/2018	Gniadek	
2018/0172923	A1	6/2018	Bauco	
2018/0252872	A1	9/2018	Chen	
2018/0341069	A1	11/2018	Takano	
2019/0064447	A1	2/2019	Chang et al.	
2019/0204513	A1	7/2019	Davidson et al.	

FOREIGN PATENT DOCUMENTS

CN	2836038	Y	11/2006
CN	2836038	Y	11/2006
CN	201383588	Y	1/2010
CN	201383588	Y	1/2010
CN	2026500189	U	12/2013
CN	106997078		8/2017
DE	19507669	A1	9/1996
DE	202006011910	U1	3/2007
DE	102006019335	U1	10/2007
EP	1074868	A1	2/2001
EP	1074868	A1	7/2001
EP	1211537	A2	6/2002
EP	1211537	A3	6/2002
EP	1245980	A1	10/2002
EP	1566674	A2	8/2005
GB	2111240	A	6/1983
JP	2000089059	A	3/2000
JP	03752331	B2	3/2006
JP	2009229545	A	10/2009
JP	2009276493	A	11/2009
JP	04377820	B2	12/2009
KR	2009005382	A	1/2009
KR	200905382	U	6/2009
KR	1371686	B1	3/2014
TW	200821653	A	5/2008
WO	200179904	A2	10/2001
WO	WO2001079904	A2	10/2001
WO	2004027485	A1	4/2004
WO	WO2006007120	A1	1/2006
WO	2008112986	A1	9/2008
WO	2009135787	A1	11/2009
WO	2010024851	A2	3/2010
WO	2012136702	A1	10/2012
WO	2012162385	A1	11/2012
WO	WO2012162385	A1	11/2012
WO	2014028527	A1	2/2014
WO	2014182351	A1	11/2014
WO	WO2015103783	A1	7/2015
WO	2015191024	A1	12/2015
WO	2016019993	A1	2/2016
WO	2016148741	A1	9/2016
WO	WO2019126333	A1	6/2019

OTHER PUBLICATIONS

PCT/US2018/062406 The written Opinion dated Mar. 18, 2019.
PCT/US2018/062405 International Search Report dated Apr. 3, 2019.
PCT/US2018/062405 The written Opinion dated Apr. 3, 2019.
PCT/IB2018/056133 Written Opinion dated Jan. 3, 2019.
PCY/IB/056133 Search Report dated Jan. 3, 2019.
Final Office Action, U.S. Appl. No. 16/035,691, dated Feb. 11, 2019, pp. 8.
Non-Final Office Action, U.S. Appl. No. 16/035,695, dated Sep. 28, 2018, pp. 7.
International Search Report and Written Opinion, Application No. PCT/US/2018/042202, pp. 17, dated Dec. 7, 2018.
International Search Report and Written Opinion, Application No. PCT/US19/24718, dated Jun. 26, 2019, pp. 7.
ISR for PCT/US2019/013861, Apr. 8, 2019, 3 pages.
WO for PCT/US2019/013861, Apr. 8, 2019, 11 pages.
International Search Report and Written Opinion for Application No. PCT/US2018/62406 dated Mar. 18, 2019, 12, pages, United States.
International Search Report and Written Opinion for Application No. PCT/US2019/40700 dated Sep. 27, 2019, 12, pages, United States.
International Search Report and Written Opinion for Application No. PCT/US2019/50895 dated Jan. 6, 2020, 12, pages, United States.
International Search Report and Written Opinion for Application No. PCT/US2019/50909 dated Dec. 17, 2019, 11, pages, United States.
International Search Report and Written Opinion for Application No. PCT/US2019/56564 dated Jan. 14, 2020, 14, pages, United States.
International Search Report and Written Opinion, Application No. PCT/US19/46397, dated Nov. 12, 2019, pp. 6.
International Search Report; PCT/US2018/042202 filed Jul. 16, 2018; Applicant: Senko Advanced Components, Inc.
International Preliminary Report on Patentability for PCT/US2019/022940 dated Oct. 1, 2020, 11 pages.
Extended European Search Report and Written Opinion, Application No. 18832246.5, dated Mar. 15, 2021, pp. 6.
International Search Report and Written Opinion; Application No. PCT/US2018/042202, dated Dec. 7, 2018, pp. 17.

(56) **References Cited**

OTHER PUBLICATIONS

International Search Report and Written Opinion, Application No. PCT/US2019/013861, dated Apr. 8, 2019, pp. 15.
Fiber Optic Connectors Tutorial, 2018, pp. 20.
Fiber Optic Glossary, Feb. 29, 2016, pp. 93.
"Fiber Optic Interconnect Solutions, Tactical Fiber Optical Connectors, Cables and Termini" 2006, Glenair, Inc., Glendale, California, www.mps-electronics.de, pp. 232.
"Fiber Optic Products Catalog" Nov. 2007, Tyco Electronics Corporation, Harrisburg, Pennsylvania, www.ampnetconnect.com, pp. 204.
"Fiber Optic Connectors and Assemblies Catalog" 2009, Huber & Suhner Fiver Optics, Herisau, Switzerland, www.hubersuhner.com, pp. 104.

* cited by examiner

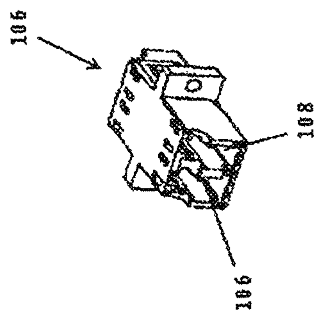


FIG. 1B
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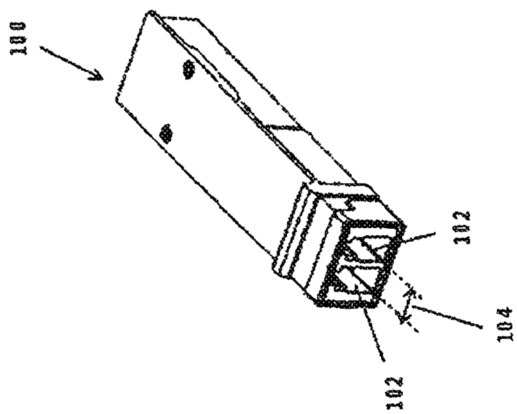


FIG. 1A
(Prior Art)

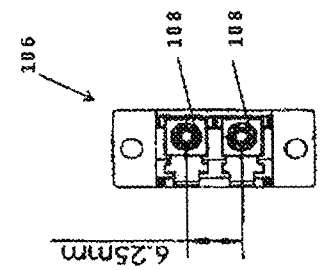


FIG. 1D
(Prior Art)

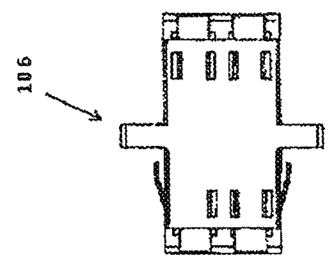


FIG. 1C
(Prior Art)

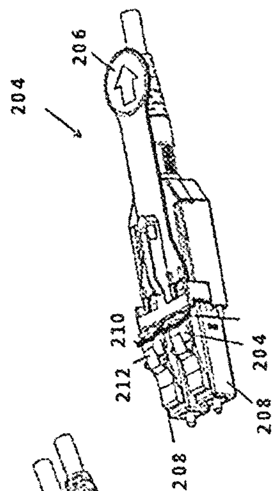


FIG. 2B
(Prior Art)

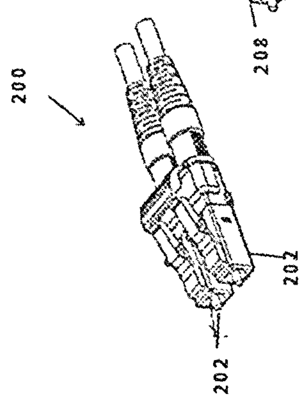


FIG. 2A
(Prior Art)

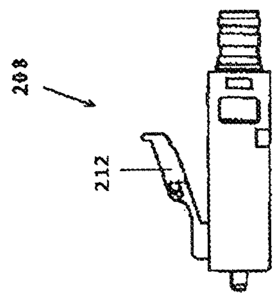


FIG. 2D
(Prior Art)

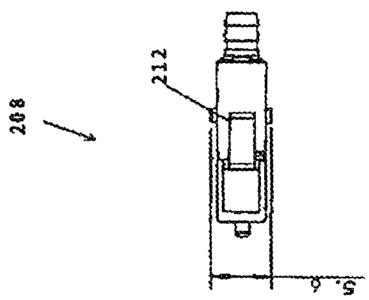


FIG. 2C
(Prior Art)

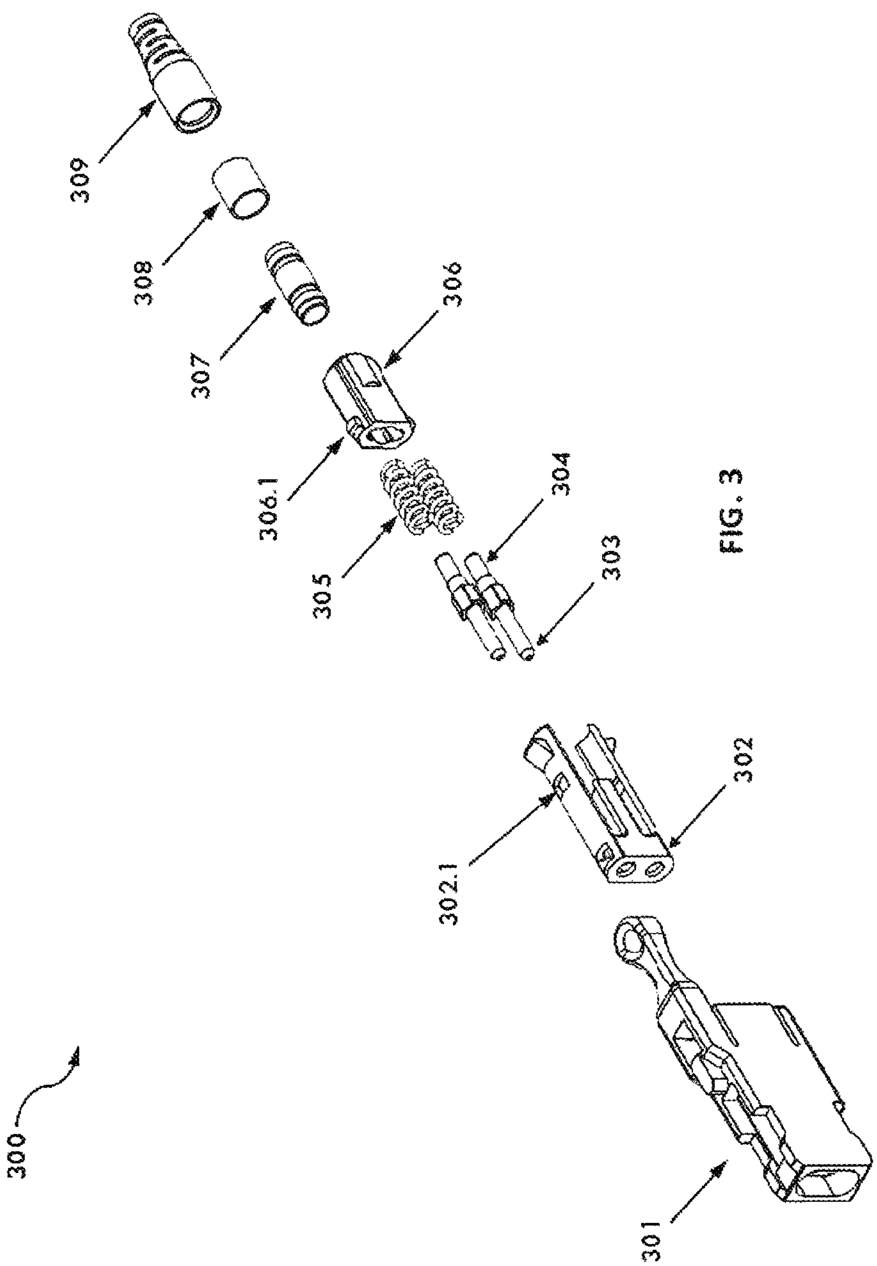


FIG. 3

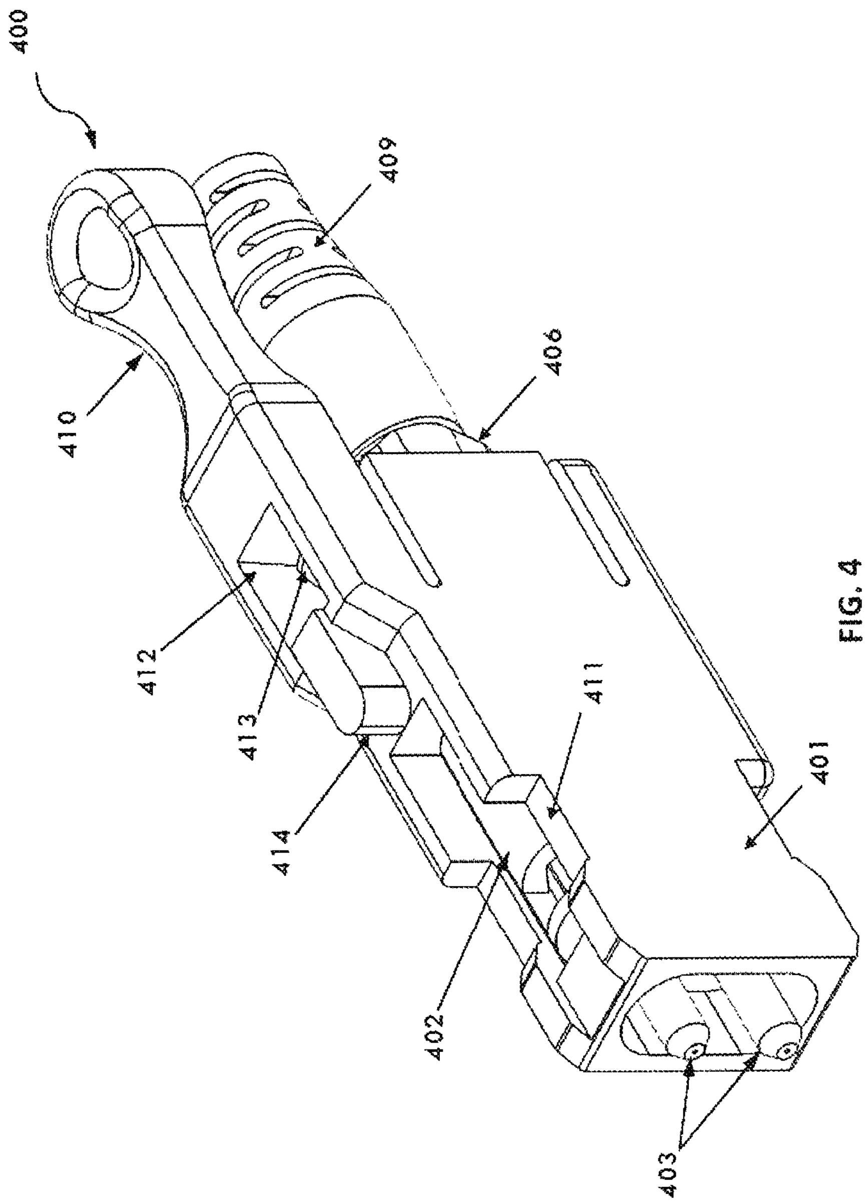


FIG. 4

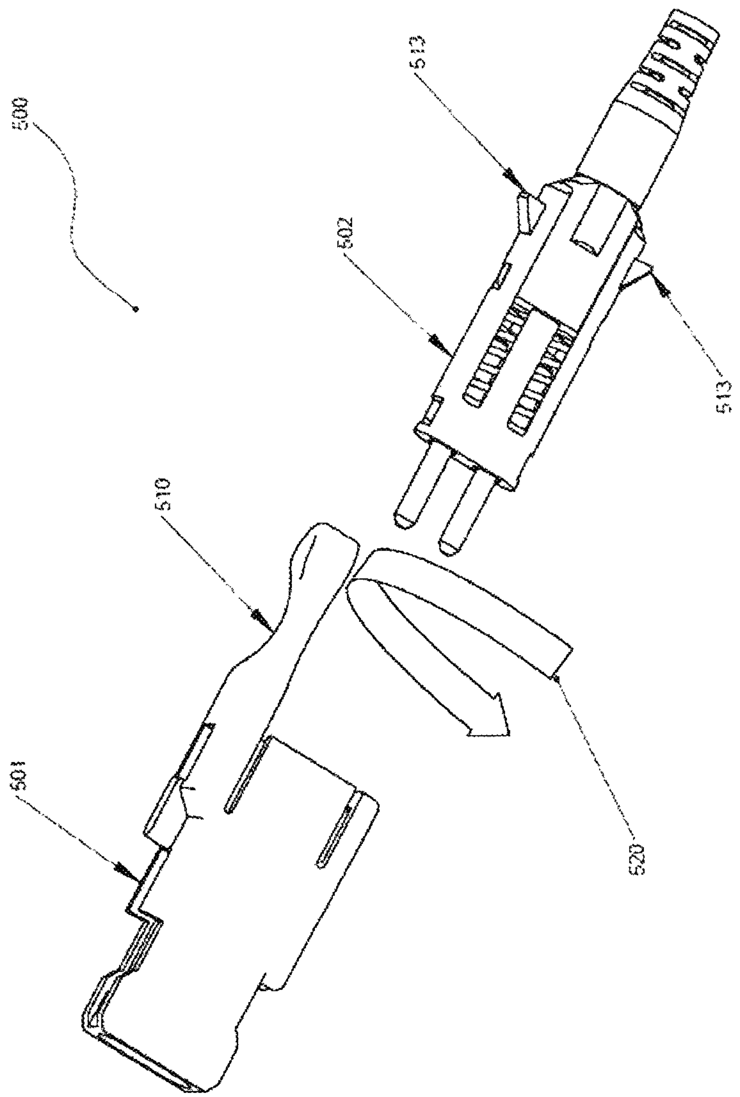


FIG. 5

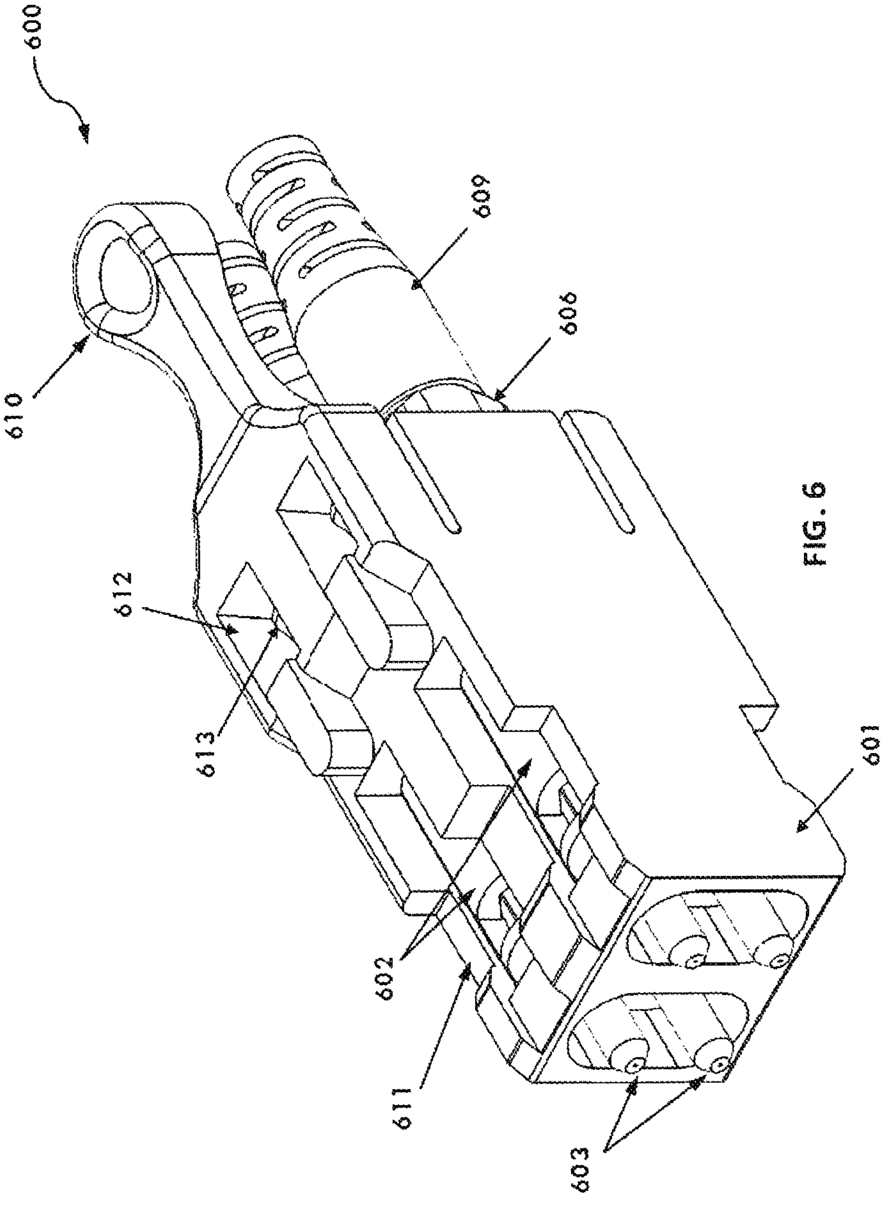


FIG. 6

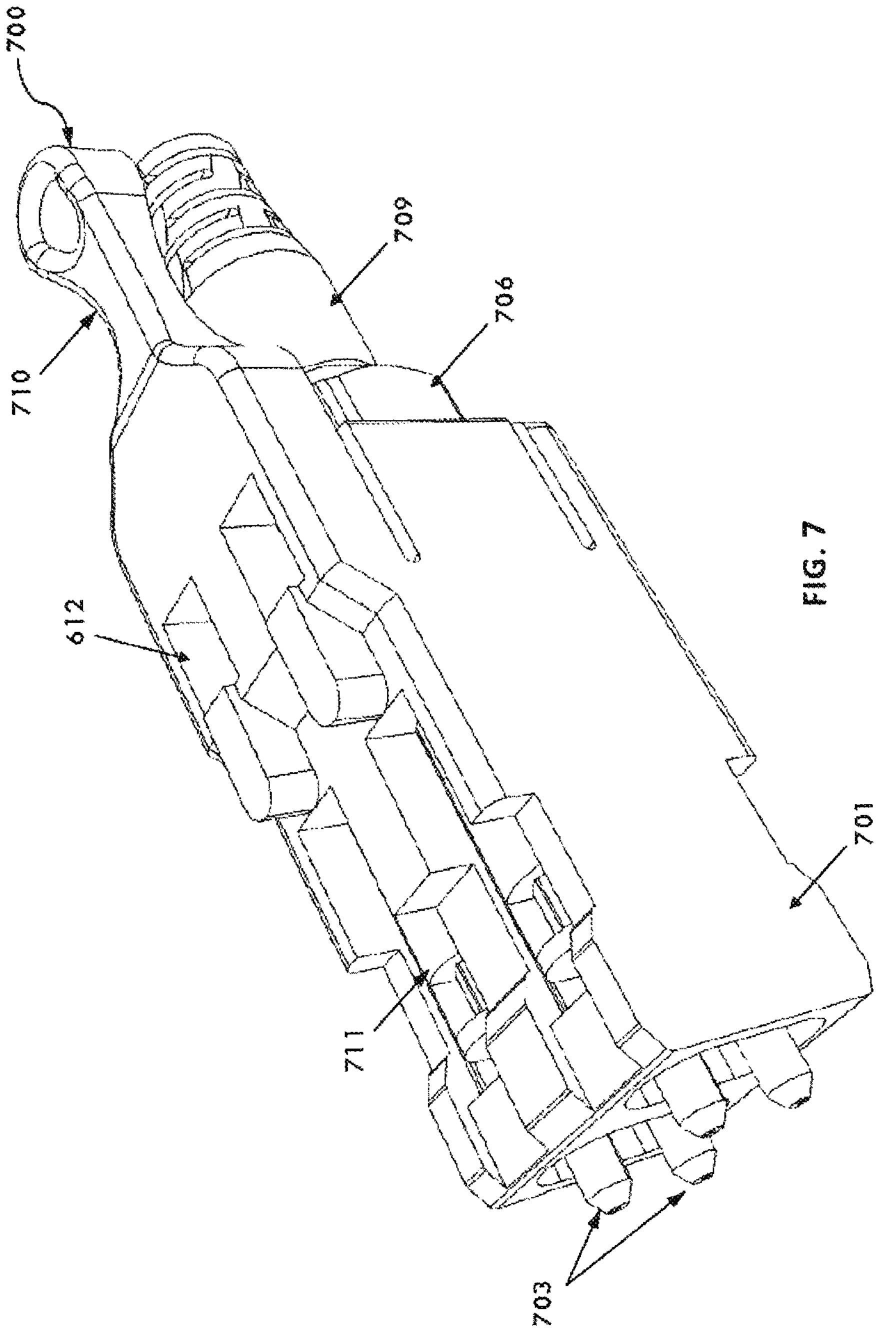


FIG. 7

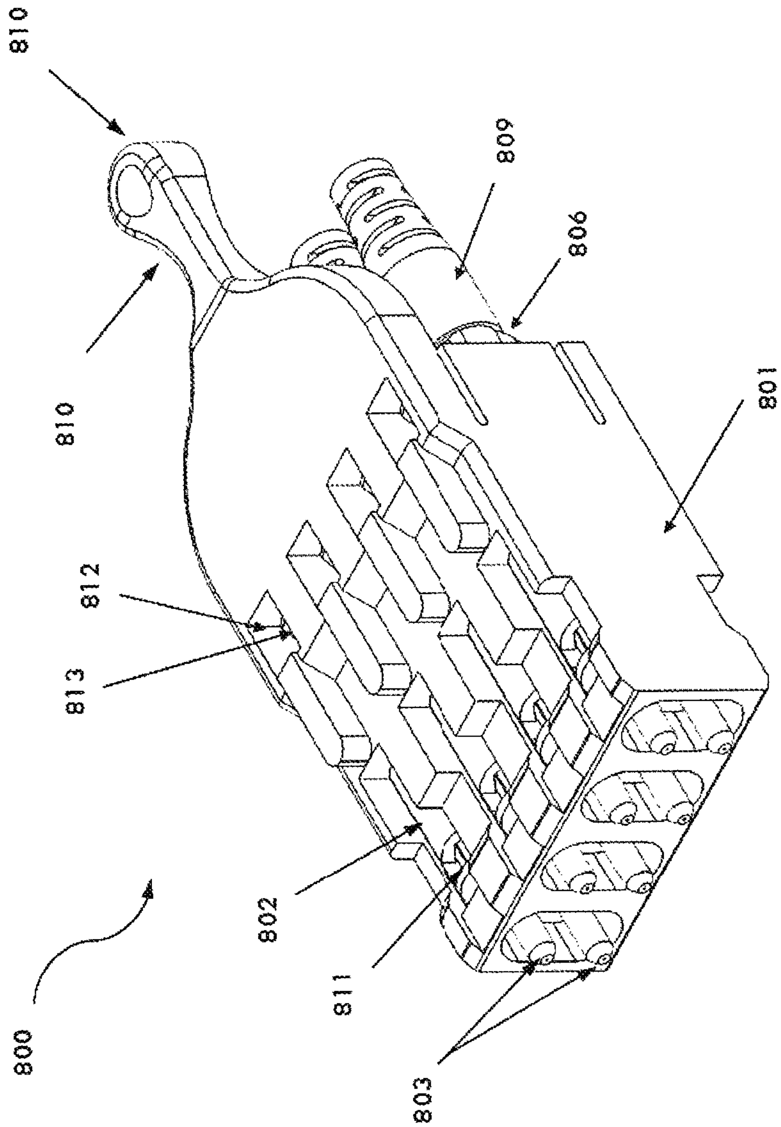


FIG. 8

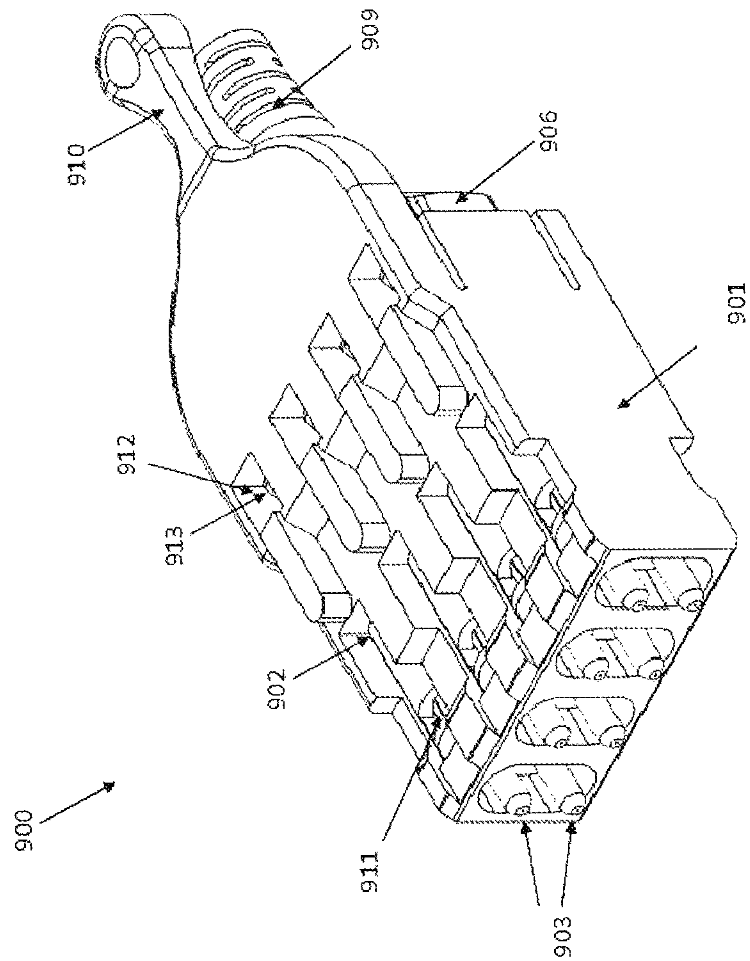


FIG. 9

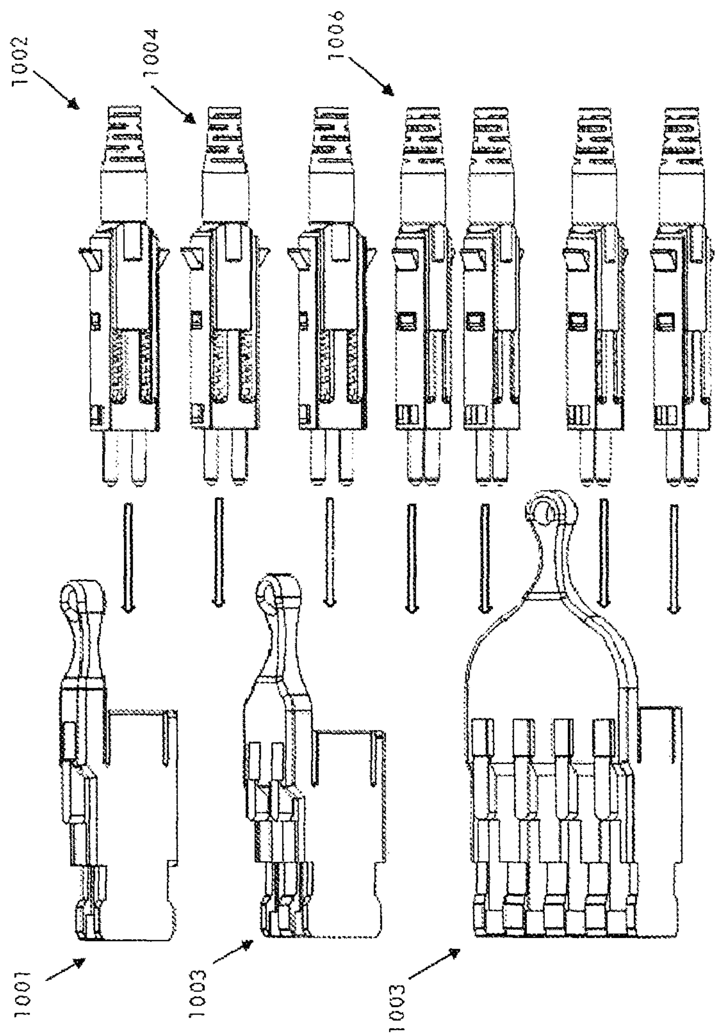


FIG. 10

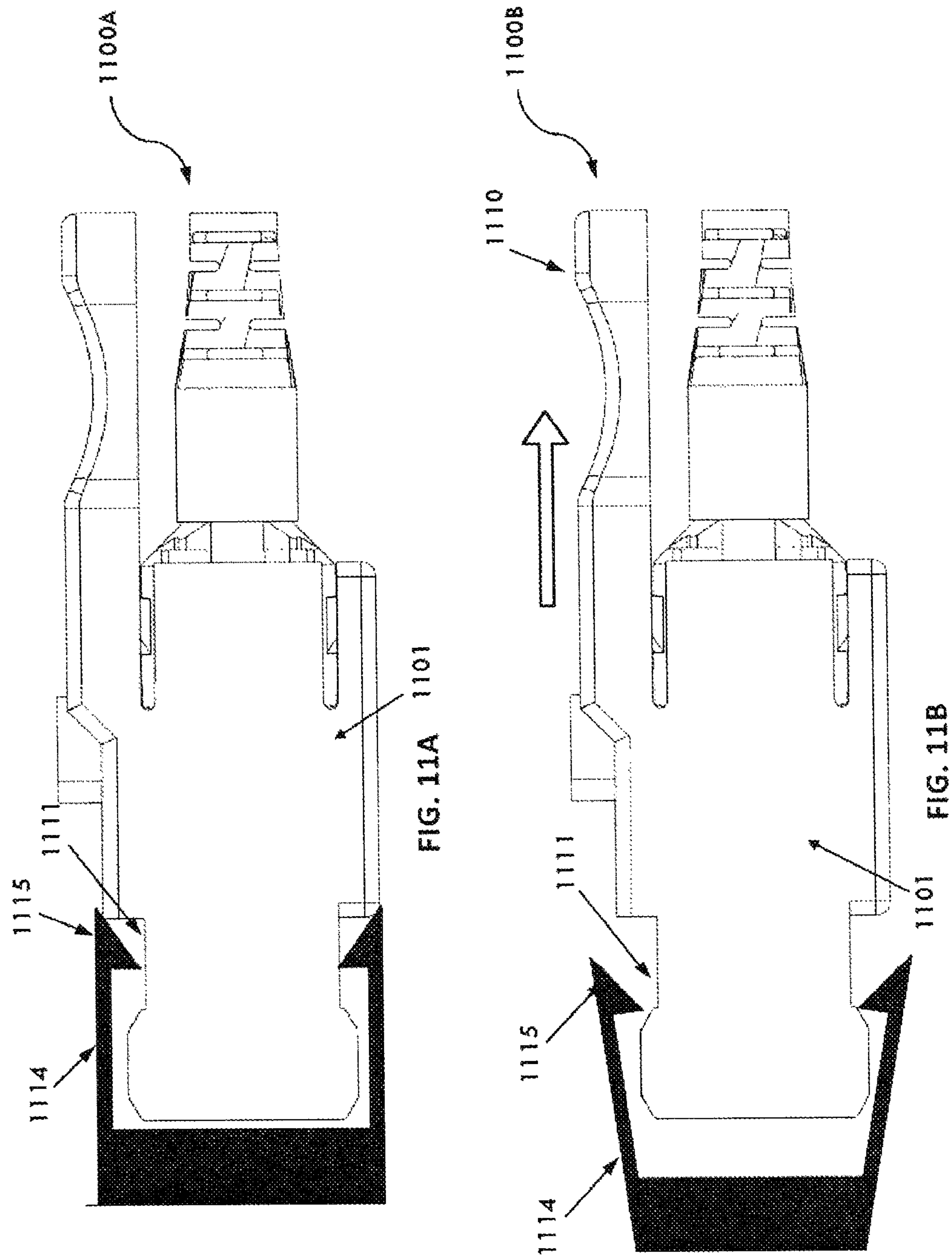


FIG. 11A

FIG. 11B

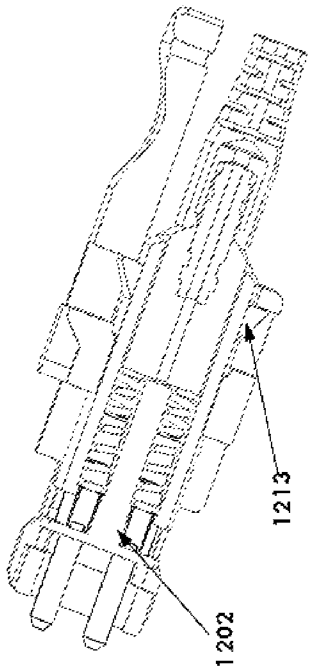


FIG. 12B

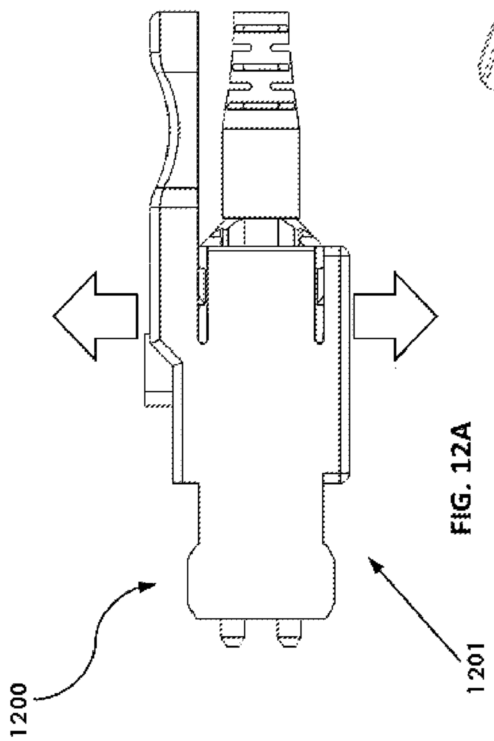


FIG. 12A

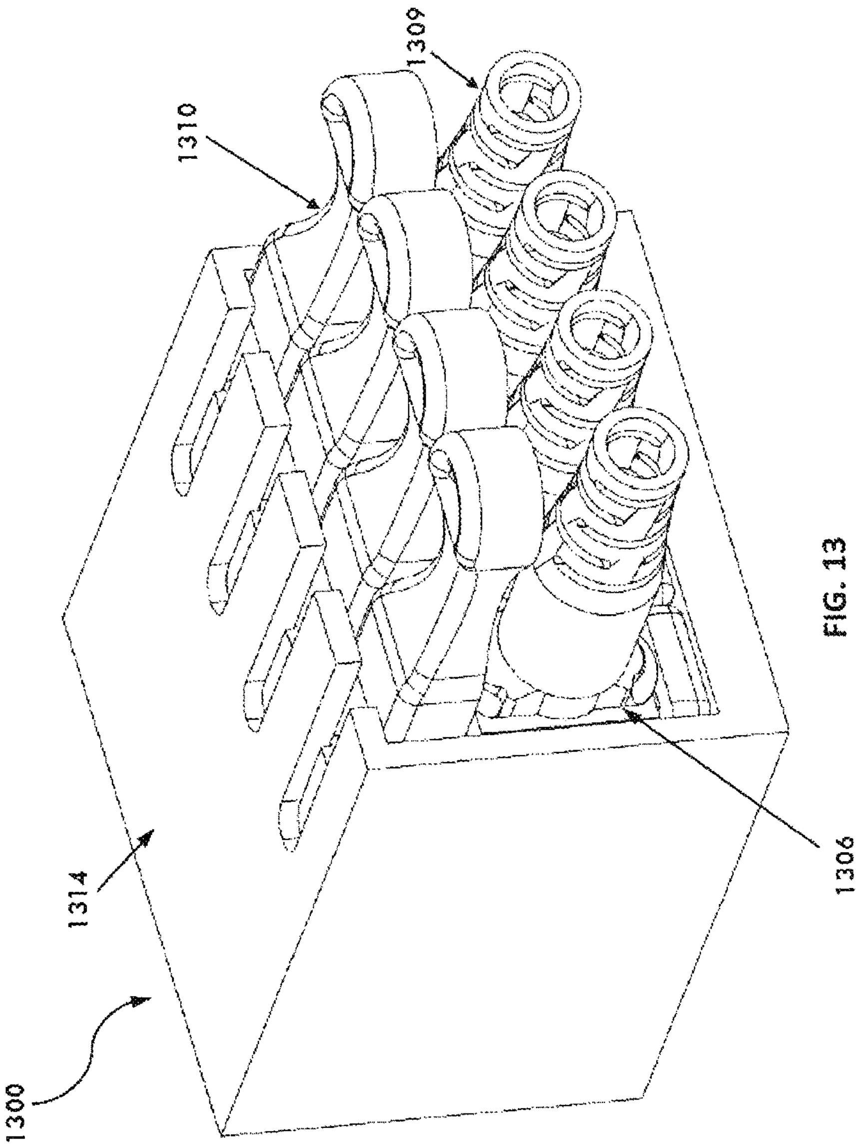


FIG. 13

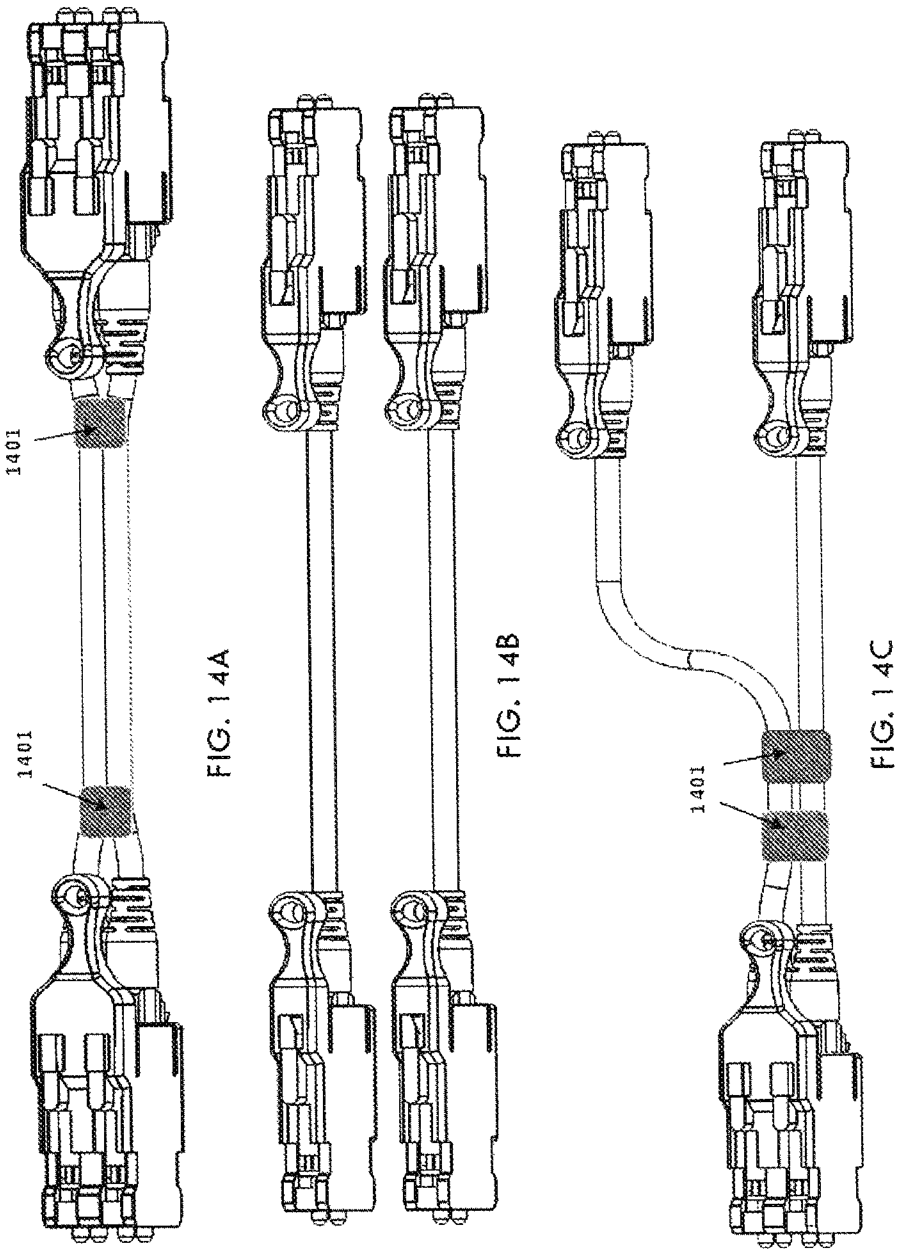


FIG. 14A

FIG. 14B

FIG. 14C

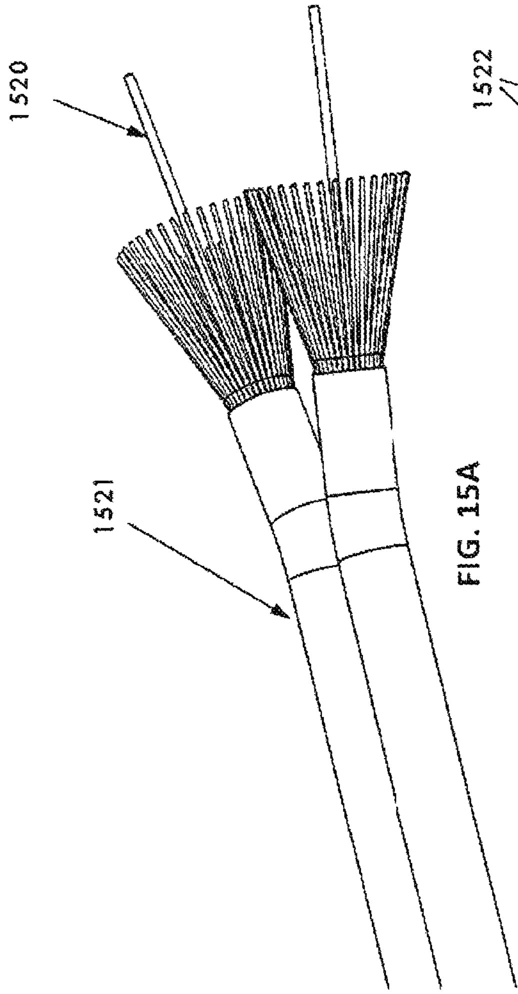


FIG. 15A

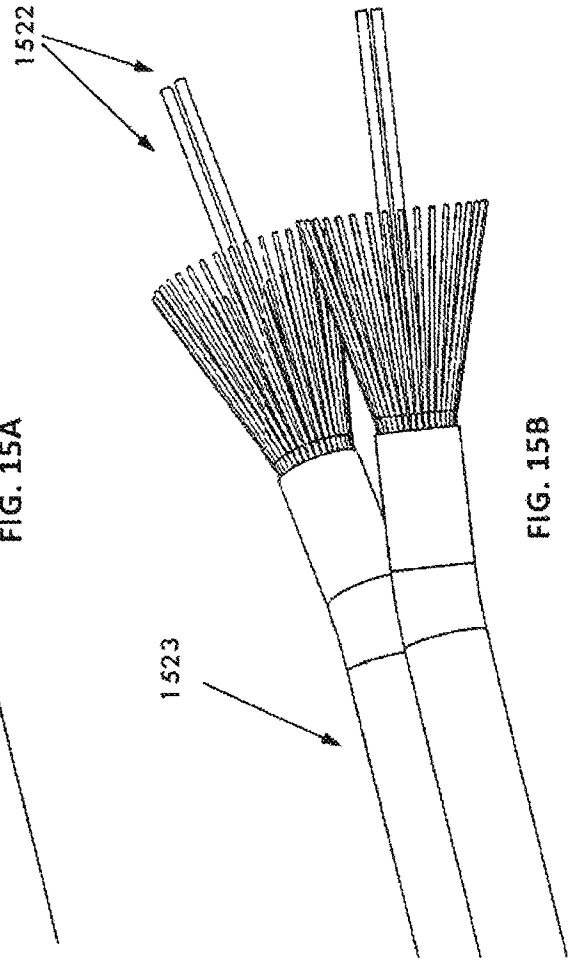
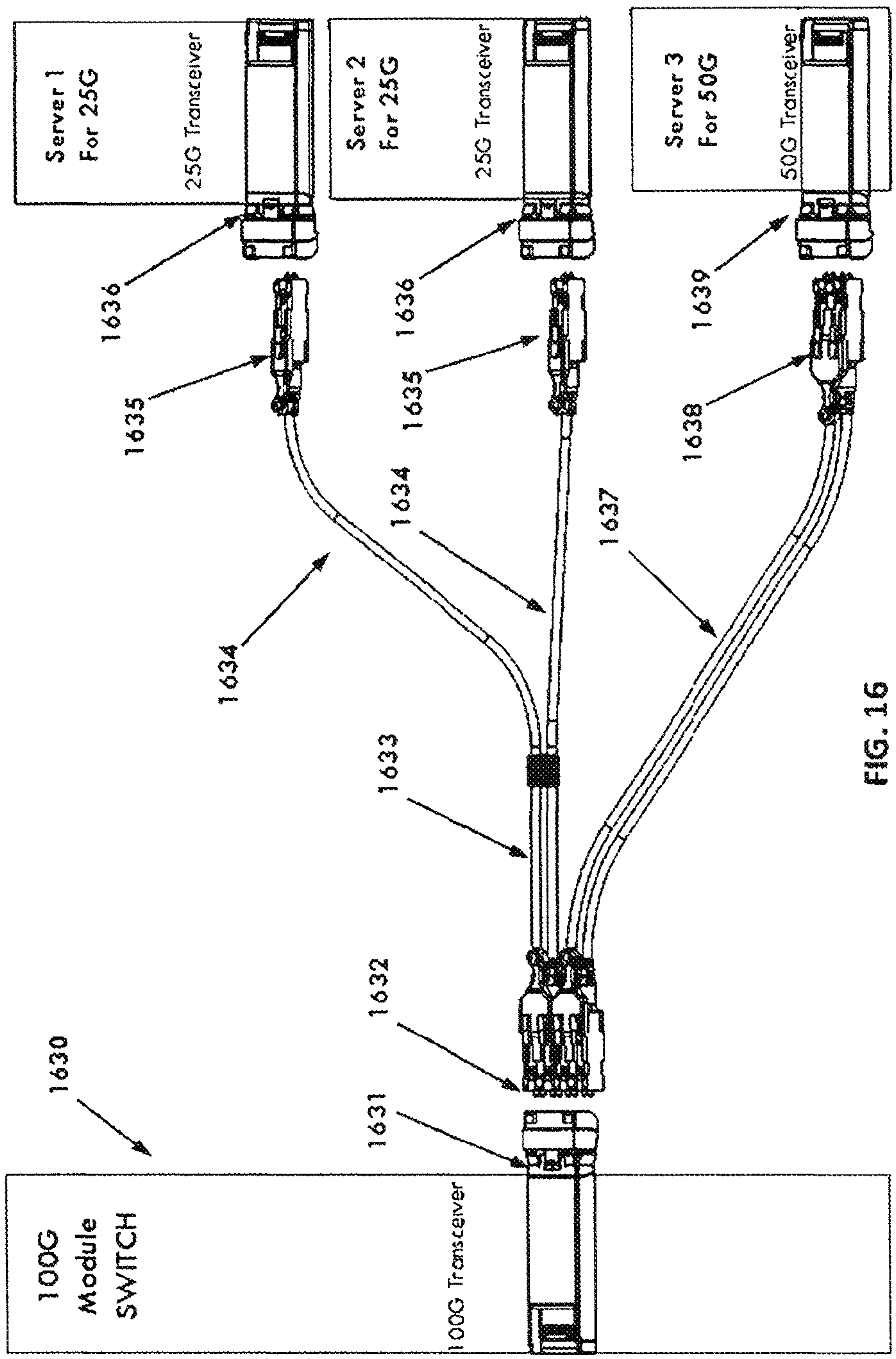


FIG. 15B



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For 25G
25G Transceiver
Server 2
For 25G
25G Transceiver
Server 3
For 50G
50G Transceiver
1636
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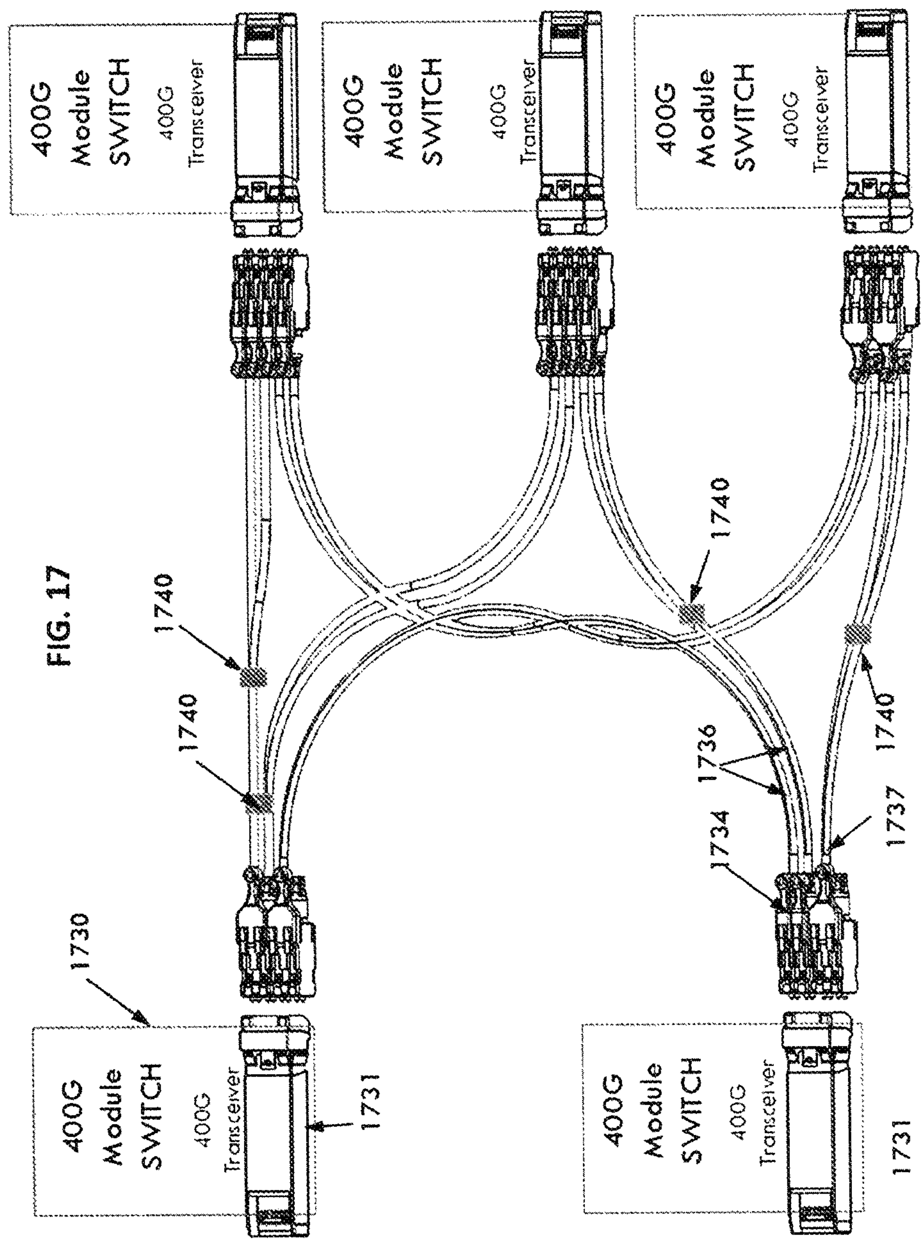
1634
1633
1632
1631
1630
100G
Module
SWITCH
100G Transceiver

FIG. 16

FIG. 17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400G
Transceiver
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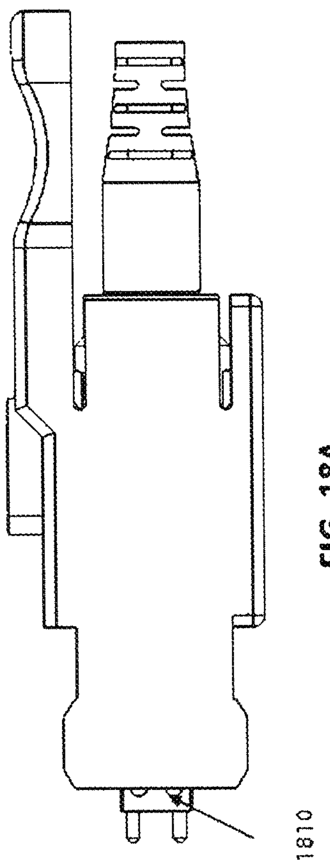

FIG. 18A

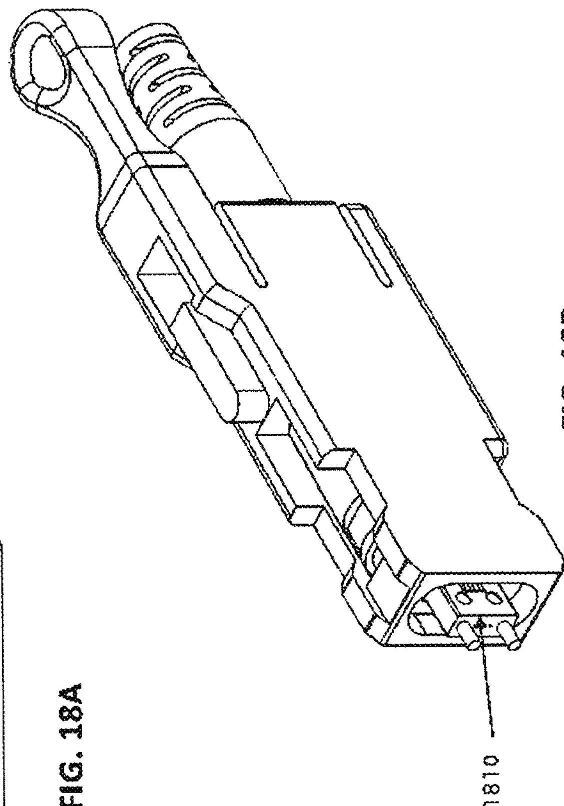

FIG. 18B

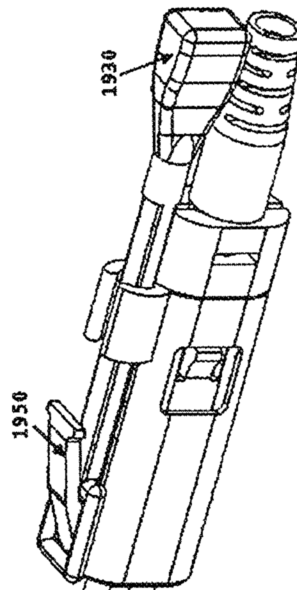

FIG. 19B

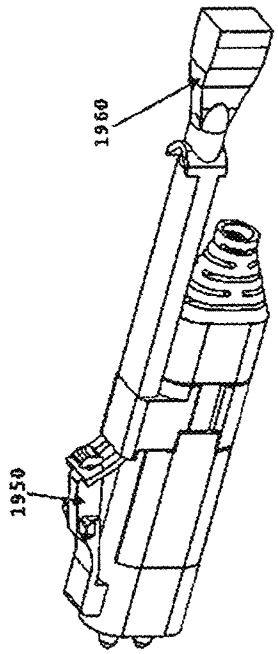

FIG. 19D

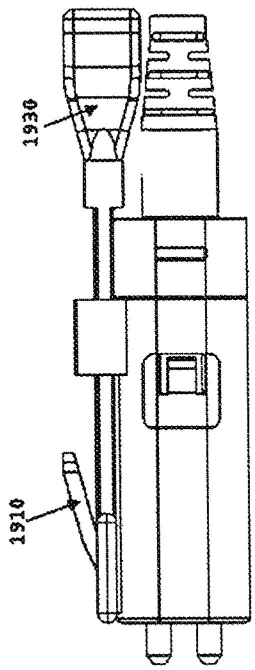

FIG. 19A

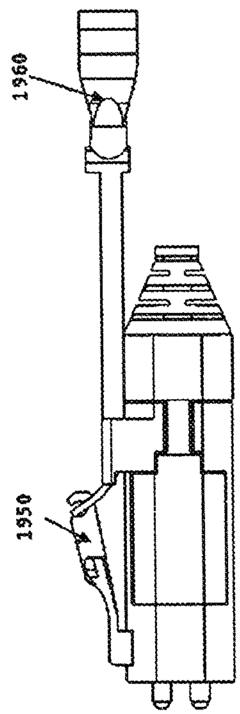

FIG. 19C

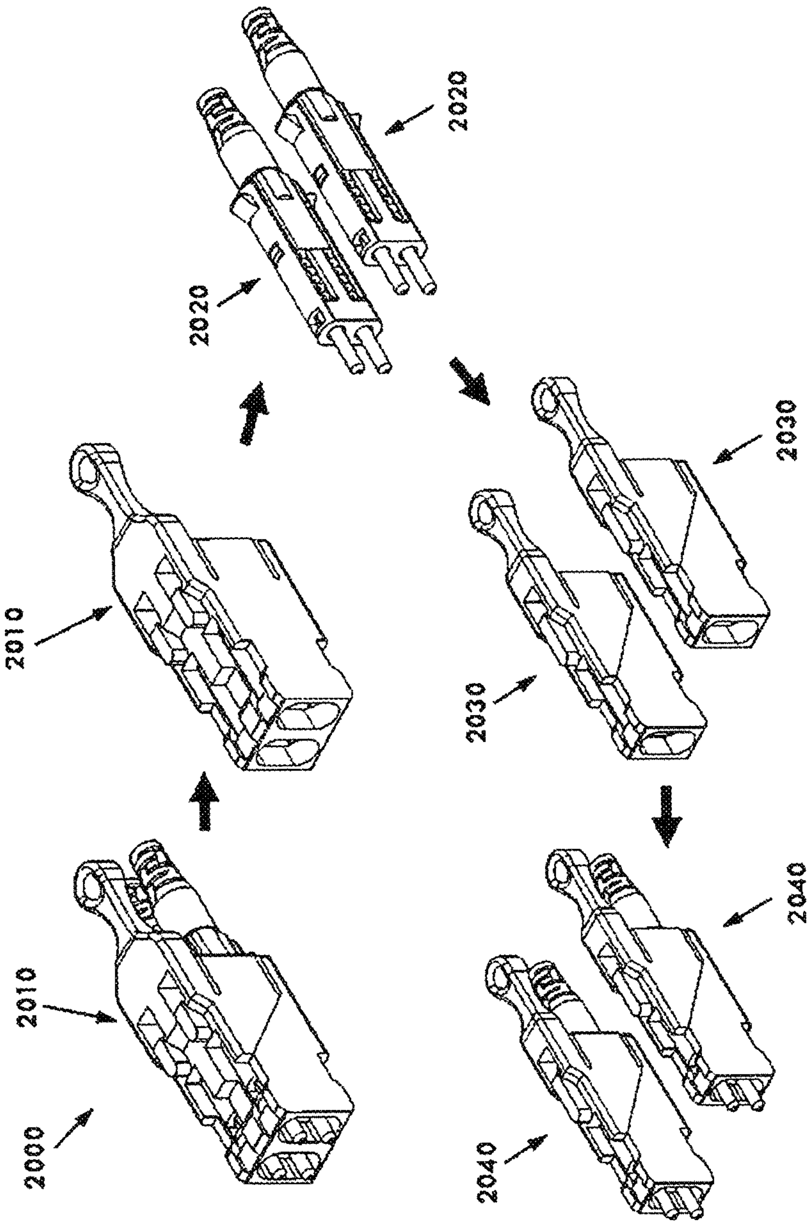

FIG. 20

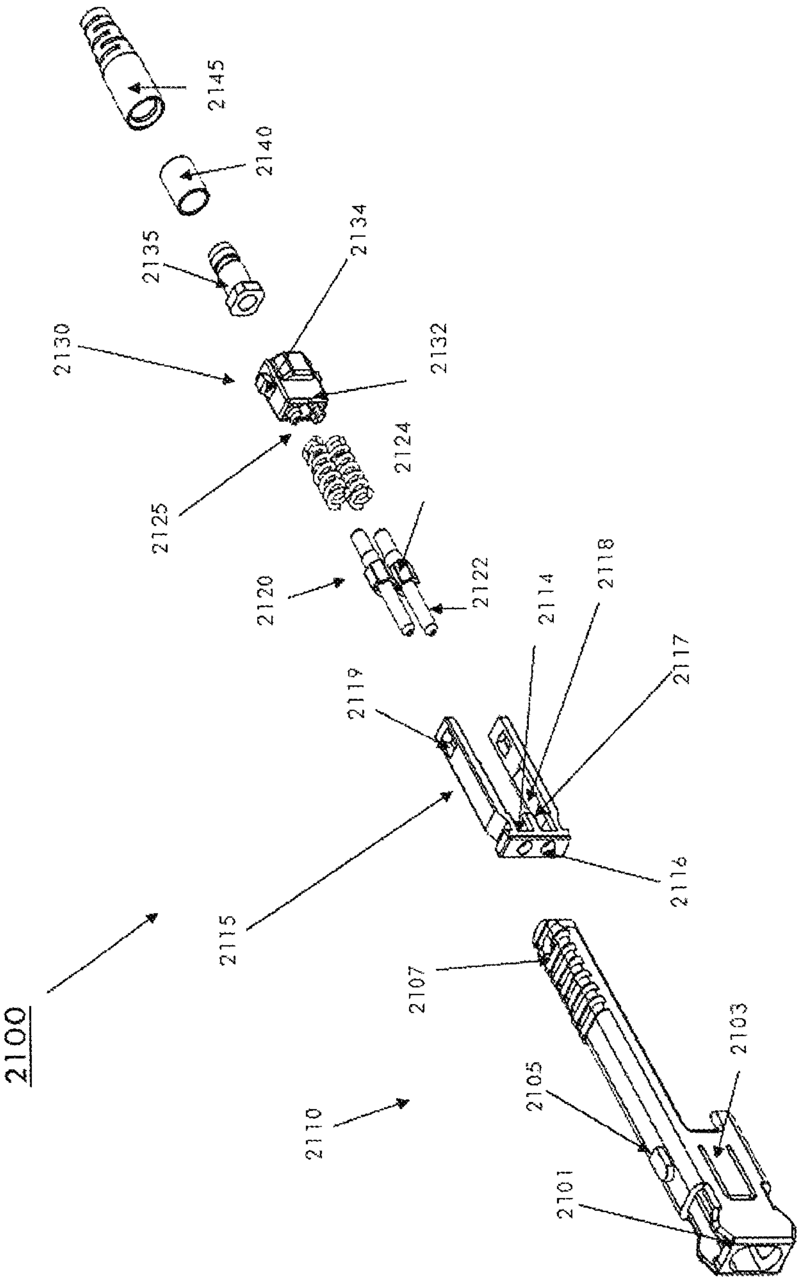
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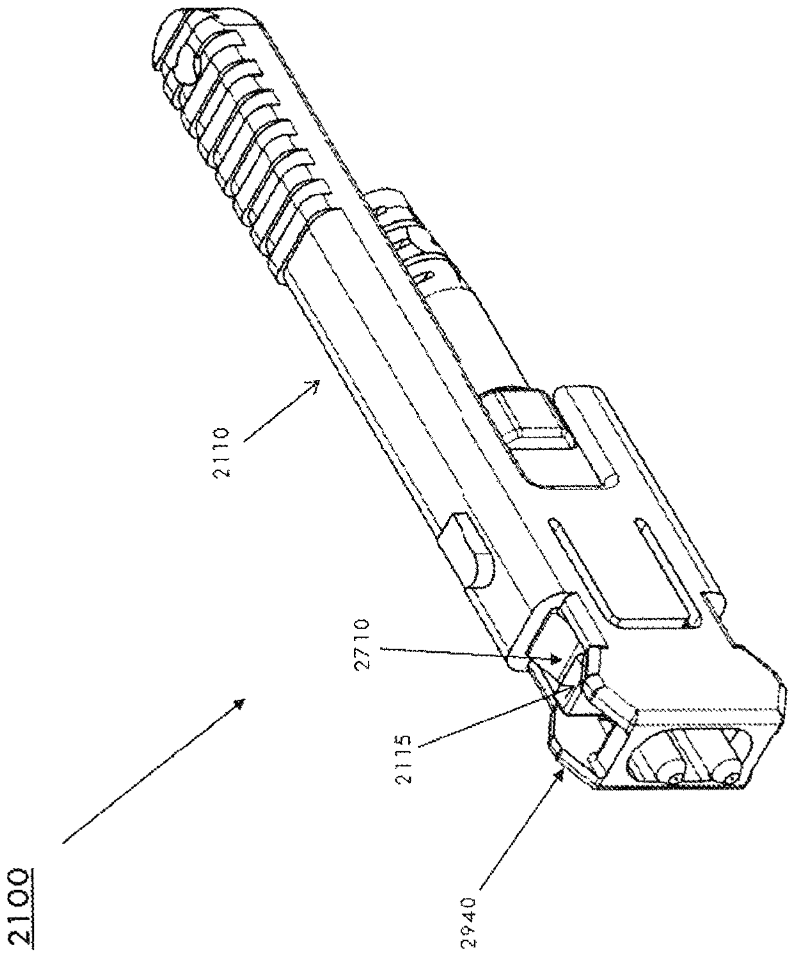
FIG. 21A



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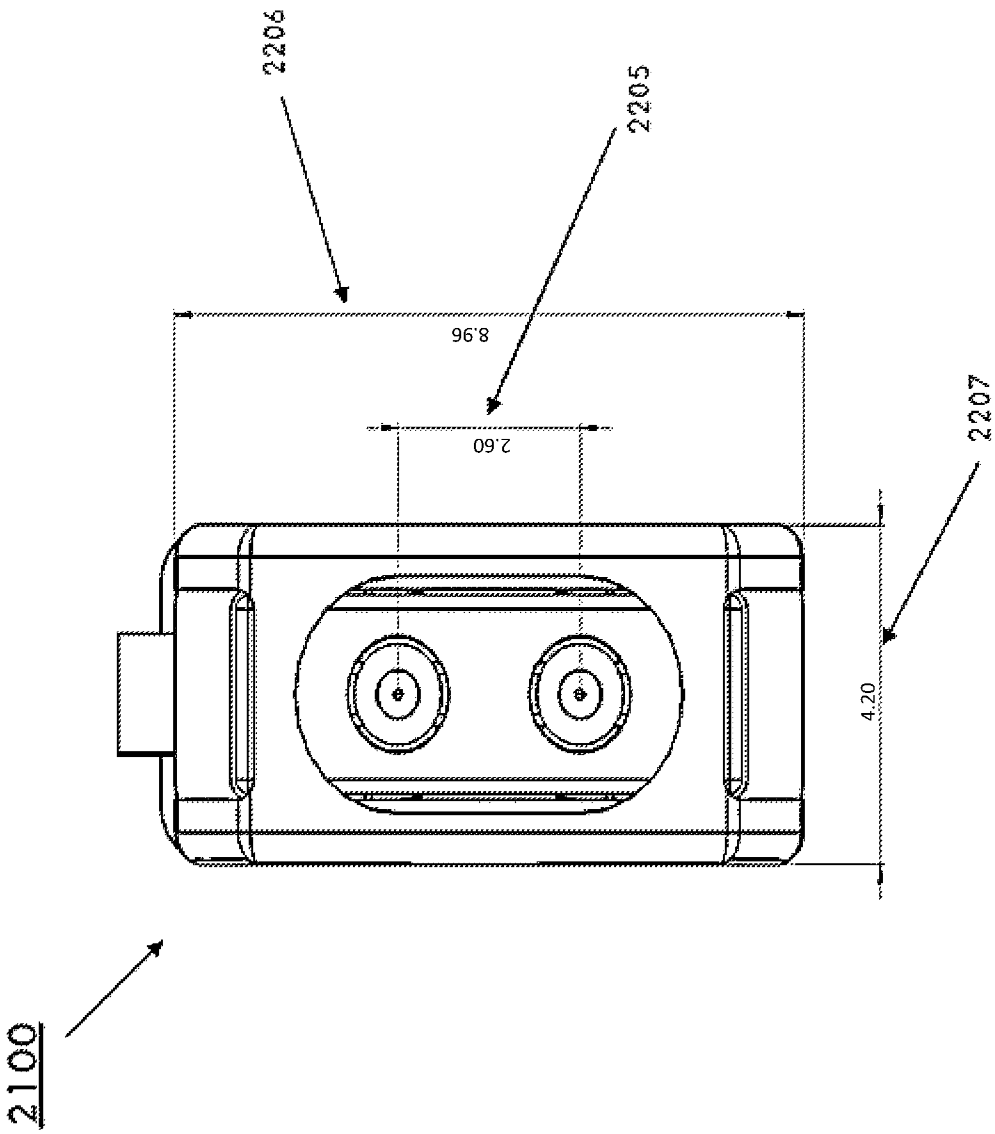

FIG. 22

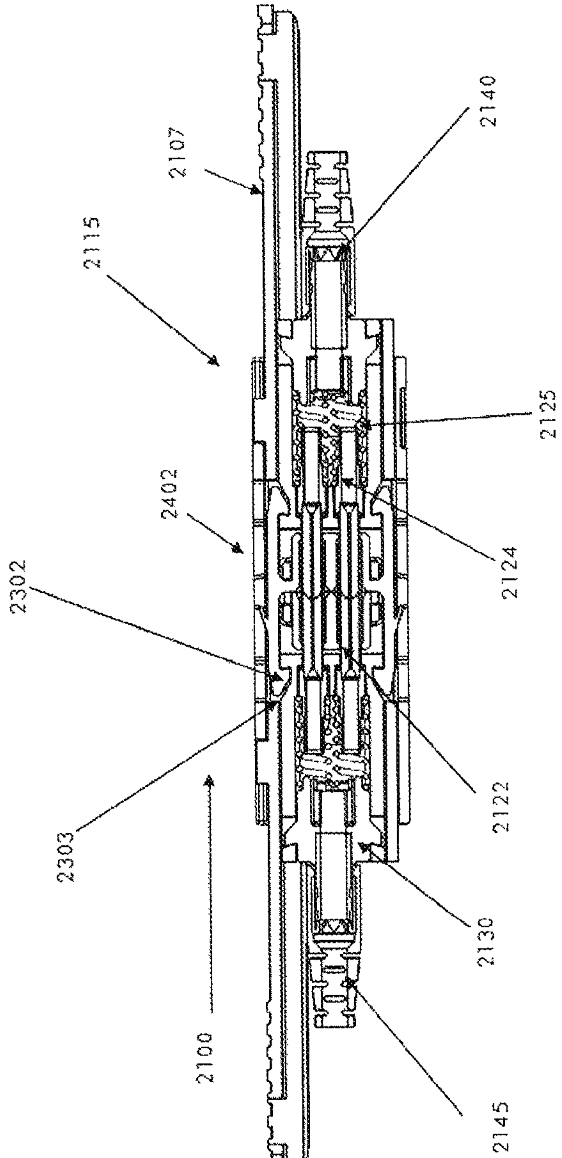

FIG. 23A

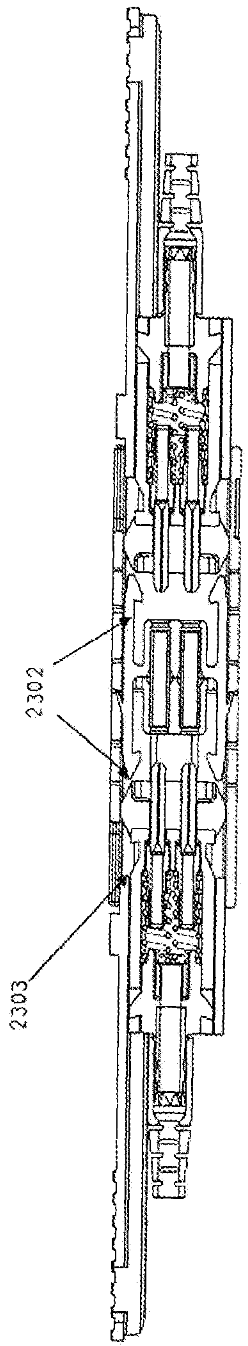

FIG. 23B

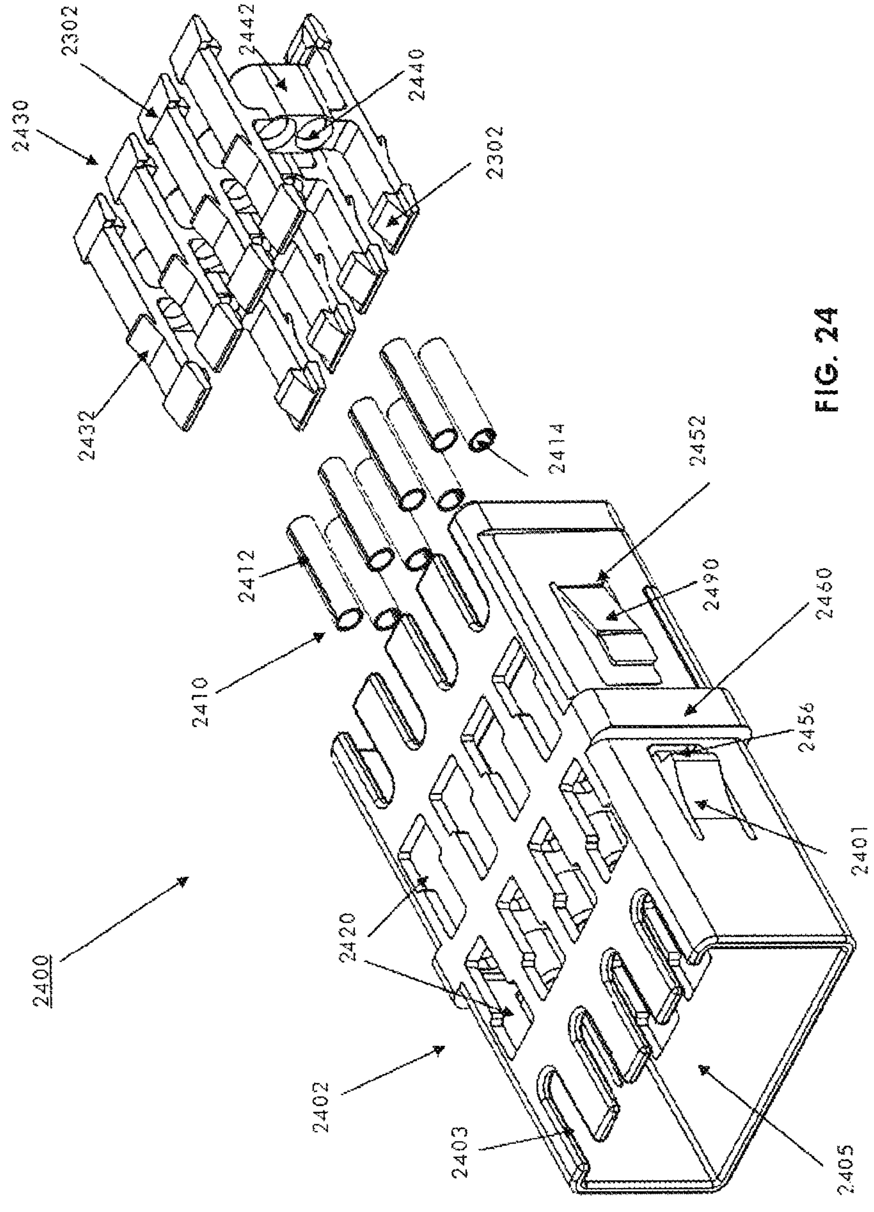
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FIG. 24

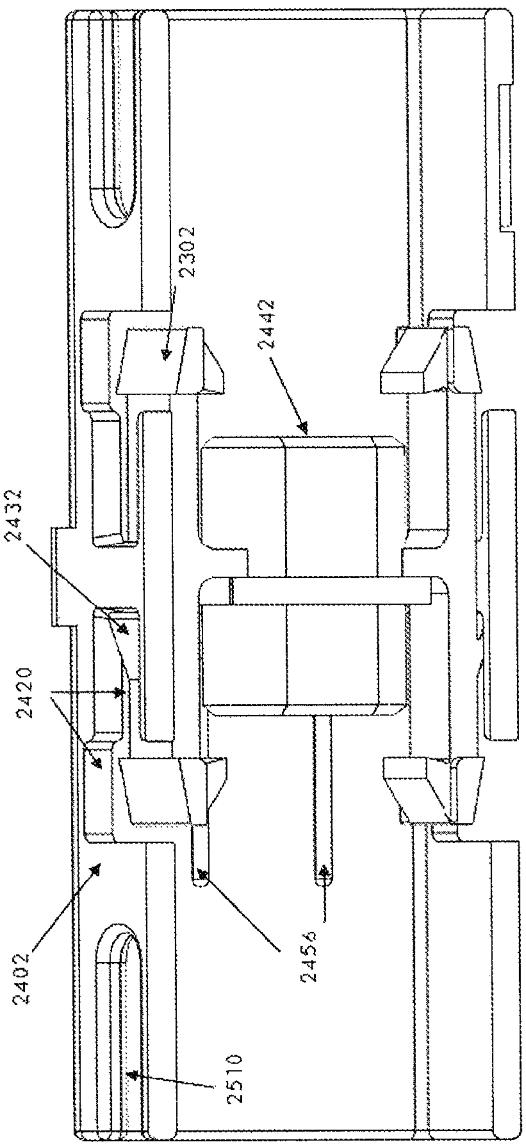

FIG. 25A

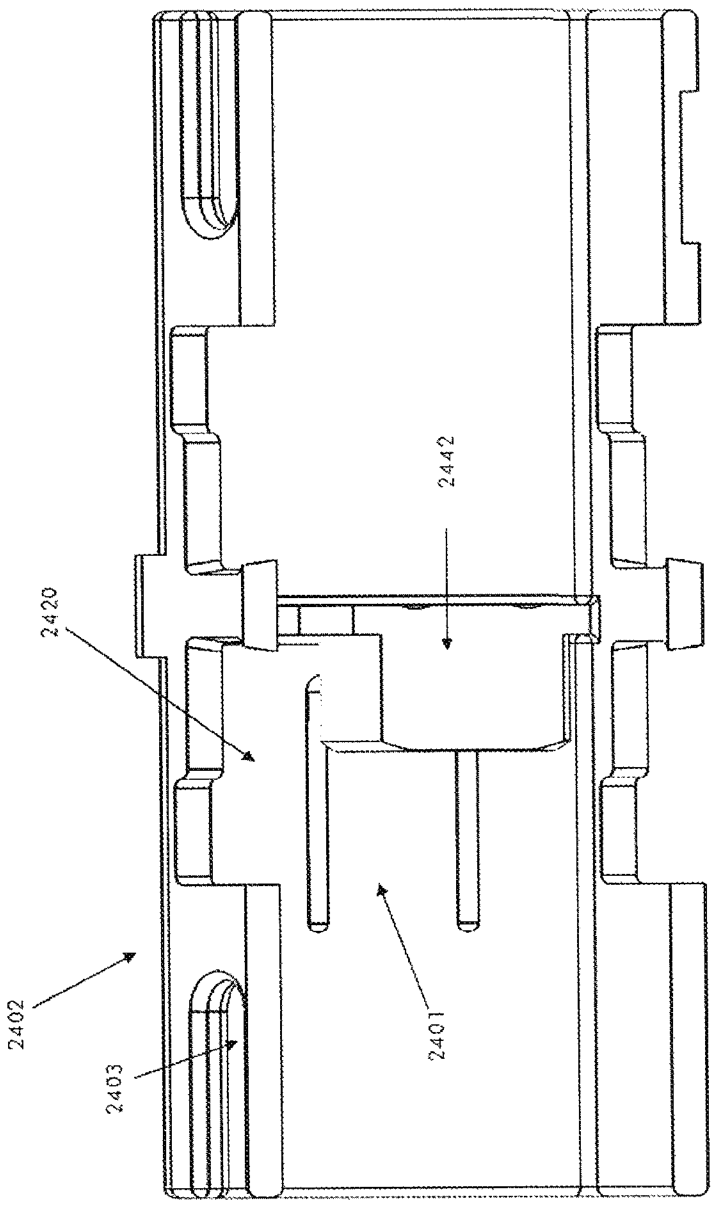

FIG. 25B

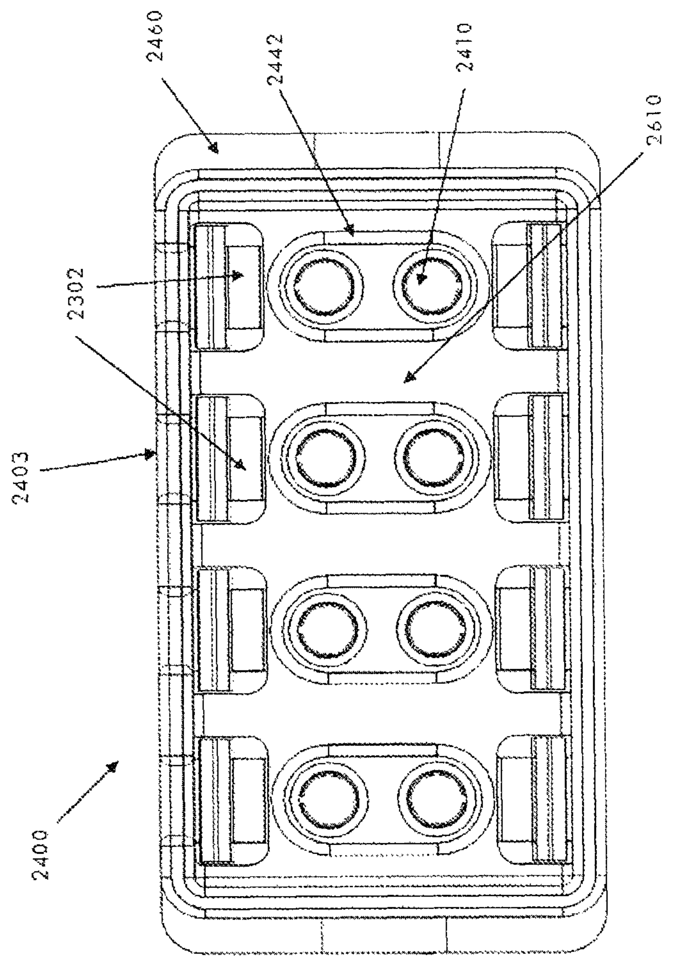

FIG. 26

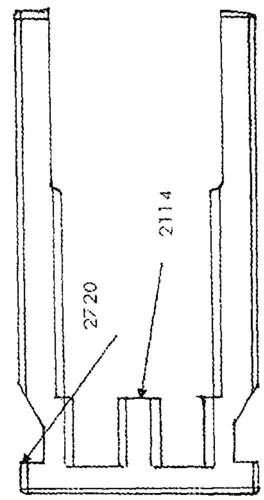

FIG. 27B

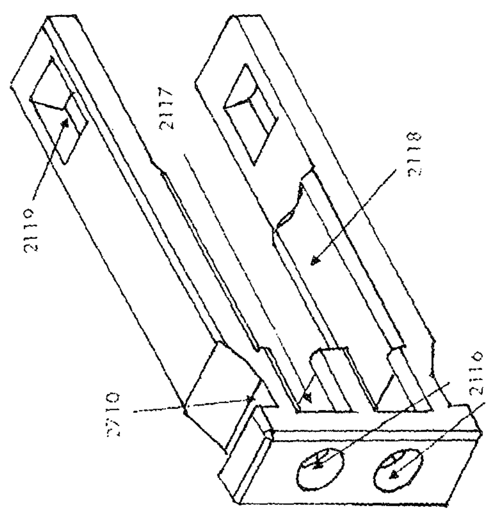

FIG. 27A

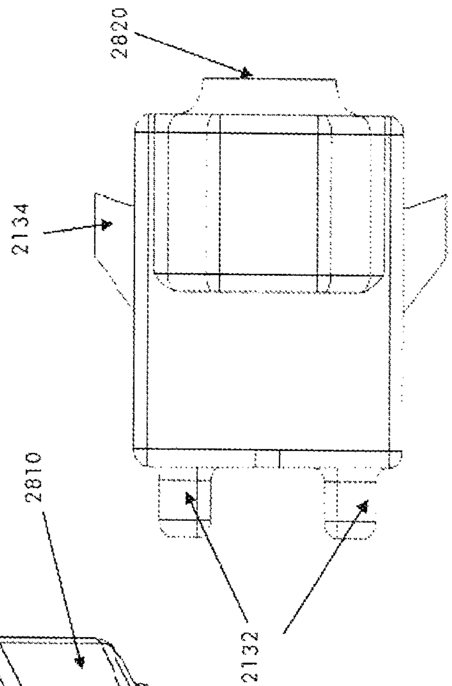

FIG. 28B

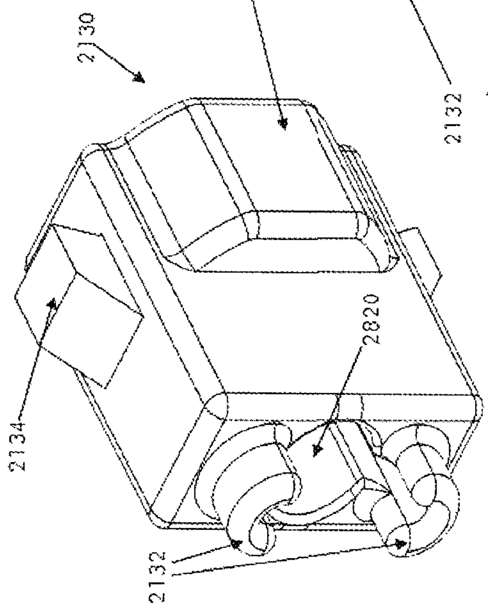

FIG. 28A

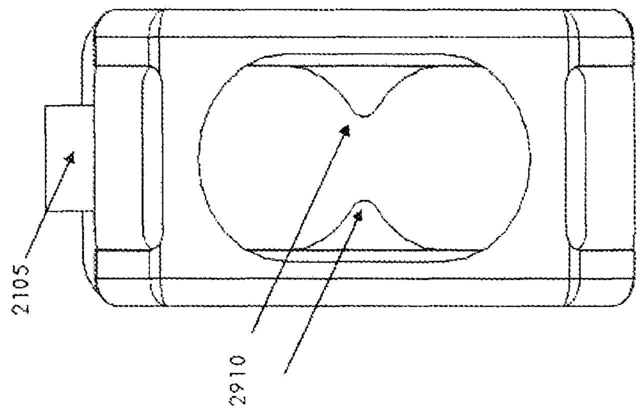

FIG. 29B

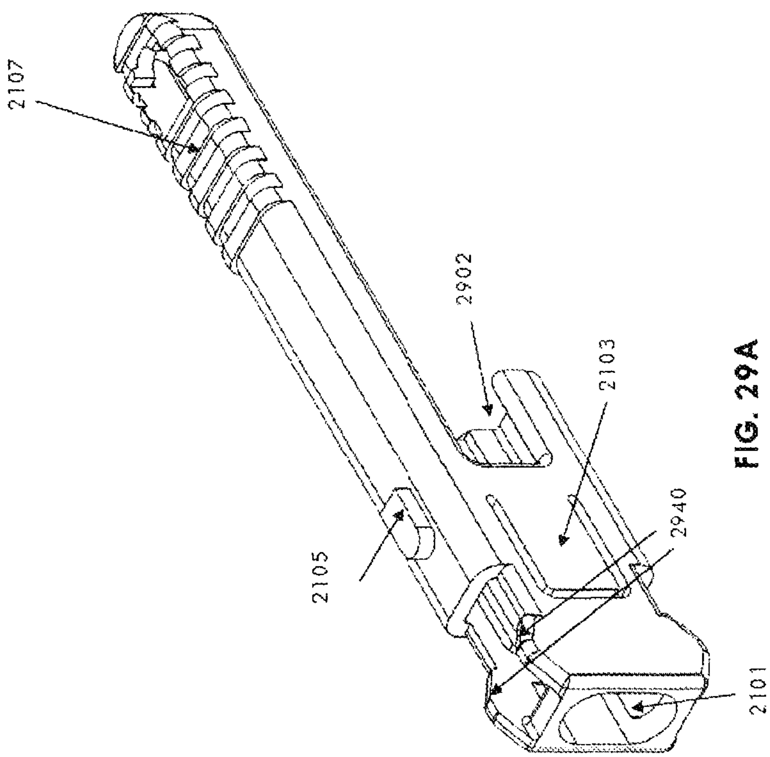

FIG. 29A

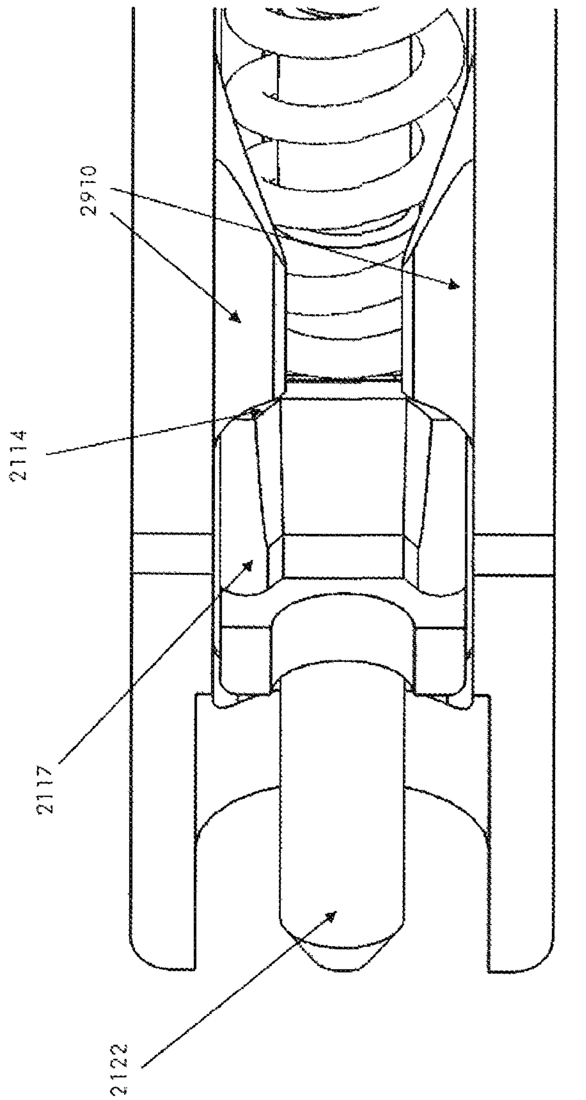

FIG. 29C

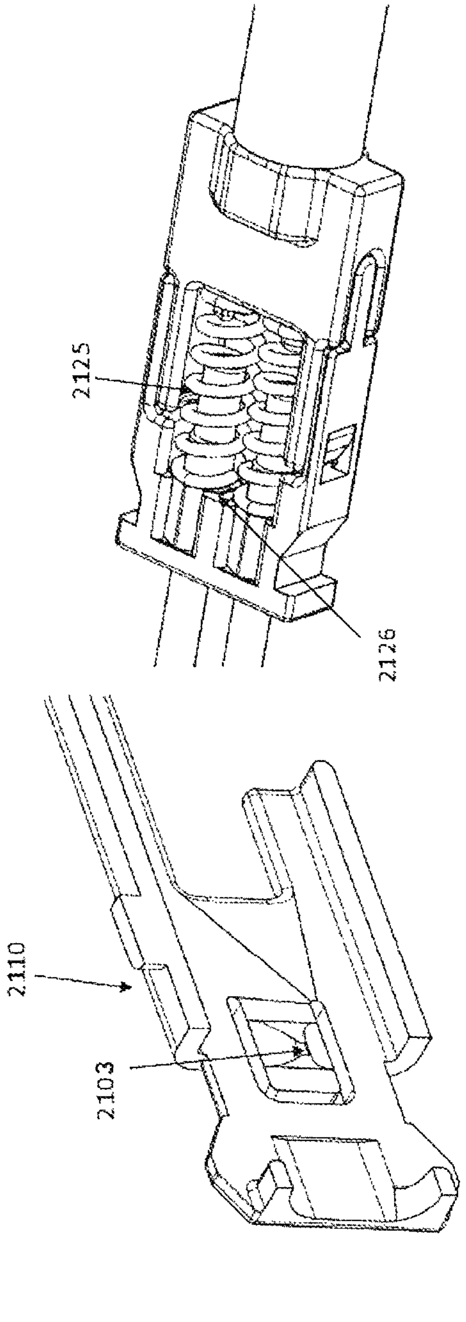

FIG. 29D

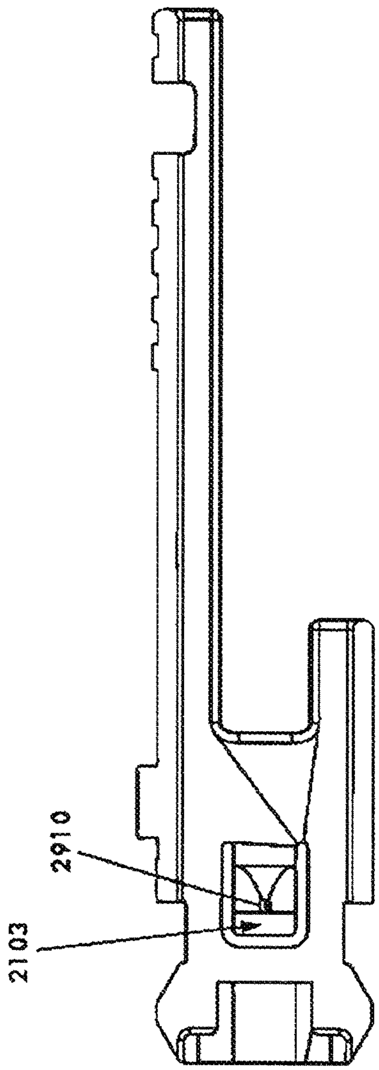

FIG. 29E

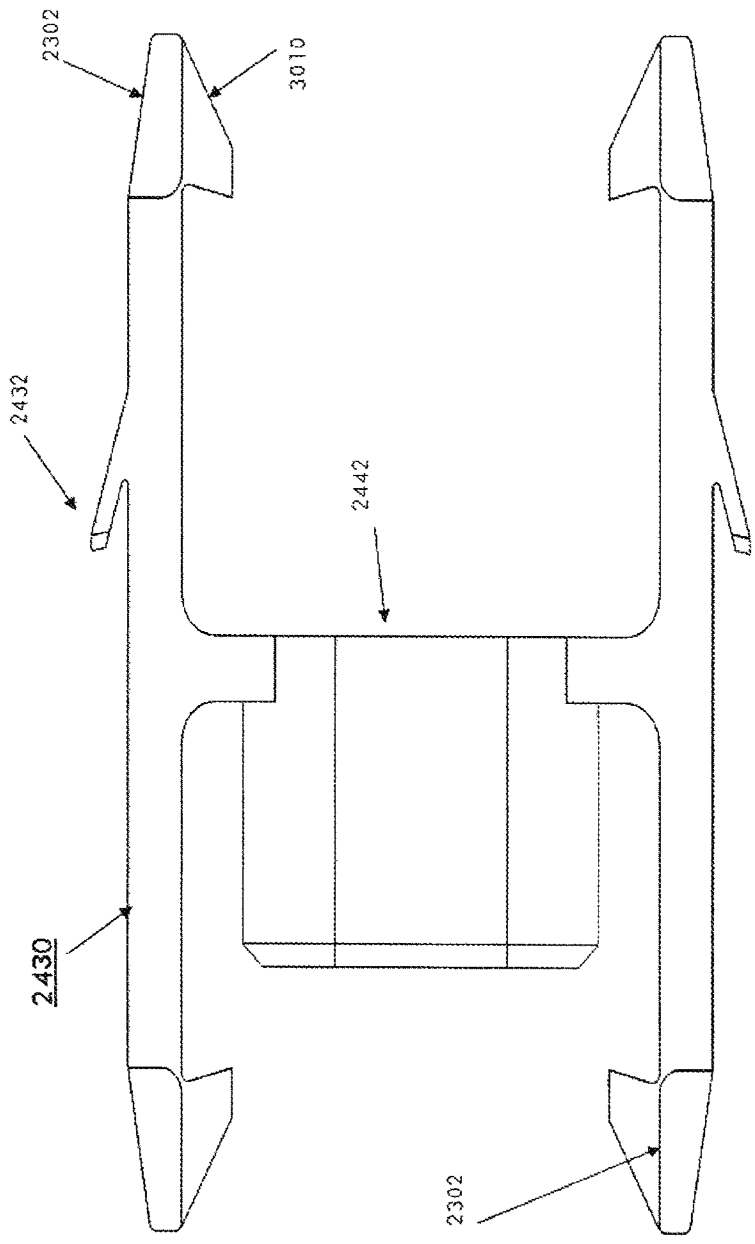

FIG. 30

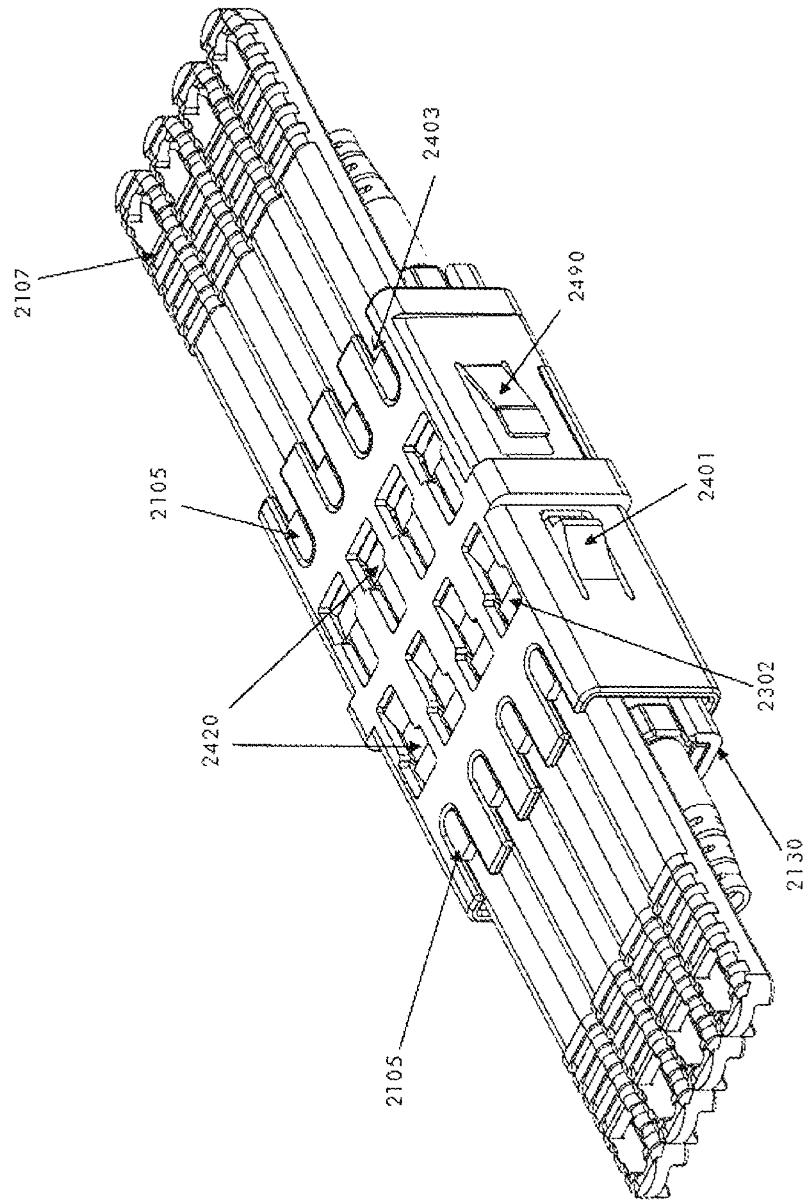

FIG. 31

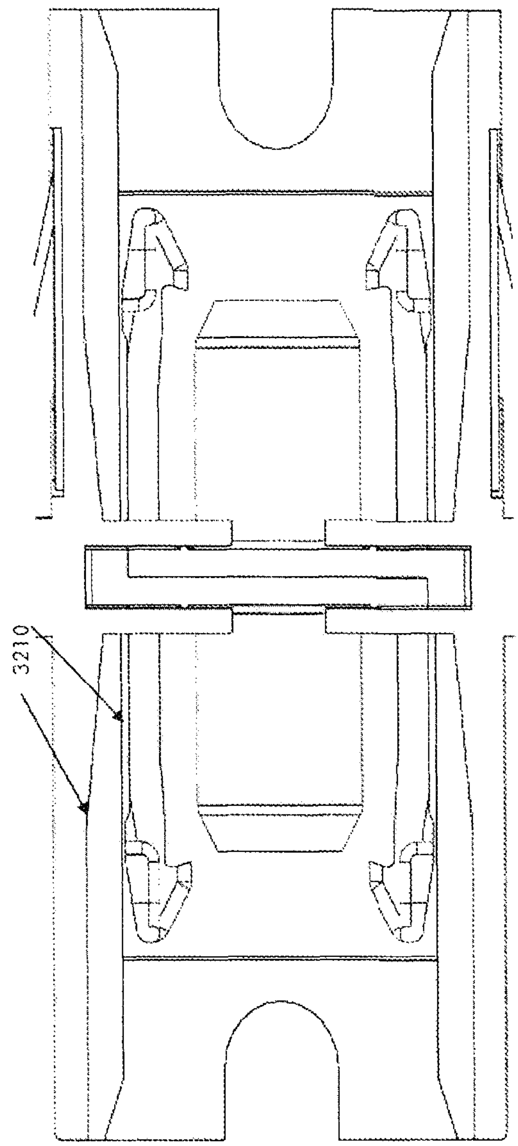

FIG. 32A

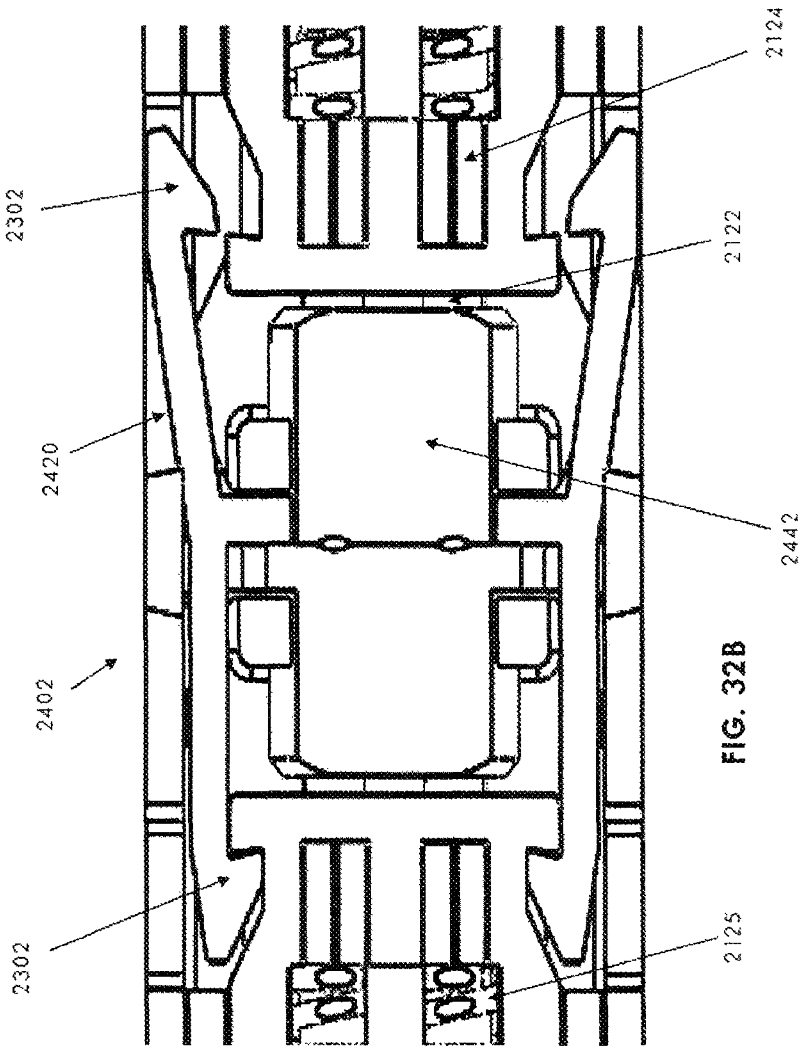

FIG. 32B

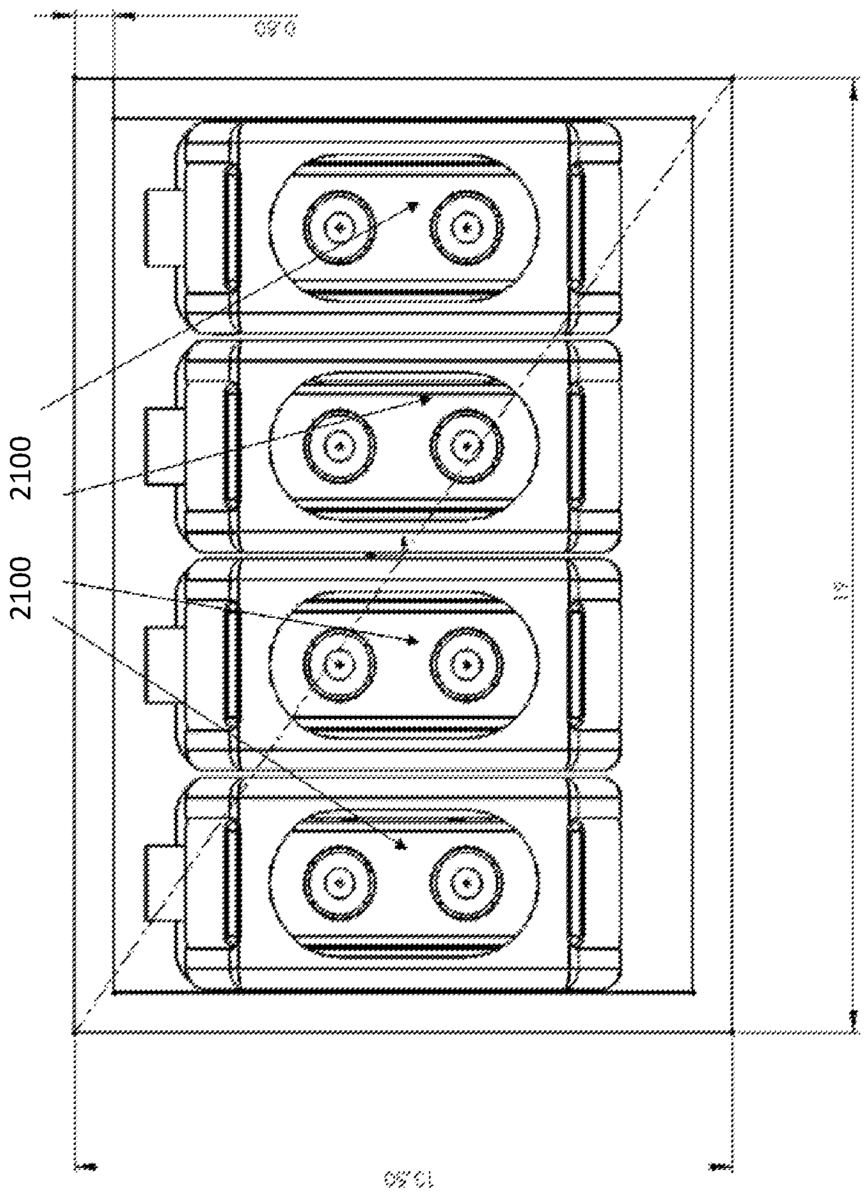

FIG. 33A

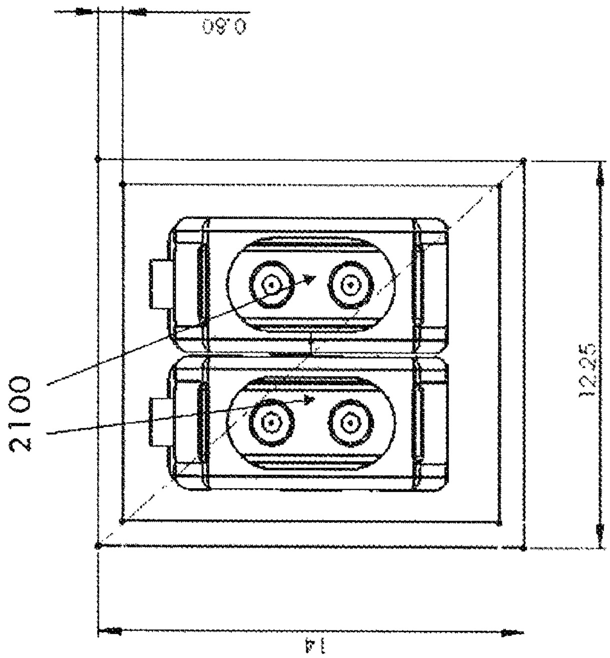

FIG. 33B

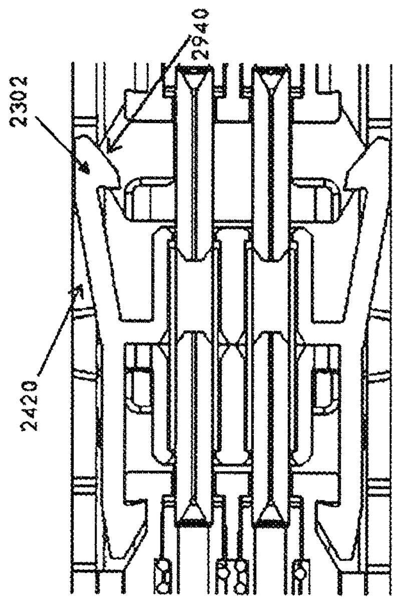

FIG. 34B

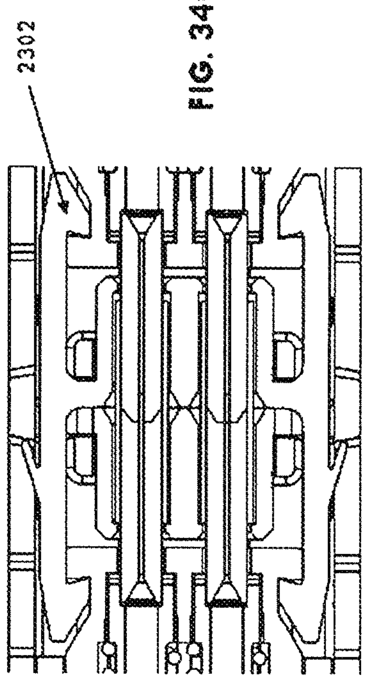

FIG. 34C

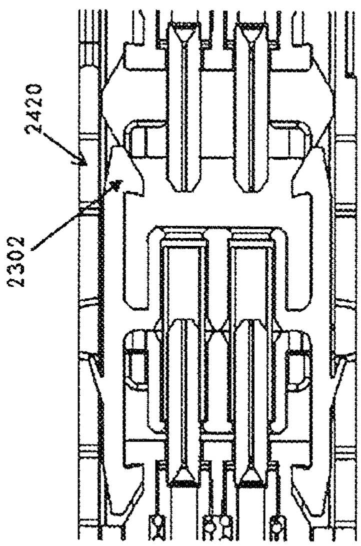

FIG. 34A

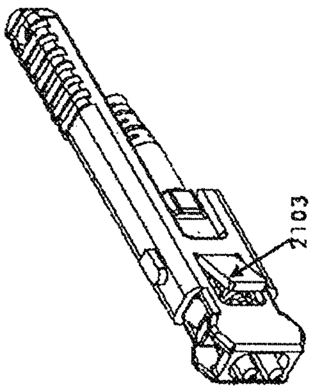

FIG. 35B

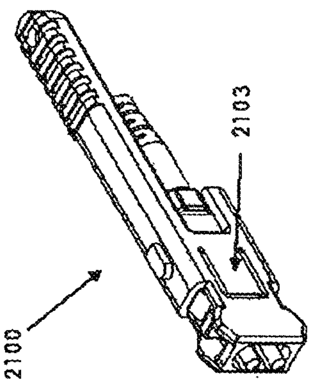

FIG. 35A

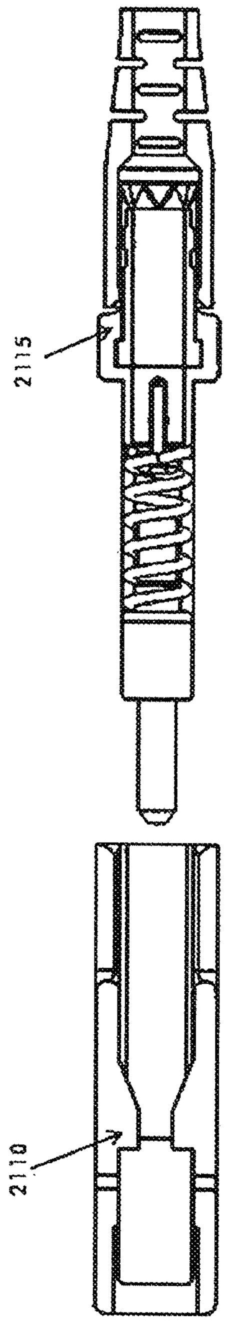

FIG. 35C

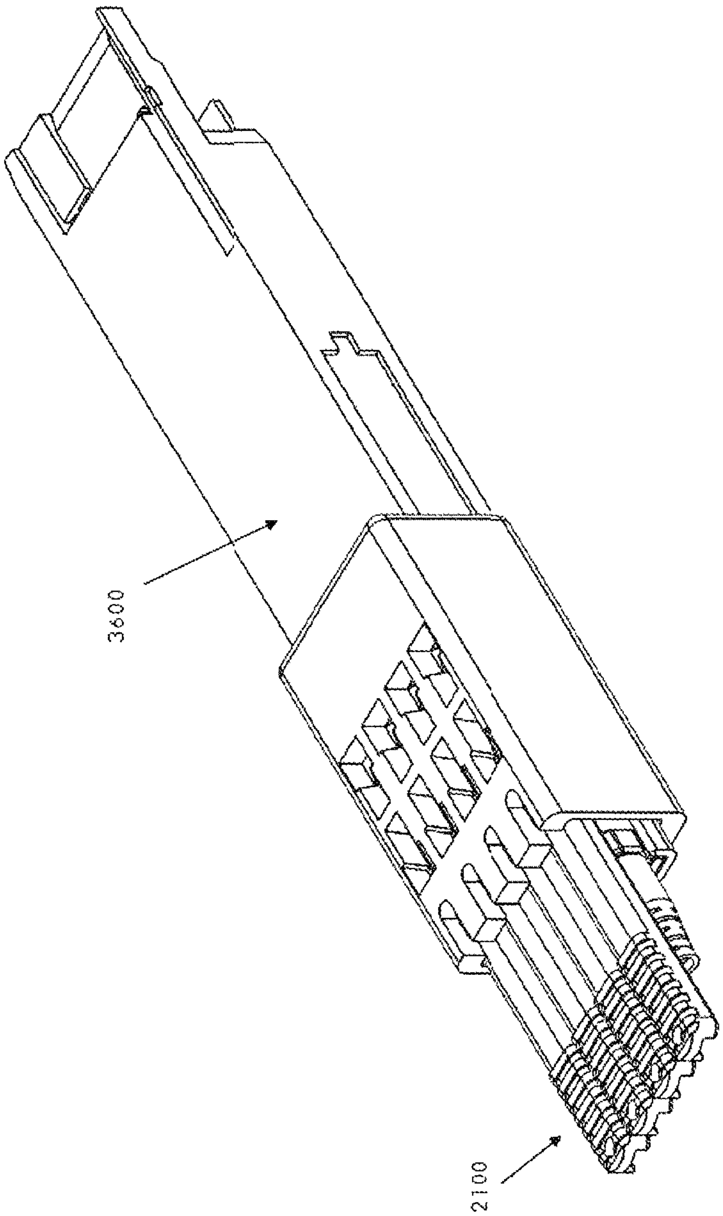

FIG. 36A

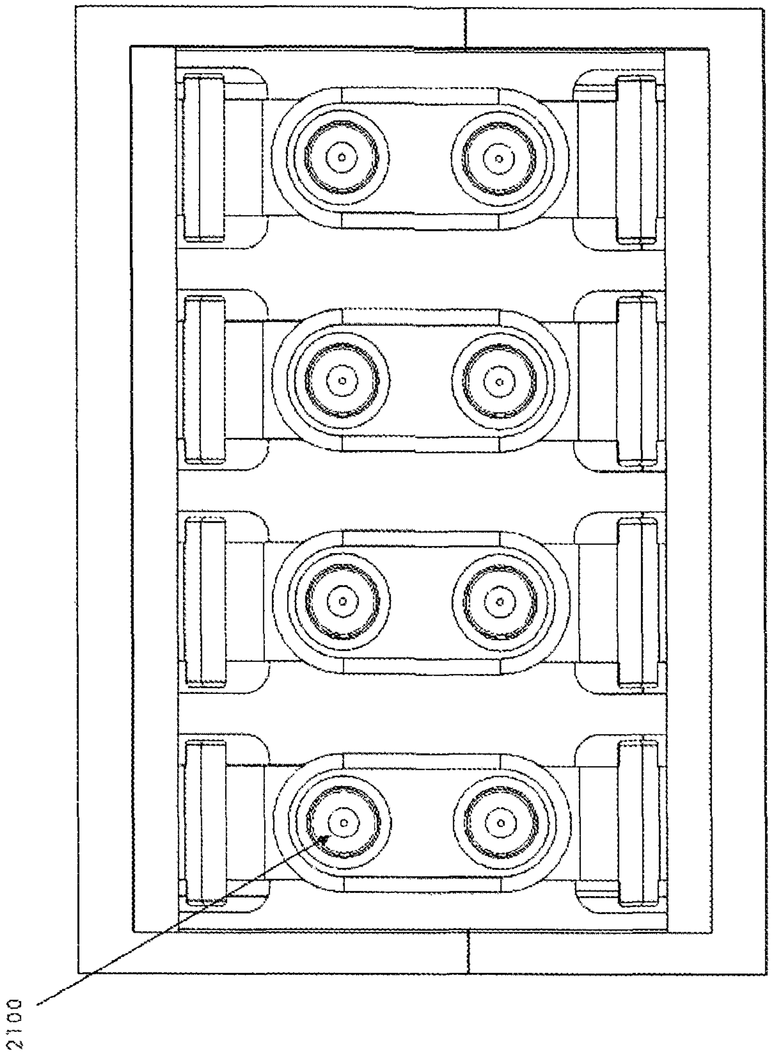

FIG. 36B

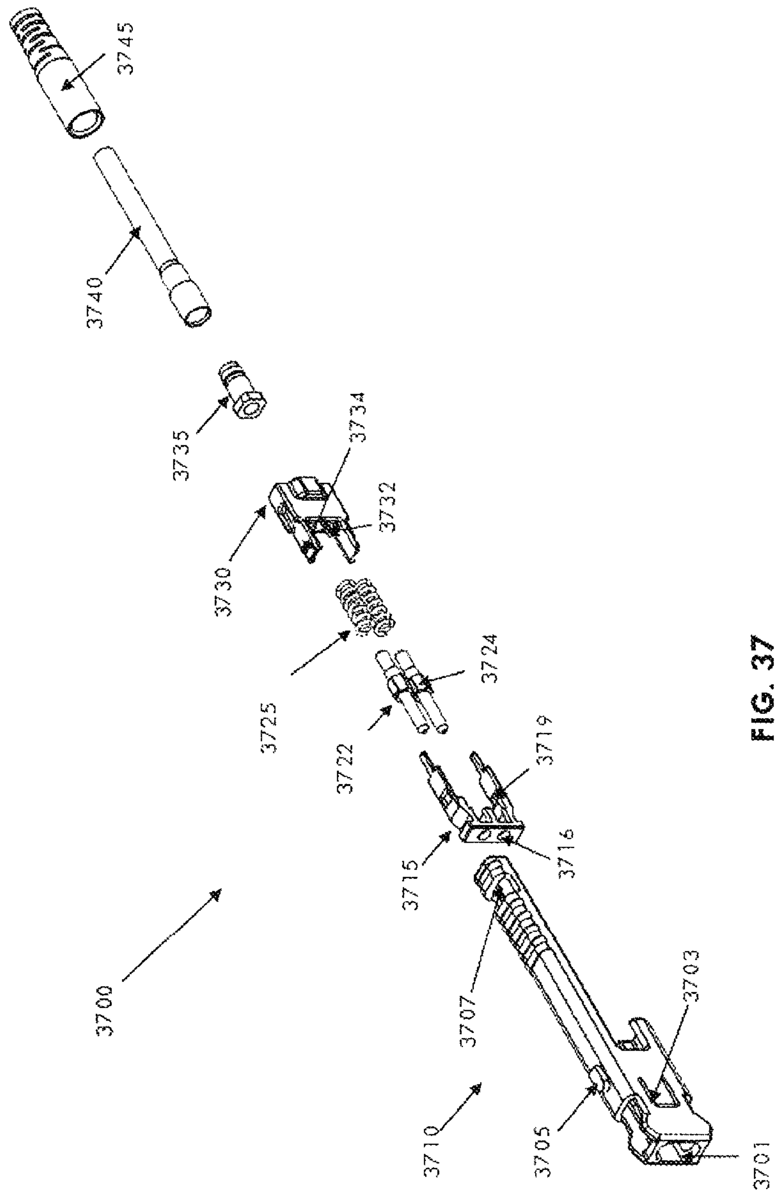
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FIG. 37

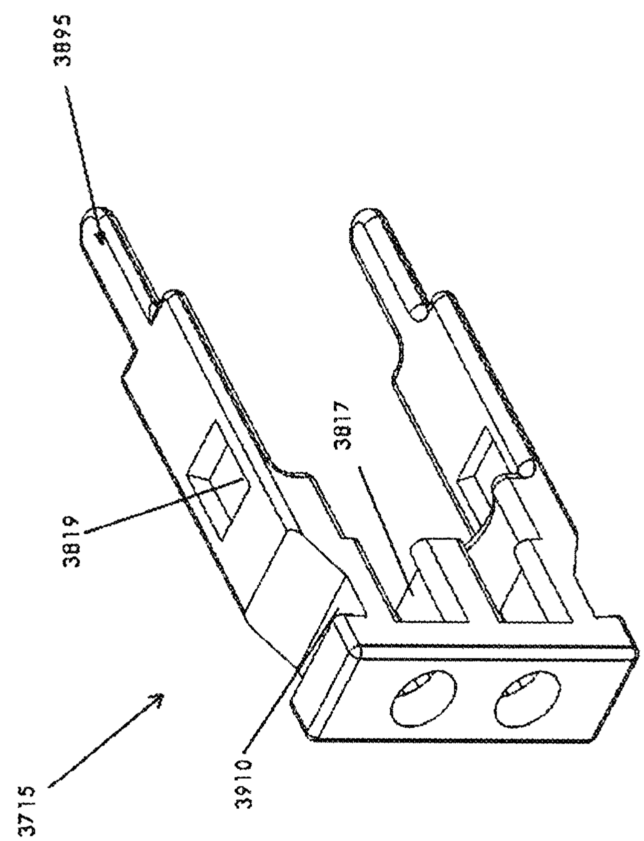

FIG. 38

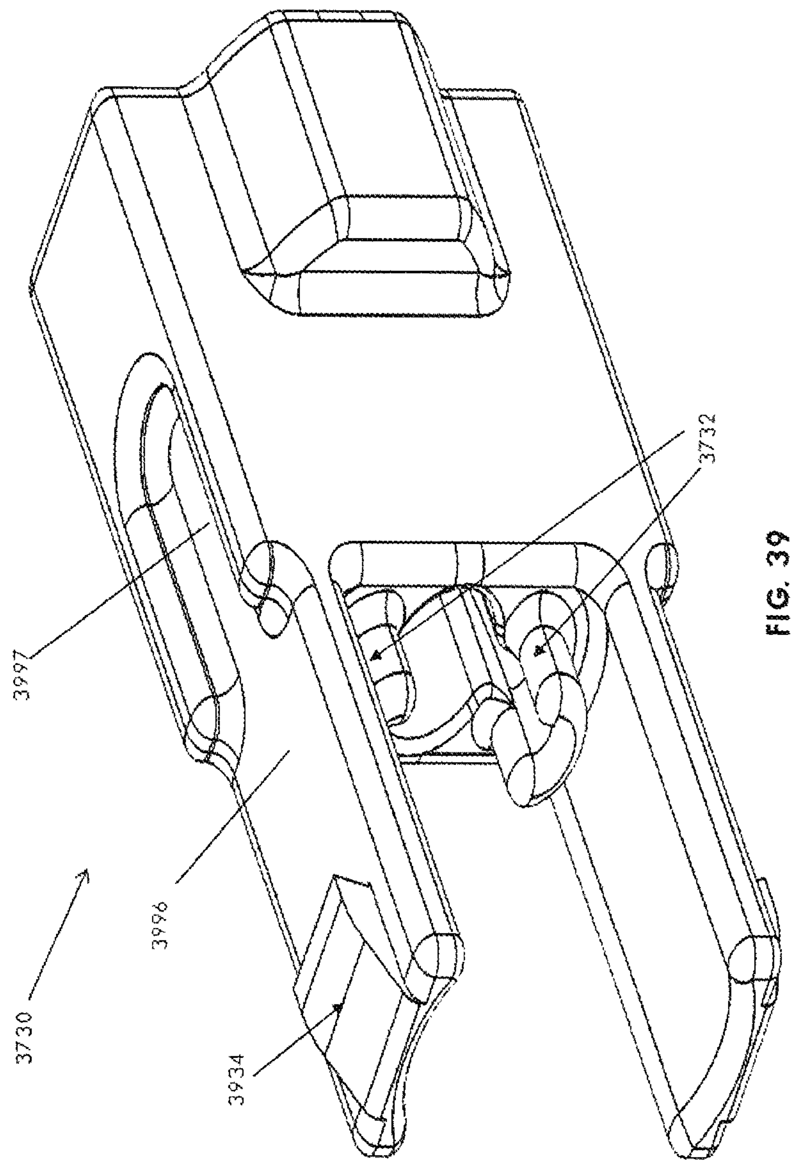

FIG. 39

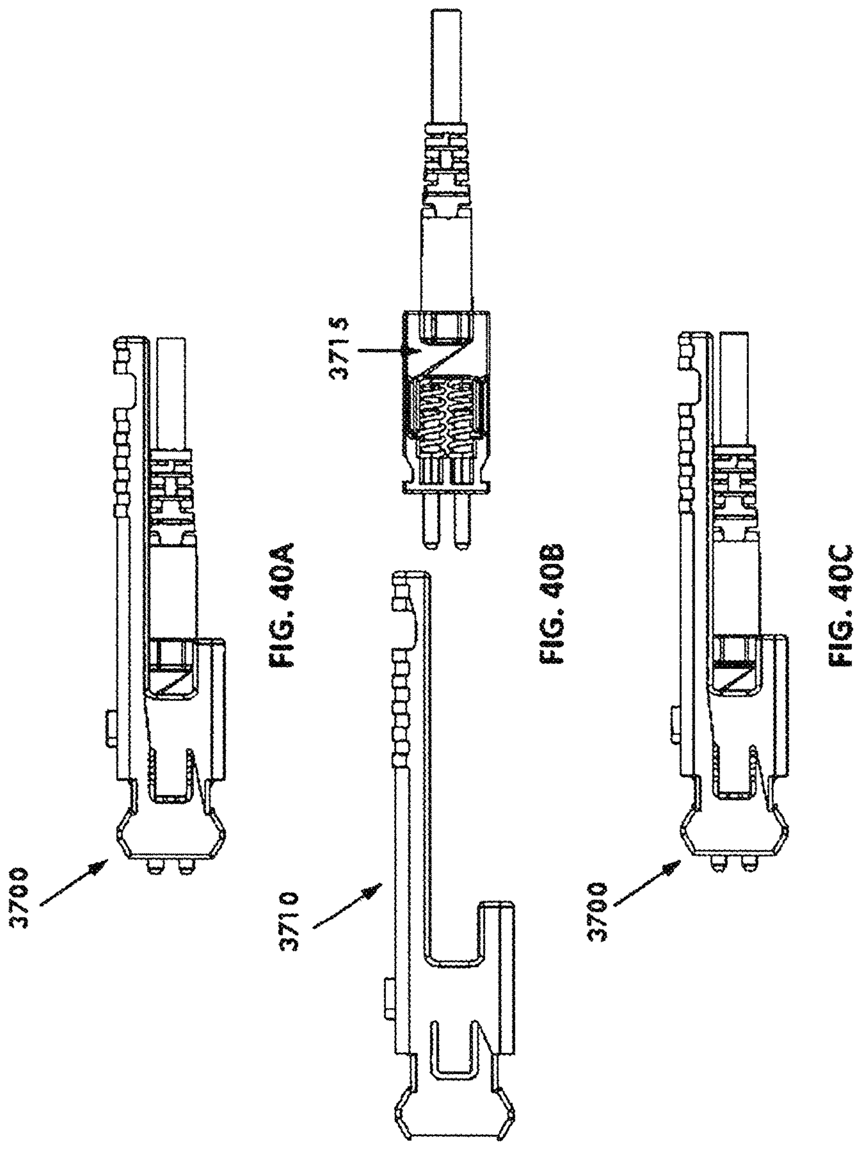

FIG. 40A

FIG. 40B

FIG. 40C

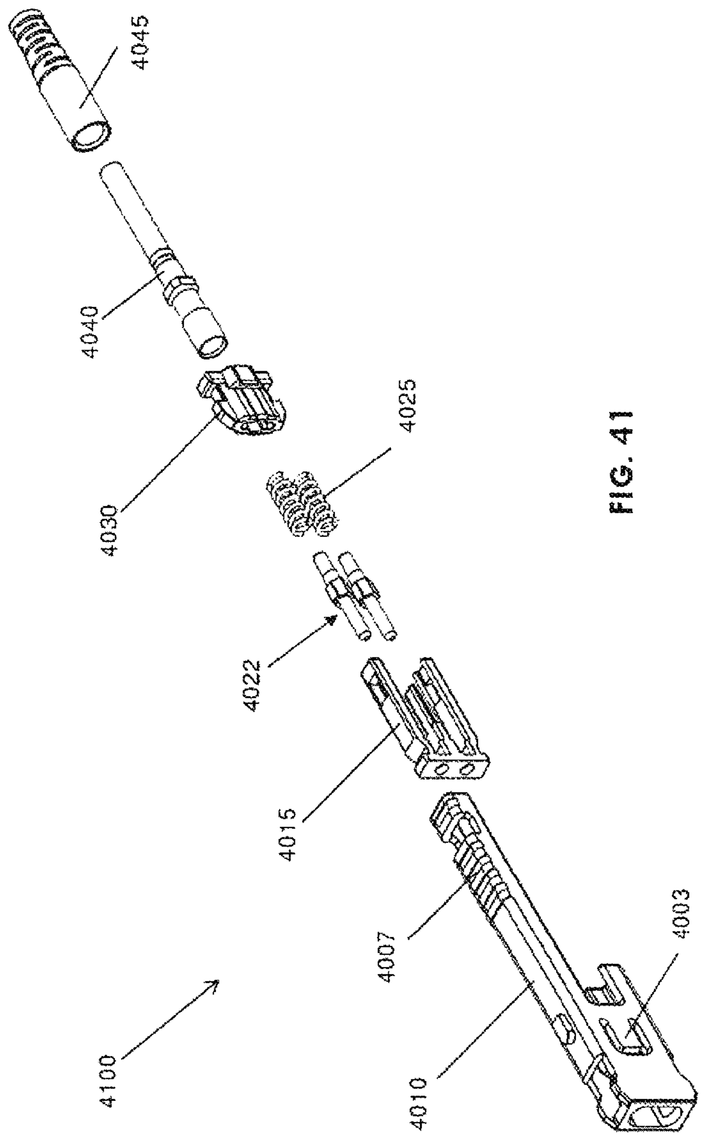

FIG. 41

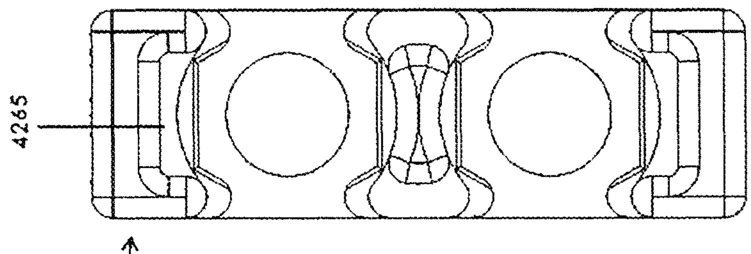

FIG. 42B

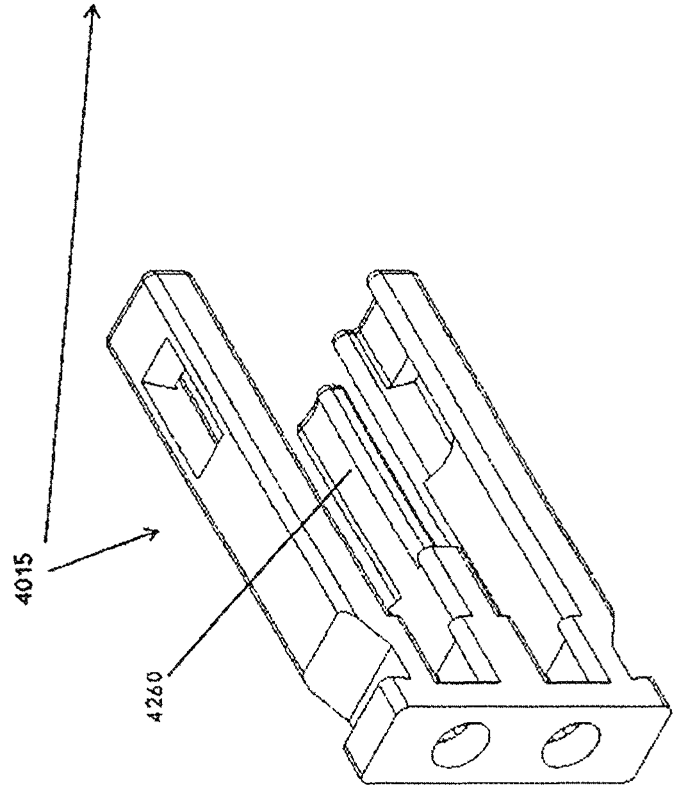

FIG. 42A

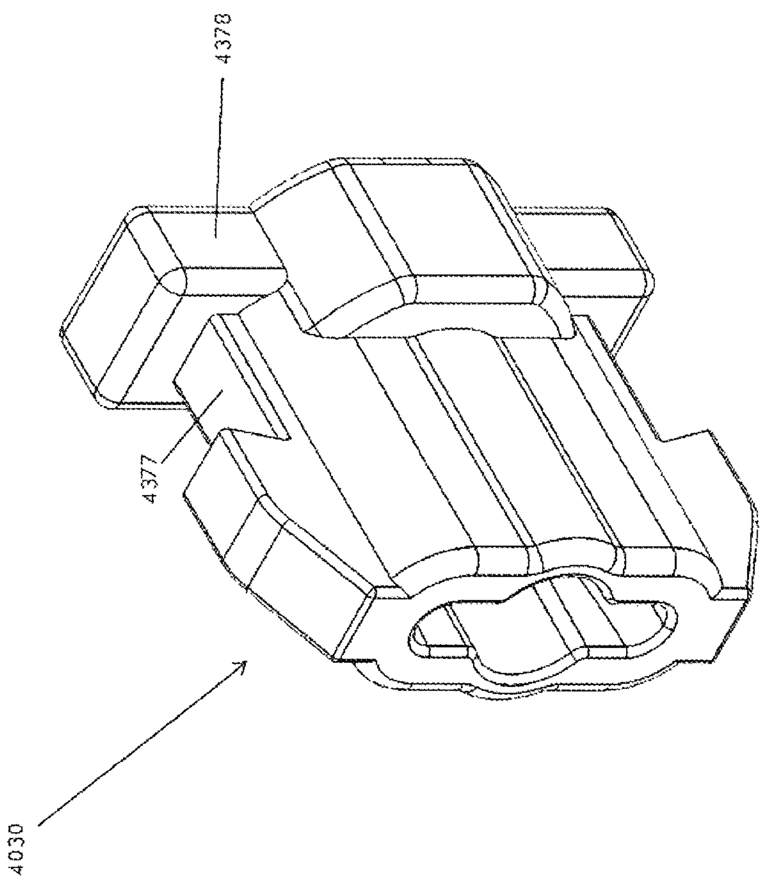

FIG. 43

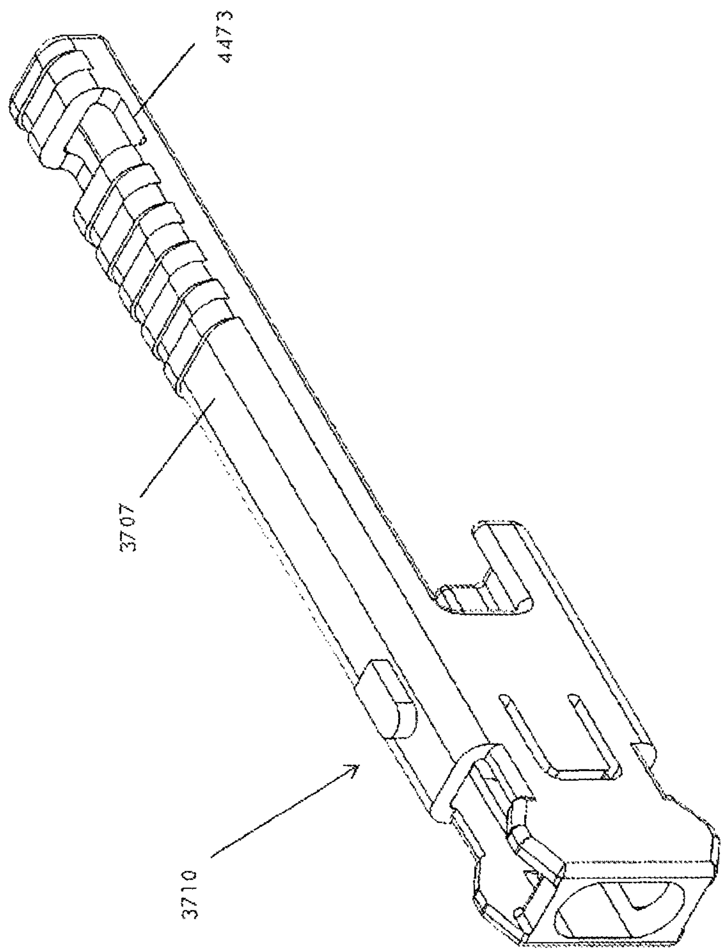

FIG. 44A

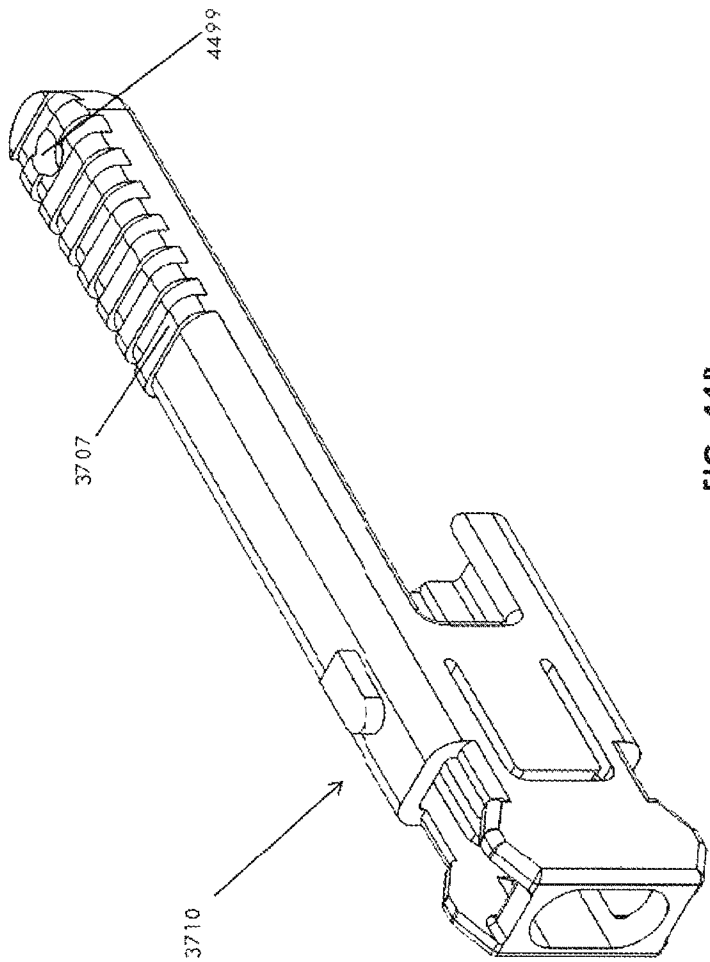

FIG. 44B

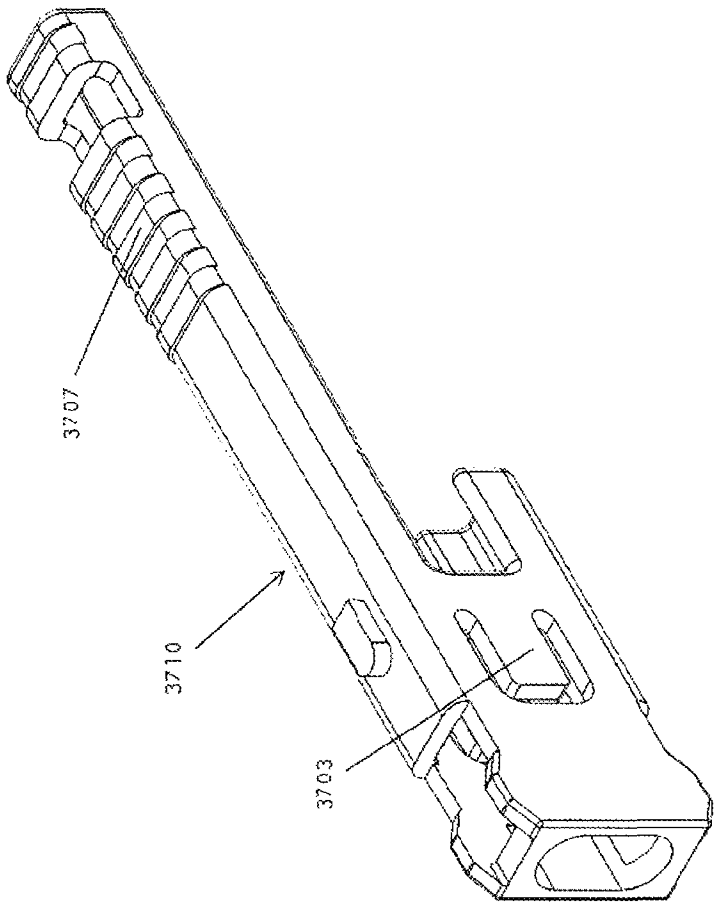

FIG. 44C

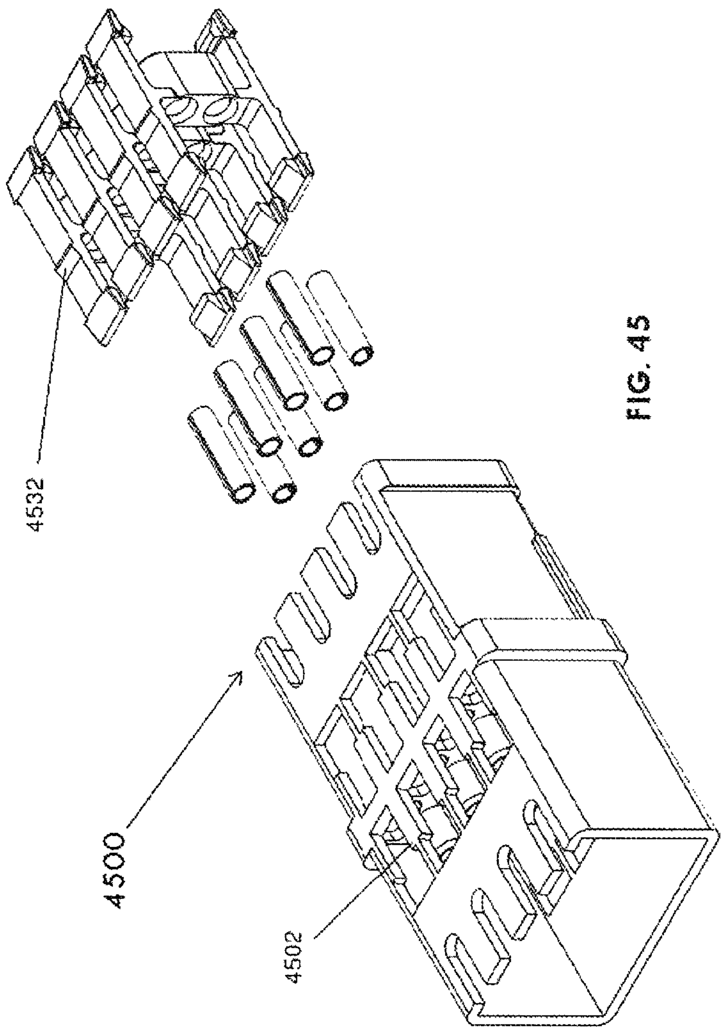

FIG. 45

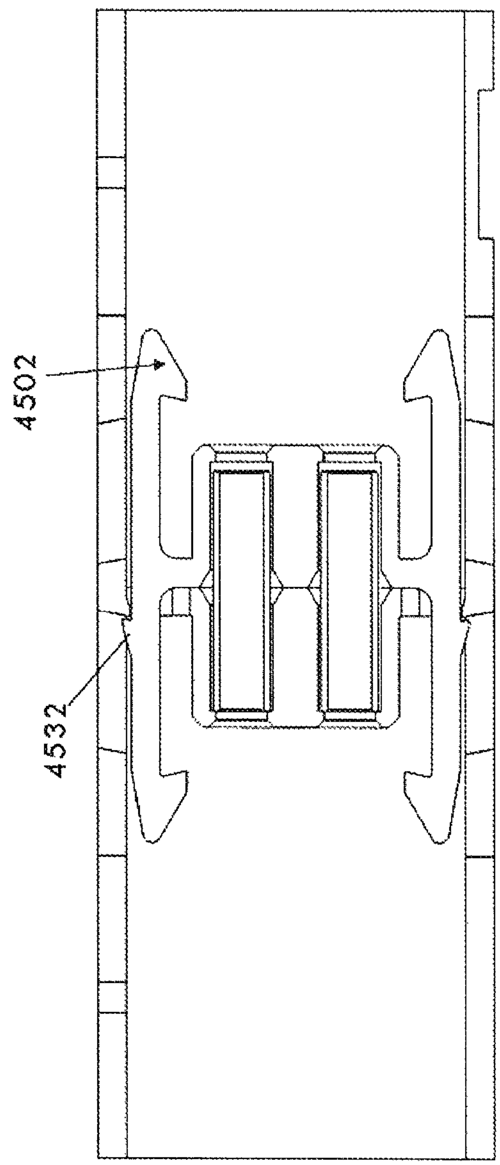

FIG. 46

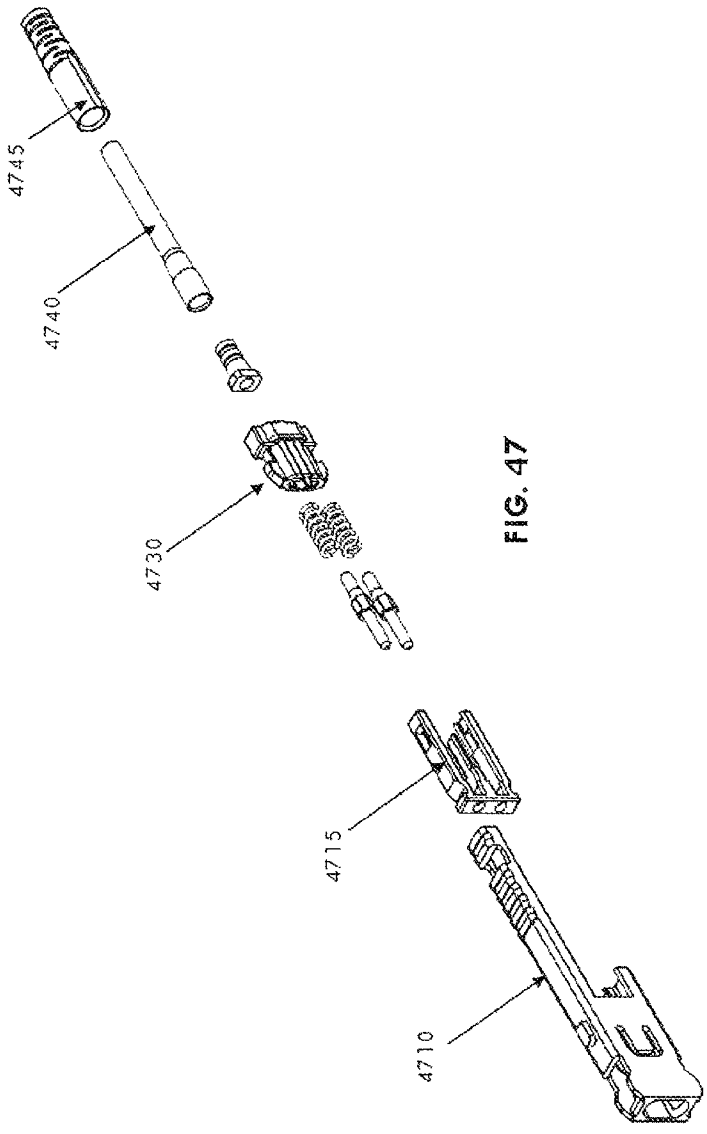

FIG. 47

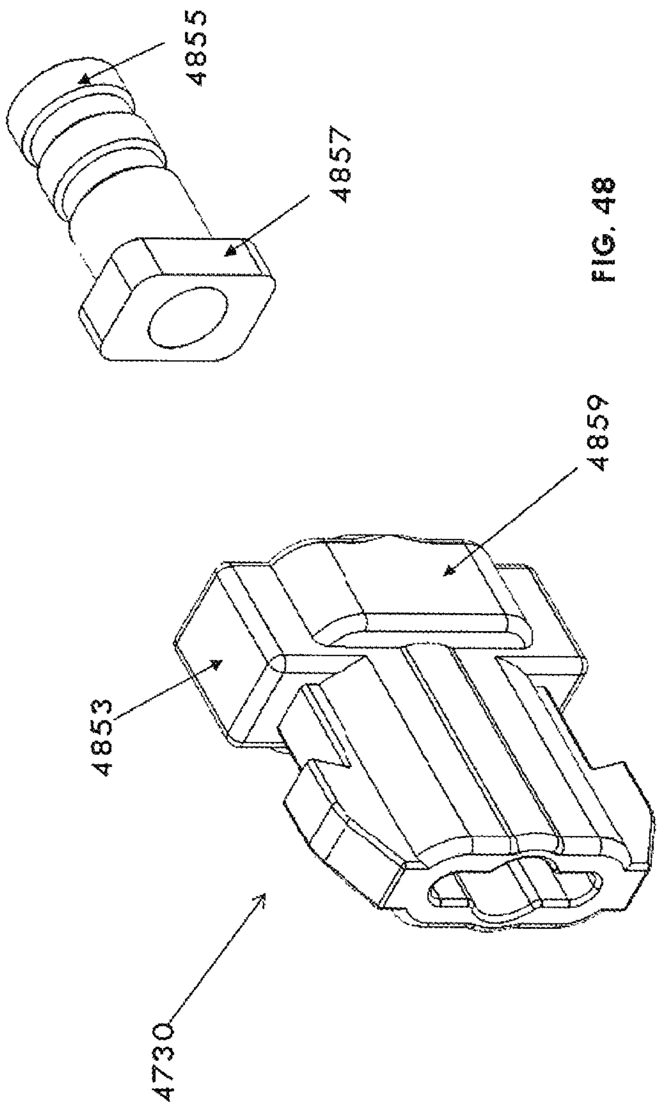

FIG. 48

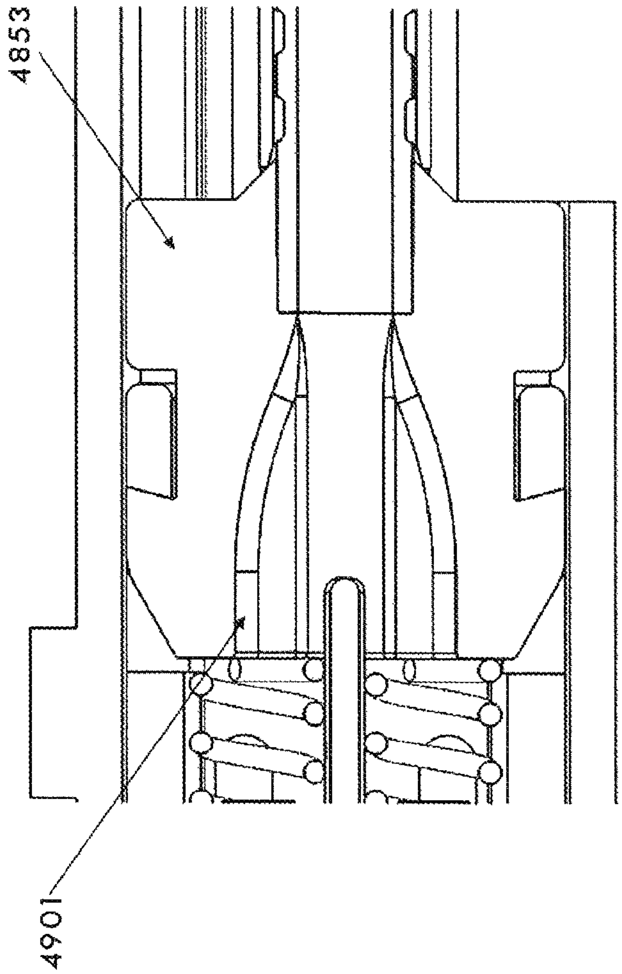

FIG. 49

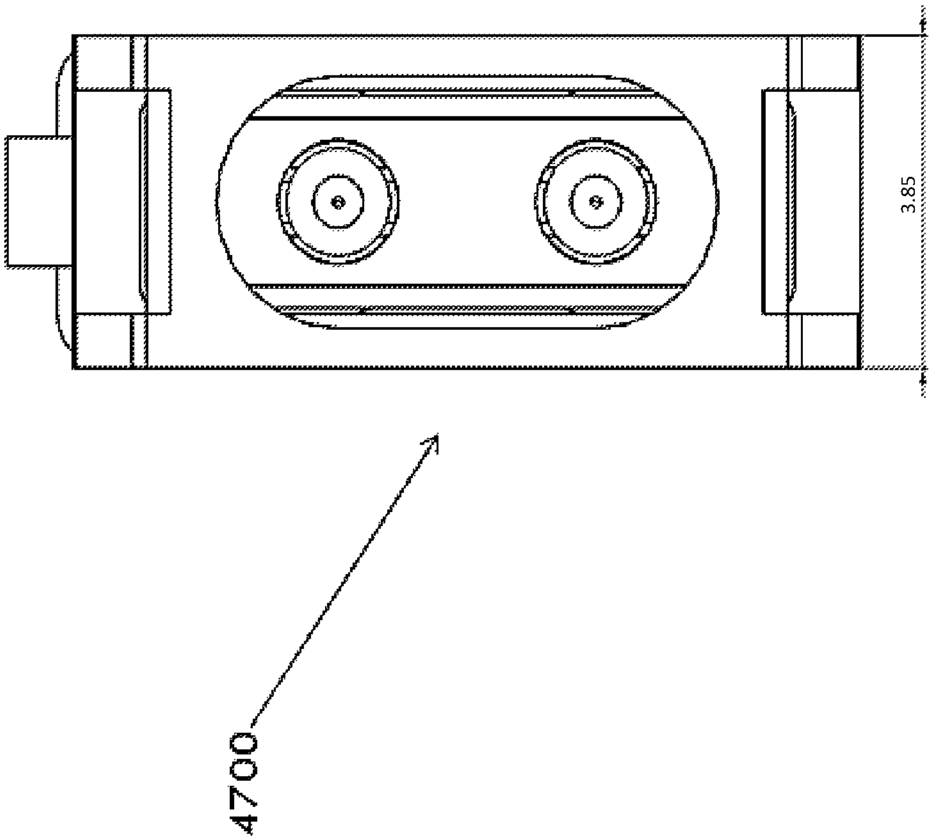

FIG. 50

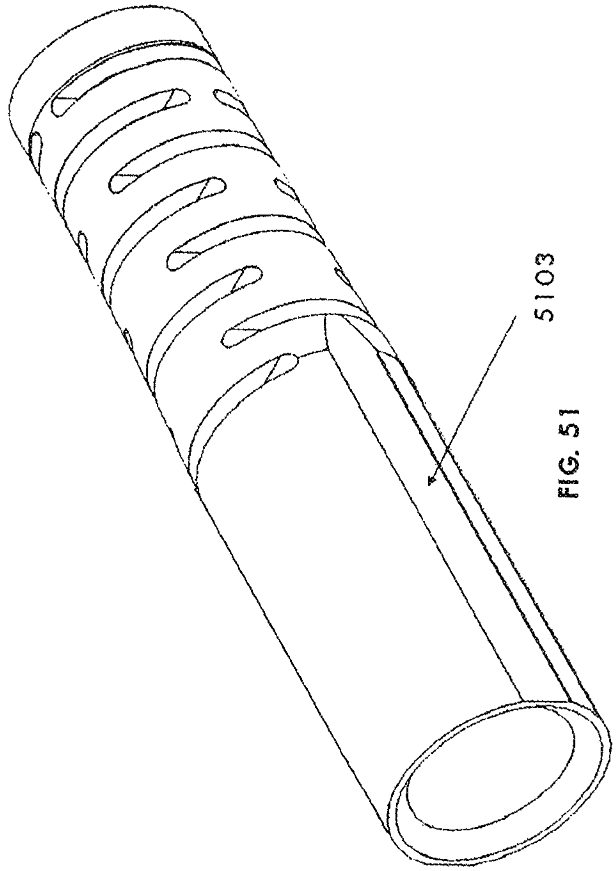

FIG. 51

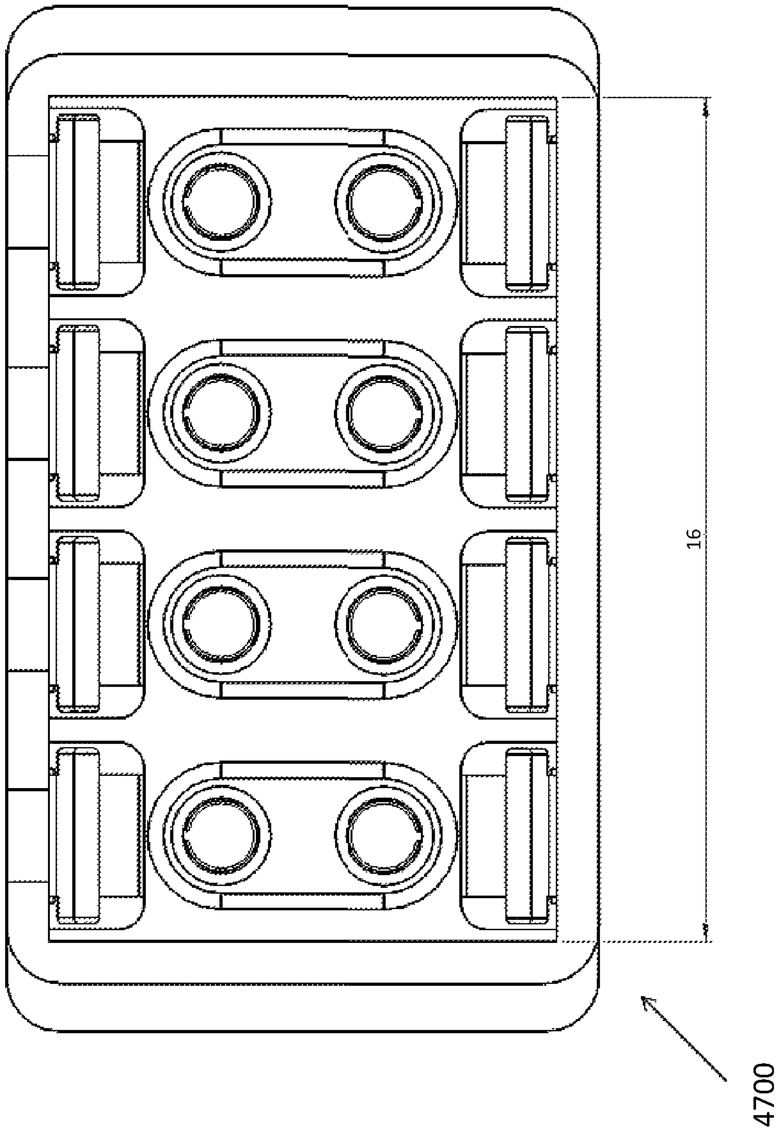

FIG. 52

ULTRA-SMALL FORM FACTOR OPTICAL CONNECTORS USED AS PART OF A RECONFIGURABLE OUTER HOUSING

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority as continuation of U.S. patent application Ser. No. 17/090,855 filed Nov. 5, 1920 entitled "ULTRA-SMALL FORM FACTOR OPTICAL CONNECTORS USED AS A PART OF A RECONFIGURABLE OUTER HOUSING" which is a continuation of U.S. patent application Ser. No. 16/414,546 filed May 16, 2019 entitled "ULTRA-SMALL FORM FACTOR OPTICAL CONNECTORS USED AS PART OF A RECONFIGURABLE OUTER HOUSING" which is a continuation of U.S. patent application Ser. No. 16/388,053 filed Apr. 18, 2019 entitled "Ultra-Small Form Factor Optical Connectors", which is a continuation of U.S. patent application Ser. No. 16/035,691, filed Jul. 15, 2018 entitled "Ultra-Small Form Factor Optical Connectors" now U.S. Pat. No. 10,281,668 granted May 7, 2019, which claims priority to the following: U.S. Provisional Patent Application Ser. Nos. 62/532,710 filed Jul. 14, 2017, 62/549,655 filed Aug. 24, 2017, and 62/588,276 filed Nov. 17, 2017, all the disclosures of which are incorporated by reference herein.

FIELD OF THE INVENTION

The present disclosure relates generally to ultra-small form factor optical connectors and related connections within adapters and optical transceivers.

BACKGROUND

The prevalence of the Internet has led to unprecedented growth in communication networks. Consumer demand for service and increased competition has caused network providers to continuously find ways to improve quality of service while reducing cost.

Certain solutions have included deployment of high-density interconnect panels. High-density interconnect panels may be designed to consolidate the increasing volume of interconnections necessary to support the fast-growing networks into a compacted form factor, thereby increasing quality of service and decreasing costs such as floor space and support overhead. However, room for improvement in the area of data centers, specifically as it relates to fiber optic connections, still exists. For example, manufacturers of connectors and adapters are always looking to reduce the size of the devices, while increasing ease of deployment, robustness, and modifiability after deployment. In particular, more optical connectors may need to be accommodated in the same footprint previously used for a smaller number of connectors in order to provide backward compatibility with existing data center equipment. For example, one current footprint is known as the small form-factor pluggable transceiver footprint (SFP). This footprint currently accommodates two LC-type ferrule optical connections. However, it may be desirable to accommodate four optical connections (two duplex connections of transmit/receive) within the same footprint. Another current footprint is the quad small form-factor pluggable (QSFP) transceiver footprint. This footprint currently accommodates four LC-type ferrule optical connections. However, it may be desirable to accommodate eight optical connections of LC-type ferrules (four duplex connections of transmit/receive) within the same footprint.

In communication networks, such as data centers and switching networks, numerous interconnections between mating connectors may be compacted into high-density panels. Panel and connector producers may optimize for such high densities by shrinking the connector size and/or the spacing between adjacent connectors on the panel. While both approaches may be effective to increase the panel connector density, shrinking the connector size and/or spacing may also increase the support cost and diminish the quality of service.

In a high-density panel configuration, adjacent connectors and cable assemblies may obstruct access to the individual release mechanisms. Such physical obstructions may impede the ability of an operator to minimize the stresses applied to the cables and the connectors. For example, these stresses may be applied when the user reaches into a dense group of connectors and pushes aside surrounding optical fibers and connectors to access an individual connector release mechanism with his/her thumb and forefinger. Overstressing the cables and connectors may produce latent defects, compromise the integrity and/or reliability of the terminations, and potentially cause serious disruptions to network performance.

While an operator may attempt to use a tool, such as a screwdriver, to reach into a dense group of connectors and activate a release mechanism, adjacent cables and connectors may obstruct the operator's line of sight, making it difficult to guide the tool to the release mechanism without pushing aside the adjacent cables. Moreover, even when the operator has a clear line of sight, guiding the tool to the release mechanism may be a time-consuming process. Thus, using a tool may not be effective at reducing support time and increasing the quality of service.

SUMMARY OF THE INVENTION

An optical connector holding two or more LC-type optical ferrules is provided. The optical connector includes an outer body, an inner front body accommodating the two or more LC-type optical ferrules, ferrule springs for urging the optical ferrules towards a mating receptacle, and a back body for supporting the ferrule springs. The outer body and the inner front body are configured such that four LC-type optical ferrules are accommodated in a small form-factor pluggable (SFP) transceiver footprint or eight LC-type optical ferrules are accommodated in a quad small form-factor pluggable (QSFP) transceiver footprint. A mating receptacle (transceiver or adapter) includes a receptacle hook and a housing with an opening that accommodates the receptacle hook in a flexed position as the optical connector makes connection with the mating receptacle by introducing the receptacle hook into an optical receptacle hook recess.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**A is a perspective view of a prior art standard 6.25 mm pitch LC connector SFP;

FIG. **1**B is a perspective view of a prior art standard 6.25 mm pitch LC adapter;

FIG. **1**C is a top view of the prior art adapter of FIG. **1**B;

FIG. **1**D is a front view of the prior art adapter of FIG. **1**B, showing the 6.25 mm pitch;

FIG. **2**A is a perspective view of a prior art LC duplex connector;

FIG. **2**B is a perspective view of a prior art LC duplex connector with a remote release pull tab;

FIG. **2**C is a top view of a prior art LC connector used in the embodiments shown in FIGS. **2**A and **2**B;

FIG. **2**D is a side view of the prior art LC connector of FIG. **2**C;

FIG. **3** is an exploded view of one embodiment of a connector;

FIG. **4** is a perspective view of one embodiment of a connector;

FIG. **5** is a perspective view of one embodiment of a connector with the outer housing removed from the front body.

FIG. **6** is a perspective view of one embodiment of a duplex connector;

FIG. **7** is a perspective view of another embodiment of a duplex connector;

FIG. **8** is a perspective view of one embodiment of a quad connector;

FIG. **9** is another perspective view of one embodiment of a quad connector;

FIG. **10** shows various embodiments of adapter types;

FIG. **11**A is a side view of a connector connected to an adapter;

FIG. **11**B is a side view of a connector being removed from an adapter;

FIG. **12**A is a side view of the outer housing of a connector being removed;

FIG. **12**B is a perspective view of a transparent outer housing of a connector showing the front body;

FIG. **13** is a perspective view of one embodiment of a quad connector inserted into a corresponding adapter;

FIGS. **14**A-C are illustrative examples of cable management using various embodiments of connectors;

FIG. **15**A-B are illustrative examples of cable management using multiple fiber strands per jacket;

FIG. **16** is an illustrative example of using a cable management system using multiple fiber strands per jacket.

FIG. **17** is another illustrative example of using a cable management system using multiple fiber strands per jacket.

FIGS. **18**A-B are various views of one embodiment of a MT connector.

FIGS. **19**A-D are illustrative examples of possible alternative connector designs.

FIG. **20** shows moving two connectors from a duplex connector to two simplex connectors.

FIG. **21**A is an exploded view of a micro optical connector according to an embodiment.

FIG. **21**B is a perspective view of the assembled micro optical connector of FIG. **21**A.

FIG. **22** is a front view of the micro optical connector of FIG. **21**B showing overall connector dimensions and ferrule pitch.

FIG. **23**A is a cross-sectional view of the micro optical connector of FIG. **21**B latched into the adapter of FIG. **24**.

FIG. **23**B is a cross-sectional view of the micro optical connectors of FIG. **21**B unlatched from the adapter of FIG. **24**.

FIG. **24** is an exploded view of an adapter for the micro optical connectors of FIG. **21**B.

FIG. **25**A is a cross-sectional view of the adapter of FIG. **24**, assembled.

FIG. **25**B is a cross-sectional side view of the adapter housing of FIG. **24**.

FIG. **26** is a front view of the assembled adapter of FIG. **24**.

FIG. **27**A is an isometric view of the front body of the micro optical connector of FIG. **21**A.

FIG. **27**B is a right side view of the front body of FIG. **27**A.

FIG. **28**A is an isometric view of the back body of the micro optical connector of FIG. **21**A.

FIG. **28**B is a side view of the back body of FIG. **28**A.

FIG. **29**A is an isometric view of the outer housing of the micro optical connector of FIG. **21**A.

FIG. **29**B is a front view of the outer housing of FIG. **29**A.

FIG. **29**C is a cross-sectional view of the outer housing of FIG. **29**A showing the top of an orientation protrusion.

FIG. **29**D is an inner view of the outer housing of FIG. **29**A;

FIG. **29**E is an inner view of the outer housing of FIG. **29**A.

FIG. **30** is a side view of an adapter hook of the adapter of FIG. **24**.

FIG. **31** is an isometric view of the adapter of FIG. **24** assembled with the micro optical connectors of FIG. **21**B.

FIG. **32**A is cross-sectional view of a prior art connector showing a latch gap.

FIG. **32**B is a cross-sectional view of the micro optical connector of FIG. **21**B latched (left) and unlatched (right) within the adapter of FIG. **24**, assembled.

FIG. **33**A depicts the micro optical connector of FIG. **21**B in a QSFP footprint, depicting dimensions in millimeters.

FIG. **33**B depicts the micro optical connectors of FIG. **21**B in an SFP footprint, depicting dimensions in millimeters.

FIG. **34**A-**34**C depicts adapter hooks interacting with the micro optical connectors of FIG. **21**B before (FIG. **34**A), during (FIG. **34**B), and after (FIG. **34**C) latching.

FIG. **35**A-FIG. **35**C depicts the micro optical connector of FIG. **21**B side flap operation before (FIG. **35**A), during (FIG. **35**B), and after (FIG. **35**C) latching.

FIG. **36**A depicts plural micro optical connectors in a transceiver.

FIG. **36**B is a front view of the transceiver of FIG. **36**A.

FIG. **37** is an exploded view of a micro optical connector according to a further embodiment.

FIG. **38** is an isometric view of a front body of the micro optical connector of FIG. **37**.

FIG. **39** is an isometric view of a back body of the micro optical connector of FIG. **37**.

FIGS. **40**A, **40**B, and **40**C depict a technique for reversing polarity of the optical connector of FIG. **37**.

FIG. **41** is an exploded view of a micro optical connector according to a further embodiment.

FIG. **42**A is an isometric view of the front body of the micro optical connector of FIG. **41**.

FIG. **42**B is a side view of the front body of FIG. **42**A.

FIG. **43** is an isometric view of the back body of the micro optical connector of FIG. **41**.

FIGS. **44**A, **44**B, and **44**C are isometric views of the outer housings that may be used with any of the micro optical connectors of FIGS. **21**A, **37**, and **41**.

FIG. **45** is an exploded view of an adapter according to a further embodiment.

FIG. **46** is a cross-section of the adapter of FIG. **45**, assembled.

FIG. **47** is an exploded view of a connector according to another embodiment.

FIG. **48** is an isometric view of the back body and the back post of the connector of FIG. **47**.

FIG. **49** is a cross-section of the back post of FIG. **47** assembled with optical fibers.

FIG. **50** is a front view of the connector of FIG. **47**.

FIG. **51** is an isometric view of the boot of the connector of FIG. **47**.

FIG. **52** is a front view of the adapter of FIG. **45**.

DETAILED DESCRIPTION

This disclosure is not limited to the particular systems, devices and methods described, as these may vary. The terminology used in the description is for the purpose of describing the particular versions or embodiments only, and is not intended to limit the scope.

As used in this document, the singular forms "a," "an," and "the" include plural references unless the context clearly dictates otherwise. Unless defined otherwise, all technical and scientific terms used herein have the same meanings as commonly understood by one of ordinary skill in the art. Nothing in this disclosure is to be construed as an admission that the embodiments described in this disclosure are not entitled to antedate such disclosure by virtue of prior invention. As used in this document, the term "comprising" means "including, but not limited to."

The following terms shall have, for the purposes of this application, the respective meanings set forth below.

A connector, as used herein, refers to a device and/or components thereof that connects a first module or cable to a second module or cable. The connector may be configured for fiber optic transmission or electrical signal transmission. The connector may be any suitable type now known or later developed, such as, for example, a ferrule connector (FC), a fiber distributed data interface (FDDI) connector, an LC connector, a mechanical transfer (MT) connector, a square connector (SC) connector, a CS connector, or a straight tip (ST) connector. The connector may generally be defined by a connector housing body. In some embodiments, the housing body may incorporate any or all of the components described herein.

A "fiber optic cable" or an "optical cable" refers to a cable containing one or more optical fibers for conducting optical signals in beams of light. The optical fibers can be constructed from any suitable transparent material, including glass, fiberglass, and plastic. The cable can include a jacket or sheathing material surrounding the optical fibers. In addition, the cable can be connected to a connector on one end or on both ends of the cable.

Various embodiments described herein generally provide a remote release mechanism such that a user can remove cable assembly connectors that are closely spaced together on a high density panel without damaging surrounding connectors, accidentally disconnecting surrounding connectors, disrupting transmissions through surrounding connectors, and/or the like. Various embodiments also provide narrow-pitch LC duplex connectors and narrow-width multi-fiber connectors, for use, for example, with future narrow-pitch LC SFPs and future narrow width SFPs. The remote release mechanisms allow use of the narrow-pitch LC duplex connectors and narrow-width multi-fiber connectors in dense arrays of narrow-pitch LC SFPs and narrow-width multi-fiber SFPs.

FIG. **1**A shows a perspective view of a prior art standard 6.25 mm pitch LC connector SFP **100**. The SFP **100** is configured to receive a duplex connector and provides two receptacles **102**, each for receiving a respective LC connector. The pitch **104** is defined as the axis-to-axis distance between the central longitudinal axes of each of the two receptacles **102**. FIG. **1**B shows a perspective view of a prior art standard 6.25 mm pitch LC adapter **106**. The adapter **106** is also configured to receive a duplex connector, and provides two receptacles **108**, each for receiving a respective LC connector. FIG. **1**C is a top view of the adapter **106** of FIG. **1**B. The pitch of the adapter **106** is defined similarly to that of the SFP **100**, as the axis-to-axis distance between the central longitudinal axes of each of the two receptacles **108**, as illustrated in FIG. **1**D, which shows a front view of the adapter **106**.

FIG. **2**A shows a prior art LC duplex connector **200** that may be used with the conventional SFP **100** and the conventional adapter **106**. The LC duplex connector **200** includes two conventional LC connectors **202**. FIG. **2**B shows another prior art LC duplex connector **204** having a remote release pull tab **206**, and including two conventional LC connectors **208**. As shown, the remote release pull tab includes two prongs **210**, each configured to couple to the extending member **212** of a respective LC connector **208**. FIGS. **2**C and **2**D show top and side views, respectively, of the conventional LC connector **208**, having a width of 5.6 mm, and further showing the extending member **212**.

As discussed herein, current connectors may be improved by various means, such as, for example, reducing the footprint, increasing the structural strength, enabling polarity changes, etc. Various embodiments disclosed herein offer improvements over the current state of the art, as will be further discussed below.

In some embodiments, as shown in FIG. **3**, a connector **300** may comprise various components. Referring to FIG. **3**, an illustrative embodiment of a connector **300** is shown in an exploded view to display detail. In some embodiments, and as discussed further herein, a connector **300** may have an outer housing **301**, a front body **302**, one or more ferrules **303**, one or more ferrule flanges **304**, one or more springs **305**, a back body **306**, a back post **307**, a crimp ring **308**, and a boot **309**. In some embodiments, the back body **306** may comprise one or more protrusions **306.1** which may interlock with a window/cutout **302.1** in the front body **302**. This may allow for the back body **306** and the front body **302** to be securely fastened together around the ferrule(s) **303**, ferrule flange(s) **304**, and the spring(s) **305**. The elements of FIG. **3** are configured such that two optical connectors having four LC-type optical ferrules may be accommodated in a small form-factor pluggable (SFP) transceiver footprint or at least two optical connectors having a total of eight LC-type optical ferrules may be accommodated in a quad small form-factor pluggable (QSFP) transceiver footprint.

Referring now to FIG. **4**, an embodiment is shown wherein the connector **400** is assembled. In some embodiments, the assembled connector may have an outer housing **401**, a front body **402** positioned within the outer housing, one or more ferrules **403**, one or more ferrule flanges (not shown), one or more springs (not shown), a back body **406**, a back post (not shown), a crimp ring (not shown), a boot **409**, and a push-pull tab **410**. In some embodiments, the connector may have one or more latching mechanisms made up of a window **412** on the outer housing **401** near the push-pull tab **410** and a protrusion **413** on the front body. The latching mechanism made up of the window **412** and protrusion **413** securely attaches the outer housing **401** to the front body **402**. In a further embodiment, the outer housing **401** may have a recess **411** to receive a locking tab or locking mechanism from an adapter (depicted in FIG. **13**, below). The recess **411** of the outer housing **401** is used to interlock with an adapter (depicted in FIG. **13**, below) or transceiver receptacle to secure the connector into the adapter. As would be understood by one skilled in the art, the push-pull tab **410** enables removal of the connector from a receptacle without requiring additional tools. Alternatively, the push-pull tab may be eliminated and the connector removed manually. In one or more further embodiments, the outer housing **401** may also have a key **414**. The key **414** may keep the connector in a given orientation when inserted into a receptacle such as an adapter or transceiver.

FIG. **5** depicts a procedure for changing the polarity of the optical connectors of the present disclosure. As shown in FIG. **5**, in some embodiments, the latching mechanism of the connector **500** may be made up of two main parts: a window (not visible) and one or more protrusions **513**. As illustrated in FIG. **5**, the outer housing **501** can slide on to or be removed from the front body **502** by disengaging the latching mechanisms formed by the protrusion **513** exiting through the window, whereby it contacts a rear wall of the window (refer to FIG. **4** for an illustrated example of the outer housing being attached to the front body via the latching mechanism). In some embodiments, the push-pull tab **510** may be permanently attached to the outer housing **501**, as shown.

The front body **502** may be removed from the outer housing **501**, rotated 180° as indicated by arrow **520**, and re-inserted into the outer housing. This allows for a change in the polarity of the front body **502**, as shown by the arrow diagram in FIG. **5**, and therefore the ferrules can switch quickly and easily without unnecessarily risking the delicate fiber cables and ferrules.

In some embodiments, it may be beneficial to connect two or more connectors together to increase structural integrity, reduce the overall footprint, and cut manufacturing costs. Accordingly, as shown in FIG. **6**, a connector **600** may in some embodiments, utilize an outer housing **601** that is capable of holding two front bodies **602**. Various other embodiments are disclosed herein, and it should be noted that the embodiments disclosed herein are all non-limiting examples shown for explanatory purposes only.

Accordingly, although the embodiment shown in FIG. **6** utilizes a duplex outer housing **601**, additional or alternative embodiments may exist with more capacity, for example, six or eight optical connectors within a single outer housing. As shown in FIG. **6**, in some embodiments, the outer housing **601** may accept two front bodies **602**, each with two separate ferrules **603**. As shown, the front body(s) **602** may securely fasten to the outer housing **601** via the latching mechanism **612** and **613**. In additional embodiments, the push-pull tab **610** may be modified, as shown, such that a single tab can be used to free the two or more connectors from an adapter. As illustrated in FIG. **6**, the uni-body push-pull tab **610** and the outer housing **601** may have two windows **612** with which to receive multiple protrusions **613** of the front body(s) **602**. As discussed herein the recesses **611** of the outer housing **601** are used to secure the connectors to an adapter (depicted in FIG. **13** below). In one or more further embodiments, the connectors may have individual back bodies **606** and boots **609** (i.e., one back body/boot per front body) as shown.

Alternatively, in some embodiments, such as that shown in FIG. **7**, the connector **700** may have a single boot **709** and a duplex (i.e., uni-body) back body **706** instead of individual back bodies (e.g., such as shown in FIG. **6**). In some embodiments, the duplex back body **706** may have different dimensions than that of the individual back bodies of FIG. **6**, such as, for example, they may be longer to accommodate the need for routing the fiber after it exits the boot **709**. As with other embodiments discussed herein, the connector shown in FIG. **7** may also include an outer housing (e.g., duplex outer housing) **701**, one or more ferrules **703**, at least one latching mechanism formed by the protrusion (not shown) exiting through one or more windows **712**, and a push-pull tab **710**.

As stated, it may be beneficial to connect two or more connectors together to increase structural integrity, reduce the overall footprint, and cut manufacturing costs. Accordingly, similar to FIG. **6**, FIG. **8** shows a connector **800** that may, in some embodiments, utilize an outer housing **801** that is capable of holding multiple (e.g., four) front bodies **802**.

As shown in FIG. **8**, some embodiments may have an outer housing **801** able to accept up to four front bodies **802**, each with one or more ferrules **803**. As shown, each front body **802** may securely fasten to the outer housing **801** via the latching mechanism **812** and **813**. In additional embodiments, the push-pull tab **810** may be modified such that a single tab can be used to remove the up to four connectors from an adapter. As illustrated in FIG. **8**, the push-pull tab **810** may include four recesses **811**, which as discussed herein are used to secure the connector to a receptacle such as an adapter (shown in FIG. **13**, below) or the front receptacle portion of a transceiver. In one or more further embodiments, the connectors may have individual back bodies **806** and boots **809** (i.e., one back body/boot per front body) as shown.

Similar to FIG. **8**, FIG. **9** shows an embodiment where the outer housing **901** is able to accept up to four front bodies **902**, each with one or more ferrules **903**. As shown, each front body **902** may securely fasten to the outer housing **901** via the latching mechanism **912** and **913**. In additional embodiments, the push-pull tab **910** may be modified such that a single tab can be used to remove the up to four CS connectors from an adapter. As illustrated in FIG. **9**, the push-pull tab **910** may include four recesses **911**, which as discussed herein are used to secure the connector to an adapter (shown in FIG. **13**, below) or the optical receptacle portion of a transceiver. The FIG. **9** embodiment may utilize a single back body **906** and a single boot **909**. In one or more further embodiments, the connectors may have individual back bodies **906** and boots **909** (i.e., one back body/boot for all four front bodies) as shown.

In another aspect, the present disclosure provides method for reconfiguring optical cables in which the outer housings of the connectors may be removed and the remaining portion of the assembled connector is inserted into a housing having a larger or smaller capacity.

For example, the outer housings of plural two-ferrule capacity housings may be removed and the connector inner body and associated components inserted into a second outer housing that has either a four-ferrule or eight-ferrule capacity. Alternatively, an outer housing with a four-ferrule capacity may be removed and the inner bodies and associated components are inserted into two second outer housings, each of the two second housings having a two-ferrule capacity. Similarly, an outer housing with an eight-ferrule capacity may be removed and replaced by two four-ferrule capacity housing or a four-ferrule capacity and two two-ferrule capacity housings. In this manner, cables may be flexibly reconfigured to match the capacity of a mating optical-electrical component such as a transceiver. This aspect of the present disclosure is demonstrated in connection with FIG. **10**.

Referring now to FIG. **10**, various embodiments may exist such as a single housing **1001** which receives a single connector **1002**. Additional embodiments may also exist, such as a duplex housing **1003** which receives two connectors **1004** and/or a quad housing **1005** which may receive up to four connectors **1006**. It should be understood by one skilled in the art that various other embodiments may exist that are not explicitly shown. For example, a housing with the capacity for 5, 6, 7, 8, 9, 10 or more connectors may be utilized for various embodiments disclosed herein. As shown below, it is desirable to have flexible housing configurations so that connectors may be grouped and ungrouped between optical and optoelectronic components such as adapters and transceivers.

Alternatively, in some embodiments the connector may utilize one or more duplex back bodies with a single boot, similar to that shown in FIG. **7**. Thus, similar to FIG. **7**, an embodiment may allow for a further reduced footprint, less cabling, and easier maintenance of the connector. Accordingly, one or more embodiments may have an outer housing that may accept up to four front bodies, each with one or more ferrules. In some embodiments, each front body may securely fasten to the outer housing via a latching mechanism. In additional embodiments, the push-pull tab may be modified such that a single tab can be used to free the up to four front bodies from an adapter. The push-pull tab may include four openings with which to receive multiple locking tabs of the outer housing. As discussed herein the locking tabs of the outer housing are used to secure the connectors to an adapter (shown in FIG. **13**) or the optical receptacle portion of a transceiver.

In further embodiments, the connector may utilize a single uni-body back body with a single boot (i.e., as shown in FIG. **9**). Thus, an embodiment may allow for a further reduced foot print, less cabling, and easier maintenance of the connector. Accordingly, one or more embodiments may have an outer housing that may accept up to four front bodies, each with one or more ferrules. Each front body may securely fasten to the outer housing via the latching mechanism as discussed herein. In additional embodiments, the push-pull tab may be modified such that a single tab can be used to remove up to four connectors from an adapter. The push-pull tab may include four openings with which to receive multiple locking tabs of the outer housing. As discussed herein the locking tabs of the outer housing are used to secure the connectors to an adapter.

The optical connectors of the present disclosure are all configured to be received in a receptacle. As used herein, the term "receptacle" relates generically to a housing that receives an optical connector. A receptacle includes both optical adapters, that is, components that mate two or more optical connectors, and transceivers, which include an optical receptacle to hold connectors that are to communicate with an optoelectronic component (e.g., a component that converts optical signals to electrical signals). As shown in FIG. **11**A, in one embodiment **1100**A, the outer housing **1101** may comprise one or more recesses **1111**. As discussed and shown herein, the one or more recesses may allow for a receptacle **1114** to securely connect to the connector **1100**A. Accordingly, in some embodiments, the receptacle **1114** may have a receptacle hook **1115**, which is flexible and can secure the connector **1100**A into the receptacle via latching onto the wall of the recess **1111**, as shown. This latching takes place when the outer housing **1101** is pushed forward into the receptacle. The sloped portions of the outer housing **1101** allow the receptacle hook **1115** to slide up and over the front of the outer housing thereby securing the connector **1100**A into the receptacle.

Additionally or alternatively, in some embodiments, such as that shown in FIG. **11**B, a connector **1100**B may be removed from a receptacle **1114** by pulling the connector away from the adapter as indicated by the directional arrow. In some embodiments, the force may be applied by a user via the push-pull tab **1110**. Alternatively, when a push-pull tab is not present, the connector may still be manually removed from a receptacle. As shown in FIG. **11**B, as the connector **1100**B is removed from the receptacle **1114**, the flexible receptacle hooks **1115** separate and slide up the slope of the end of the connector and allow for removal of the connector from the receptacle.

Referring now to FIGS. **12**A and **12**B, as discussed herein and previously shown in FIG. **5**, the front body **1202** can be removed from the outer housing **1201**. In some embodiments, a portion of the outer body **1201** can be flexibly extended away from the front body **1202** as shown by the arrows in FIG. **12**A. As discussed herein, in some embodiments, the front body **1202** may comprise a protrusion **1213** which interlocks with a window (not shown) on the outer housing **1201**. Accordingly, when force is applied to the outer housing **1201** in a manner that removes the one or more protrusions **1213** from the one or more windows (not shown, see FIG. **4**), the front body **1202** may be removed from the outer housing.

Referring now to FIG. **13**, an embodiment **1300** is shown in which the connector (not shown in its entirety) is inserted into a receptacle such as adapter **1314**. In this specific non-limiting example, the connector is similar to that shown in FIG. **8** (i.e., comprising four front bodies each with their own back body **1306** and boot **1309**). However, unlike FIG. **8**, the embodiment shown here utilizes four individual push-pull tabs **1310** instead of a duplex push-pull tab system which manipulates two latching tabs per push-pull tab to allow the connector to be removed from the adapter **1314**.

Various benefits and details have been discussed herein with regard to the connectors and their modular ability (e.g., to include multiple connectors into a single housing). In addition to the reduced footprint, structural improvements, and cost reduction, various embodiments herein may also be beneficial with regard to reducing the burden of cabling in a data center environment. Illustrative embodiments shown in FIGS. **14**A through **14**C depict cable configurations that may be used to reduce the complexity of optical cables in a compact environment. Note that any of the optical connectors described in this disclosure may be used in these embodiments, including the optical connectors of FIGS. **21**B, **37**, and **41**, to be discussed in detail below. FIG. **14**A shows two duplex cables similar to the cable shown in FIG. **6**. In some embodiments, one or more detachable clips **1401** may be attached to two or more zip cables to prevent the zip cables from detaching. This allows for two or more cables to be bundled and reduce the risk of entanglement with additional cables. FIG. **14**B is an illustrative example of how easily an embodiment can separate into two individual connectors by unbinding the cables and thus quickly and easily creating two independent fiber optic channels that can move and be connected independently. FIG. **14**C shows an embodiment in which a duplex connector like that of FIGS. **6** and **14**A is connected to two separate individual connectors. Through the variable housing configurations depicted above in FIG. **10**, the cable of FIG. **14**A can be reconfigured as the cables of either **14**B or FIG. **14**C.

In addition to binding existing fiber cables, some embodiments herein may utilize a new four fiber zip cable. Referring now to FIG. **15**A, a conventional zip cable (i.e., one with a single fiber strand **1520** per jacket **1521**) is shown in comparison with an embodiment in which two fibers **1522** per jacket **1523** are utilized. It should be understood that this is merely a non-limiting example. In some embodiments, multiple fibers may be included per jacket, such as, for example, four fibers per jacket in order to utilize the single boot **909** and uni-body rear body **906** of the connector shown in FIG. **9**.

A specific example using multi-strand cables is shown in FIG. **16** for illustrative purposes only. It should be understood that numerous alternatives and modifications are possible, such as, for example, that shown in FIGS. **18**A-**18**B and FIGS. **19**A-**19**D. As shown, a switch (e.g., **100**G switch) **1630** is shown with a transceiver (e.g., **100**G transceiver) **1631**. The transceiver **1631** has a receptacle to receive duplex connectors **1632**. From each of the two duplex connectors **1632**, a four fiber cable **1633** extends to connect to various other connectors and transceivers. In some embodiments, as discussed herein, a clip (e.g., detachable clip) **1640** may connect two or more cables (e.g., **1633**) to ensure the zip cables do not come apart. As shown, one four fiber cable **1633** is split into two two-fiber cables **1634**, which are then each attached to a single simplex connector **1635** and placed into a transceiver (e.g., **25**G transceiver) **1636**. As further shown, one of the four fiber cables **1637** is connected to a single duplex connector **1638**, which is then inserted into another transceiver (e.g., **50**G transceiver) **1639**.

An additional or alternative embodiment is shown in FIG. **17**. As shown, one or more switches (e.g., **400**G switches) **1730** and **1732** are shown each with a transceiver (e.g., **400**G transceiver) **1731** and **1733**. The first transceiver **1731** has a receptacle that is receiving two simplex (single) connectors **1734** and one duplex (dual) connector **1735**. From each of the two simplex connectors **1734**, a two fiber cable **1736** extends to connect to various other connectors and transceivers. Similar to FIGS. **14** and **16**, some embodiments may have a clip (e.g., detachable clip) **1740** that may connect two or more cables (e.g., **1736**, **1738**, etc.) to ensure the zip cables do not come apart. From the duplex connector **1735** a four-fiber cable **1737** is split into two two-fiber cables **1738**, which are then each attached to a single simplex connector each and placed into a transceiver (e.g., **400**G transceiver).

Accordingly, embodiments described herein allow for improvements over the current state of the art. By way of specific example, connectors generally have three types of fixed cables. Moreover, some cables may be bifurcated. As such, the cable cannot be split once installed and the polarity of the cables cannot be changed. Alternatively, the embodiments discussed herein may allow a user to change from a four-way to a 2-Duplex, to a 4-simplex connector, etc. (e.g., FIG. **20**). Moreover, as discussed herein, the individual connectors can be split into individual connectors anytime, even after deployment. Additionally, the polarity can be changed within the connectors easily in a manner that does not risk damage to the one or more ferrules and fibers, as discussed above. It should also be noted that the depicted connectors are used herein merely for illustrative purposes, and that various other connectors may be used in any embodiment (e.g., an MT connector, such as that shown in FIGS. **18**A-**18**B, and the optical connectors of FIGS. **21**, **37**, and **41**).

FIGS. **18**A-**18**B depict an optical connector including an MT ferrule **1810** in a housing that is substantially similar to the housing **301** of FIG. **3**. As with the embodiment of FIG. **3**, the various features of the connector are configured such that two optical connectors having two MT-type optical ferrules may be accommodated in a small form-factor pluggable (SFP) transceiver footprint or at least four optical connectors having a total of four MT-type optical ferrules may be accommodated in a quad small form-factor pluggable (QSFP) transceiver footprint.

FIGS. **19**A-**19**D show alternative embodiments of the optical connectors of FIG. **3** in which the push-pull tabs are not integrated with the optical connector housing. As seen in FIGS. **19**A-**19**B, a push-pull tab **1930** is a separable element from a connector housing. The push-pull tab **1930** actuates a latch **1910** for inserting and extracting the connector from an adapter or transceiver. An alternative latching mechanism is depicted in FIGS. **19**C-**19**D. Latch **1950** includes a notch that is actuated by push-pull tab **1960**.

FIG. **20** depicts the disassembly of a four-connector housing (two duplex connectors in a single housing) into two duplex connectors. This may be performed in changing, for example, a connector as shown in FIG. **14**A to a connector as shown in FIG. **14**C. In FIG. **20**, an optical connector **2000** is depicted including a housing **2010** that houses two duplex connectors (four optical fibers). The housing **2010** is removed, leaving the two duplex connectors **2020**. Two housings **2030** are then provided and two individual duplex connectors **2040** are then created from the initial single housing connector **2000**. This reconfigurable housing simplifies cable management, for example, when optical cables are interconnected between lower-speed transceivers and higher-speed transceivers as seen in FIG. **16**.

FIG. **21**A depicts an embodiment of an optical connector **2100**, shown in exploded view while **21**B depicts the optical connector **2100** in an assembled view. Optical connector **2100** may include an outer housing **2110**, a front body **2115**, one or more ferrules **2122**, one or more ferrule flanges **2124**, one or more springs **2125**, a back body **2130**, a back post **2135**, a crimp ring **2140**, and a boot **2145**. The outer housing **2110** may include a longitudinal bore for accommodating the front body **2115** and a ferrule assembly **2120**, a connector alignment key **2105** used during interconnection, a connector flap **2103** and an optional pull tab **2107** to facilitate removal of the connector **2100** when connected in a dense array of optical connectors. Optionally, the ferrules may be LC-type ferrules having an outer diameter of 1.25 mm.

In prior art optical connectors, an inner enclosed housing was used in place of open front body **2115**. Front body **2115** includes top and bottom portions but no sidewalls, termed "open sidewalls" in this embodiment. By using front body **2115**, space occupied by the prior art inner housing sidewalls becomes available to increase the density of optical connectors within a given footprint, an advantage over prior art connectors. It was determined that the outer housing **2110**, combined with the front body **2115**, provided sufficient mechanical strength and ferrule protection, advantageously providing the space for additional optical connectors. Removal of sidewalls increases available space by 1-2 millimeters.

Note that, in this embodiment, the outer housing is configured to hold two optical ferrules **2122**. Typically, two optical ferrules may be used in a "transmit" and "receive" pairing of optical fibers, called a duplex connector. However, the outer housing may be configured to hold more or fewer optical ferrules including a single optical ferrule, multiples of single optical ferrules, or multiple pairs of optical ferrules, depending upon the application. Further, the front body **2115** may be removed from the outer housing **2110** and the front body placed in a larger outer housing with other front bodies to form a larger optical connector in a manner to be discussed in more detail below. In particular, two front bodies may be used with a four-ferrule outer housing or four front bodies may be used with an eight-ferrule outer housing.

Turning to FIGS. **29**A and **29**B, isometric and front views of the outer housing **2110** are shown. As seen in the front view of FIG. **29**B and the cross-sectional view of FIG. **29**C, connector orientation protrusions **2910** are provided within the interior of the outer housing **2110**. Connector protrusion **2910** is further seen in the inner view of the housing, FIG. **29**E. When the front body is inserted within the longitudinal bore **2101** of outer housing **2110**, the outer housing connector flap **2103** locks the outer housing **2110** to the front body **2115** in the following manner. As the front body **2115** is inserted into the outer housing **2110**, the outer housing locking surface **2114**, best seen in FIG. **27**C, engages the connector orientation protrusion **2910**, seen in an inside view of the outer housing in FIG. **29**D, labelled as "Flap A", flexing the connector flap **2103** outwardly from the outer housing body **2110**, depicted in the inset of FIG. **29**C. The flap protrusion mating location is indicated as "mating place B" in FIG. **29**D. Once the locking surface **2114** passes beyond the orientation protrusion, the connector flap returns to its original position (FIG. **29**A), and the protrusion **2910** engages locking surface **2114** and any withdrawal of the front body assembly from the outer housing **2110** is prevented as the proximal end face of the connector flap **2103** is stopped by protrusion **2910**.

FIGS. **35**A-**35**C depict the sequence of operations to remove an assembled front body from the outer housing in order to reverse polarity or to aggregate plural connectors in a multi-connector housing. To separate the front body from the outer housing, the connector flap **2103** is flexed outward using a finger or a tool, as depicted in FIG. **35**B. Flexing the connector flap **2103** outwardly causes the protrusion **2910** to disengage from the front body's outer housing locking surface **2114**, permitting the front body/ferrule assembly **2115** to be removed from the outer housing. This may be performed when it is desired to reverse the polarity of the connector (to be discussed below) or when desiring to aggregate plural connectors into a larger connector housing as discussed above. The separated components are depicted in FIG. **35**C, that is, front body **2115** with the ferrule assembled therein and outer housing **2110**.

In some embodiments, the back body **2130** may comprise one or more protrusions or hooks **2134**, best seen in FIGS. **28**A and **28**B, which may interlock with a back body hook window/cutout **2119** in the front body **2115**. This may allow for the back body **2130** and the front body **2115** to be securely fastened together around the ferrule(s) **2122**, ferrule flange(s) **2124**, and the spring(s) **2125**. The back body **2130** includes a cable bore **2820**, spring guides **2132**, and side protrusions **2810**.

During assembly, the ferrule flanges **2124** fit into ferrule flange alignment slots **2117** (see FIGS. **27**A and **27**B) adjacent the ferrule openings **2116** of the front body **2115**, compressing the springs **2125** (preload) which are positioned along front body spring holders **2118**. The ends of the springs **2125** are secured on spring guides **2132** (FIGS. **28**A, **28**B) of back body **2130** by spring tension. As seen in the assembled cross-sectional views of FIGS. **23**A and **23**B, the springs **2125** are positioned to urge the ferrules **2122** into contact with mating connectors or transceiver optics, ensuring minimum insertion loss. As further seen in FIGS. **27**A and **27**B, the front body includes a receptacle hook recess **2710** with a receptacle hook retainer surface **2720** the receiver a receptacle hook when mating with an adapter or with a transceiver receptacle, as shown in further detail below.

Further reductions in connector size may be obtained by reducing the size of springs **2125**, see FIG. **21**. By using a maximum spring outer diameter of 2.5 mm, the pitch of the ferrules, that is to say, the spacing between adjacent ferrules, may be reduced to 2.6 mm when coupled with the removal of inner housing walls and walls separating adjacent ferrules. This advantage is best seen in FIG. **22** which depicts the front of connector **2100** showing overall connector dimensions and ferrule pitch. The connector size 4.2×8.96×30.85 mm (excluding optional pull tab **2107** and connector alignment key **2105**) with a ferrule pitch of 2.6 mm.

As best seen in FIG. **21**B, the outer housing **2110** and the front body **2115** together provide a receptacle hook ramp **2940** (on the outer housing) used to guide a receptacle hook into a receptacle hook recess **2170** (in the front body **2115**), also shown in FIGS. **27**A and **27**B (receptacle hook recess **2710** and receptacle hook retainer surface **2720**). The receptacle hook, to be discussed in more detail below, may be from an adapter or a transceiver to secure the optical connector **2100** thereto.

The optical connectors **2100** may be used in a variety of connection environments. In some applications, the optical connectors **2100** will mate with other optical connectors. Typically, this mating will occur with a receptacle such as an adapter or optical transceiver receptacle. An exemplary adapter **2400** depicted in FIG. **24** in an exploded view and depicted in FIG. **31** having four mating pairs of optical connectors **2100** latched therein. In other applications, as when an optical signal is to be converted to an electrical signal, the micro optical connectors **2100** will mate with an optical receptacle in a transceiver **3600** as shown in FIG. **36**. Typically, transceiver **3600** may be found in a data center, switching center, or any other location where optical signals are to be converted to electrical signals. Transceivers are often a part of another electrical device such as a switch or a server, as is known in the art. Although much of the connection operation of this embodiment will be described with respect to an adapter, **2400**, it is understood that substantially similar mechanical retention mechanisms are positioned within the receptacle of transceiver **3600** so that any description of connector retention in adapter **2400** applies in a substantially similar way to retention of an optical connector within transceiver **3600**. An example of a transceiver optical receptacle is depicted in FIG. **36**B (holding optical connectors **2100**); as seen in FIG. **36**B, the connection environment is substantially similar to one-half of an adapter **2400**.

Turning to FIG. **24**, further size reductions in the overall optical assembly of connectors plus adapter or connectors plus transceiver may be obtained through various connection mechanisms to be described with respect to the adapter **2400** but also apply to optical connection features within the front end of transceiver **3600**. The adapter **2400** includes an adapter housing **2402** having an adapter alignment assembly **2430** positioned therein. The adapter alignment assembly **2430** includes alignment sleeves **2410** positioned within alignment sleeve openings **2440** of alignment sleeve holders **2442**. The adapter alignment assembly further includes receptacle hooks **2302** that will grip optical connectors **2100** through front body connector hook recess **2710** of FIG. **21**B. As seen in FIG. **30**, receptacle hooks **2302** include an inner surface **3110**. The adapter housing **2402** further includes connector alignment slots **2403** that mate with connector alignment key **2105** of FIG. **21**A. The connectors **2100** are received through connector opening **2405** of the adapter housing **2402** which also includes flex tab **2401**, cutout **2456**, mount plate **2452** and panel hook **2490**. To assemble the adapter alignment assembly **2430** in the adapter housing **2402**, adapter housing hooks **2432** are provided. Adapter housing hooks **2432** are received in housing adapter hook openings.

It should be understood that above description of connection mechanisms with respect to adapter **2400** may be applied in a substantially similar way with respect to the receptacle of transceiver **3600**. Particularly, the receptacle of transceiver **3600** may include a receptacle housing having a receptacle alignment assembly positioned therein. The receptacle alignment assembly includes alignment sleeves positioned within alignment sleeve openings of alignment sleeve holders. The receptacle alignment assembly further includes receptacle hooks that will grip optical connectors **2100** through front body connector hook recess **2710** of FIG. **21**B. As seen in FIG. **30**, receptacle hooks **2302** include an inner surface **3110**. The receptacle housing further includes connector alignment slots that mate with connector alignment key of FIG. **21**A. The connectors **2100** are received through connector opening of the receptacle housing which also includes flex tab, cutout, mount plate and panel hook. To assemble the receptacle alignment assembly in the receptacle housing, receptacle housing hooks are provided. Receptacle housing hooks are received in housing receptacle hook openings.

To further reduce the size of optical connectors and associated mating components, the adapter housing **2402** includes receptacle hook openings **2420**, seen in FIGS. **25**A and **25**B. Receptacle hook openings **2420** accommodate the clearance required by receptacle hooks **2302** when they flex upwards prior to latching with connectors **2100**. The interaction of the receptacle hooks **2302**, having slanted inner surfaces **3110**, with the receptacle hook openings **2420** is best seen in FIGS. **32**B and **34**A-C. Prior to latching (FIG. **34**A), the receptacle hook **2302** is in an unflexed condition within the receptacle (adapter or transceiver). As the connector **2100** is inserted into the adapter housing **2402** or the transceiver, the receptacle ramp **2490** pushes against the receptacle hook inner surfaces **3110**, flexing receptacle hook **2302** into the receptacle hook opening **2420**. Without providing the opening, additional clearance would need to be provided to accommodate the flexing of the receptacle hook **2302**. This additional required clearance is depicted in the prior art connector/adapter of FIG. **32**A. As seen in FIG. **32**A, a connector latch gap **3210** must be provided in the prior art to accommodate the prior art connector hooks, increasing the overall footprint of the prior art connector/adapter assembly. By providing receptacle hook openings **2420** in the present disclosure, approximately 2.25 mm of valuable footprint real estate is obtained which may be used to increase connector density.

Another improvement in adapter size is obtained by removing prior art adapter walls between adjacent connectors. This is best seen in the front view of an assembled adapter **2400** shown in FIG. **26**. As seen, pairs of ferrule alignment sleeves **2410** are separated only by connector gap **2610** with a 4.35 mm pitch between adjacent connectors. The adapter size is 19.0×10.71×32.5 mm (excluding the adapter flange **2460**). Also seen in FIG. **26** is the connector alignment slot **2403**, alignment sleeve holder **2442**, and a front view of receptacle hooks **2302**.

FIG. **31** depicts an assembled adapter **2400** with four pairs of mating connectors **2100** latched therein. Note that in the latched position, receptacle hooks **2302** do not extend into

receptacle hook openings **2420**. This is further visible in the cross-sectional view of an assembled adapter **2400** of FIG. **25**A. Connector alignment keys **2105** are positioned within connector alignment slots **2403**. As seen in the cross-sectional view of FIG. **23**A, the push-pull tab **2017** may extend beyond the connector boot **2145** providing clearance to easily grip the tab and remove a connector. Also seen in FIG. **31** is adapter flex tab **2401** and panel hook **2490** for interaction with racks or other equipment.

Through the various features described above, the density of optical connectors **2100** that may be provided in the standard transceiver footprint connector spaces may be doubled. For example, in a small form factor pluggable (SFP) footprint of 14×12.25 mm, two connectors **2100** having four LC-type ferrules **2122** of 1.25 mm outer diameter may be accommodated as seen in FIG. **33**B. Similarly, in a quad small form factor pluggable (QSFP) footprint of 13.5×19 mm, four connectors **2100** having a total of eight LC-type ferrules **2122** may be accommodated as seen in FIG. **33**A. Further, by providing the connectors in transmit and receive pairs, greater flexibility in optical routing is obtained, as demonstrated by previous FIGS. **16** and **17**.

Turning to FIG. **37**, another embodiment of an optical connector is depicted. In this embodiment, the last two digits of each element correspond to the similar elements in the optical connector of FIG. **21**A et seq. In FIG. **37**, connector **3700** may include an outer housing **3710**, a front body **3715**, one or more ferrules **3722**, one or more ferrule flanges **3724**, one or more springs **3725**, a back body **3730**, a back post **3735**, a crimp ring **3740** (depicted with an optional heat shrink tube extending therefrom), and a boot **3745**. The outer housing **3710** may include a longitudinal bore **3701** for accommodating the front body **3715** and ferrules **3722**, a connector alignment key **3705** used during interconnection, a connector flap **3703** and an optional pull tab **3707** to facilitate removal of the connector **3700** when connected in a dense array of optical connectors. Optionally, the ferrules may be LC-type ferrules having an outer diameter of 1.25 mm.

In FIG. **38** an isometric view of the front body **3715** is depicted. In this embodiment, the back body hook cutout **3819** has been moved forward, advantageously strengthening the assembled connector in side load environments. An alignment tab **3895** is provided for mating with a receiving recess on the back body. The receptacle hook recess **3910** operates in a substantially similar manner to the recess of FIG. **21**A, described above. A ferrule flange alignment slot **3817** is also provided.

In FIG. **39**, the back body **3730** is depicted, showing alignment tab recess **3997** for receiving alignment tab **3895**. The front body hook **3934**, for interconnecting in back body hook cutout **3819**, extends outwardly from the main portion of the back body through extended hook arm **3996**. Through the extended hook arm **3996** and the alignment tab **3895**, breakage during side loads is reduced as the load is redistributed more evenly across the entire connector, reducing stress on the backpost.

As seen in FIGS. **40**A-**40**C, the assembled front body **3715** may be removed from the outer housing **3710**, rotated 180° as indicated by the arrow (FIG. **40**B), and re-inserted into the outer housing (FIG. **40**C). This allows for a change in the polarity of the front body **3715**, and therefore the ferrules can switch quickly and easily without unnecessarily risking the delicate fiber cables and ferrules. As described previously with respect to FIGS. **35**A-**35**C, connector flap **3703** is flexed outward to release the front body from the outer housing.

Turning to FIG. **41**, another embodiment of an optical connector is depicted. In this embodiment, the last two digits of each element correspond to the similar elements in the micro optical connectors of FIG. **21**A and FIG. **37**. In FIG. **41**, connector **4100** may include an outer housing **4110**, a front body **4115**, one or more ferrules **4122**, one or more springs **4125**, a back body **4130**, a crimp ring **4140**, and a boot **4145**. The outer housing **4110** may include a connector flap **4103** and an optional pull tab **4107** to facilitate removal of the connector **4100** when connected in a dense array of optical connectors. Optionally, the ferrules may be LC-type ferrules having an outer diameter of 1.25 mm.

As seen in FIG. **42**A, the front body **4015** in this embodiment includes a middle wall **4260** interposed between the ferrules and springs when the front body is assembled. This middle wall reduces the possibility of the springs becoming entangled with each other, binding the connector and breaking the optical fibers. The front body **4015** also includes an alignment cut out guide **4625**, seen in the side view of FIG. **42**B. The alignment cut out guides the back body **4030** into the front body **4015** during assembly of the connecter, and also further reduces the side load that leads to connector breakage or disconnection of the front body and the back body **4030**.

Back body **4030**, depicted in an enlarged view in FIG. **43**, includes an alignment guide **4377** that fits into the alignment cut out guide **4265** of FIG. **42**B. The wall structure **4378** also stops the front body to prevent over-compressing the springs and provides strength under a side load.

Various modifications to the outer housing, depicted in FIGS. **44**A-**44**C, may be used with any of the optical connectors depicted in FIGS. **21**, **37**, and **41** or earlier embodiments. In FIG. **44**A, the push-pull tab **3707** may include a release recess **4473**. Release recess **4473** permits insertion of a tool or fingernail to remove the connector from an adapter or transceiver, without disturbing adjacent connectors. Similarly, FIG. **44**B depicts a release hole **4499** in push-pull tab **3707** to permit insertion of an extraction tool to remove the connector from an adapter or transceiver. FIG. **44**C shows a modified connector flap **3703** with an increased cutout size of 1 mm to make it easier to insert a tool or a finger to flex the flap **3703** and remove the front body assembly when making a polarity change or aggregating the front body with other front bodies in a larger outer housing.

Another embodiment of an adapter/transceiver receptacle is depicted in FIG. **45**. Unlabeled elements are substantially similar to elements depicted in FIG. **24**. In this FIG., adapter housing hooks **4532** can be seen along with receptacle hooks **4502**. Turning to the cross-sectional view of the assembled adapter in FIG. **46**, the engagement of these elements may be seen.

Another embodiment of an optical connector **4700** is depicted in FIG. **47**. The optical connector of FIG. **47** includes outer housing **4710**, front body **4715**, ferrules **4722**, springs **4725**, back body **4730**, backpost **4735**, crimp ring **4740**, and boot **4745**. Here, the emphasis is on the back body, **4730**. A more detailed view of the back body **4730** is presented in FIG. **48**. In this embodiment, the backpost flange has a substantially rectangular shape in order to narrow the overall connector profile by approximately 0.5 mm. Back post overmolding **4859** accommodates the back post flange **4857** and reduces the potential for back post breakage. The back wall **4853** is extended in length to 3 mm from 1.5 mm to improve the sideload strength of the overall connector. The crimp ring positioning **4855** is inversed from earlier embodiments to improve holding of aramid fiber from an optical fiber cable, improving cable retention of the back post.

Many advantages are achieved by the backpost of FIG. **48**. In addition to increased connector strength, a longer fiber path **4901** is provided as shown in FIG. **49**. This longer fiber path, approximately 1.5 mm longer than in previous embodiments, allows for a gentler curve as the fibers are split from the fiber optic cable, improving insertion and return loss of the fibers. In FIG. **49**, the back wall **4853** can be seen as a portion of the back body **4730**.

In view of the various modifications of this embodiment, FIG. **50** depicts a connector **4700** front view showing overall reduced connector width of 3.85 mm. Such a size reduction permits **4** optical connectors (a total of 8 ferrules) to be accommodated in a transceiver or connector footprint of 16 mm (including tolerances). Thus, the connectors of the present invention may be used to connect 8 LC-ferrule-housed fibers in a QSFP footprint.

To further decrease the space required by the optical connectors, a side thickness reduction may be carried out on the boot of connector **4700**. Side thickness reduction **5103**, depicted in FIG. **51**, narrows the thickness of the boot on either side, reducing the space required by the boot to the 3.85 mm profile of connector **4700**. Thus four connectors will fit in the QSFP transceiver footprint. This footprint is shown in the adapter front view of FIG. **52**—as noted above, the front view of an adapter and that of a transceiver are substantially similar from the optical perspective. In FIG. **52**, the adapter inner wall is reduced from 17.4 mm to 16 mm. All of the modifications set forth in the FIG. **47** et seq. embodiment make it possible for the four connectors to fit in the profile of FIG. **52**.

In the above detailed description, reference is made to the accompanying drawings, which form a part hereof. In the drawings, similar symbols typically identify similar components, unless context dictates otherwise. The illustrative embodiments described in the detailed description, drawings, and claims are not meant to be limiting. Other embodiments may be used, and other changes may be made, without departing from the spirit or scope of the subject matter presented herein. It will be readily understood that the aspects of the present disclosure, as generally described herein, and illustrated in the Figures, can be arranged, substituted, combined, separated, and designed in a wide variety of different configurations, all of which are explicitly contemplated herein.

The present disclosure is not to be limited in terms of the particular embodiments described in this application, which are intended as illustrations of various aspects. Many modifications and variations can be made without departing from its spirit and scope, as will be apparent to those skilled in the art. Functionally equivalent methods and apparatuses within the scope of the disclosure, in addition to those enumerated herein, will be apparent to those skilled in the art from the foregoing descriptions. Such modifications and variations are intended to fall within the scope of the appended claims. The present disclosure is to be limited only by the terms of the appended claims, along with the full scope of equivalents to which such claims are entitled. It is to be understood that this disclosure is not limited to particular methods, reagents, compounds, compositions or biological systems, which can, of course, vary. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to be limiting.

With respect to the use of substantially any plural and/or singular terms herein, those having skill in the art can translate from the plural to the singular and/or from the singular to the plural as is appropriate to the context and/or application. The various singular/plural permutations may be expressly set forth herein for sake of clarity.

It will be understood by those within the art that, in general, terms used herein, and especially in the appended claims (for example, bodies of the appended claims) are generally intended as "open" terms (for example, the term "including" should be interpreted as "including but not limited to," the term "having" should be interpreted as "having at least," the term "includes" should be interpreted as "includes but is not limited to," et cetera). While various compositions, methods, and devices are described in terms of "comprising" various components or steps (interpreted as meaning "including, but not limited to"), the compositions, methods, and devices can also "consist essentially of" or "consist of" the various components and steps, and such terminology should be interpreted as defining essentially closed-member groups. It will be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present. For example, as an aid to understanding, the following appended claims may contain usage of the introductory phrases "at least one" and "one or more" to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles "a" or "an" limits any particular claim containing such introduced claim recitation to embodiments containing only one such recitation, even when the same claim includes the introductory phrases "one or more" or "at least one" and indefinite articles such as "a" or "an" (for example, "a" and/or "an" should be interpreted to mean "at least one" or "one or more"); the same holds true for the use of definite articles used to introduce claim recitations. In addition, even if a specific number of an introduced claim recitation is explicitly recited, those skilled in the art will recognize that such recitation should be interpreted to mean at least the recited number (for example, the bare recitation of "two recitations," without other modifiers, means at least two recitations, or two or more recitations). Furthermore, in those instances where a convention analogous to "at least one of A, B, and C, et cetera" is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (for example, "a system having at least one of A, B, and C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, et cetera). In those instances where a convention analogous to "at least one of A, B, or C, et cetera" is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (for example, "a system having at least one of A, B, or C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, et cetera). It will be further understood by those within the art that virtually any disjunctive word and/or phrase presenting two or more alternative terms, whether in the description, claims, or drawings, should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms. For example, the phrase "A or B" will be understood to include the possibilities of "A" or "B" or "A and B."

In addition, where features or aspects of the disclosure are described in terms of Markush groups, those skilled in the art will recognize that the disclosure is also thereby described in terms of any individual member or subgroup of members of the Markush group.

As will be understood by one skilled in the art, for any and all purposes, such as in terms of providing a written description, all ranges disclosed herein also encompass any and all possible subranges and combinations of subranges thereof. Any listed range can be easily recognized as sufficiently describing and enabling the same range being broken down into at least equal halves, thirds, quarters, fifths, tenths, et cetera As a non-limiting example, each range discussed herein can be readily broken down into a lower third, middle third and upper third, et cetera As will also be understood by one skilled in the art all language such as "up to," "at least," and the like include the number recited and refer to ranges which can be subsequently broken down into subranges as discussed above. Finally, as will be understood by one skilled in the art, a range includes each individual member. Thus, for example, a group having 1-3 cells refers to groups having 1, 2, or 3 cells. Similarly, a group having 1-5 cells refers to groups having 1, 2, 3, 4, or 5 cells, and so forth.

Various of the above-disclosed and other features and functions, or alternatives thereof, may be combined into many other different systems or applications. Various presently unforeseen or unanticipated alternatives, modifications, variations or improvements therein may be subsequently made by those skilled in the art, each of which is also intended to be encompassed by the disclosed embodiments.

The invention claimed is:

1. An optical fiber connector comprising:

a housing having a longitudinal axis and a front end portion and a rear end portion spaced apart along the longitudinal axis, the housing comprising opposite first and second end walls spaced apart along a transverse axis oriented perpendicular to the longitudinal axis, the housing comprising opposite first and second side walls spaced apart along a lateral axis oriented perpendicular to the longitudinal axis and the transverse axis;

an MT ferrule received in the housing and exposed through the front end portion of the housing for making an optical connection, the MT ferrule configured to receive plurality of fibers such that the fibers are spaced apart in a row that extends parallel to a fiber alignment axis, the MT ferrule further comprising first and second guide pin openings spaced apart along the fiber alignment axis; and

a polarity key disposed on the first end wall;

wherein each of the first and second end walls has a lateral dimension along the lateral axis and each of the first and second side walls has a transverse dimension along the transverse axis, the lateral dimension being less than the transverse dimension;

wherein the optical fiber connector is configured to latch with a mating adapter and wherein the optical fiber connector is configured to be actuated to unlatch from the mating adapter by displacing a first portion of the optical fiber connector rearward relative to a second portion of the optical fiber connector, wherein said displacing the first portion of the optical fiber connector rearward relative to the second portion of the optical fiber connector displaces the polarity key rearward relative to the MT ferrule.

2. The optical fiber connector as set forth in claim **1**, wherein the optical fiber connector is free of a polarity key disposed on the second end wall.

3. The optical fiber connector as set forth in claim **1**, wherein each of the first and second side walls is substantially flat.

4. The optical fiber connector as set forth in claim **1**, wherein the polarity key extends from a rear end adjacent the rear end portion of the housing to a front end rearwardly spaced apart from the front end portion of the housing.

5. The optical fiber connector as set forth in claim **1**, further comprising a remote release.

6. The optical fiber connector as set forth in claim **5**, wherein the remote release includes a front longitudinal segment disposed on the first end wall of the housing.

7. The optical fiber connector as set forth in claim **1**, further comprising a strain relief boot extending from the rear end portion of the housing.

8. The optical fiber connector as set forth in claim **1**, wherein the MT ferrule is configured to receive at least eight optical fibers in a row extending parallel to the fiber alignment axis.

9. The optical fiber connector as set forth in claim **1**, wherein the connector is an SN type connector.

10. The optical fiber connector as set forth in claim **1**, wherein the connector includes an adapter latching feature along the first end wall of the housing.

11. The optical fiber connector as set forth in claim **1**, wherein the adapter latching feature is a latch recess configured to latch with a bendable latch hook of the mating adapter.

12. The optical fiber connector as set forth in claim **1**, wherein the connector includes a first latch recess along the first end wall of the housing and second latch recess along the second end wall of the housing, each of the first and second latch recesses configured to latch with a respective bendable latch hook of the mating adapter.

13. A connection system comprising the optical fiber connector of claim **1** and an adapter comprising a perimeter wall defining a receptacle in which to matingly receive said optical fiber connector of claim **1** and another optical fiber connector such that the first side wall of said optical fiber connector of claim **1** is in side-by-side relation with an opposing side wall of the other optical fiber connector.

14. The connection system of claim **13**, wherein the perimeter wall includes a plurality of longitudinal keyways, each longitudinal keyway capable of receiving the polarity key of said optical fiber connector of claim **1** therein.

15. The optical fiber connector as set forth in claim **1**, wherein the optical fiber connector is configured such that said optical fiber connector and another identical optical connector can fit in a small form-factor pluggable transceiver footprint.

16. The optical fiber connector as set forth in claim **1**, wherein the optical fiber connector is configured such that said optical fiber connector and three other identical optical connectors can fit in a quad small form-factor pluggable transceiver footprint.

17. An optical fiber connector comprising:

a housing;

an MT ferrule received in the housing, the MT ferrule configured to receive plurality of fibers such that the fibers are spaced apart in a row that extends parallel to a fiber alignment axis, the MT ferrule further comprising first and second guide pin openings spaced apart along the fiber alignment axis; and

a polarity key disposed on the housing such that the polarity key is configured to be spaced apart along the fiber alignment axis above the MT ferrule;

wherein the optical fiber connector is configured to latch with a mating adapter and wherein the optical fiber connector is configured to be actuated to unlatch from the mating adapter by displacing a first portion of the optical fiber connector rearward relative to a second portion of the optical fiber connector, wherein said displacing the first portion of the optical fiber connector rearward relative to the second portion of the optical fiber connector displaces the polarity key rearward relative to the MT ferrule.

18. The optical fiber connector as set forth in claim **17**, wherein the connector includes an adapter latching feature spaced apart along the fiber alignment axis above the MT ferrule.

19. The optical fiber connector as set forth in claim **18**, wherein the adapter latching feature is a latch recess configured to latch with a bendable latch hook of the mating adapter.

20. The optical fiber connector as set forth in claim **17**, wherein the optical fiber connector is free of a polarity key spaced apart along the fiber alignment axis below the MT ferrule.

21. The optical fiber connector as set forth in claim **17**, wherein the housing has a generally rectangular cross-sectional shape including upper and lower walls spaced apart above and below the MT ferrule along the fiber alignment axis and first and second lateral walls spaced apart on opposite lateral sides of the MT ferrule, each of the first and second lateral walls being substantially flat.

22. A connection system comprising the optical fiber connector of claim **17** and an adapter comprising a perimeter wall defining a receptacle in which to matingly receive said optical fiber connector of claim **17** and another optical fiber connector such that said optical fiber connector of claim **17** and the other optical fiber connector are located side-by-side in the receptacle along a connector alignment axis perpendicular to the fiber alignment axis.

23. The optical fiber connector as set forth in claim **17**, wherein the optical fiber connector is configured such that said optical fiber connector and another identical optical connector can fit in a small form-factor pluggable transceiver footprint.

24. The optical fiber connector as set forth in claim **17**, wherein the optical fiber connector is configured such that said optical fiber connector and three other identical optical connectors can fit in a quad small form-factor pluggable transceiver footprint.

25. The optical fiber connector as set forth in claim **1**, further comprising a ferrule spring yieldably biasing the MT ferrule forward in the housing, the ferrule spring configured to be compressed by a force urging the MT ferrule rearward in relation to the housing, wherein said displacing the first portion of the fiber optic connector rearward relative to the second portion of the optical fiber connector displaces the polarity key rearward relative to the MT ferrule independently of any movement of the MT ferrule in relation to the housing caused by resilient extension of the ferrule spring.

26. The optical fiber connector as set forth in claim **1**, further comprising a ferrule spring yieldably biasing the MT ferrule forward in the housing, the ferrule spring having a front end and a rear end, the ferrule spring configured to be compressed by a force urging the MT ferrule rearward in relation to the housing, the rear end of the ferrule spring being supported in the housing such that the rear end is stationary in the housing and the front end moves toward the rear end when the ferrule spring is compressed, wherein said displacing the first portion of the optical fiber connector rearward relative to the second portion of the optical fiber connector displaces the polarity key rearward relative to the rear end of the ferrule spring.

27. The optical fiber connector as set forth in claim **17**, further comprising a ferrule spring yieldably biasing the MT ferrule forward in the housing, the ferrule spring configured to be compressed by a force urging the MT ferrule rearward in relation to the housing, wherein said displacing the first portion of the fiber optic connector rearward relative to the second portion of the optical fiber connector displaces the polarity key rearward relative to the MT ferrule independently of any movement of the MT ferrule in relation to the housing caused by resilient extension of the ferrule spring.

28. The optical fiber connector as set forth in claim **17**, further comprising a ferrule spring yieldably biasing the MT ferrule forward in the housing, the ferrule spring having a front end and a rear end, the ferrule spring configured to be compressed by a force urging the MT ferrule rearward in relation to the housing, the rear end of the ferrule spring being supported in the housing such that the rear end is stationary in the housing and the front end moves toward the rear end when the ferrule spring is compressed, wherein said displacing the first portion of the optical fiber connector rearward relative to the second portion of the optical fiber connector displaces the polarity key rearward relative to the rear end of the ferrule spring.

* * * * *

EXHIBIT D

US011415760B2

(12) **United States Patent**
Takano et al.

(10) **Patent No.: US 11,415,760 B2**
(45) **Date of Patent: *Aug. 16, 2022**

(54) **NARROW WIDTH ADAPTERS AND CONNECTORS WITH PULL TAB RELEASE**

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(72) Inventors: **Kazuyoshi Takano**, Tokyo (JP); **Jeffrey Gniadek**, Oxford, ME (US)

(73) Assignee: **Senko Advanced Components, Inc.**, Hudson (MA)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **17/494,291**

(22) Filed: **Oct. 5, 2021**

(65) **Prior Publication Data**

US 2022/0029356 A1 Jan. 27, 2022

Related U.S. Application Data

(63) Continuation of application No. 16/695,901, filed on Nov. 26, 2019, now Pat. No. 11,152,748, which is a continuation of application No. 16/213,244, filed on Dec. 7, 2018, now Pat. No. 10,520,690, which is a continuation of application No. 15/044,838, filed on Feb. 16, 2016, now Pat. No. 10,158,194, which is a continuation-in-part of application No. 14/996,865, filed on Jan. 15, 2016, now Pat. No. 9,595,786.

(51) **Int. Cl.**
G02B 6/38 (2006.01)
H01R 13/633 (2006.01)

(52) **U.S. Cl.**
CPC ***G02B 6/3879*** (2013.01); *G02B 6/3893* (2013.01); *H01R 13/6335* (2013.01)

(58) **Field of Classification Search**
CPC .. G02B 6/3825; G02B 6/3879; G02B 6/3885; G02B 6/3893; H01R 13/627; H01R 13/6271; H01R 13/6272; H01R 13/6275; H01R 13/62933
USPC 385/76, 77, 88, 92; 439/133, 304, 345, 439/346, 350, 352, 353, 354, 357, 358, 439/370
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,052,186 B1 *	5/2006	Bates	G02B 6/3879 385/139
7,297,013 B2 *	11/2007	Caveney	H01R 13/6272 439/352
8,556,645 B2 *	10/2013	Crain	H01R 13/633 439/352
9,048,568 B2 *	6/2015	Chien	H01R 13/633
9,063,303 B2 *	6/2015	Irwin	G02B 6/3885

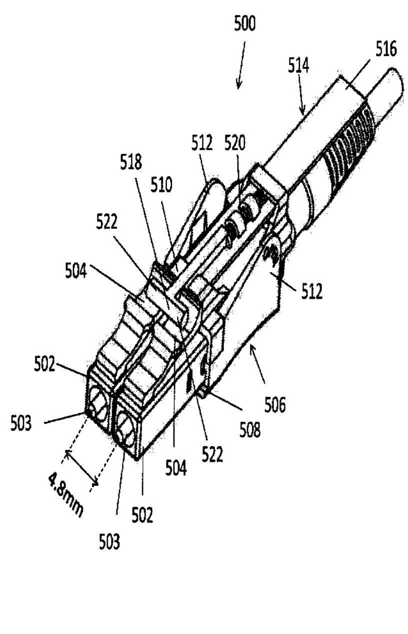
(Continued)

Primary Examiner — Robert Tavlykaev

(57) **ABSTRACT**

Narrow width fiber optic connectors having spring loaded remote release mechanisms to facilitate access and usage of the connectors in high density arrays. A narrow width fiber optic connector comprises a multi-fiber connector, wherein a width of said narrow width fiber optic connector is less than about 5.25 mm, a housing configured to hold the multi-fiber connector and further comprising a connector recess, and a pull tab having a ramp area configured to disengage a latch of one of an adapter and an SFP from said connector recess. The pull tab may include a spring configured to allow the latch of one of the adapter and the SFP to engage with the connector recess.

17 Claims, 19 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

2013/0022317	A1 *	1/2013	Norris	G02B 6/3865 385/78
2017/0351037	A1 *	12/2017	Watanabe	G02B 6/3885

* cited by examiner

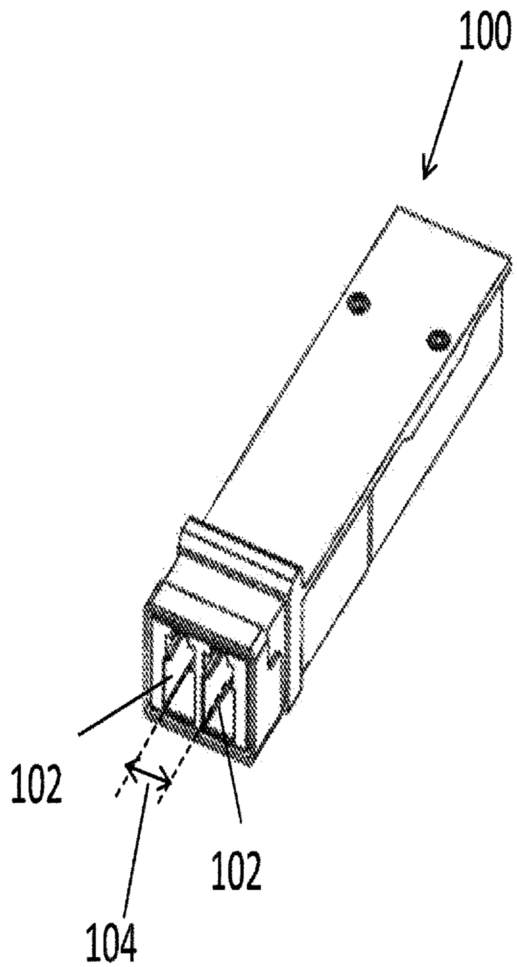


FIG. 1A
(Prior Art)

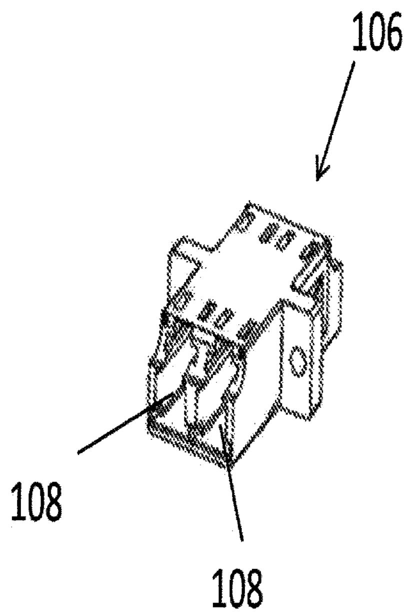


FIG. 1B
(Prior Art)

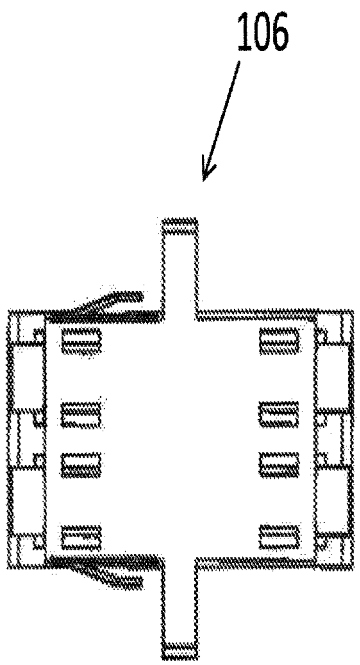


FIG. 1C
(Prior Art)

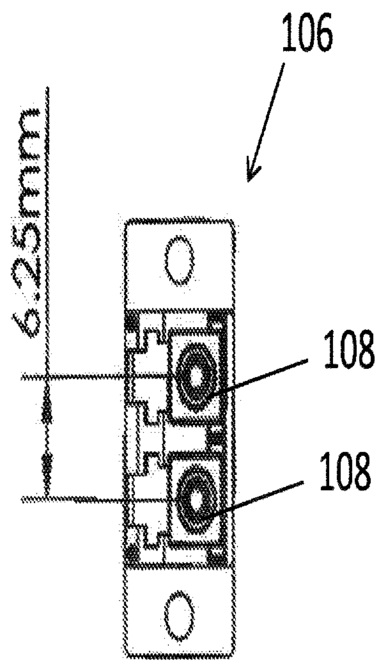


FIG. 1D
(Prior Art)

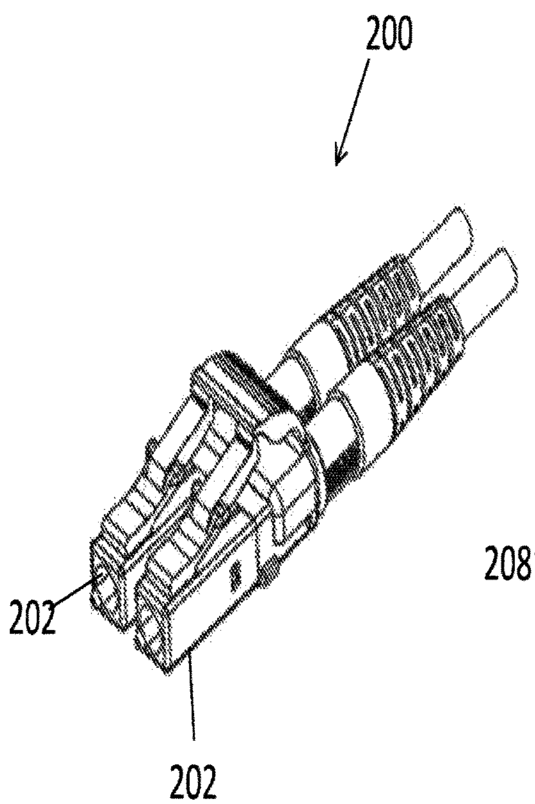


FIG. 2A
(Prior Art)

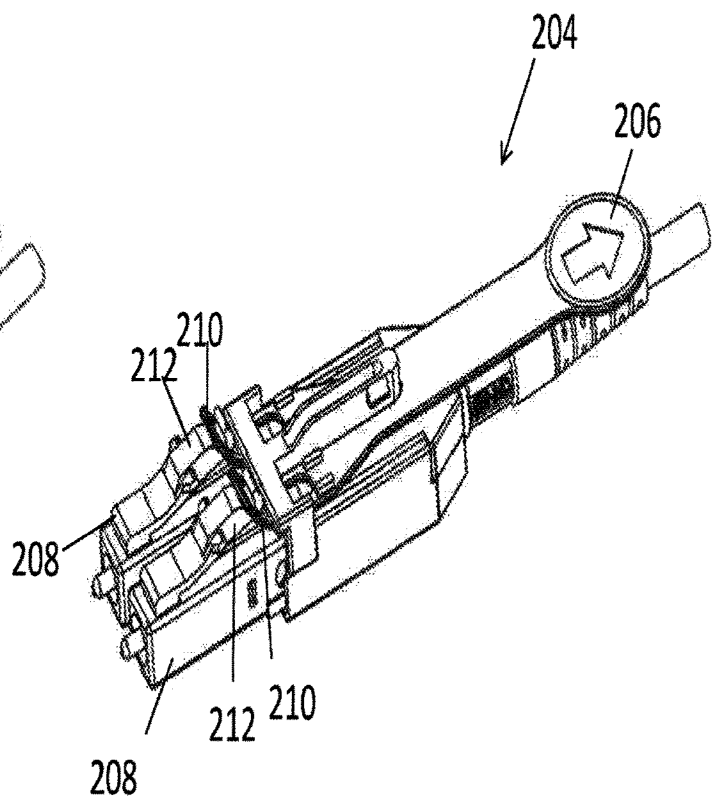


FIG. 2B
(Prior Art)

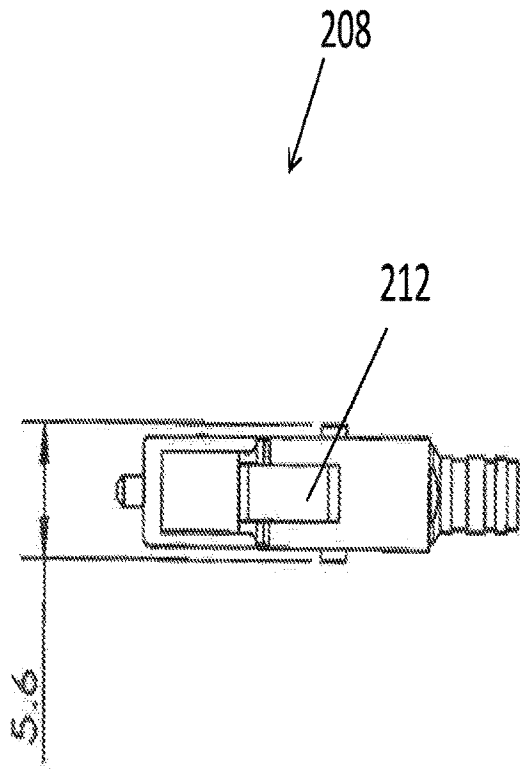


FIG. 2C
(Prior Art)

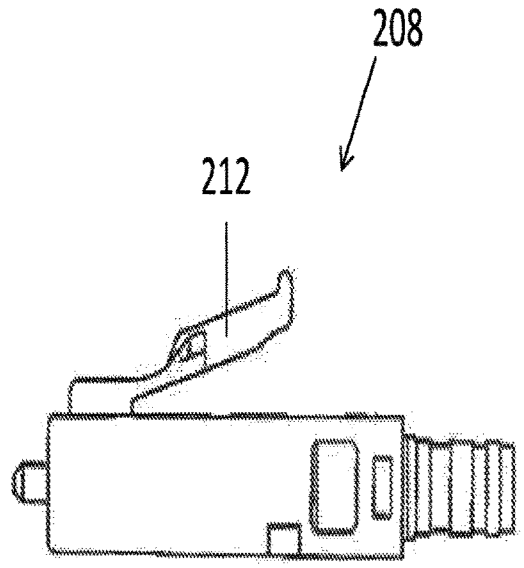


FIG. 2D
(Prior Art)

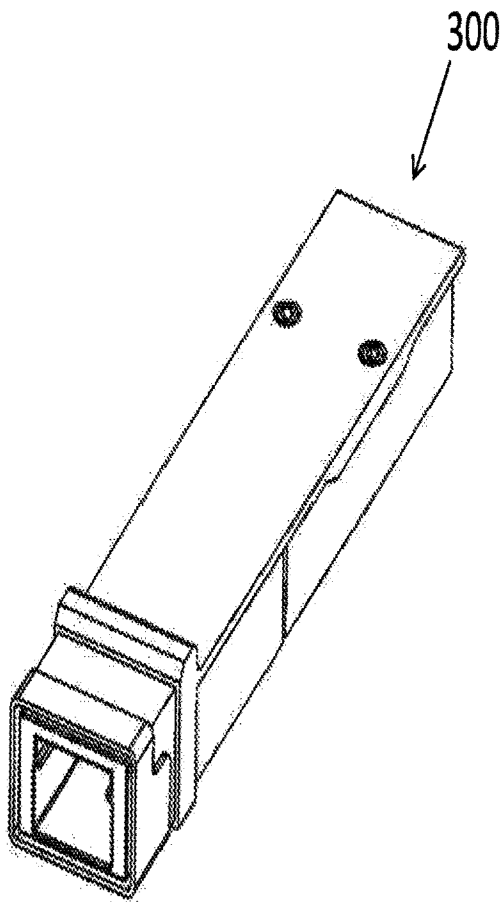


FIG. 3

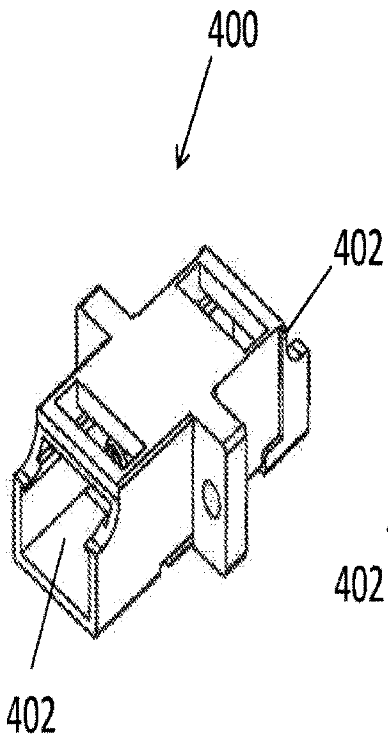


FIG. 4A

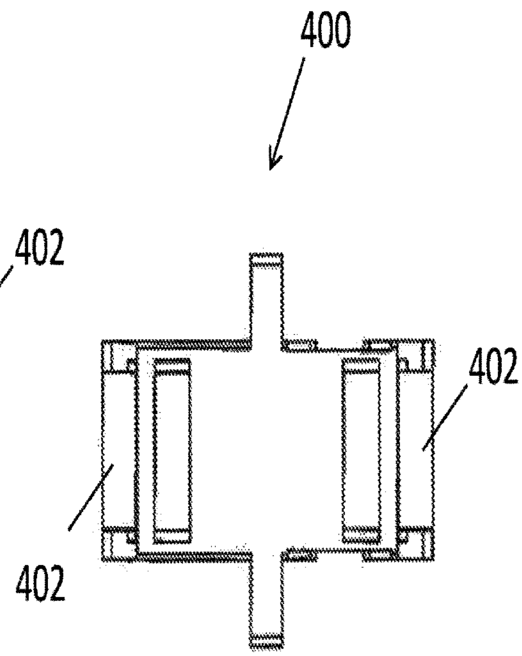


FIG. 4B

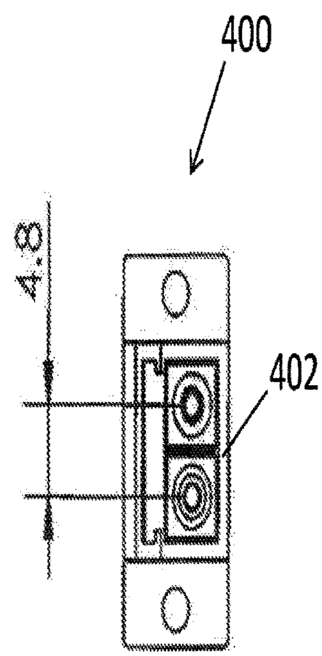


FIG. 4C

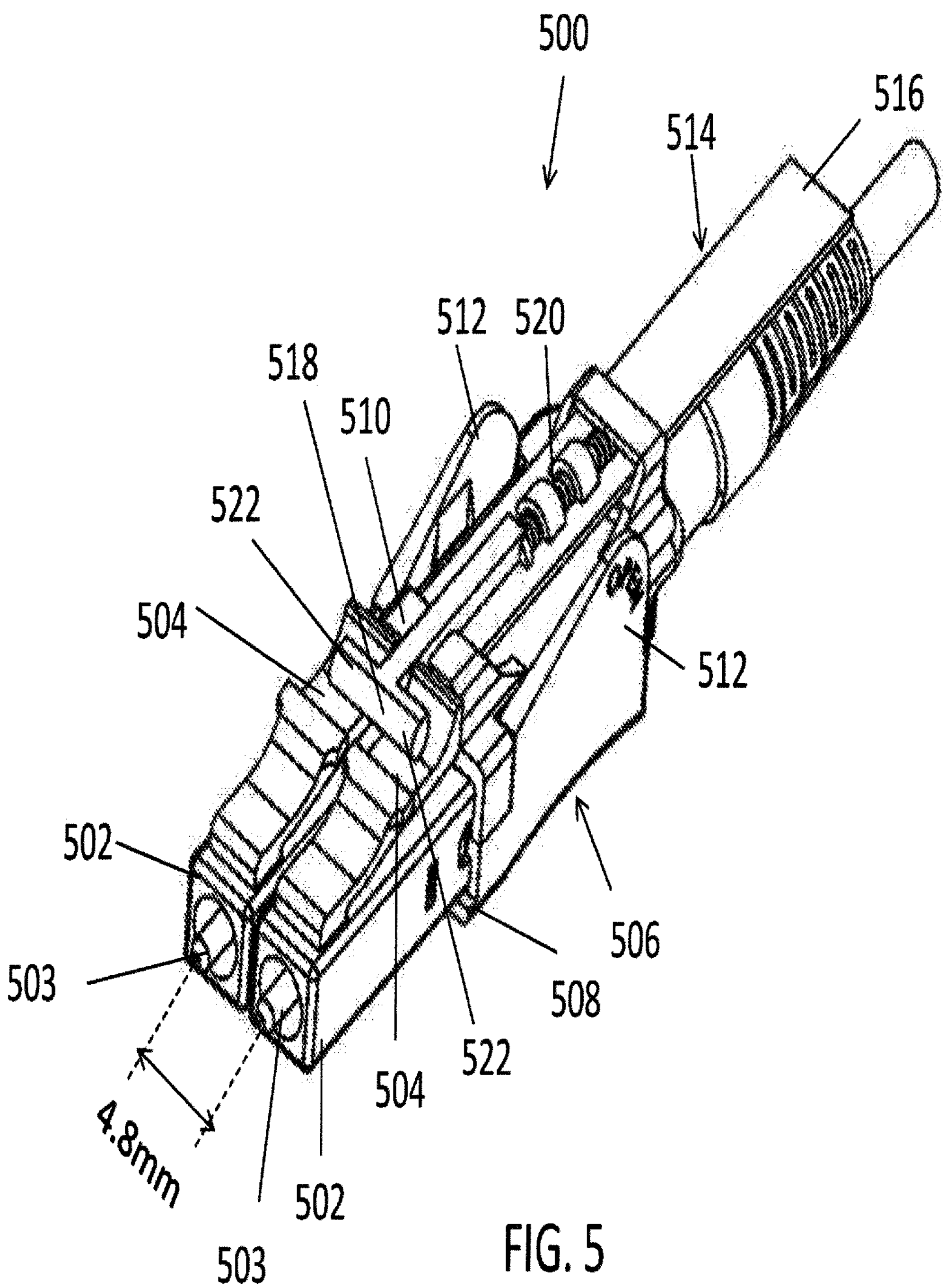

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FIG. 5

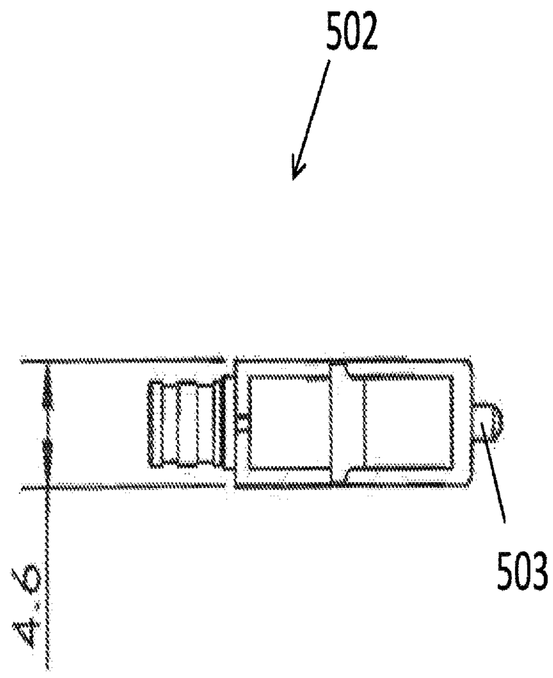

FIG. 6A

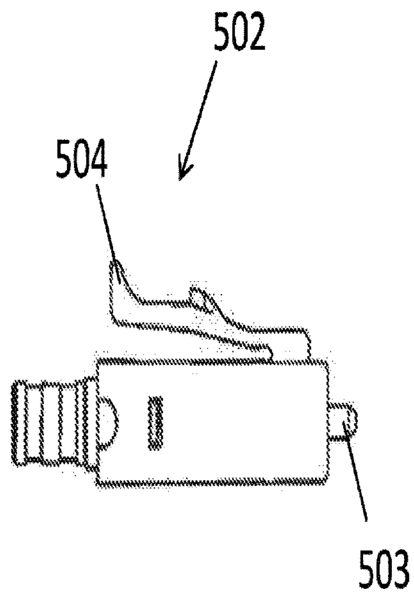

FIG. 6B

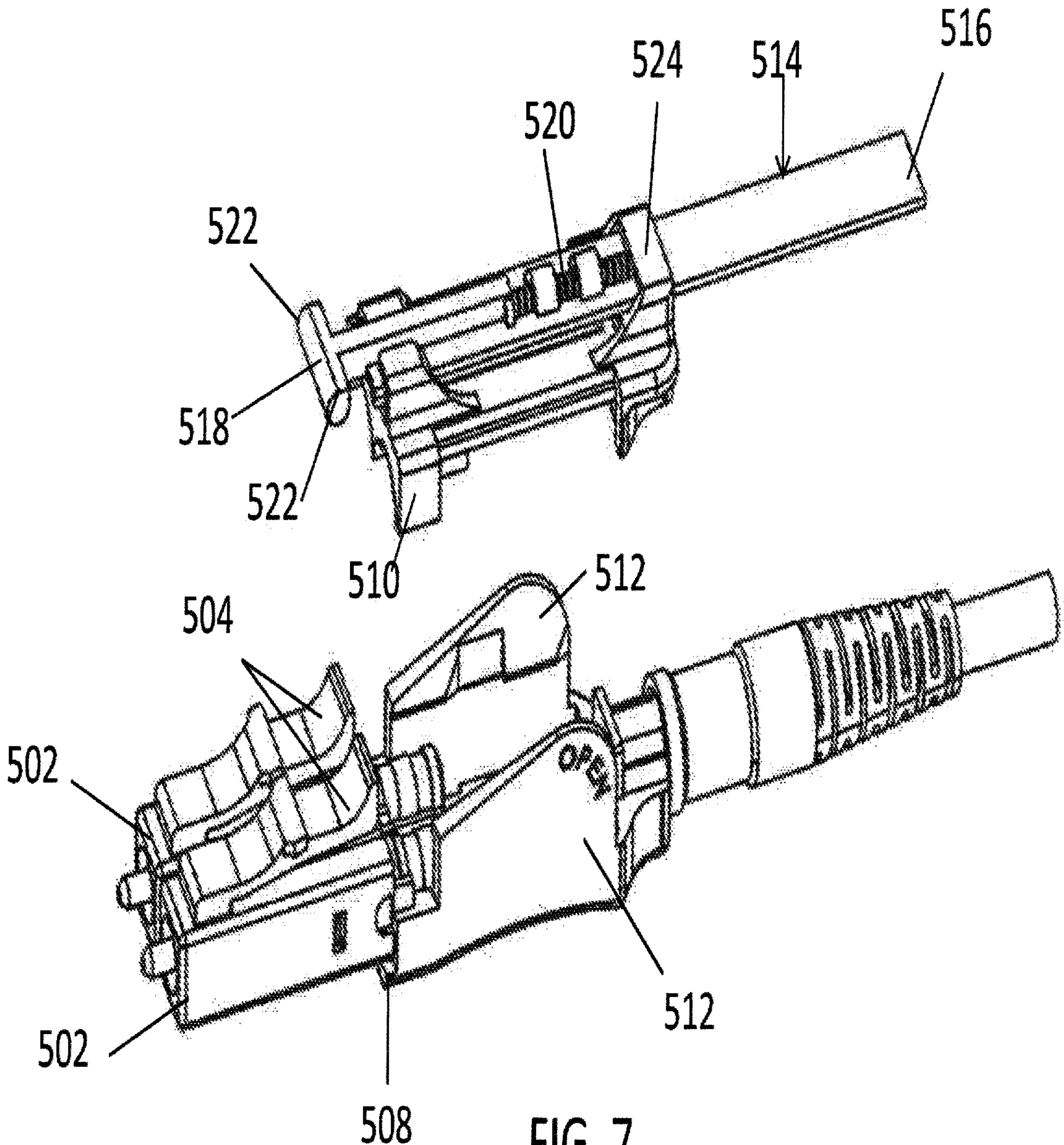

FIG. 7

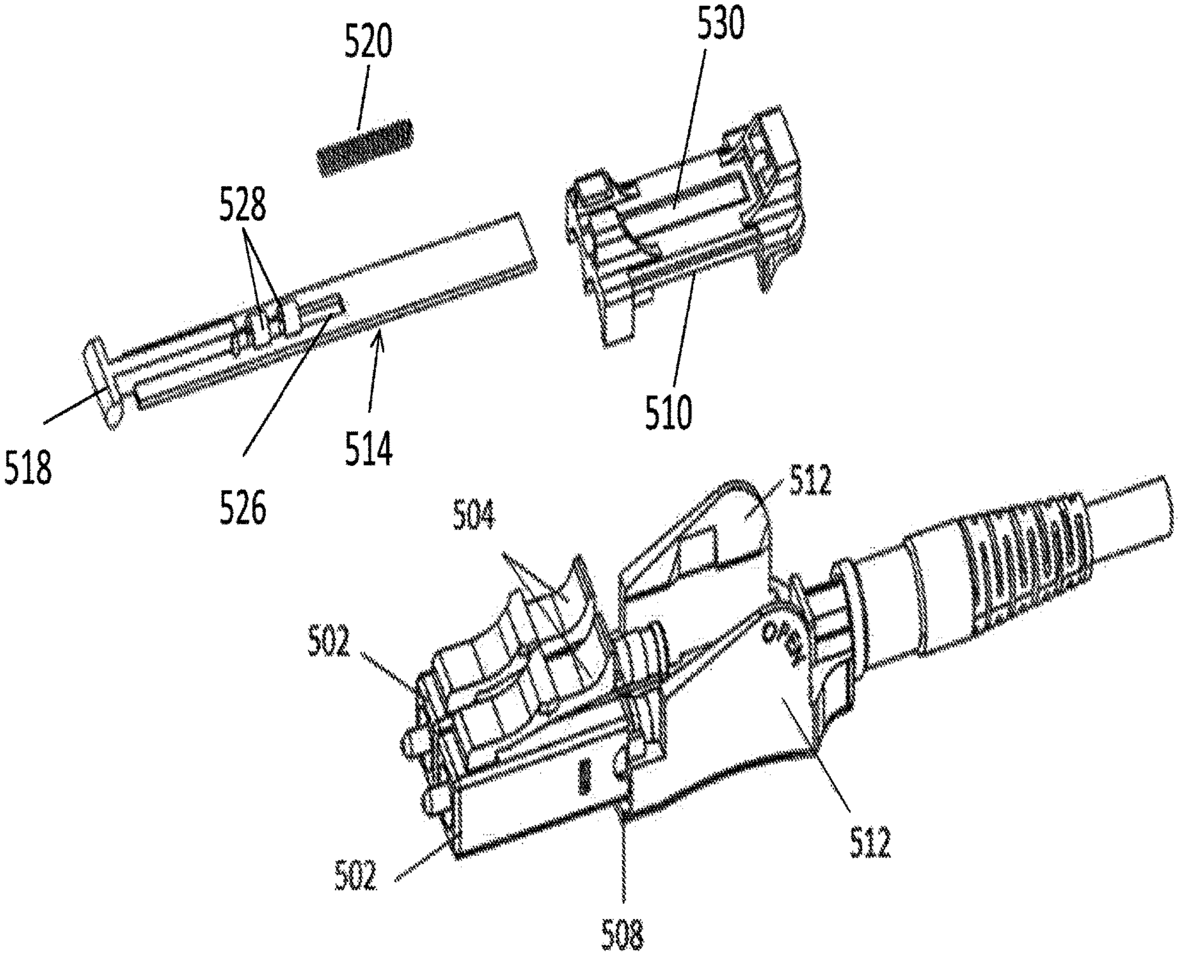

FIG. 8

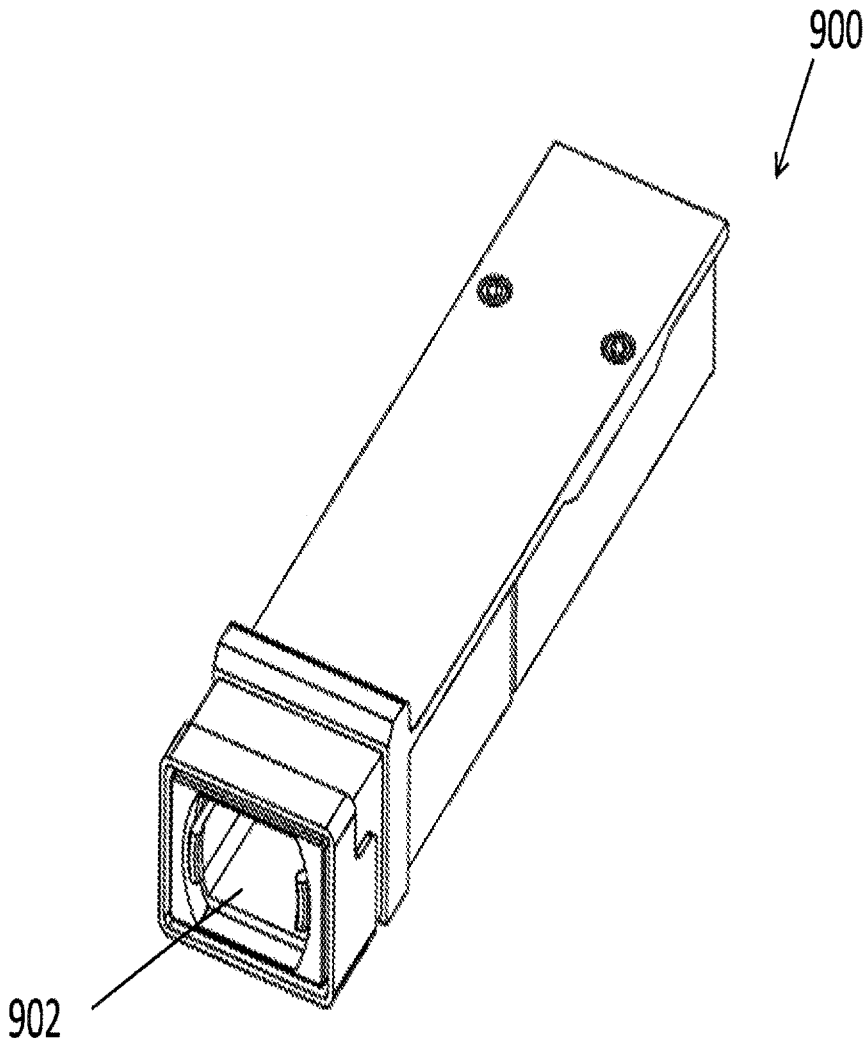

FIG. 9
(Prior Art)

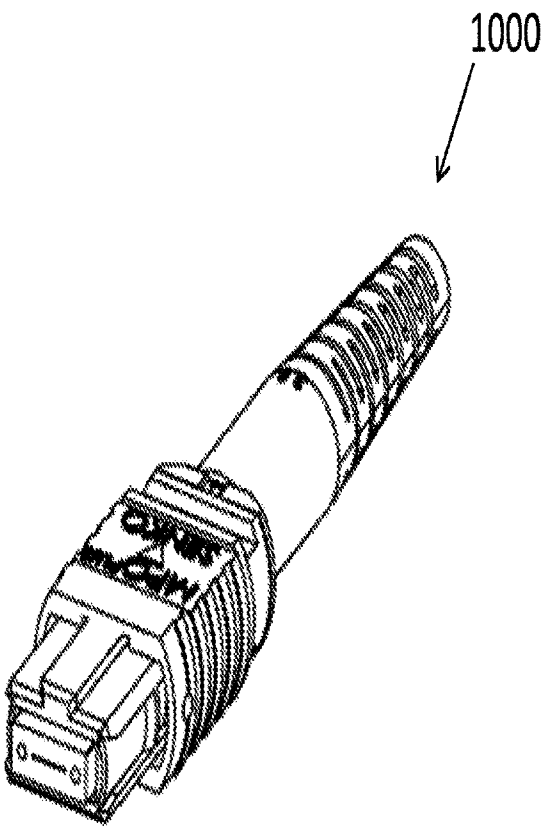

FIG. 10A
(Prior Art)

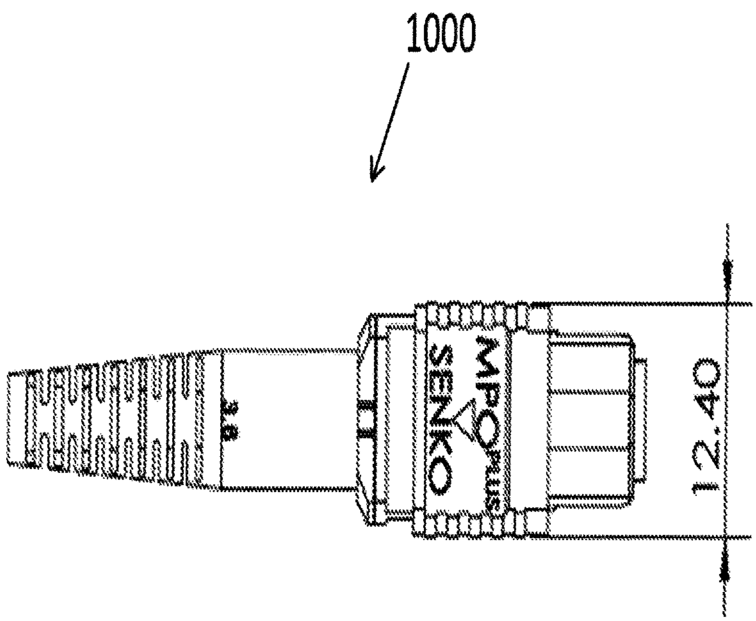

FIG. 10B
(Prior Art)

FIG. 10C
(Prior Art)

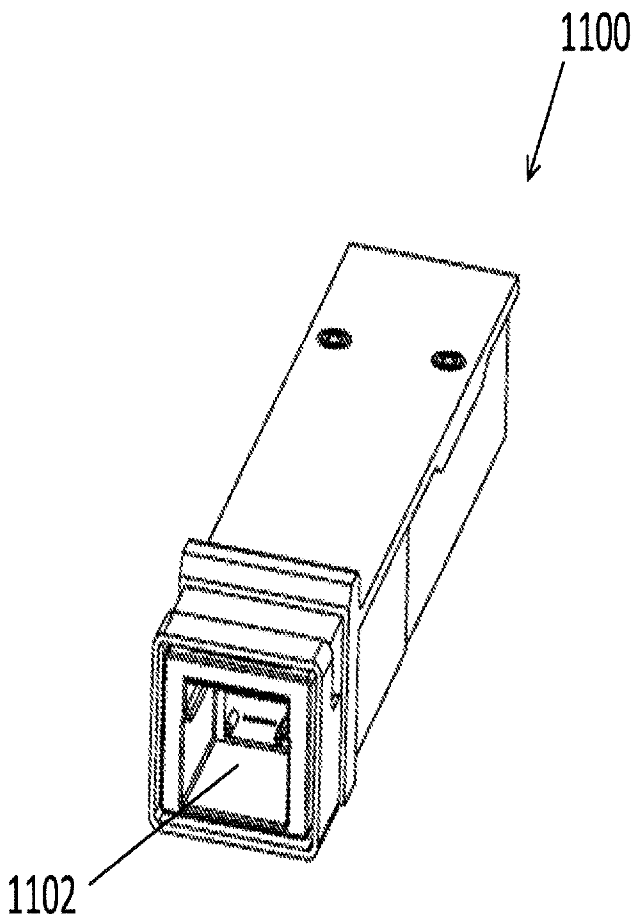

FIG. 11

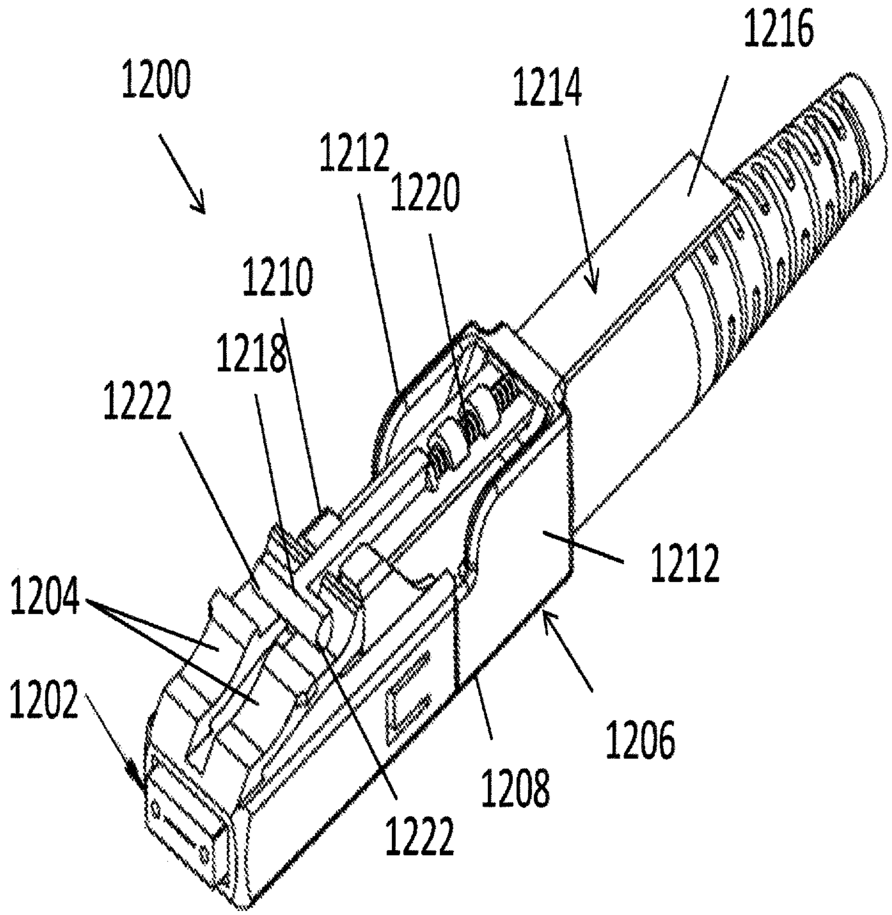
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FIG. 12A

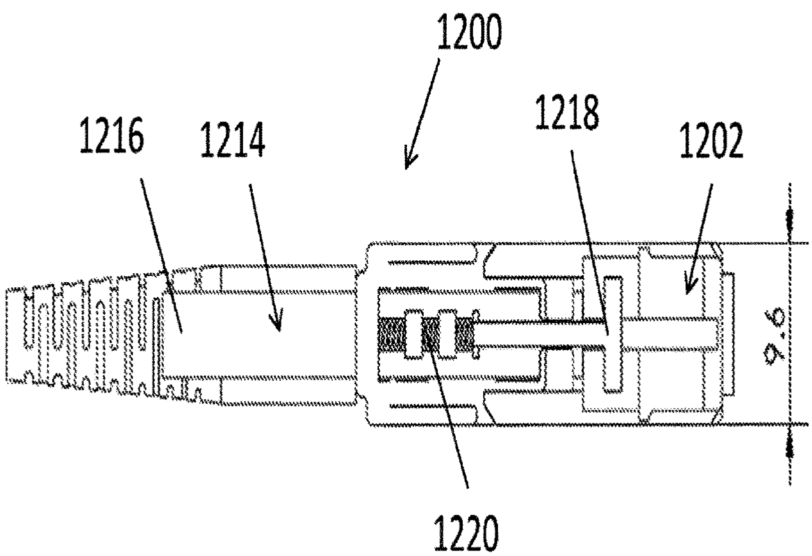

FIG. 12B

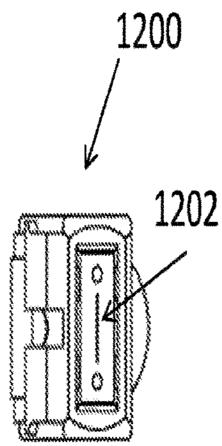

FIG. 12C

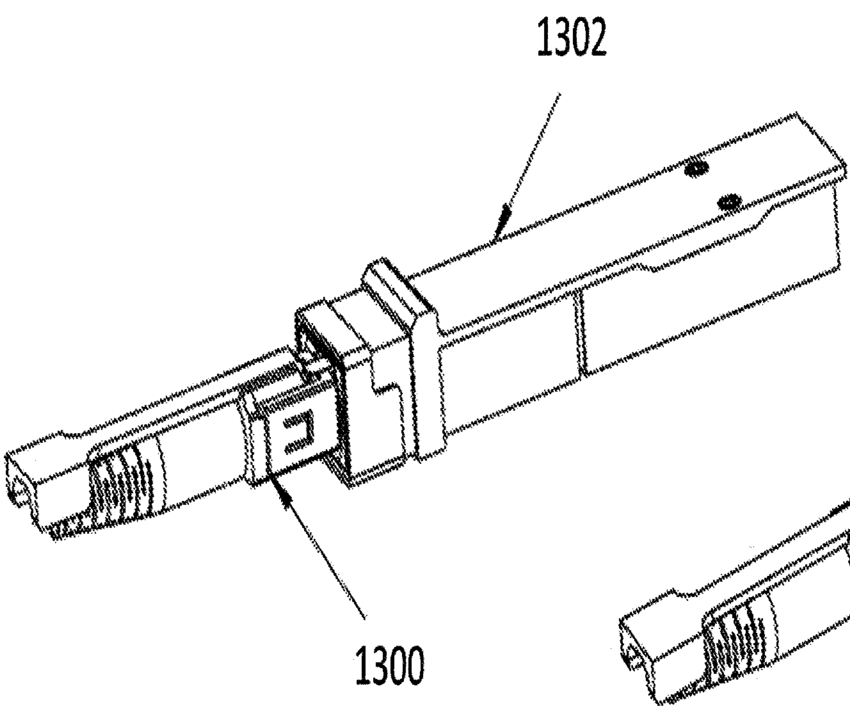

FIG. 13A

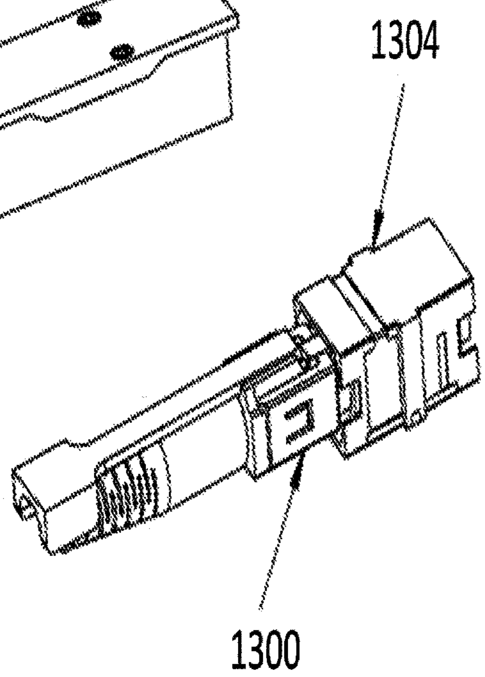

FIG. 13B

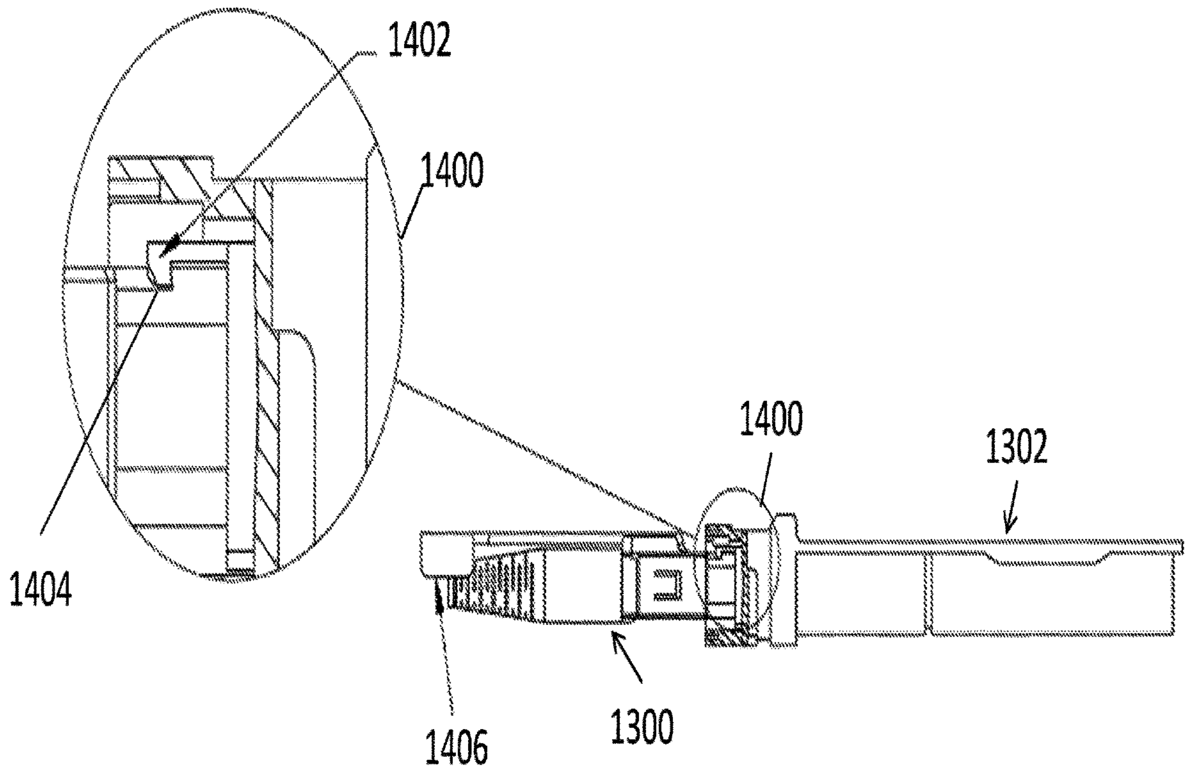

FIG. 14

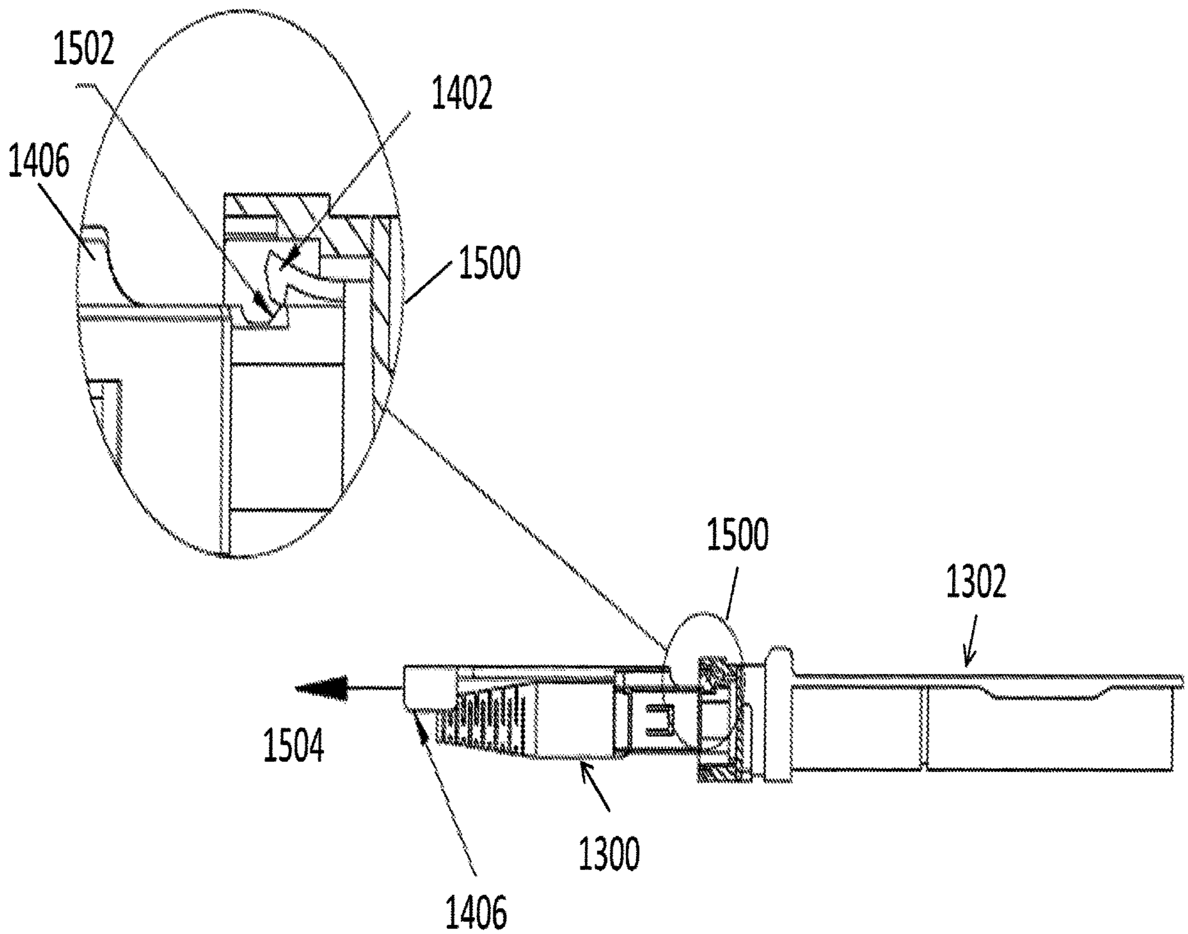

FIG. 15

NARROW WIDTH ADAPTERS AND CONNECTORS WITH PULL TAB RELEASE

CROSS-REFERENCE TO RELATED-APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 16/695,901 filed Nov. 26, 2019 which is a continuation of U.S. patent application Ser. No. 16/213,244 filed Dec. 7, 2018, which is a continuation of U.S. patent application Ser. No. 15/044,838 filed Feb. 16, 2016, now U.S. Pat. No. 10,158,194 granted on Dec. 18, 2018, which is a continuation-in-part of U.S. patent application Ser. No. 14/996,865 filed on Jan. 15, 2016, now U.S. Pat. No. 9,595,786 granted on Mar. 14, 2017, and application Ser. No. 15/044,838 claim priority to International Application No. PCT/US16/13629 filed on Jan. 15, 2016 and Taiwan Patent Application No. 105101374 filed on Jan. 18, 2016, each of which are incorporated herein by reference in their entirety.

BACKGROUND

The present disclosure relates generally to connectors having remote release, and more specifically to narrow width adapters and connectors, such as narrow pitch distance LC duplex adapters and connectors with spring loaded remote release, and narrow width multi-fiber connectors.

The prevalence of the Internet has led to unprecedented growth in communication networks. Consumer demand for service and increased competition has caused network providers to continuously find ways to improve quality of service while reducing cost.

Certain solutions have included deployment of high-density interconnect panels. High-density interconnect panels may be designed to consolidate the increasing volume of interconnections necessary to support the fast-growing networks into a compacted form factor, thereby increasing quality of service and decreasing costs such as floor space and support overhead. However, the deployment of high-density interconnect panels have not been fully realized.

In communication networks, such as data centers and switching networks, numerous interconnections between mating connectors may be compacted into high-density panels. Panel and connector producers may optimize for such high densities by shrinking the connector size and/or the spacing between adjacent connectors on the panel. While both approaches may be effective to increase the panel connector density, shrinking the connector size and/or spacing may also increase the support cost and diminish the quality of service.

In a high-density panel configuration, adjacent connectors and cable assemblies may obstruct access to the individual release mechanisms. Such physical obstructions may impede the ability of an operator to minimize the stresses applied to the cables and the connectors. For example, these stresses may be applied when the user reaches into a dense group of connectors and pushes aside surrounding optical fibers and connectors to access an individual connector release mechanism with his/her thumb and forefinger. Overstressing the cables and connectors may produce latent defects, compromise the integrity and/or reliability of the terminations, and potentially cause serious disruptions to network performance.

While an operator may attempt to use a tool, such as a screwdriver, to reach into the dense group of connectors and activate the release mechanism, the adjacent cables and

connectors may obstruct the operator's line of sight, making it difficult to guide the tool to the release mechanism without pushing aside the surrounding cables. Moreover, even when the operator has a clear line of sight, guiding the tool to the release mechanism may be a time-consuming process. Thus, using a tool may not be effective at reducing support time and increasing the quality of service.

Small Form Factor Pluggable Transceivers (SFP) are used presently in telecommunication infrastructures within rack mounted copper-to-fiber media converters, and are also known as Ethernet switches and/or patching hubs. These infrastructure Ethernet and fiber optic connections are evolving daily to increase connection density due to limited space for such equipment. Although fiber optic connectors have become smaller over the years, they have not been designed to be any smaller than necessary to plug into commonly sized and readily available SFPs. However, as transceiver technologies develop, smaller SFPs will be used to create higher density switches and/or patching hub equipment. Accordingly, there is a need for fiber optic connectors that will meet the needs of future developments in smaller SFPs.

SUMMARY

Aspects of the present disclosure are directed to providing adapters and fiber optic connectors for future developments in smaller SFPs, including for example narrow pitch SFPs for LC type duplex connectors, as well as narrow width SFPs for MPO connectors. Aspects of the present disclosure also provide spring loaded remote release mechanisms to facilitate access and usage of the narrow pitch connectors in high density arrays or panels.

According to one aspect, there is provided a narrow width fiber optic connector comprising a multi-fiber connector, wherein a width of said narrow width fiber optic connector is less than about 12.4 mm, a housing configured to hold the multi-fiber connector and further comprising a connector recess, and a pull tab having a ramp area configured to disengage a latch of one of an adapter and an SFP from said connector recess. The multi-fiber connector may include a multi-fiber MT ferrule. In some embodiments, the width of said narrow width fiber optic connector may be less than or equal to about 9.6 mm. The pull tab may include a spring configured to allow the latch of one of the adapter and the SFP to engage with the connector recess.

According to another aspect, there is provided a narrow pitch fiber optic connector comprising a plurality of LC connectors arranged such that a pitch of said narrow pitch connector is less than about 5.25 mm, a housing configured to hold the plurality of LC connectors and further comprising a connector recess, and a pull tab having a ramp area configured to disengage a latch of one of an adapter and an SFP from said connector recess. In some embodiments, the pitch may be less than or equal to about 4.8 mm. The pull tab may include a spring configured to allow the latch of one of the adapter and the SFP to engage with the connector recess. In some embodiments, the pull tab may include a distal end for remotely unlatching the narrow pitch connector. The narrow pitch connector may be a duplex connector. In some embodiments, the housing may include a bottom housing and a top housing coupled to the bottom housing. The bottom housing may include a side wall configured to open. The side wall may include a raised profile at a rear end thereof.

According to another aspect, there is provided a narrow pitch fiber optic connector comprising a plurality of LC connectors arranged such that a pitch of said narrow pitch

connector is less than about 5.25 mm, a plurality of latching arms coupled to the plurality of LC connectors, a housing configured to hold the plurality of LC connectors, and a pull tab coupled to the plurality of latching arms and configured to remotely unlatch the narrow pitch connector. In some embodiments, the pitch may be less than or equal to about 4.8 mm.

In some embodiments, the pull tab may include a spring configured to provide a force such that the latching arms return to an undisplaced position. The pull tab may include a distal end for remotely unlatching the narrow pitch connector and a proximal end configured to couple the pull tab to the plurality of latching arms. The proximal end may include a single prong configured to engage the plurality of latching arms. The proximal end may include a plurality of pins configured to slide along a semi-circular profile of the plurality of latching arms. In various embodiments, the narrow pitch connector is a duplex connector.

In various embodiments, the housing may include a bottom housing and a top housing coupled to the bottom housing. The bottom housing may include a side wall configured to open. The side wall may include a raised profile at a rear end thereof. The top housing may be configured to retain the pull tab. The pull tab may be further configured to be pushed down so as to unlatch the narrow pitch connector without resulting in any horizontal movement of the pull tab.

According to another aspect, there is disclosed a duplex fiber optic connector comprising two LC connectors arranged such that a pitch of said duplex LC connector is less than about 5.25 mm, and a pull tab coupled to said two LC connectors so as to remotely unlatch said duplex connector when pulled horizontally, wherein the pull tab is spring loaded. In one embodiment, the pitch may be less than or equal to about 4.8 mm.

In some embodiments, the pull tab may include a proximal end configured to couple to respective latching arms of the two LC connectors. The duplex fiber optic connector may further comprise a housing having side walls configured to open. The housing may further comprise a top housing configured to receive the pull tab. The pull tab may be further configured to be pushed down so as to unlatch the duplex connector without resulting in any horizontal movement of the pull tab.

According to another aspect, there is disclosed a narrow pitch adapter comprising a recess configured to receive a duplex fiber optic connector having a pitch less than about 5.25 mm. In some embodiments, the pitch may be less than or equal to about 4.8 mm.

According to another aspect, there is disclosed a narrow width fiber optic connector comprising a multi-fiber connector, wherein a width of said narrow width fiber optic connector is less than about 12.4 mm, at least one latching arm coupled to the multi-fiber connector, a housing configured to hold the multi-fiber connector, and a pull tab coupled to the at least one latching arms and configured to remotely unlatch the narrow width connector. The multi-fiber connector may include a multi-fiber MT ferrule. In some embodiments, the width may be less than or equal to about 9.6 mm. In some embodiments, the pull tab may include a spring configured to provide a force such that the at least one latching arm returns to an undisplaced position.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**A is a perspective view of a prior art standard 6.25 mm pitch LC connector SFP;

FIG. **1**B is a perspective view of a prior art standard 6.25 mm pitch LC adapter;

FIG. **1**C is a top view of the prior art adapter of FIG. **1**B;

FIG. **1**D is a front view of the prior art adapter of FIG. **1**B, showing the 6.25 mm pitch;

FIG. **2**A is a perspective view of a prior art LC duplex connector;

FIG. **2**B is a perspective view of a prior art LC duplex connector with a remote release pull tab;

FIG. **2**C is a top view of a prior art LC connector used in the embodiments shown in FIGS. **2**A and **2**B;

FIG. **2**D is a side view of the prior art LC connector of FIG. **2**C;

FIG. **3** is a perspective view of a future narrow pitch LC SFP for receiving connectors disclosed herein according to aspects of the present disclosure;

FIG. **4**A is a perspective view of one embodiment of a narrow pitch LC adapter according to aspects of the present disclosure;

FIG. **4**B is a top view of the narrow pitch LC adapter of FIG. **4**A;

FIG. **4**C is a front view of the narrow pitch LC adapter of FIG. **4**A, showing a 4.8 mm pitch;

FIG. **5** is a perspective view of one embodiment of a narrow pitch LC duplex connector with remote release according to aspects of the present disclosure;

FIG. **6**A is a top view of an LC connector used in the embodiment of FIG. **5** according to aspects of the present disclosure;

FIG. **6**B is a side view of the LC connector of FIG. **6**A according to aspects of the present disclosure;

FIG. **7** is a perspective view of narrow pitch LC duplex connector of FIG. **5**, with the release mechanism being removed according to aspects of the present disclosure;

FIG. **8** is a perspective disassembled view of the narrow pitch LC duplex connector of FIG. **5** according to aspects of the present disclosure;

FIG. **9** is a perspective view of a prior art standard MPO SFP;

FIG. **10**A is a perspective view of a prior art standard MPO connector;

FIG. **10**B is a top view of the prior art MPO connector of FIG. **10**A, having a width of 12.4 mm;

FIG. **10**C is a front view of the prior art MPO connector of FIG. **10**A;

FIG. **11** is a perspective view of a future narrow width multi-fiber SFP for receiving connectors disclosed herein according to aspects of the present disclosure;

FIG. **12**A is a perspective view of one embodiment of a narrow width multi-fiber connector with remote release according to aspects of the present disclosure;

FIG. **12**B is a top view of the narrow width multi-fiber connector of FIG. **12**A, having a width of 9.6 mm according to aspects of the present disclosure;

FIG. **12**C is a front view of the narrow width multi-fiber connector of FIG. **12**A according to aspects of the present disclosure;

FIG. **13**A is a perspective view of a narrow width multi-fiber connector inserted into a narrow width SFP having an SFP latch according to aspects of the present disclosure;

FIG. **13**B is a perspective view of a narrow width multi-fiber connector inserted into a narrow width adapter having an adapter latch according to aspects of the present disclosure;

FIG. **14** is a side view of a narrow width multi-fiber connector of FIG. **13**A having a recess engaged with an SFP latch in a normal pull tab position according to aspects of the present disclosure; and

FIG. **15** is a side view of the narrow width multi-fiber connector of FIG. **13**A, being disengaged from the SFP latch by retracting the pull tab according to aspects of the present disclosure.

DETAILED DESCRIPTION

This disclosure is not limited to the particular systems, devices and methods described, as these may vary. The terminology used in the description is for the purpose of describing the particular versions or embodiments only, and is not intended to limit the scope.

As used in this document, the singular forms "a," "an," and "the" include plural references unless the context clearly dictates otherwise. Unless defined otherwise, all technical and scientific terms used herein have the same meanings as commonly understood by one of ordinary skill in the art. Nothing in this disclosure is to be construed as an admission that the embodiments described in this disclosure are not entitled to antedate such disclosure by virtue of prior invention. As used in this document, the term "comprising" means "including, but not limited to."

The following terms shall have, for the purposes of this application, the respective meanings set forth below.

A connector, as used herein, refers to a device and/or components thereof that connects a first module or cable to a second module or cable. The connector may be configured for fiber optic transmission or electrical signal transmission. The connector may be any suitable type now known or later developed, such as, for example, a ferrule connector (FC), a fiber distributed data interface (FDDI) connector, an LC connector, a mechanical transfer (MT) connector, an SC connector, an SC duplex connector, or a straight tip (ST) connector. The connector may generally be defined by a connector housing body. In some embodiments, the housing body may incorporate any or all of the components described herein.

A "fiber optic cable" or an "optical cable" refers to a cable containing one or more optical fibers for conducting optical signals in beams of light. The optical fibers can be constructed from any suitable transparent material, including glass, fiberglass, and plastic. The cable can include a jacket or sheathing material surrounding the optical fibers. In addition, the cable can be connected to a connector on one end or on both ends of the cable.

Various embodiments described herein generally provide a remote release mechanism such that a user can remove cable assembly connectors that are closely spaced together on a high density panel without damaging surrounding connectors, accidentally disconnecting surrounding connectors, disrupting transmissions through surrounding connectors, and/or the like. Various embodiments also provide narrow pitch LC duplex connectors and narrow width multi-fiber connectors, for use, for example, with future narrow pitch LC SFPs and future narrow width SFPs. The remote release mechanisms allow use of the narrow pitch LC duplex connectors and narrow width multi-fiber connectors in dense arrays of narrow pitch LC SFPs and narrow width multi-fiber SFPs.

FIG. **1**A shows a perspective view of a prior art standard 6.25 mm pitch LC connector SFP **100**. The SFP **100** is configured to receive a duplex connector, and provides two receptacles **102**, each for receiving a respective LC connector. The pitch **104** is defined as the axis-to-axis distance between the central longitudinal axes of each of the two receptacles **102**. FIG. **1**B shows a perspective view of a prior art standard 6.25 mm pitch LC adapter **106**. The adapter **106** is also configured to receive a duplex connector, and provides two receptacles **108**, each for receiving a respective LC connector. FIG. **1**C is a top view of the adapter **106** of FIG. **1**B. The pitch **110** of the adapter **106** is defined similarly to that of the SFP **100**, as the axis-to-axis distance between the central longitudinal axes of each of the two receptacles **108**, as illustrated in FIG. **1**D, which shows a front view of the adapter **106**.

FIG. **2**A shows a prior art LC duplex connector **200** that may be used with the conventional SFP **100** and the conventional adapter **106**. The LC duplex connector **200** includes two conventional LC connectors **202**. FIG. **2**B shows another prior art LC duplex connector **204** having a remote release pull tab **206**, and including two conventional LC connectors **208**. As shown, the remote release pull tab includes two prongs **210**, each configured to couple to the extending member **212** of a respective LC connector **208**. FIGS. **2**C and **2**D show top and side views, respectively, of the conventional LC connector **208**, having a width of 5.6 mm, and further showing the extending member **212**.

Various embodiments disclosed herein are configured for use with a future SFP, such as the narrow pitch LC SFP **300** shown in FIG. **3**, having a pitch less than that of conventional 6.25 mm and 5.25 mm pitches. Various embodiments utilize LC type fiber optic connectors in duplex arrangements (having transmitting and receiving fibers) but with a connector axis-to-axis distance that is less than the conventional 6.25 mm and 5.25 mm pitches, as described further below.

According to another aspect, there is disclosed embodiments of narrow pitch duplex LC adapters. FIGS. **4**A to **4**C show one embodiment of a narrow pitch adapter **400**. The narrow pitch adapter **400** has receptacles **402** on opposite ends thereof, configured for mating two narrow pitch LC duplex connectors according to aspects disclosed herein. FIG. **4**B shows a top view of the adapter **400**. FIG. **4**C shows a front view, further illustrating that the adapter **400** has a pitch of 4.8 mm. The adapter **400** is configured to receive a duplex LC connector, with a pitch of the adapter corresponding to the axis-to-axis distance between the LC connectors of the LC duplex connector. Although the adapter **400** has a pitch of 4.8 mm, various embodiments of narrow pitch adapters disclosed herein may have a different pitch that is less than that of the pitch of conventional adapters, for example less than 6.25 mm and less than about 5.25 mm. In some embodiments, the pitch may be about 4.8 mm or less.

In addition to the need for narrow connectors, there is a need for remote unlatching of the narrow connectors used in dense narrow SFP arrays. This is because finger access to connectors is nearly impossible without disruption to the service of adjacent optical fibers. Although there are current designs of remotely unlatching fiber optic connectors, as shown for example in FIG. **2**B, they have proven to be difficult to function as desired when plugged into the die cast construction that is typical of all SFP's. The die cast SFP is not one that is ever free of sharp edges and internal flashing (burrs) that can interfere with the normal flexing motion of the plastic latches of the fiber optic connectors. The interference between metal edges and burrs may prevent the fiber optic connector's plastic latch from either becoming fully engaged or easily disengaged, especially with latches that are remotely triggered by pull tabs that project a distance behind the connector so as to keep fingers from disturbing adjacent optical fibers.

To make the latching/unlatching of the connectors from the SFP more reliable, various embodiments disclosed herein add a spring force to the remote latching component (pull tab), for example as shown and described in relation to FIGS. **5**, **7**, **8** and **12** below, to ensure that the connector latches are allowed to return to the undisplaced position and thereby become fully engaged inside the SFP's recess.

FIG. **5** shows one embodiment of a narrow pitch connector **500** according to aspects disclosed herein. The narrow pitch connector **500** is a duplex LC connector including two LC connectors **502**. Each of the LC connectors **502** includes a respective ferrule **503** and a respective extending member or latching arm **504**. The connector **500** has a pitch of 4.8 mm, defined as the axis-to-axis distance between the central axes of the LC connectors **502**. In other embodiments, the connector pitch may be less than that of the pitch of conventional connectors, for example less than 6.25 mm and less than about 5.25 mm. In some embodiments, the pitch may be about 4.8 mm or less.

The connector **500** further includes a housing **506** having a bottom housing **508** and a top housing **510**. The bottom housing **508** includes side walls **512**. In various embodiments, the housing of the connector may be a switchable housing. The side walls may be configured to open so as to facilitate opening of the housing, for example to change polarity of the connector. The side walls **512** may be raised towards the rear of the connector, as shown in FIG. **5**. One advantage of raising the side walls towards the rear of the connector is easier access. In other embodiments, the side walls may be raised at another location.

The connector **500** further includes a pull tab **514** having a distal end **516** and a proximal end **518**. The pull tab **514** further includes a spring **520** configured to provide a force such that the connector latching arms **504** return to the undisplaced position and thereby become fully engaged inside the SFP's recess. The distal end **516** of the pull tab **514** may be pulled to remotely release the connector **500** from an SFP or adapter. The proximal end **518** of the pull tab **514** is uniquely shaped so as to engage with the unique profile of the latching arms **504** of the narrow pitch LC connector **500**. The proximal end **518** engages both latching arms **504** of the duplex LC connector **500**. That is, the proximal end **518** includes a single prong configured to engage the latching arms of both connectors **502**. At the proximal end **518** of the pull tab **514** there are outwardly pointing pins **522** configured to rest directly above and slide along the semi-circular surface of latching arms **504** of the duplex LC connectors **502**. The horizontal and rearward path direction of the pins **522** causes the semi-circular profile of the connector latching arms **504** to flex downward. Because the pins **522** are not contained inside ramped grooves of the connector latching arms **504**, the pull tab **514** can also be pushed down at a location directly behind the LC connectors **502** rather than pulling the tab in a rearward motion from a remote distance behind the connectors, such as from the distal end **516**. The action of pushing down the connectors' integral levers or latching arms **504** unlatches the connector **500**. In some cases, the horizontal motion of the pull tab **514** may not be desirable. Thus, the connector latching arms **504** may be pushed down without resulting in a horizontal motion of the pull tab **514**.

FIGS. **6**A and **6**B show top and side views, respectively, of the LC connector **502** of the narrow pitch connector **500**. FIG. **6**A further shows that the LC connector **502** has a width of 4.6 mm. FIG. **6**B shows the semi-circular profile of the latching arm **504**.

FIG. **7** shows a partially disassembled view of the narrow pitch connector **500** of FIG. **5**. The top housing **510** is separated from the bottom housing **508**. The pull tab **514** is coupled to the top housing **510** and configured to slide longitudinally along the length of the connector. The top housing **510** also includes a restraint **524** configured to receive the pull tab **514**.

FIG. **8** shows a further disassembled view of the narrow pitch connector **500**. Specifically, the pull tab **514** is shown to be separated from the top housing **510**, and the spring **520** is removed from the pull tab. The pull tab **514** includes a longitudinal recess **526** configured to receive the spring **520**, and at least one restraint **528** configured to retain the spring. The top housing **510** also includes a recess **530** configured to accommodate at least a portion of the pull tab **514**, such as the spring **520** and the proximal end **518**. In various embodiments, the pull tab may be removably coupled to the connector via the top housing.

FIG. **9** shows a perspective view of a prior art standard MPO SFP **900**. The SFP **900** is configured to receive a standard MPO connector, and provides a receptacle **902** for receiving an MPO connector having a conventional width, as shown for example in FIGS. **10**A to **10**C.

FIG. **10**A shows a perspective view of a conventional MPO connector **1000**. As shown in FIG. **10**B, the conventional MPO connector **1000** has a width of 12.4 mm. FIG. **10**C shows a front view of the MPO connector **1000**.

FIG. **11** shows an embodiment of a future narrow width multi-fiber SFP **1100** according to aspects of the present disclosure. Various embodiments disclosed herein are configured for use with the narrow width multi-fiber SFP **1100**, having a width less than that of conventional MPO connectors, that is less than about 12.4 mm. The narrow width multi-fiber SFP has a receptacle **1102** configured to receive a narrow width multi-fiber connector, such as a narrow width connector having an MT ferrule.

FIG. **12**A shows one embodiment of a narrow width connector **1200** according to aspects disclosed herein. The narrow width connector **1200** is a multi-fiber connector including a multi-fiber MT/MPO ferrule **1202**. The connector **1200** includes two extending members or latching arms **1204**. In other embodiments, the connector may include at least one latching arm. The connector **1200** has a width of 9.6 mm, as shown in the top view of the connector **1200** in FIG. **12**B. In other embodiments, the connector width may be less than that of the width of conventional multi-fiber connectors, for example less than the 12.4 mm of the conventional MPO connector shown in FOG. **10**B. In some embodiments, the width may be about 9.6 mm or less.

The connector **1200** further includes a housing **1206** having a bottom housing **1208** and a top housing **1210**. The bottom housing **1208** includes side walls **1212**. In various embodiments, the housing of the connector may be a switchable housing. The side walls may be configured to open so as to facilitate opening of the housing, for example to change polarity of the connector. The side walls **1212** may be raised towards the rear of the connector. One advantage of raising the side walls towards the rear of the connector is easier access. The side walls may also be raised at another location.

The connector **1200** further includes a pull tab **1214** having a distal end **1216** and a proximal end **1218**. The pull tab **1214** further includes a spring **1220** configured to provide a force such that the connector latching arms **1204** return to the undisplaced position and thereby become fully engaged inside the SFP's recess. The distal end **1216** of the pull tab **1214** may be pulled to remotely release the connector **1200** from an SFP or adapter. The proximal end **1218** of the pull tab **1214** is uniquely shaped so as to engage with the unique profile of the latching arms **1204** of the narrow width multi-fiber connector **1200**. The proximal end **1218** engages both latching arms **1204** of the multi-fiber connector **1200**. That is, the proximal end **1218** includes a single prong configured to engage the latching arms **1204**. At the proximal end **1218** of the pull tab **1214** there are outwardly pointing pins **1222** configured to rest directly above and slide along the semi-circular surface of latching arms **1204**. The horizontal and rearward path direction of the pins **1222** causes the semi-circular profile of the connector latching arms **1204** to flex downward. Because the pins **1222** are not contained inside ramped grooves of the connector latching arms **1204**, the pull tab **1214** can also be pushed down at a location directly behind the latching arms **1204** rather than pulling the tab in a rearward motion from a remote distance behind the connector, such as from the distal end **1216**. The action of pushing down the connector's integral levers or latching arms **1204** unlatches the connector **1200**. In some cases, the horizontal motion of the pull tab **1214** may not be desirable. Thus, the connector latching arms **1204** may be pushed down without resulting in a horizontal motion of the pull tab **1214**.

FIGS. **12**B and **12**C show top and front views, respectively, of the narrow width multi-fiber connector **1200**. FIG. **12**B further shows that the connector **1200** has a width of 9.6 mm.

In various embodiments described above, the narrow width connectors have latching arms configured to engage with a fixed or immovable recess within a narrow width SFP or a narrow width adapter. In these embodiments, the pull tab of the connector displaces the flexible latching arm of the connector so as to disengage the latching arm from the recess of the SFP or the adapter. For example, the latching arms bend down as the pull tab is pulled back, so as to disengage the connector from the SFP or the adapter.

In other embodiments, as further described for example in relation with FIGS. **13** to **15** below, the remote latch release pull tab may be configured to couple with a latch or a hook within the adapter or the SFP. In these embodiments, the flexible latching arm of the connector is moved into the main cavity of the SFP or the adapter, and the latch of the SFP or the adapter engages a recess of the connector when the pull tab is in a normal location that is pushed forward by a spring. The pull tab may be configured to have a ramp area such that when the pull tab is pulled back, the latch of the SFP or the adapter is lifted by the retracted pull tab, thereby disengaging the latch of the SFP or the adapter from the connector.

FIG. **13**A shows a narrow pitch multi-fiber connector **1300** inserted into a narrow pitch SFP **1302** such that a recess of the connector engages an SFP latch. FIG. **13**B shows the narrow pitch connector **1300** inserted into a narrow pitch adapter **1304** such that a recess of the connector engages a latch of the adapter.

FIG. **14** shows a side view of the narrow width connector **1300** of FIG. **13**A coupled to the narrow width SFP **1302**. Details of the coupling are shown within the circle **1400**. Specifically, the SFP **1302** includes an SFP latch **1402**. The connector **1300** includes a recess **1404**. For example, the connector housing may comprise a recess **1404**. The pull tab **1406** may be spring loaded as described in relation to various embodiments. This allows the pull tab **1406** to return to a position that will allow the SFP latch **1402** to engage with the connector recess **1404**. When the pull tab **1406** is in the normal pull tab location, that is pushed forward by a spring, as shown in FIG. **14**, the SFP latch **1402** is engaged with the connector recess **1404** as illustrated within the circle **1400**.

FIG. **15** shows a side view of the narrow width connector **1300** of FIG. **13**A as it is disengaged from the narrow width SFP **1302**. Details of the decoupling are shown within the circle **1500**. The pull tab **1406** includes a taper or a ramp area **1502**. As the pull tab **1406** is pulled back in the direction of the arrow **1504** as shown, the SFP latch **1402** is lifted by the ramp area of the retracted pull tab, thereby disengaging the SFP latch **1402** from the connector as illustrated within the circle **1500**. The same effect described herein in conjunction with FIG. **15** also occurs in other embodiments of connectors coupled to a narrow width adapter as shown for example in FIG. **13**A.

Although FIGS. **14** and **15** illustrate coupling of the connector to a narrow width SFP, in other embodiments of the connector may be coupled to a narrow width adapter having an adapter latch, similar to that of the SFP latch. Further, although the embodiments shown in FIGS. **13** to **15** include a narrow width multi-fiber connector, embodiments also work with narrow pitch LC connectors.

In the above detailed description, reference is made to the accompanying drawings, which form a part hereof. In the drawings, similar symbols typically identify similar components, unless context dictates otherwise. The illustrative embodiments described in the detailed description, drawings, and claims are not meant to be limiting. Other embodiments may be used, and other changes may be made, without departing from the spirit or scope of the subject matter presented herein. It will be readily understood that the aspects of the present disclosure, as generally described herein, and illustrated in the Figures, can be arranged, substituted, combined, separated, and designed in a wide variety of different configurations, all of which are explicitly contemplated herein.

The present disclosure is not to be limited in terms of the particular embodiments described in this application, which are intended as illustrations of various aspects. Many modifications and variations can be made without departing from its spirit and scope, as will be apparent to those skilled in the art. Functionally equivalent methods and apparatuses within the scope of the disclosure, in addition to those enumerated herein, will be apparent to those skilled in the art from the foregoing descriptions. Such modifications and variations are intended to fall within the scope of the appended claims. The present disclosure is to be limited only by the terms of the appended claims, along with the full scope of equivalents to which such claims are entitled. It is to be understood that this disclosure is not limited to particular methods, reagents, compounds, compositions or biological systems, which can, of course, vary. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to be limiting.

With respect to the use of substantially any plural and/or singular terms herein, those having skill in the art can translate from the plural to the singular and/or from the singular to the plural as is appropriate to the context and/or application. The various singular/plural permutations may be expressly set forth herein for sake of clarity.

It will be understood by those within the art that, in general, terms used herein, and especially in the appended claims (for example, bodies of the appended claims) are generally intended as "open" terms (for example, the term "including" should be interpreted as "including but not limited to," the term "having" should be interpreted as "having at least," the term "includes" should be interpreted as "includes but is not limited to," et cetera). While various compositions, methods, and devices are described in terms of "comprising" various components or steps (interpreted as meaning "including, but not limited to"), the compositions, methods, and devices can also "consist essentially of" or "consist of" the various components and steps, and such terminology should be interpreted as defining essentially closed-member groups. It will be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present. For example, as an aid to understanding, the following appended claims may contain usage of the introductory phrases "at least one" and "one or more" to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles "a" or "an" limits any particular claim containing such introduced claim recitation to embodiments containing only one such recitation, even when the same claim includes the introductory phrases "one or more" or "at least one" and indefinite articles such as "a" or "an" (for example, "a" and/or "an" should be interpreted to mean "at least one" or "one or more"); the same holds true for the use of definite articles used to introduce claim recitations. In addition, even if a specific number of an introduced claim recitation is explicitly recited, those skilled in the art will recognize that such recitation should be interpreted to mean at least the recited number (for example, the bare recitation of "two recitations," without other modifiers, means at least two recitations, or two or more recitations). Furthermore, in those instances where a convention analogous to "at least one of A, B, and C, et cetera" is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (for example, "a system having at least one of A, B, and C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, et cetera). In those instances where a convention analogous to "at least one of A, B, or C, et cetera" is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (for example, "a system having at least one of A, B, or C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, et cetera). It will be further understood by those within the art that virtually any disjunctive word and/or phrase presenting two or more alternative terms, whether in the description, claims, or drawings, should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms. For example, the phrase "A or B" will be understood to include the possibilities of "A" or "B" or "A and B."

In addition, where features or aspects of the disclosure are described in terms of Markush groups, those skilled in the art will recognize that the disclosure is also thereby described in terms of any individual member or subgroup of members of the Markush group.

As will be understood by one skilled in the art, for any and all purposes, such as in terms of providing a written description, all ranges disclosed herein also encompass any and all possible subranges and combinations of subranges thereof. Any listed range can be easily recognized as sufficiently describing and enabling the same range being broken down into at least equal halves, thirds, quarters, fifths, tenths, et cetera As a non-limiting example, each range discussed herein can be readily broken down into a lower third, middle third and upper third, et cetera As will also be understood by one skilled in the art all language such as "up to," "at least," and the like include the number recited and refer to ranges which can be subsequently broken down into subranges as discussed above. Finally, as will be understood by one skilled in the art, a range includes each individual member. Thus, for example, a group having 1-3 cells refers to groups having 1, 2, or 3 cells. Similarly, a group having 1-5 cells refers to groups having 1, 2, 3, 4, or 5 cells, and so forth.

Various of the above-disclosed and other features and functions, or alternatives thereof, may be combined into many other different systems or applications. Various presently unforeseen or unanticipated alternatives, modifications, variations or improvements therein may be subsequently made by those skilled in the art, each of which is also intended to be encompassed by the disclosed embodiments.

The invention claimed is:

1. An optical fiber connector configured for mating with a receptacle, the optical fiber connector comprising:

an MT ferrule configured to hold a plurality of optical fibers;

a connector housing having a front end portion and a rear end portion spaced apart along a longitudinal axis, the connector housing configured to hold the MT ferrule such that the MT ferrule is exposed through the front end portion for making an optical connection;

a depressible latching arm connected to the connector housing for latching with the receptacle when the optical fiber connector is mated with the receptacle to releasably retain the optical fiber connector in the receptacle; and

a remote release connected to the connector housing for movement relative to the connector housing along the longitudinal axis, the remote release being configured to be pulled rearward along the longitudinal axis to depress the depressible latching arm for releasing the optical fiber connector from the receptacle;

wherein the connector housing has a generally rectangular perimeter including opposite first and second walls and opposite third and fourth walls, the depressible latching arm being located on an exterior of the first wall;

wherein the first wall of the connector housing defines a groove, the remote release being slidably received in the groove;

wherein the remote release comprises a lower portion and a narrower portion above the lower portion, the lower portion being wider than the narrower portion; and

wherein the groove includes an inner portion and an outer portion, the inner portion being wider than the outer portion, the inner portion of the groove being configured to slidably receive the lower portion of the latch release and the outer portion of the groove being configured to slidably receive the narrower portion of the latch release such that the first wall releasably retains the latch release in the groove.

2. The optical fiber connector as set forth in claim **1**, wherein the depressible latching arm has a front end portion and a rear end portion spaced apart along the longitudinal axis, the depressible latching arm extending transversely outward away from the first wall as the depressible latching arm extends longitudinally from the front end portion to the rear end portion.

3. The optical fiber connector as set forth in claim **2**, wherein the optical fiber connector is free of depressible latching arms on an exterior of any of the second, third, and fourth walls.

4. The optical fiber connector as set forth in claim **1**, wherein the optical fiber connector is configured so that upon release of the remote release after being pulled rearward along the longitudinal axis to depress the depressible latching arm, the depressible latching arm resiliently returns toward an un-depressed position.

5. The optical fiber connector as set forth in claim **1**, wherein the depressible latching arm is a first depressible latching arm, the optical fiber connector further comprising a second depressible latching arm spaced apart from the first depressible latching arm.

6. The optical fiber connector as set forth in claim **5**, wherein the remote release is further configured to depress the second depressible latching arm when the remote release is pulled rearward along the longitudinal axis.

7. The optical fiber connector as set forth in claim **5**, wherein the remote release comprises a first edge for engaging the first depressible latching arm and a second edge for engaging the second depressible latching arm, the first and second edges being spaced apart from one another.

8. The optical fiber connector as set forth in claim **7**, wherein the remote release further comprises an elongate section between the first edge and the second edge.

9. The optical fiber connector as set forth in claim **1**, wherein the remote release comprises a front section and wherein the optical fiber connector is configured such that the front section is yieldably biased along the longitudinal axis toward the front end portion of the connector housing.

10. The optical fiber connector as set forth in claim **9**, further comprising a resilient biasing member engaging the front section of the remote release to yieldably bias the remote release toward the front end portion of the connector housing.

11. The optical fiber connector as set forth in claim **10**, wherein the depressible latching arm is configured to engage the front section of the remote release at a first point of contact and the resilient biasing member is configured to engage the front section of the remote release at a second point of contact, the second point of contact being spaced apart from the first point of contact along the longitudinal axis toward the rear end portion of the connector housing.

12. The optical fiber connector as set forth in claim **1**, wherein the MT ferrule is configured to receive a plurality of fibers such that the fibers are spaced apart in a row that extends parallel to a fiber alignment axis, the MT ferrule comprising first and second guide pin openings spaced apart along the fiber alignment axis.

13. The optical fiber connector as set forth in claim **12**, wherein the optical fiber connector has an outer cross-sectional dimension along the fiber alignment axis and wherein the outer cross-sectional dimension is less than an outer cross-sectional dimension of a standard MPO connector along a fiber alignment axis of the standard MPO connector.

14. The optical fiber connector as set forth in claim **1**, wherein the connector housing is configured to enable a polarity of the optical fiber connector to be selectively reversed.

15. An optical connection system comprising the optical fiber connector as set forth in claim **1** and a receptacle for mating with the optical fiber connector.

16. The optical connection system as set forth in claim **15**, wherein the receptacle comprises a rectangular perimeter wall.

17. The optical connection system as set forth in claim **16**, wherein the receptacle includes a recess, the depressible latching arm being configured to latch with the recess when the optical fiber connector and the receptacle are mated.

* * * * *

EXHIBIT E

US010191230B2

(12) **United States Patent**
Wong et al.

(10) **Patent No.: US 10,191,230 B2**
(45) **Date of Patent: Jan. 29, 2019**

(54) **OPTICAL CONNECTORS WITH REVERSIBLE POLARITY**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **15/884,327**

(22) Filed: **Jan. 30, 2018**

(65) **Prior Publication Data**

US 2018/0217340 A1 Aug. 2, 2018

Related U.S. Application Data

(60) Provisional application No. 62/581,961, filed on Nov. 6, 2017, provisional application No. 62/546,920, filed on Aug. 17, 2017, provisional application No. 62/485,042, filed on Apr. 13, 2017, provisional application No. 62/463,901, filed on Feb. 27, 2017, provisional application No. 62/463,898, filed on Feb. 27, 2017, provisional application No. 62/457,150,
(Continued)

(51) **Int. Cl.**
G02B 6/38 (2006.01)

(52) **U.S. Cl.**
CPC ***G02B 6/3893*** (2013.01); ***G02B 6/3821*** (2013.01)

(58) **Field of Classification Search**
CPC G02B 6/38; G02B 6/3821; G02B 6/3893
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,721,945 A 3/1973 Hults
4,327,964 A 5/1982 Haesly et al.
(Continued)

FOREIGN PATENT DOCUMENTS

CA 2495693 A1 4/2004
CN 2836038 Y 11/2006
(Continued)

OTHER PUBLICATIONS

EP Search Report and Opinion dated Mar. 2015 EP 14187661.
(Continued)

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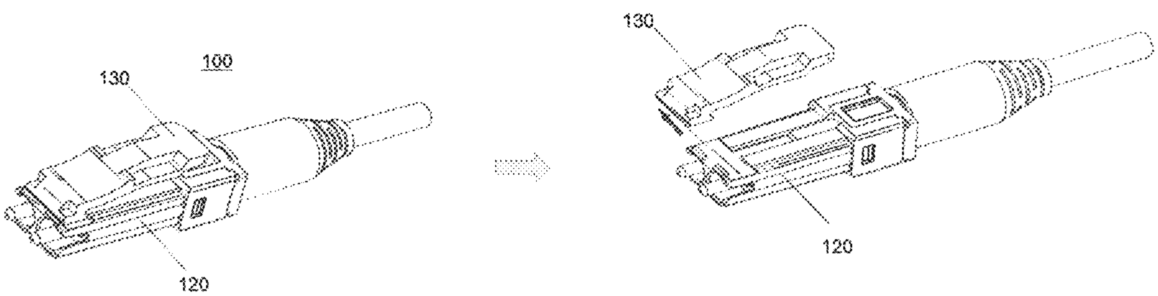
(57) **ABSTRACT**

Reversible polarity fiber optic connectors are provided having housings at least partially surrounding first and second optical ferrules with walls above and beneath the ferrules. Positioning removable elements such as latches, removable arms, or push-pull tabs on the first wall above the ferrules yields fiber optic connectors with a first polarity type, and positioning the removable elements on the second wall beneath the ferrules yields fiber optic connectors with a second, opposite polarity type. Various engagement mechanisms are provided on either the connector housing walls or on the removable elements, or both, to assist in affixing the removable element to the connector housing.

25 Claims, 22 Drawing Sheets



Related U.S. Application Data

filed on Feb. 9, 2017, provisional application No. 62/452,147, filed on Jan. 30, 2017.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,478,473	A *	10/1984	Frear	H01R 13/622 439/312
4,762,388	A	8/1988	Tanaka et al.	
4,764,129	A	8/1988	Jones et al.	
4,840,451	A	6/1989	Sampson et al.	
4,872,736	A	10/1989	Myers et al.	
4,979,792	A	12/1990	Weber et al.	
5,026,138	A *	6/1991	Boudreau	G02B 6/4202 385/51
5,041,025	A	8/1991	Haitmanek	
D323,143	S	1/1992	Ohkura et al.	
5,212,752	A	5/1993	Stephenson et al.	
5,265,181	A	11/1993	Chang	
5,289,554	A	2/1994	Cubukciyan et al.	
5,317,663	A	5/1994	Beard et al.	
5,335,301	A	8/1994	Newman et al.	
5,348,487	A	9/1994	Marazzi et al.	
5,444,806	A	8/1995	de Marchi et al.	
5,481,634	A	1/1996	Anderson et al.	
5,506,922	A	4/1996	Grois et al.	
5,521,997	A	5/1996	Rovenolt et al.	
5,570,445	A	10/1996	Chou et al.	
5,588,079	A	12/1996	Tanabe et al.	
5,684,903	A	11/1997	Kyomasu et al.	
5,687,268	A	11/1997	Stephenson et al.	
5,781,681	A	7/1998	Manning	
5,937,130	A	8/1999	Amberg et al.	
5,956,444	A	9/1999	Ouda et al.	
5,971,626	A	10/1999	Knodell et al.	
6,041,155	A	3/2000	Anderson et al.	
6,049,040	A	4/2000	Biles et al.	
6,134,370	A	10/2000	Childers et al.	
6,178,283	B1	1/2001	Weigel	
RE37,080	E	3/2001	Stephenson et al.	
6,206,577	B1	3/2001	Hall	
6,206,581	B1	3/2001	Driscoll et al.	
6,227,717	B1	5/2001	Ott et al.	
6,238,104	B1	5/2001	Yamakawa et al.	
6,247,849	B1	6/2001	Liu	
6,364,537	B1 *	4/2002	Maynard	G02B 6/3831 385/55
6,379,052	B1 *	4/2002	de Jong	G02B 6/3806 385/59
6,461,054	B1	10/2002	Iwase	
6,471,412	B1	10/2002	Belenkiy et al.	
6,478,472	B1	11/2002	Anderson et al.	
6,485,194	B1 *	11/2002	Shirakawa	G02B 6/381 385/78
6,530,696	B1	3/2003	Ueda	
6,551,117	B2	4/2003	Poplawski et al.	
6,579,014	B2	6/2003	Metlon et al.	
6,623,172	B1 *	9/2003	de Jong	G02B 6/3806 385/59
6,634,796	B2 *	10/2003	de Jong	G02B 6/3831 385/139
6,634,801	B1	10/2003	Waldron	
6,648,520	B2	11/2003	McDonald et al.	
6,682,228	B2	1/2004	Rathnam et al.	
6,695,486	B1	2/2004	Falkenberg et al.	
6,854,894	B1	2/2005	Yunker et al.	
6,865,362	B2	3/2005	Otsuka et al.	
6,869,227	B2 *	3/2005	Del Grosso	G02B 6/4471 385/71
6,872,039	B2	3/2005	Baus et al.	
6,935,789	B2	8/2005	Gross, III et al.	
7,036,993	B2	5/2006	Luther	
7,077,576	B2	7/2006	Luther	
7,090,406	B2	8/2006	Melton et al.	
7,090,407	B2	8/2006	Melton et al.	
7,091,421	B2	8/2006	Kukita et al.	
7,111,990	B2	9/2006	Melton et al.	
7,113,679	B2	9/2006	Melton et al.	
D533,504	S	12/2006	Lee	
D534,124	S	12/2006	Taguchi	
7,150,587	B2	12/2006	Luther et al.	
7,153,041	B2	12/2006	Mine et al.	
7,198,409	B2	4/2007	Smith et al.	
7,207,724	B2	4/2007	Gurreri	
D543,146	S	5/2007	Chen et al.	
7,258,493	B2	8/2007	Milette	
7,264,402	B2	9/2007	Theuerkorn	
7,281,859	B2	10/2007	Mudd	
D558,675	S	1/2008	Chein et al.	
7,315,682	B1	1/2008	En Lin et al.	
7,325,976	B2	2/2008	Gurreri et al.	
7,325,980	B2	2/2008	Pepe	
7,329,137	B2	2/2008	Martin et al.	
7,331,718	B2	2/2008	Yazaki et al.	
7,354,291	B2	4/2008	Caveney et al.	
7,371,082	B2	5/2008	Zimmel et al.	
7,387,447	B2	6/2008	Mudd	
7,390,203	B2	6/2008	Murano	
D572,661	S	7/2008	En Lin et al.	
7,431,604	B2	10/2008	Waters et al.	
7,463,903	B2	12/2008	Cody	
7,465,180	B2	12/2008	Kusuda et al.	
7,510,335	B1	3/2009	Su et al.	
7,513,695	B1	4/2009	Lin et al.	
7,540,666	B2	6/2009	Luther	
7,581,775	B2	7/2009	Lin et al.	
7,591,595	B2	9/2009	Lu et al.	
7,594,766	B1	9/2009	Sasser	
7,641,398	B2	1/2010	O'Riorden et al.	
7,695,199	B2	4/2010	Teo et al.	
7,699,533	B2	4/2010	Milette	
7,785,019	B2	8/2010	Lewallen	
7,824,113	B2	11/2010	Wong et al.	
7,867,395	B2	1/2011	Ekholm et al.	
D641,709	S	7/2011	Yamauchi	
8,152,385	B2 *	4/2012	de Jong	G02B 6/3879 385/53
8,186,890	B2	5/2012	Lu	
8,192,091	B2	6/2012	Hsu et al.	
8,202,009	B2	6/2012	Lin et al.	
8,251,733	B2	8/2012	Wu	
8,267,595	B2	9/2012	Lin et al.	
8,270,796	B2	9/2012	Nhep	
8,408,815	B2	4/2013	Lin et al.	
8,465,317	B2	6/2013	Gniadek et al.	
8,534,928	B2	9/2013	Cooke	
8,622,634	B2	1/2014	Arnold	
8,636,424	B2	1/2014	Kuffel et al.	
8,651,749	B2	2/2014	Dainese Junior et al.	
8,676,022	B2 *	3/2014	Jones	G02B 6/3849 385/139
8,678,670	B2	3/2014	takahashi	
8,727,638	B2	5/2014	Lee	
8,770,863	B2	7/2014	Cooke et al.	
9,310,569	B2 *	4/2016	Lee	G02B 6/3825
9,366,829	B2	6/2016	Czosnowski	
9,465,172	B2 *	10/2016	Shih	G02B 6/3879
9,557,495	B2 *	1/2017	Raven	G02B 6/3879
9,658,409	B2	5/2017	Gniadek	
9,709,753	B1	7/2017	Chang	
9,778,425	B2	10/2017	Nguyen	
9,798,084	B2	10/2017	Kuffel	
9,829,645	B2 *	11/2017	Good	G02B 6/3883
9,880,361	B2 *	1/2018	Childers	G02B 6/3831
9,946,035	B2 *	4/2018	Gustafson	G02B 6/3821
10,031,296	B2 *	7/2018	Good	G02B 6/3831
2001/0026661	A1 *	10/2001	de Jong	G02B 6/3831 385/56
2002/0191919	A1	12/2002	Nolan	
2003/0053787	A1	3/2003	Lee	
2004/0052473	A1	3/2004	Seo et al.	
2004/0136657	A1	7/2004	Ngo	
2004/0141693	A1	7/2004	Szilagyi et al.	
2004/0161958	A1	8/2004	Togami et al.	

(56) **References Cited**

U.S. PATENT DOCUMENTS

2004/0184741	A1*	9/2004	Del Grosso	G02B 6/3851 385/71
2004/0234209	A1	11/2004	Cox et al.	
2005/0111796	A1	5/2005	Matasek et al.	
2005/0141817	A1	6/2005	Yazaki et al.	
2005/0207709	A1*	9/2005	Del Grosso	G02B 6/4472 385/71
2006/0089049	A1	4/2006	Sedor	
2006/0127025	A1	6/2006	Haberman	
2006/0269194	A1	11/2006	Luther et al.	
2006/0274411	A1	12/2006	Yamauchi	
2007/0025665	A1	2/2007	Dean	
2007/0079854	A1	4/2007	You	
2007/0098329	A1	5/2007	Shimoji et al.	
2007/0149062	A1	6/2007	Long	
2007/0028409	A1	8/2007	Yamada	
2007/0230874	A1	10/2007	Lin	
2007/0232115	A1	10/2007	Burke et al.	
2007/0243749	A1	10/2007	Wu	
2008/0008430	A1	1/2008	Kewitsch	
2008/0044137	A1	2/2008	Luther et al.	
2008/0069501	A1	3/2008	Mudd et al.	
2008/0101757	A1	5/2008	Lin et al.	
2008/0226237	A1	9/2008	O'Riorden et al.	
2008/0267566	A1	10/2008	Lin et al.	
2009/0022457	A1	1/2009	De Jong et al.	
2009/0028507	A1	1/2009	Jones et al.	
2009/0196555	A1	8/2009	Lin et al.	
2009/0214162	A1	8/2009	O'Riorden et al.	
2009/0220197	A1	9/2009	Gniadek	
2010/0034502	A1	2/2010	Lu et al.	
2010/0092136	A1	4/2010	Nhep	
2010/0220961	A1*	9/2010	de Jong	G02B 6/3879 385/77
2010/0247041	A1	9/2010	Szilagyi	
2010/0322561	A1	12/2010	Lin et al.	
2011/0044588	A1	2/2011	Larson et al.	
2011/0131801	A1	6/2011	Nelson et al.	
2011/0177710	A1	7/2011	Tobey	
2012/0099822	A1	4/2012	Kuffel et al.	
2012/0189260	A1	7/2012	Kowalczyk et al.	
2012/0269485	A1	10/2012	Haley et al.	
2012/0301080	A1	11/2012	Gniadek	
2013/0071067	A1	3/2013	Lin	
2013/0089995	A1	4/2013	Gniadek et al.	
2013/0094816	A1	4/2013	Lin et al.	
2013/0121653	A1	5/2013	Shitama et al.	
2013/0170797	A1	7/2013	Ott	
2013/0183012	A1	7/2013	Cabanne Lopez et al.	
2013/0216185	A1	8/2013	Klavuhn et al.	
2013/0259429	A1	10/2013	Czosnowski et al.	
2013/0272671	A1*	10/2013	Jones	G02B 6/3831 385/139
2013/0308915	A1*	11/2013	Buff	G02B 6/4452 385/135
2013/0308916	A1*	11/2013	Buff	G02B 6/4452 385/135
2013/0322825	A1	12/2013	Cooke et al.	
2014/0016901	A1	1/2014	Lambourn et al.	
2014/0050446	A1	2/2014	Chang	
2014/0133808	A1	5/2014	Hill et al.	
2014/0334780	A1	11/2014	Nguyen et al.	
2014/0348477	A1	11/2014	Chang	
2015/0212282	A1*	7/2015	Lin	G02B 6/3893 385/76
2015/0241644	A1*	8/2015	Lee	G02B 6/3825 385/76
2015/0277059	A1*	10/2015	Raven	G02B 6/3879 385/78
2013/0378113		12/2015	Good et al.	
2015/0378113	A1	12/2015	Good et al.	
2016/0116685	A1*	4/2016	Wong	G02B 6/3825 385/56
2016/0216458	A1*	7/2016	Shih	G02B 6/3871
2016/0259135	A1	9/2016	Gniadek	
2017/0023746	A1*	1/2017	Good	G02B 6/3831
2017/0176691	A1*	6/2017	Childers	G02B 6/3831
2017/0254966	A1	9/2017	Gniadek	
2017/0293088	A1*	10/2017	Manes	G02B 6/3825
2017/0293089	A1*	10/2017	Gustafson	G02B 6/3821
2017/0293090	A1*	10/2017	Hopper	G02B 6/3821
2018/0128987	A1*	5/2018	Good	G02B 6/3883
2018/0156988	A1*	6/2018	Gniadek	G02B 6/387
2018/0156999	A1*	6/2018	Buff	G02B 6/4452
2018/0164511	A1*	6/2018	Childers	G02B 6/3831
2018/0172923	A1*	6/2018	Bauco	G02B 6/3873
2018/0172924	A1*	6/2018	Bauco	G02B 6/3873
2018/0172942	A1*	6/2018	Bauco	G02B 6/3873
2018/0217339	A1*	8/2018	Ma	G02B 6/3893
2018/0217340	A1*	8/2018	Wong	G02B 6/3893

FOREIGN PATENT DOCUMENTS

CN	201383588	Y	1/2010
CN	2026500189	U	12/2013
DE	202006011910	U1	3/2007
DE	102006019335	A1	10/2007
EP	1211537	A2	6/2002
EP	1245980	A2	10/2002
EP	1566674	A1	8/2005
GB	2111240	A	6/1983
JP	2008229545	A	10/2009
JP	2009276493	A	11/2009
TW	200821653	A	5/2008
WO	2001/79904	A2	10/2001
WO	2004/027485	A1	4/2004
WO	2008/112986	A1	9/2008
WO	2009/135787	A1	11/2009
WO	2010-024851	A2	3/2010
WO	2012/136702	A1	10/2012
WO	2012/162385	A1	11/2012
WO	2013/052070	A1	4/2013
WO	2014/028527	A2	2/2014
WO	2014/182351	A2	11/2014

OTHER PUBLICATIONS

EP Search Report and Opinion dated Feb. 2015 EP 14168005.
Fiber Optic Connectors and Assemblies Catalog 2009 Huber &Suhner.
Fiber Optic Interconnect Solutions Tactical Fiber Optic Connectors, Cables and Termini Glenair, 2006.
Fiber Optic Products Catalog Nov. 2007 Tyco Electronics.
ISR and Opinion dated Apr. 2012, PCT/US2012/058799.
ISR and Opinion dated Aug. 2012, PCT/US2012/039126.
ISR and Opinion dated Jan. 2016, PCT/US2013/54784.
ISR and Opinion dated Aug. 2014, PCT/US2014/041500.
ISR and Opinion dated May 2014, PCT/US2014/012137.
ISR and Opinion dated Aug. 2008, PCT/US2008/057023.
International Preliminary Report on Patentability dated Sep. 2017 from US2015/059458, dated Nov. 6, 2015.
ISR and Opinion dated Apr. 13, 2018 PCT/US2018/016049.
ISR and Opinion dated Feb. 2017, PCT/US2017/13286.
ISR and Opinion dated Aug. 2017, PCT/US2017/40178.
AFOP to introduce LC Slimpac(TM) Uniboot Connectors as high density connector solutions Aug. 26, 2014.

* cited by examiner

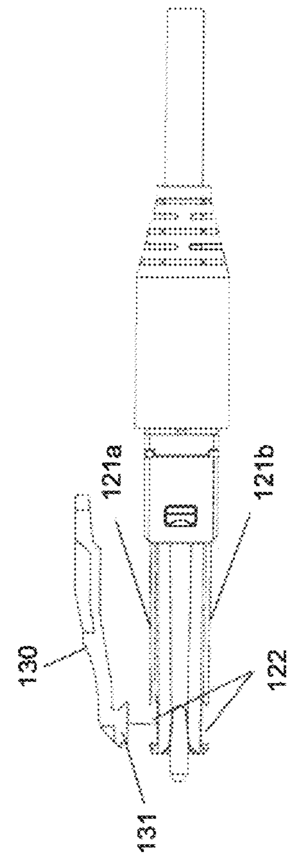


FIG. 1B

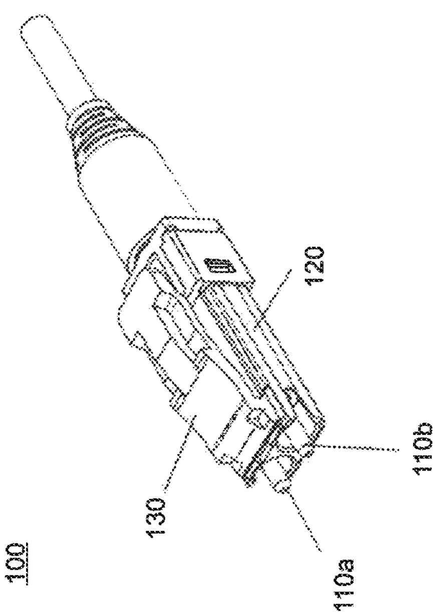


FIG. 1A

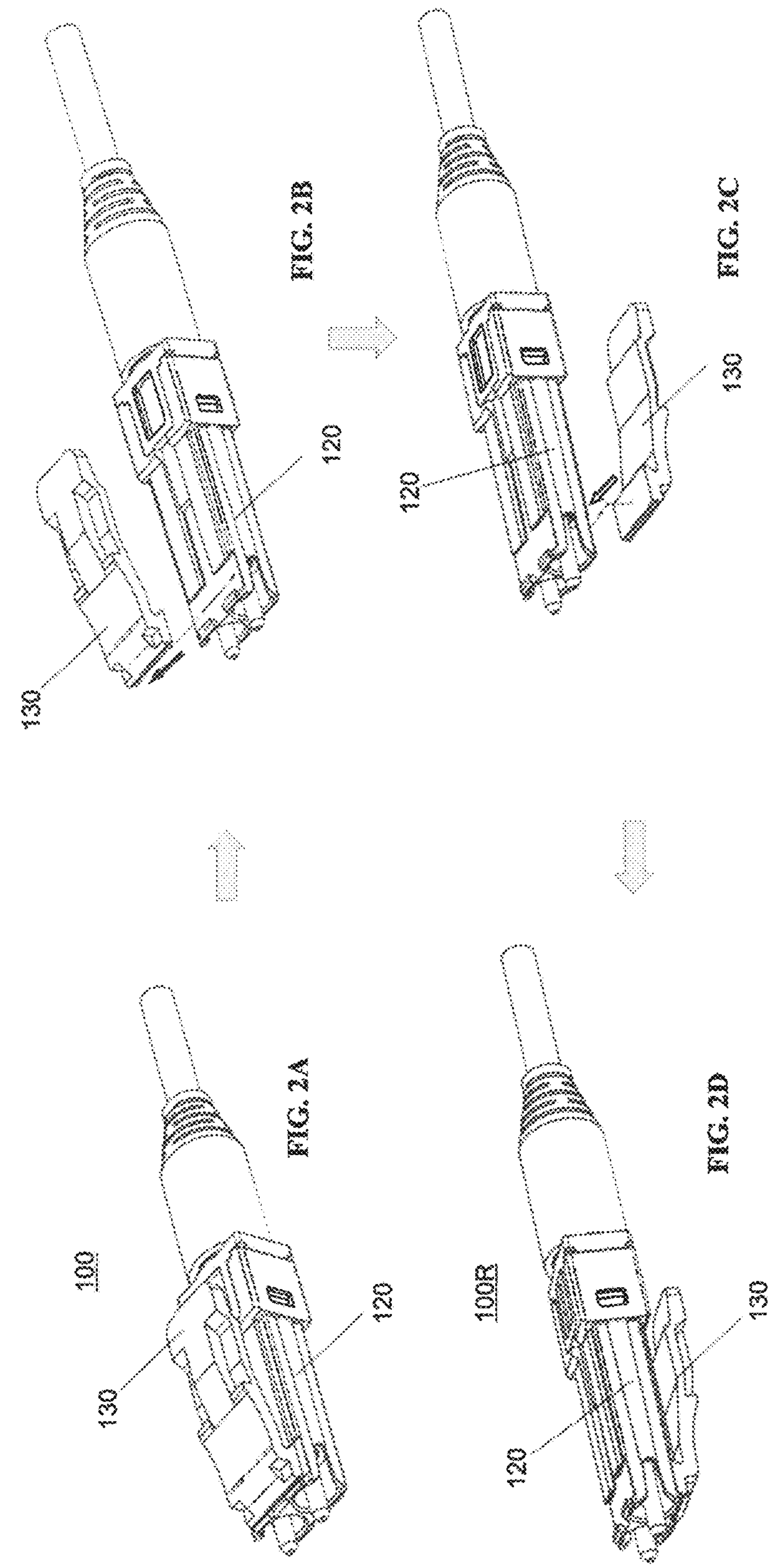


FIG. 2B
120
130
FIG. 2C
130
120
FIG. 2A
100
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FIG. 2D
100R
130
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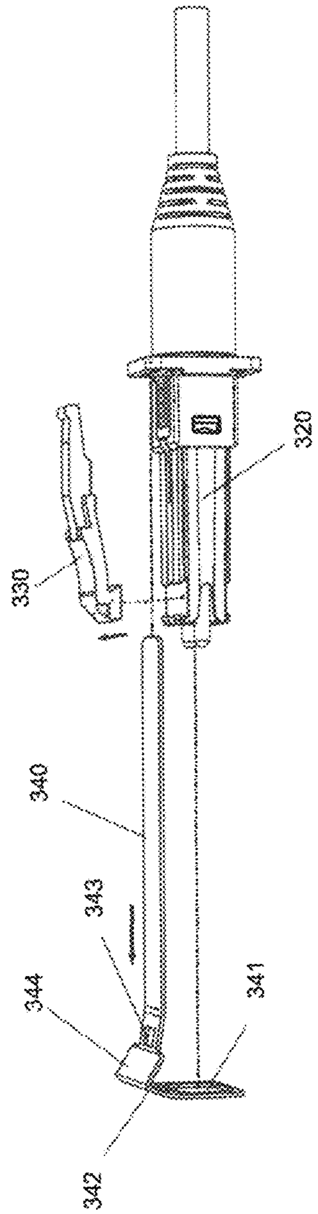


FIG. 3B

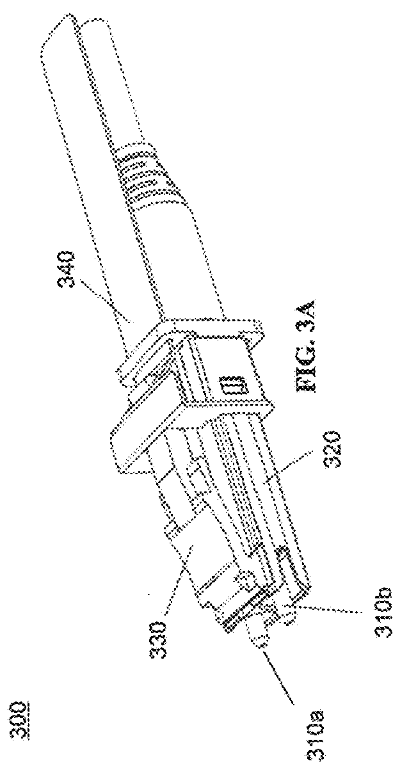


FIG. 3A

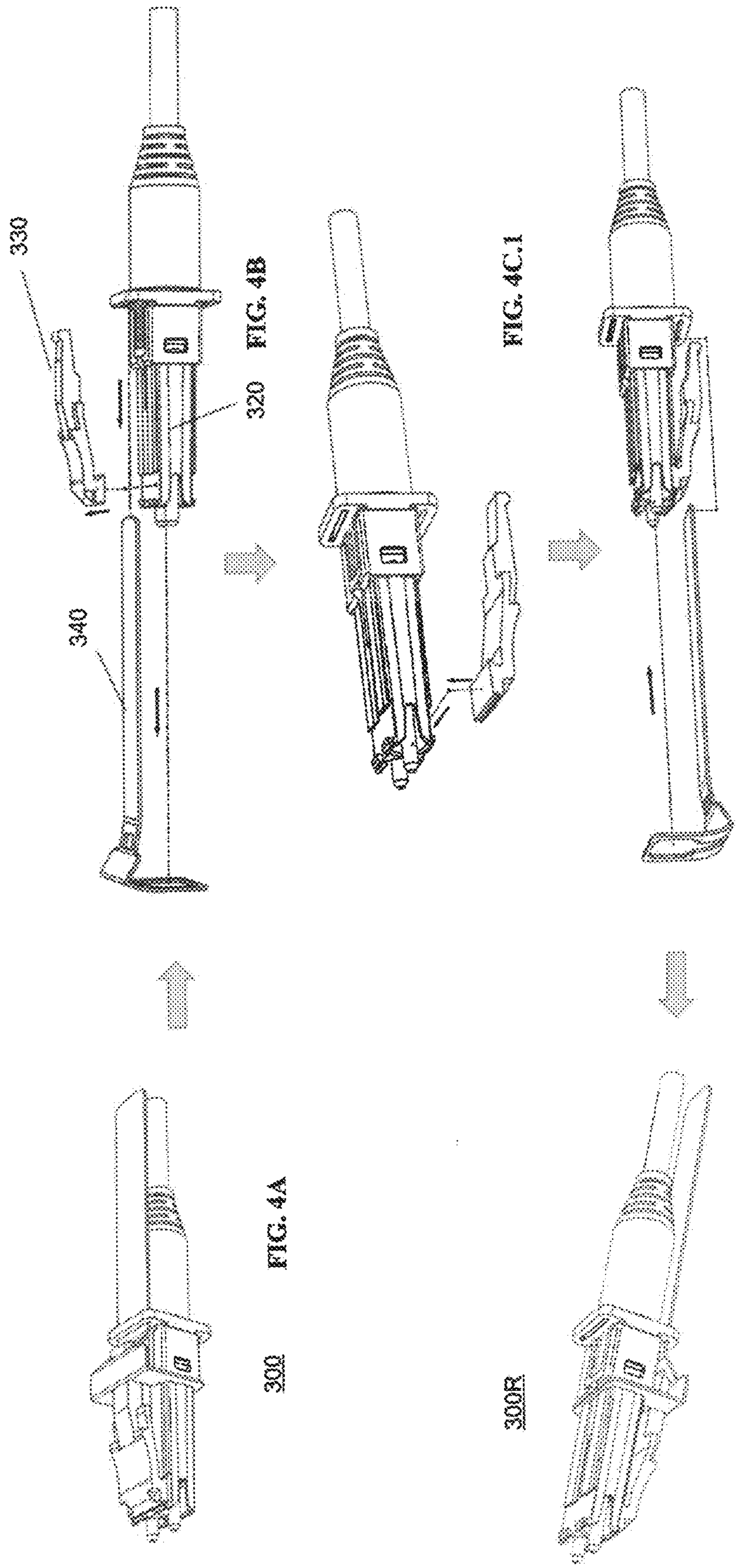


FIG. 4B

FIG. 4C.1

FIG. 4C.2

FIG. 4A

FIG. 4D

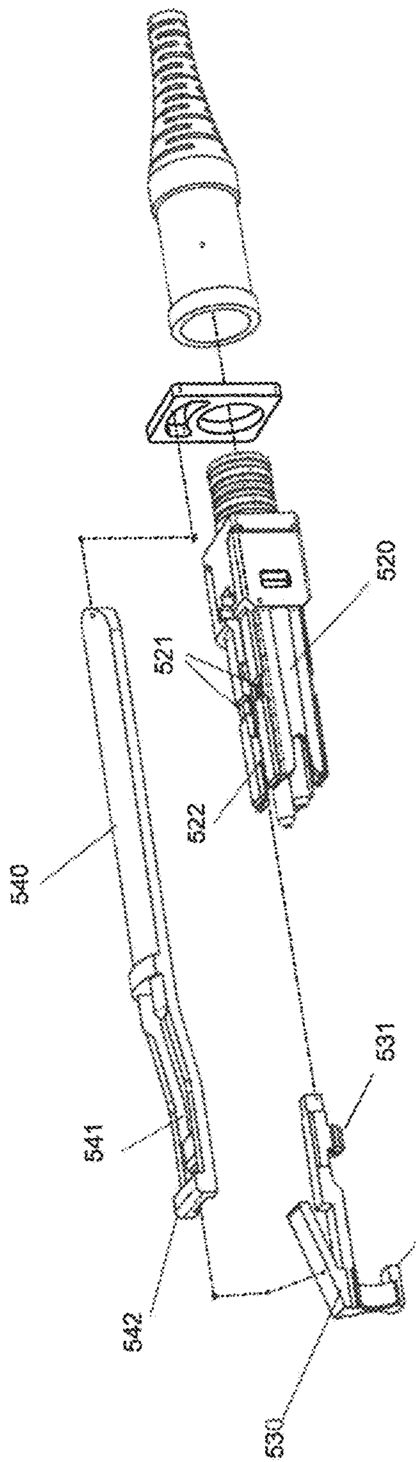


FIG. 5B

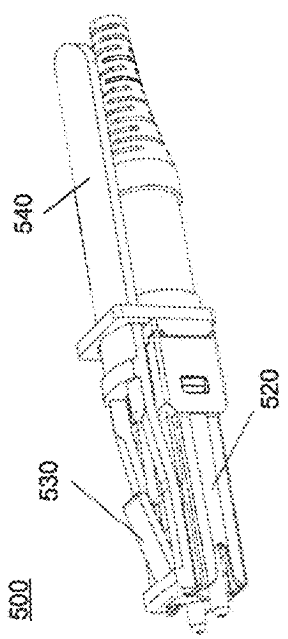


FIG. 5A

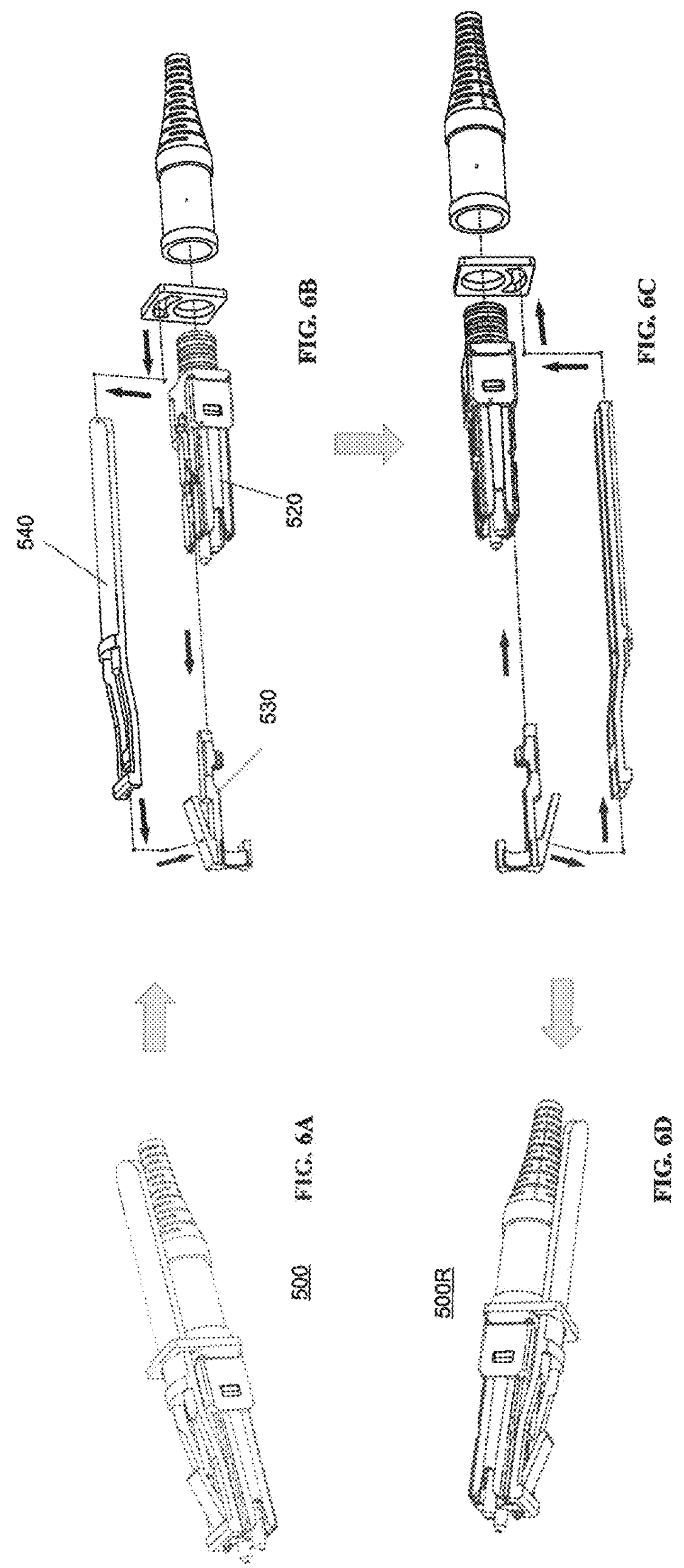


FIG. 6A

FIG. 6B

FIG. 6C

FIG. 6D

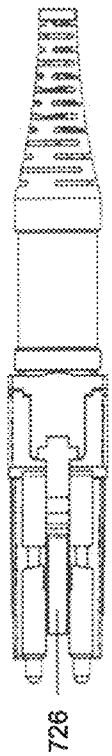


FIG. 7C

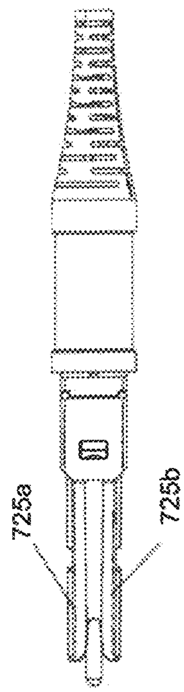


FIG. 7D

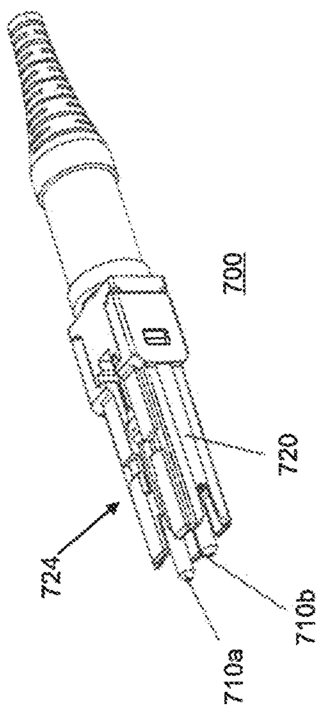


FIG. 7A

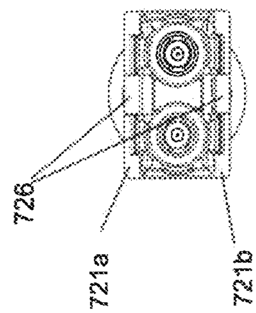


FIG. 7B

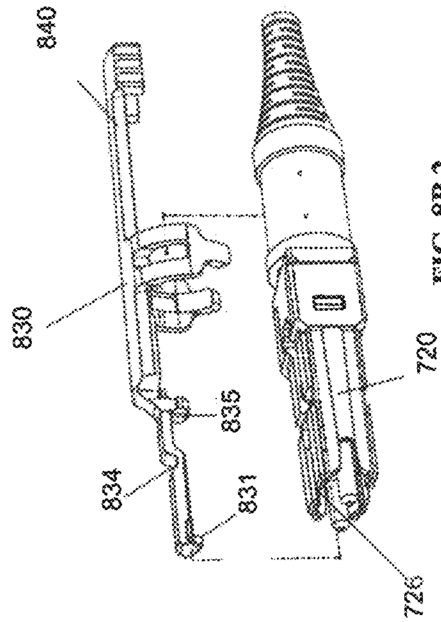


FIG. 8B.2

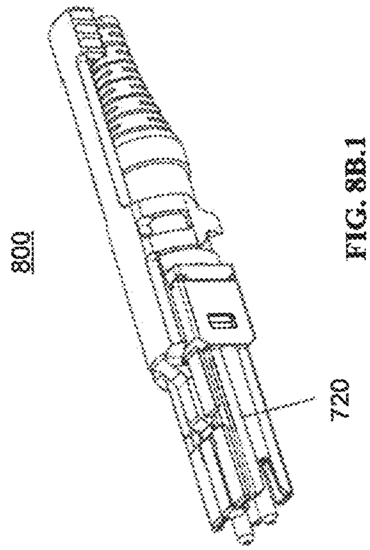


FIG. 8B.1

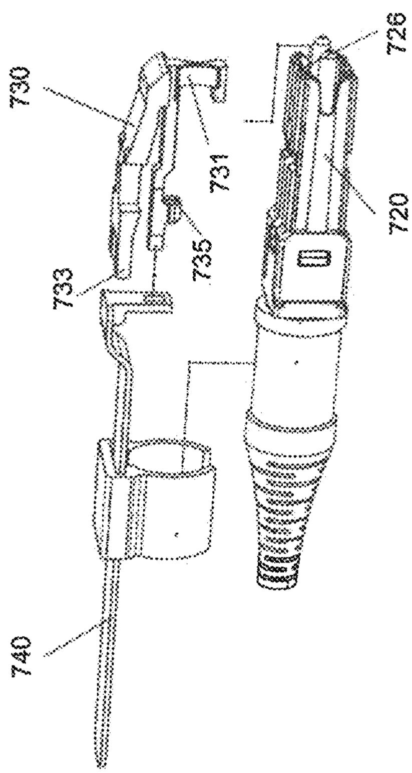


FIG. 8A.2

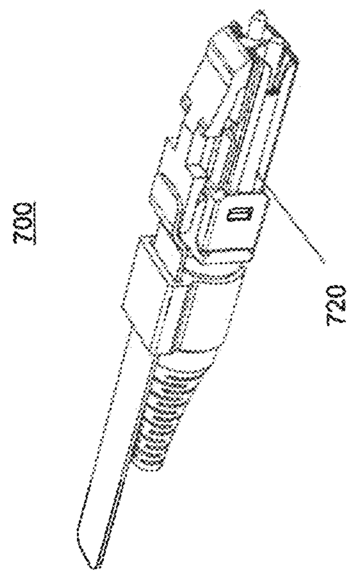


FIG. 8A.1

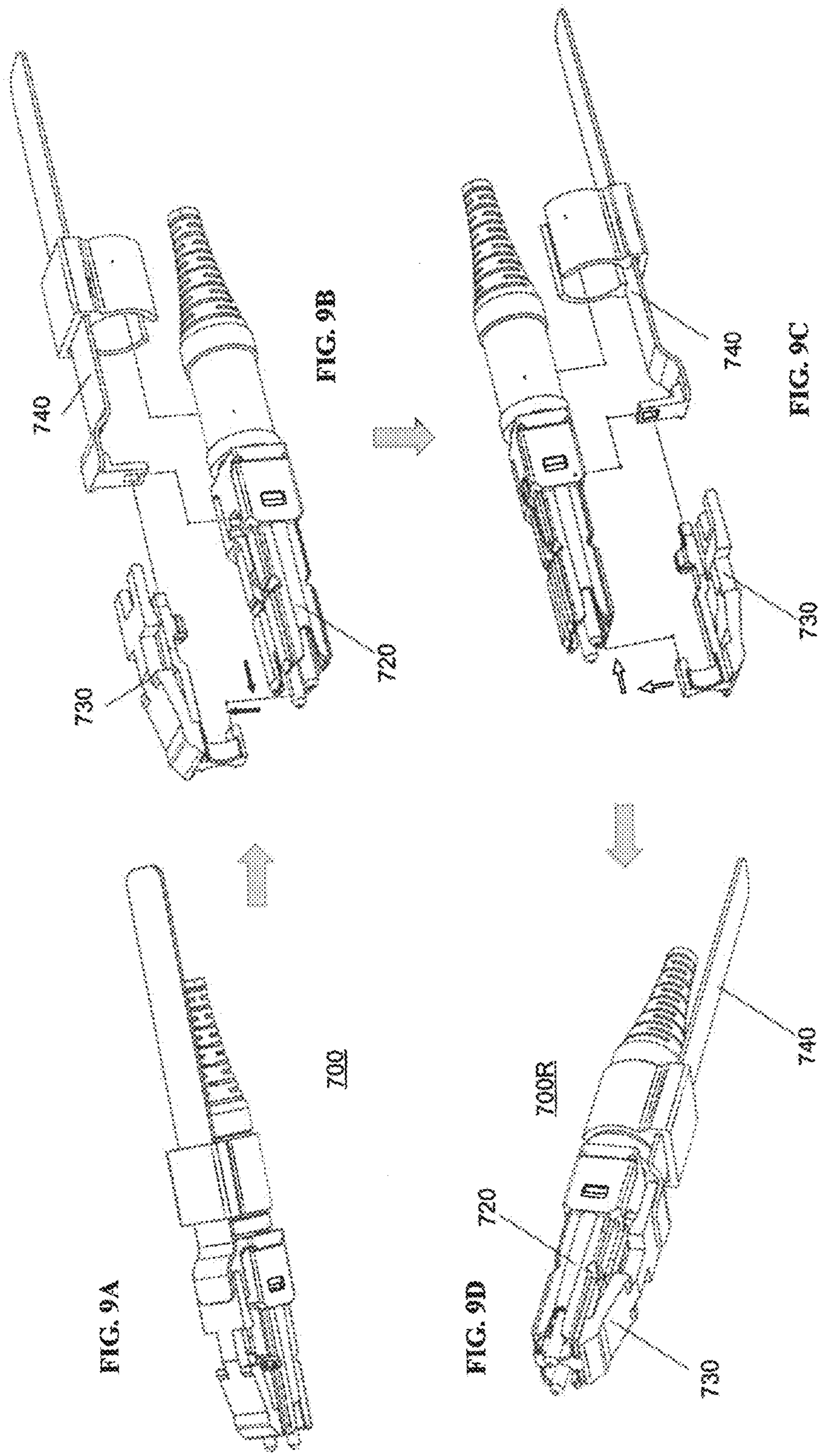


FIG. 9A

FIG. 9B

FIG. 9C

FIG. 9D

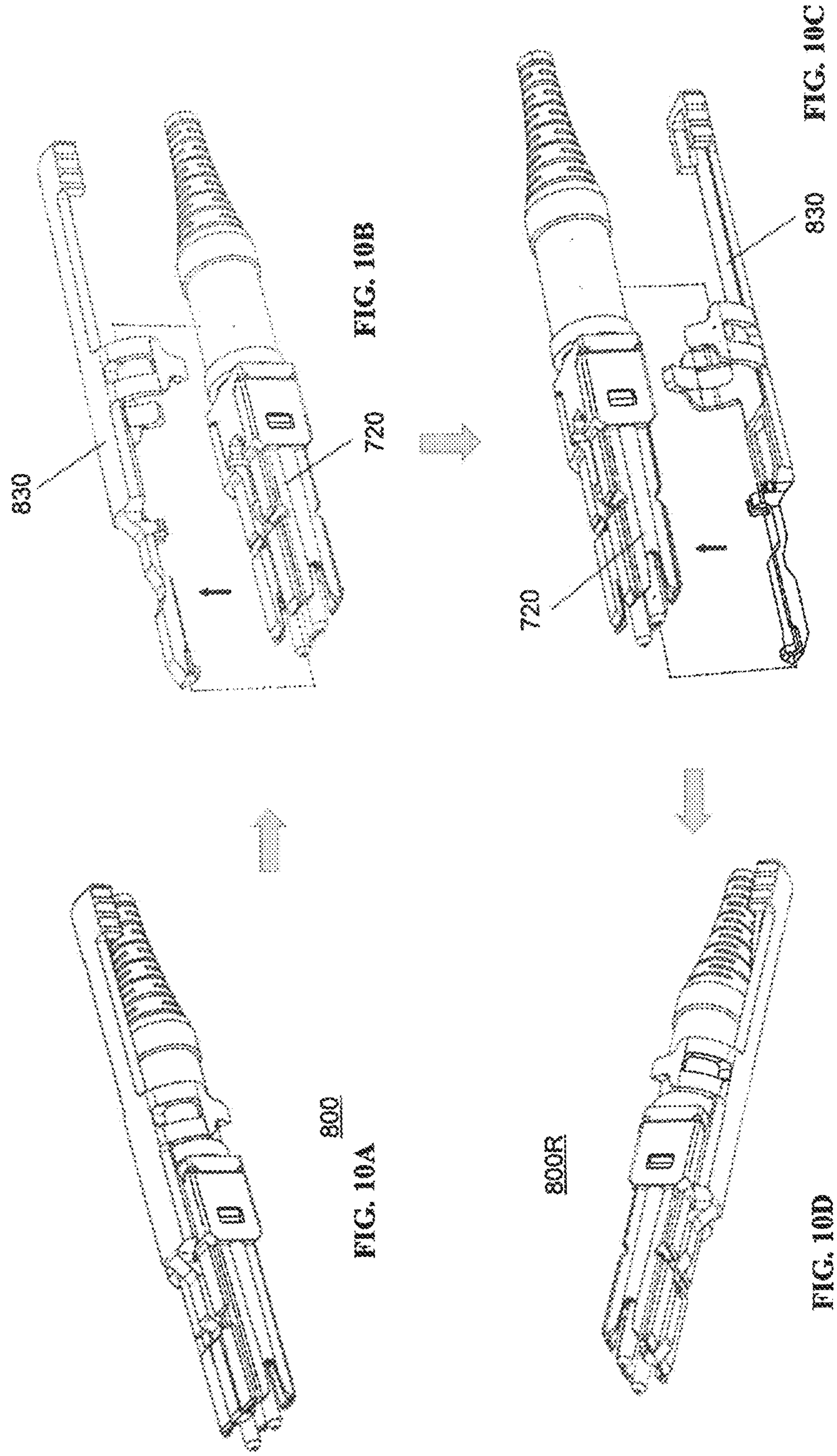


FIG. 10A

FIG. 10B

FIG. 10C

FIG. 10D

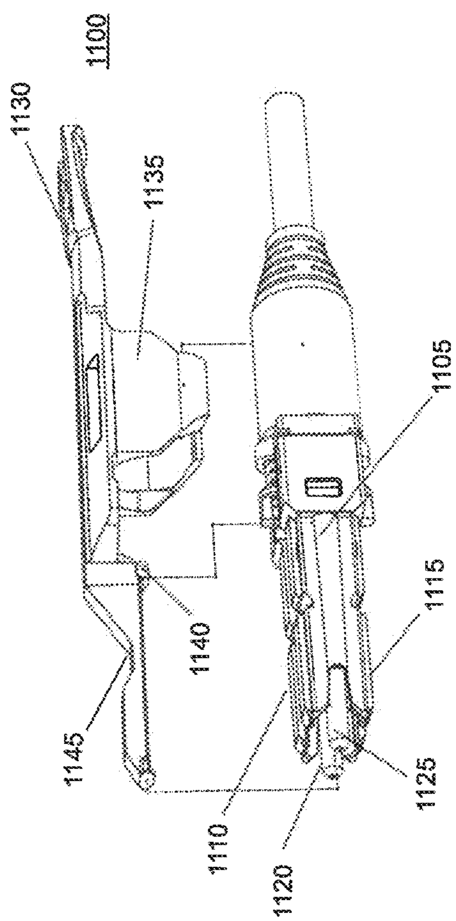


FIG. 11A

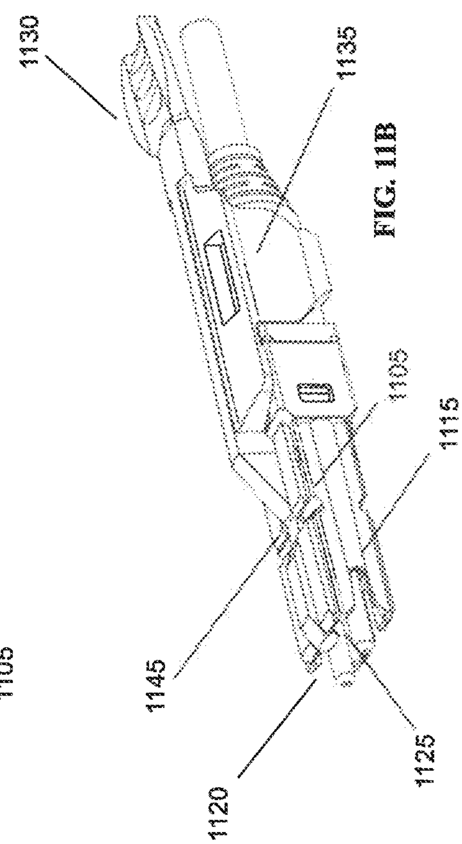


FIG. 11B

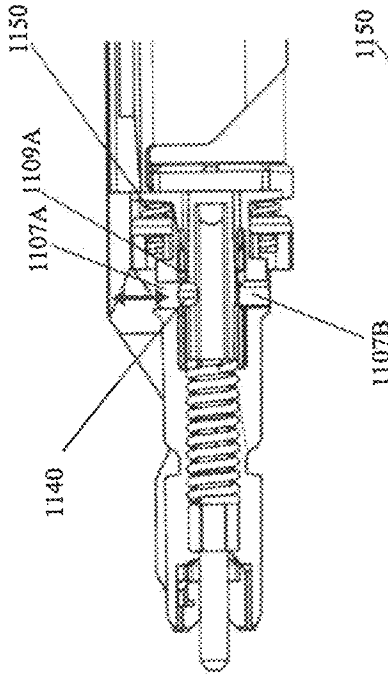


FIG. 12B

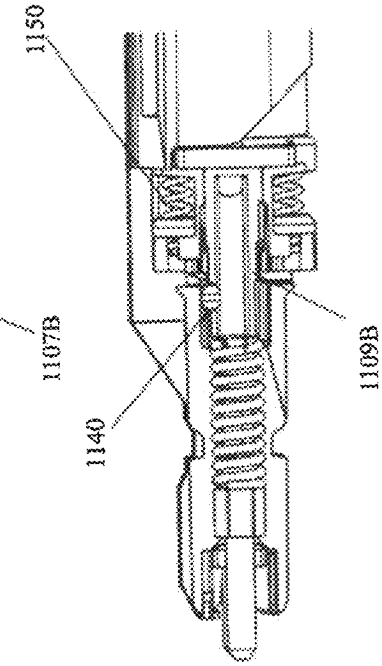


FIG. 12D

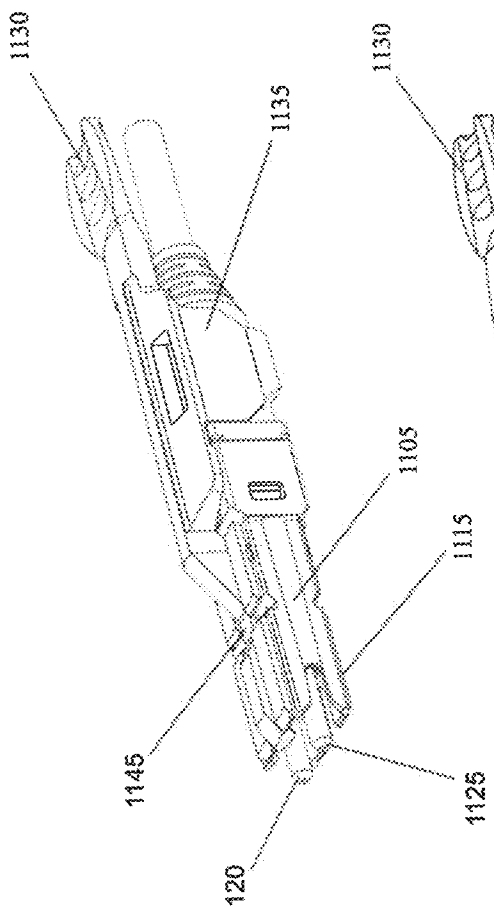


FIG. 12A

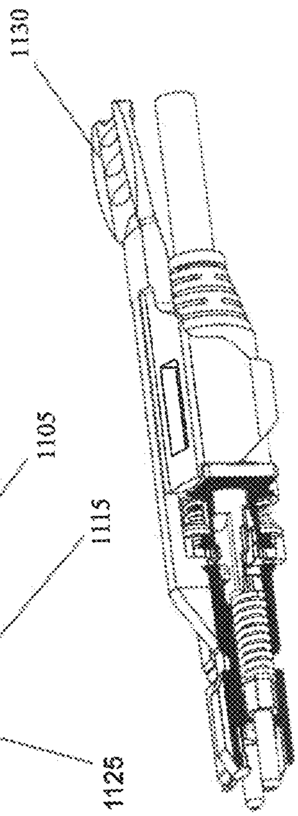


FIG. 12C

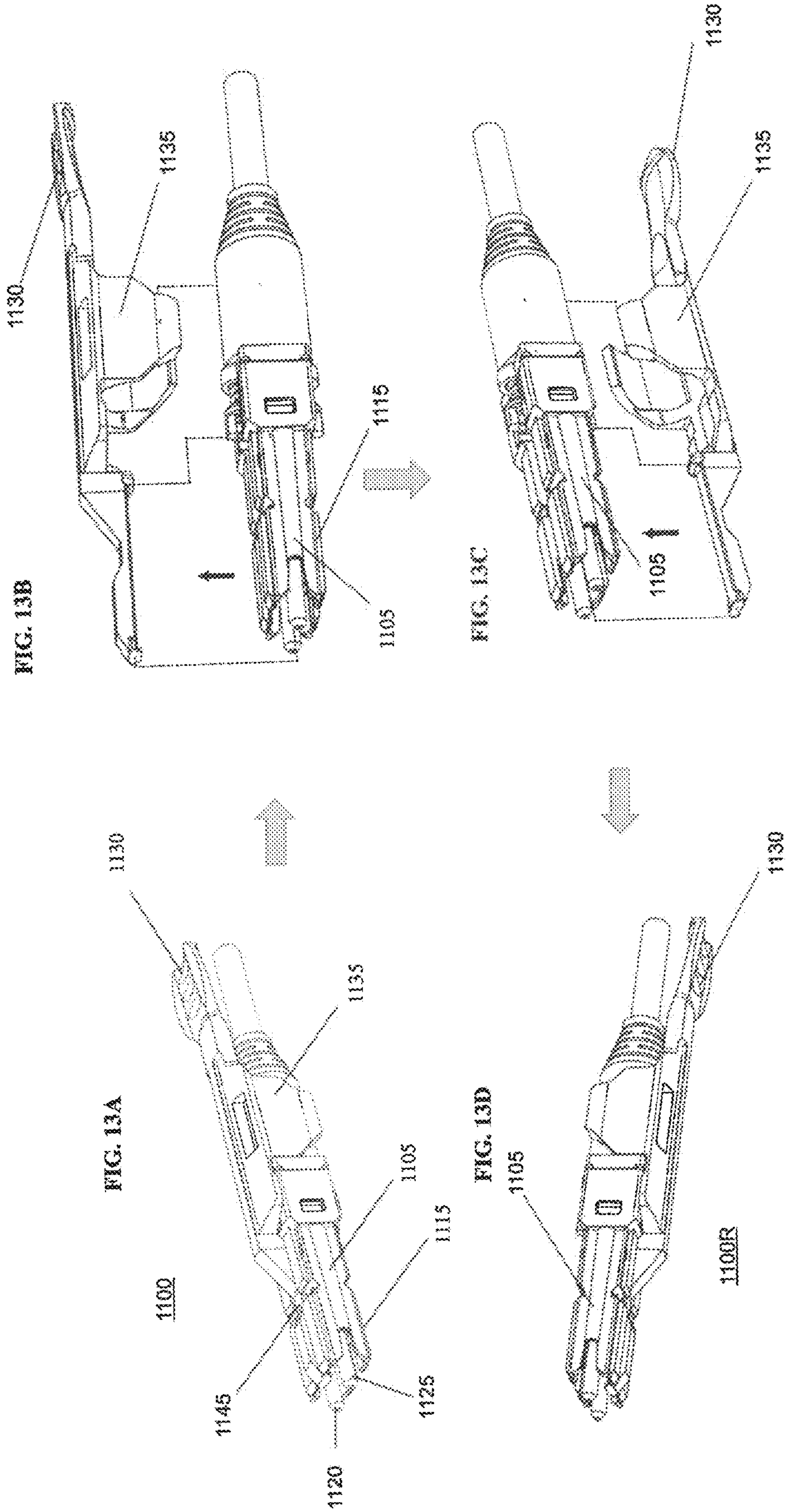


FIG. 13A

FIG. 13B

FIG. 13C

FIG. 13D

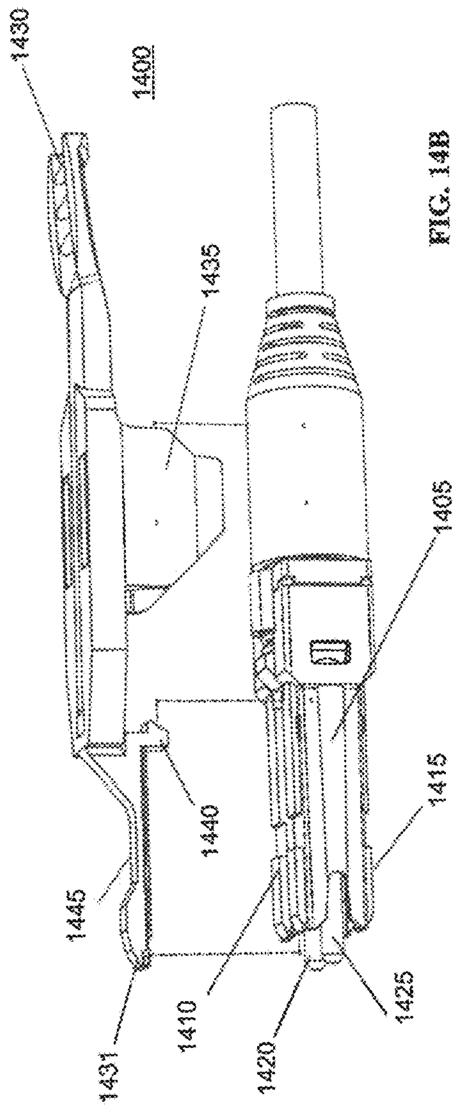


FIG. 14A

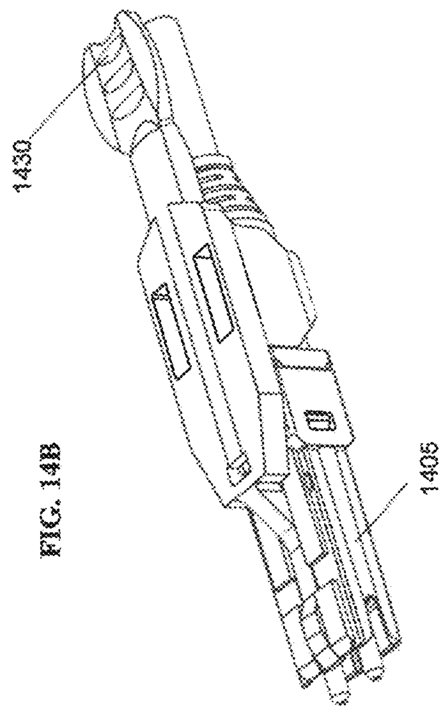


FIG. 14B

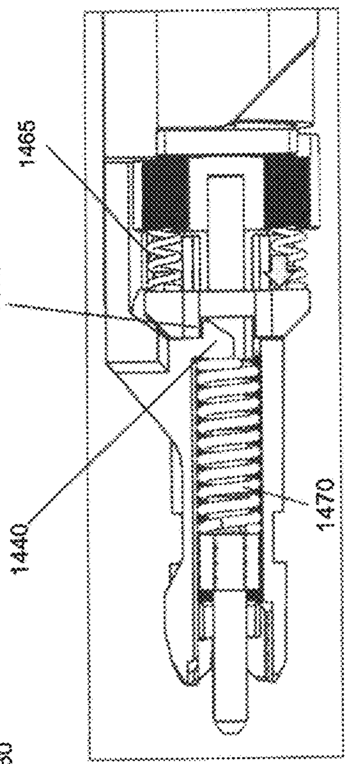


FIG. 15B

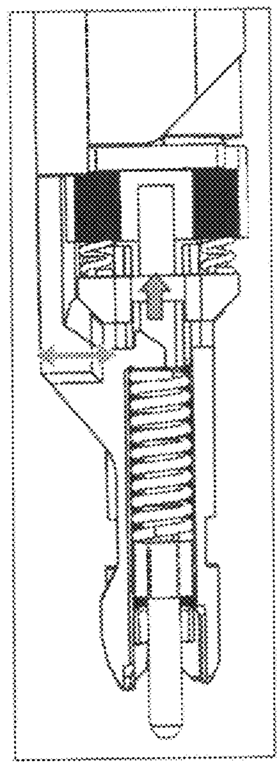


FIG. 15D

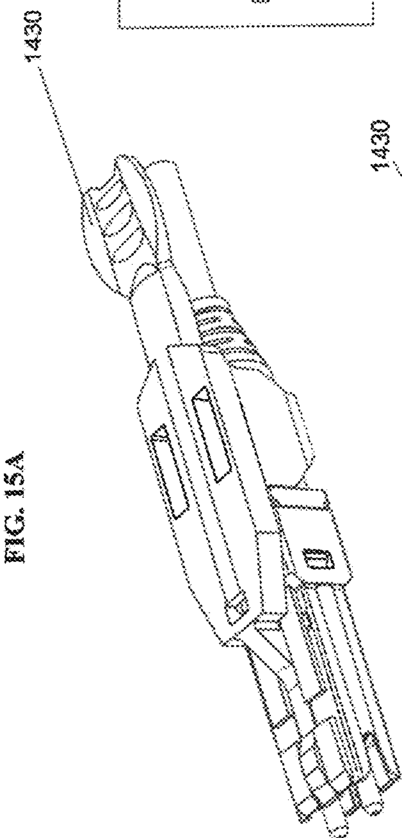


FIG. 15A

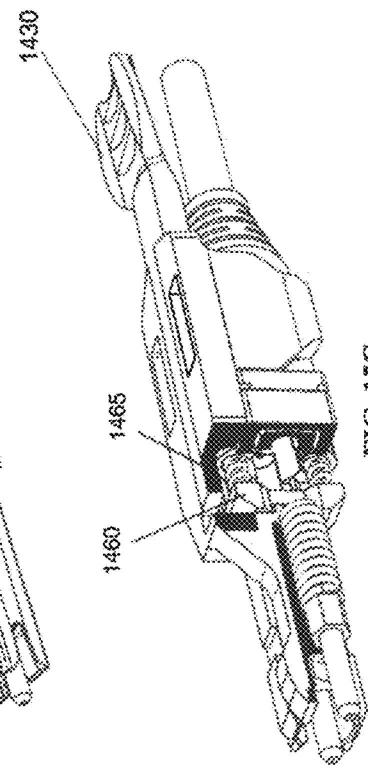


FIG. 15C

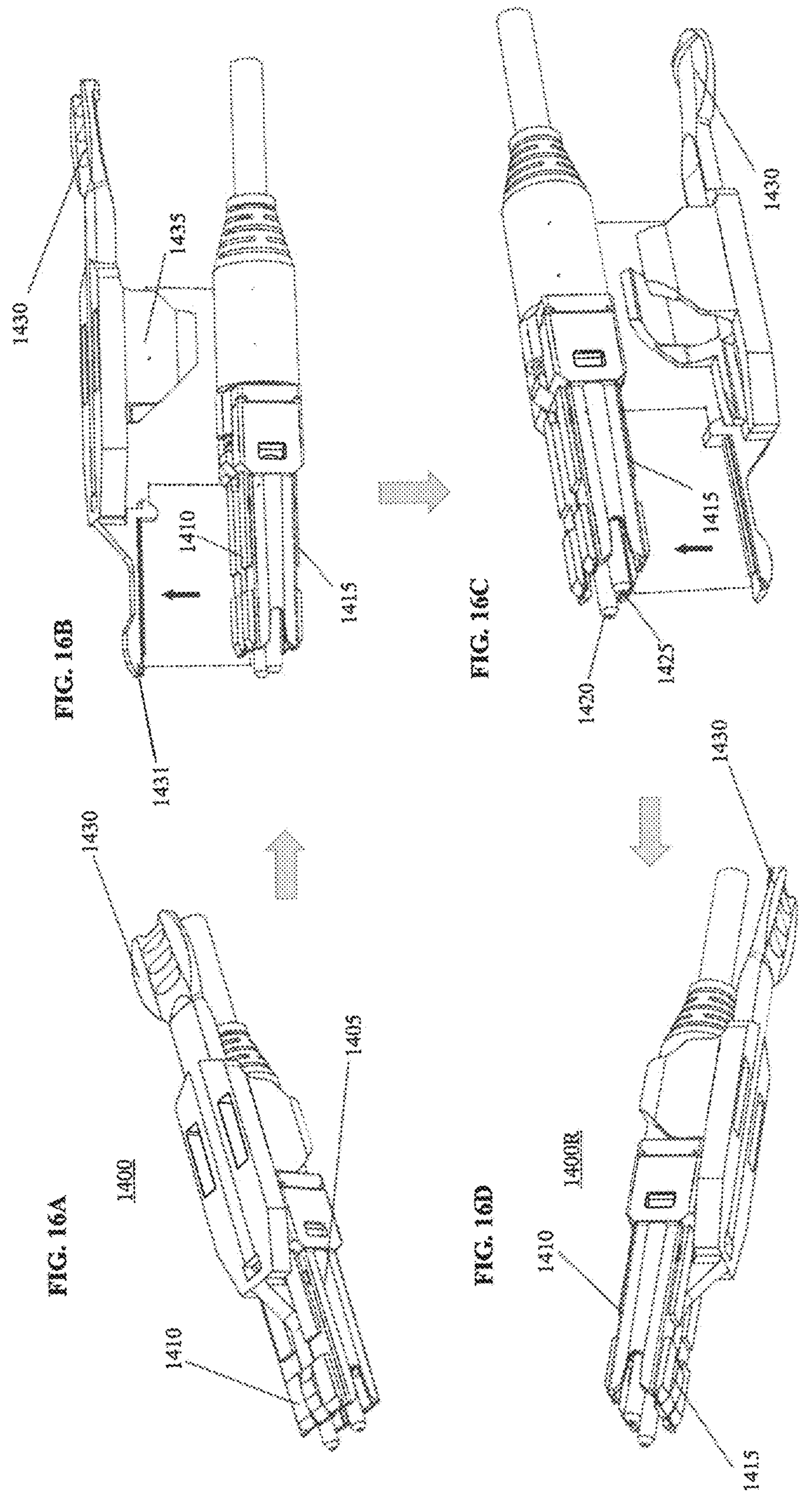


FIG. 16A

FIG. 16B

FIG. 16C

FIG. 16D

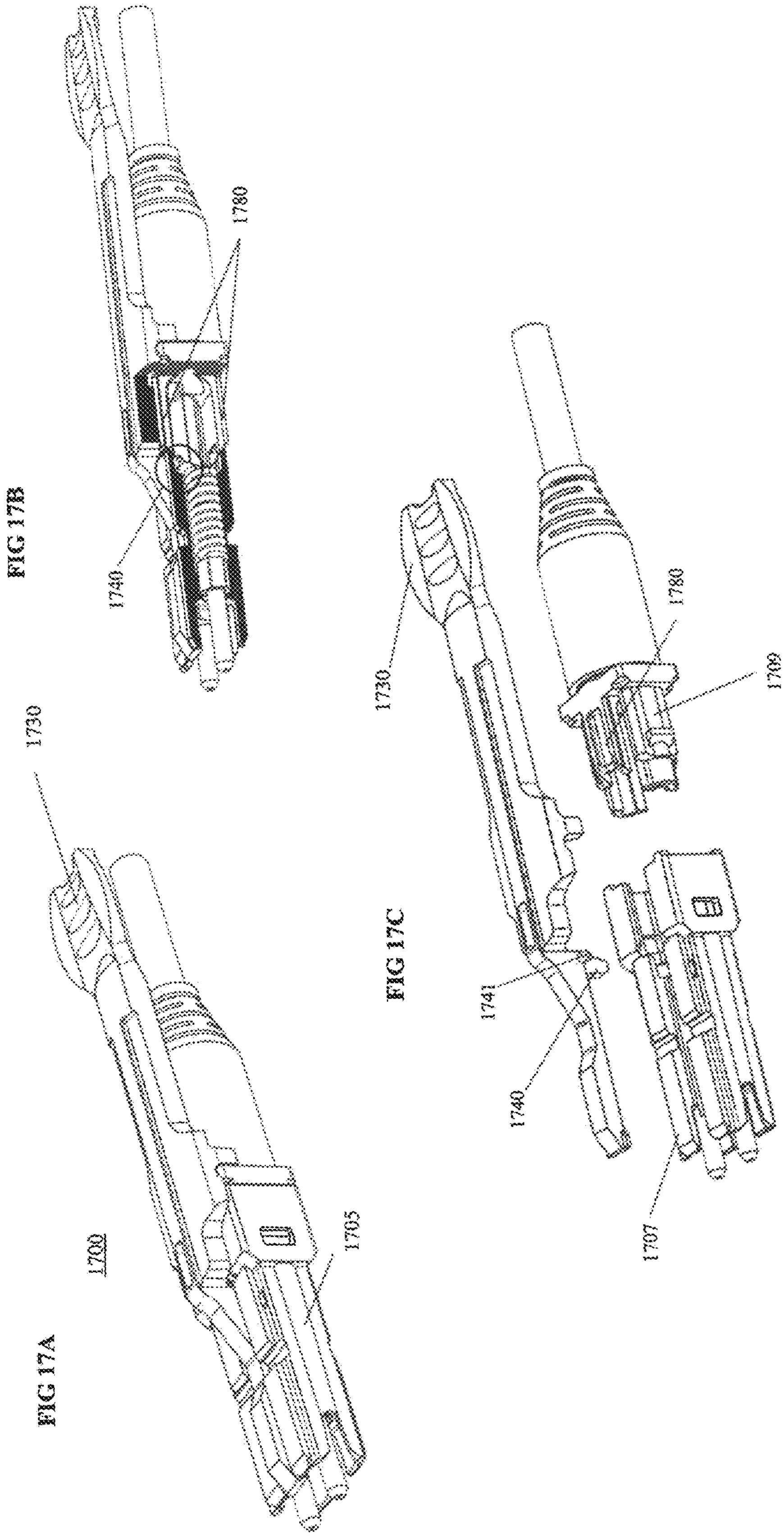


FIG 17B

FIG 17C

FIG 17A

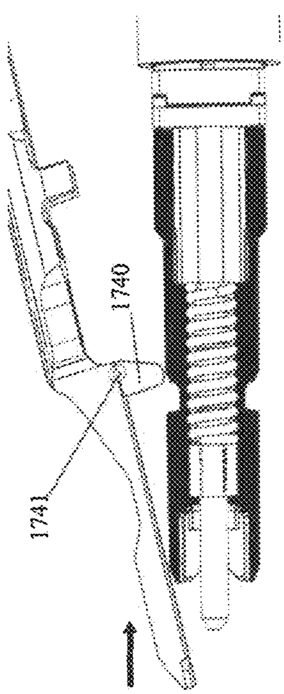


FIG. 18A

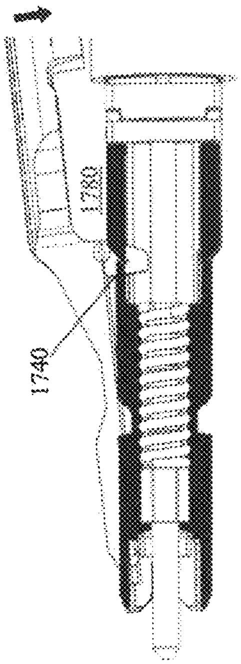


FIG 18B

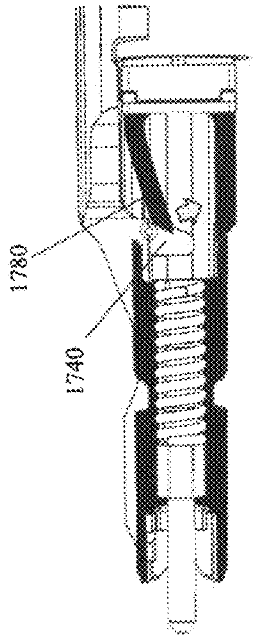


FIG. 18C

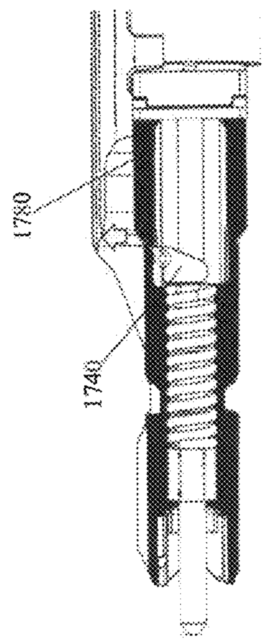
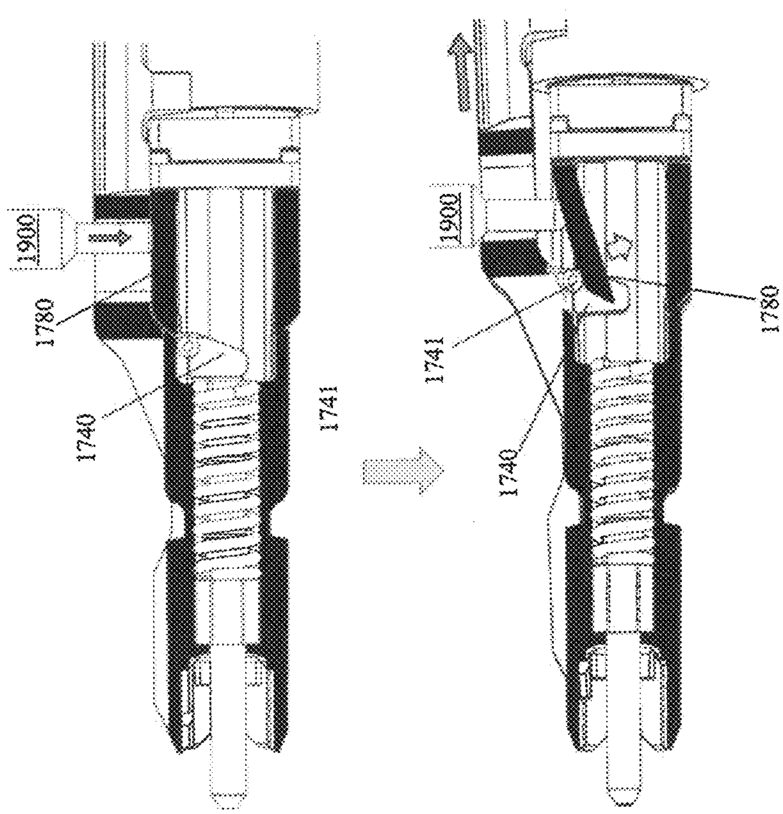


FIG. 18D

FIG. 19A

FIG. 19B



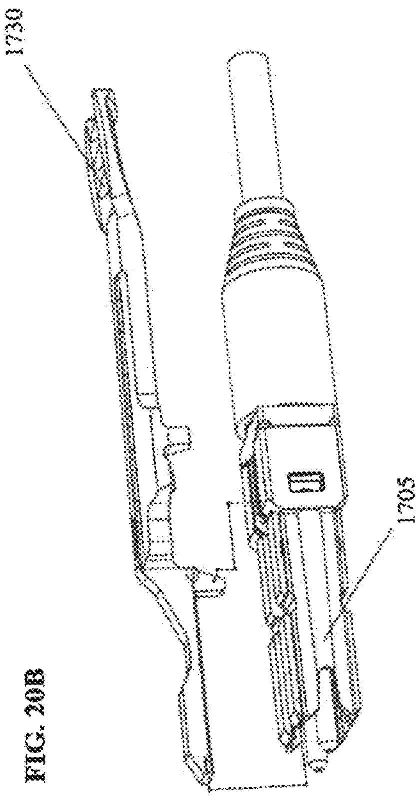


FIG. 20B

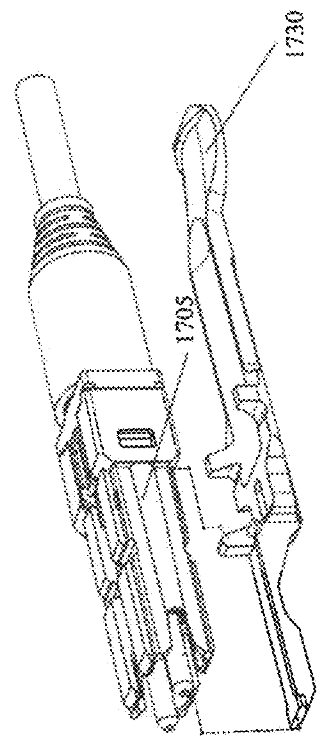


FIG. 20C

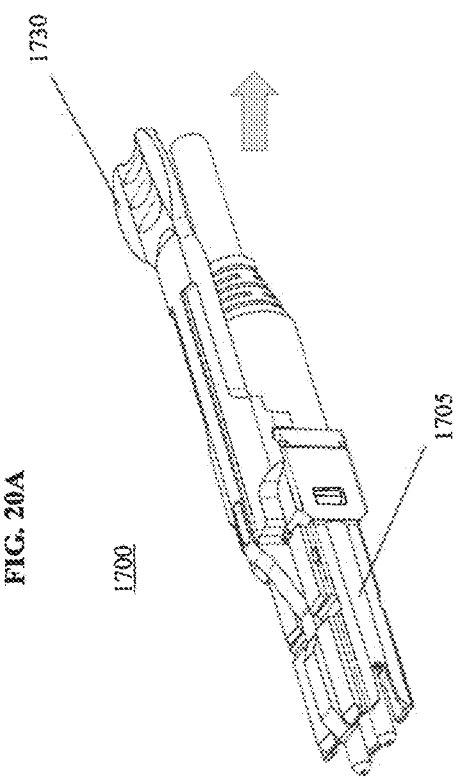


FIG. 20A

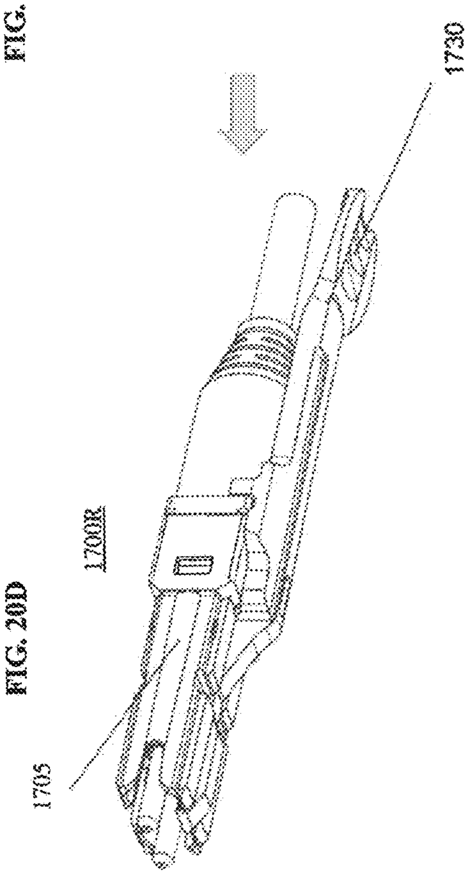


FIG. 20D

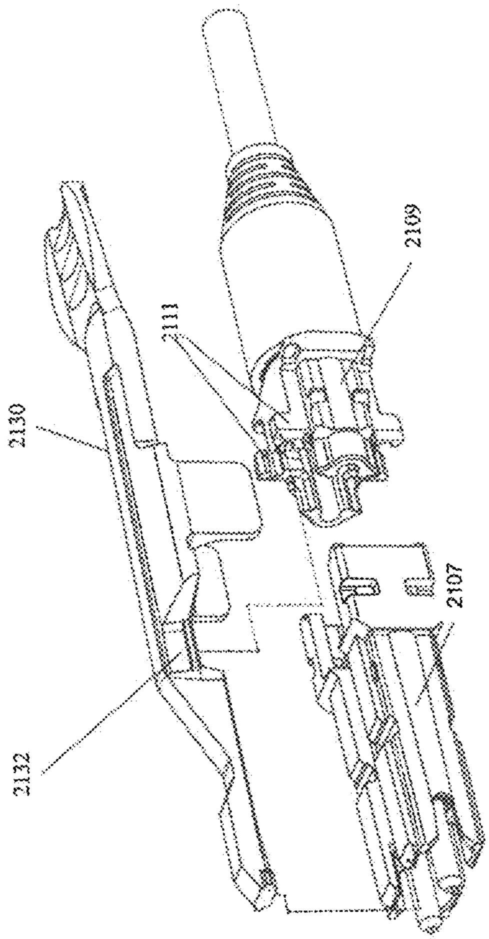


FIG. 21B

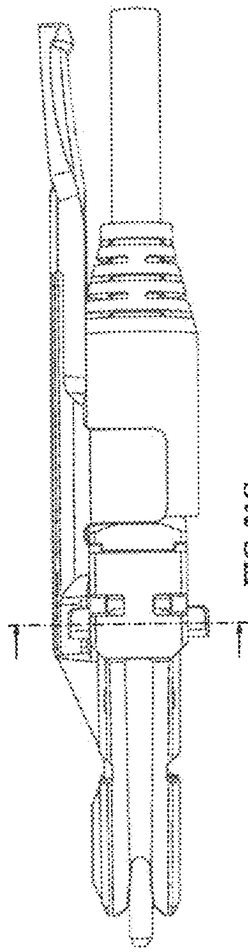


FIG. 21C

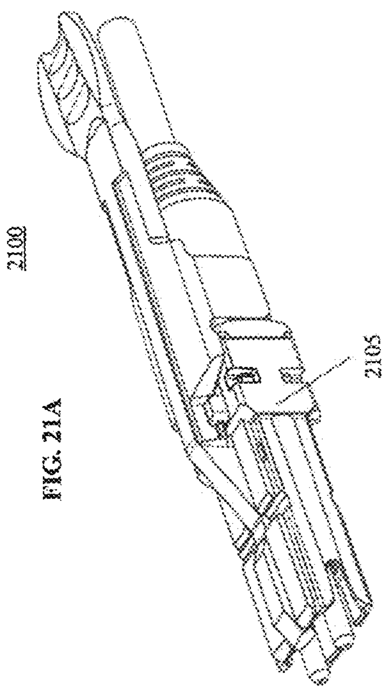


FIG. 21A

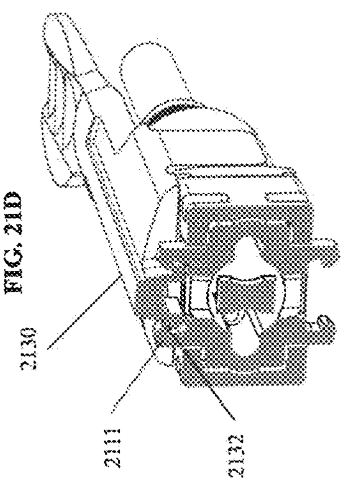


FIG. 21D

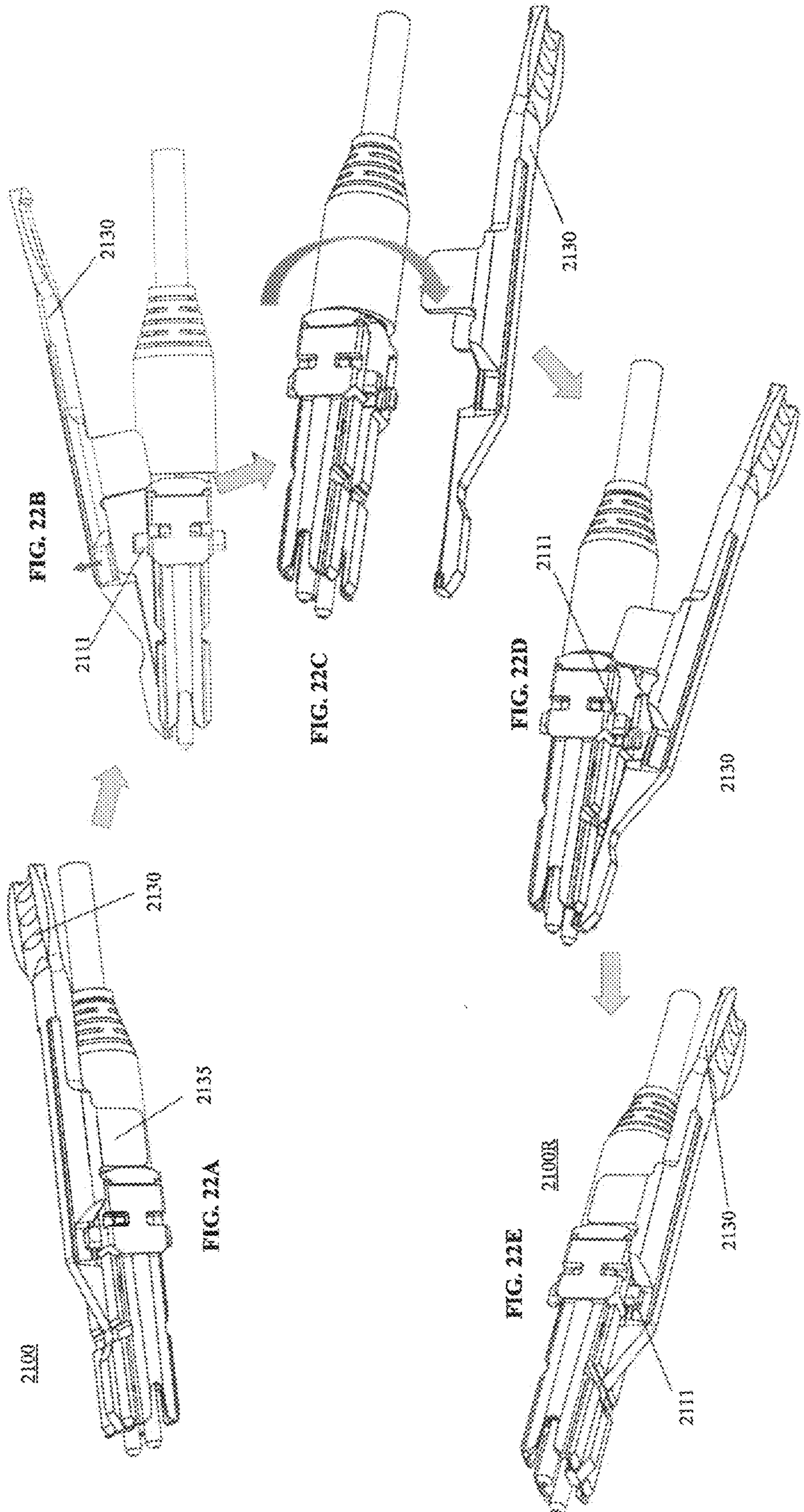


FIG. 22A

FIG. 22B

FIG. 22C

FIG. 22D

FIG. 22E

OPTICAL CONNECTORS WITH REVERSIBLE POLARITY

CROSS-REFERENCE TO RELATED PATENT APPLICATIONS

The present application claims priorities to U.S. Provisional Patent Applications No. 62/452,147 filed Jan. 30, 2017, No. 62/457,150 filed Feb. 9, 2017, No. 62/463,898 filed Feb. 27, 2017, No. 62/463,901 filed Feb. 27, 2017, No. 62/485,042 filed Apr. 13, 2017, No. 62/546,920, filed Aug. 17, 2017, and No. 62/581,961 filed Nov. 6, 2017; the disclosures of which are incorporated herein by reference in their entireties.

FIELD OF THE INVENTION

The present disclosure relates generally optical connectors with reversible polarity.

BACKGROUND

The prevalence of the Internet has led to unprecedented growth in communication networks. Consumer demand for service and increased competition has caused network providers to continuously find ways to improve quality of service while reducing cost.

Certain solutions have included deployment of high-density interconnect panels. High-density interconnect panels may be designed to consolidate the increasing volume of interconnections necessary to support the fast-growing networks into a compacted form factor, thereby increasing quality of service and decreasing costs such as floor space and support overhead. However, room for improvement in the area of data centers, specifically as it relates to fiber optic connections, still exists. For example, manufacturers of connectors are always looking to reduce the size of the devices, while increasing ease of deployment, robustness, and modifiability after deployment. In particular, more optical connectors may need to be accommodated in the same footprint previously used for a smaller number of connectors in order to provide backward compatibility with existing data center equipment. For example, one current footprint is known as the small form-factor pluggable footprint (SFP). This footprint currently accommodates two LC-type ferrule optical connections. However, it may be desirable to accommodate four optical connections (two duplex connections of transmit/receive) within the same footprint. Another current footprint is the quad small form-factor pluggable (QSFP) footprint. This footprint currently accommodates four LC-type ferrule optical connections. However, it may be desirable to accommodate eight optical connections of LC-type ferrules (four duplex connections of transmit/receive) within the same footprint.

In communication networks, such as data centers and switching networks, numerous interconnections between mating connectors may be compacted into high-density panels. Panel and connector producers may optimize for such high densities by shrinking the connector size and/or the spacing between adjacent connectors on the panel. While both approaches may be effective to increase the panel connector density, shrinking the connector size and/or spacing may also increase the support cost and diminish the quality of service.

In a high-density panel configuration, adjacent connectors and cable assemblies may obstruct access to the individual release mechanisms. Such physical obstructions may impede the ability of an operator to minimize the stresses applied to the cables and the connectors. For example, these stresses may be applied when the user reaches into a dense group of connectors and pushes aside surrounding optical fibers and connectors to access an individual connector release mechanism with his/her thumb and forefinger. Overstressing the cables and connectors may produce latent defects, compromise the integrity and/or reliability of the terminations, and potentially cause serious disruptions to network performance.

Accordingly, there is a need for smaller fiber optic connectors that will meet the needs of future developments in smaller SFPs and are reconfigurable for flexible deployment.

SUMMARY OF THE INVENTION

In a first aspect, the present disclosure provides a reversible polarity fiber optic connector including at least first and second optical ferrules and a connector housing at least partially surrounding the first and second optical ferrules. The housing has a first exterior wall positioned above the first and second optical ferrules and a second exterior wall positioned beneath the first and second optical ferrules. A latch coupling is positioned on each of the first and second exterior walls of the housing. A removable latch may engage either the first or second exterior wall latch coupling on the connector housing. Positioning the removable latch on the first exterior wall yields a fiber optic connector with a first polarity and positioning the removable latch on the second exterior wall yields a fiber optic connector with a second, opposite polarity.

In another aspect, the present disclosure provides a reversible polarity fiber optic connector with exchangeable arms for changing connector type. Thus, a common connector body may be formed into different connector types. The connector includes at least first and second optical ferrules and a common connector housing at least partially surrounding the first and second optical ferrules. The housing has a first exterior wall positioned above the first and second optical ferrules and a second exterior wall positioned beneath the first and second optical ferrules. A coupling surface is positioned on each of the first and second exterior walls of the common connector housing. To create a connector, a removable arm engages either the first or second exterior wall coupling surface; the removable arm includes either a latch or a latch recess depending upon the type of optical connector to be formed. Further, positioning the removable arm on the first exterior wall of the connector housing yields a fiber optic connector with a first polarity and positioning the removable arm on the second exterior surface of the housing yields a fiber optic connector with a second, opposite polarity.

In another aspect, the present disclosure provides a reversible polarity fiber optic connector with a push-pull tab. The connector includes at least first and second optical ferrules and has a connector housing at least partially surrounding the first and second optical ferrules. A first exterior wall is positioned above the first and second optical ferrules and a second exterior wall is positioned beneath the first and second optical ferrules. A first aperture is in the first exterior wall of the housing and a second aperture is in the second exterior wall of the housing. A removable push-pull tab includes a protrusion for positioning within either of the first or second apertures in the first and second exterior walls, respectively, of the connector housing. Positioning the removable push-pull tab with its protrusion within the first aperture yields a fiber optic connector with a first polarity and positioning the removable push-pull tab with its protrusion within the second aperture yields a fiber optic connector with a second, opposite polarity.

In yet another aspect, the present disclosure provides a reversible polarity fiber optic connector including at least first and second optical ferrules and a connector housing at least partially surrounding the first and second optical ferrules. A first exterior wall is positioned above the first and second optical ferrules and a second exterior wall is positioned beneath the first and second optical ferrules. A removable push-pull tab is provided. A first push-pull tab retainer is positioned on the first exterior wall and a second push-pull tab retainer is positioned on the second exterior wall. Positioning the removable push-pull tab in the retainer on the first exterior wall of the connector housing yields a fiber optic connector with a first polarity and positioning the removable push-pull tab in the retainer on the second exterior wall of the housing yields a fiber optic connector with a second, opposite polarity.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**A is a perspective view of one embodiment of a reversible polarity fiber optic connector according to some aspects of the present disclosure;

FIG. **1**B is a side view of the reversible polarity fiber optic connector of FIG. **3**A with the removable latch being removed from the connector housing;

FIG. **2**A is a perspective view of the reversible polarity fiber optic connector of FIG. **1**A;

FIG. **2**B is an exploded view of a step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. **2**A;

FIG. **2**C is an exploded view of a next step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. **2**A;

FIG. **2**D is a perspective view of the fiber optic connector of FIG. **1**A with its polarity reversed;

FIG. **3**A is a perspective view of an embodiment of a reversible polarity fiber optic connector with a pull tab according to aspects of the present disclosure;

FIG. **3**B is an exploded view of the reversible polarity fiber optic connector of FIG. **3**A;

FIG. **4**A is a perspective view of the polarity of the reversible polarity fiber optic connector of FIG. **3**A;

FIG. **4**B is an exploded view of a step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. **4**A;

FIG. **4**C.**1** is an exploded view of positioning the latch in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. **4**A;

FIG. **4**C.**2** is an exploded view of attaching the removed components of FIG. **4**B in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. **4**A;

FIG. **4**D is a perspective view of the reversible polarity fiber optic connector of FIG. **4**A with its polarity reversed;

FIG. **5**A is a perspective view of another embodiment of a reversible polarity fiber optic connector with a pull tab according to aspects of the present disclosure;

FIG. **5**B is an exploded view of the reversible polarity fiber optic connector of FIG. **5**A;

FIG. **6**A is a perspective view of the polarity of the fiber optic connector of FIG. **5**A;

FIG. **6**B is an exploded view of a step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. **5**A;

FIG. **6**C is an exploded view of a next step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. **6**A;

FIG. **6**D is a perspective view of the reversible polarity fiber optic connector of FIG. **6**A with its polarity reversed;

FIG. **7**A is a perspective view of a common connector housing of a reversible polarity fiber optic connector with exchangeable arms for changing connector type in an embodiment according to aspects of the present disclosure;

FIG. **7**B is the front view of the common connector housing of FIG. **7**A;

FIG. **7**C is the top view of the common connector housing of FIG. **7**A;

FIG. **7**D is the side view of the common connector housing of FIG. **7**A;

FIG. **8**A.**1** shows how the common connector housing of FIG. **7**A is used to create a latch-type connector;

FIG. **8**A.**2** is an exploded view of FIG. **8**A.**1**;

FIG. **8**B.**1** shows how the common connector housing of FIG. **7**A is used to create a recess-type connector;

FIG. **8**B.**2** is an exploded view of FIG. **8**B.**1**;

FIG. **9**A is a perspective view of FIG. **8**A.**1** of the polarity of the latch-type fiber optic connector of FIG. **8**A.**1**;

FIG. **9**B is an exploded view of a step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. **8**A.**1**;

FIG. **9**C is an exploded view of a next step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. **8**A.**1**;

FIG. **9**D is a perspective view of the reversible polarity fiber optic connector of FIG. **8**A.**1** with its polarity reversed;

FIG. **10**A is a perspective view of FIG. **8**B.**1** of the polarity of the recess-type fiber optic connector of FIG. **8**B.**1**;

FIG. **10**B is an exploded view of a step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. **8**B.**1**;

FIG. **10**C is an exploded view of a next step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. **8**B.**1**;

FIG. **10**D is a perspective view of the reversible polarity fiber optic connector of FIG. **8**B.**1** with its polarity reversed;

FIGS. **11**A and **11**B respectively depict exploded and perspective views of a reversible polarity optical connector according to a further embodiment of the disclosure;

FIGS. **12**A-**12**D depict the operation of the reversible polarity optical connector of FIGS. **11**A and **11**B;

FIGS. **13**A-**13**D depict the process for changing the polarity of the optical connector of FIGS. **11**A and **11**B;

FIGS. **14**A and **14**B respectively depict exploded and perspective views of a reversible polarity optical connector according to a further embodiment of the disclosure;

FIGS. **15**-**15**D depict the operation of the reversible polarity optical connector of FIGS. **14**A and **14**B;

FIGS. **16**A-**16**D depict the process for changing the polarity of the optical connector of FIGS. **14**A and **14**B;

FIGS. **17**A-**17**C respectively depict perspective, partial cross-section, and exploded views of a reversible polarity optical connector according to a further embodiment of the disclosure;

FIGS. **18**A-**18**D depict the assembly of the push-pull tab to the connector body of the connector of FIGS. **17**A-**17**C;

FIGS. **19**A-**19**B depict the removal of the push-pull tab from the connector body using a tool;

FIGS. **20**A-**20**D depict the process for changing the polarity of the optical connector of FIGS. **17**A-**17**C.

DETAILED DESCRIPTION

This disclosure is not limited to the particular systems, devices and methods described, as these may vary. The terminology used in the description is for the purpose of describing the particular versions or embodiments only, and is not intended to limit the scope.

As used in this document, the singular forms "a," "an," and "the" include plural references unless the context clearly dictates otherwise. Unless defined otherwise, all technical and scientific terms used herein have the same meanings as commonly understood by one of ordinary skill in the art. Nothing in this disclosure is to be construed as an admission that the embodiments described in this disclosure are not entitled to antedate such disclosure by virtue of prior invention. As used in this document, the term "comprising" means "including, but not limited to."

The following terms shall have, for the purposes of this application, the respective meanings set forth below.

The connectors of the present disclosure may be configured for fiber optic transmission or electrical signal transmission. The connector may be any suitable type now known or later developed, such as, for example, a ferrule connector (FC), a fiber distributed data interface (FDDI) connector, an LC connector, a mechanical transfer (MT) connector, a square connector (SC) connector, an SC duplex connector, or a straight tip (ST) connector. The connector may generally be defined by a connector housing. In some embodiments, the housing may incorporate any or all of the components described herein.

Various embodiments described herein generally provide a remote release mechanism such that a user can remove cable assembly connectors that are closely spaced together without damaging surrounding connectors, accidentally disconnecting surrounding connectors, disrupting transmissions through surrounding connectors, and/or the like. Various embodiments also provide narrow pitch LC duplex connectors and narrow width multi-fiber connectors.

As discussed herein, current connectors may be improved by various means, such as, for example, reducing the footprint, increasing the structural strength, enabling polarity changes, etc. Various embodiments disclosed herein offer improvements over the current state of the art, as will be further discussed below.

In some embodiments, the fiber optic connector may be a narrow pitch duplex LC connector including two LC connectors. In some embodiments, such as that shown, the two LC connectors may comprise a single combined unit. In alternative embodiments, the LC connectors may be separate members, wherein an air gap exists between the two members, or wherein the two separate members are located adjacent and flush to each other (i.e., no air gap exists). In some embodiments, each of the LC connectors includes a respective ferrule and a respective extending member or modular arm. The connector may have a pitch of 4.8 mm, defined as the axis-to-axis distance between the central axes of the LC connectors. In other embodiments, the connector pitch may be less than that of the pitch of conventional connectors, for example less than 6.25 mm and less than about 5.25 mm. In some embodiments, the pitch may be about 4.8 mm or less.

In current designs, if a fiber optic connector, particularly a duplex connector, needs to have the ferrules rotated or swapped, for example, for exchanging transmit and receive optical fibers, it can be a time consuming and difficult process. Generally, if a duplex connector needs to be rotated, current systems require twisting the individual LC connector tips 180 degrees. However, this process also twists the fibers that enter the connector tip. Twisting the fiber at any stage of the connection can cause wear and/or damage to the delicate fibers. Thus, most systems involve an alternative solution, wherein the duplex connector is partially or completely disassembled in order to access the ferrules or fibers and manually relocate them within the duplex connector. However, swapping ferrules side to side is a delicate operation. In order to prevent damage to the internal fibers, great care must be taken. Thus, this operation usually requires specialized tools and preparation time to perform safely and accurately.

Therefore, embodiments as described herein, allow for easy, quick, and safe swapping of the left and right side ferrules in a connector. Thus, embodiments discussed herein allow for a change in polarity of the duplex connector without twisting the fibers or performing any complex disassembly of the duplex connector.

FIGS. **1**A and **1**B depict a fiber optic connector with reversible polarity according to one aspect of the present disclosure. As shown in FIG. **1**A, a reversible polarity fiber optic connector may include first and second optical ferrules **110***a* and **110***b* and a connector housing **120** at least partially surrounding the first and second optical ferrules. A removable latch **130** is depicted in FIG. **1**A in its assembled state and in FIG. **1**B removed from the connector housing **120**.

FIG. **1**B is a side view of the reversible polarity fiber optic connector of FIG. **1**A with the removable latch **130** being separated from the connector housing. As shown, the connector housing **120** may have a first exterior wall **121***a* positioned above the first and second optical ferrules and a second exterior wall **121***b* positioned beneath the first and second optical ferrules. A latch coupling **122** is positioned on each of the first and second exterior walls of the housing. The removable latch **130** may include a protrusion **131** for engaging the housing latch coupling **122**. In particular, the latch coupling **122** may include angled walls that interact with slanted edges of the protrusion **131** to prevent accidental disassembly of the latch **130**. Although the latch coupling **122** is depicted as a recess on the housing accommodating a latch protrusion, these elements may be reversed with the latch including a recess and the housing including a protrusion. Other mechanical coupling mechanisms may be used to interconnect the housing and the removable latch. For example, an embodiment may involve a coupling system wherein the removable latch is inserted into a recess in the connector housing and twisted (e.g., 90°, 180°, etc.) to secure the latch to the recess. Alternative coupling may use a more complex shape. For example, a u-shaped recess in the connector housing may engage a cooperatively-shaped projection in the latch that is inserted and fed through the u-shape until secure. It should thus be understood, that any system or method of coupling may be used to attach the removable latch to the connector housing, including various locations (e.g., sliding from the front, sides, back, bottom, top, etc.).

FIGS. **2**A-**2**D depict the process for changing the polarity of the fiber optic connector of FIG. **1**A from a first polarity, FIG. **2**A to a second, opposite polarity, FIG. **2**D. The removable latch **130** may be removed from the latch coupling on the first exterior wall of the connector housing, FIG. **2**B, positioned adjacent the second exterior wall on beneath the ferrules, FIG. **2**C, and then coupled with the latch coupling on the second exterior wall of the connector housing to yield a connector **100**R, FIG. **2**D, having the opposite polarity of connector **100**. In this manner, transmit and receive optical fibers may be reversed without necessitating any fiber twist or complex repositioning of the optical ferrules.

In typical embodiments, the latch of the connector housing is required to be flexible. Thus, when a latch and a connector housing (e.g., duplex connector) are built as one unified member (as is currently done), the fiber optic connector is built of a similar flexible or less rigid material. Building the connector housing out of a plastic or polymeric material, limits the amount of rigidity that it can have. Thus, as fiber optic connectors continue to reduce in size, the strength of the housing has been reduced. Therefore, it would be advantageous to build the connector housing out of a more robust material while still allowing the latch to remain flexible. In order to accomplish this, in some embodiments according to aspects of the present disclosure, the connector housing may be manufactured out of a very rigid or strong material (e.g., steel, graphene, carbon, metal alloys, or any material of suitable properties). Because the connector housing and the removable latch need only interlock with each other, the removable latch may still be made out of a more flexible material. Thus, the removable nature of the latch disclosed herein allow for a more robust and secure overall design when dealing with the shrinking footprint of fiber optic connectors.

FIG. **3**A is a perspective view of another embodiment of a reversible polarity fiber optic connector **300**. As shown, the reversible polarity fiber optic connector may further comprise a pull tab **340** for engaging a removable latch **330**. The pull tab **340** depresses the latch **330** as the tab is pulled in a direction away from the fiber optic ferrules.

FIG. **3**B is an exploded view of the reversible polarity fiber optic connector of FIG. **3**A. As shown, the pull tab **340** may comprise a first opening **341** and a second opening **344**. The first opening **341** is configured to allow the connector housing and the removable latch to pass through while the second opening is configured to accommodate the tip of the latch. The pull tab may further comprise a first deformable portion **342** and a second deformable portion **344**. In operation, the first deformable portion **342** cooperates with the second deformable portion **344** to depress the removable latch when the pull tab is pulled in a direction away from the ferrules.

FIGS. **4**A-**4**D depict the process for changing the polarity of the fiber optic connector **300** from a first polarity, FIG. **4**A to a second polarity **300**R, FIG. **4**D. The pull tab **340** may be disengaged from the connector housing **320** and the removable latch **330** on the first exterior wall of the connector housing, FIG. **2**B. The removable latch is then detached from the latch coupling on the first exterior wall of the connector housing, FIG. **4**C.**1**. Next, the removable latch is engaged with the latch coupling on the second exterior wall of the connector housing, beneath the ferrules, FIG. **4**C.**2**. Finally, the pull tab **340** is positioned surrounding the connector housing and engaging the removable latch tip, resulting in the assembled optical connector **300**R having polarity opposite to that of connector **300**, FIG. **4**D.

FIGS. **5**A and **5**B are a perspective view and exploded view, respectively, of another embodiment of a reversible polarity fiber optic connector **500**. The connector **500** includes a connector housing **520**, a latch **530**, and a pull tab **540**. On the first and second exterior walls of connector housing **520** are latch couplings that include a groove **522**. A recess **521** is also provided in the housing. The latch **530** includes a protrusion **531** that is received within groove **522**. The latch further includes a projection **532** that is received in the housing between the optical ferrules. The pull tab **540** includes an opening **541** for engaging the removable latch **530**. A front protrusion **542** is configured to depress the removable latch **530** when the pull tab is pulled in a direction away from the ferrule side of the optical connector.

FIGS. **6**A-**6**D depict the process for changing the polarity of the fiber optic connector **500** from a first polarity, FIG. **6**A to a second polarity, FIG. **6**D. The pull tab **540** is disengaged from the connector housing and the removable latch **530** on the first exterior wall of the connector housing, FIG. **6**B, and the removable latch is decoupled from the latch coupling on the first exterior wall of the connector housing. Then the removable latch may be coupled with the latch coupling on the second exterior wall of the connector housing, beneath the optical ferrules in FIG. **6**C, and the pull tab **540** is engaged with the connector housing and the removable latch on the second exterior wall of the connector housing to create reverse polarity connector **500**R, FIG. **6**D.

It is of interest within the optical connectivity industry to have multiple styles of optical connectors for multiple purposes and/or multiple implementation styles. Thus, in order to more easily provide flexibility, a solution is needed that allows for on-the-fly, in-the-field, or in manufacturing modification of the connector. The below embodiment provides a universal type fiber optic connector which has a unique housing design that allows for different latches or arms to be attached.

FIG. **7**A is a perspective view of a common connector housing **720** of a reversible polarity fiber optic connector **700** with exchangeable arms for changing connector type in an embodiment according to aspects of the present disclosure. As shown, the reversible polarity fiber optic connector may comprise first and second optical ferrules **710***a* and **710***b* and the common connector housing **720** at least partially surrounding the first and second optical ferrules.

FIGS. **7**B, **7**C and **7**D are the front view, top view and side view, respectively, of the common connector housing **720**. As shown, the common connector housing may have a first exterior wall **725***a* positioned above the first and second optical ferrules and a second exterior wall **725***b* positioned beneath the first and second optical ferrules. The connector housing **720** may further have a coupling surface **724** positioned on each of the first and second exterior walls and include a receiving track **726** in the coupling surface.

FIG. **8**A.**1** shows the common connector housing **720** used to create a latch-type connector **700** and FIG. **8**B.**1** shows the common connector housing **720** used to create a recess-type connector **800**. Both of connectors **700** and **800** include a removable arm **730** or **830** for engaging either of the first and second exterior wall coupling surfaces **724** on the connector housing, FIGS. **8**A.**2** and **8**B.**2** respectively. The removable arms **730** and **830** may each respectively include a projection **735** or **835** for engaging in the receiving track **726** of the coupling surface **724**, FIGS. **8**A.**2** and **8**B.**2** respectively. As with the previous embodiments, positioning the removable arm on the first exterior wall of the connector housing yields a fiber optic connector with a first polarity and positioning the removable arm on the second exterior surface of the housing yields a fiber optic connector with the opposite polarity.

Still referring to FIGS. **8**A.**2** and **8**B.**2** respectively the removable arms may include either a latch or a recess: removable arm **730** includes a latch **733** while removable arm **830** includes a recess **834**. Thus, a latch-type connector **700** is created through assembly of the removable latch arm to the common connector body **720** as shown in FIG. **8**A.**1** and a recess-type connector **800** is created through assembly of the removable recess arm to the common connector body **720** as shown in FIG. **8**B.**1**.

The fiber optic connector may further include a pull tab. When a removable arm with a latch **730** is positioned on the coupling surface of the common connector housing **720** to create a latch-type connector **700**, the pull tab **740** is a separate element from the removable arm, FIG. **8**A.**2**. When a removable arm includes a recess **830** is positioned on the coupling surface of the common connector housing **720** to create a recess-type connector **800**, the pull tab **840** is integrated with the removable arm, FIG. **8**B.**2**.

FIGS. **9**A-**9**D depict the process for changing the polarity of the latch-type fiber optic connector from a first polarity **700**, FIG. **9**A to a second polarity **700**R, FIG. **9**D. The sub-assembly of the removable arm **730** and the pull tab **740** may be decoupled from the coupling surface **724** of the first exterior wall of the connector housing, FIG. **9**B. Then the sub-assembly of the removable arm **730** and the pull tab **740** may be coupled with the coupling surface of the second exterior wall of the connector housing, FIG. **9**C, creating the opposite polarity connector **700**R.

FIGS. **10**A-**10**C depicts the process for changing the polarity of the recess-type fiber optic connector **800** from a first polarity, FIG. **10**A to a second polarity, FIG. **10**D. The removable arm **830** with a recess and a pull tab as an integral structure may be decoupled from the coupling surface **724** of the first exterior wall of the connector housing, FIG. **10**B. Then the removable arm may be coupled with the coupling surface **724** of the second exterior wall of the common connector housing **720**, FIG. **10**C to create opposite polarity optical connector **800**R, FIG. **10**D.

FIGS. **11**A and **11**B depict a further embodiment **1100** of the reversible polarity optical connectors of the present disclosure. In FIG. **11**A, a push-pull tab **1130** may interconnect with either a first exterior wall **1110** of housing **1105** or with a second exterior wall **1115** of housing **1105**. Ferrules **1120** and **1125** are at least partially surrounded by housing **1105** and may be LC connectors in an embodiment. As in previous embodiments, the push-pull tab may include a tab recess **1145**. Alternatively, push-pull tab **1130** may include a latch (not shown). Various features of the push-pull tab **1130** are provided to assist in affixing the push-pull tab to the first exterior wall **1110** or the second exterior wall **1115** of the housing **1105**. This includes push-pull tab clips **1135** that clip onto the optical connector, optionally in a boot region, and protrusion **1140** that fits within a first aperture, **1109**A, beneath the housing exterior wall **1110** or a second aperture, **1109**B, beneath housing exterior wall **1115** (to be discussed in more detail below), and projection **1131** for inserting into the housing between ferrules **1120** and **1125**. Each of these features is fully reversible such that the push-pull tab is easily removed and repositioned on the opposite exterior wall to change polarity of the connector.

As best seen in FIGS. **12**B and **12**D, push-pull tab protrusion **1140** may be inserted into first aperture **1109**A of housing **1105** through a first exterior housing aperture **1107**A. Alternatively, in the reverse-polarity configuration, the push-pull tab protrusion **1140** may be inserted into second housing aperture **1109**B through second exterior housing aperture **1107**B. When the push-pull tab **1130** is moved forward, the protrusion slides within the aperture **1109**A or **1109**B, as shown in FIG. **12**B. To maintain the push-pull tab in a forward-biased position, tab position spring **1150** is provided. During insertion or removal of the protrusion **1140**, tab position spring **1150** is compressed, depicted in FIG. **12**B. When the position spring **1150** is in its relaxed (uncompressed) position, FIGS. **12**C and **12**D, the protrusion **1140** is slid forward within the aperture **1109**A or **1109**B.

To change polarity of the optical connector **1100**, FIGS. **13**A-**13**D, the push-pull tab **1130** is removed by withdrawing the protrusion **1140** from the housing **1105** through exterior housing aperture **1107**A along with detaching clips **1135** and decoupling projection **1131**, thus releasing the push-pull tab from the first exterior housing wall **1110** (FIG. **138**). The push-pull tab is moved toward second exterior housing wall **1115** and the protrusion **1140** is inserted into aperture **1109**B through exterior housing aperture **1107**B in FIG. **13**C. Projection **1131** is fitted between ferrules **1120** and **1125** and clips **1135** are affixed to the connector. The resultant connector **1100**R of **13**D is of opposite polarity to the connector **1100** of FIG. **13**A.

Various alternatives to the protrusion **1140** of optical connector **1100** may be used in the optical connectors of this disclosure. For example, the protrusion may be provided by the connector housing with receiving elements provided in the push-pull tab. Variations to the shape of the projection and apertures may be made without affecting the function of the reversible-polarity connector.

Another alternative embodiment is depicted in FIGS. **14**A and **14**B in which a hook-shaped protrusion **1440** is provided for engagement within the connector housing. As in the previous embodiment, the push-pull tab **1430** includes a tab recess **1445**, connector-attachment clips **1435** and projection **1431** for positioning between ferrules **1420** and **1425**. In FIG. **14**B, the push-pull tab **1430** is positioned on first exterior housing wall **1410** and has a first polarity. In this position, the hook-shaped protrusion **1440** engages a housing projection **1460**, held in a forward-biased position by push-pull tab position spring **1465**, as seen in FIGS. **15**B and **15**D. To release the protrusion **1440**, push-pull tab position spring **1465** is compressed in FIG. **15**C such that housing projection **1460** is retracted sufficiently to allow removal of protrusion **1440** through the housing **1405**, FIG. **15**D.

To change polarity of the optical connector **1400** from the first polarity of FIG. **16**A, the push-pull tab **1430** is removed by withdrawing the protrusion **1440** from the housing **1405** through the housing along with detaching clips **1435** and decoupling projection **1431**, thus releasing the push-pull tab from the first exterior housing wall **1110** (FIG. **16**B). The push-pull tab is moved toward second exterior housing wall **1415** and the protrusion **1440** is inserted into the housing **1405**. Projection **1431** is fitted between ferrules **1420** and **1425** and clips **1435** are affixed to the connector in FIG. **16**C. The resultant connector **1400**R of FIG. **16**D is of opposite polarity to the connector of FIG. **16**A.

Protrusions from a push-pull tab may be inserted into a housing via features other than a housing aperture. Such a connector is depicted in FIG. **17** and features a deformable housing region to allow entry of a push-pull tab protrusion during affixing of the push-pull tab to the connector housing. As seen in FIG. **17**A, the connector **1700** includes a connector housing **1705** which may optionally include a back body housing portion **1709** for connecting with a housing front portion **1707** (FIG. **17**C). The back body housing portion **1709** includes a deformable region **1780**, seen in the partial cross-section of FIG. **17**B and the perspective view of FIG. **17**C. The push-pull tab **1730** includes a protrusion **1740** with a projection **1741** extending therefrom.

Turning to FIG. **18**, to affix the push-pull tab to the connector housing, the protrusion **1740** penetrates the deformable region **1780** (FIG. **18**B) causing the deformable region to yield and accept entry of the protrusion **1740** into the housing. As the projection **1741** enters the housing as depicted in FIG. **18**C, the deformable region **1780** returns to its original position (FIG. **18**D), securing the push-pull tab **1730** to the connector housing.

Removal of the push-pull tab **1730** is depicted in FIGS. **19**A and **19**B. A removal tool **1900**, which may be shaped similar to a small screwdriver, depresses deformable region **1780**, allowing projection **1741** to slide along an edge of the deformable region **1780**, followed by the protrusion **1740**, releasing the push-pull tab **1730**.

To change polarity of the optical connector **1700** from the first polarity of FIG. **20**A, the push-pull tab **1730** is removed in FIG. **20**B by using the removal tool technique depicted in FIGS. **19**A and **19**B. The push-pull tab is moved toward the second exterior housing wall and the protrusion **1740** is inserted into the housing **1705** through the deformable region **1780** in FIG. **20**C. The resultant connector **1700**R of FIG. **20**D is of opposite polarity to the connector of FIG. **20**A.

In another aspect of the disclosure, a retaining member may be provided in the connector housing to retain a push-pull tab. As seen in FIGS. **21**A-**21**D, a connector **2100** having a housing **2105** is provided with a housing front portion **2107** and a back portion **2109**. FIG. **21**A depicts an assembled connector **2100** with housing **2105**. FIG. **21**B depicts an exploded view of connector **2100** of FIG. **21**A. Push-pull tab **2130** has a receiving surface **2132**, which during use of connector **2100** provides a surface over which retainer **2111** can slide across during tab movement. Extending from the housing back portion is a retainer **2111** which may include a pair of retaining clips, as shown, or any other structure configured to retain the push-pull tab **2130**. FIG. **21**C depicts connector **2100** showing a section view cut given by the arrows and broken line near the proximal end of connector **2100**. Optionally, when the retainer **2111** includes clips, the clips may be hook-shaped as seen in the cross-sectional view of FIG. **21**D. As shown in FIG. **21**D, receiving surface **2132** may be a recess with a protrusion along the edge that engages the hook-shaped edge of the clips.

FIG. **22**A through FIG. **22**E depicts the operation of polarity change for connector **2100** of FIG. **21**A-FIG. **21**D. FIG. **22**A depicts connector **2100** with pull-push tab clips **2135** (opposing side not shown) engaged around connector. To operate connector **2100**, user can move push-pull tab **2130** forward or toward front of connector or backward or toward rear of connector, and as describe in FIG. **21** above tab moves along connector receiving surface **2123**. This engages or releases connector **2100** from a receptacle as is known in the art. To change the polarity of connector **2100** from the polarity depicted in FIG. **22**A to the second, opposite polarity of FIG. **22**E, the retainer **2111** is removed from receiving surface **2132**. Referring to FIG. **21**B, lifting push-pull tab **2130** in direction of up-arrow, separates retainer **2111** from receiving surface. As shown in FIG. **22**C, push-pull tab clips separate from the connector as the retainer is removed. Continuing with FIG. **22**C, push-pull tab **2130** is moved to the opposite housing exterior wall in FIG. **22**C. FIG. **22**D depicts receiving surface **2132** engages with the retainer **2111**. In FIG. **21**E the assembled connector **2100**R having the opposite polarity to the connector of FIG. **22**A is depicted, fully assembled. Retainer **2111** is in contact with receiving surface **2132**, and push-pull tab **2130** is secured to connector body, as show in FIG. **22**E.

In the above detailed description, reference is made to the accompanying drawings, which form a part hereof. In the drawings, similar symbols typically identify similar components, unless context dictates otherwise. The illustrative embodiments described in the detailed description, drawings, and claims are not meant to be limiting. Other embodiments may be used, and other changes may be made, without departing from the spirit or scope of the subject matter presented herein. It will be readily understood that the aspects of the present disclosure, as generally described herein, and illustrated in the Figures, can be arranged, substituted, combined, separated, and designed in a wide variety of different configurations, all of which are explicitly contemplated herein.

The present disclosure is not to be limited in terms of the particular embodiments described in this application, which are intended as illustrations of various aspects. Many modifications and variations can be made without departing from its spirit and scope, as will be apparent to those skilled in the art. Functionally equivalent methods and apparatuses within the scope of the disclosure, in addition to those enumerated herein, will be apparent to those skilled in the art from the foregoing descriptions. Such modifications and variations are intended to fall within the scope of the appended claims. The present disclosure is to be limited only by the terms of the appended claims, along with the full scope of equivalents to which such claims are entitled. It is to be understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to be limiting.

With respect to the use of substantially any plural and/or singular terms herein, those having skill in the art can translate from the plural to the singular and/or from the singular to the plural as is appropriate to the context and/or application. The various singular/plural permutations may be expressly set forth herein for sake of clarity.

It will be understood by those within the art that, in general, terms used herein, and especially in the appended claims (for example, bodies of the appended claims) are generally intended as "open" terms (for example, the term "including" should be interpreted as "including but not limited to," the term "having" should be interpreted as "having at least," the term "includes" should be interpreted as "includes but is not limited to," et cetera). While various compositions, methods, and devices are described in terms of "comprising" various components or steps (interpreted as meaning "including, but not limited to"), the compositions, methods, and devices can also "consist essentially of" or "consist of" the various components and steps, and such terminology should be interpreted as defining essentially closed-member groups. It will be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present. For example, as an aid to understanding, the following appended claims may contain usage of the introductory phrases "at least one" and "one or more" to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles "a" or "an" limits any particular claim containing such introduced claim recitation to embodiments containing only one such recitation, even when the same claim includes the introductory phrases "one or more" or "at least one" and indefinite articles such as "a" or "an" (for example, "a" and/or "an" should be interpreted to mean "at least one" or "one or more"); the same holds true for the use of definite articles used to introduce claim recitations. In addition, even if a specific number of an introduced claim recitation is explicitly recited, those skilled in the art will recognize that such recitation should be interpreted to mean at least the recited number (for example, the bare recitation of "two recitations," without other modifiers, means at least two recitations, or two or more recitations). Furthermore, in those instances where a convention analogous to "at least one of A, B, and C, et cetera" is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (for example, "a system having at least one of A, B, and C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, et cetera). In those instances where a convention analogous to "at least one of A, B, or C, et cetera" is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (for example, "a system having at least one of A, B, or C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, et cetera). It will be further understood by those within the art that virtually any disjunctive word and/or phrase presenting two or more alternative terms, whether in the description, claims, or drawings, should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms. For example, the phrase "A or B" will be understood to include the possibilities of "A" or "B" or "A and B."

In addition, where features or aspects of the disclosure are described in terms of Markush groups, those skilled in the art will recognize that the disclosure is also thereby described in terms of any individual member or subgroup of members of the Markush group.

As will be understood by one skilled in the art, for any and all purposes, such as in terms of providing a written description, all ranges disclosed herein also encompass any and all possible subranges and combinations of subranges thereof. Any listed range can be easily recognized as sufficiently describing and enabling the same range being broken down into at least equal halves, thirds, quarters, fifths, tenths, et cetera As a non-limiting example, each range discussed herein can be readily broken down into a lower third, middle third and upper third, et cetera As will also be understood by one skilled in the art all language such as "up to," "at least," and the like include the number recited and refer to ranges which can be subsequently broken down into subranges as discussed above. Finally, as will be understood by one skilled in the art, a range includes each individual member. Thus, for example, a group having 1-3 cells refers to groups having 1, 2, or 3 cells. Similarly, a group having 1-5 cells refers to groups having 1, 2, 3, 4, or 5 cells, and so forth.

Various of the above-disclosed and other features and functions, or alternatives thereof, may be combined into many other different systems or applications. Various presently unforeseen or unanticipated alternatives, modifications, variations or improvements therein may be subsequently made by those skilled in the art, each of which is also intended to be encompassed by the disclosed embodiments.

The invention claimed is:

1. A reversible polarity fiber optic connector comprising:
- at least first and second optical ferrules;
- a connector housing at least partially surrounding the first and second optical ferrules and having a first exterior wall positioned above the first and second optical ferrules and a second exterior wall positioned beneath the first and second optical ferrules;
- a latch coupling positioned on each of the first and second exterior walls of the housing;
- a removable latch for engaging either of the first and second exterior wall latch couplings on the connector housing;
- wherein positioning the removable latch on the first exterior wall of the connector housing yields a fiber optic connector with a first polarity and positioning the removable latch on the second exterior wall of the housing yields a fiber optic connector with a second polarity, the second polarity being opposite to the first polarity.

2. The reversible polarity fiber optic connector of claim **1**, wherein
- each of the latch couplings on the first and second exterior walls of the connector housing includes at least a recess with angled walls; and
- the latch includes at least a protrusion with slanted edges for coupling with the angled walls of the recess on the first exterior wall when the fiber optic connector is configured in the first polarity or the angled walls of the recess on the second exterior wall when the fiber optic connector is configured in the second polarity.

3. The reversible polarity fiber optic connector of claim **1**, further comprising a pull tab for engaging the removable latch; wherein pulling the pull tab in a direction away from the first and second ferrules causes the removable latch to be depressed.

4. The reversible polarity fiber optic connector of claim **3**, wherein the pull tab comprises at least a first opening and a seconding opening for engaging the removable latch;
- wherein the first opening is configured to allow the connector housing and the removable latch to pass through; and
- the second opening is configured to allow the removable latch to partially pass through.

5. The reversible polarity fiber optic connector of claim **3**, wherein the pull tab further comprises a first deformable portion and a second deformable portion;
- wherein the first deformable portion is configured to cooperate with the second deformable portion to depress the removable latch when the pull tab is pulled in a direction away from the first and second ferrules.

6. The reversible polarity fiber optic connector of claim **1**, wherein
- each of the latch couplings on the first and second exterior walls of the connector housing includes a groove; and
  - at least a projection for coupling with the groove on the first exterior wall when the fiber optic connector is configured in the first polarity or the groove on the second exterior wall when the fiber optic connector is configured in the second polarity.

7. The reversible polarity fiber optic connector of claim **6**, further comprising a pull tab for engaging the removable latch; wherein pulling the pull tab in a direction away from the reversible polarity fiber optic connector depresses the removable latch.

8. The reversible polarity fiber optic connector of claim **7**, wherein the pull tab comprises:
- an opening for engaging the removable latch; and
- a front protrusion configured to depress the removable latch when the pull tab is pulled in a direction away from the first and second ferrules.

9. A reversible polarity fiber optic connector with exchangeable arms for changing connector type comprising:
- at least first and second optical ferrules;

a common connector housing at least partially surrounding the first and second optical ferrules and having a first exterior wall positioned above the first and second optical ferrules and a second exterior wall positioned beneath the first and second optical ferrules;

a coupling surface positioned on each of the first and second exterior walls of the common connector housing;

a removable arm for engaging either of the first and second exterior wall coupling surfaces on the common connector housing, the removable arm including either a latch or a latch recess;

wherein positioning the removable arm on the first exterior wall of the connector housing yields a fiber optic connector with a first polarity and positioning the removable arm on the second exterior surface of the housing yields a fiber optic connector with a second polarity, the second polarity being opposite to the first polarity.

10. The reversible polarity fiber optic connector of claim **9** wherein positioning a removable arm with a latch on the coupling surface creates a latch-type connector and positioning a removable arm with a recess creates a recess-type connector.

11. The reversible polarity fiber optic connector of claim **9** wherein the housing includes a receiving track in the coupling surface and the removable arm includes a projection for engaging in the receiving track in the coupling surface.

12. The reversible polarity fiber optic connector of claim **9** further comprising a pull tab.

13. The reversible polarity fiber optic connector of claim **12** wherein the removable arm includes a latch and the pull tab is a separate element from the removable arm.

14. The reversible fiber optic connector of claim **12** wherein removable arm includes a recess and the pull tab is integrated with the removable arm.

15. A reversible polarity fiber optic connector comprising:

at least first and second optical ferrules;

a connector housing at least partially surrounding the first and second optical ferrules and having a first exterior wall positioned above the first and second optical ferrules and a second exterior wall positioned beneath the first and second optical ferrules;

a first aperture in the first exterior wall of the housing and a second aperture in the second exterior wall of the housing;

a removable push-pull tab including a protrusion for positioning through either of the first or second apertures in the first and second exterior walls, respectively, of the connector housing;

wherein positioning the removable push-pull tab with its protrusion in the first aperture of the first exterior wall of the connector housing yields a fiber optic connector with a first polarity and positioning the removable push-pull tab with its protrusion in the second aperture of the second exterior wall of the housing yields a fiber optic connector with a second polarity, the second polarity being opposite to the first polarity.

16. The reversible polarity fiber optic connector of claim **15** further comprising first and second apertures respectively beneath the first and second exterior walls of the housing for receiving the protrusion.

17. The reversible polarity fiber optic connector of claim **15**, further comprising a spring to urge the push-pull tab forward.

18. The reversible polarity fiber optic connector of claim **15**, wherein the push-pull tab protrusion is retained by a housing latch, the housing latch being urged forward by a spring.

19. A reversible polarity fiber optic connector comprising:

at least first and second optical ferrules;

a connector housing at least partially surrounding the first and second optical ferrules and having a first exterior wall positioned above the first and second optical ferrules and a second exterior wall positioned beneath the first and second optical ferrules;

a first deformable region in the first exterior wall of the housing and a second deformable region in the second exterior wall of the housing;

a removable push-pull tab including a protrusion for positioning within though either of the first or second deformable regions in the first and second exterior walls, respectively, of the connector housing;

wherein positioning the removable push-pull tab with its protrusion through the first deformable region of the first exterior wall of the connector housing yields a fiber optic connector with a first polarity and positioning the removable push-pull tab with its protrusion through the second deformable region of the second exterior wall of the housing yields a fiber optic connector with a second polarity, the second polarity being opposite to the first polarity.

20. The combination of the reversible polarity fiber optic connector of claim **19** and a tool for deforming the deformable region of either the first exterior wall of the housing or the second exterior wall of the housing.

21. The reversible polarity fiber optic connector of claim **19**, further comprising a spring to urge the push-pull tab forward.

22. The reversible polarity fiber optic connector of claim **19** further comprising first and second apertures respectively beneath the first and second exterior walls of the housing for receiving the protrusion from the deformable region.

23. A reversible polarity fiber optic connector comprising:

at least first and second optical ferrules;

a connector housing at least partially surrounding the first and second optical ferrules and having a first exterior wall positioned above the first and second optical ferrules and a second exterior wall positioned beneath the first and second optical ferrules;

a removable push-pull tab;

a first push-pull tab retainer positioned on the first exterior wall and a second push-pull tab retainer positioned on the second exterior wall;

wherein positioning the removable push-pull tab in the retainer on the first exterior wall of the connector housing yields a fiber optic connector with a first polarity and positioning the removable push-pull tab in the retainer on the second exterior wall of the housing yields a fiber optic connector with a second polarity, the second polarity being opposite to the first polarity.

24. The reversible polarity fiber optic connector of claim **23** wherein the first and second push-pull tab retainers each include a projection.

25. The reversible polarity fiber optic connector of claim **23** wherein each projection is a clip for receiving a portion of the push-pull tab.

* * * * *

EXHIBIT F

US010191230C1

(12) **EX PARTE REEXAMINATION CERTIFICATE** (11755th)

United States Patent

Wong et al.

(10) **Number: US 10,191,230 C1**

(45) **Certificate Issued: Nov. 16, 2020**

(54) **OPTICAL CONNECTORS WITH REVERSIBLE POLARITY**

(71) Applicant: **SENKO Advanced Components, Inc.**, Marlborough, MA (US)

(72) Inventors: **Kimman Wong**, Hong Kong (HK); **Jeffrey Gniadek**, Northbridge, MA (US); **Kazuyoshi Takano**, Southborough, MA (US); **Siu Kei Ma**, Hong Kong (HK)

(73) Assignee: **SENKO ADVANCED COMPONENTS, INC**, Marlborough, MA (US)

Reexamination Request:
No. 90/014,456, Feb. 19, 2020

Reexamination Certificate for:

Patent No.:	**10,191,230**
Issued:	**Jan. 29, 2019**
Appl. No.:	**15/884,327**
Filed:	**Jan. 30, 2018**

Related U.S. Application Data

(60) Provisional application No. 62/581,961, filed on Nov. 6, 2017, provisional application No. 62/546,920, filed on Aug. 17, 2017, provisional application No. 62/485,042, filed on Apr. 13, 2017, provisional application No. 62/463,901, filed on Feb. 27, 2017, provisional application No. 62/463,898, filed on Feb. 27, 2017, provisional application No. 62/457,150, filed on Feb. 9, 2017, provisional application No. 62/452,147, filed on Jan. 30, 2017.

(51) **Int. Cl.**
G02B 6/38 (2006.01)
G02B 6/40 (2006.01)

(52) **U.S. Cl.**
CPC ***G02B 6/3893*** (2013.01); ***G02B 6/3821*** (2013.01); ***G02B 6/3879*** (2013.01); *G02B 6/406* (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

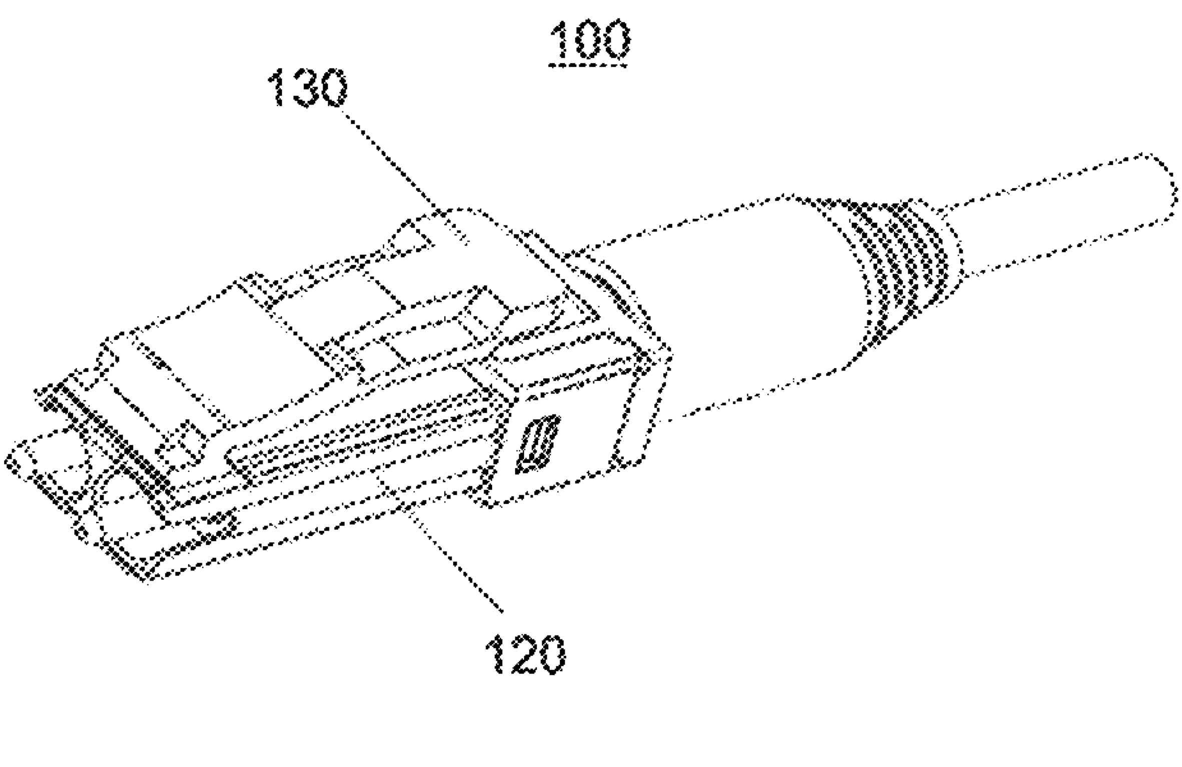
(56) **References Cited**

To view the complete listing of prior art documents cited during the proceeding for Reexamination Control Number 90/014,456, please refer to the USPTO's public Patent Application Information Retrieval (PAIR) system under the Display References tab.

Primary Examiner — William C Doerrler

(57) **ABSTRACT**

Reversible polarity fiber optic connectors are provided having housings at least partially surrounding first and second optical ferrules with walls above and beneath the ferrules. Positioning removable elements such as latches, removable arms, or push-pull tabs on the first wall above the ferrules yields fiber optic connectors with a first polarity type, and positioning the removable elements on the second wall beneath the ferrules yields fiber optic connectors with a second, opposite polarity type. Various engagement mechanisms are provided on either the connector housing walls or on the removable elements, or both, to assist in affixing the removable element to the connector housing.



EX PARTE REEXAMINATION CERTIFICATE

THE PATENT IS HEREBY AMENDED AS INDICATED BELOW.

Matter enclosed in heavy brackets [ ] appeared in the patent, but has been deleted and is no longer a part of the patent; matter printed in italics indicates additions made to the patent.

AS A RESULT OF REEXAMINATION, IT HAS BEEN DETERMINED THAT:

Claims **1**, **9**, **15**, **19** and **23** are determined to be patentable as amended.

Claims **2-8**, **10-14**, **16-18**, **20-22**, **24** and **25**, dependent on an amended claim, are determined to be patentable.

New claims **26-34** are added and determined to be patentable.

1. A reversible polarity fiber optic connector comprising:

at least first and second optical ferrules;

a connector housing *having a longitudinal axis and comprising an exterior portion* at least partially surrounding the first and second optical ferrules [and having] *such that the exterior portion extends 360° circumferentially with respect to the longitudinal axis about a space in which each of the first and second optical ferrules are received, the exterior portion comprising* a first exterior wall positioned above the first and second optical ferrules and a second exterior wall positioned beneath the first and second optical ferrules;

a latch coupling positioned on each of the first and second exterior walls of the connector housing;

a removable latch for engaging either of the first and second exterior wall latch couplings on the connector housing;

wherein positioning the removable latch on the first exterior wall of the connector housing yields a fiber optic connector with a first polarity and positioning the removable latch on the second exterior wall of the connector housing yields a fiber optic connector with a second polarity, the second polarity being opposite to the first polarity.

9. A reversible polarity fiber optic connector with exchangeable arms for changing connector type comprising:

at least first and second optical ferrules;

a common connector housing *having a longitudinal axis and comprising an exterior portion* at least partially surrounding the first and second optical ferrules [and having] *such that the exterior portion extends 360° circumferentially with respect to the longitudinal axis about a space in which each of the first and second optical ferrules are received, the exterior portion comprising* a first exterior wall positioned above the first and second optical ferrules and a second exterior wall positioned beneath the first and second optical ferrules;

a coupling surface positioned on each of the first and second exterior walls of the common connector housing;

a removable arm for engaging either of the first and second exterior wall coupling surfaces on the common connector housing, the removable arm including either a latch or a latch recess;

wherein positioning the removable arm on the first exterior wall of the *common* connector housing yields a fiber optic connector with a first polarity and positioning the removable arm on the second exterior surface of the *common connector* housing yields a fiber optic connector with a second polarity, the second polarity being opposite to the first polarity.

15. A reversible polarity fiber optic connector comprising:

at least first and second optical ferrules;

a connector housing *having a longitudinal axis and comprising an exterior portion* at least partially surrounding the first and second optical ferrules [and having] *such that the exterior portion extends 360° circumferentially with respect to the longitudinal axis about a space in which each of the first and second optical ferrules are received, the exterior portion comprising* a first exterior wall positioned above the first and second optical ferrules and a second exterior wall positioned beneath the first and second optical ferrules;

a first aperture in the first exterior wall of the connector housing and a second aperture in the second exterior wall of the connector housing;

a removable push-pull tab including a protrusion for positioning through either of the first or second apertures in the first and second exterior walls, respectively, of the connector housing;

wherein positioning the removable push-pull tab with its protrusion in the first aperture of the first exterior wall of the connector housing yields a fiber optic connector with a first polarity and positioning the removable push-pull tab with its protrusion in the second aperture of the second exterior wall of the connector housing yields a fiber optic connector with a second polarity, the second polarity being opposite to the first polarity.

19. A reversible polarity fiber optic connector comprising:

at least first and second optical ferrules;

a connector housing *having a longitudinal axis and comprising an exterior portion* at least partially surrounding the first and second optical ferrules [and having] *such that the exterior portion extends 360° circumferentially with respect to the longitudinal axis about a space in which each of the first and second optical ferrules are received, the exterior portion comprising* a first exterior wall positioned above the first and second optical ferrules and a second exterior wall positioned beneath the first and second optical ferrules;

a first deformable region in the first exterior wall of the connector housing and a second deformable region in the second exterior wall of the connector housing;

a removable push-pull tab including a protrusion for positioning within though either of the first or second deformable regions in the first and second exterior walls, respectively, of the connector housing;

wherein positioning the removable push-pull tab with its protrusion through the first deformable region of the first exterior wall of the connector housing yields a fiber optic connector with a first polarity and positioning the removable push-pull tab with its protrusion through the second deformable region of the second exterior wall of the *connector* housing yields a fiber optic connector with a second polarity, the second polarity being opposite to the first polarity.

23. A reversible polarity fiber optic connector comprising:

at least first and second optical ferrules;

a connector housing *having a longitudinal axis and comprising an exterior portion* at least partially surrounding the first and second optical ferrules [and having] *such that the exterior portion extends 360° circumferentially with respect to the longitudinal axis about a* *space in which each of the first and second optical ferrules are received, the exterior portion comprising* a first exterior wall positioned above the first and second optical ferrules and a second exterior wall positioned beneath the first and second optical ferrules;

a removable push-pull tab;

a first push-pull tab retainer positioned on the first exterior wall and a second push-pull tab retainer positioned on the second exterior wall;

wherein positioning the removable push-pull tab in the retainer on the first exterior wall of the connector housing yields a fiber optic connector with a first polarity and positioning the removable push-pull tab in the retainer on the second exterior wall of the connector housing yields a fiber optic connector with a second polarity, the second polarity being opposite to the first polarity.

26. The reversible polarity fiber optic connector of claim 1, wherein latch coupling includes a receiving track, wherein the removable latch comprises a projection for engaging each receiving track, and wherein the projection has a dovetail shape.

27. The reversible polarity fiber optic connector of claim 1, wherein the removable latch comprises a base portion and a depressible latch having a front end portion connected to the base portion, a free rear end portion spaced apart from the front end portion along the axis and being raised relative to the front end portion, and an outward facing longitudinal surface extending along the axis from the front end portion to the free rear end portion, the removable latch being bendable such that the free rear end portion can be depressed toward the base portion.

28. The reversible polarity fiber optic connector of claim 27, further comprising a remote release including an elongate front section configured to extend longitudinally along the connector housing and engage the depressible latch arm and an elongate rear section extending rearward from the elongate front section, the elongate front section of the remote release being slidably connected to the removable latch such that the elongate front section can move rearward relative to removable latch.

29. The reversible polarity fiber optic connector of claim 28, wherein the elongate front section comprises an opening configured to receive the depressible latch arm and a front end portion defining a front end of the opening, the front end portion of the front elongate section being configured to slide rearward along the outward facing surface of the depressible latch arm when the elongate front section moves rearward to depress the depressible latch arm.

30. The reversible polarity fiber optic connector of claim 27, wherein each latch coupling includes a groove having an open axial end and the removable latch comprises a protrusion on the base portion configured to be inserted into the groove through the open axial end.

31. The reversible polarity fiber optic connector as set forth in claim 1, further comprising first and second ferrule springs received on the first and second ferrules, respectively, wherein the connector housing comprises a single front body and a single back body configured to attach to the single front body such that the first and second ferrule springs are compressed simultaneously between the single back body and the single front body.

32. The reversible polarity fiber optic connector as set forth in claim 1, wherein the first and second optical ferrules have a pitch of about 4.8 mm or less.

33. The reversible polarity fiber optic connector as set forth in claim 1, wherein the connector housing is a single combined housing for each of the first and second optical ferrules.

34. The reversible polarity fiber optic connector as set forth in claim 1, wherein the exterior portion of the housing radially overlaps a longitudinal segment of each of the first and second optical ferrules with respect to the axis.

* * * * *

EXHIBIT G

US011181701B2

(12) **United States Patent**
Wong et al.

(10) **Patent No.: US 11,181,701 B2**
(45) **Date of Patent: Nov. 23, 2021**

(54) **OPTICAL CONNECTORS WITH REVERSIBLE POLARITY AND METHOD OF USE**

(71) Applicant: **Senko Advanced Components, Inc.**, Marlborough, MA (US)

(72) Inventors: **Kim Man Wong**, Kowloon (HK); **Jeffrey Gniadek**, Oxford, ME (US); **Kazuyoshi Takano**, Tokyo (JP); **Siu Kei Ma**, Kowloon (HK)

(73) Assignee: **Senko Advanced Components, Inc.**, Marlborough, MA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **17/200,134**

(22) Filed: **Mar. 12, 2021**

(65) **Prior Publication Data**

US 2021/0199901 A1 Jul. 1, 2021

Related U.S. Application Data

(63) Continuation of application No. 16/297,607, filed on Mar. 9, 2019, now Pat. No. 10,976,505, which is a continuation of application No. PCT/US2018/016049, filed on Jan. 30, 2018.

(60) Provisional application No. 62/581,961, filed on Nov. 6, 2017, provisional application No. 62/546,920, filed on Aug. 17, 2017, provisional application No. 62/485,042, filed on Apr. 13, 2017, provisional application No. 62/463,901, filed on Feb. 27, 2017, provisional application No. 62/463,898, filed on Feb. 27, 2017, provisional application No. 62/457,150, filed on Feb. 9, 2017, provisional application No. 62/452,147, filed on Jan. 30, 2017.

(51) **Int. Cl.**
G02B 6/38 (2006.01)

(52) **U.S. Cl.**
CPC ***G02B 6/3893*** (2013.01); ***G02B 6/3821*** (2013.01); ***G02B 6/3879*** (2013.01)

(58) **Field of Classification Search**
CPC ... G02B 6/3893; G02B 6/3821; G02B 6/3879
USPC 385/78
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2004/0062487 A1 4/2004 Mickievicz
2013/0322825 A1 * 12/2013 Cooke G02B 6/3831 385/59

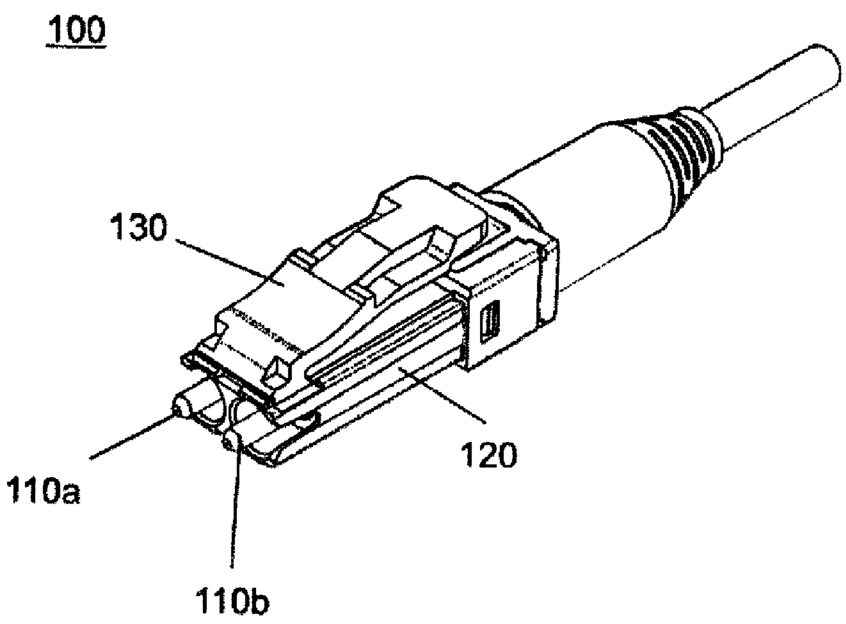
* cited by examiner

Primary Examiner — Jerry M Blevins

(57) **ABSTRACT**

Reversible polarity fiber optic connectors are provided having housings at least partially surrounding first and second optical ferrules with walls above and beneath the ferrules. Positioning removable elements such as latches, removable arms, or push-pull tabs on the first wall above the ferrules yields fiber optic connectors with a first polarity type, and positioning the removable elements on the second wall beneath the ferrules yields fiber optic connectors with a second, opposite polarity type. Various engagement mechanisms are provided on either the connector housing walls or on the removable elements, or both, to assist in affixing the removable element to the connector housing.

53 Claims, 22 Drawing Sheets



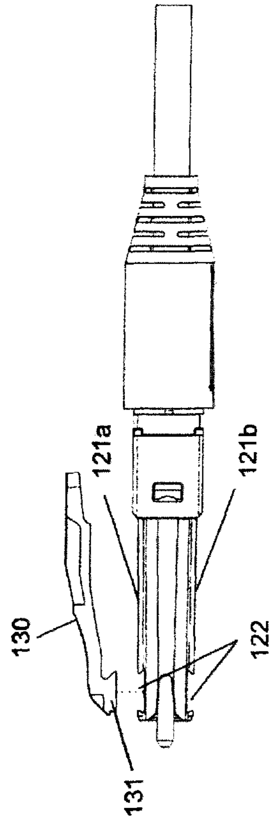


FIG. 1B

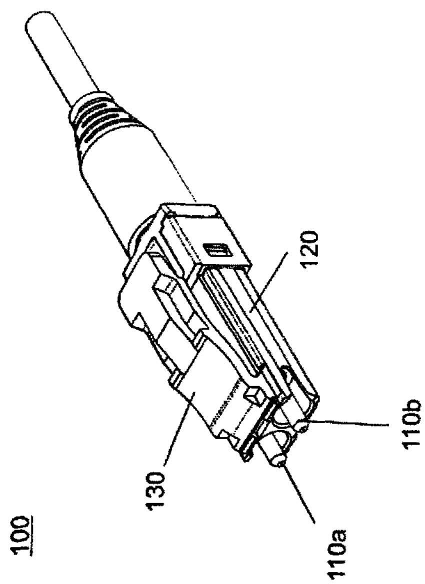


FIG. 1A

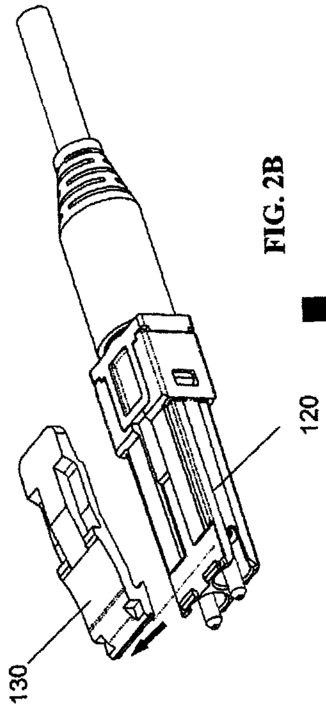


FIG. 2B

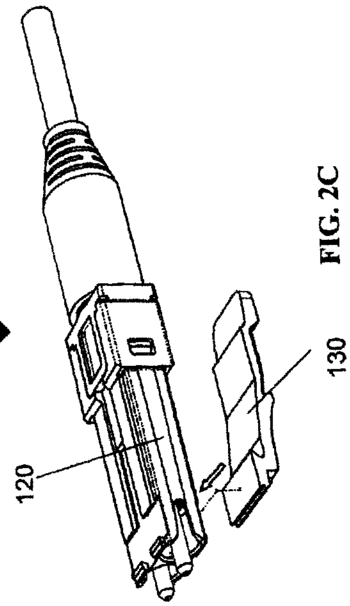


FIG. 2C

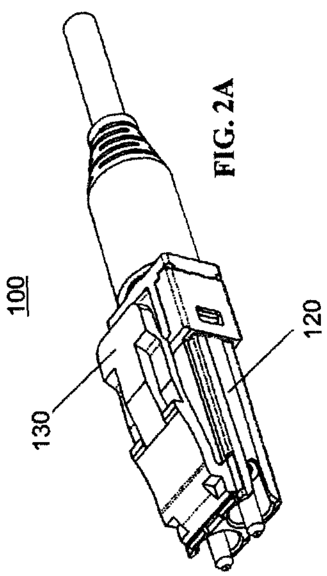


FIG. 2A

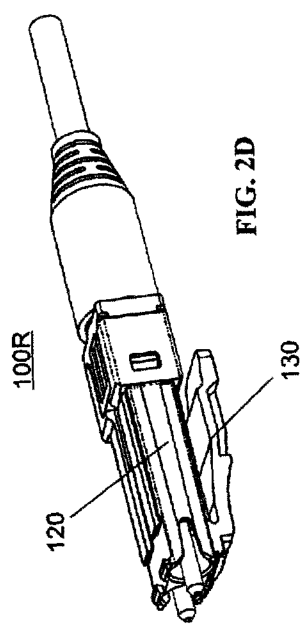


FIG. 2D

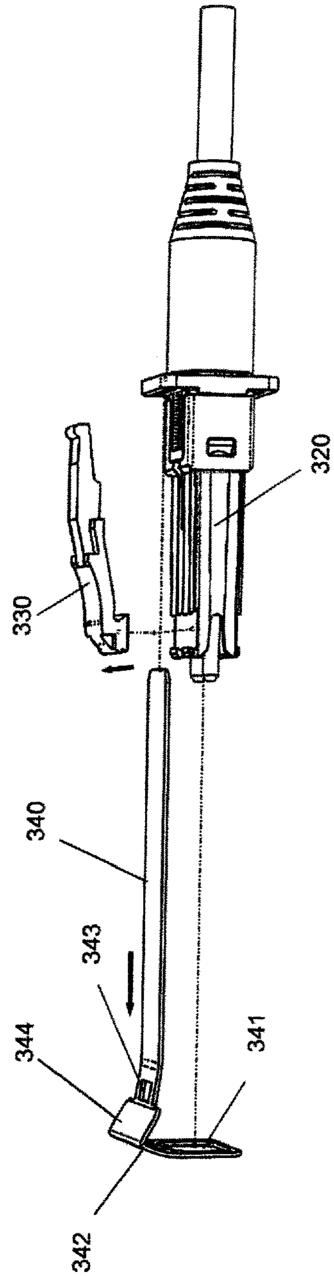


FIG. 3B

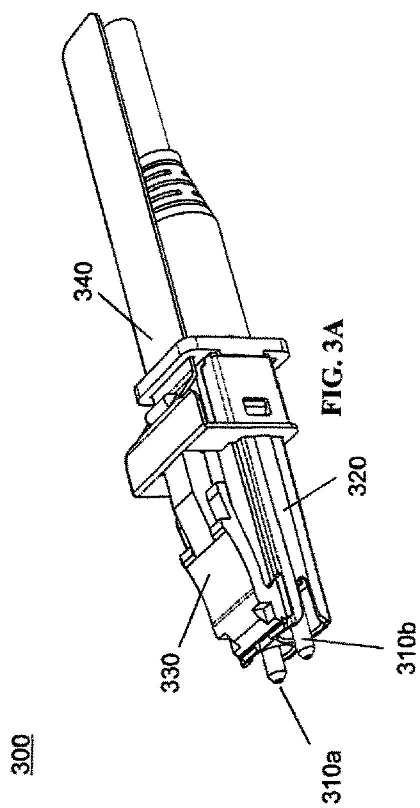


FIG. 3A

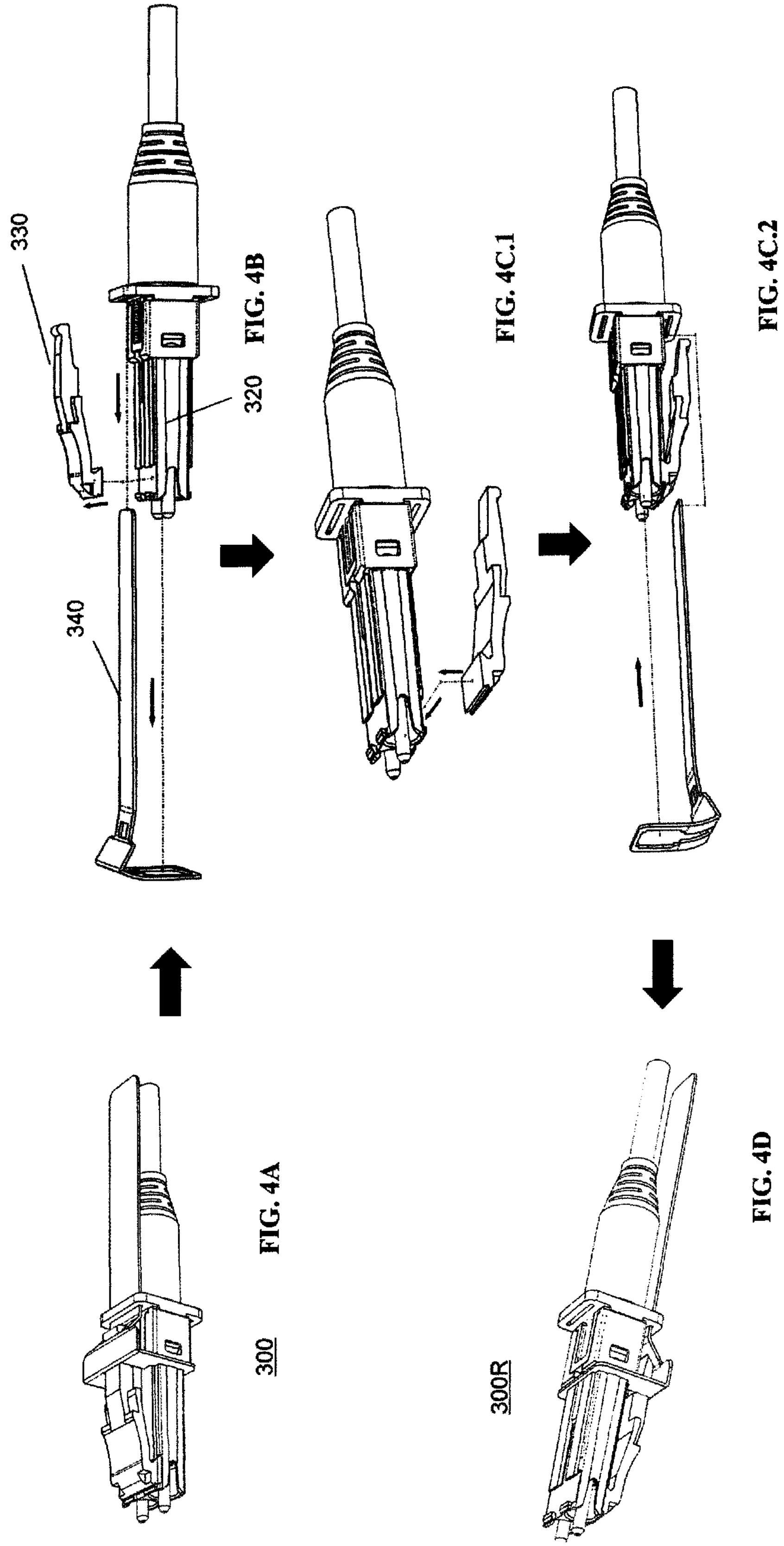


FIG. 4B

FIG. 4C.1

FIG. 4C.2

FIG. 4A

FIG. 4D

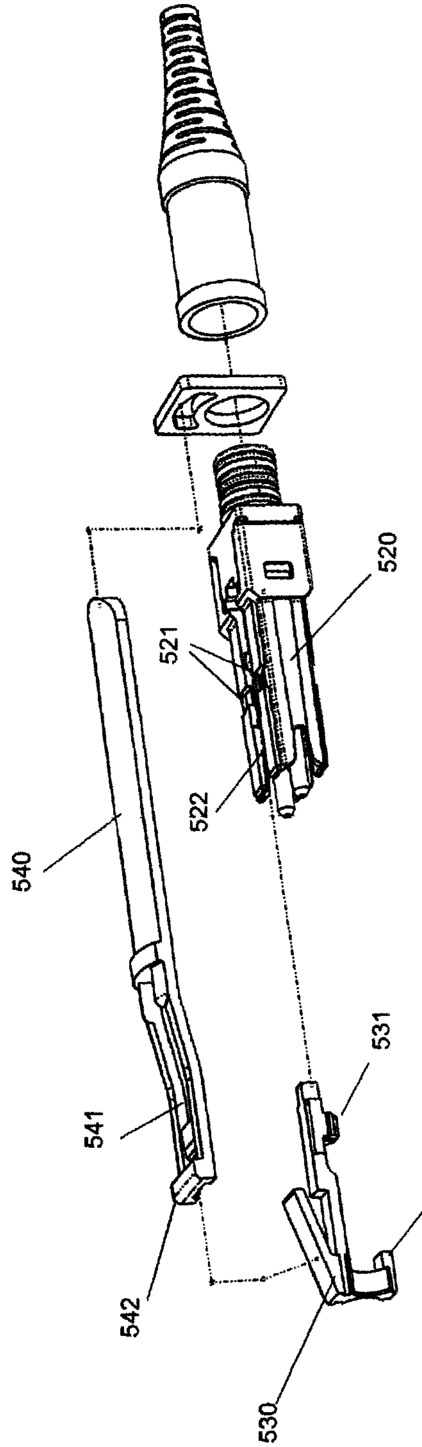


FIG. 5B

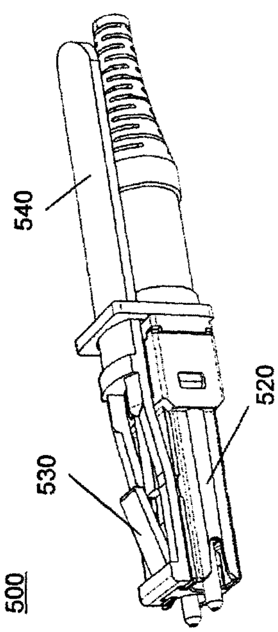


FIG. 5A

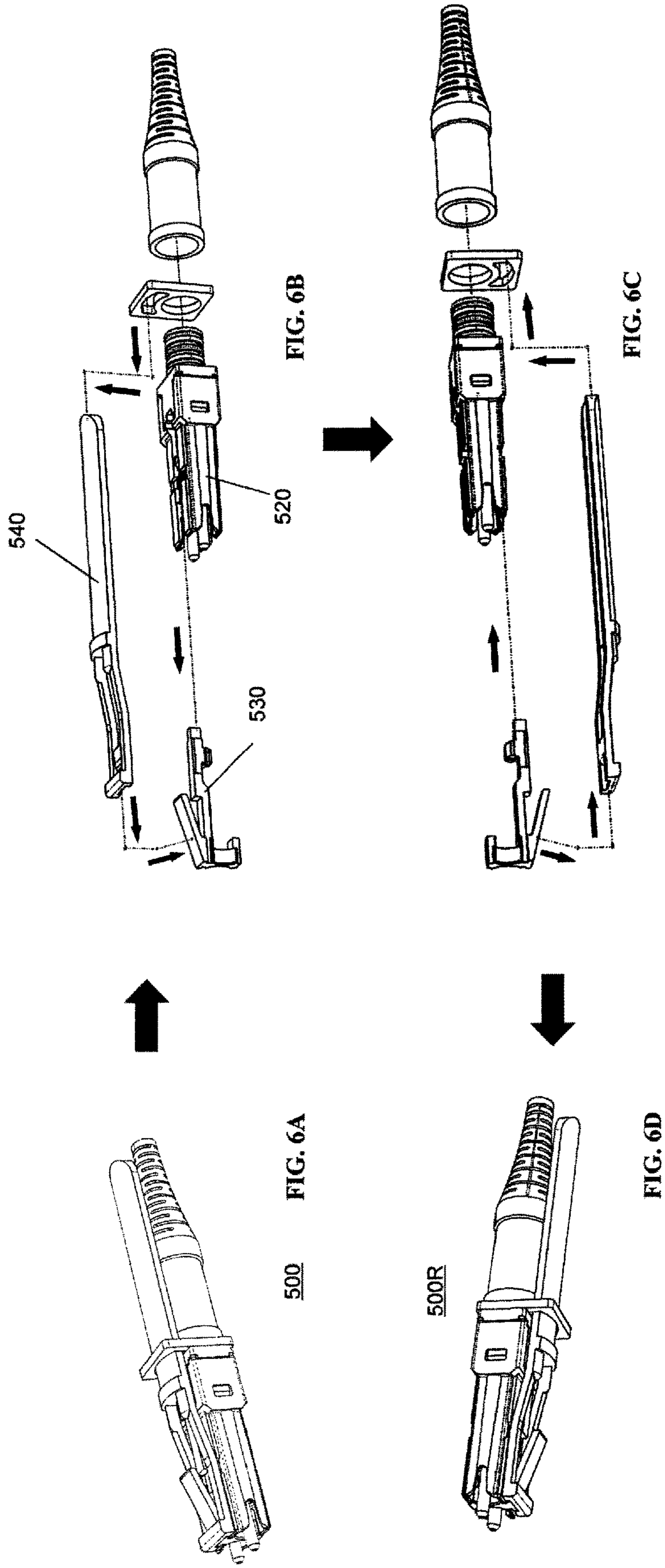


FIG. 6B
540
520
530
FIG. 6C
FIG. 6A
500
500R
FIG. 6D

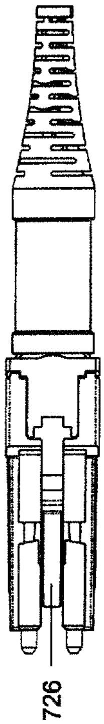


FIG. 7C

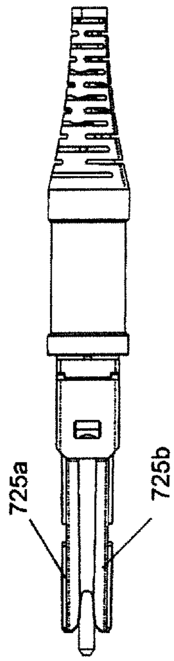


FIG. 7D

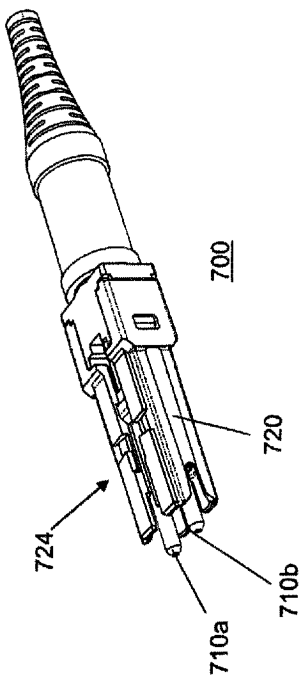


FIG. 7A

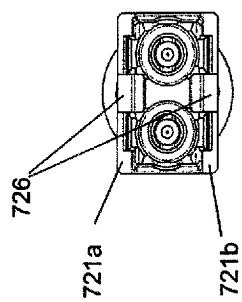


FIG. 7B

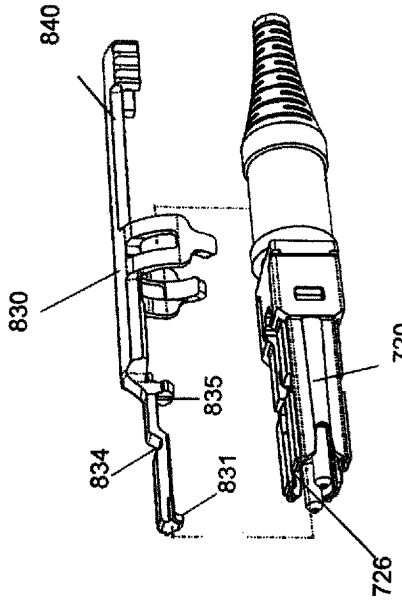


FIG. 8B.2

800

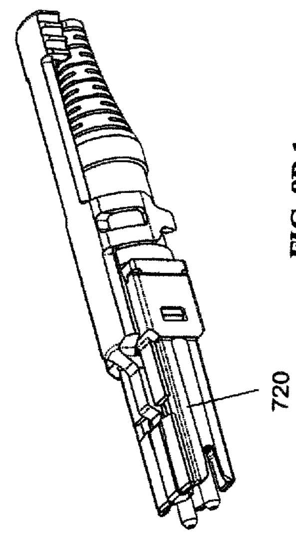


FIG. 8B.1

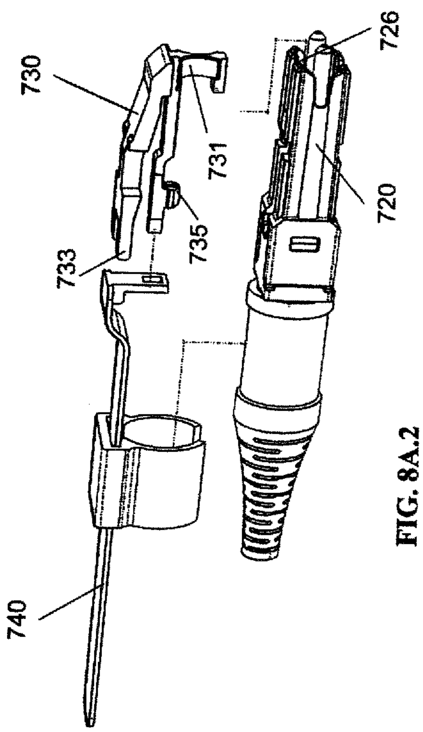


FIG. 8A.2

700

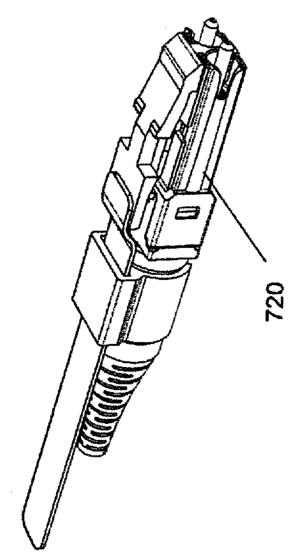


FIG. 8A.1

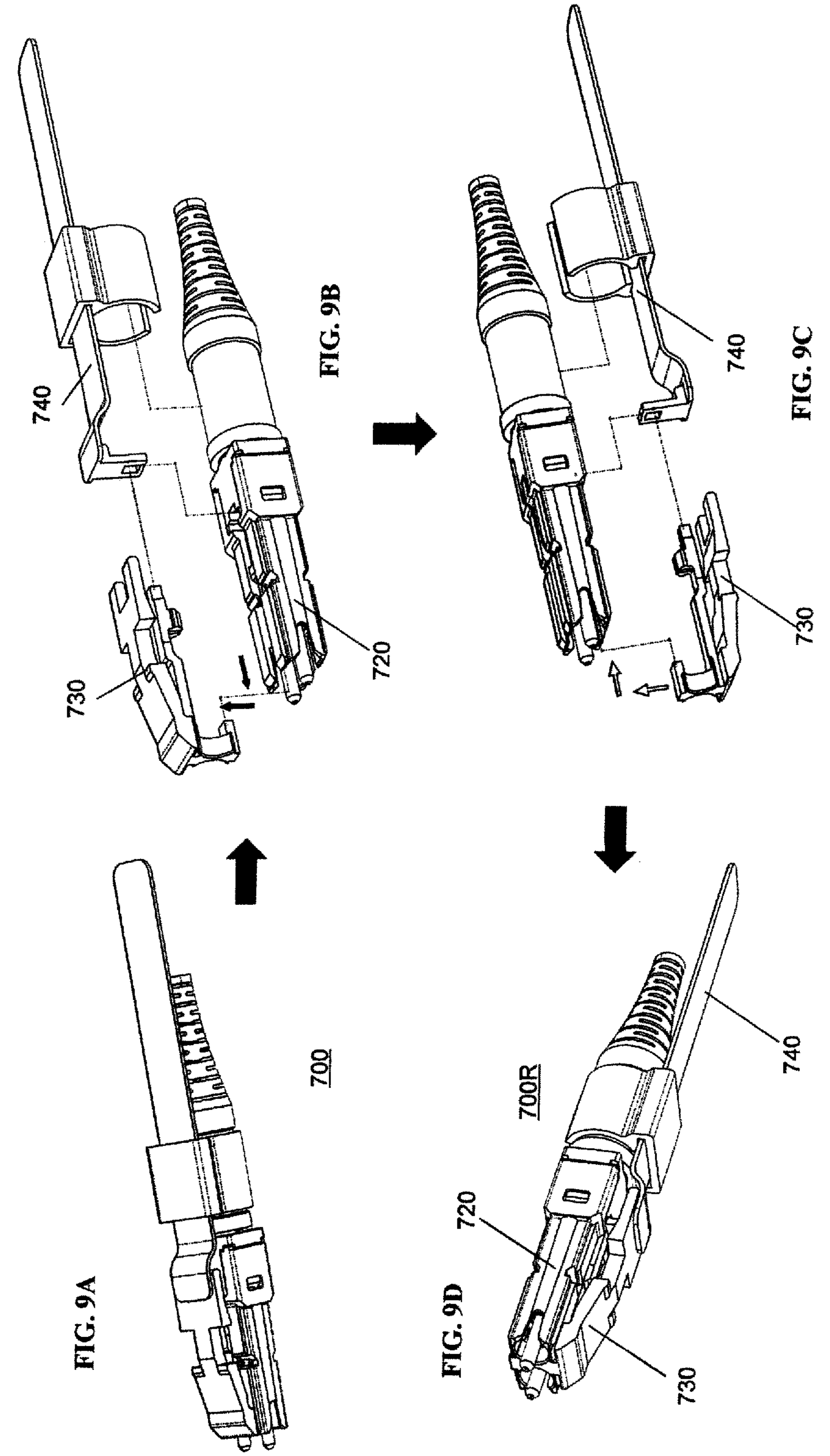


FIG. 9A

FIG. 9B

FIG. 9C

FIG. 9D

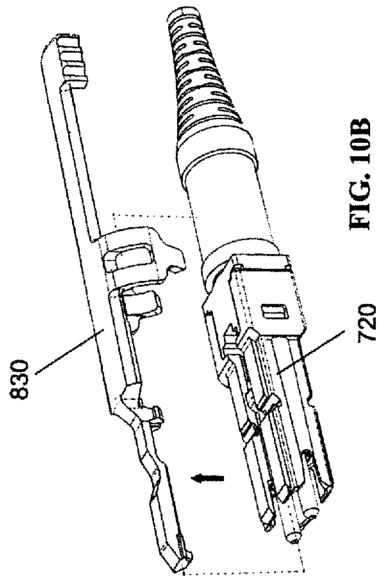


FIG. 10B

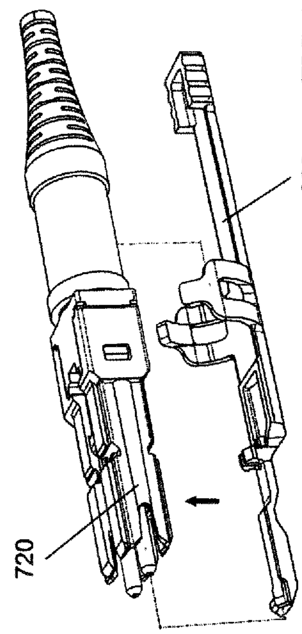


FIG. 10C

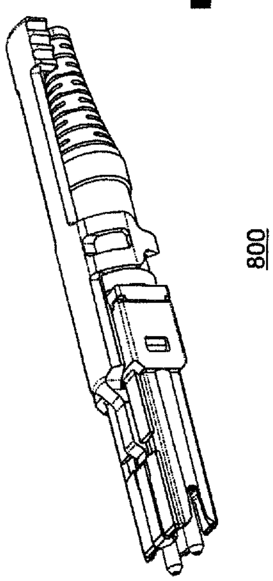


FIG. 10A

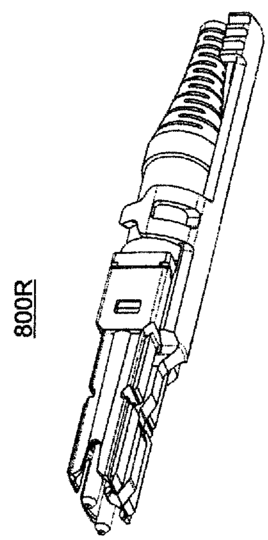


FIG. 10D

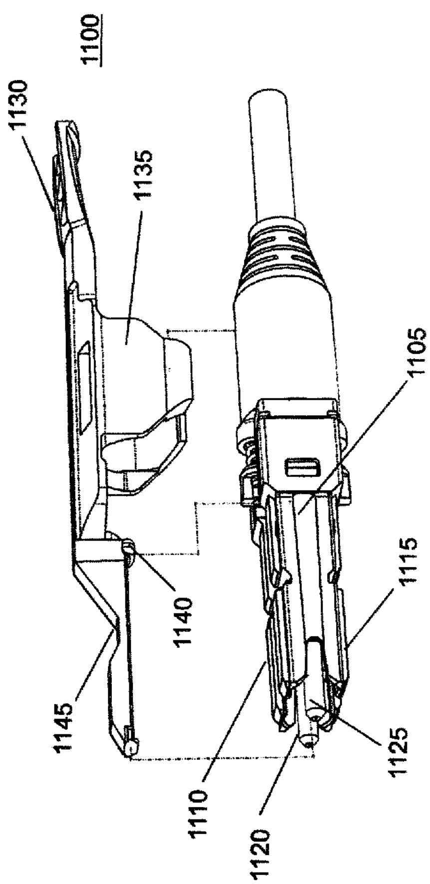


FIG. 11A

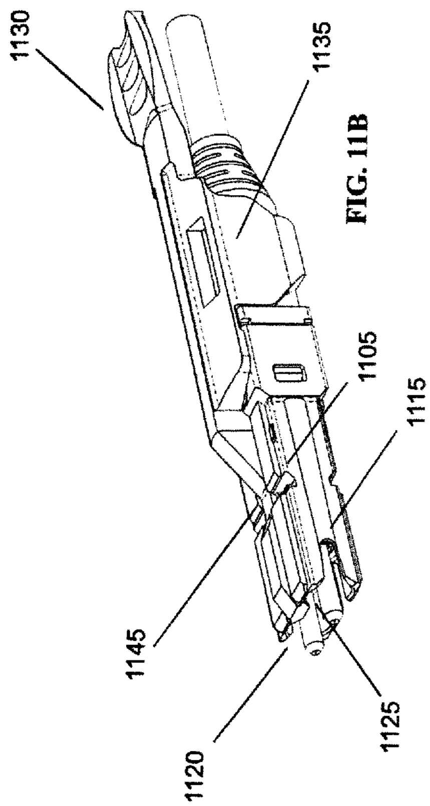


FIG. 11B

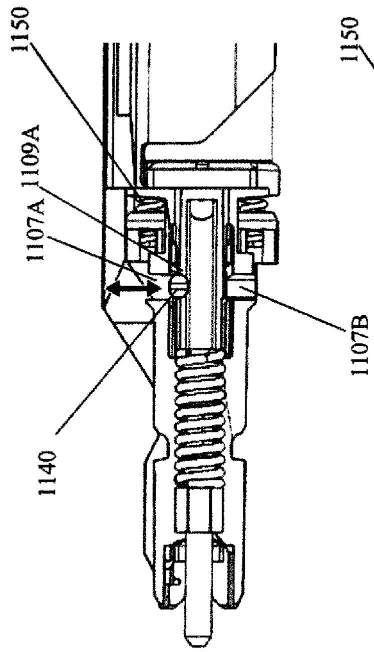


FIG. 12B

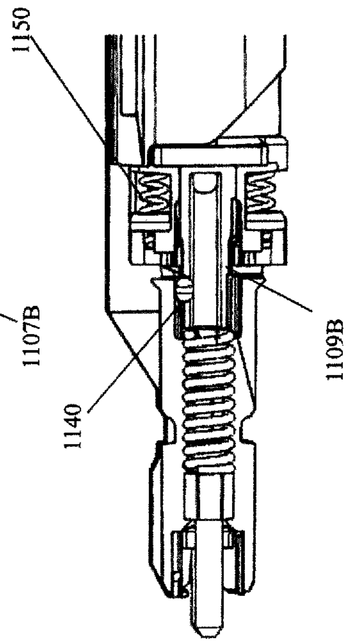


FIG. 12D

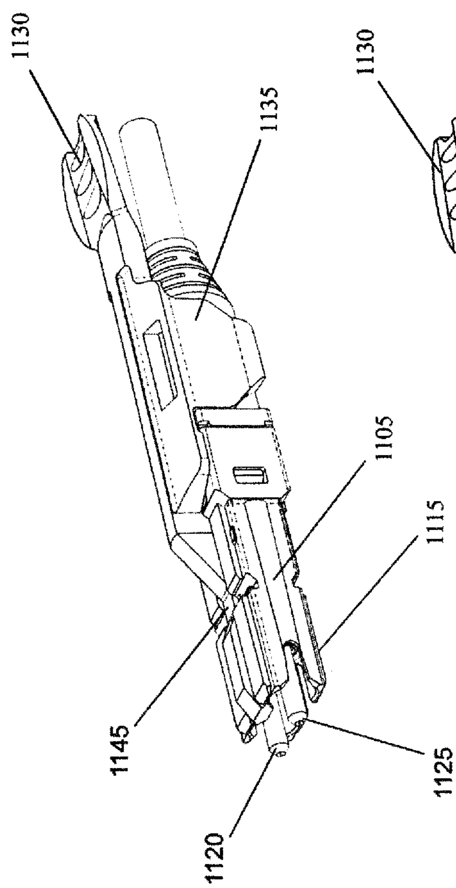


FIG. 12A

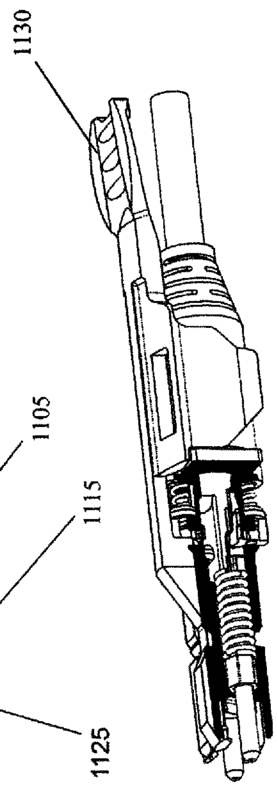


FIG. 12C

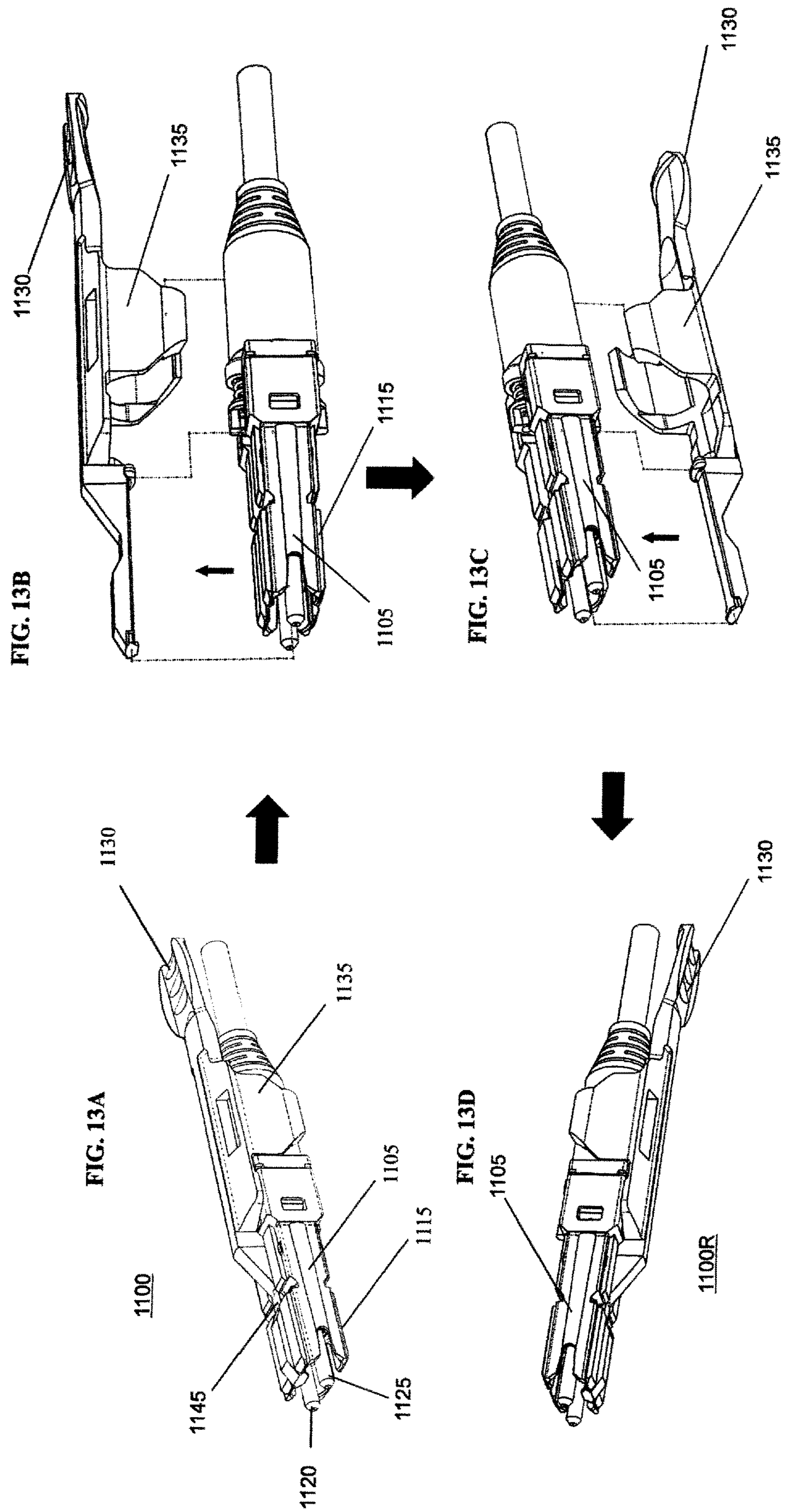


FIG. 13B
1130
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FIG. 13C
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1105
FIG. 13A
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FIG. 13D
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1130
1100R

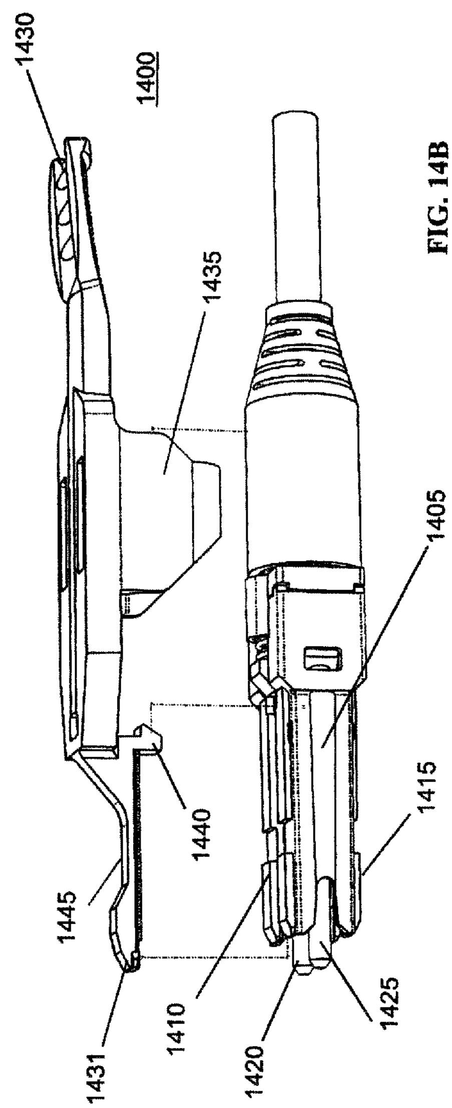


FIG. 14A

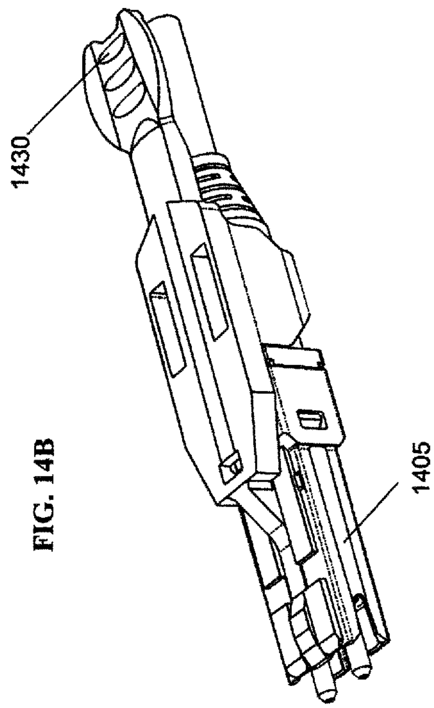


FIG. 14B

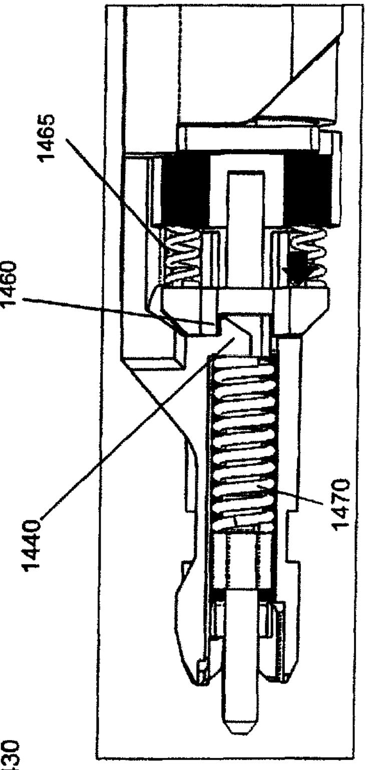


FIG. 15B

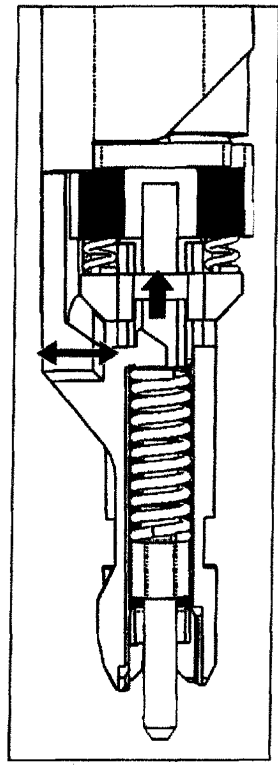


FIG. 15D

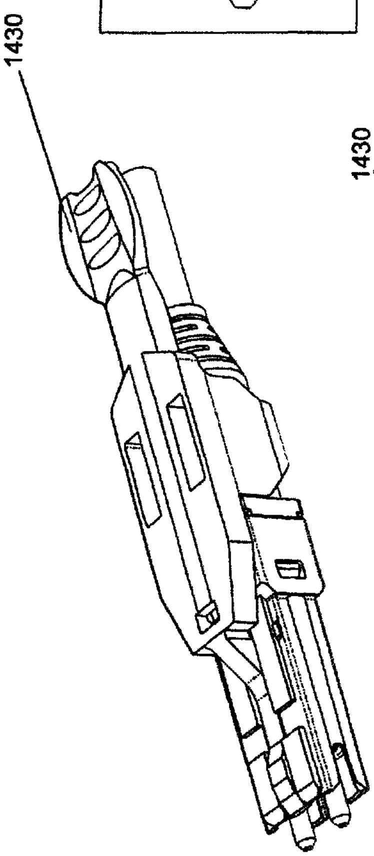


FIG. 15A

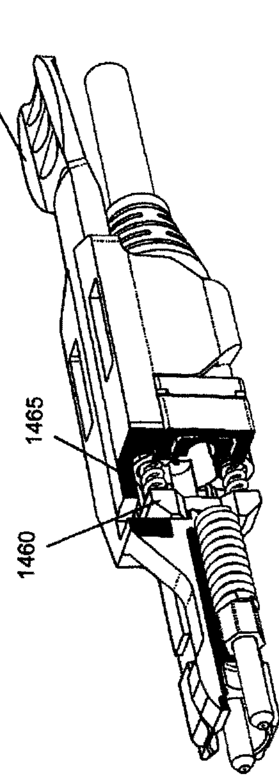


FIG. 15C

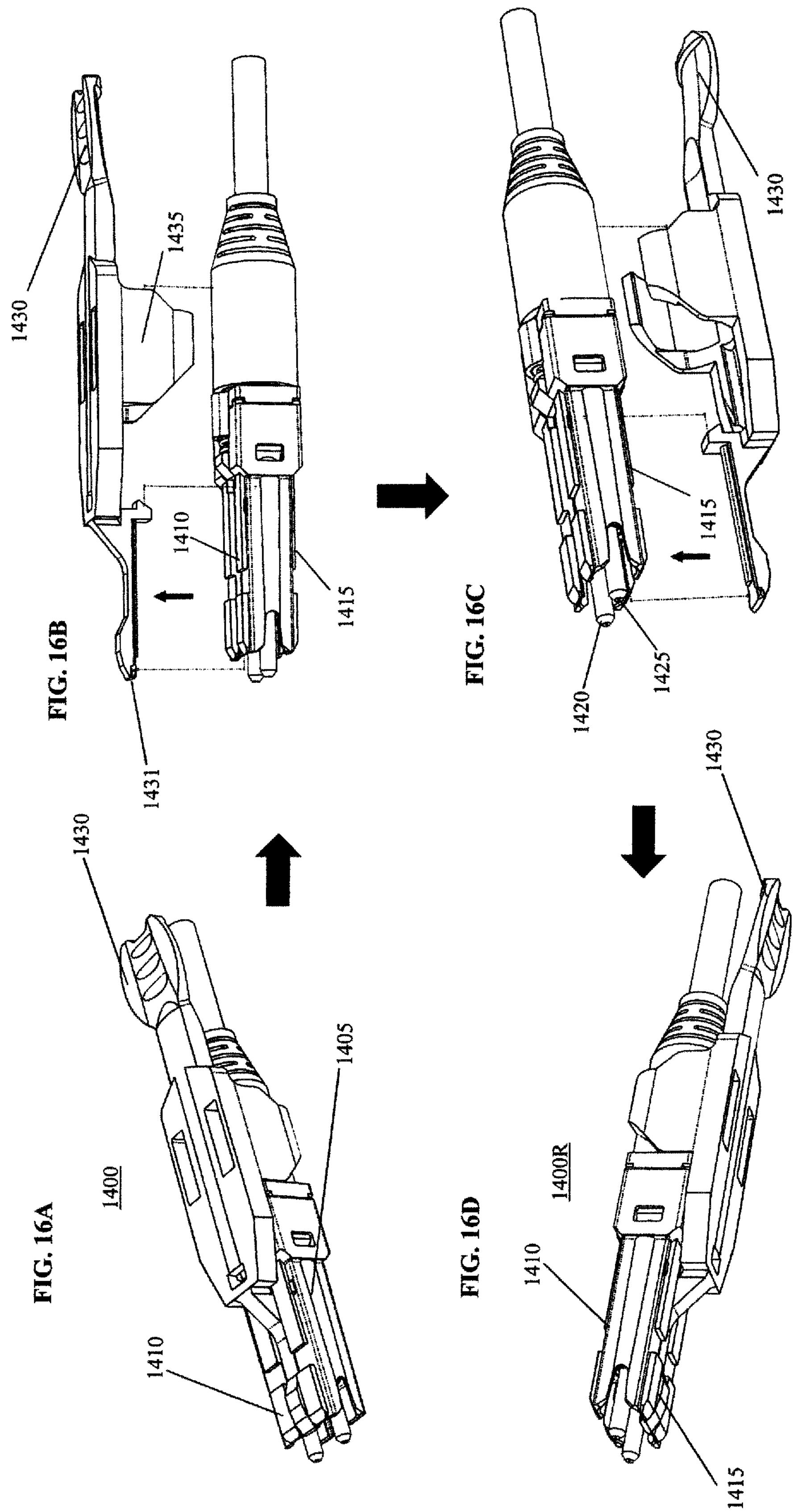


FIG. 16A
1400
1430
1405
1410
FIG. 16B
1430
1435
1410
1415
1431
FIG. 16C
1430
1415
1420
1425
FIG. 16D
1400R
1430
1410
1415

FIG 17B

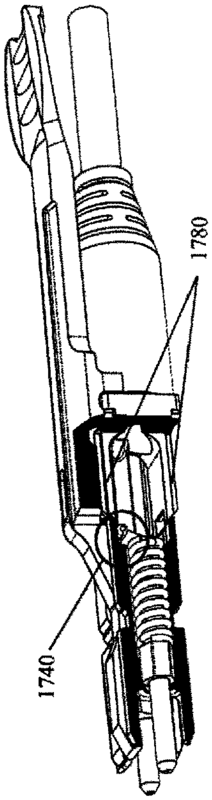


FIG 17A

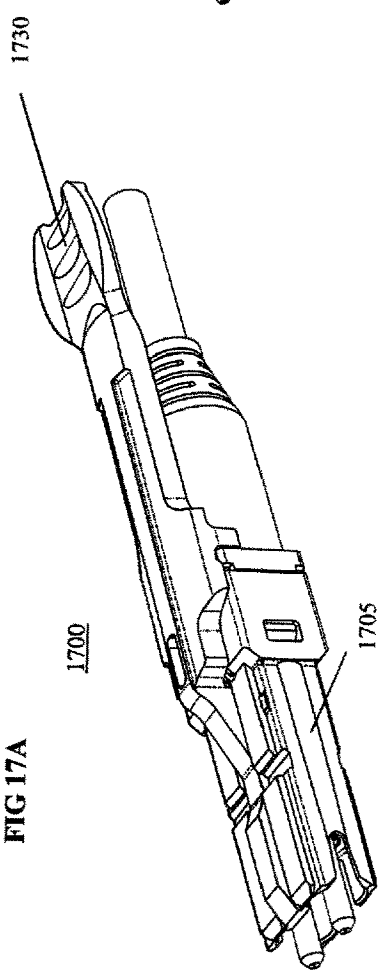
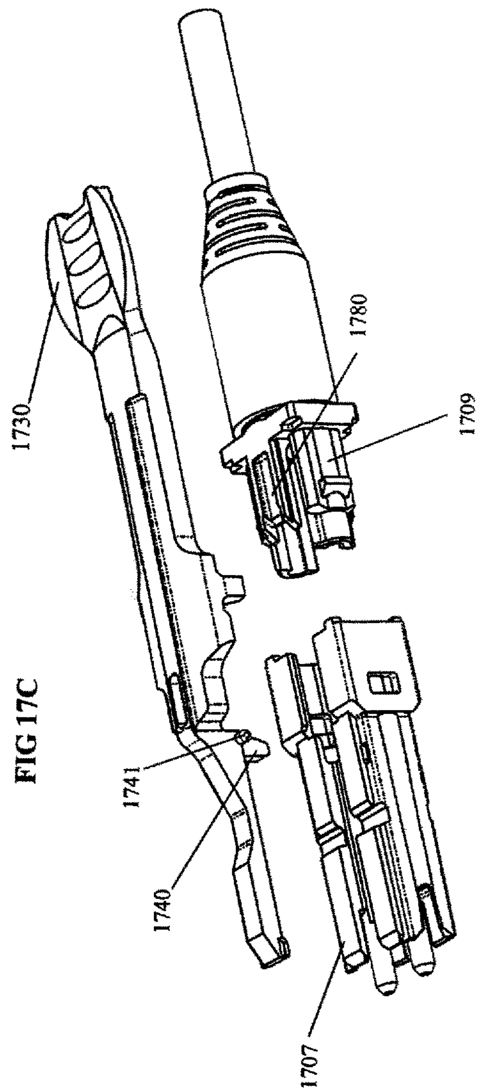


FIG 17C



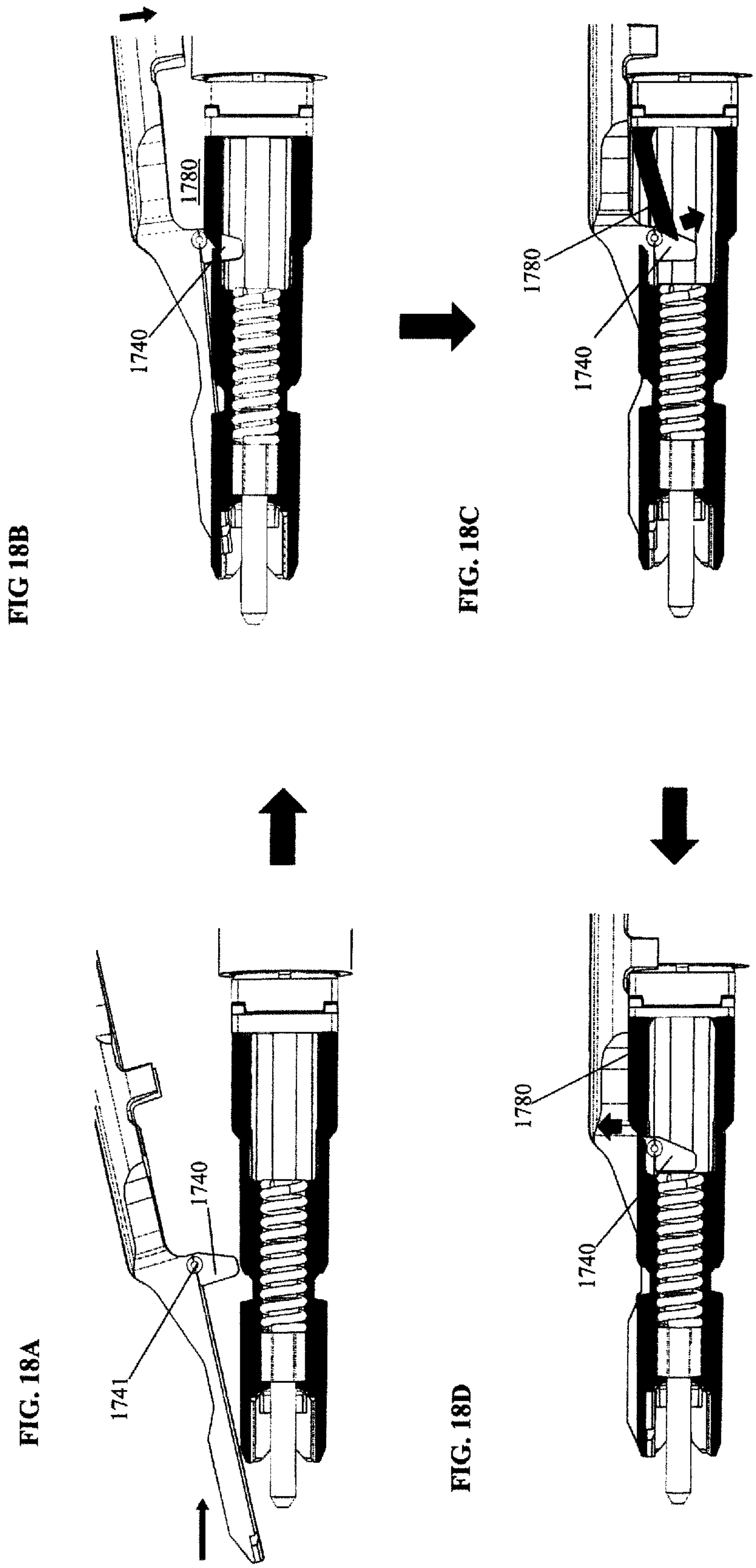


FIG 18B

FIG. 18C

FIG. 18A

FIG. 18D

FIG. 19A

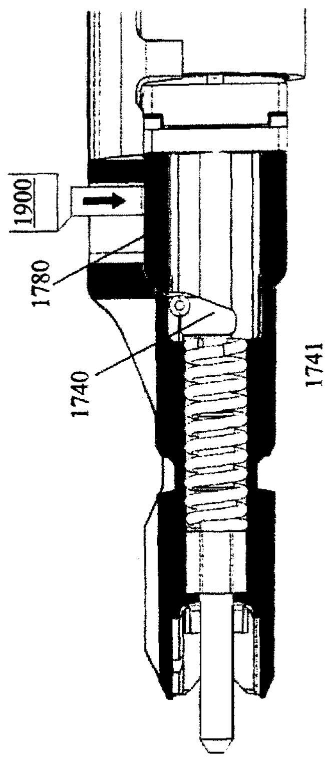
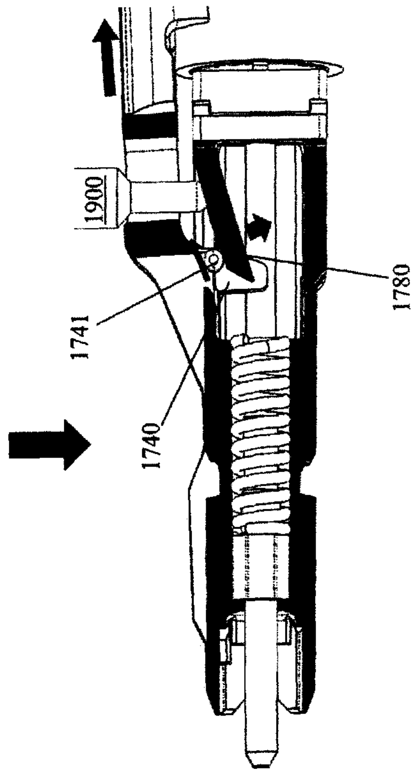


FIG. 19B



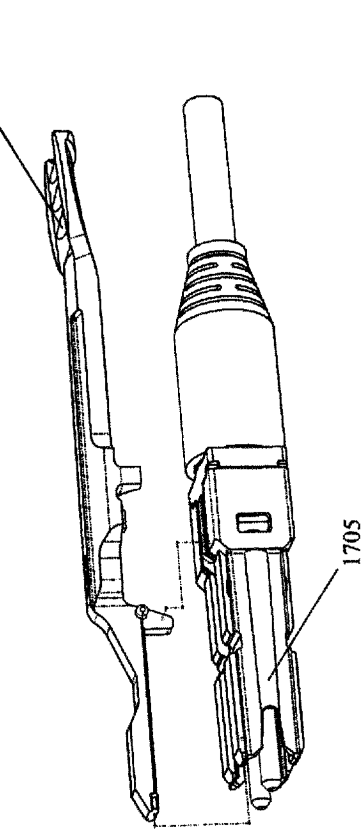


FIG. 20B

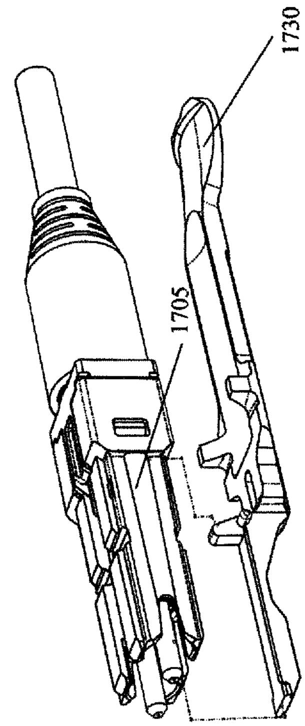


FIG. 20C

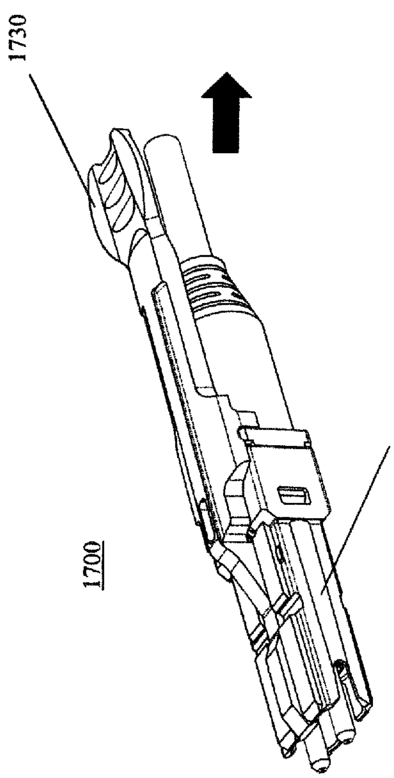


FIG. 20A

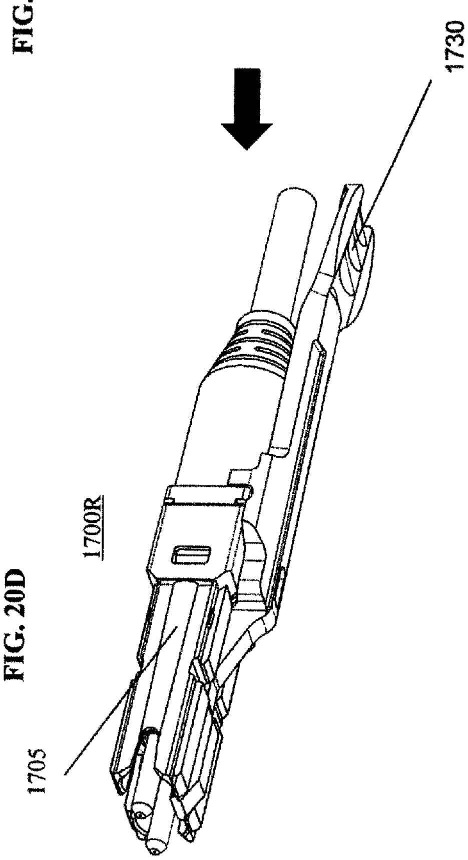


FIG. 20D

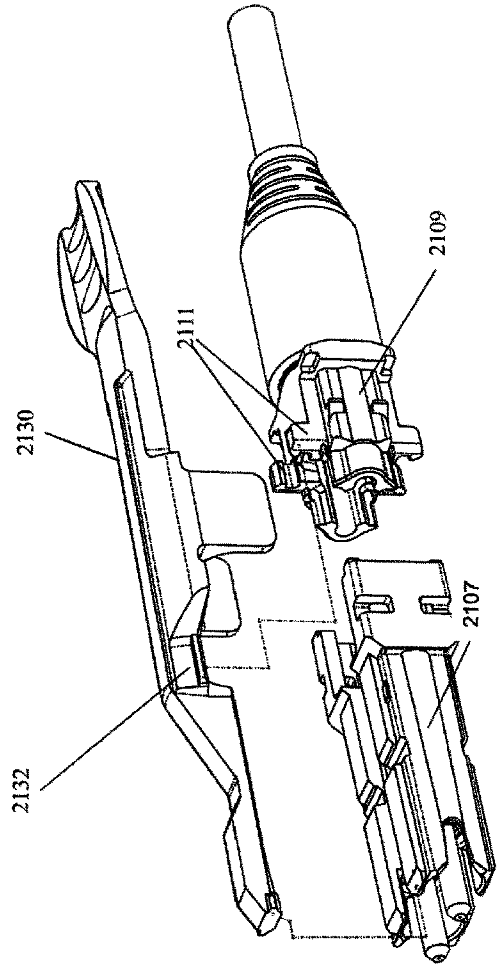


FIG. 21B

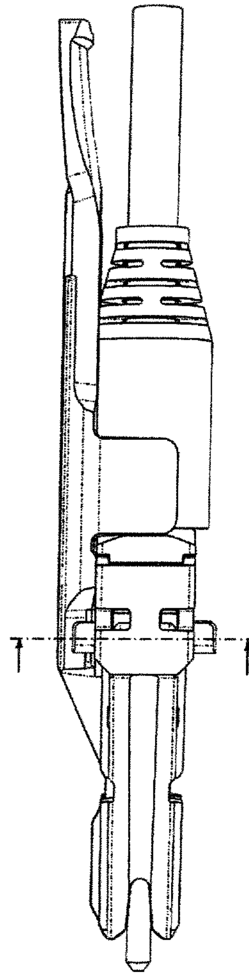


FIG. 21C

2100

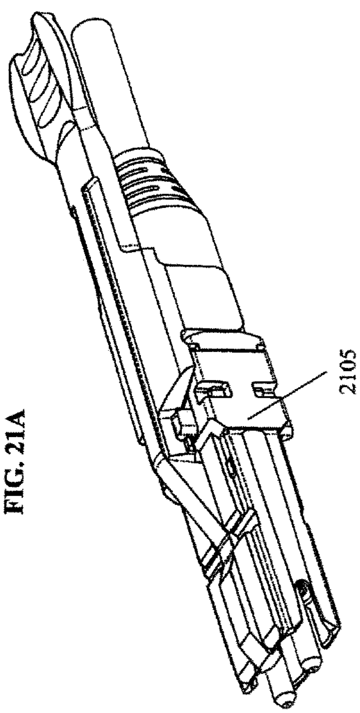


FIG. 21A

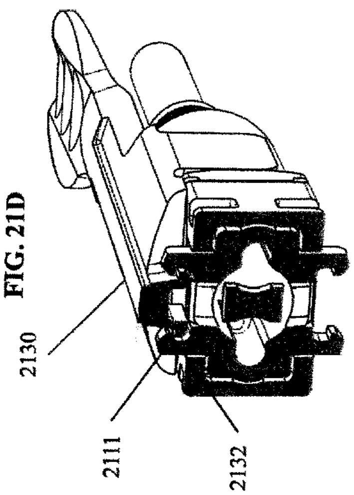


FIG. 21D

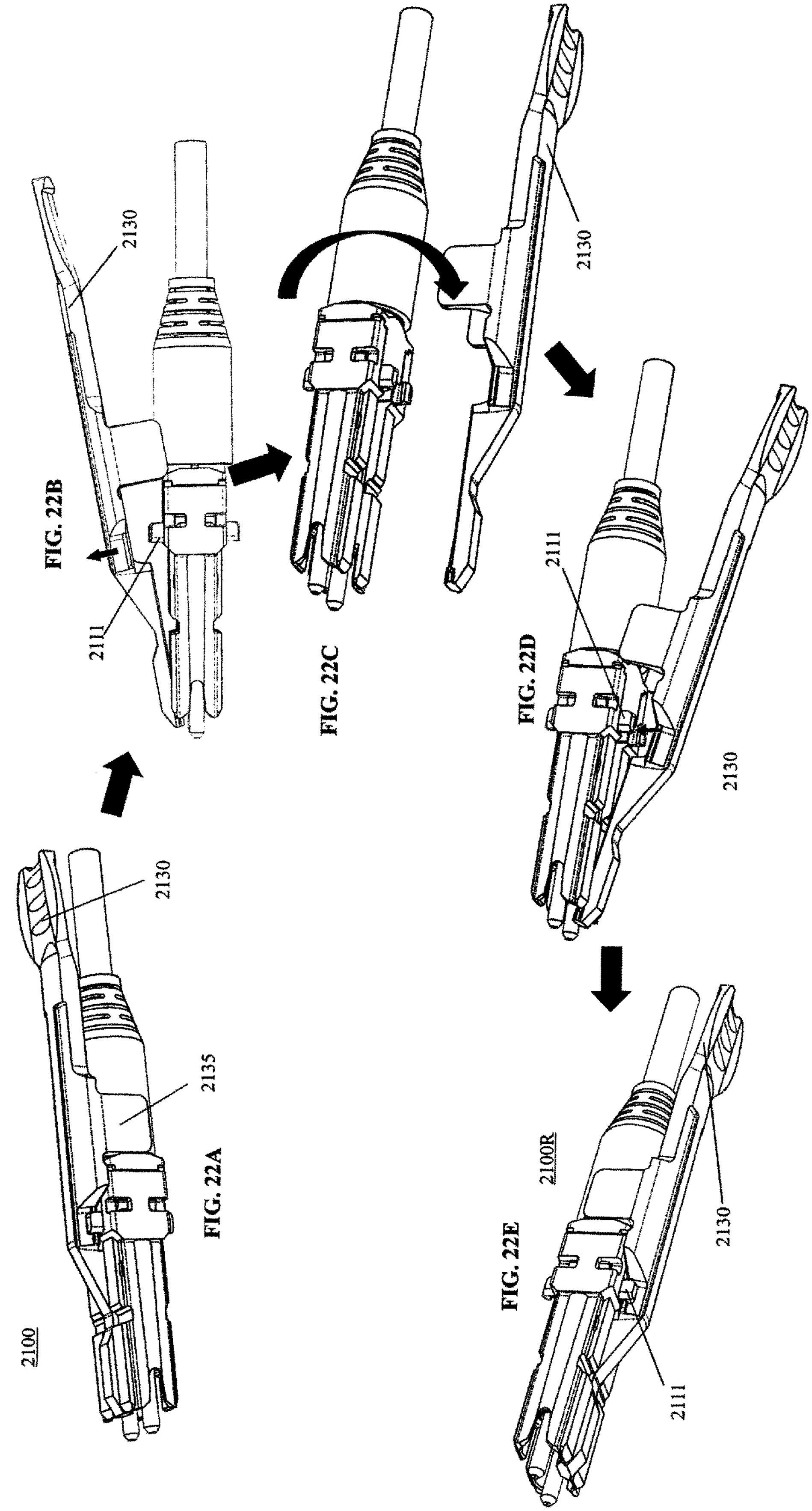


FIG. 22A
2100
2130
2135
FIG. 22B
2130
2111
FIG. 22C
2130
FIG. 22D
2111
2130
FIG. 22E
2100R
2130
2111

OPTICAL CONNECTORS WITH REVERSIBLE POLARITY AND METHOD OF USE

CROSS-REFERENCE TO RELATED PATENT APPLICATIONS

The present application is a continuation of the U.S. application Ser. No. 16/297,607 filed on Mar. 9, 2019, titled "OPTICAL CONNECTORS WITH REVERSIBLE POLARITY AND METHOD OF USE", which is a Continuation of PCT/US18/16049 filed on Jan. 30, 2018, titled "Optical Connectors with Reversible Polarity", which claims priorities to U.S. Provisional Patent Applications No. 62/452,147 filed Jan. 30, 2017, No. 62/457,150 filed Feb. 9, 2017, No. 62/463,898 filed Feb. 27, 2017, No. 62/463,901 filed Feb. 27, 2017, No. 62/485,042 filed Apr. 13, 2017, No. 62/546,920, filed Aug. 17, 2017, and No. 62/581,961 filed Nov. 6, 2017; the disclosures of which are incorporated herein by reference in their entireties.

FIELD OF THE INVENTION

The present disclosure relates generally optical connectors with reversible polarity.

BACKGROUND

The prevalence of the Internet has led to unprecedented growth in communication networks. Consumer demand for service and increased competition has caused network providers to continuously find ways to improve quality of service while reducing cost.

Certain solutions have included deployment of high-density interconnect panels. High-density interconnect panels may be designed to consolidate the increasing volume of interconnections necessary to support the fast-growing networks into a compacted form factor, thereby increasing quality of service and decreasing costs such as floor space and support overhead. However, room for improvement in the area of data centers, specifically as it relates to fiber optic connections, still exists. For example, manufacturers of connectors are always looking to reduce the size of the devices, while increasing ease of deployment, robustness, and modifiability after deployment. In particular, more optical connectors may need to be accommodated in the same footprint previously used for a smaller number of connectors in order to provide backward compatibility with existing data center equipment. For example, one current footprint is known as the small form-factor pluggable footprint (SFP). This footprint currently accommodates two LC-type ferrule optical connections. However, it may be desirable to accommodate four optical connections (two duplex connections of transmit/receive) within the same footprint. Another current footprint is the quad small form-factor pluggable (QSFP) footprint. This footprint currently accommodates four LC-type ferrule optical connections. However, it may be desirable to accommodate eight optical connections of LC-type ferrules (four duplex connections of transmit/receive) within the same footprint.

In communication networks, such as data centers and switching networks, numerous interconnections between mating connectors may be compacted into high-density panels. Panel and connector producers may optimize for such high densities by shrinking the connector size and/or the spacing between adjacent connectors on the panel. While both approaches may be effective to increase the panel

connector density, shrinking the connector size and/or spacing may also increase the support cost and diminish the quality of service.

In a high-density panel configuration, adjacent connectors and cable assemblies may obstruct access to the individual release mechanisms. Such physical obstructions may impede the ability of an operator to minimize the stresses applied to the cables and the connectors. For example, these stresses may be applied when the user reaches into a dense group of connectors and pushes aside surrounding optical fibers and connectors to access an individual connector release mechanism with his/her thumb and forefinger. Overstressing the cables and connectors may produce latent defects, compromise the integrity and/or reliability of the terminations, and potentially cause serious disruptions to network performance.

Accordingly, there is a need for smaller fiber optic connectors that will meet the needs of future developments in smaller SFPs and are reconfigurable for flexible deployment.

SUMMARY OF THE INVENTION

In a first aspect, the present disclosure provides a reversible polarity fiber optic connector including at least first and second optical ferrules and a connector housing at least partially surrounding the first and second optical ferrules. The housing has a first exterior wall positioned above the first and second optical ferrules and a second exterior wall positioned beneath the first and second optical ferrules. A latch coupling is positioned on each of the first and second exterior walls of the housing. A removable latch may engage either the first or second exterior wall latch coupling on the connector housing. Positioning the removable latch on the first exterior wall yields a fiber optic connector with a first polarity and positioning the removable latch on the second exterior wall yields a fiber optic connector with a second, opposite polarity.

In another aspect, the present disclosure provides a reversible polarity fiber optic connector with exchangeable arms for changing connector type. Thus, a common connector body may be formed into different connector types. The connector includes at least first and second optical ferrules and a common connector housing at least partially surrounding the first and second optical ferrules. The housing has a first exterior wall positioned above the first and second optical ferrules and a second exterior wall positioned beneath the first and second optical ferrules. A coupling surface is positioned on each of the first and second exterior walls of the common connector housing. To create a connector, a removable arm engages either the first or second exterior wall coupling surface; the removable arm includes either a latch or a latch recess depending upon the type of optical connector to be formed. Further, positioning the removable arm on the first exterior wall of the connector housing yields a fiber optic connector with a first polarity and positioning the removable arm on the second exterior surface of the housing yields a fiber optic connector with a second, opposite polarity.

In another aspect, the present disclosure provides a reversible polarity fiber optic connector with a push-pull tab. The connector includes at least first and second optical ferrules and has a connector housing at least partially surrounding the first and second optical ferrules. A first exterior wall is positioned above the first and second optical ferrules and a second exterior wall is positioned beneath the first and second optical ferrules. A first aperture is in the first exterior wall of the housing and a second aperture is in the second exterior wall of the housing. A removable push-pull tab includes a protrusion for positioning within either of the first or second apertures in the first and second exterior walls, respectively, of the connector housing. Positioning the removable push-pull tab with its protrusion within the first aperture yields a fiber optic connector with a first polarity and positioning the removable push-pull tab with its protrusion within the second aperture yields a fiber optic connector with a second, opposite polarity.

In yet another aspect, the present disclosure provides a reversible polarity fiber optic connector including at least first and second optical ferrules and a connector housing at least partially surrounding the first and second optical ferrules. A first exterior wall is positioned above the first and second optical ferrules and a second exterior wall is positioned beneath the first and second optical ferrules. A removable push-pull tab is provided. A first push-pull tab retainer is positioned on the first exterior wall and a second push-pull tab retainer is positioned on the second exterior wall. Positioning the removable push-pull tab in the retainer on the first exterior wall of the connector housing yields a fiber optic connector with a first polarity and positioning the removable push-pull tab in the retainer on the second exterior wall of the housing yields a fiber optic connector with a second, opposite polarity.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**A is a perspective view of one embodiment of a reversible polarity fiber optic connector according to some aspects of the present disclosure;

FIG. **1**B is a side view of the reversible polarity fiber optic connector of FIG. **3**A with the removable latch being removed from the connector housing;

FIG. **2**A is a perspective view of the reversible polarity fiber optic connector of FIG. **1**A;

FIG. **2**B is an exploded view of a step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. **2**A;

FIG. **2**C is an exploded view of a next step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. **2**A;

FIG. **2**D is a perspective view of the fiber optic connector of FIG. **1**A with its polarity reversed;

FIG. **3**A is a perspective view of an embodiment of a reversible polarity fiber optic connector with a pull tab according to aspects of the present disclosure;

FIG. **3**B is an exploded view of the reversible polarity fiber optic connector of FIG. **3**A;

FIG. **4**A is a perspective view of the polarity of the reversible polarity fiber optic connector of FIG. **3**A;

FIG. **4**B is an exploded view of a step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. **4**A;

FIG. **4**C.**1** is an exploded view of positioning the latch in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. **4**A;

FIG. **4**C.**2** is an exploded view of attaching the removed components of FIG. **4**B in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. **4**A;

FIG. **4**D is a perspective view of the reversible polarity fiber optic connector of FIG. **4**A with its polarity reversed;

FIG. **5**A is a perspective view of another embodiment of a reversible polarity fiber optic connector with a pull tab according to aspects of the present disclosure;

FIG. **5**B is an exploded view of the reversible polarity fiber optic connector of FIG. **5**A;

FIG. **6**A is a perspective view of the polarity of the fiber optic connector of FIG. **5**A;

FIG. **6**B is an exploded view of a step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. **5**A;

FIG. **6**C is an exploded view of a next step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. **6**A;

FIG. **6**D is a perspective view of the reversible polarity fiber optic connector of FIG. **6**A with its polarity reversed;

FIG. **7**A is a perspective view of a common connector housing of a reversible polarity fiber optic connector with exchangeable arms for changing connector type in an embodiment according to aspects of the present disclosure;

FIG. **7**B is the front view of the common connector housing of FIG. **7**A;

FIG. **7**C is the top view of the common connector housing of FIG. **7**A;

FIG. **7**D is the side view of the common connector housing of FIG. **7**A;

FIG. **8**A.**1** shows how the common connector housing of FIG. **7**A is used to create a latch-type connector;

FIG. **8**A.**2** is an exploded view of FIG. **8**A.**1**;

FIG. **8**B.**1** shows how the common connector housing of FIG. **7**A is used to create a recess-type connector;

FIG. **8**B.**2** is an exploded view of FIG. **8**B.**1**;

FIG. **9**A is a perspective view of FIG. **8**A.**1** of the polarity of the latch-type fiber optic connector of FIG. **8**A.**1**;

FIG. **9**B is an exploded view of a step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. **8**A.**1**;

FIG. **9**C is an exploded view of a next step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. **8**A.**1**;

FIG. **9**D is a perspective view of the reversible polarity fiber optic connector of FIG. **8**A.**1** with its polarity reversed;

FIG. **10**A is a perspective view of FIG. **8**B.**1** of the polarity of the recess-type fiber optic connector of FIG. **8**B.**1**;

FIG. **10**B is an exploded view of a step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. **8**B.**1**;

FIG. **10**C is an exploded view of a next step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. **8**B.**1**;

FIG. **10**D is a perspective view of the reversible polarity fiber optic connector of FIG. **8**B.**1** with its polarity reversed;

FIGS. **11**A and **11**B respectively depict exploded and perspective views of a reversible polarity optical connector according to a further embodiment of the disclosure;

FIGS. **12**A-**12**D depict the operation of the reversible polarity optical connector of FIGS. **11**A and **11**B;

FIGS. **13**A-**13**D depict the process for changing the polarity of the optical connector of FIGS. **11**A and **11**B;

FIGS. **14**A and **14**B respectively depict exploded and perspective views of a reversible polarity optical connector according to a further embodiment of the disclosure;

FIGS. **15**A-**15**D depict the operation of the reversible polarity optical connector of FIGS. **14**A and **14**B;

FIGS. **16**A-**16**D depict the process for changing the polarity of the optical connector of FIGS. **14**A and **14**B;

FIGS. **17**A-**17**C respectively depict perspective, partial cross-section, and exploded views of a reversible polarity optical connector according to a further embodiment of the disclosure;

FIGS. **18**A-**18**D depict the assembly of the push-pull tab to the connector body of the connector of FIGS. **17**A-**17**C;

FIGS. **19**A-**19**B depict the removal of the push-pull tab from the connector body using a tool;

FIGS. **20**A-**20**D depict the process for changing the polarity of the optical connector of FIGS. **17**A-**17**C.

FIGS. **21**A-**21**D depict the process of changing polarity of an optical connector according to an embodiment of the invention.

FIGS. **22**A-**22**E depict the process for changing the polarity of an optical connector according to an embodiment of the invention.

DETAILED DESCRIPTION

This disclosure is not limited to the particular systems, devices and methods described, as these may vary. The terminology used in the description is for the purpose of describing the particular versions or embodiments only, and is not intended to limit the scope.

As used in this document, the singular forms "a," "an," and "the" include plural references unless the context clearly dictates otherwise. Unless defined otherwise, all technical and scientific terms used herein have the same meanings as commonly understood by one of ordinary skill in the art. Nothing in this disclosure is to be construed as an admission that the embodiments described in this disclosure are not entitled to antedate such disclosure by virtue of prior invention. As used in this document, the term "comprising" means "including, but not limited to."

The following terms shall have, for the purposes of this application, the respective meanings set forth below.

The connectors of the present disclosure may be configured for fiber optic transmission or electrical signal transmission. The connector may be any suitable type now known or later developed, such as, for example, a ferrule connector (FC), a fiber distributed data interface (FDDI) connector, an LC connector, a mechanical transfer (MT) connector, a square connector (SC) connector, an SC duplex connector, or a straight tip (ST) connector. The connector may generally be defined by a connector housing. In some embodiments, the housing may incorporate any or all of the components described herein.

Various embodiments described herein generally provide a remote release mechanism such that a user can remove cable assembly connectors that are closely spaced together without damaging surrounding connectors, accidentally disconnecting surrounding connectors, disrupting transmissions through surrounding connectors, and/or the like. Various embodiments also provide narrow pitch LC duplex connectors and narrow width multi-fiber connectors.

As discussed herein, current connectors may be improved by various means, such as, for example, reducing the footprint, increasing the structural strength, enabling polarity changes, etc. Various embodiments disclosed herein offer improvements over the current state of the art, as will be further discussed below.

In some embodiments, the fiber optic connector may be a narrow pitch duplex LC connector including two LC connectors. In some embodiments, such as that shown, the two LC connectors may comprise a single combined unit. In alternative embodiments, the LC connectors may be separate members, wherein an air gap exists between the two members, or wherein the two separate members are located adjacent and flush to each other (i.e., no air gap exists). In some embodiments, each of the LC connectors includes a respective ferrule and a respective extending member or modular arm. The connector may have a pitch of 4.8 mm, defined as the axis-to-axis distance between the central axes of the LC connectors. In other embodiments, the connector pitch may be less than that of the pitch of conventional connectors, for example less than 6.25 mm and less than about 5.25 mm. In some embodiments, the pitch may be about 4.8 mm or less.

In current designs, if a fiber optic connector, particularly a duplex connector, needs to have the ferrules rotated or swapped, for example, for exchanging transmit and receive optical fibers, it can be a time consuming and difficult process. Generally, if a duplex connector needs to be rotated, current systems require twisting the individual LC connector tips 180 degrees. However, this process also twists the fibers that enter the connector tip. Twisting the fiber at any stage of the connection can cause wear and/or damage to the delicate fibers. Thus, most systems involve an alternative solution, wherein the duplex connector is partially or completely disassembled in order to access the ferrules or fibers and manually relocate them within the duplex connector. However, swapping ferrules side to side is a delicate operation. In order to prevent damage to the internal fibers, great care must be taken. Thus, this operation usually requires specialized tools and preparation time to perform safely and accurately.

Therefore, embodiments as described herein, allow for easy, quick, and safe swapping of the left and right side ferrules in a connector. Thus, embodiments discussed herein allow for a change in polarity of the duplex connector without twisting the fibers or performing any complex disassembly of the duplex connector.

FIGS. **1**A and **1**B depict a fiber optic connector with reversible polarity according to one aspect of the present disclosure. As shown in FIG. **1**A, a reversible polarity fiber optic connector may include first and second optical ferrules **110***a* and **110***b* and a connector housing **120** at least partially surrounding the first and second optical ferrules. A removable latch **130** is depicted in FIG. **1**A in its assembled state and in FIG. **1**B removed from the connector housing **120**.

FIG. **1**B is a side view of the reversible polarity fiber optic connector of FIG. **1**A with the removable latch **130** being separated from the connector housing. As shown, the connector housing **120** may have a first exterior wall **121***a* positioned above the first and second optical ferrules and a second exterior wall **121***b* positioned beneath the first and second optical ferrules. A latch coupling **122** is positioned on each of the first and second exterior walls of the housing. The removable latch **130** may include a protrusion **131** for engaging the housing latch coupling **122**. In particular, the latch coupling **122** may include angled walls that interact with slanted edges of the protrusion **131** to prevent accidental disassembly of the latch **130**. Although the latch coupling **122** is depicted as a recess on the housing accommodating a latch protrusion, these elements may be reversed with the latch including a recess and the housing including a protrusion. Other mechanical coupling mechanisms may be used to interconnect the housing and the removable latch. For example, an embodiment may involve a coupling system wherein the removable latch is inserted into a recess in the connector housing and twisted (e.g., 90°, 180°, etc.) to secure the latch to the recess. Alternative coupling may use a more complex shape. For example, a u-shaped recess in the connector housing may engage a cooperatively-shaped projection in the latch that is inserted and fed through the u-shape until secure. It should thus be understood, that any system or method of coupling may be used to attach the removable latch to the connector housing, including various locations (e.g., sliding from the front, sides, back, bottom, top, etc.).

FIGS. **2**A-**2**D depict the process for changing the polarity of the fiber optic connector of FIG. **1**A from a first polarity, FIG. **2**A to a second, opposite polarity, FIG. **2**D. The removable latch **130** may be removed from the latch coupling on the first exterior wall of the connector housing, FIG. **2**B, positioned adjacent the second exterior wall on beneath the ferrules, FIG. **2**C, and then coupled with the latch coupling on the second exterior wall of the connector housing to yield a connector **100**R, FIG. **2**D, having the opposite polarity of connector **100**. In this manner, transmit and receive optical fibers may be reversed without necessitating any fiber twist or complex repositioning of the optical ferrules.

In typical embodiments, the latch of the connector housing is required to be flexible. Thus, when a latch and a connector housing (e.g., duplex connector) are built as one unified member (as is currently done), the fiber optic connector is built of a similar flexible or less rigid material. Building the connector housing out of a plastic or polymeric material, limits the amount of rigidity that it can have. Thus, as fiber optic connectors continue to reduce in size, the strength of the housing has been reduced. Therefore, it would be advantageous to build the connector housing out of a more robust material while still allowing the latch to remain flexible. In order to accomplish this, in some embodiments according to aspects of the present disclosure, the connector housing may be manufactured out of a very rigid or strong material (e.g., steel, graphene, carbon, metal alloys, or any material of suitable properties). Because the connector housing and the removable latch need only interlock with each other, the removable latch may still be made out of a more flexible material. Thus, the removable nature of the latch disclosed herein allow for a more robust and secure overall design when dealing with the shrinking footprint of fiber optic connectors.

FIG. **3**A is a perspective view of another embodiment of a reversible polarity fiber optic connector **300**. As shown, the reversible polarity fiber optic connector may further comprise a pull tab **340** for engaging a removable latch **330**. The pull tab **340** depresses the latch **330** as the tab is pulled in a direction away from the fiber optic ferrules.

FIG. **3**B is an exploded view of the reversible polarity fiber optic connector of FIG. **3**A. As shown, the pull tab **340** may comprise a first opening **341** and a second opening **344**. The first opening **341** is configured to allow the connector housing and the removable latch to pass through while the second opening is configured to accommodate the tip of the latch. The pull tab may further comprise a first deformable portion **342** and a second deformable portion **344**. In operation, the first deformable portion **342** cooperates with the second deformable portion **344** to depress the removable latch when the pull tab is pulled in a direction away from the ferrules.

FIGS. **4**A-**4**D depict the process for changing the polarity of the fiber optic connector **300** from a first polarity, FIG. **4**A to a second polarity **300**R, FIG. **4**D. The pull tab **340** may be disengaged from the connector housing **320** and the removable latch **330** on the first exterior wall of the connector housing, FIG. **2**B. The removable latch is then detached from the latch coupling on the first exterior wall of the connector housing, FIG. **4**C.**1**. Next, the removable latch is engaged with the latch coupling on the second exterior wall of the connector housing, beneath the ferrules, FIG. **4**C.**2**. Finally, the pull tab **340** is positioned surrounding the connector housing and engaging the removable latch tip, resulting in the assembled optical connector **300**R having polarity opposite to that of connector **300**, FIG. **4**D.

FIGS. **5**A and **5**B are a perspective view and exploded view, respectively, of another embodiment of a reversible polarity fiber optic connector **500**. The connector **500** includes a connector housing **520**, a latch **530**, and a pull tab **540**. On the first and second exterior walls of connector housing **520** are latch couplings that include a groove **522**. A recess **521** is also provided in the housing. The latch **530** includes a protrusion **531** that is received within groove **522**. The latch further includes a projection **532** that is received in the housing between the optical ferrules. The pull tab **540** includes an opening **541** for engaging the removable latch **530**. A front protrusion **542** is configured to depress the removable latch **530** when the pull tab is pulled in a direction away from the ferrule side of the optical connector.

FIGS. **6**A-**6**D depict the process for changing the polarity of the fiber optic connector **500** from a first polarity, FIG. **6**A to a second polarity, FIG. **6**D. The pull tab **540** is disengaged from the connector housing and the removable latch **530** on the first exterior wall of the connector housing, FIG. **6**B, and the removable latch is decoupled from the latch coupling on the first exterior wall of the connector housing. Then the removable latch may be coupled with the latch coupling on the second exterior wall of the connector housing, beneath the optical ferrules in FIG. **6**C, and the pull tab **540** is engaged with the connector housing and the removable latch on the second exterior wall of the connector housing to create reverse polarity connector **500**R, FIG. **6**D.

It is of interest within the optical connectivity industry to have multiple styles of optical connectors for multiple purposes and/or multiple implementation styles. Thus, in order to more easily provide flexibility, a solution is needed that allows for on-the-fly, in-the-field, or in manufacturing modification of the connector. The below embodiment provides a universal type fiber optic connector which has a unique housing design that allows for different latches or arms to be attached.

FIG. **7**A is a perspective view of a common connector housing **720** of a reversible polarity fiber optic connector **700** with exchangeable arms for changing connector type in an embodiment according to aspects of the present disclosure. As shown, the reversible polarity fiber optic connector may comprise first and second optical ferrules **710***a* and **710***b* and the common connector housing **720** at least partially surrounding the first and second optical ferrules.

FIGS. **7**B, **7**C and **7**D are the front view, top view and side view, respectively, of the common connector housing **720**. As shown, the common connector housing may have a first exterior wall **725***a* positioned above the first and second optical ferrules and a second exterior wall **725***b* positioned beneath the first and second optical ferrules. The connector housing **720** may further have a coupling surface **724** positioned on each of the first and second exterior walls and include a receiving track **726** in the coupling surface.

FIG. **8**A.**1** shows the common connector housing **720** used to create a latch-type connector **700** and FIG. **8**B.**1** shows the common connector housing **720** used to create a recess-type connector **800**. Both of connectors **700** and **800** include a removable arm **730** or **830** for engaging either of the first and second exterior wall coupling surfaces **724** on the connector housing, FIGS. **8**A.**2** and **8**B.**2** respectively. The removable arms **730** and **830** may each respectively include a projection **735** or **835** for engaging in the receiving track **726** of the coupling surface **724**, FIGS. **8**A.**2** and **8**B.**2** respectively. As with the previous embodiments, positioning the removable arm on the first exterior wall of the connector housing yields a fiber optic connector with a first polarity and positioning the removable arm on the second exterior surface of the housing yields a fiber optic connector with the opposite polarity.

Still referring to FIGS. **8**A.**2** and **8**B.**2** respectively the removable arms may include either a latch or a recess: removable arm **730** includes a latch **733** while removable arm **830** includes a recess **834**. Thus, a latch-type connector **700** is created through assembly of the removable latch arm to the common connector body **720** as shown in FIG. **8**A.**1** and a recess-type connector **800** is created through assembly of the removable recess arm to the common connector body **720** as shown in FIG. **8**B.**1**.

The fiber optic connector may further include a pull tab. When a removable arm with a latch **730** is positioned on the coupling surface of the common connector housing **720** to create a latch-type connector **700**, the pull tab **740** is a separate element from the removable arm, FIG. **8**A.**2**. When a removable arm includes a recess **830** is positioned on the coupling surface of the common connector housing **720** to create a recess-type connector **800**, the pull tab **840** is integrated with the removable arm, FIG. **8**B.**2**.

FIGS. **9**A-**9**D depict the process for changing the polarity of the latch-type fiber optic connector from a first polarity **700**, FIG. **9**A to a second polarity **700**R, FIG. **9**D. The sub-assembly of the removable arm **730** and the pull tab **740** may be decoupled from the coupling surface **724** of the first exterior wall of the connector housing, FIG. **9**B. Then the sub-assembly of the removable arm **730** and the pull tab **740** may be coupled with the coupling surface of the second exterior wall of the connector housing, FIG. **9**C, creating the opposite polarity connector **700**R.

FIGS. **10**A-**10**C depicts the process for changing the polarity of the recess-type fiber optic connector **800** from a first polarity, FIG. **10**A to a second polarity, FIG. **10**D. The removable arm **830** with a recess and a pull tab as an integral structure may be decoupled from the coupling surface **724** of the first exterior wall of the connector housing, FIG. **10**B. Then the removable arm may be coupled with the coupling surface **724** of the second exterior wall of the common connector housing **720**, FIG. **10**C to create opposite polarity optical connector **800**R, FIG. **10**D.

FIGS. **11**A and **11**B depict a further embodiment **1100** of the reversible polarity optical connectors of the present disclosure. As shown in FIG. **11**A or FIG. **12**A, a push-pull tab **1130** may interconnect with either a first exterior wall **1110** of housing **1105** or with a second exterior wall **1115** of housing **1105**. Ferrules **1120** and **1125** are at least partially surrounded by housing **1105** and may be LC connectors in an embodiment. As in previous embodiments, the push-pull tab may include a tab recess **1145**, as shown in FIG. **12**A or FIG. **11**A. Alternatively, push-pull tab **1130** may include a latch (not shown). Various features of the push-pull tab **1130** are provided to assist in affixing the push-pull tab to the first exterior wall **1110** or the second exterior wall **1115** of the housing **1105**. This includes push-pull tab clips **1135** that clip onto the optical connector, optionally in a boot region, and protrusion **1140** that fits within a first aperture, **1109**A, beneath the housing exterior wall **1110** or a second aperture, **1109**B, beneath housing exterior wall **1115** (to be discussed in more detail below), and projection **1131** for inserting into the housing between ferrules **1120** and **1125**. Each of these features is fully reversible such that the push-pull tab is easily removed and repositioned on the opposite exterior wall to change polarity of the connector.

As best seen in FIGS. **12**B and **12**D, push-pull tab protrusion **1140** may be inserted into first aperture **1109**A of housing **1105** through a first exterior housing aperture **1107**A. Alternatively, in the reverse-polarity configuration, the push-pull tab protrusion **1140** may be inserted into second housing aperture **1109**B through second exterior housing aperture **1107**B. When the push-pull tab **1130** is moved forward, the protrusion slides within the aperture **1109**A or **1109**B, as shown in FIG. **12**B. To maintain the push-pull tab in a forward-biased position, tab position spring **1150** is provided. During insertion or removal of the protrusion **1140**, tab position spring **1150** is compressed, depicted in FIG. **12**B. When the position spring **1150** is in its relaxed (uncompressed) position, FIGS. **12**C and **12**D, the protrusion **1140** is slid forward within the aperture **1109**A or **1109**B.

To change polarity of the optical connector **1100**, FIGS. **13**A-**13**D, the push-pull tab **1130** is removed by withdrawing the protrusion **1140** from the housing **1105** through exterior housing aperture **1107**A along with detaching clips **1135** and decoupling projection **1131**, thus releasing the push-pull tab from the first exterior housing wall **1110** (FIG. **13**B). The push-pull tab is moved toward second exterior housing wall **1115** and the protrusion **1140** is inserted into aperture **1109**B through exterior housing aperture **1107**B in FIG. **13**C. Projection **1131** is fitted between ferrules **1120** and **1125** and clips **1135** are affixed to the connector. The resultant connector **1100**R of **13**D is of opposite polarity to the connector **1100** of FIG. **13**A.

Various alternatives to the protrusion **1140** of optical connector **1100** may be used in the optical connectors of this disclosure. For example, the protrusion may be provided by the connector housing with receiving elements provided in the push-pull tab. Variations to the shape of the projection and apertures may be made without affecting the function of the reversible-polarity connector.

Another alternative embodiment is depicted in FIGS. **14**A and **14**B in which a hook-shaped protrusion **1440** is provided for engagement within the connector housing. As in the previous embodiment, the push-pull tab **1430** includes a tab recess **1445**, connector-attachment clips **1435** and projection **1431** for positioning between ferrules **1420** and **1425**. In FIG. **14**B, the push-pull tab **1430** is positioned on first exterior housing wall **1410** and has a first polarity. In this position, the hook-shaped protrusion **1440** engages a housing projection **1460**, held in a forward-biased position by push-pull tab position spring **1465**, as seen in FIGS. **15**B and **15**D. To release the protrusion **1440**, push-pull tab position spring **1465** is compressed in FIG. **15**C such that housing projection **1460** is retracted sufficiently to allow removal of protrusion **1440** through the housing **1405**, FIG. **15**D. FIG. **15**A depicts connector with pull tab **1430** fully assembled.

To change polarity of the optical connector **1400** from the first polarity of FIG. **16**A, the push-pull tab **1430** is removed by withdrawing the protrusion **1440** from the housing **1405** through the housing along with detaching clips **1435** and decoupling projection **1431**, thus releasing the push-pull tab from the first exterior housing wall **1110** (FIG. **16**B). The push-pull tab is moved toward second exterior housing wall **1415** and the protrusion **1440** is inserted into the housing **1405**. Projection **1431** is fitted between ferrules **1420** and **1425** and clips **1435** are affixed to the connector in FIG. **16**C. The resultant connector **1400**R of FIG. **16**D is of opposite polarity to the connector of FIG. **16**A.

Protrusions from a push-pull tab may be inserted into a housing via features other than a housing aperture. Such a connector is depicted in FIG. **17** and features a deformable housing region to allow entry of a push-pull tab protrusion during affixing of the push-pull tab to the connector housing. As seen in FIG. **17**A, the connector **1700** includes a connector housing **1705** which may optionally include a back body housing portion **1709** for connecting with a housing front portion **1707** (FIG. **17**C). The back body housing portion **1709** includes a deformable region **1780**, seen in the partial cross-section of FIG. **17**B and the perspective view of FIG. **17**C. The push-pull tab **1730** includes a protrusion **1740** with a projection **1741** extending therefrom.

Turning to FIG. **18**A, to affix the push-pull tab to the connector housing, the protrusion **1740** penetrates the deformable region **1780** (FIG. **18**B) causing the deformable region to yield and accept entry of the protrusion **1740** into the housing. As the projection **1741** enters the housing as depicted in FIG. **18**C, the deformable region **1780** returns to its original position (FIG. **18**D), securing the push-pull tab **1730** to the connector housing.

Removal of the push-pull tab **1730** is depicted in FIGS. **19**A and **19**B. A removal tool **1900**, which may be shaped similar to a small screwdriver, depresses deformable region **1780**, allowing projection **1741** to slide along an edge of the deformable region **1780**, followed by the protrusion **1740**, releasing the push-pull tab **1730**.

To change polarity of the optical connector **1700** from the first polarity of FIG. **20**A, the push-pull tab **1730** is removed in FIG. **20**B by using the removal tool technique depicted in FIGS. **19**A and **19**B. The push-pull tab is moved toward the second exterior housing wall and the protrusion **1740** is inserted into the housing **1705** through the deformable region **1780** in FIG. **20**C. The resultant connector **1700**R of FIG. **20**D is of opposite polarity to the connector of FIG. **20**A.

In another aspect of the disclosure, a retaining member may be provided in the connector housing to retain a push-pull tab. As seen in FIGS. **21**A-**21**D, a connector **2100** having a housing **2105** is provided with a housing front portion **2107** and a back portion **2109**. FIG. **21**A depicts an assembled connector **2100** with housing **2105**. FIG. **21**B depicts an exploded view of connector **2100** of FIG. **21**A. Push-pull tab **2130** has a receiving surface **2132**, which during use of connector **2100** provides a surface over which retainer **2111** can slide across during tab movement. Extending from the housing back portion is a retainer **2111** which may include a pair of retaining clips, as shown, or any other structure configured to retain the push-pull tab **2130**, as shown in FIG. **21**B. FIG. **21**C depicts connector **2100** showing a section view cut given by the arrows and broken line near the proximal end of connector **2100**. Optionally, when the retainer **2111** includes clips, the clips may be hook-shaped as seen in the cross-sectional view of FIG. **21**D. As shown in FIG. **21**D, receiving surface **2132** may be a recess with a protrusion along the edge that engages the hook-shaped edge of the clips.

FIG. **22**A through FIG. **22**E depicts the operation of polarity change for connector **2100** of FIG. **21**A-FIG. **21**D. FIG. **22**A depicts connector **2100** with pull-push tab clips **2135** (opposing side not shown) engaged around connector. To operate connector **2100**, user can move push-pull tab **2130** forward or toward front of connector or backward or toward rear of connector, and as describe in FIG. **21**B above tab moves along connector receiving surface **2123**. This engages or releases connector **2100** from a receptacle as is known in the art. To change the polarity of connector **2100** from the polarity depicted in FIG. **22**A to the second, opposite polarity of FIG. **22**E, the retainer **2111** is removed from receiving surface **2132**. Referring to FIG. **22**B, lifting push-pull tab **2130** in direction of up-arrow, separates retainer **2111** from receiving surface. As shown in FIG. **22**C, push-pull tab clips separate from the connector as the retainer is removed. Continuing with FIG. **22**C, push-pull tab **2130** is moved to the opposite housing exterior wall in FIG. **22**C. FIG. **22**D depicts receiving surface **2132** engages with the retainer **2111**. In FIG. **21**E the assembled connector **2100**R having the opposite polarity to the connector of FIG. **22**A is depicted, fully assembled. Retainer **2111** is in contact with receiving surface **2132**, and push-pull tab **2130** is secured to connector body, as shown in FIG. **22**E.

In the above detailed description, reference is made to the accompanying drawings, which form a part hereof. In the drawings, similar symbols typically identify similar components, unless context dictates otherwise. The illustrative embodiments described in the detailed description, drawings, and claims are not meant to be limiting. Other embodiments may be used, and other changes may be made, without departing from the spirit or scope of the subject matter presented herein. It will be readily understood that the aspects of the present disclosure, as generally described herein, and illustrated in the Figures, can be arranged, substituted, combined, separated, and designed in a wide variety of different configurations, all of which are explicitly contemplated herein.

The present disclosure is not to be limited in terms of the particular embodiments described in this application, which are intended as illustrations of various aspects. Many modifications and variations can be made without departing from its spirit and scope, as will be apparent to those skilled in the art. Functionally equivalent methods and apparatuses within the scope of the disclosure, in addition to those enumerated herein, will be apparent to those skilled in the art from the foregoing descriptions. Such modifications and variations are intended to fall within the scope of the appended claims. The present disclosure is to be limited only by the terms of the appended claims, along with the full scope of equivalents to which such claims are entitled. It is to be understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to be limiting.

With respect to the use of substantially any plural and/or singular terms herein, those having skill in the art can translate from the plural to the singular and/or from the singular to the plural as is appropriate to the context and/or application. The various singular/plural permutations may be expressly set forth herein for sake of clarity.

It will be understood by those within the art that, in general, terms used herein, and especially in the appended claims (for example, bodies of the appended claims) are generally intended as "open" terms (for example, the term "including" should be interpreted as "including but not limited to," the term "having" should be interpreted as "having at least," the term "includes" should be interpreted as "includes but is not limited to," et cetera). While various compositions, methods, and devices are described in terms of "comprising" various components or steps (interpreted as meaning "including, but not limited to"), the compositions, methods, and devices can also "consist essentially of" or "consist of" the various components and steps, and such terminology should be interpreted as defining essentially closed-member groups. It will be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present. For example, as an aid to understanding, the following appended claims may contain usage of the introductory phrases "at least one" and "one or more" to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles "a" or "an" limits any particular claim containing such introduced claim recitation to embodiments containing only one such recitation, even when the same claim includes the introductory phrases "one or more" or "at least one" and indefinite articles such as "a" or "an" (for example, "a" and/or "an" should be interpreted to mean "at least one" or "one or more"); the same holds true for the use of definite articles used to introduce claim recitations. In addition, even if a specific number of an introduced claim recitation is explicitly recited, those skilled in the art will recognize that such recitation should be interpreted to mean at least the recited number (for example, the bare recitation of "two recitations," without other modifiers, means at least two recitations, or two or more recitations). Furthermore, in those instances where a convention analogous to "at least one of A, B, and C, et cetera" is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (for example, "a system having at least one of A, B, and C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, et cetera). In those instances where a convention analogous to "at least one of A, B, or C, et cetera" is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (for example, "a system having at least one of A, B, or C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, et cetera). It will be further understood by those within the art that virtually any disjunctive word and/or phrase presenting two or more alternative terms, whether in the description, claims, or drawings, should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms. For example, the phrase "A or B" will be understood to include the possibilities of "A" or "B" or "A and B."

In addition, where features or aspects of the disclosure are described in terms of Markush groups, those skilled in the art will recognize that the disclosure is also thereby described in terms of any individual member or subgroup of members of the Markush group.

As will be understood by one skilled in the art, for any and all purposes, such as in terms of providing a written description, all ranges disclosed herein also encompass any and all possible subranges and combinations of subranges thereof. Any listed range can be easily recognized as sufficiently describing and enabling the same range being broken down into at least equal halves, thirds, quarters, fifths, tenths, et cetera As a non-limiting example, each range discussed herein can be readily broken down into a lower third, middle third and upper third, et cetera As will also be understood by one skilled in the art all language such as "up to," "at least," and the like include the number recited and refer to ranges which can be subsequently broken down into subranges as discussed above. Finally, as will be understood by one skilled in the art, a range includes each individual member. Thus, for example, a group having 1-3 cells refers to groups having 1, 2, or 3 cells. Similarly, a group having 1-5 cells refers to groups having 1, 2, 3, 4, or 5 cells, and so forth.

Various of the above-disclosed and other features and functions, or alternatives thereof, may be combined into many other different systems or applications. Various presently unforeseen or unanticipated alternatives, modifications, variations or improvements therein may be subsequently made by those skilled in the art, each of which is also intended to be encompassed by the disclosed embodiments.

The invention claimed is:

1. A fiber optic connector comprising:

at least first and second optical ferrules;

a connector housing having a longitudinal axis and comprising an exterior portion at least partially surrounding the first and second optical ferrules such that the exterior portion circumscribes a space in which each of the first and second optical ferrules are received, the exterior portion comprising a first exterior wall and a second exterior wall on an opposite side of the space from the first exterior wall;

a latch coupling positioned on each of the first and second exterior walls of the connector housing;

a removable latch for engaging either of the first and second exterior wall latch couplings on the connector housing, whereby the removable latch couples to the respective latch coupling;

wherein each latch coupling comprises a groove extending along the axis and having an open axial end; and

wherein the removable latch comprises a protrusion for being inserted into the open axial end of the groove by movement relative to the housing along the axis.

2. The fiber optic connector of claim **1**, wherein the protrusion is movable along the longitudinal axis in each groove with respect to the connector housing.

3. The fiber optic connector of claim **1**, wherein the removable latch comprises a base portion and a depressible latch arm connected to the base portion.

4. The fiber optic connector of claim **3**, wherein the depressible latch arm has a front end portion connected to the base portion, a free rear end portion spaced apart from the front end portion along the axis, and an outward facing longitudinal surface extending along the axis from the front end portion to the free rear end portion.

5. The fiber optic connector of claim **4**, wherein the free end portion of the depressible latch arm is configured to be received in an opening of a receptacle and comprises a rearward facing surface that is configured to engage the receptacle when received in the opening to inhibit removal of the fiber optic connector from the receptacle.

6. The fiber optic connector of claim **5**, wherein the free rear end portion of the depressible latch arm is raised relative to the front end portion and wherein the removable latch is bendable such that the free rear end portion can be depressed toward the base portion to remove the free rear end portion from the opening and unlatch the fiber optic connector from the receptacle.

7. The fiber optic connector of claim **6**, further comprising a remote release including an elongate front section configured to extend longitudinally along the connector housing and engage the depressible latch arm and an elongate rear section extending rearward from the elongate front section, the elongate front section of the remote release being slidably connected to the removable latch and the connector housing such that the elongate front section can move rearward relative to removable latch and the connector housing.

8. The fiber optic connector of claim **7**, wherein the elongate front section comprises an opening configured to receive the depressible latch arm.

9. The fiber optic connector of claim **8**, wherein the elongate front section comprises a front end portion having a rearward facing surface defining a front end of the opening, the rearward facing surface being configured to oppose the outward facing surface of the depressible latch arm when the depressible latch arm is received in the opening.

10. The fiber optic connector of claim **9**, wherein the free rear end portion of the depressible latch arm is configured to be raised in relation to the front end portion of the elongate front section when the depressible latch arm is received in the opening.

11. The fiber optic connector of claim **10**, wherein the front end portion of the elongate front section is configured to slide rearward along the outward facing surface of the depressible latch arm when the elongate front section moves rearward to depress the depressible latch arm.

12. The fiber optic connector as set forth in claim **1**, wherein the connector housing comprises a single front body and a single back body.

13. The fiber optic connector as set forth in claim **12**, further comprising first and second ferrule springs received on the first and second optical ferrules, respectively.

14. The fiber optic connector as set forth in claim **13**, wherein each of the first and second optical ferrules comprises a ferrule flange having a forward facing surface and the single front body comprises a transverse wall configured to simultaneously engage the forward facing surfaces of the first and second optical ferrule flanges.

15. The fiber optic connector as set forth in claim **14**, wherein the single back body is configured to attach to the single front body such that the back body simultaneously compresses each of the first and second ferrule springs between the back body and the first and second ferrule flanges engaged with the transverse wall.

16. The fiber optic connector as set forth in claim **1**, wherein the first and second optical ferrules have a pitch less than 6.25 mm.

17. The fiber optic connector as set forth in claim **1**, wherein the first and second optical ferrules have a pitch less than 5.25 mm.

18. The fiber optic connector as set forth in claim **1**, wherein the first and second optical ferrules have a pitch of about 4.8 mm or less.

19. The fiber optic connector as set forth in claim **1**, wherein the first and second optical ferrules are configured to receive first and second optical fibers, wherein the fiber optic connector further comprises a single cable boot through which the first and second optical fibers are passable to the first and second optical ferrules.

20. A reversible polarity fiber optic connector comprising:

at least first and second optical ferrules, each of the first and second ferrules comprising a ferrule flange;

first and second ferrule springs received on the first and second optical ferrules, respectively;

a connector housing comprising an exterior portion at least partially surrounding the first and second optical ferrules such that the exterior portion circumscribes a space in which each of the first and second optical ferrules are received, the exterior portion comprising a first exterior wall and a second exterior wall on an opposite side of the space from the first exterior wall, the connector housing comprising a single front body and a single back body, the single front body comprising a transverse wall configured to simultaneously engage the ferrule flanges of the first and second optical ferrules, the single back body being configured to attach to the single front body such that the back body simultaneously compresses each of the first and second ferrule springs between the back body and the first and second ferrule flanges engageable with the transverse wall;

a latch coupling positioned on each of the first and second exterior walls of the housing;

a removable latch for engaging either of the first and second exterior wall latch couplings on the connector housing;

wherein positioning the removable latch on the first exterior wall of the connector housing yields a fiber optic connector with a first polarity and positioning the removable latch on the second exterior wall of the housing yields a fiber optic connector with a second polarity, the second polarity being opposite to the first polarity.

21. The reversible polarity fiber optic connector as set forth in claim **20**, wherein each latch coupling comprises a groove extending along the axis and having an open axial end.

22. The reversible polarity fiber optic connector as set forth in claim **21**, wherein the removable latch is configured for being inserted into the open axial end of each groove by movement relative to the housing along the axis.

23. The reversible polarity fiber optic connector of claim **20**, wherein the removable latch comprises a base portion and a depressible latch arm connected to the base portion.

24. The reversible polarity fiber optic connector of claim **23**, wherein the depressible latch arm has a front end portion connected to the base portion, a free rear end portion spaced apart from the front end portion along the axis, and an outward facing longitudinal surface extending along the axis from the front end portion to the free rear end portion.

25. The reversible polarity fiber optic connector of claim **24**, wherein the free end portion of the latch arm is configured to be received in an opening of a receptacle and comprises a rearward facing surface that is configured to engage the receptacle when received in the opening to inhibit removal of the reversible polarity fiber optic connector from the receptacle.

26. The reversible polarity fiber optic connector of claim **25**, wherein the free rear end portion of the depressible latch arm is raised relative to the front end portion and wherein the removable latch is bendable such that the free rear end portion can be depressed toward the base portion to remove the free rear end portion from the opening and unlatch the reversible polarity fiber optic connector from the receptacle.

27. The reversible polarity fiber optic connector of claim **26**, further comprising a remote release including an elongate front section configured to extend longitudinally along the connector housing and engage the depressible latch arm and an elongate rear section extending rearward from the elongate front section, the elongate front section of the remote release being slidably connected to the removable latch and the connector housing such that the elongate front section can move rearward relative to removable latch and the connector housing.

28. The reversible polarity fiber optic connector of claim **27**, wherein the elongate front section comprises an opening configured to receive the depressible latch arm.

29. The reversible polarity fiber optic connector of claim **28**, wherein the elongate front section comprises a front end portion having a rearward facing surface defining a front end of the opening, the rearward facing surface being configured to oppose the outward facing surface of the depressible latch arm when the depressible latch arm is received in the opening.

30. The reversible polarity fiber optic connector of claim **29**, wherein the free rear end portion of the depressible latch arm is configured to be raised in relation to the front end portion of the elongate front section when the depressible latch arm is received in the opening.

31. The reversible polarity fiber optic connector of claim **30**, wherein the front end portion of the elongate front section is configured to slide rearward along the outward facing surface when the elongate front section moves rearward to depress the depressible latch arm.

32. The reversible polarity fiber optic connector as set forth in claim **20**, wherein the first and second optical ferrules have a pitch less than 6.25 mm.

33. The reversible polarity fiber optic connector as set forth in claim **20**, wherein the first and second optical ferrules have a pitch less than 5.25 mm.

34. The fiber optic connector as set forth in claim **20**, wherein the first and second optical ferrules have a pitch of about 4.8 mm or less.

35. The fiber optic connector as set forth in claim **20**, wherein the first and second optical ferrules are configured to receive first and second optical fibers, wherein the fiber optic connector further comprises a single cable boot through which the first and second optical fibers are passable to the first and second optical ferrules.

36. A fiber optic connector comprising:

at least first and second optical ferrules;

a connector housing comprising an exterior portion at least partially surrounding the first and second optical ferrules such that the exterior portion circumscribes a space in which each of the first and second optical ferrules are received, the exterior portion comprising a first exterior wall and a second exterior wall on an opposite side of the space from the first exterior wall;

a removable latch configured to selectively and releasably couple to each of the first and second exterior walls of the housing, the removable latch comprising a base portion and a depressible latch arm connected to the base portion, the depressible latch arm having a font end portion connected to the base portion, a free rear end portion spaced apart from the front end portion along the axis, and an outward facing longitudinal surface extending along the axis from the front end portion to the free rear end portion, the free rear end portion of the latch arm being configured to be received in an opening of a receptacle and comprising a rearward facing surface that is configured to engage the receptacle when received in the opening to inhibit removal of the fiber optic connector from the receptacle, the free rear end portion of the depressible latch arm being raised relative to the front end portion, the removable latch being bendable such that the free rear end portion can be depressed toward the base portion to remove the free rear end portion from the opening and unlatch the fiber optic connector from the receptacle; and

a remote release including an elongate front section configured to extend longitudinally along the connector housing and engage the depressible latch arm and an elongate rear section extending rearward from the elongate front section, the elongate front section of the remote release being slidably connected to the removable latch and the connector housing such that the elongate front section can move rearward relative to removable latch and the connector housing, the elongate front section comprising an opening configured to receive the depressible latch arm, the elongate front section comprising a front end portion having a rearward facing surface defining a front end of the opening, the rearward facing surface being configured to oppose the outward facing surface of the depressible latch arm when the depressible latch arm is received in the opening;

wherein the free rear end portion of the depressible latch arm is configured to be raised in relation to the front end portion of the elongate front section when the depressible latch arm is received in the opening,

wherein the front end portion of the elongate front section is configured to slide rearward along the outward facing surface when the elongate front section moves rearward to depress the depressible latch arm.

37. The fiber optic connector as set forth in claim **36**, wherein the first and second optical ferrules have a pitch less than 6.25 mm.

38. The fiber optic connector as set forth in claim **37**, wherein the connector housing comprises a single front body and a single back body.

39. The fiber optic connector as set forth in claim **38**, further comprising first and second ferrule springs received on the first and second ferrules, respectively.

40. The fiber optic connector as set forth in claim **39**, wherein each of the first and second ferrules comprises a ferrule flange having a forward facing surface and the single front body comprises a transverse wall configured to simultaneously engage the forward facing surfaces of the first and second optical ferrule flanges.

41. The fiber optic connector as set forth in claim **40**, wherein the single back body is configured to attach to the single front body such that the back body simultaneously compresses each of the first and second ferrule springs between the back body and the first and second ferrule flanges engaged with the transverse wall.

42. The fiber optic connector as set forth in claim **41**, wherein each of the first and second exterior walls of the connector housing includes a groove extending along the axis and having an open axial end.

43. The fiber optic connector as set forth in claim **42**, wherein the removable latch is configured for being inserted into the open axial end of each groove by movement relative to the housing along the axis.

44. The fiber optic connector as set forth in claim **43**, wherein the pitch is less than 5.25 mm.

45. The fiber optic connector as set forth in claim **44**, wherein the pitch is 4.8 mm or less.

46. The fiber optic connector as set forth in claim **36**, wherein each of the first and second exterior walls of the connector housing includes a groove extending along the axis and having an open axial end.

47. The reversible polarity fiber optic connector as set forth in claim **46**, wherein the removable latch is configured for being inserted into the open axial end of each groove by movement relative to the housing along the axis.

48. The fiber optic connector as set forth in claim **47**, wherein the first and second optical ferrules have a pitch less than 6.25 mm.

49. The fiber optic connector as set forth in claim **48**, wherein the pitch is less than 5.25 mm.

50. The fiber optic connector as set forth in claim **49**, wherein the pitch is 4.8 mm or less.

51. The fiber optic connector as set forth in claim **36**, wherein the first and second optical ferrules have a pitch less than 5.25 mm.

52. The fiber optic connector as set forth in claim **51**, wherein the first and second optical ferrules have a pitch of 4.8 mm or less.

53. The fiber optic connector as set forth in claim **36**, wherein the first and second optical ferrules are configured to receive first and second optical fibers, wherein the fiber optic connector further comprises a single cable boot through which the first and second optical fibers are passable to the first and second optical ferrules.

* * * * *

EXHIBIT H

US011061190B2

(12) **United States Patent**
Takano et al.

(10) **Patent No.: US 11,061,190 B2**
(45) **Date of Patent: *Jul. 13, 2021**

(54) **SMALL FORM FACTOR FIBER OPTIC CONNECTOR WITH MULTI-PURPOSE BOOT ASSEMBLY**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **16/782,196**

(22) Filed: **Feb. 5, 2020**

(65) **Prior Publication Data**

US 2020/0209487 A1 Jul. 2, 2020

Related U.S. Application Data

(60) Division of application No. 16/368,828, filed on Mar. 28, 2019, now Pat. No. 10,705,300, and a (Continued)

(51) **Int. Cl.**
G02B 6/38 (2006.01)
G02B 6/42 (2006.01)
G02B 6/40 (2006.01)

(52) **U.S. Cl.**
CPC ***G02B 6/387*** (2013.01); ***G02B 6/3825*** (2013.01); ***G02B 6/3879*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC G02B 6/378
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

585,194 A 6/1897 Favor
678,283 A 7/1901 Schaefer
(Continued)

FOREIGN PATENT DOCUMENTS

CA 2495693 4/2004
CN 2836038 Y 11/2006
(Continued)

OTHER PUBLICATIONS

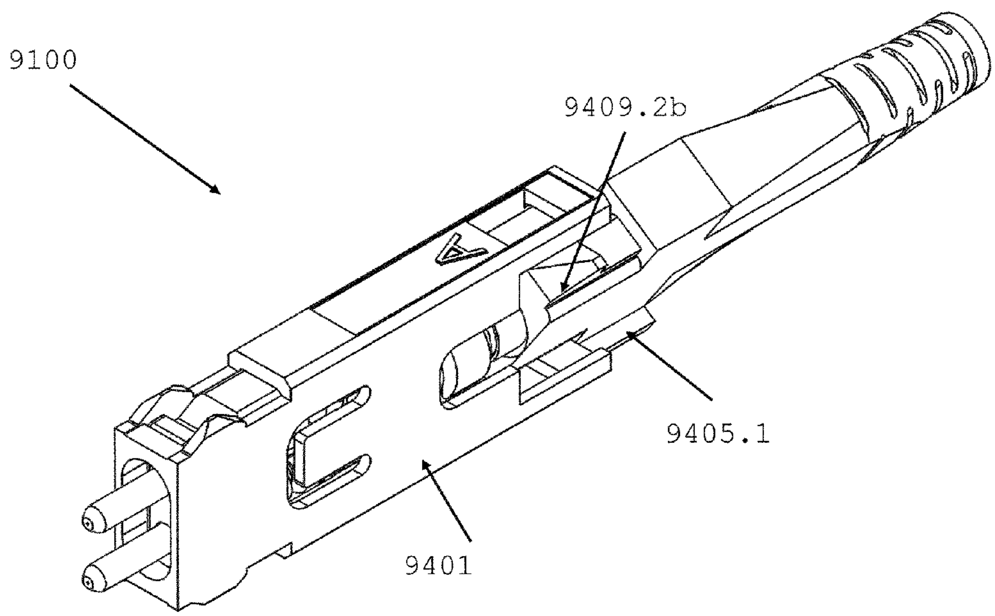
PCT/US2018/062406 International Search Report dated Mar. 18, 2019.
(Continued)

Primary Examiner — Eric Wong

(57) **ABSTRACT**

An optical connector holding two or more LC-type optical ferrules is provided. The optical connector includes an outer body, an inner front body accommodating the two or more LC-type optical ferrules, ferrule springs for urging the optical ferrules towards a mating connection, and a back body for supporting the ferrule springs. A removable inner front body for polarity change is disclosed. A multi-purpose rotatable boot assembly for polarity change is disclosed. The multi-purpose boot assembly can be pushed and pulled to insert and remove the micro connector from an adapter receptacle.

20 Claims, 32 Drawing Sheets



Related U.S. Application Data

continuation of application No. 16/103,555, filed on Aug. 14, 2018, now Pat. No. 10,718,911, which is a continuation-in-part of application No. 16/035,691, filed on Jul. 15, 2018, now Pat. No. 10,281,668.

(60) Provisional application No. 62/649,539, filed on Mar. 28, 2018, provisional application No. 62/588,276, filed on Nov. 17, 2017, provisional application No. 62/549,655, filed on Aug. 24, 2017, provisional application No. 62/532,710, filed on Jul. 14, 2017.

(52) **U.S. Cl.**
CPC ***G02B 6/3887*** (2013.01); ***G02B 6/3893*** (2013.01); ***G02B 6/403*** (2013.01); ***G02B 6/406*** (2013.01); ***G02B 6/4292*** (2013.01); *G02B 6/3821* (2013.01)

(56) **References Cited**

U.S. PATENT DOCUMENTS

681,132 A 8/1901 Norton
3,721,945 A 3/1973 Hults
4,150,790 A 4/1979 Potter
4,240,695 A 12/1980 Evans
4,327,964 A 5/1982 Haesly et al.
4,478,473 A 10/1984 Frear
4,762,388 A 8/1988 Tanaka
4,764,129 A 8/1988 Jones
4,840,451 A 6/1989 Sampson
4,872,736 A 10/1989 Myers
4,979,792 A 12/1990 Weber
5,026,138 A 6/1991 Boudreau
5,031,981 A 7/1991 Peterson
5,041,025 A 8/1991 Haitmanek
5,073,045 A 12/1991 Abendschein
D323,143 S 1/1992 Ohkura et al.
5,101,463 A 3/1992 Cubukciyan
5,146,813 A 9/1992 Stanfill, Jr.
5,159,652 A 10/1992 Grassin D'Alphonse
5,212,752 A 5/1993 Stephenson et al.
5,265,181 A 11/1993 Chang
5,289,554 A 2/1994 Cubukciyan
5,315,679 A 5/1994 Baldwin
5,317,663 A 5/1994 Beard
5,321,784 A 6/1994 Cubukciyan
5,335,301 A 8/1994 Newman
5,348,487 A 9/1994 Marazzi
5,418,875 A 5/1995 Nakano
5,444,806 A 8/1995 de Marchi
5,481,634 A 1/1996 Anderson
5,506,922 A 4/1996 Grois
5,521,997 A 5/1996 Rovenolt
5,570,445 A 10/1996 Chou
5,588,079 A 12/1996 Tanabe
5,602,951 A 2/1997 Shiota
5,684,903 A 11/1997 Kyomasu
5,687,268 A 11/1997 Stephenson
5,781,681 A 7/1998 Manning
5,845,036 A 12/1998 De Marchi
5,862,282 A 1/1999 Matsuura
5,915,987 A 6/1999 Reed
5,930,426 A 7/1999 Harting
5,937,130 A 8/1999 Amberg
5,953,473 A 9/1999 Shimotsu et al.
5,956,444 A 9/1999 Duda et al.
5,971,626 A 10/1999 Knodell
6,041,155 A 3/2000 Anderson
6,049,040 A 4/2000 Biles
6,095,862 A 8/2000 Doye
6,134,370 A 10/2000 Childers
6,178,283 B1 1/2001 Weigel
RE37,080 E 3/2001 Stephenson
6,206,577 B1 3/2001 Hall, III
6,206,581 B1 3/2001 Driscoll
6,227,717 B1 5/2001 Ott
6,238,104 B1 5/2001 Yamakawa
6,240,228 B1 5/2001 Chen
6,247,849 B1 6/2001 Liu
6,250,817 B1 6/2001 Lampert
6,276,840 B1 8/2001 Weiss
6,318,903 B1 11/2001 Andrews
6,364,537 B1 4/2002 Maynard
6,379,052 B1 4/2002 de Jong
6,422,759 B1 7/2002 Kevern
6,447,170 B1 9/2002 Takahashi et al.
6,450,695 B1 9/2002 Matsumoto
6,461,054 B1 10/2002 Iwase
6,471,412 B1 10/2002 Belenkiy
6,478,472 B1 11/2002 Anderson
6,485,194 B1 11/2002 Shirakawa
6,527,450 B1 3/2003 Miyachi
6,530,696 B1 3/2003 Ueda
6,551,117 B2 4/2003 Poplawski
6,565,262 B2 5/2003 Childers
6,572,276 B1 6/2003 Theis
6,579,014 B2 6/2003 Melton
6,585,194 B1 7/2003 Brushwood
6,623,172 B1 9/2003 de Jong et al.
6,634,796 B2 10/2003 de Jong
6,634,801 B1 10/2003 Waldron
6,648,520 B2 11/2003 McDonald
6,668,113 B2 12/2003 Togami
6,682,228 B2 1/2004 Rathnam
6,685,362 B2 2/2004 Burkholder
6,695,486 B1 2/2004 Falkenberg
6,817,272 B2 11/2004 Holland
6,854,894 B1 2/2005 Yunker
6,869,227 B2 3/2005 Del Grosso
6,872,039 B2 3/2005 Baus
6,935,789 B2 8/2005 Gross, III
7,036,993 B2 5/2006 Luther et al.
7,052,186 B1 5/2006 Bates
7,077,576 B2 7/2006 Luther
7,090,406 B2 8/2006 Melton et al.
7,090,407 B2 8/2006 Melton et al.
7,091,421 B2 8/2006 Kukita
7,111,990 B2 9/2006 Melton et al.
7,113,679 B2 9/2006 Melton et al.
D533,504 S 12/2006 Lee
D534,124 S 12/2006 Taguchi
7,150,567 B1 12/2006 Luther
7,153,041 B2 12/2006 Mine
7,198,409 B2 4/2007 Smith
7,207,724 B2 4/2007 Gurreri
D543,124 S 5/2007 Raatikainen
D543,146 S 5/2007 Chen et al.
7,258,493 B2 8/2007 Milette
7,264,402 B2 9/2007 Theuerkorn
7,281,859 B2 10/2007 Mudd
7,297,013 B2 11/2007 Caveney et al.
D558,675 S 1/2008 Chien et al.
7,315,682 B1 1/2008 En Lin
7,325,976 B2 2/2008 Gurreri
7,325,980 B2 2/2008 Pepe
7,329,137 B2 2/2008 Martin
7,331,718 B2 2/2008 Yazaki
7,354,291 B2 4/2008 Caveney
7,371,082 B2 5/2008 Zimmel
7,387,447 B2 6/2008 Mudd
7,390,203 B2 6/2008 Murano
D572,661 S 7/2008 En Lin et al.
7,431,604 B2 10/2008 Waters
7,463,803 B2 12/2008 Cody
7,465,180 B2 12/2008 Kusuda
7,473,124 B1 1/2009 Briant
7,504,666 B2 3/2009 Vittu
7,507,103 B1 3/2009 Phillips et al.
7,510,335 B1 3/2009 Su
7,513,695 B1 4/2009 Lin
7,534,128 B2 5/2009 Caveney
7,540,666 B2 6/2009 Luther
7,561,775 B2 7/2009 Lin et al.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,588,373	B1	9/2009	Sato	
7,591,595	B2	9/2009	Lu	
7,594,766	B1	9/2009	Sasser	
7,641,398	B2	1/2010	O'Riorden	
7,651,361	B2	1/2010	Henry	
7,695,199	B2	4/2010	Teo	
7,699,533	B2	4/2010	Milette	
7,712,970	B1	5/2010	Lee	
7,717,625	B2	5/2010	Margolin	
7,785,019	B2	8/2010	Lewallen et al.	
7,824,113	B2	11/2010	Wong	
7,837,395	B2	11/2010	Lin	
D641,708	S	7/2011	Yamauchi	
8,083,450	B1	12/2011	Smith	
8,152,385	B2	4/2012	de Jong	
8,186,890	B2	5/2012	Lu	
8,192,091	B2	6/2012	Hsu	
8,202,009	B2	6/2012	Lin	
8,221,007	B2	7/2012	Peterhans	
8,251,733	B2	8/2012	Wu	
8,267,595	B2	9/2012	Lin	
8,270,796	B2	9/2012	Nhep	
8,408,815	B2	4/2013	Lin	
8,414,196	B2	4/2013	Lu	
8,465,317	B2	6/2013	Gniadek	
8,534,928	B2	9/2013	Cooke	
8,550,728	B2	10/2013	Takahashi	
8,556,645	B2	10/2013	Crain	
8,559,781	B2	10/2013	Childers	
8,622,634	B2	1/2014	Arnold	
8,636,424	B2	1/2014	Kuffel	
8,641,293	B2	2/2014	Lin et al.	
8,651,749	B2	2/2014	Dainese Júnior	
8,676,022	B2	3/2014	Jones	
8,678,670	B2	3/2014	Takahashi	
8,727,638	B2	5/2014	Lee	
8,757,894	B2	6/2014	Katoh	
8,764,308	B2	7/2014	Irwin	
8,770,863	B2	7/2014	Cooke	
8,869,661	B2	10/2014	Opstad	
8,998,305	B2	4/2015	Obata et al.	
9,028,270	B1	5/2015	Vanderwoud	
9,052,474	B2	6/2015	Jiang	
9,063,296	B2	6/2015	Dong	
9,250,402	B2	2/2016	Ishii	
9,310,569	B2	4/2016	Lee	
9,366,829	B2	6/2016	Czosnowski	
9,411,110	B2	8/2016	Barnette, Jr.	
9,448,370	B2	9/2016	Xue	
9,465,172	B2	10/2016	Shih	
9,485,194	B2	11/2016	Singla et al.	
9,486,136	B2	11/2016	Bone	
9,494,744	B2	11/2016	de Jong	
9,548,557	B2	1/2017	Liu	
9,551,842	B2	1/2017	Theuerkorn	
9,557,495	B2	1/2017	Raven	
9,568,686	B2	2/2017	Fewkes	
9,581,768	B1	2/2017	Baca	
9,599,778	B2	3/2017	Wong et al.	
9,658,409	B2	5/2017	Gniadek	
9,678,283	B1	6/2017	Chang	
9,684,130	B2 *	6/2017	Veatch	G02B 6/3831
9,684,313	B2	6/2017	Chajec	
9,709,753	B1	7/2017	Chang	
9,778,425	B2	10/2017	Nguyen	
9,798,084	B2	10/2017	Verslegers et al.	
9,829,644	B2	11/2017	Nguyen et al.	
9,829,645	B2	11/2017	Good	
9,829,653	B1	11/2017	Nishiguchi	
9,869,825	B2	1/2018	Bailey	
9,880,361	B2	1/2018	Childers	
9,946,035	B2	4/2018	Gustafson	
9,971,103	B2	5/2018	De Jong et al.	
9,989,711	B2	6/2018	Ott	
10,031,296	B2	7/2018	Good	
10,067,301	B2	9/2018	Murray	
10,107,972	B1	10/2018	Gniadek	
10,114,180	B2	10/2018	Suzic	
10,146,011	B2	12/2018	Nhep	
10,185,099	B2	1/2019	Chang et al.	
10,444,444	B2	10/2019	Ma et al.	
2002/0168148	A1	11/2002	Gilliland	
2002/0172467	A1	11/2002	Anderson et al.	
2002/0191919	A1	12/2002	Nolan	
2003/0053787	A1	3/2003	Lee	
2003/0063862	A1	4/2003	Fillion	
2003/0157825	A1	8/2003	Kane	
2004/0052473	A1	3/2004	Seo	
2004/0109646	A1	6/2004	Anderson	
2004/0136657	A1	7/2004	Ngo	
2004/0141693	A1	7/2004	Szilagyi	
2004/0161958	A1	8/2004	Togami	
2004/0234209	A1	11/2004	Cox	
2004/0247252	A1	12/2004	Ehrenreich	
2005/0036744	A1	2/2005	Caveney	
2005/0111796	A1	5/2005	Matasek	
2005/0141817	A1	6/2005	Yazaki et al.	
2005/0207709	A1	9/2005	Del Grosso et al.	
2006/0013539	A1	1/2006	Thaler	
2006/0076061	A1	4/2006	Bush	
2006/0089049	A1	4/2006	Sedor	
2006/0127025	A1	6/2006	Haberman	
2006/0140453	A1	6/2006	Geng	
2006/0153503	A1	7/2006	Suzuki	
2006/0160429	A1	7/2006	Dawiedczyk	
2006/0193562	A1	8/2006	Theuerkorn	
2006/0269194	A1	11/2006	Luther et al.	
2006/0274411	A1	12/2006	Yamauchi	
2007/0025665	A1	2/2007	Dean	
2007/0028409	A1	2/2007	Yamada	
2007/0079854	A1	4/2007	You	
2007/0098329	A1	5/2007	Shimoji	
2007/0149028	A1	6/2007	Yu	
2007/0149062	A1	6/2007	Long	
2007/0230874	A1	10/2007	Lin	
2007/0232115	A1	10/2007	Burke	
2007/0243749	A1	10/2007	Wu	
2008/0008430	A1	1/2008	Kewitsch	
2008/0012986	A1	1/2008	Tai	
2008/0044137	A1	2/2008	Luther	
2008/0056647	A1	3/2008	Margolin	
2008/0064334	A1	3/2008	Hamadi	
2008/0069501	A1	3/2008	Mudd et al.	
2008/0101757	A1	5/2008	Lin et al.	
2008/0226237	A1	9/2008	O'Riorden	
2008/0267566	A1	10/2008	En Lin	
2009/0022457	A1	1/2009	de Jong	
2009/0028507	A1	1/2009	Jones	
2009/0047818	A1	2/2009	Irwin	
2009/0092360	A1	4/2009	Lin et al.	
2009/0135787	A1	5/2009	Uemura et al.	
2009/0176401	A1	7/2009	Gu	
2009/0196555	A1	8/2009	Lin	
2009/0214162	A1	8/2009	O'Riorden	
2009/0290938	A1	11/2009	Asaoka	
2010/0034502	A1	2/2010	Lu et al.	
2010/0054668	A1	3/2010	Nelson	
2010/0061069	A1	3/2010	Cole	
2010/0092136	A1	4/2010	Nhep	
2010/0220961	A1	9/2010	de Jong	
2010/0239220	A1	9/2010	Lin et al.	
2010/0247041	A1	9/2010	Szilagyi	
2010/0267742	A1	10/2010	Plate	
2010/0284656	A1	11/2010	Morra	
2010/0322561	A1	12/2010	Lin et al.	
2011/0044588	A1	2/2011	Larson	
2011/0045683	A1	2/2011	Foung	
2011/0058773	A1	3/2011	Peterhans	
2011/0131801	A1	6/2011	Nelson	
2011/0155810	A1	6/2011	Taniguchi	
2011/0177710	A1	7/2011	Tobey	
2011/0239220	A1	9/2011	Gibson	
2011/0299814	A1 *	12/2011	Nakagawa	G02B 6/3879 385/78

(56) **References Cited**

U.S. PATENT DOCUMENTS

2012/0099822	A1	4/2012	Kuffel et al.
2012/0155810	A1	6/2012	Nakagawa
2012/0162385	A1	6/2012	Park et al.
2012/0189260	A1	7/2012	Kowalczyk
2012/0237177	A1	9/2012	Minota
2012/0259429	A1	10/2012	Han et al.
2012/0269485	A1	10/2012	Haley
2012/0301080	A1	11/2012	Gniadek
2012/0308183	A1	12/2012	Irwin
2012/0328248	A1	12/2012	Larson
2013/0019423	A1	1/2013	Srutkowski
2013/0071067	A1	3/2013	Lin
2013/0089995	A1	4/2013	Gniadek et al.
2013/0094816	A1	4/2013	Lin
2013/0101258	A1	4/2013	Hikosaka
2013/0121653	A1	5/2013	Shitama
2013/0170797	A1	7/2013	Ott
2013/0183012	A1	7/2013	Cabanne Lopez
2013/0216185	A1	8/2013	Klavuhn
2013/0308915	A1	11/2013	Buff
2013/0322825	A1	12/2013	Cooke et al.
2014/0016901	A1	1/2014	Lambourn
2014/0023322	A1	1/2014	Gniadek
2014/0028527	A1	1/2014	Becker et al.
2014/0050446	A1	2/2014	Chang
2014/0056562	A1	2/2014	Limbert
2014/0133808	A1	5/2014	Hill
2014/0169727	A1	6/2014	Veatch
2014/0182351	A1	7/2014	Miller et al.
2014/0219621	A1	8/2014	Barnette, Jr.
2014/0226946	A1	8/2014	Cooke
2014/0241644	A1	8/2014	Kang
2014/0241678	A1	8/2014	Bringuier
2014/0241688	A1	8/2014	Isenhour
2014/0334780	A1	11/2014	Nguyen
2014/0348477	A1	11/2014	Chang
2015/0003788	A1	1/2015	Chen
2015/0111417	A1	4/2015	Vanderwoud
2015/0191024	A1	4/2015	Tu et al.
2015/0177463	A1	6/2015	Lee
2015/0198766	A1	7/2015	Takahashi
2015/0212282	A1	7/2015	Lin
2015/0220917	A1	8/2015	Algreatly
2015/0241644	A1	8/2015	Lee
2015/0301294	A1	10/2015	Chang
2015/0331201	A1	11/2015	Takano
2015/0355417	A1	12/2015	Takano
2015/0370021	A1	12/2015	Chan
2015/0378113	A1	12/2015	Good et al.
2016/0116685	A1	4/2016	Wong et al.
2016/0131849	A1	5/2016	Takano
2016/0139343	A1	5/2016	Dean, Jr.
2016/0148741	A1	5/2016	Krtamura
2016/0161681	A1	6/2016	Banal, Jr.
2016/0172852	A1	6/2016	Tamura
2016/0178852	A1	6/2016	Takano et al.
2016/0195682	A1	7/2016	Takano et al.
2016/0231512	A1	8/2016	Seki
2016/0259135	A1	9/2016	Gniadek
2016/0266326	A1	9/2016	Gniadek
2016/0291262	A1	10/2016	Chang et al.
2016/0320572	A1	11/2016	Gniadek
2016/0349458	A1	12/2016	Murray
2016/0370545	A1	12/2016	Jiang
2017/0003458	A1	1/2017	Gniadek
2017/0023746	A1	1/2017	Good
2017/0176691	A1	6/2017	Childers et al.
2017/0205587	A1	7/2017	Chang
2017/0205590	A1	7/2017	Bailey
2017/0205591	A1	7/2017	Takano
2017/0212313	A1	7/2017	Elenabaas
2017/0212316	A1	7/2017	Takano
2017/0254961	A1	9/2017	Kamada
2017/0276275	A1	9/2017	Beemer
2017/0276887	A1	9/2017	Allen
2017/0293088	A1	10/2017	Manes et al.
2017/0293089	A1	10/2017	Gustafson et al.
2017/0343740	A1	11/2017	Nguyen
2018/0128988	A1	5/2018	Chang
2018/0156988	A1	6/2018	Gniadek
2018/0172923	A1	6/2018	Bauco
2018/0217339	A1	8/2018	Ma et al.
2018/0217340	A1	8/2018	Livong et al.
2018/0252872	A1	9/2018	Chen
2018/0341069	A1	11/2018	Takano
2019/0204513	A1	7/2019	Davidson

FOREIGN PATENT DOCUMENTS

CN	201383588	Y	1/2010
CN	202600189	U	12/2012
DE	19507669	A1	9/1996
DE	19507669	C2	10/1998
DE	202006011910	U1	4/2007
DE	102006019335	A1	10/2007
EP	1211537	A2	6/2002
EP	1211537	A3	6/2002
EP	1245980	A2	10/2002
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EP	1566674	A1	8/2005
EP	1245980	B1	6/2006
EP	1074868	B1	9/2007
EP	1566674	B1	5/2009
GB	2111240	A	6/1983
GB	2111240	B	9/1985
JP	2000089059	A	3/2000
JP	03752331	B2	3/2006
JP	2009229545	A	10/2009
JP	2009276493	A	11/2009
JP	04377820	B2	12/2009
KR	2009005382	A	1/2009
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KR	1371686	B1	3/2014
TW	200821653	A	5/2008
WO	WO2001019904	A1	3/2001
WO	WO2001079904	A2	10/2001
WO	WO2001079904	A3	3/2002
WO	WO2004027485	A1	4/2004
WO	WO2006007120	A1	1/2006
WO	2008/11986	A1	9/2008
WO	2009/135787	A1	11/2009
WO	WO2010024851	A2	3/2010
WO	WO2010024851	A3	6/2010
WO	WO2012136702	A1	10/2012
WO	2012/162385	A1	11/2012
WO	2014/182531	A1	11/2014
WO	WO2015103783	A1	7/2015
WO	2015/191024	A1	12/2015
WO	WO2016019993	A1	2/2016
WO	2016/148741	A1	9/2016
WO	WO2019126333	A1	6/2019

OTHER PUBLICATIONS

PCT/US2018/062406 The written Opinion dated Mar. 18, 2019.
PCT/US2018/062405 International Search Report dated Apr. 3, 2019.
PCT/US2018/062405 The written Opinion dated Apr. 3, 2019.
International Search Report and Written Opinion, Application No. PCT/IB2018/056133, dated Jan. 1, 2019, pp. 7.
Non-Final Office Action, U.S. Appl. No. 16/035,695, dated Sep. 28, 2018, pp. 7.
ISR for PCT/US2019/013861, dated Apr. 8, 2019, 3 pages.
WO for PCT/US2019/013861, dated Apr. 8, 2019, 11 pages.
Fiber Optic Connectors and Assemblies Catalog, 2009, Huber & Suhner Fiber Optics, Herisau, Switzerland.
Final Office Action, U.S. Appl. No. 16/035,691, dated Feb. 11, 2019, pp. 8.
International Search Report and Written Opinion for Application No. PCT/US2018/62406 dated Mar. 18, 2019, 12, pages.
International Search Report and Written Opinion for Application No. PCT/US2019/40700 dated Sep. 27, 2019, 12, pages.

(56) **References Cited**

OTHER PUBLICATIONS

International Search Report and Written Opinion for Application No. PCT/US2019/50895 dated Jan. 6, 2020, 12, pages.
International Search Report and Written Opinion for Application No. PCT/US2019/50909 dated Dec. 17, 2019, 11, pages.
International Search Report and Written Opinion for Application No. PCT/US2019/56564 dated Jan. 14, 2020, 14, pages.
International Search Report and Written Opinion, Application No. PCT/US2018/042202, pp. 17, dated Dec. 7, 2018.
International Search Report and Written Opinion, Application No. PCT/US19/24718, dated Jun. 26, 2019, pp. 7.
International Search Report and Written Opinion, Application No. PCT/US19/46397, dated Nov. 12, 2019, pp. 6.
International Search Report and Written Opinion for PCT Application No. PCT/IB2018/056133, Jan. 3, 2019, 7 pages.
PCY/IB/056133 Search Report dated Jan. 3, 2019.
Fiber Optic Interconnect Solutions, Tactical Fiber Optic Connector Cables and Termini, 2006, Glenair, Inc., Glendale, California.
Fiber Optic Products Catalog, Nov. 2007, Tyco Electronics Corporation, Harrisburg, Pennsylvania.
International Search Report and Written Opinion dated Apr. 27, 2012 for PCT/US2011/058799.
International Search Report and Written Opinion dated Aug. 27, 2012 for PCT/US2012/039126.
International Search Report and Written Opinion dated Jan. 16, 2014 for PCT/US2013/54784.
International Search Report and Written Opinion dated Oct. 9, 2014 for PCT/US2014/041500.
International Search Report and Written Opinion dated May 14, 2014 for PCT/US2014/012137.
International Search Report and Written Opinion dated Aug. 21, 2008 for PCT/US2008/057023.
International Search Report dated May 19, 2019 for PCT/US2016/028266.
ISR WO2014028527ISR dated Feb. 20, 2014.
ISR WO2015US57610ISR dated Jan. 21, 2016.
International Preliminary Report on Patentability, Application No. PCT/US2018/015733, dated Aug. 8, 2019, pp. 9.
Non-Final Office Action, U.S. Appl. No. 15/882,343, dated Nov. 19, 2018, pp. 12.
European Search Report and Written Opinion dated Mar. 3, 2015 for EP 14187661.
European Search Report and Written Opinion dated Feb. 19, 2015 for EP 14168005.
International Preliminary Report on Patentability dated Aug. 22, 2016 from related International Application No. PCT/US2015/059458, International Filing Date Nov. 6, 2015.

* cited by examiner

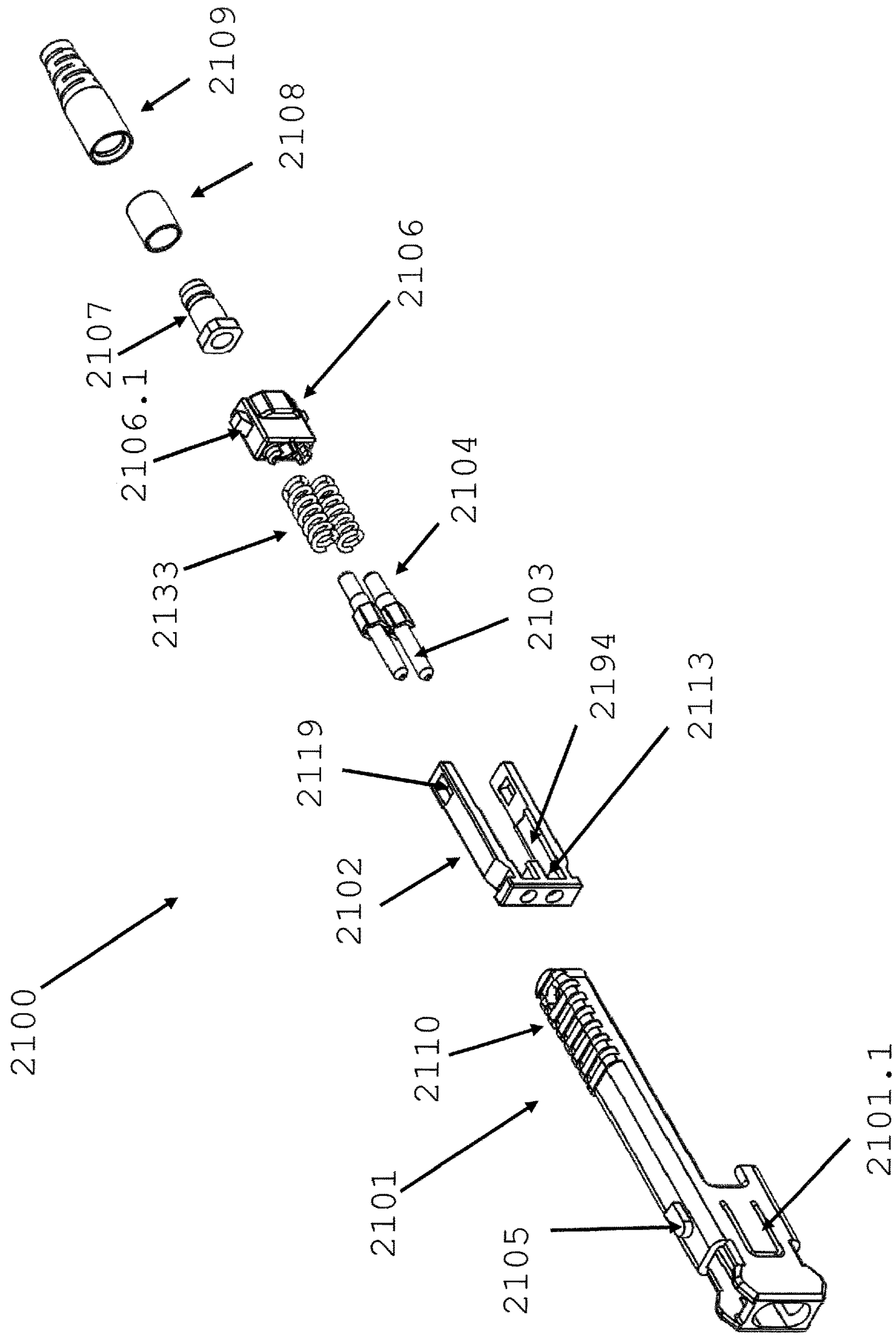

2109
2108
2106
2107
2106.1
2104
2133
2103
2194
2113
2119
2102
2100
2110
2101.1
2101
2105

FIG. 1.

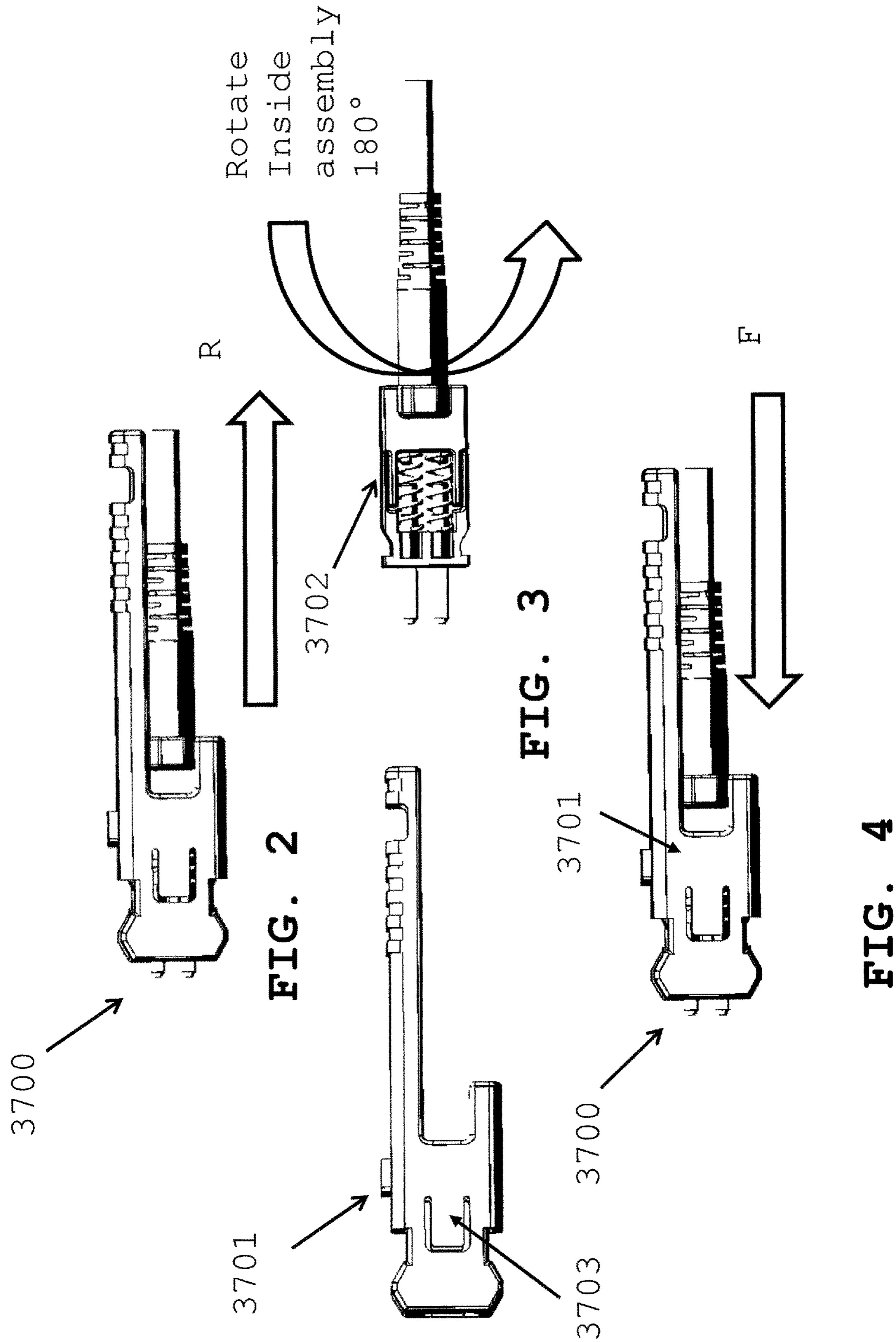


FIG. 2

FIG. 3

FIG. 4

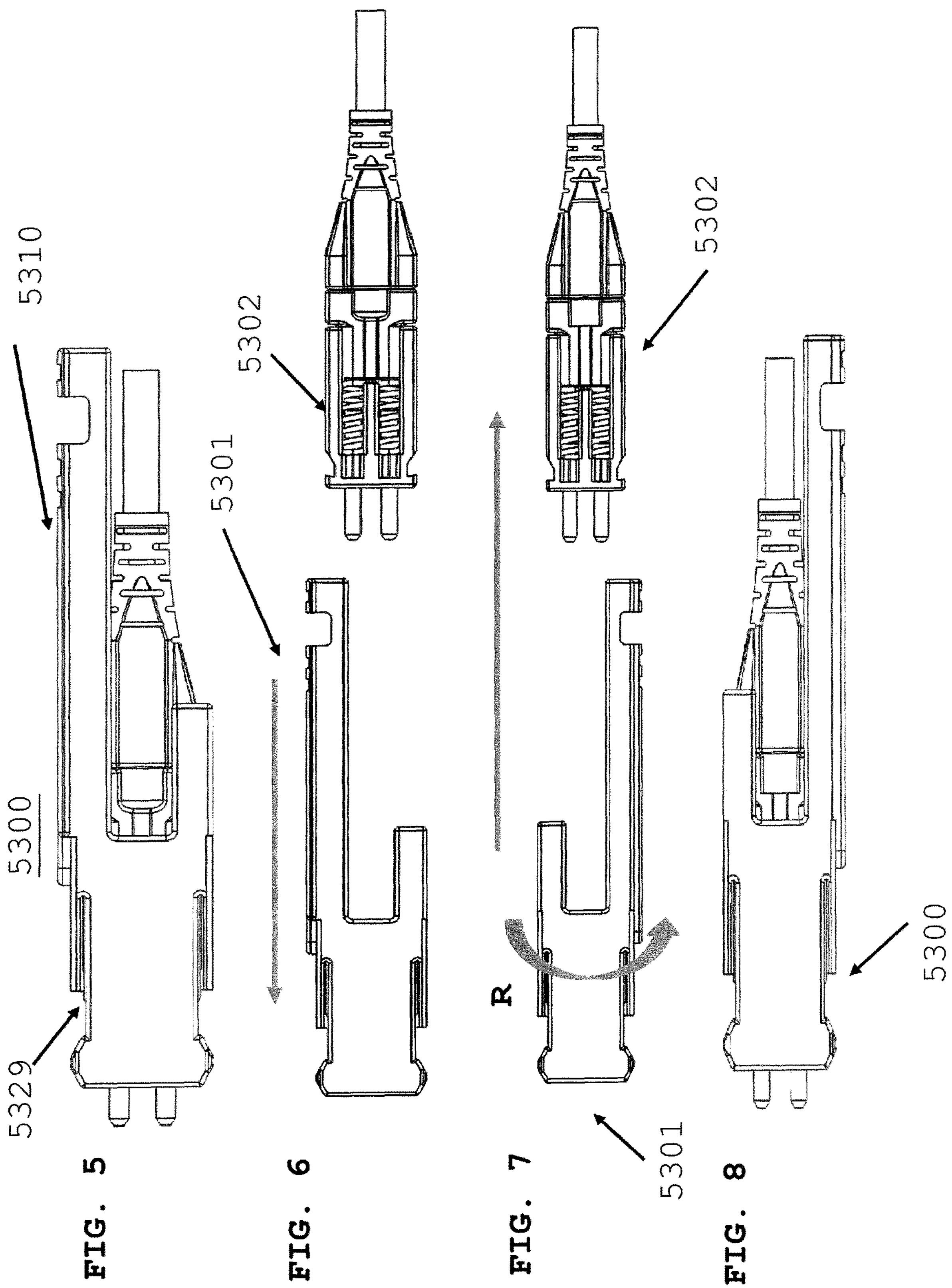


FIG. 5
5310
5300
5329
FIG. 6
5302
5301
FIG. 7
R
5301
FIG. 8
5302
5300

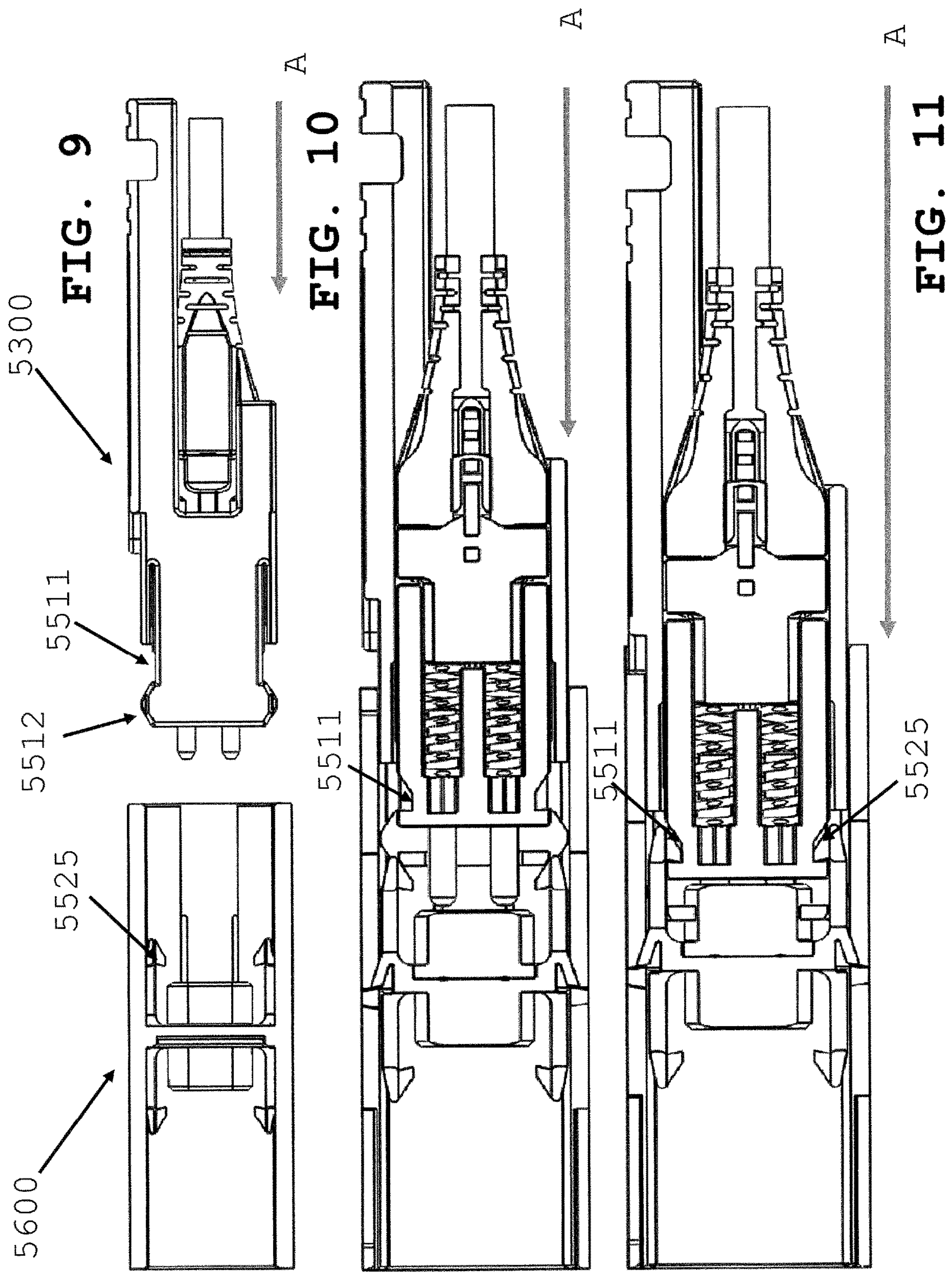


FIG. 9
5300
5511
5512
5525
5600
A
FIG. 10
5511
A
FIG. 11
5511
5525
A

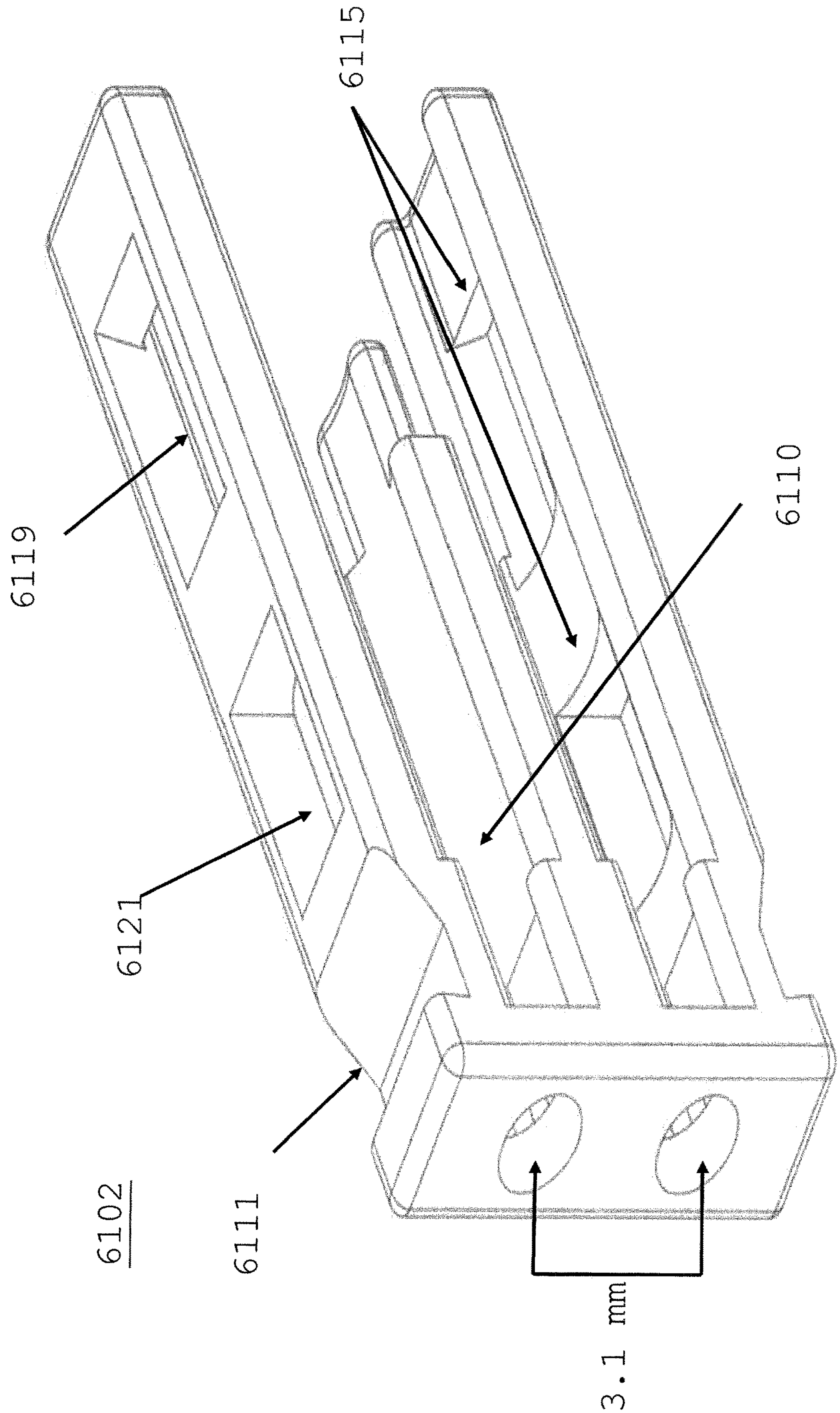


FIG. 12

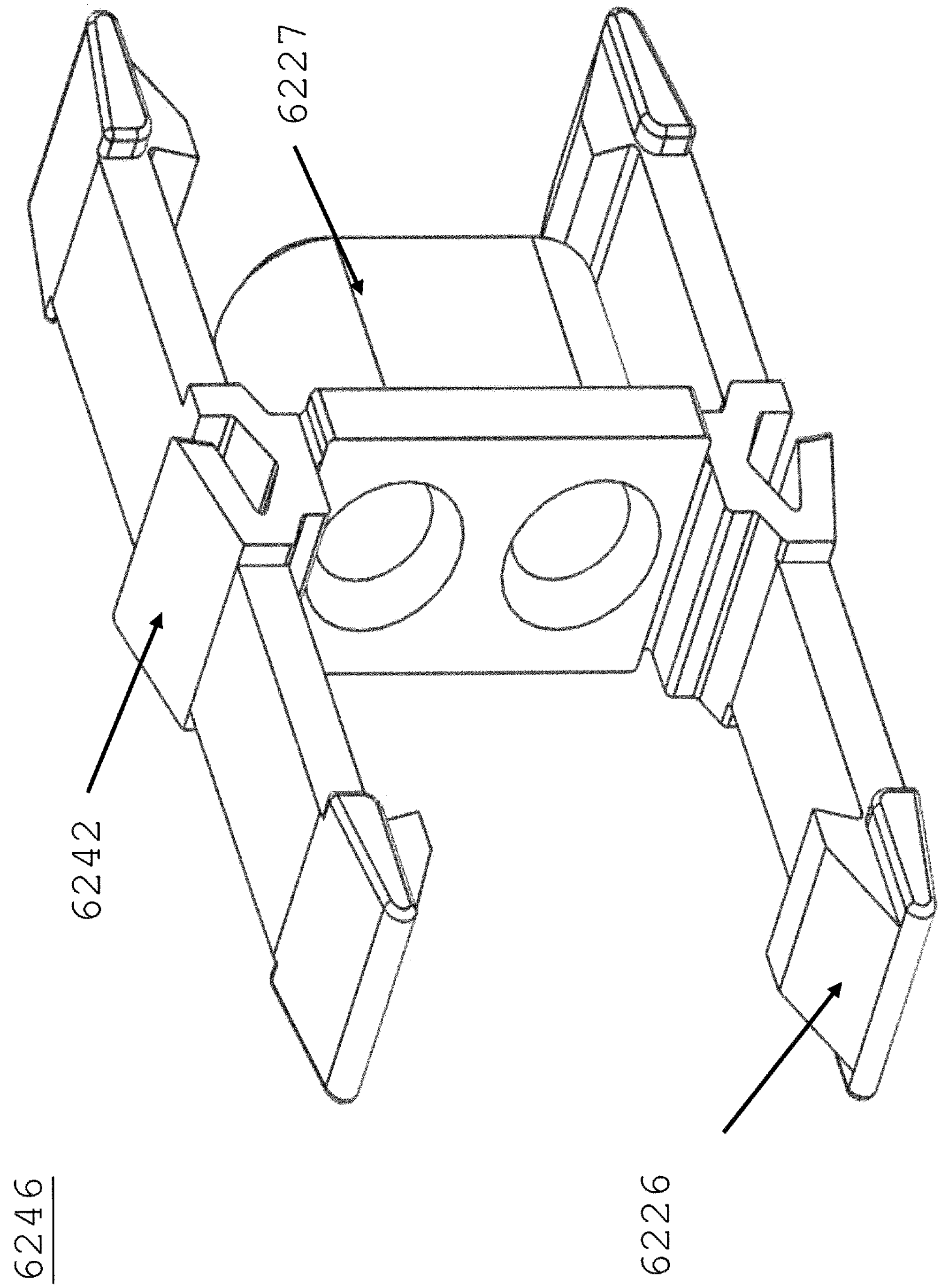


FIG. 13

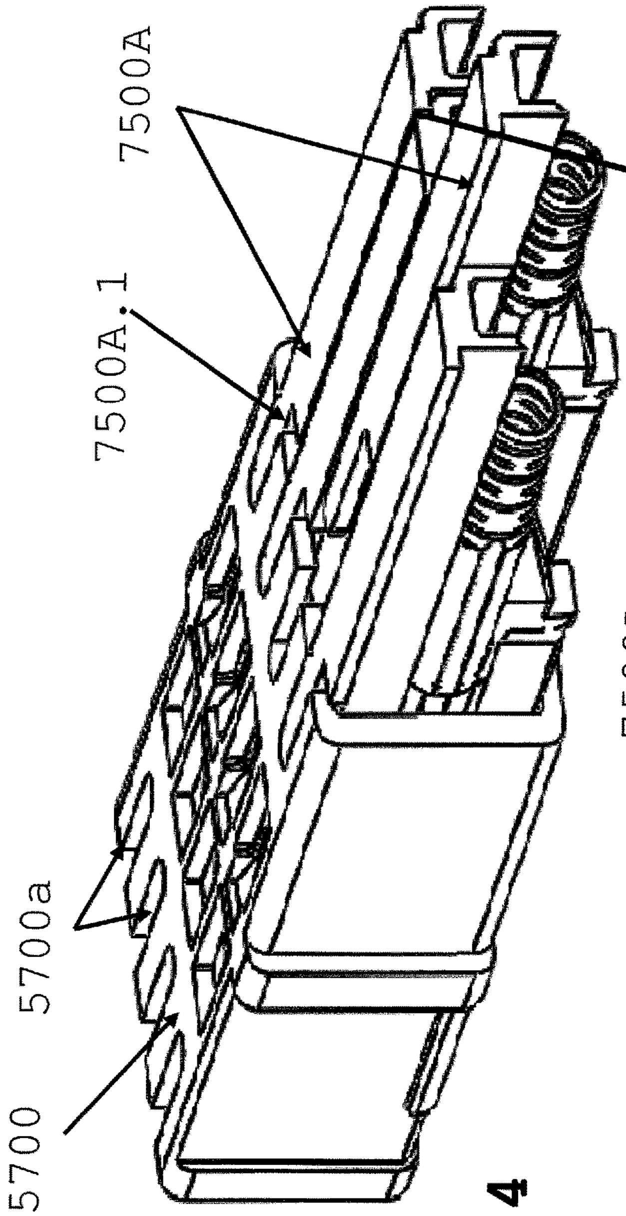


FIG. 14

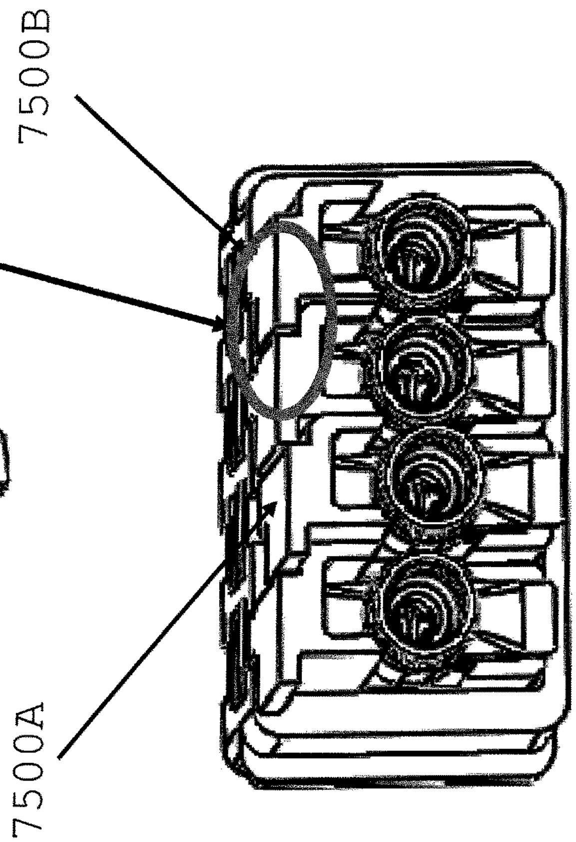


FIG. 15

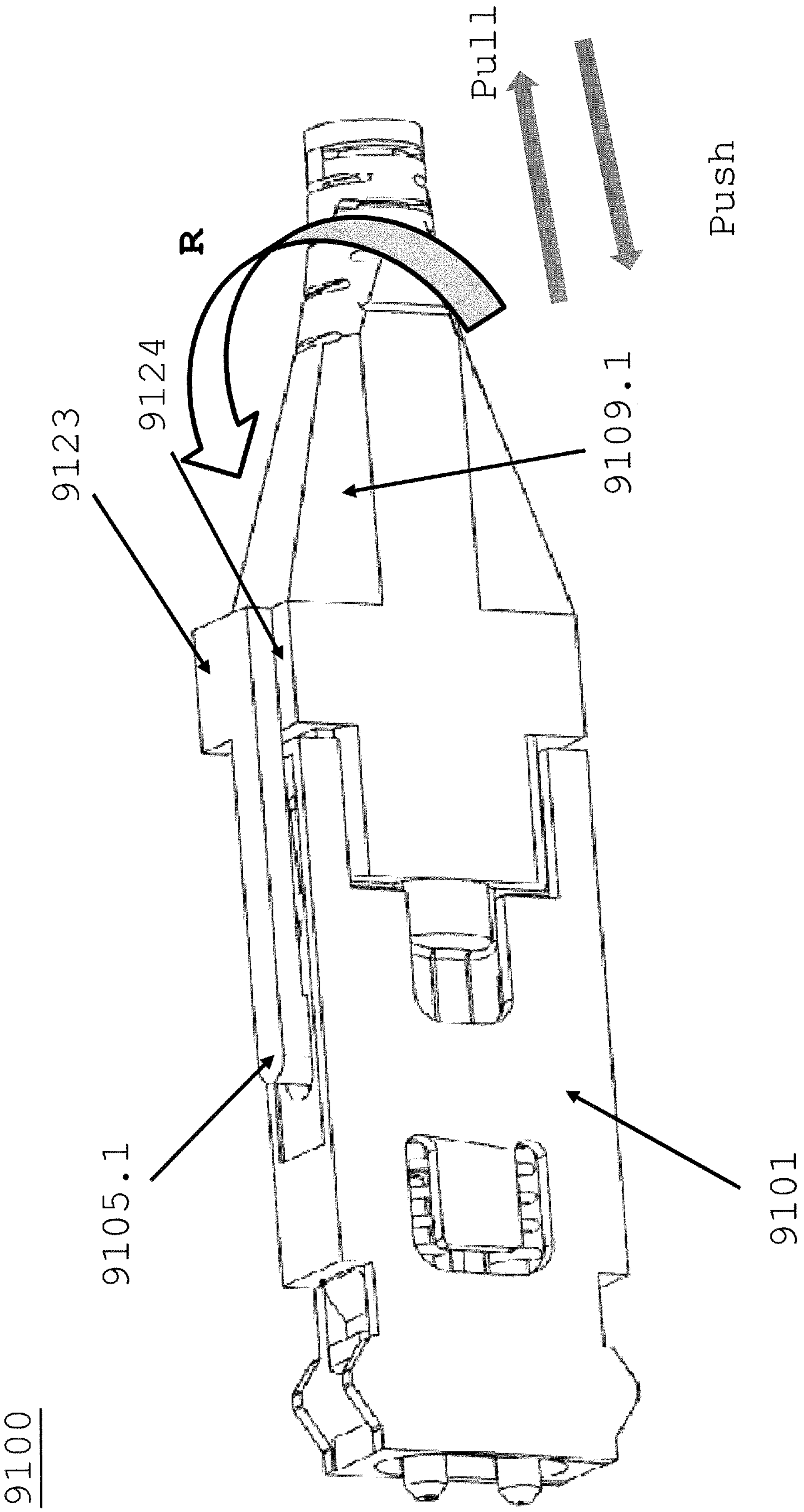


FIG. 16

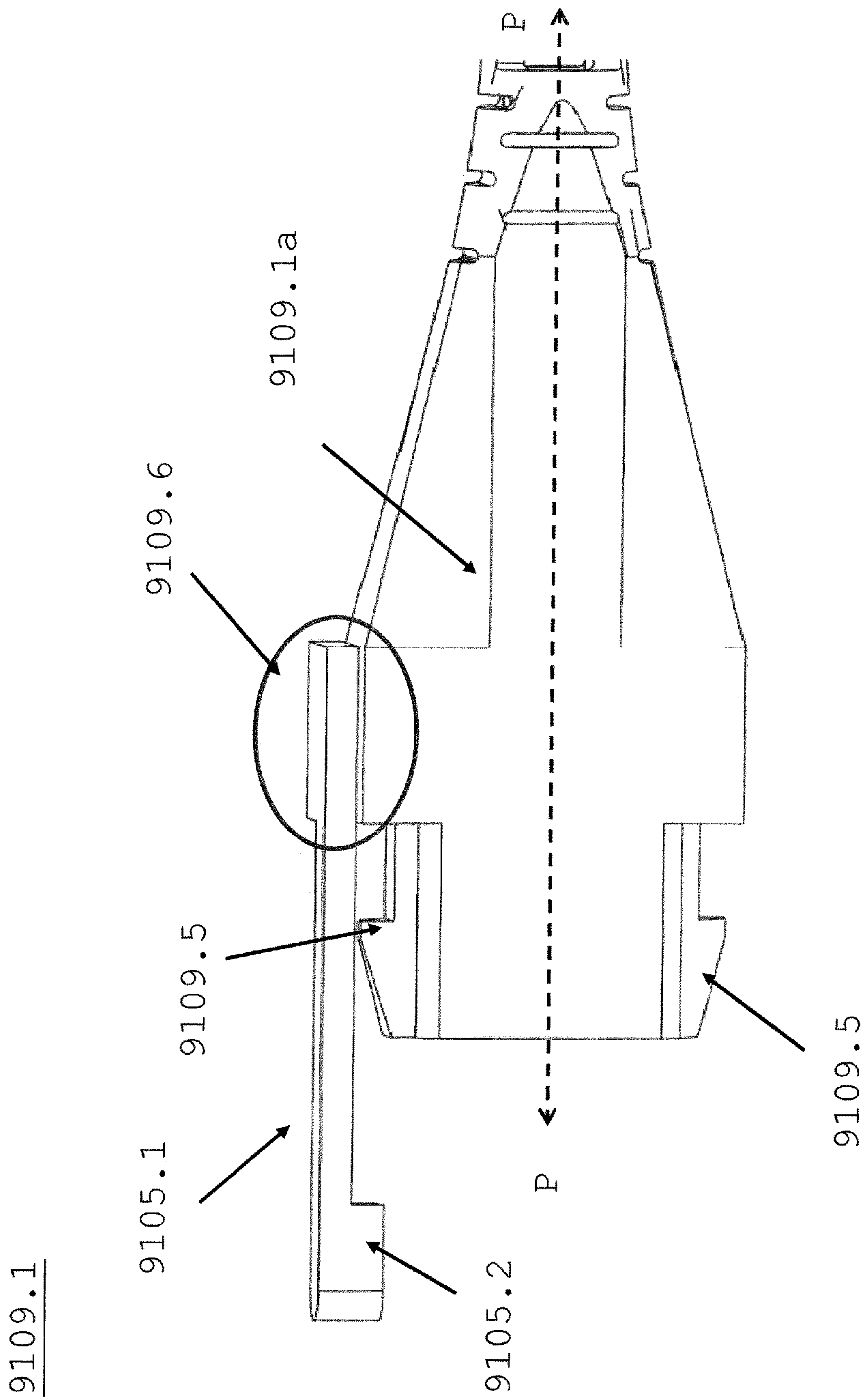


FIG. 17

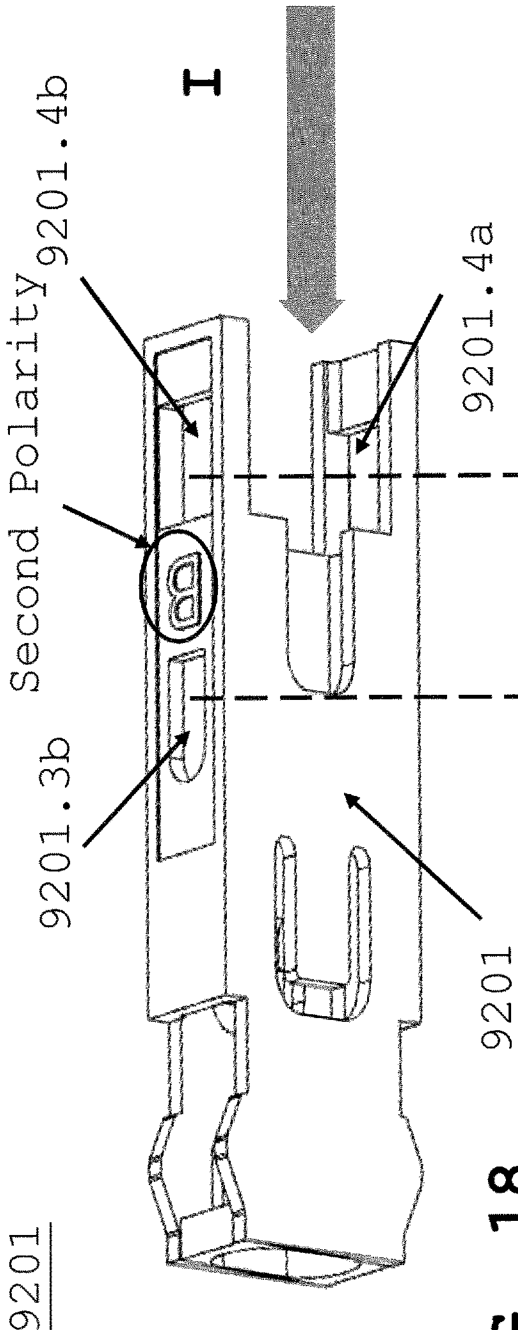

9201
9201.4b
Second Polarity
9201.3b
I
9201.4a
9201

FIG. 18

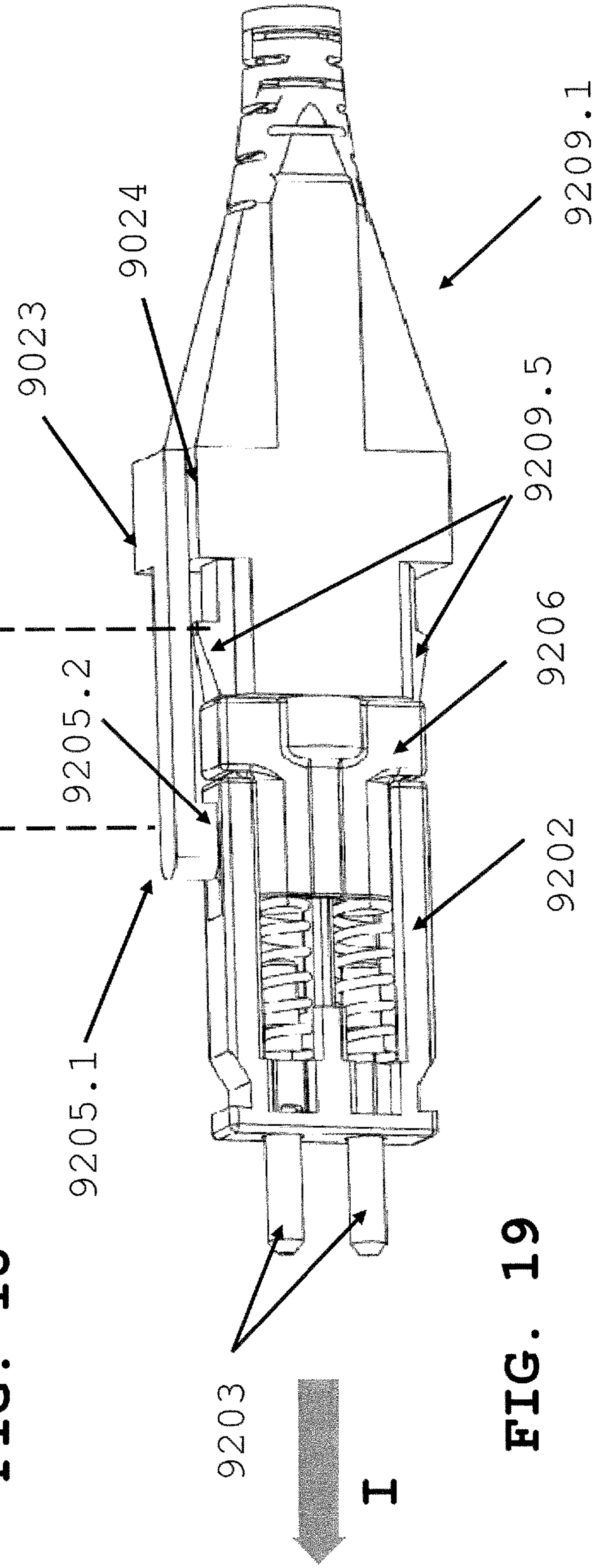

9209.1
9024
9023
9209.5
9206
9205.2
9202
9205.1
9203
I

FIG. 19

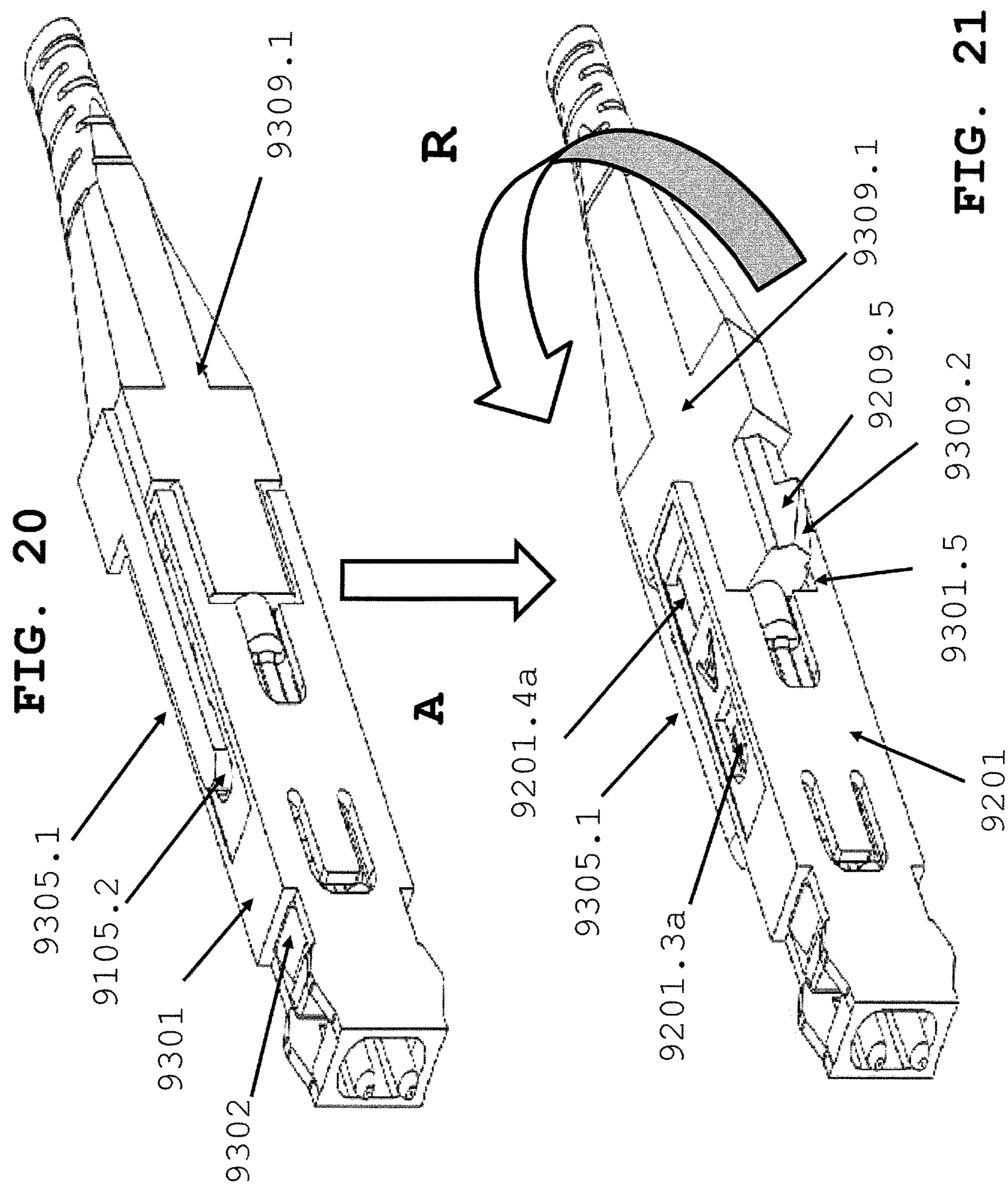

9309.1
9305.1
9105.2
9301
9302
A
R
9309.1
9209.5
9309.2
9301.5
9201.4a
9305.1
9201.3a
9201

FIG. 20

FIG. 21

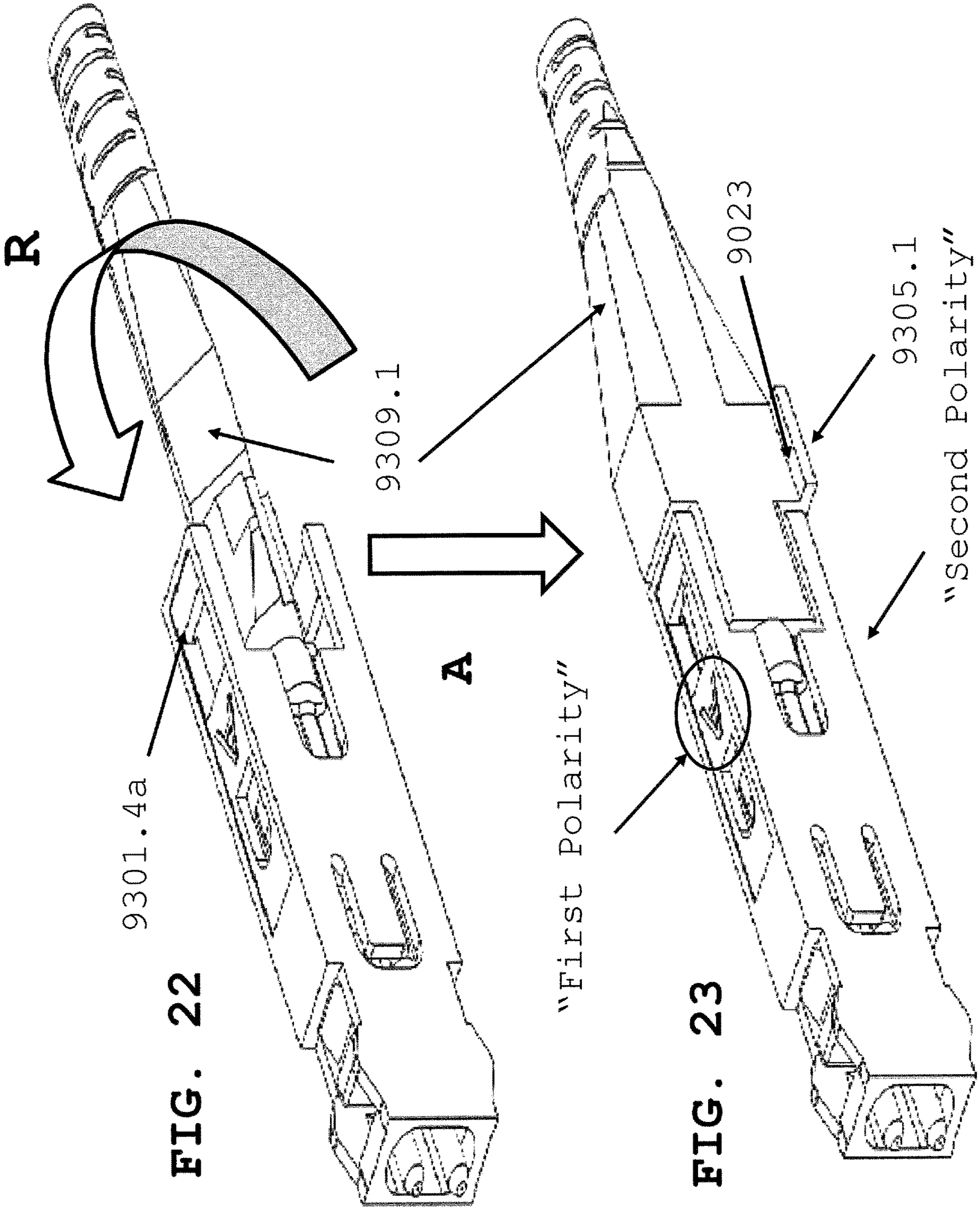


FIG. 22

FIG. 23

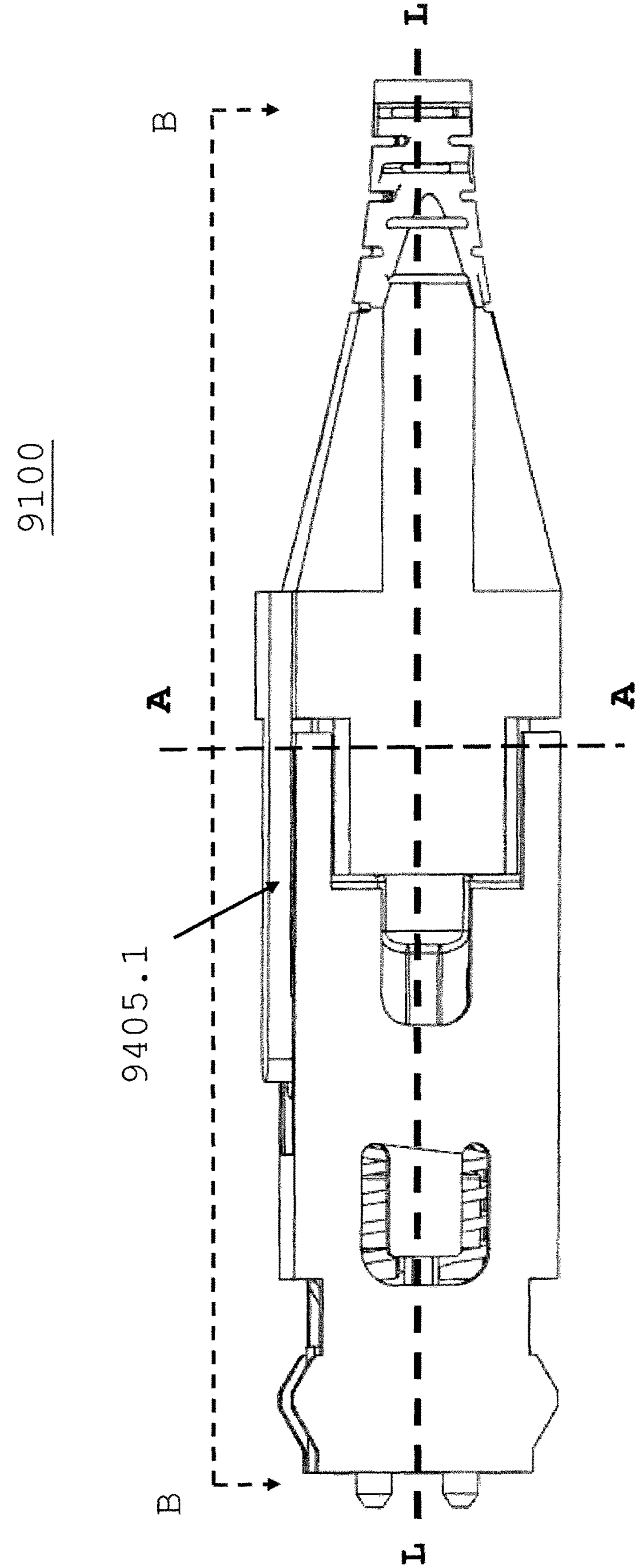


FIG. 24

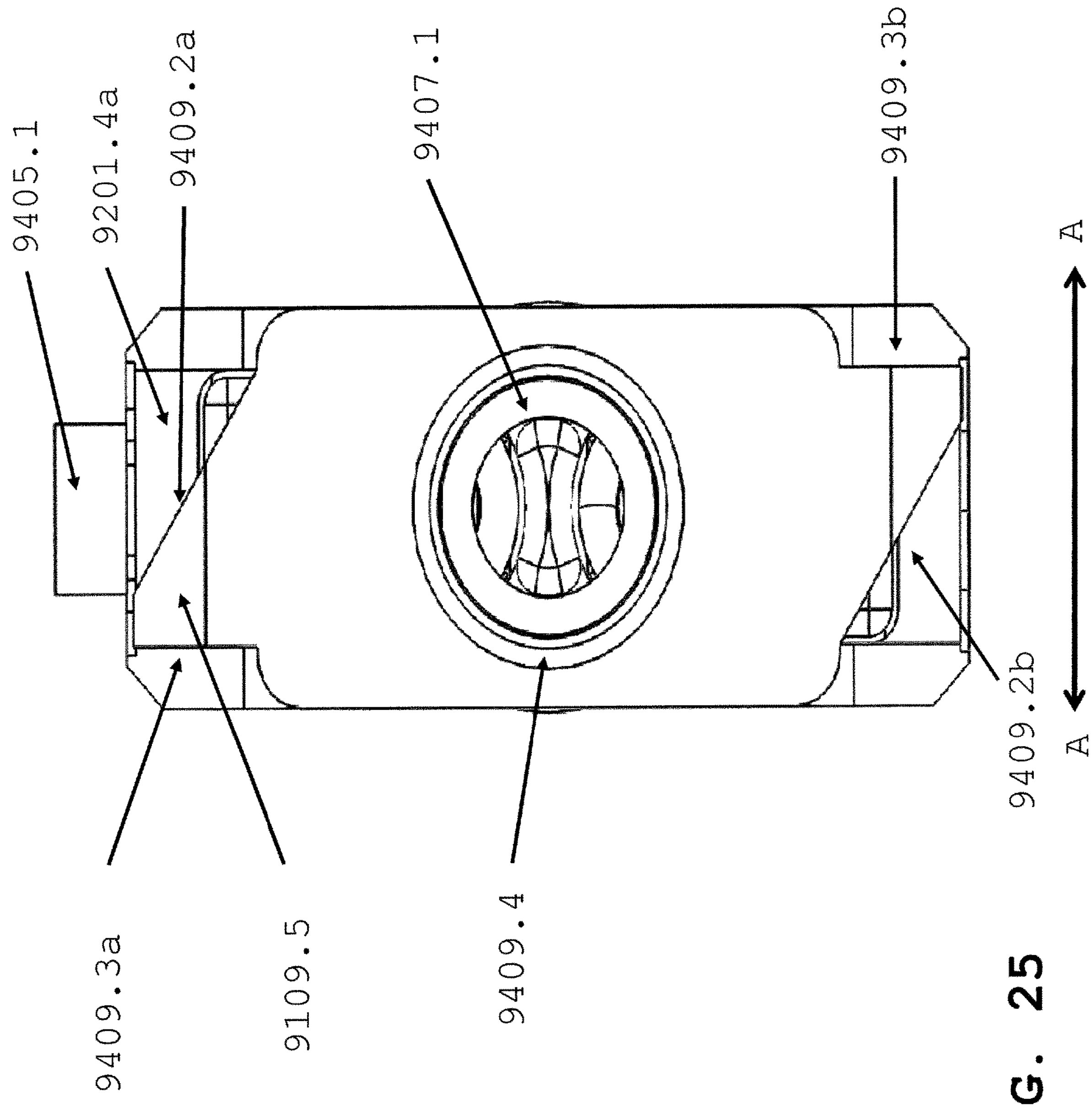

9405.1
9201.4a
9409.2a
9407.1
9409.3b
A
A
9409.2b
9409.3a
9109.5
9409.4

FIG. 25

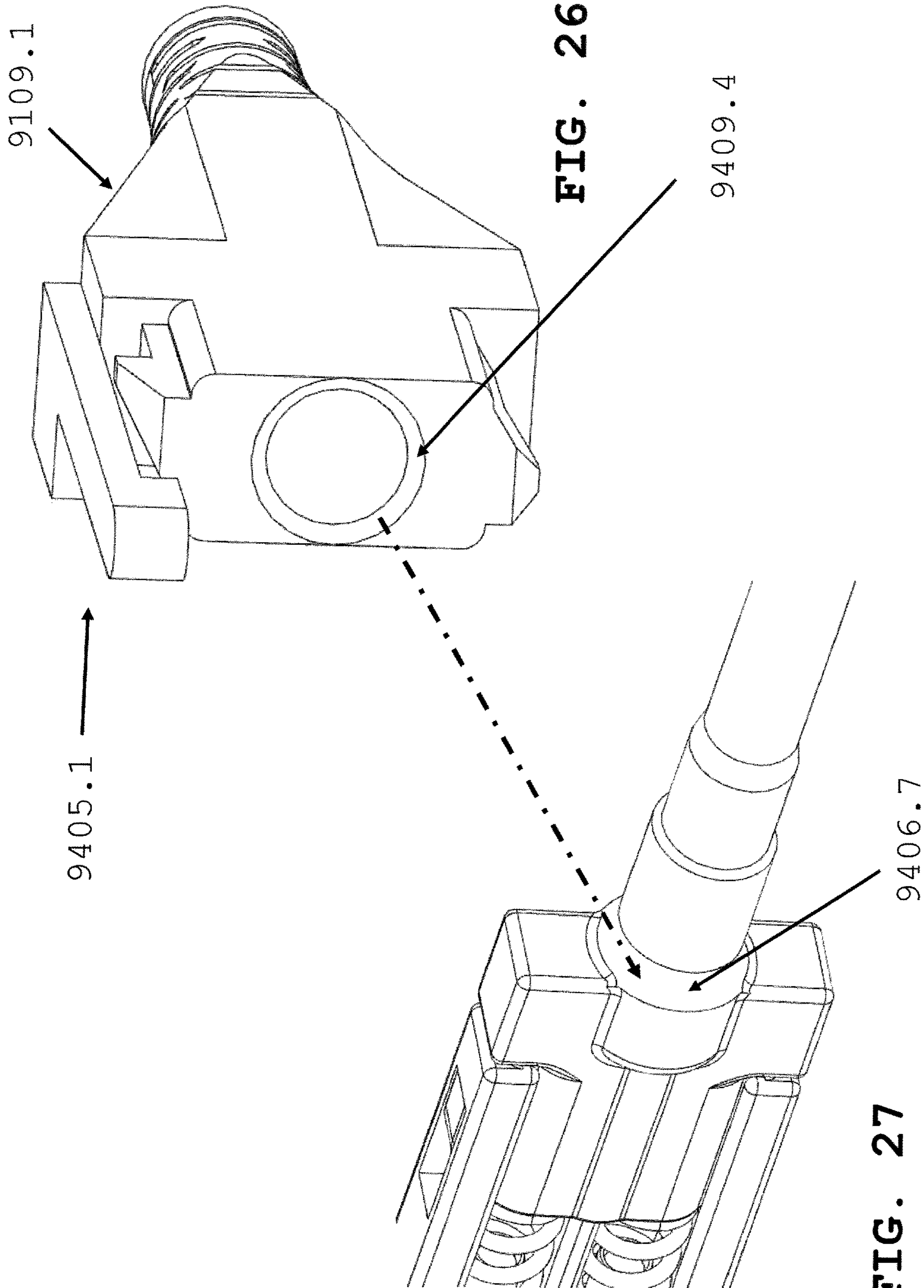


FIG. 26

FIG. 27

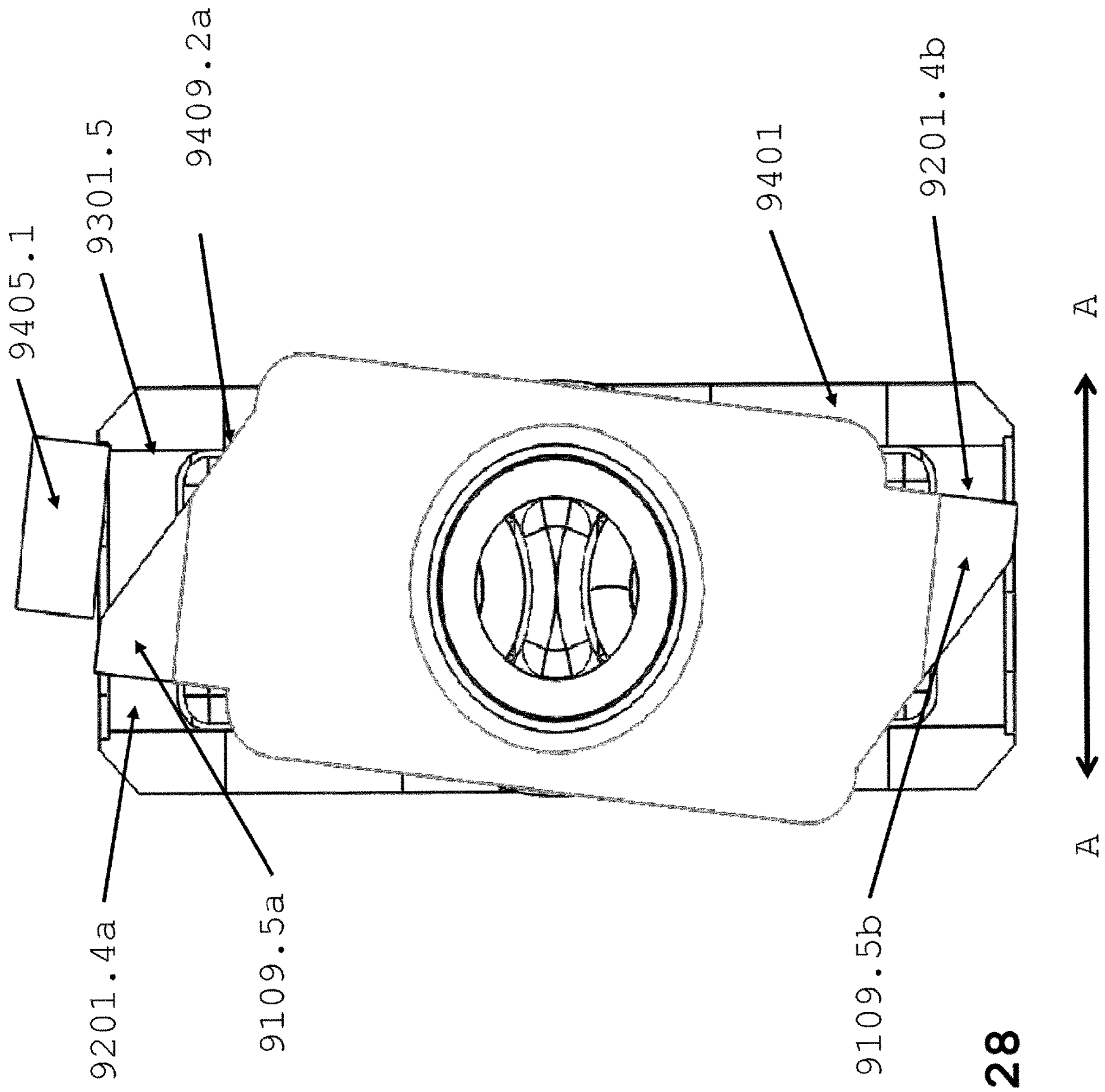


FIG. 28

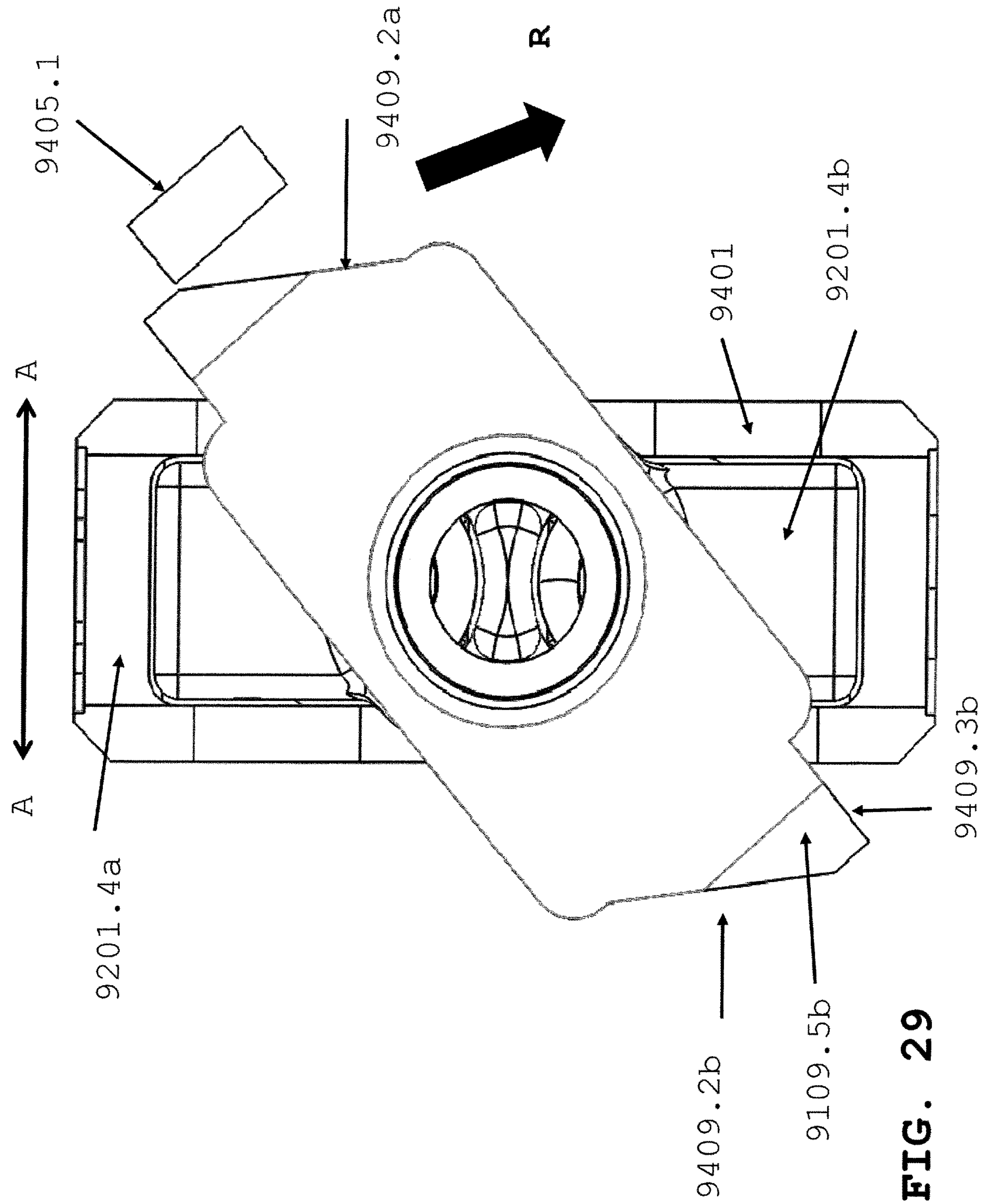


FIG. 29

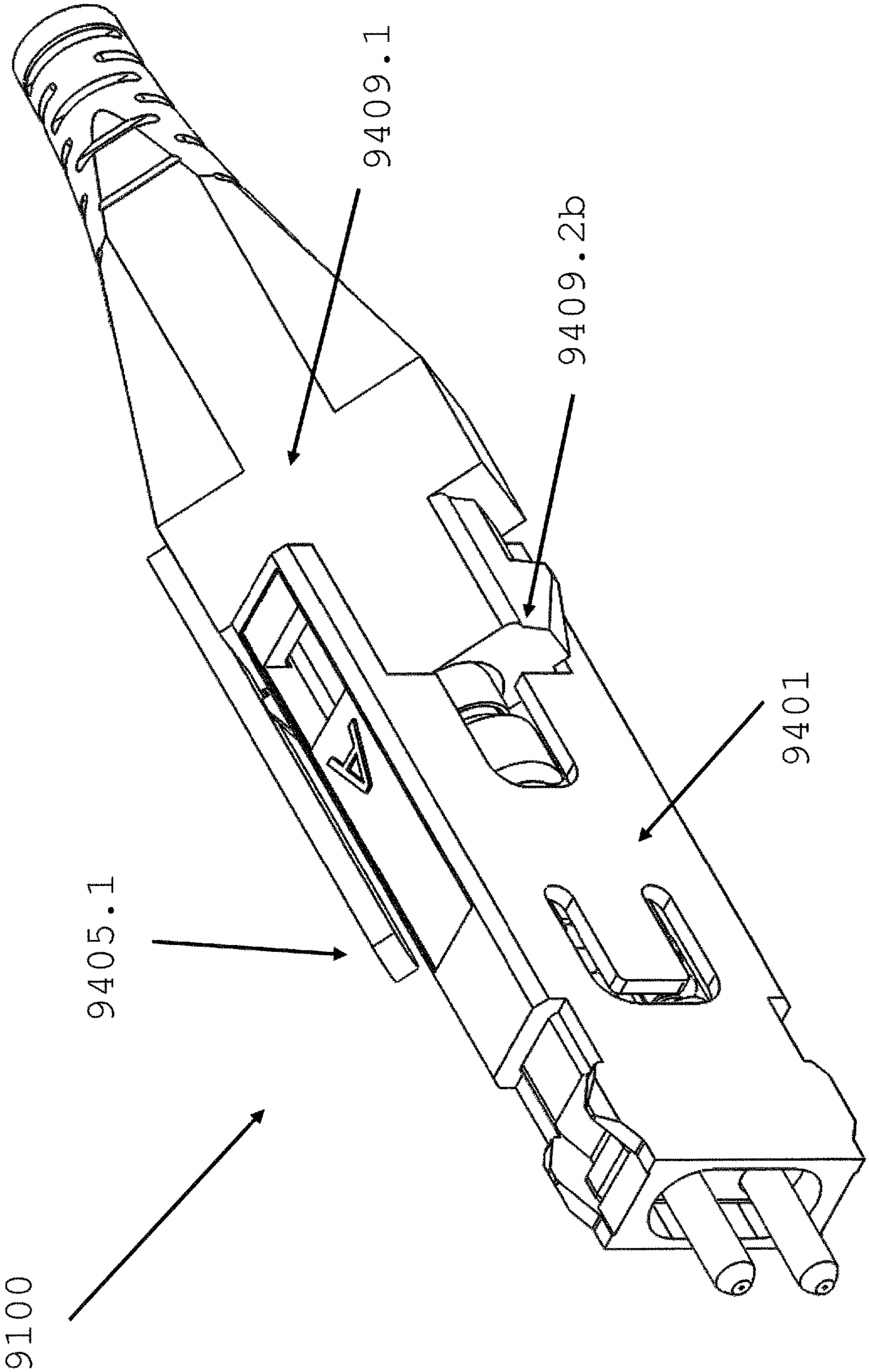


FIG. 30

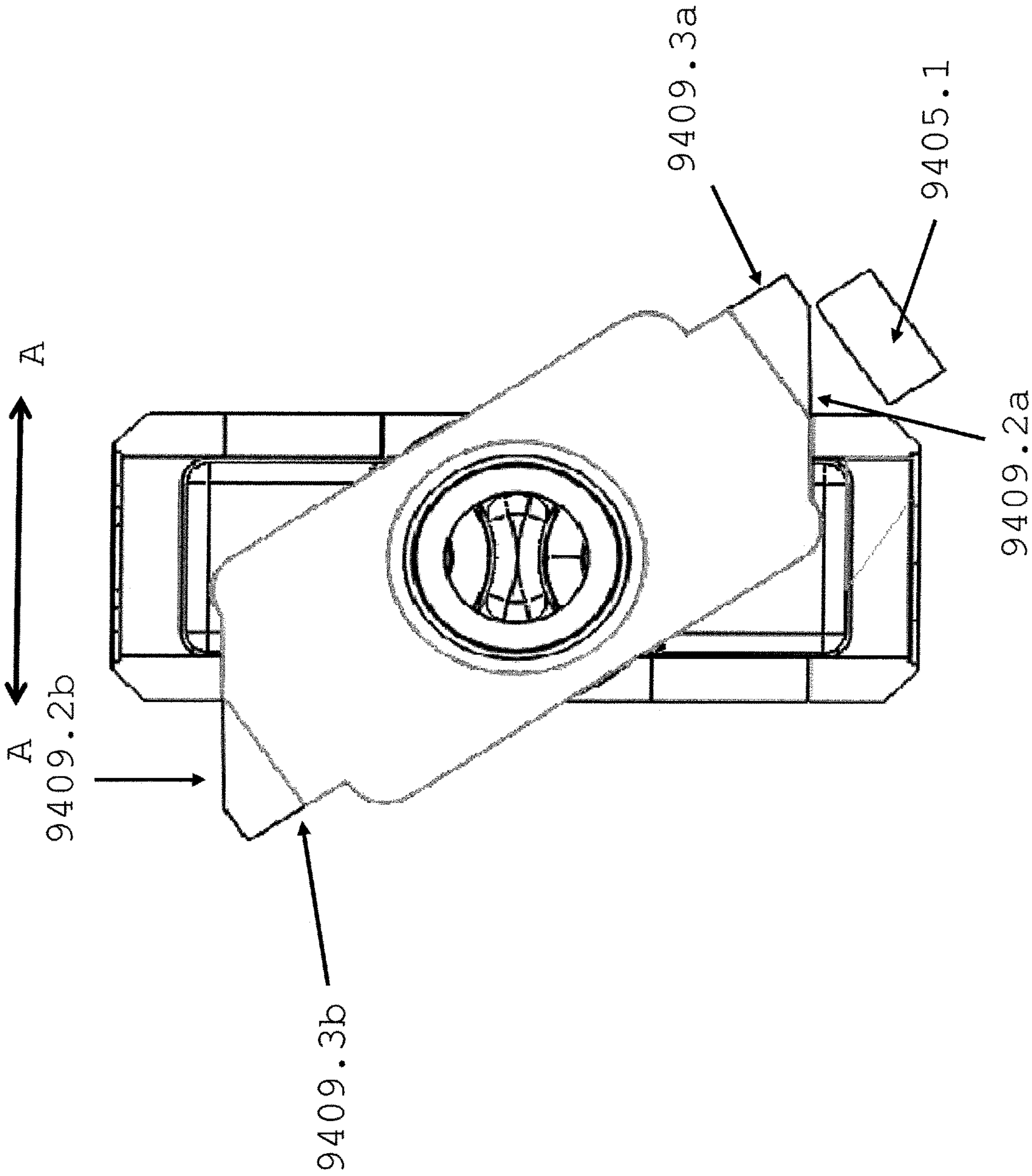


FIG. 31

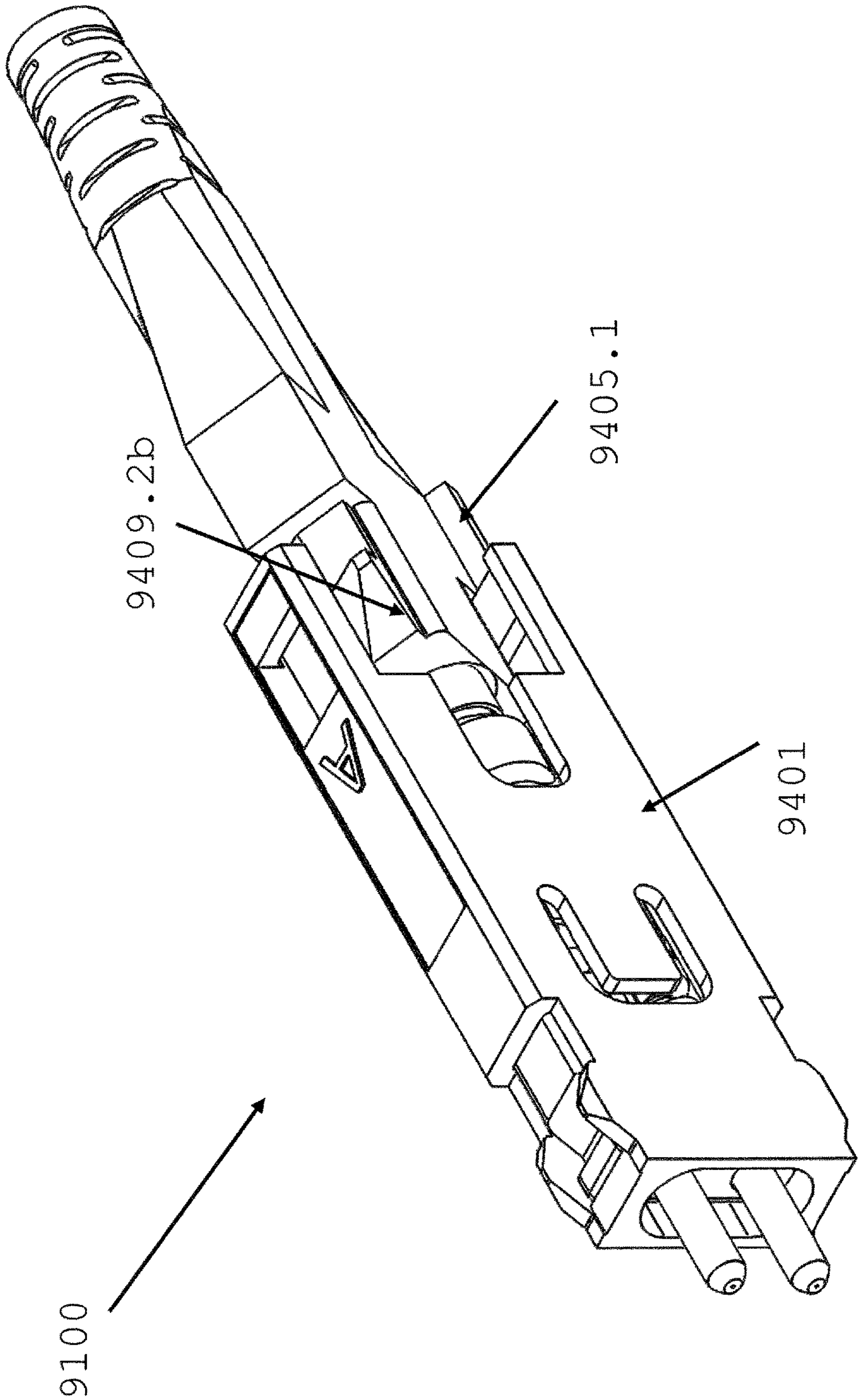


FIG. 32

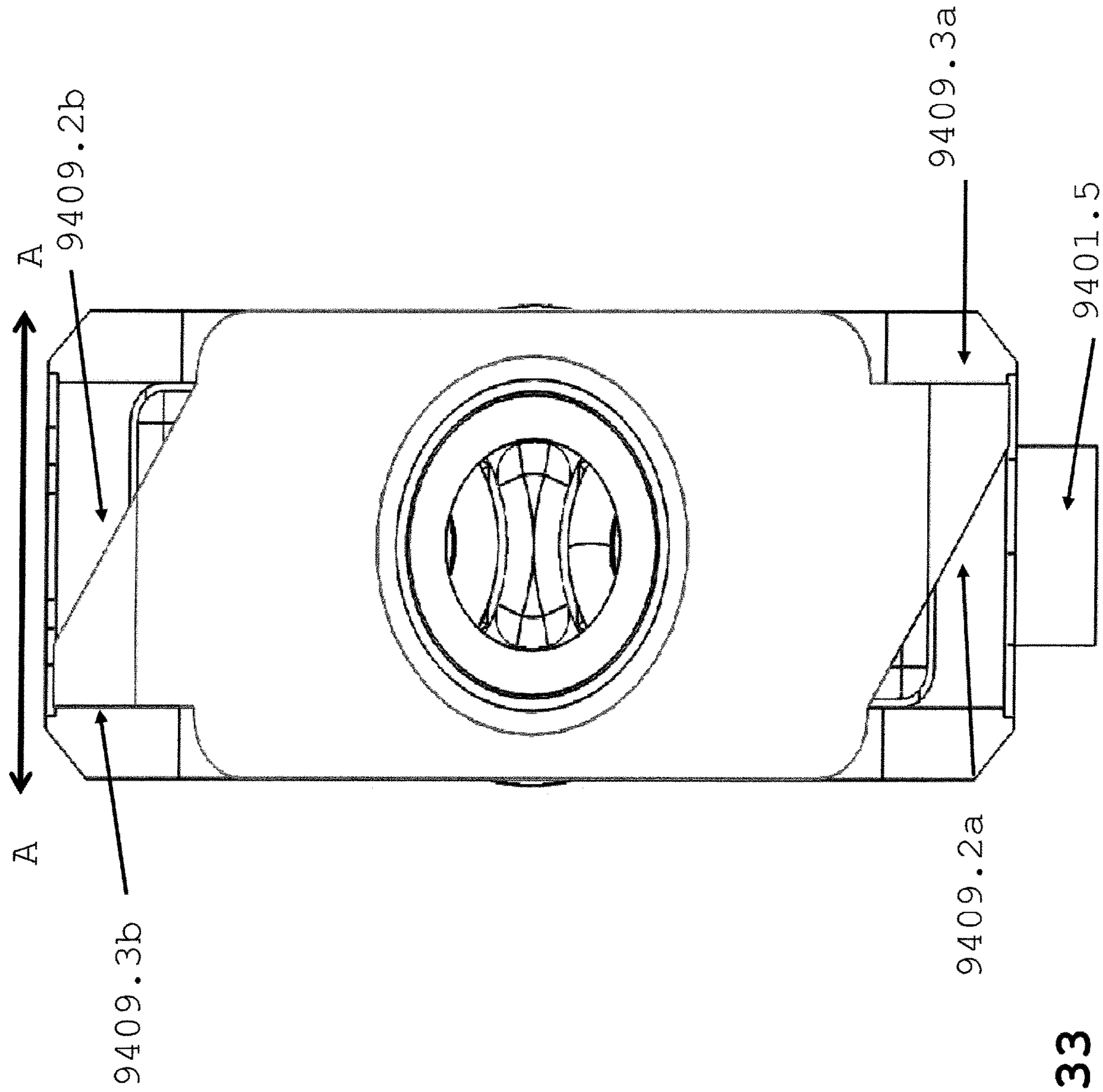


FIG. 33

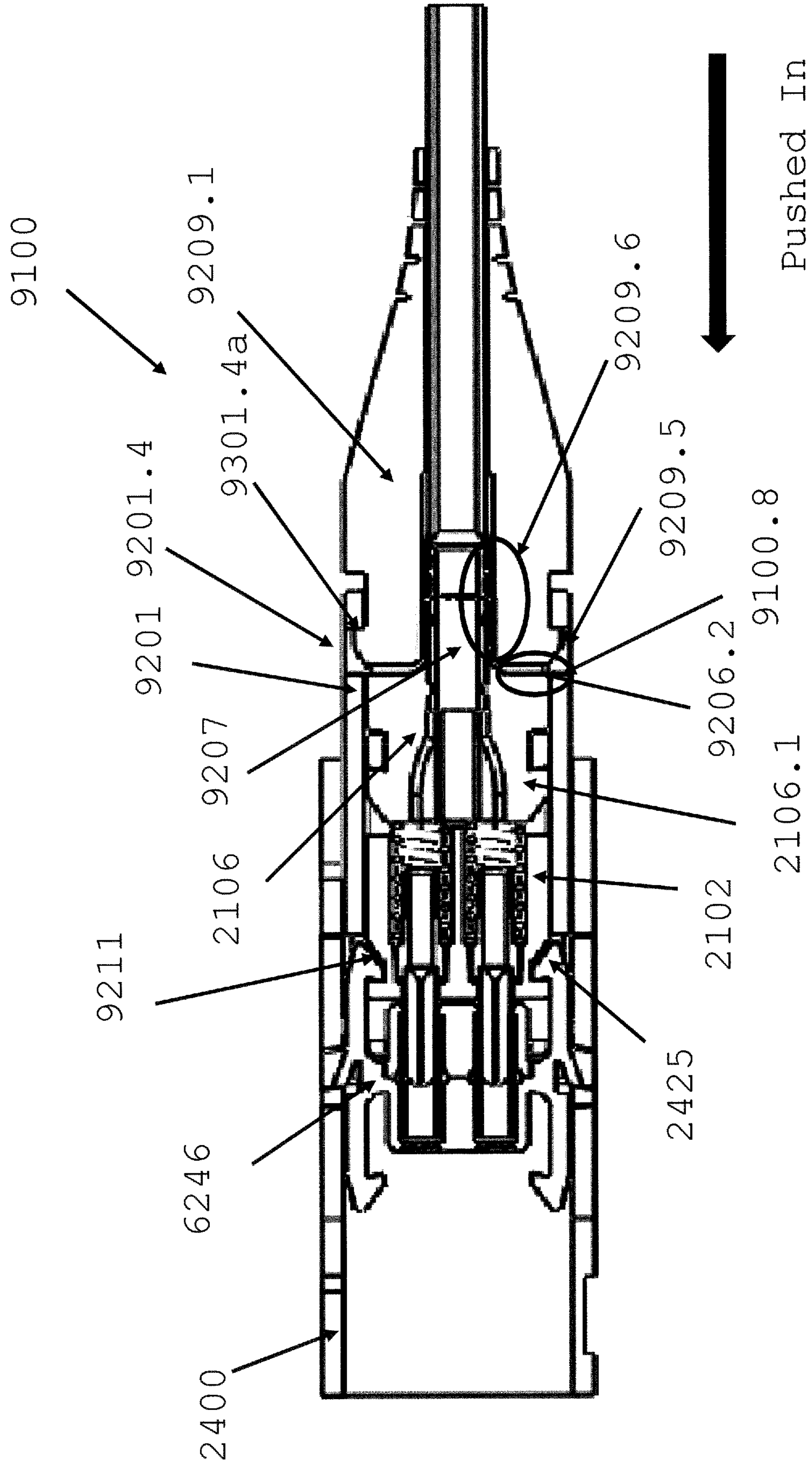

9100
9209.1
9301.4a
9201.4
9201
9207
2106
9211
6246
2400
Pushed In
9209.6
9209.5
9100.8
9206.2
2106.1
2102
2425

FIG. 34

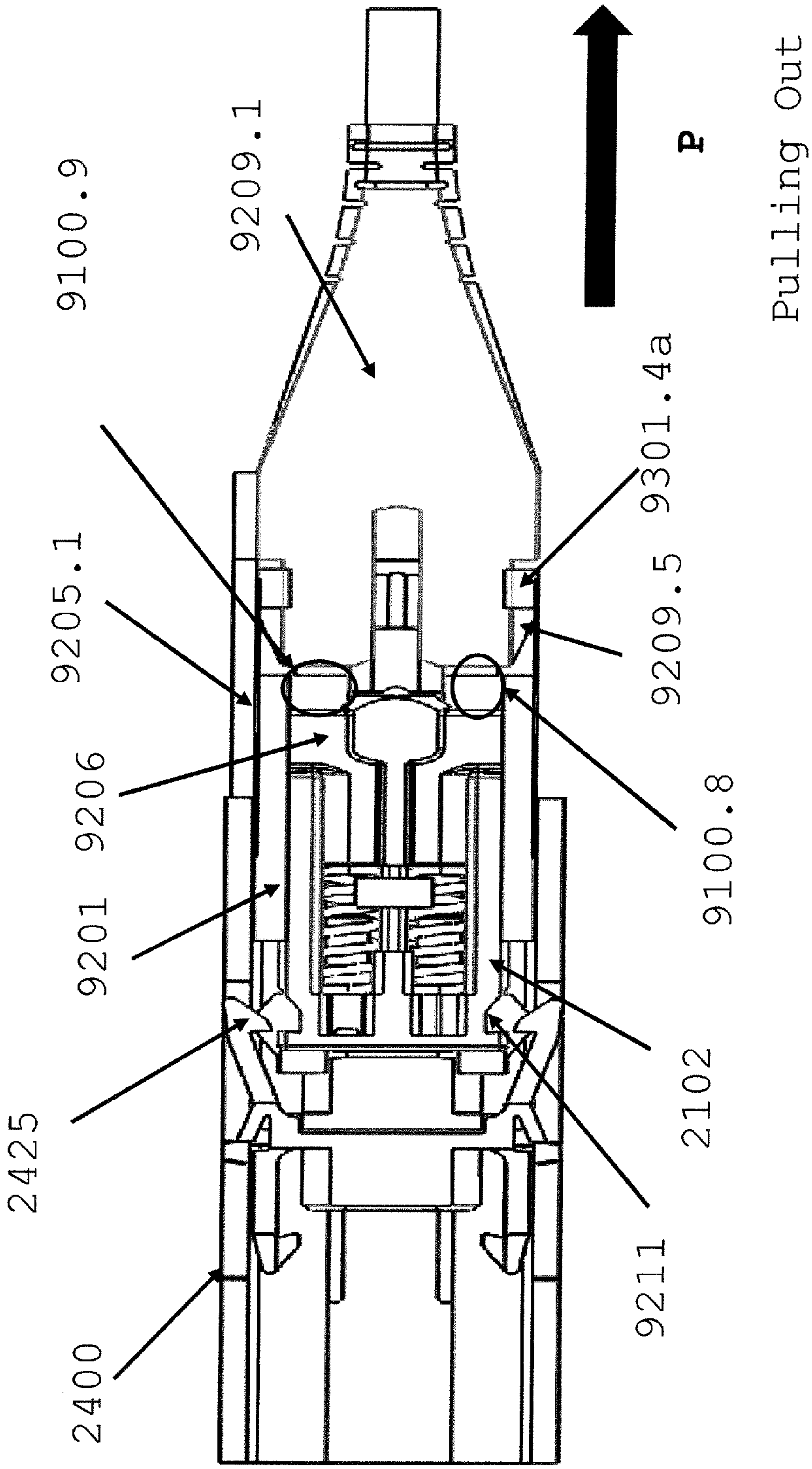

9100.9
9209.1
P
Pulling Out
9301.4a
9205.1
9209.5
9206
9100.8
9201
2102
2425
9211
2400

FIG. 35

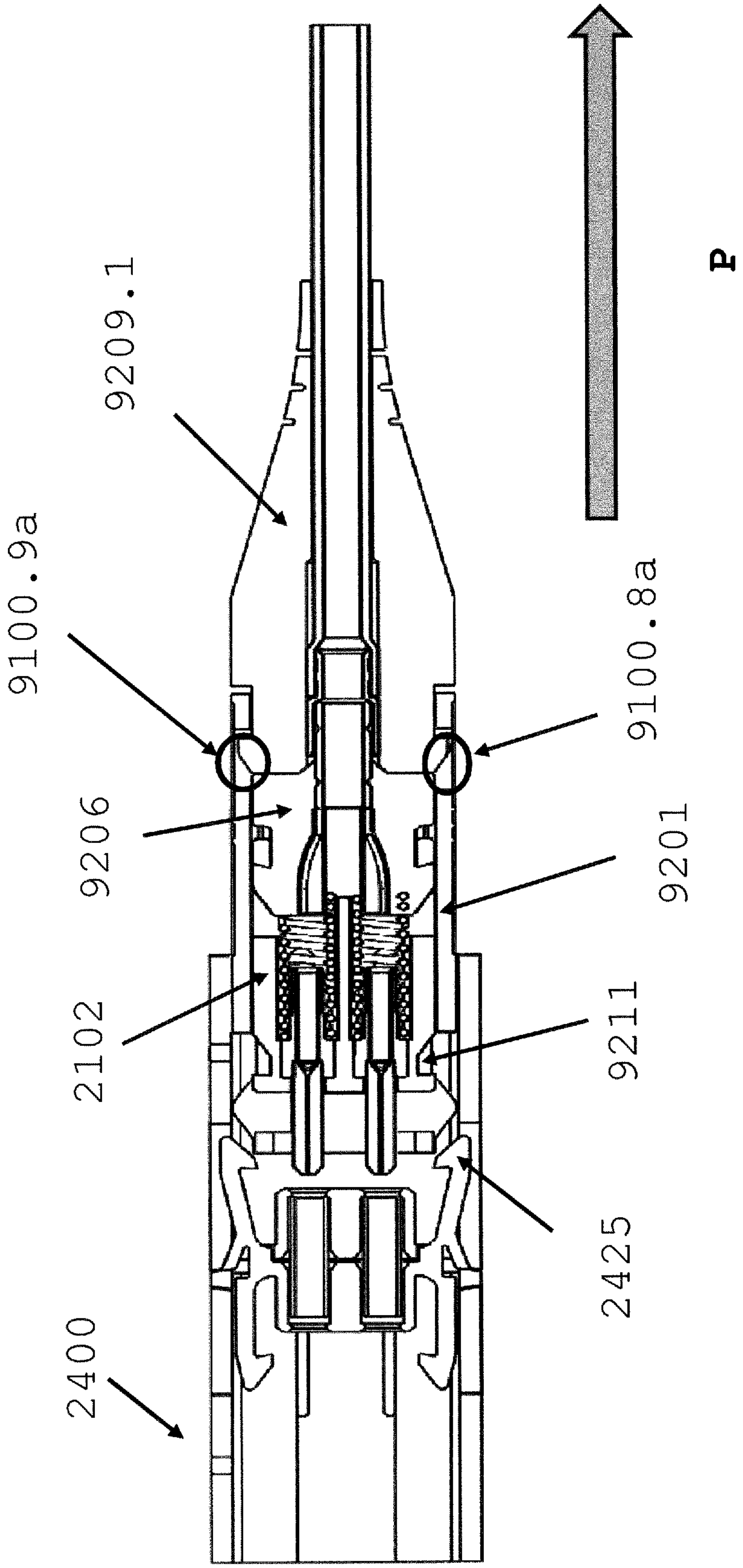


FIG. 36

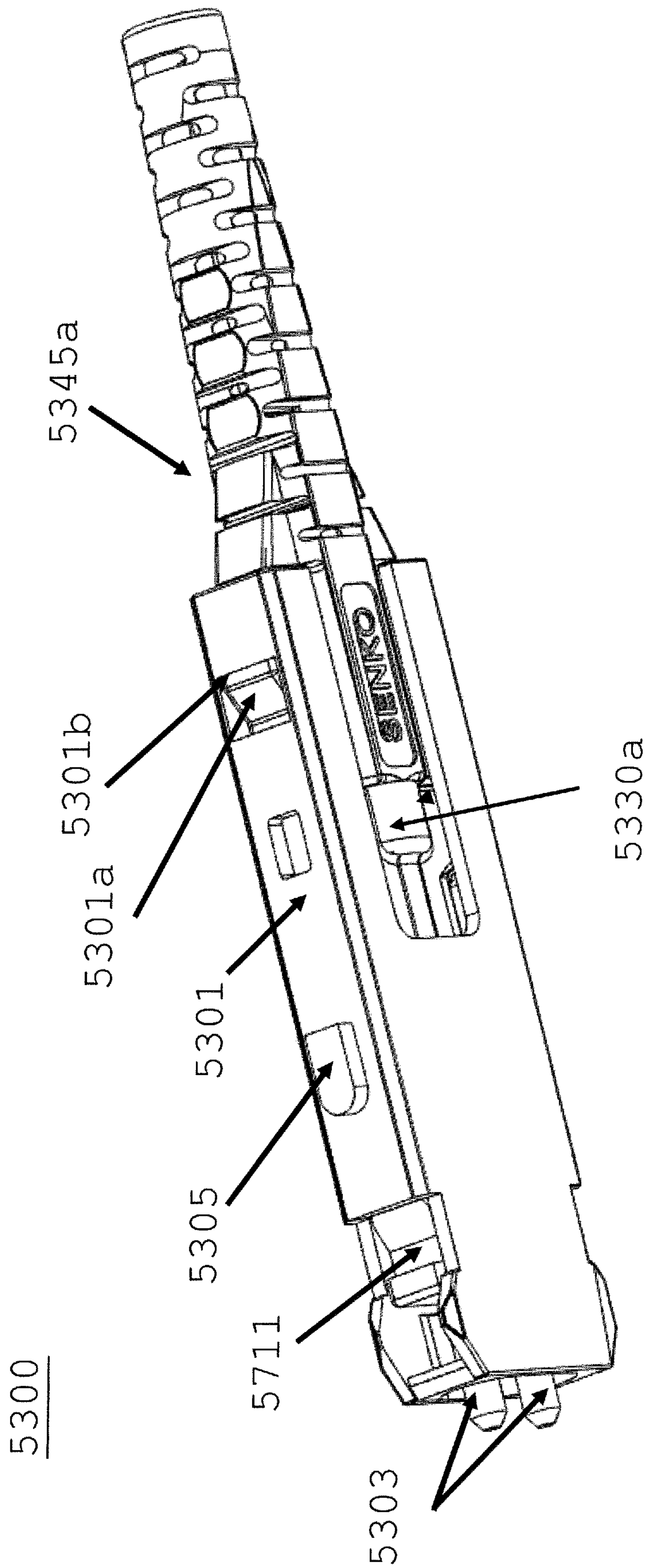


FIG. 37

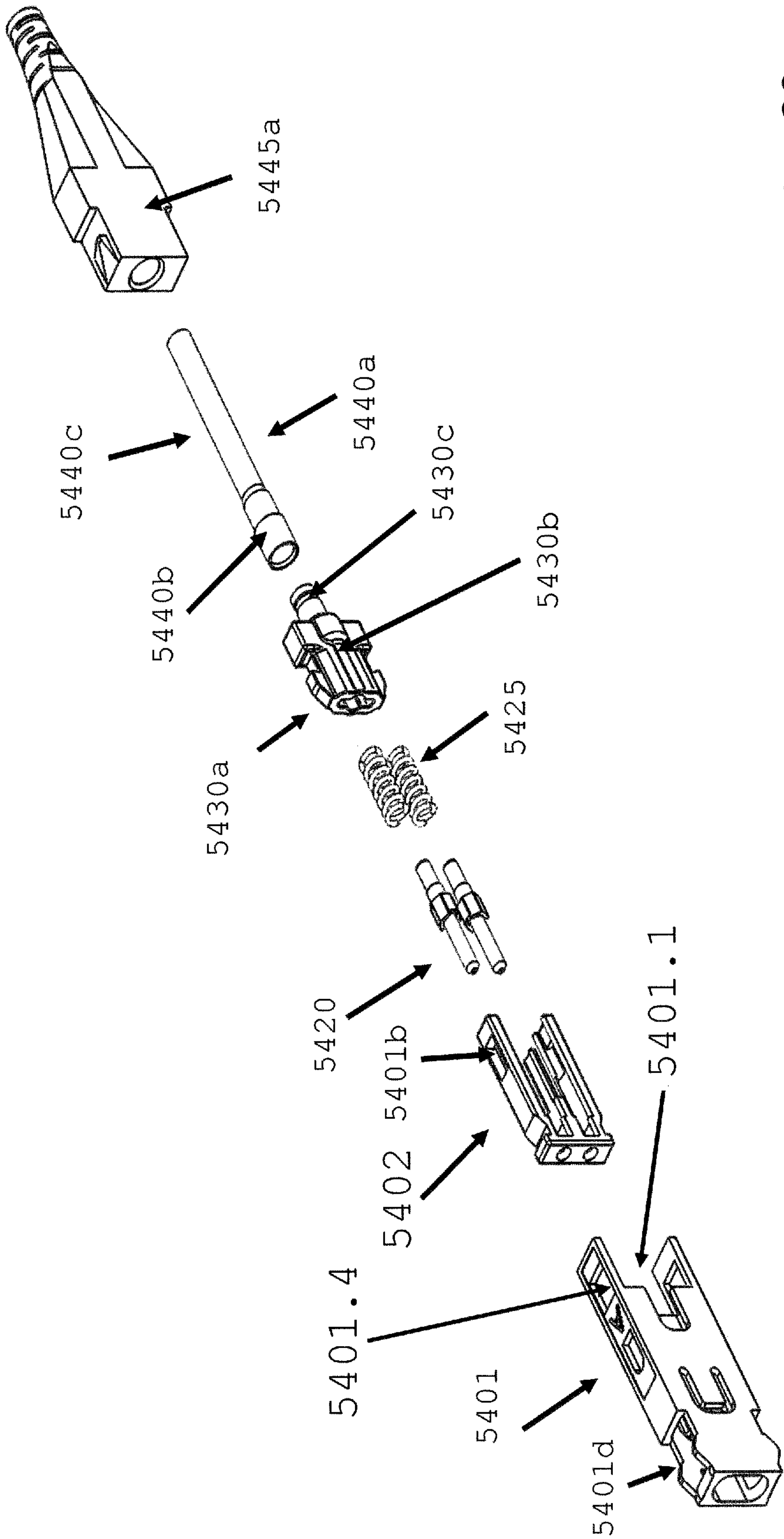

5445a
5440c
5440a
5430c
5440b
5430b
5425
5430a
5420
5401b
5402
5401.1
5401.4
5401
5401d

FIG. 38

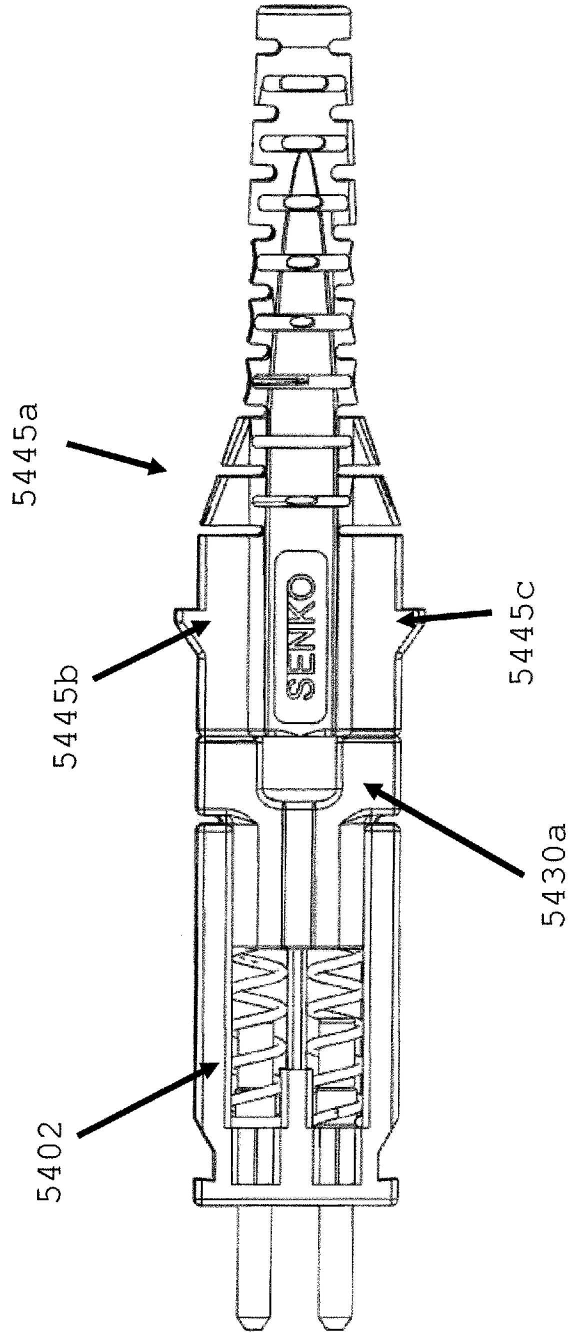


FIG. 39

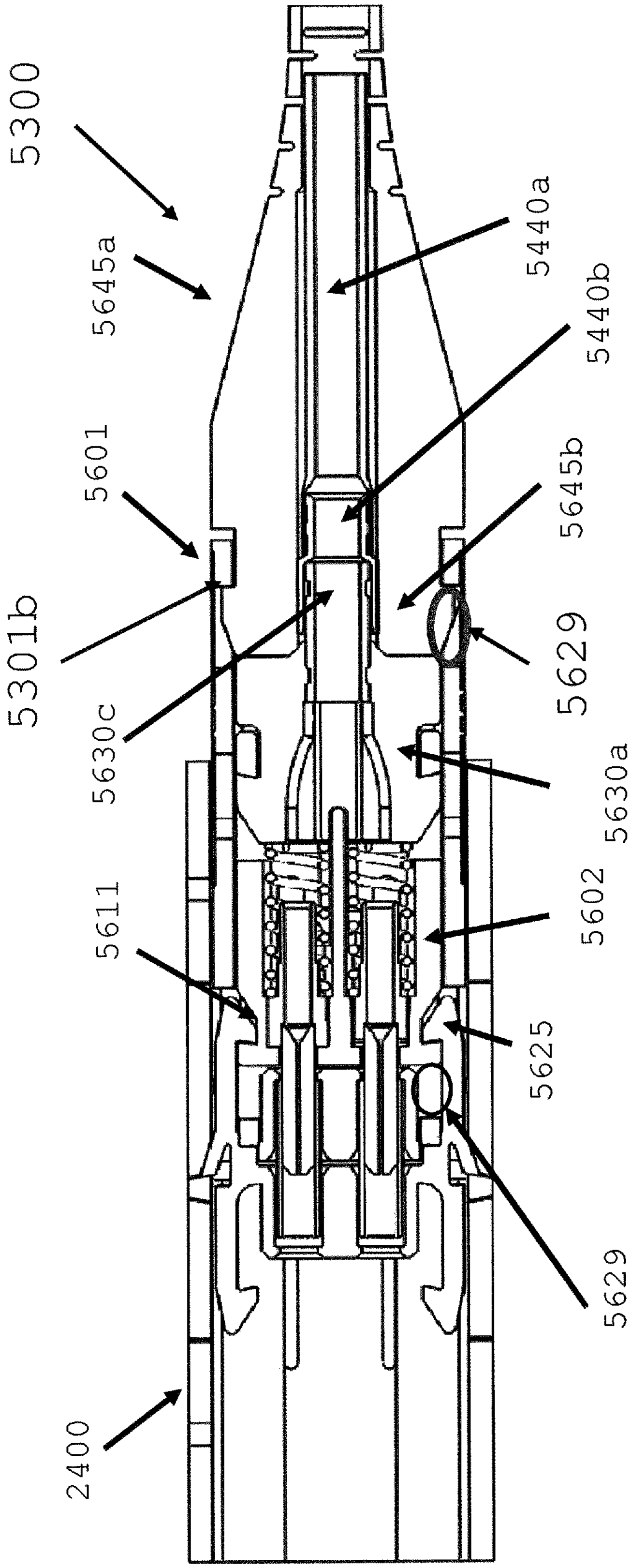
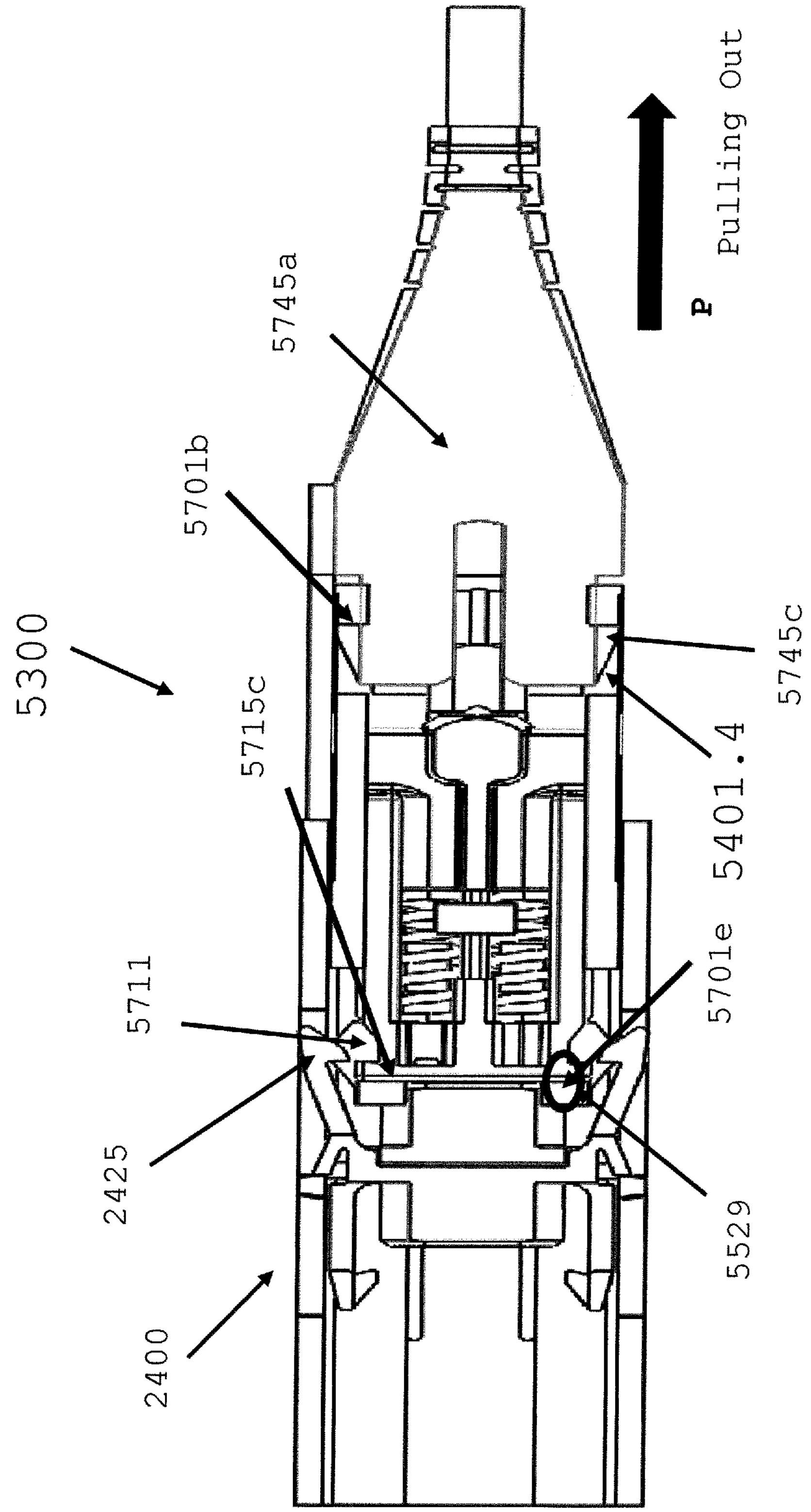

5300
5645a
5601
5301b
5630c
5611
2400
5440a
5440b
5645b
5629
5630a
5602
5625
5629

FIG. 40



P Pulling Out
5745a
5701b
5300
5715c
5745c
5401.4
5701e
5711
2425
5529
2400

FIG. 41

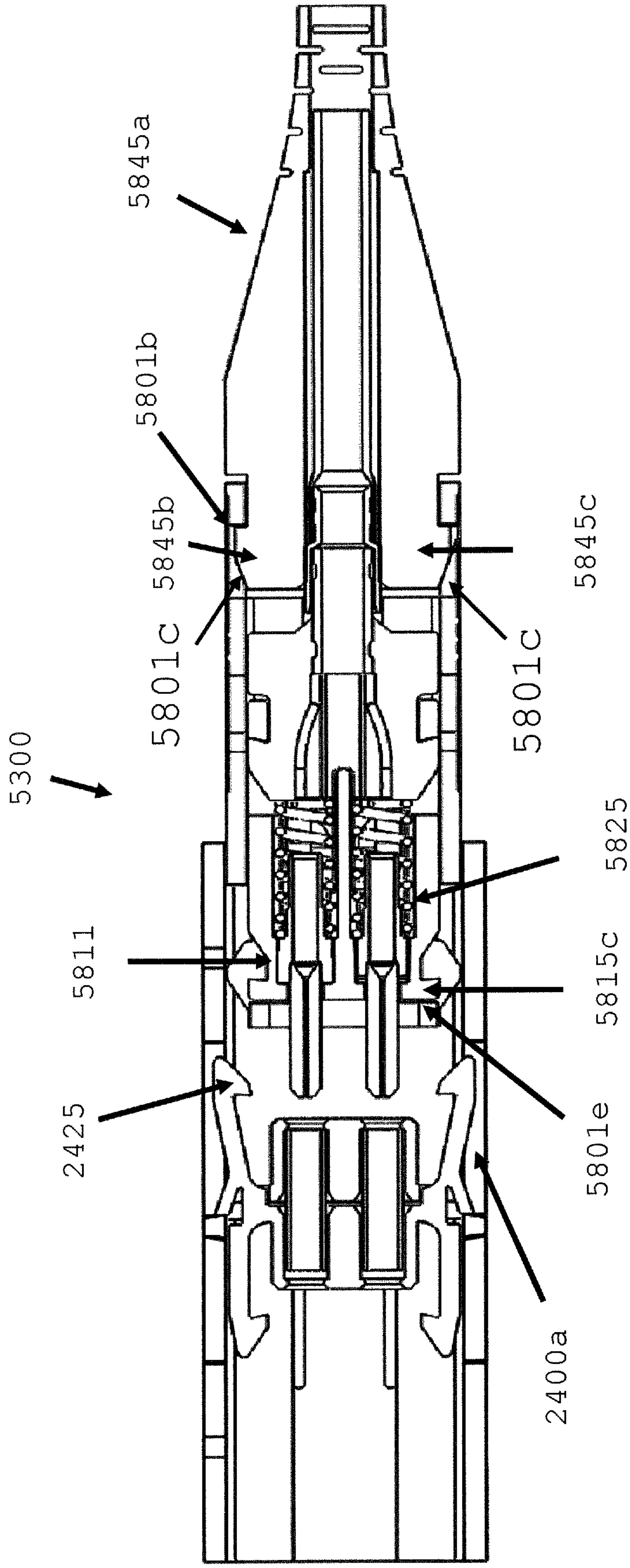

5845a
5801b
5845b
5845c
5801c
5801c
5300
5825
5811
5815c
2425
5801e
2400a

FIG. 42

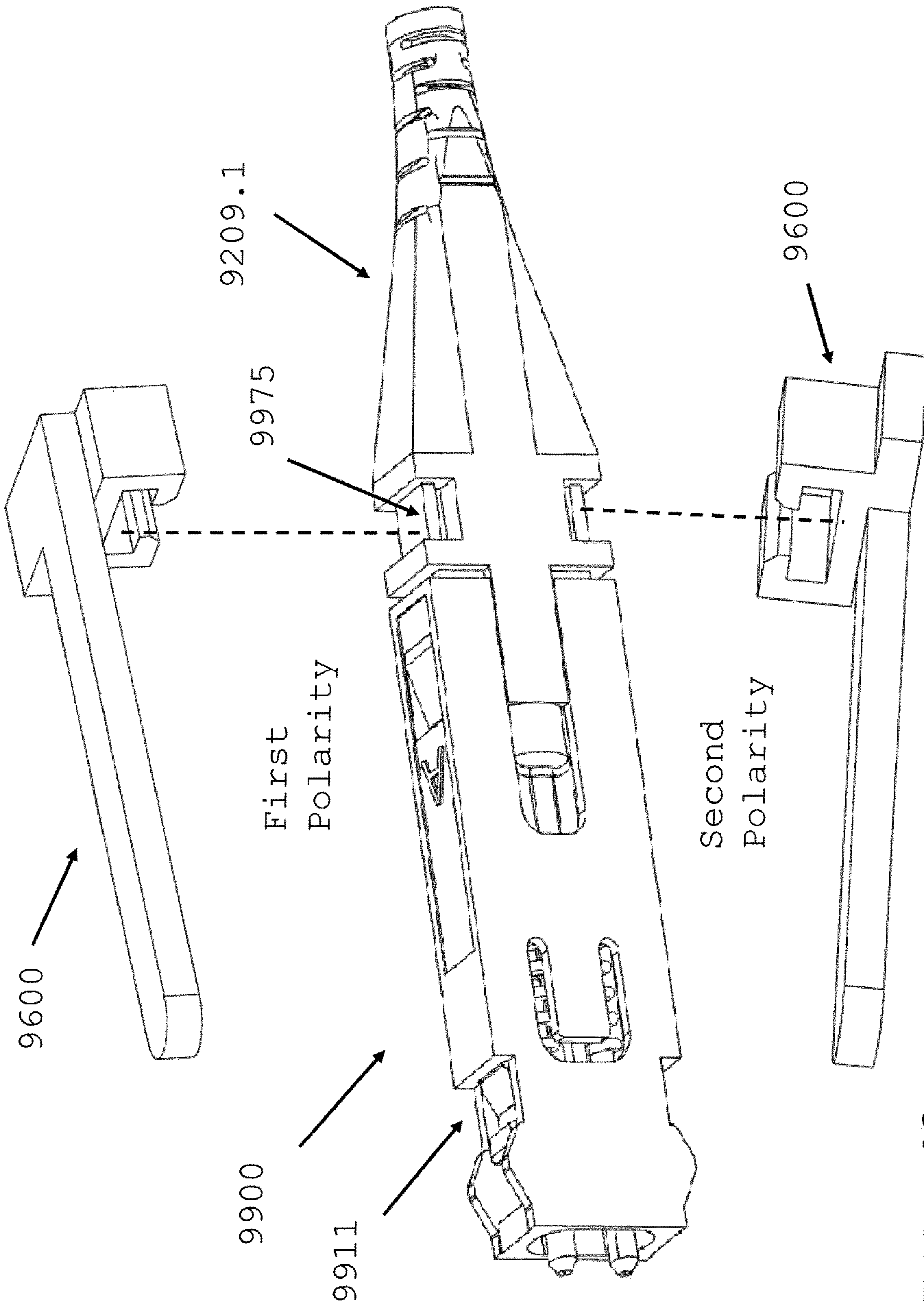

9209.1
9975
9600
9600
First Polarity
Second Polarity
9900
9911

FIG. 43

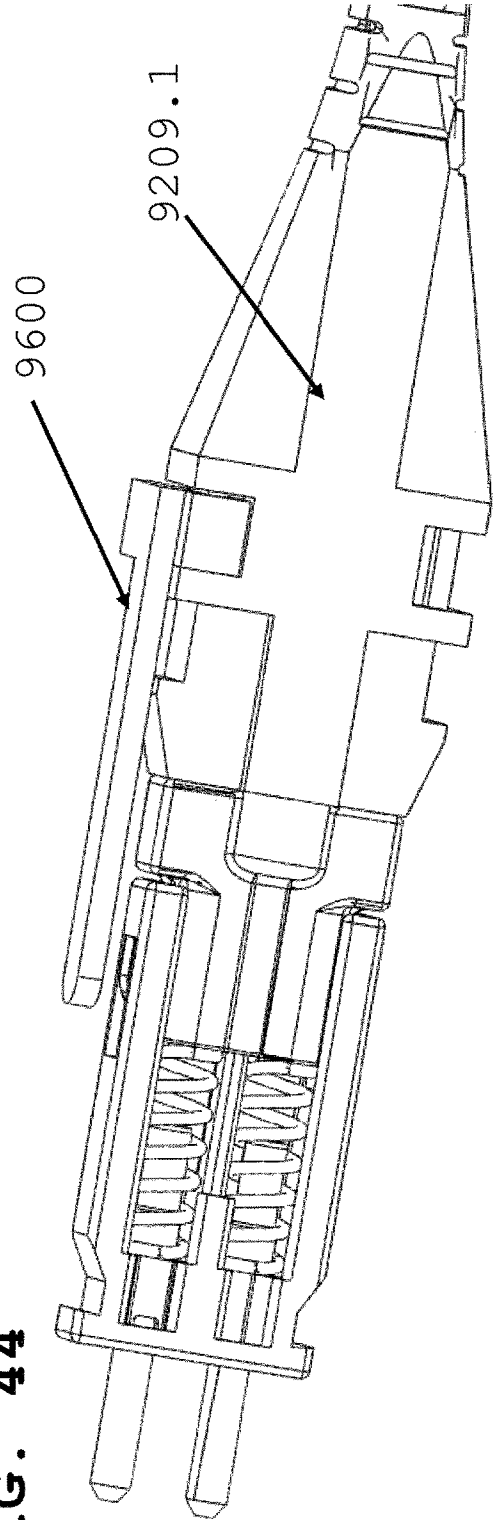


FIG. 44

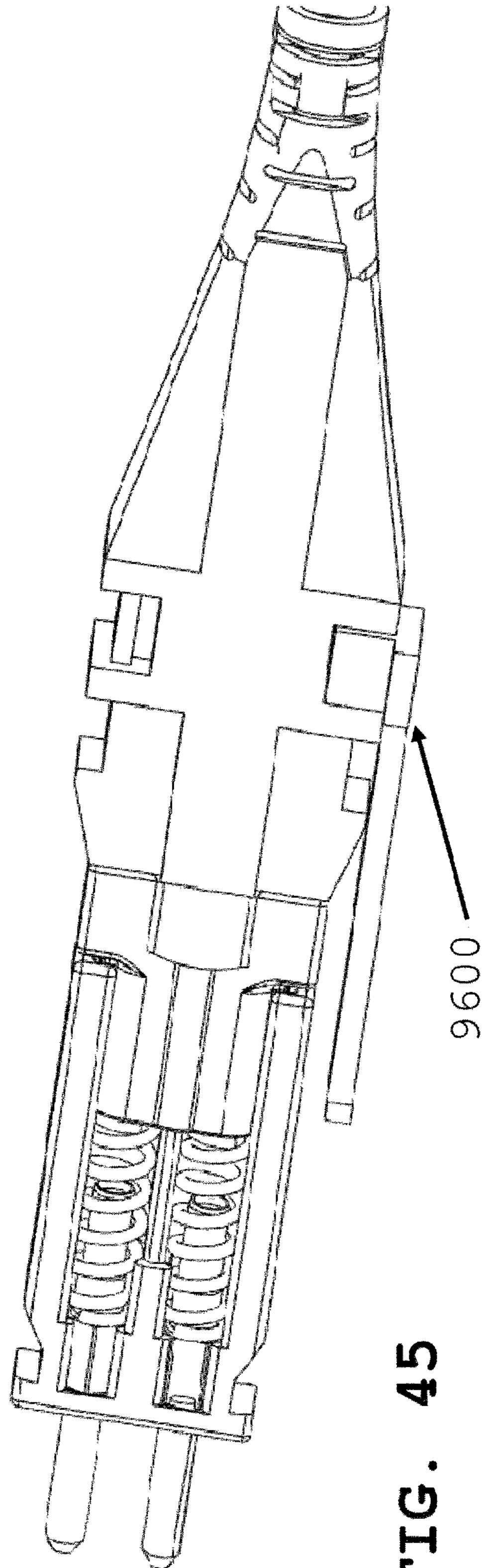


FIG. 45

SMALL FORM FACTOR FIBER OPTIC CONNECTOR WITH MULTI-PURPOSE BOOT ASSEMBLY

RELATED APPLICATIONS

This application is a divisional under 35 USC 121 that claims priority to U.S. patent application Ser. No. 16/368,828, titled "Small Factor Fiber Optic Connector with Multi-Purpose Boot", filed on Mar. 28, 2018, which claims priority to U.S. Patent Application 62/649,539 titled "Micro Connector with Multi-Purpose Boot", filed on Mar. 28, 2018; and further claims priority to U.S. patent with Ser. No. 16/103,555 filed on Aug. 14, 2018 entitled "Ultra-Small Form Factor Optical Connectors Using A Push-Pull Boot Receptacle Release", which is a continuation in-part of U.S. patent application Ser. No. 16/035,691 filed Jul. 15, 2018, entitled "Ultra-Small Factor Optical Connectors", which claims priority from U.S. Provisional Application Ser. No. 62/588,276 filed Nov. 17, 2017; U.S. Provisional Application Ser. No. 62/549,655 filed Aug. 24, 2017; and U.S. Provisional Application Ser. No. 62/532,710 filed Jul. 14, 2017 all of the above applications are incorporated by reference in this non-provisional patent application.

FIELD OF THE INVENTION

The present disclosure relates generally to ultra-small form factor optical connectors, termed "micro optical connectors," and related connections within adapters and optical transceivers.

BACKGROUND

The prevalence of the Internet has led to unprecedented growth in communication networks. Consumer demand for service and increased competition has caused network providers to continuously find ways to improve quality of service while reducing cost.

Certain solutions have included deployment of high-density interconnect panels. High-density interconnect panels may be designed to consolidate the increasing volume of interconnections necessary to support the fast-growing networks into a compacted form factor, thereby increasing quality of service and decreasing costs such as floor space and support overhead. However, room for improvement in the area of data centers, specifically as it relates to fiber optic connects, still exists. For example, manufacturers of connectors and adapters are always looking to reduce the size of the devices, while increasing ease of deployment, robustness, and modifiability after deployment. In particular, more optical connectors may need to be accommodated in the same footprint previously used for a smaller number of connectors in order to provide backward compatibility with existing data center equipment. For example, one current footprint is known as the small form-factor pluggable transceiver footprint (SFP). This footprint currently accommodates two LC-type ferrule optical connections. However, it may be desirable to accommodate four optical connections (two duplex connections of transmit/receive) within the same footprint. Another current footprint is the quad small form-factor pluggable (QSFP) transceiver footprint. This footprint currently accommodates four LC-type ferrule optical connections. However, it may be desirable to accommodate eight optical connections of LC-type ferrules (four duplex connections of transmit/receive) within the same footprint.

In communication networks, such as data centers and switching networks, numerous interconnections between mating connectors may be compacted into high-density panels. Panel and connector producers may optimize for such high densities by shrinking the connector size and/or the spacing between adjacent connectors on the panel. While both approaches may be effective to increase the panel connector density, shrinking the connector size and/or spacing may also increase the support cost and diminish the quality of service.

In a high-density panel configuration, adjacent connectors and cable assemblies may obstruct access to the individual release mechanisms. Such physical obstructions may impede the ability of an operator to minimize the stresses applied to the cables and the connectors. For example, these stresses may be applied when the user reaches into a dense group of connectors and pushes aside surrounding optical fibers and connectors to access an individual connector release mechanism with his/her thumb and forefinger. Overstressing the cables and connectors may produce latent defects, compromise the integrity and/or reliability of the terminations, and potentially cause serious disruptions to network performance.

While an operator may attempt to use a tool, such as a screwdriver, to reach into a dense group of connectors and activate a release mechanism, adjacent cables and connectors may obstruct the operator's line of sight, making it difficult to guide the tool to the release mechanism without pushing aside the adjacent cables. Moreover, even when the operator has a clear line of sight, guiding the tool to the release mechanism may be a time-consuming process. Thus, using a tool may not be effective at reducing support time and increasing the quality of service.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an exploded view of a micro optical connector improved according to disclosed embodiments of push/pull and polarity change in present invention.

FIGS. **2-4** depict a technique polarity changing of the micro connector of FIG. **1**

FIGS. **5-8** depict polarity changing according to an another embodiment of the present invention of a micro-connector.

FIG. **9-11** depict inserting the micro-connector of FIG. **1** into an adapter.

FIG. **12** is a perspective view of a front body according to an embodiment of the present invention.

FIG. **13** is a perspective view of another embodiment of an adapter hook and alignment assembly.

FIG. **14** is a perspective view of micro connectors of FIG. **1** inserted into an adapter.

FIG. **15** is a perspective rear view of a group of micro connectors of FIG. **14**.

FIG. **16** is a perspective view of a micro connector with multi-purpose push/pull-rotatable boot (FIG. **17**) for insert/removal of connector from adapter and for polarity change.

FIG. **17** is a perspective view of multi-purpose rotatable boot assembly with an alignment and offset key releasable attached to the boot assembly.

FIG. **18** is a perspective view of an outer housing of the micro connector of FIG. **16**.

FIG. **19** is a perspective view of front body and boot removed from FIG. **18** outer housing.

FIG. **20** is a perspective view of the micro connector in a first polarity position.

FIG. **21** is a perspective view of the connector of FIG. **20** being rotated in direction "R" to a second polarity.

FIG. **22** depicts micro connector of FIG. **20** being rotated further to the second polarity.

FIG. **23** depicts micro connector of FIG. **20** in the second polarity.

FIG. **24** is side view of micro connector of FIG. **16** with a cross section cut "A-A".

FIG. **25** is a view along cross section cut "A-A" of the micro connector of FIG. **16** in a first polarity position.

FIG. **26** is an end view of the boot assembly illustrating an opening for fiber optic cabling.

FIG. **27** is a perspective view of end of a back body, with fiber optic cabling.

FIG. **28** is perspective view along cross section "A-A" at a start of boot rotation to change a micro connector from a first polarity to a second polarity.

FIG. **29** is perspective view along cross section "A-A" in furtherance of boot rotation to change the micro connector from a first polarity to a second polarity.

FIG. **30** is a perspective view of the micro connector in furtherance of boot rotation.

FIG. **31** is a perspective view along cross section "A-A" just prior to completion to a second polarity of the micro connector.

FIG. **32** is a perspective view of the micro connector just prior to completion to a second polarity.

FIG. **33** is a perspective view along cross section "A-A" of micro connector FIG. **16** in a second polarity position.

FIG. **34** is a perspective view along a longitudinal cross section of a micro connector of FIG. **16**, latched into an adapter receptacle with multi-purpose rotatable boot assembly biased forward or pushed in.

FIG. **35** is a perspective view of FIG. **34** as multi-purpose rotatable boot assembly is partially pulled in direction "P".

FIG. **36** is a perspective view of FIG. **34** as multi-purpose rotatable boot assembly (FIG. **17**) is release from adapter hook but still under influence of pulling force "P".

FIG. **37** is perspective view of a micro connector with another push/pull release embodiment incorporated therein.

FIG. **38** is an exploded view of FIG. **37** connector.

FIG. **39** is a side perspective inner view of a micro connector of FIG. **37** without an outer housing.

FIG. **40** is a cross-section view of connector of FIG. **37** latched into a receptacle.

FIG. **41** is a cross-section view of connector of FIG. **37** partial removed using push/pull release boot according to the present invention.

FIG. **42** is a cross-section view of connector of FIG. **37** released from an adapter receptacle.

FIG. **43** is an exploded view of another embodiment of a micro connector with a releasably attached clip defining a first and a second polarity.

FIG. **44** is an assembly view of the micro connector of FIG. **43** in a first polarity.

FIG. **45** is an assembled view of the micro connector of FIG. **43** in a second polarity.

DETAILED DESCRIPTION

The following terms shall have, for the purposes of this application, the respective meanings set forth below.

A connector, as used herein, refers to a device and/or components thereof that connects a first module or cable to a second module or cable. The connector maybe configured for fiber optic transmission or electrical signal transmission. The connector may be any suitable type now known or later developed, such as, for example, a ferrule connector (FC), a fiber distributed data interface (FDDI) connector, an LC connector, a mechanical transfer (MT) connector, a square connector (SC) connector, an SC duplex connector, or a straight tip (ST) connector. The connector maybe generally defined by a connector housing body. In some embodiments, the housing body may incorporate any or all of the components described herein.

A "fiber optic cable" or an "optical cable" refers to a cable containing one or more optical fibers for conducting optical signals in beams of light. The optical fibers can be constructed from any suikeyle transparent material, including glass, fiberglass, and plastic. The cable can include a jacket or sheathing material surrounding the optical fibers. In addition, the cable can be connected to a connector on one end or on both ends of the cable.

Various embodiments described herein generally provide a remote release mechanism such that a user can remove cable assembly connectors that are closely spaced together on a high density panel without damaging surrounding connectors, accidentally disconnecting surrounding connectors, disrupting transmissions through surrounding connectors, and/or the like. Various embodiments also provide narrow pitch LC duplex connectors and narrow width multi-fiber connectors, for use, for example, with future narrow pitch LC SFPs and future narrow width SFPs. The remote release mechanisms allow use of the narrow pitch LC duplex connectors and narrow width multi-fiber connectors in dense arrays of narrow pitch LC SFPs and narrow width multi-fiber SFPs.

FIG. **1** depicts an embodiment of micro optical connector **2100**, shown in exploded view. Micro optical connector **2100** may include outer housing **2101**, front body **2102**, one or more ferrules **2103**, one or more ferrule flanges **2104**, one or more springs **2133**, back body **2106**, the latter has a wing **2106.1** on the top and bottom of the body, the wing **2106.1** is secured within an opening **2119** at a distal end of front body **2102**, back post **2107**, crimp ring **2108**, and boot **2109**. Front body **2102** side walls are open not closed, a channel **2194** for aligning ferrule flanges **2104**, and an alignment sleeve opening **2113** to accept ferrule **2103**. Outer housing **2101** may include a longitudinal bore for accommodating front body **2102** and ferrule **2103**, springs **2133** and back body **2106**, connector alignment key **2105** used during interconnection, connector flap **2101.1** and an optional pull key **2110** to facilitate removal of connector **2100** when connected in a dense array of optical connectors. Optionally, the ferrules may be LC-type ferrules having an outer diameter of 1.25 mm. Connector flap **2101.1** secures front body **2102** within outer housing **2101**. Alignment key **2105** is also used as blocking structure to indicated connector polarity orientation as disclosed herein. Polarity is determined by the ferrules **9203** (Refer to FIG. **19**), where a first ferrule is for Tx or transmit and a second ferrule is for Rx or receive. As known in the art, a mismatch of ferrules **9203** with opposing ferrules secured in an opposing adapter port, the signal would be lost. Alignment key performs a dual function, when the boot assembly is rotated, the alignment key is repositioned, so upon insertion into an adapter, the connector can be blocked by the key. This in effect disallows the user to insert the connector within the adapter receptacle, thus, preventing a mismatch of signal between opposing connectors across an adapter interface. As disclosed below, starting at FIG. **18** an additional aid may be markings located on the connector housing, indicating "A" or "B" polarity of the connector ferrules after rotating the boot.

As depicted FIGS. **2-4**, FIG. **2** micro connector **3700** includes an assembled front body **3702** that may be removed from outer housing **3701**, rotated 180° as indicated by the arrow (FIG. **3**), and re-inserted into the outer housing (FIG. **4**). This allows for a change in the polarity of the connector by removing and rotating front body **3702**, and therefore the ferrules can be switched quickly and easily without unnecessarily risking the delicate fiber cables and ferrules. Referring to FIG. **2**, micro connector **3700** is fully assembled. To remove front body **3702** to change connector polarity, as shown in FIG. **3**, one or more flex key **3703** are lifted outward to release front body **3702** for removal in rearward in the direction of the arrow "<". Referring to FIG. **4**, to complete the polarity change, after rotating front body **3702** by 180 degrees as shown in FIG. **3**, front body **3702** is inserted into the outer housing in the direction of arrow "F".

FIG. **5** depicts the operation of the polarity change mechanism using outer housing **5301** (refer to FIG. **6**), where pull key **5310** is integrated with the outer housing. In FIG. **5**, micro connector **5300** is fully assembled. The user inserts a tool in access slot **5329** and lifts off outer housing **5301**, instead of flexible keys **3703** (refer to FIG. **3**). Front body **5302** is removed with the boot and cable attached as shown in FIG. **6**. Turning to FIG. **7**, the outer housing **5301** is rotated 180 degrees, as shown by the arrow "R", and placed back over front body **5302** in the direction of the second arrow as shown. The reversed polarity micro connector **5300** is shown fully assembled in FIG. **8**.

Referring to FIG. **9**, micro connector **5300** is shown just prior to insertion into adapter **5600**. Connector **5300** is partially inserted in FIG. **10**, wherein connector hook (or adapter hook) **5525** has not yet been seated in the connector recess **5511**, and FIG. **11** depicts hook **5525** seated in recess **5511**, in direction of arrow "A".

Referring to FIG. **12**, front body **6102** has two cutouts **6119** and **6121** and an extended middle wall **6110**. Cutout **6121** engages the outer housing hooks (not shown) that replaces flex key **3703** to secure the outer housing to the front body. Cutout **6121** secures the polarity change key **5310**. Cutout **6119** secures back post **2106** to front body **6102** via back post front body hook **2106.1** (refer to FIG. **2**). The material is saved at back post **2106** overmolding, by not using the flex key, and this saved material to reinforce the middle wall to better help support the ferrule springs from bending and thus help prevent distorting the ferrules. This reduced material also allowed a reduction in the connector size contribution to a 3.1 mm ferrule to ferrule pitch as shown in FIG. **12**. This distortion can increase insertion loss. Connector recess **6111** is located at the proximal end of front body **6102**, and the recess engages and locks with connector hook **5525**. Referring to FIG. **13**, adapter hook **6246** added chamfers (**6242**, **6226**) to adapter (connector) hook surfaces to improve installation of the connector into the adapter when connector ramps **5512** engage adapter (connector hook) **5525** Refer to FIG. **5**). Adapter hook assembly has an alignment sleeve holder **6227** that accepts one or more ferrules from the micro connector, and aligns the ferrules **9203** with opposing ferrules of a second micro connector (not shown).

FIG. **14** illustrates a group of micro connectors **7500**A inserted into an adapter **5700**. Adapter **5700** has plural of slots **5700***a* configured to accept an alignment key **7500**A.**1** proximal on the alignment and offset key (**7500**A, **9105**.**1**)

Alignment key, and alignment and offset key is defined as a protrusion adjacent to a side of the connector housing.

FIG. **15** depicts alignment and offset key **7500**B with the group of micro connectors **7500**A of FIG. **14**. Alignment/offset key **7500**B adds stability and reduces misalignment during insertion when key **7500**B acts as a support between connectors as shown. Key **75008** also helps determine polarity of the micro connector, as described herein.

Referring to FIGS. **16-17**, FIG. **16** depicts micro connector **9100** with an alignment and offset key **9105**.**1** having an offset portion **9123**. Offset portion **9123** engages a top surface of a side bar ledge **9124** for aligning connector **9100** into a multi-receptacle adapter next to another micro connector. Side bar ledge **9124** is located further back or nearer a distal end of a connector (e.g. closer to the cable) where side bar ledge **9124** is part of a multi-purpose rotatable boot **9109**.**1**. Micro connector **9100** outer housing **9101** is secured to boot **9100**.**1** via boot hooks **9109**.**5** (FIG. **17**) that engages second slot **9201**.**4***a* and **9201**.**4***b* in connector housing **9201** (as shown in FIG. **18**), when in polarity status "B" or status "A", as depicted on outside of micro connector housing. Multi-purpose boot is rotatable in the direction of arrow "R".

Referring to FIG. **17**, multi-purpose rotatable boot **9109**.**1** comprises releasably attached alignment and offset key **9105**.**1**, releasable at release point **9109**.**6**, also refer to FIG. **43**. Alignment and offset key **2105** may be fixed on connector outer housing, as shown in FIG. **1** or at alignment key **5305** disclosed in FIG. **37**. The alignment key may have not offset portion as disclosed in FIG. **1** and FIG. **37**, without departing from the scope of the invention, that the boot assembly is rotatable as disclosed in FIGS. **26-27** and FIGS. **25-33** and FIGS. **43-45**. It is the key protruding from the connector housing that is determines polarity upon rotation of the boot assembly as disclosed herein. Alignment key (**2105**, **9405**.**1**, **5305**, **9600**) or similar structure protruding from the outer connector housing repositioned by the rotating boot assembly and the key interaction with adapter structure that determines polarity as described herein. Referring to FIG. **17**, key **9105**.**1** has a securing protrusion **9105**.**2** at a proximal end that engages first slot **9201**.**3***b* in connector housing **9201** (refer to FIG. **18**) to further secure multi-purpose rotatable boot assembly **9109**.**1** to front body **9202** or outer housing **9201**. Multi-purpose rotatable boot assembly **9109**.**1** comprises a body **9109**.**1***a* with a passageway along line P-P for passing a fiber optic cable (refer to FIG. **26** and FIG. **27**) to the ferrules to complete the signal path.

Referring to FIG. **18**, outer housing **9201** is shown in a Second Polarity orientation "B" comprising corresponding first slot **9201**.**3***b* and second slot **9201**.**4***b*. Multi-purpose rotatable boot assembly **9209**.**1** (FIG. **19**) is inserted at a distal end of connector housing **9201** shown in the direction of arrow "I". Second slot **9201**.**4***a* corresponds to polarity position "A".

Referring to FIG. **19**, multi-purpose rotatable boot assembly **9209**.**1** comprises alignment and offset key **9205**.**1**, as described herein boot hook **9209**.**5**, side bar ledge **9024** that is configured (as described herein) to engage back body **9206**, front body **9202** and plural of ferrules **9203**. Side bar ledge **9024** accepts offset key **9023** of a second connector when two connectors are inserted into an adapter. This allows connectors to be inserted side by side into an adapter more easily, without jamming. The proximal end (or ferrules **9203** end) of assembly **9209**.**1** is inserted into a distal end of the outer housing **9201** (FIG. **18**) in the direction of arrow "1". Upon insertion, the outer housing **9201** engages with multi-purpose rotatable boot assembly **9209**.**1** as shown by the dotted lines between first slot **9201**.**3***b* and second slot **9201**.**4***b*, engaging securing protrusion **9205**.**2** on alignment and offset key **9205**.**1** and boot wing **9209**.**5**. The wing and securing protrusion are received second slot and first slot described in FIG. **18** outer housing.

Referring to FIG. **20**, front body **9302** and boot assembly **9309.1** are assembled in micro connector housing **9301** with alignment and offset key **9305.1** in a first polarity position.

Referring to FIG. **21**, multi-purpose rotatable boot assembly **9309.1** is rotated in direction "R" to convert from a first polarity "A" (refer to FIG. **20**) to Second Polarity "B" (refer to FIG. **23**), with alignment and offset key **9305.1** 180 degrees or opposite the first polarity position as depicted in FIG. **20**, to Second Polarity position "B". Boot rotation key **9305.1** may be sized as disclosed in FIG. **1**. Boot hook **9209.5** further comprises chamfer **9309.2**. Chamfer **9309.2** engages wall **9301.5** of connector outer housing and chamfer **9309.2** lifts boot hook **9209.5** out of a distal end of connector housing **9301** and is freed from second slot **9201.4***b*, and securing protrusion **9105.2** (refer to FIG. **17** and shown in FIG. **20**) lifts out of first slot **9201.3***b* thereby allowing the boot assembly to rotate as shown in the direction "R", FIG. **21**. Chamfer **9309.2** may engage wall **9301.5** using an angle or chamfer cut opposite current chamfer **9309.2** to allow for rotation in the opposite direction of FIG. **21**. Rotation of boot assembly **9309.1** changes connector **9100** from a first polarity "A", as depicted in FIG. **20**, to Second Polarity "B", as depicted in FIG. **19** (without connector housing) and FIG. **32**. Boot assembly may be rotated in a clockwise direction, without departing from the scope of the invention.

Referring to FIG. **22**, further rotation of boot assembly **9309.1** results in a change to a second polarity as shown in FIG. **23**, with alignment and offset key secured within polarity "B" first slot **9201.3***b*.

Referring to FIG. **23**, side bar ledge **9023** (as well as alignment key **9305.1**) is in Second Polarity position or "B" polarity, and when the micro connector is inserted into an adapter (not shown), the micro connector is oriented with key **9305.1** in an opposite position to FIG. **20**, so key may be blocked by corresponding adapter structure (not shown). If micro connector **9100** is blocked by adapter structure this means the micro connector is not in the correct polarity orientation to make a fiber to fiber connection via an adapter to an opposing fiber optic connector or transceiver as is known in the art. After rotation, the ferrules are reversed the top ferrule is now the bottom ferrule, and this results in a second polarity configuration. The second polarity being different from the first polarity, that is, Rx receive signal is now Tx transmit signal path and vice versa. Alignment and offset key **9405.1** has been switch from a First Polarity "A" to Second Polarity "B".

FIG. **24** is the micro connector **9100** with a cross section along "A-A" line as shown in FIGS. **25** through **33** further illustrating polarity change using multi-purpose rotatable boot assembly **9209.1**. Longitudinal cross section is provided along line "B-B" in various drawings of this application. "L-L" is the longitudinal axis of the connectors in the present invention.

Referring to FIG. **25**, a front view of the cross-section cut "A-A" of the micro connector of FIG. **24** (also FIG. **16**) further comprises an opening through which fiber cabling (not shown) travels, and crimp ring surface **9407.1** that is further surrounded by inner round **9409.4**. Referring to FIG. **26**, inner round **9409.4** engages a back post surface **9406.7** formed as an outer round shown at FIG. **27**, as the assembly **9209.1** is rotated. Inner round and outer round form mating surfaces that can freely rotate thereby allowing multi-purpose boot assembly to be rotated about fiber optic connector housing. Referring back to FIG. **25**, boot hook **9109.5** further comprises first chamfer **9409.2***a* and first stopping wall **9409.3***a*, and second chamfer **9409.2***b* and second stopping wall **9409.3***b*, in a first polarity position. Boot hooks **9109.5** rotate between second slot **9201.4***a* and second slot **9201.4***b* during polarity change. Second slot **9201.4***a* corresponds to the connector being in a "A" polarity position. Likewise, second slot **9201.4***b* corresponds to the connector being in "B" polarity configuration. Securing protrusion **9405.1** resides in first slot **9201.3***a* for "A" polarity, and then resides in first slot **920***i***.3***b* for "B" polarity after boot release **9309.1** rotation.

Referring to FIG. **28**, rotating of the boot assembly is started and chamfer **9409.2***a* engages connector housing wall **9301.5** and begins to lift first boot wing **9109.5***a* out of second slot **9201.4***a*. Likewise, a second boot wing **9109.5***b* is rotating out of second slot **9201.4***b*.

Referring to FIG. **29** upon further rotation in direction "R", securing protrusion **9105.2** (refer to FIG. **20**) on alignment and offset key **9405.1** is lifted out of first slot **9201.3***a* (refer to FIG. **20** and FIG. **21**), and boot wing **9109.5***a* is lifted out of second slot **9201.4***a* at a top surface and upon 180 degree rotation, securing protrusion **9105.2** (refer to FIG. **20**) is accepted into first slot **9201.4***b* at a bottom surface of the outer housing **9401**. Boot wing **9109.5***b* moves out of second slot **9201.4***b*.

Referring to FIG. **30**, the rotation of boot assembly **9409.1** is shown as it exits the outer housing **9401** of connector **9100**. Chamfer **9409.2***b* exits first from this view. Alignment and offset key **9405.1** is moving around the outer housing body in a counter-clockwise direction, in this view to a Second Polarity position "B".

Referring to FIG. **31**, alignment and offset key **9405.1** is almost in a second polarity position as shown, with chamfer **9409.2***b* in an opposite orientation to itself in FIG. **25**. Referring to FIG. **32**, connector **9100** shows chamfer **9409.2***b* in the opposite position to that of FIG. **30**, indicating the connector is close to its second polarity configuration with alignment and offset key **9405.1** at bottom surface of outer housing **9401**. FIG. **33** depicts connector **9100** along cross section "A-A" in its second polarity position, with chamfer **9409.2***b* in second slot **9401.4***a* at the top surface of outer housing **9401**. Polarity key **9405.1** is at the bottom surface of outer housing **9401** indicating the connector is in a second polarity configuration.

Referring to FIG. **34** a micro connector **9100** is shown along cross section "B-B" (refer to FIG. **24**) in a latched position within a receptacle of adapter **2400**. During rotation of the multi-purpose rotatable boot assembly **9209.1**, boot wing **9209.5** operates as described above in FIGS. **25-33**. This is accomplished by gap **9209.6** between boot assembly **9209.1** that allows "free-wheeling" about crimp ring **9207** as inner round **9409.4** engages back post face surface **9406.7** as described in FIGS. **26-27**. Rotating boot assembly while connector is in a latched position within adapter, boot assembly wing **9209.5** facing surface is in contact with facing surface **9206.2** of back post **2106**, as shown at interface **9100.8**. Still referring to FIG. **34**, boot wing **9209.5** face engages and releaseably locks with corresponding surface **9301.4***a* of second slot **9201.4** of outer housing **9201**, FIG. **18** and FIG. **21**. Micro connector **9100** is latched and unlatched in an adapter **2400** receptacle using push/pull boot assembly or push/pull key as described in FIGS. **9-11**, or FIGS. **34-36**, or FIGS. **37-42**. Adapter hook **2425** is seated in connector recess **9211** located in front body **9202**. In this position, boot assembly **9209.1** is up against back body **2106** as shown at interface **9100.8**, as shown by direction of arrow "Pushed In".

Referring to FIG. **35**, boot assembly **9209.1** is being pulled rearward in the direction of "P". Boot assembly

9209.1 is pulled a release distance "d" to interface **9100.8**, **9100.9** to unlatch connector from adapter interface. At the same time, adapter hook **2425** is being lifted out connector recess **9211** as micro connector **9100** is removed from adapter **2400** receptacle. Boot assembly **9209.1** moves a distance "d" because boot wing **9209.5** engages outer housing face **9301.4***a*, and pulls outer housing **9201** rearward. Outer housing **9201** is pulled rearward connector **9100** is released from this the amount of separation between the distal end of the back body and proximal end of boot assembly **9209.1**. This distance matches channel distance, FIG. **36**, **9100.9***a*, **9100.8***a* in which boot hooks slide upon pulling connector from adapter using rotatable boot assembly. Hooks **2425** lift out of recess **9211** located at a proximal end of front body **2102**, when boot assembly **9209.1** is pulled rearward at least this distance.

Referring to FIG. **36**, once boot assembly **9209.1** is fully pulled in direction of "P", connector **9100** is released from within adapter **2400**. Adapter hook **2425** is completely out of connector recess **9211**, and maximum pulling distance. Once the pull force, "P", is release from boot **9209.1**, interface distance **9100.8** returns to that of FIG. **34**, upon release of pull force "P", on boot assembly **9209.1**.

FIG. **37** depicts connector **5300** with push/pull boot assembly **5345***a* at its distal end receiving a fiber cable with a plural of fiber strands therein, and a proximal end configured to connect and secure to back body assembly **5330***a* secured with outer housing **5301**. Outer housing **5301** has alignment key **5305**, further has opening **5301***a* with stop face **5301***b* that boot wings (**5445***b*, **5445***c*) (refer to FIG. **38**) engage when boot assembly **5345***a* is pulled in a distal direction fully to release connector **5300** from a receptacle as shown in FIG. **41**, when hook **5425** is removed from recess **5711**. Ferrules **5303** provide the Tx, Rx information light signals.

FIG. **38** depicts an exploded view of connector **5300** of FIG. **37**. Boot assembly **5445***a* accepts crimp ring assembly **5440***a* having protective tube **5440***c* covering fiber strands and crimp ring **5440***b* secured to back post **5430***c* of back body assembly **5430***a* including back body **5430***b*. A pair of springs **5425** are placed over a corresponding ferrule assembly **5420** comprising a ferrule and ferrule flange. The ferrule assembly and springs are held within front body **5402** by back body assembly **5430***a*, as described for connector **2100**. Front body **5402** is inserted into distal opening **5401.1** of outer housing **5401** with boot assembly wing **5430***a* secured within a distal opening **5415***b* of front body and wing is secured through opening **5401.4** of outer housing securing outer housing, front body and back body together when assembled with push/pull boot, as depicted in FIG. **37**.

FIG. **39** depicts connector of FIG. **37** without its outer housing **5301**, in an assembled configuration. Boot assembly **5445***a* is secured on back post **5430***c* of back body **5430***a* via crimp ring **5440***a*, as described in FIG. **38**. Wings (**5445***b*, **5445***c*) secure FIG. **39** assembly within outer housing **5301**, and during release of connector **5300** from a receptacle, wings (**5445***b*, **5445***c*) pull back outer housing a specific distance "d", which releases adapter/receptacle hook or latch **5625** that is seated in recess **5611** (refer to FIG. **40**), while connector **5300** is secured within receptacle **2400**. Front body **5402** is secured to connector housing **5401** with back body **5430***a* secured to a distal end of front body **5402**, as described in FIG. **1** and elsewhere in this disclosure.

FIG. **40** depicts connector **5300** secured within receptacle **2400** of FIG. **24**. Receptacle hook or latch **5625** rests in connector recess **561.1** formed within front body **5601**, at its proximal end. A gap of distance "d" **5629** limits travel of

front body **5601** as boot release wing **5645***b* engages stop face **5301***b* of outer housing **5601**. This "d" travel removes hook **5625** from connector recess **5611** thereby unlatching or releasing connector from adapter **2400**. Crimp ring **5440***b* is shown secured to back post **5630***c*. Back body **5630***a* is secured within front body **5402** at distal openings **5401***b* (FIG. **38**).

FIG. **41** depicts connector **5300** being removed or pulled out of receptacle **2400** in direction "P". Hook or latch **2425** within receptacle housing lifts out of recess **5711** along front body ramp **5401***d* (FIG. **38**), as boot assembly **5745***a* is being pulled rearward or in a distal direction. Gap **5529** is closed as shown in FIG. **41**. Inner face of connector housing **5715***c* is flush with front face of front body **5701***e*, which stops travel of boot assembly and is configured to ensure adapter latch or hook **2425** is displaced from recess **5711** to release connector from receptacle, as shown in FIG. **42**. Boot wing **5745***c* is secured at a distal end within second slot or opening **5401.4** within connector housing **5401**.

FIG. **42** depicts connector **5300** removed from receptacle **2400** using boot assembly **5845***a*. In this embodiment, wings (**5845***b*, **5845***c*) are flush with outer housing wall **5801***b*. Wings (**5845***b*, **5845***c*) move within gap or opening **5801***c* within connector housing outer wall, as boot **5845***a* is pulled rearward to release connector from adapter **2400** as shown. Spring **5825** biases forward front body face **5815***c* to be flush with front body face **5801***e*, when pull force is released from boot assembly. Hook or latch **2425** is displaced from recess **5811**, and hook resides in adapter housing gap **2400***a* within outer housing of receptacle **2400**. This reduces the overall dimensions of the adapter to accept more connectors.

Referring to FIG. **43**, another embodiment of a polarity change is disclosed using alignment and offset key **9600**. Alignment and offset key **9600** is releaseably attached to boot clip surface **9975** as shown by the dotted line. Attaching key **9600** to a first side of the boot **9209.1**, connector **9100** is in first polarity configuration, and attaching key **9600** to a second side, connector **9100** is in a second polarity configuration. Referring to FIG. **44**, a first polarity configuration is assembled key **9600** is attached to boot **9209.1** of connector **9100**. Referring to FIG. **45**, a second polarity configuration is assembled with key **9600** is attached to the opposite side of boot **9209.1**.

In the above detailed description, reference is made to the accompanying drawings, which form a part hereof. In the drawings, similar symbols typically identify similar components, unless context dictates otherwise. Other embodiments may be used, and other changes may be made, without departing from the spirit or scope of the subject matter presented herein.

It will be understood by those within the art that, in general, terms used herein, and especially in the appended claims (for example, bodies of the appended claims) are generally intended as "open" terms (for example, the term "including" should be interpreted as "including but not limited to," the term "having" should be interpreted as "having at least," the term "includes" should be interpreted as "includes but is not limited to," et cetera). For example, as an aid to understanding, the following appended claims may contain usage of the introductory phrases "at least one" and "one or more" to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles "a" or "an" limits any particular claim containing such introduced claim recitation to embodiments containing only one such recitation, even when the same claim includes the introductory phrases "one or more" or "at least one" and indefinite articles such as "a" or "an" (for example, "a" and/or "an" should be interpreted to mean "at least one" or "one or more").

The invention claimed is:

1. An optical fiber connector comprising:

a front body configured to hold first and second ferrules;

a back body having a proximal end portion and a distal end portion spaced apart along a longitudinal axis, the proximal end portion of the back body configured to couple to the front body, the distal end portion of the back body comprising a cylindrical back post having an outer round surface extending along the longitudinal axis, the back body defining a back body passageway extending from the distal end portion through the proximal end portion; and

a rotatable boot assembly having a proximal end portion and a distal end portion spaced apart along the longitudinal axis, the rotatable boot assembly comprising a main body and a strain relief sleeve extending longitudinally from the main body to the distal end portion of the rotatable boot assembly, the rotatable boot assembly comprising a boot passageway extending from the distal end portion through the main body, the main body comprising an inner round surface extending along the longitudinal axis, the inner round surface defining a proximal end portion of the boot passageway, the rotatable boot assembly configured to be disposed on the back body such that (i) the outer round surface of the back post is matingly received in the inner round surface of the main body and (ii) the cable boot member is slidable along the longitudinal axis relative to the back body for releasing the optical fiber connector from an adapter, the optical fiber connector being configured to terminate a fiber optic cable such that a jacket of the cable is received in the strain relief sleeve in the boot passageway, the boot passageway and the back body passageway configured to align for passing first and second fibers from the fiber optic cable to the front body to complete a signal path to the first and second ferrules within the front body; the main body further comprising at least one boot hook configured for releasably securing the multi-purpose rotatable boot assembly against rotation relative to the back body, and the rotatable boot assembly further comprising an elongate arm extending longitudinally from the main body in a proximal direction along the longitudinal axis, the elongate arm being configured for selectively setting the optical fiber connector to each of a first polarity and a second polarity.

2. The optical fiber connector according to claim **1**, wherein the elongate arm is an alignment key.

3. The optical fiber connector according to claim **2**, wherein the alignment key aligns the proximal end of the optical fiber connector into the adapter.

4. The optical fiber connector according to claim **2**, wherein the alignment key further comprises an offset key, the offset key stabilizes the distal ends of the fiber optic connector and the second fiber optic connector.

5. An alignment and offset key comprising:

a main body with a proximal end closer to a ferrule within fiber optic connectors,

and a distal end closer to an incoming fiber optic cable;

the proximal end further comprises a protrusion, the protrusion is configured to be accepted into a slot made in an adapter housing for aligning the fiber optic connector upon inserting the fiber optic connector into the adapter;

the distal end further comprising an offset key, the offset key has protrusion on one side and forms a gap on the opposing side, and wherein the offset key attached to a fiber optic connector, the protrusion mates with a gap formed by a second offset key attached to a second fiber optic connector, whereby the mating stabilizes the distal end of the fiber optic connector with the second fiber optic when the connectors are secured within the adapter.

6. The optical fiber connector according to claim **1**, wherein the at least one boot hook comprises first and second boot hooks.

7. The optical fiber connector according to claim **6**, wherein the first and second boot hooks are spaced apart on diametrically opposite sides of the longitudinal axis.

8. The optical fiber connector according to claim **6**, wherein when the rotatable boot assembly is disposed on the back body, the first and second boot hooks are spaced apart on diametrically opposite sides of the back body passageway and radially overlap the back body passageway relative to the longitudinal axis.

9. The optical fiber connector according to claim **6**, wherein the first and second boot hooks are releasable to allow the rotatable boot assembly to rotate on the fiber optic cable 180° about the longitudinal axis from a first polarity position in which the elongate arm sets the optical fiber connector to the first polarity to a second polarity position in which the elongate arm sets the optical fiber connector to the second polarity.

10. The optical fiber connector according to claim **9**, wherein when the rotatable boot assembly is in the first polarity position, the first boot hook is on a first side of the back post and the second boot hook is on a second side of the back post; and wherein when the boot assembly is in the second polarity position, the first boot hook is on the second side of the back post and the second boot hook is on the first side of the back post.

11. The optical fiber connector according to claim **9**, wherein the elongate arm is connected to the main body to rotate with the main body as the rotatable boot assembly rotates between the first polarity position and the second polarity position.

12. The optical fiber connector according to claim **6**, wherein the first boot hook and the elongate arm are radially spaced apart from the longitudinal axis in a first direction and the second boot hook is radially spaced apart from the longitudinal axis in a second direction opposite the first direction.

13. The optical fiber connector according to claim **1**, wherein the boot hook is releasable to allow the rotatable boot assembly to rotate on the fiber optic cable 180° about the longitudinal axis from a first polarity position in which the elongate arm sets the optical fiber connector to the first polarity to a second polarity position in which the elongate arm sets the optical fiber connector to the second polarity.

14. The optical fiber connector according to claim **13**, wherein the elongate arm is connected to the main body to rotate with the main body as the rotatable boot assembly rotates between the first polarity position and the second polarity position.

15. The optical fiber connector according to claim **14**, wherein the front body holds the first and second ferrules such that the first ferrule is radially spaced apart from the longitudinal axis in a first direction and the second ferrule is radially spaced apart from the longitudinal axis in a second direction opposite the first direction.

16. The optical fiber connector according to claim **15**, wherein when the rotatable boot assembly is in the first polarity position, the elongate arm is radially spaced apart from the longitudinal axis in the first direction; and wherein when the boot assembly is in the second polarity position, the elongate arm is radially spaced apart from the longitudinal axis in the second direction.

17. The optical fiber connector according to claim **15**, wherein the front body comprises a contiguous ferrule support wall extending transverse to the longitudinal axis and having a first end portion radially spaced apart from the longitudinal axis in the first direction and a second end portion radially spaced apart from the longitudinal axis in the second direction, the ferrule support wall defining a first ferrule opening radially spaced between the first end portion and the longitudinal axis and a second ferrule opening radially spaced between the longitudinal axis and the second end portion, the front body configured to receive the first ferrule in the first opening and the second ferrule in the second opening, the front body further comprising a first elongate portion extending longitudinally from the first end portion of the ferrule support wall and a second elongate portion extending longitudinally from the second end portion of the ferrule support wall, the first and second elongate portions having distal end segments that define an undivided space between them that opens longitudinally through a distal end of the front body.

18. The optical fiber connector according to claim **17**, wherein the proximal end portion of the back body is configured to be received in the undivided space between the distal end segments of the first and second elongate portions.

19. The optical fiber connector according to claim **1**, wherein the back body passageway and the boot passageway form a single, undivided longitudinal passage through which the first and second fibers are passable from the cable to the first and second ferrules.

20. The optical fiber connector according to claim **1**, wherein the back body passageway comprises a distal segment along the back post, a proximal segment along the proximal end portion of the back body, and a transition segment between the distal segment and the proximal segment,

wherein the back body passageway has a first inner dimension along a first radial axis and a second inner dimension along a second radial axis perpendicular to the first radial axis,

wherein along the distal segment, the back body passageway is substantially circular such that the first inner dimension is about the same as the second inner dimension;

wherein along the proximal segment, the back body has a cross-sectional shape that is elongate along the first radial axis such that the first inner dimension is greater than the second inner dimension; and

wherein along the transition segment, as the back body passageway extends in the proximal direction along the longitudinal axis, the first inner dimension increases by a greater amount than the second inner dimension.

* * * * *

EXHIBIT I

US011391895B2

(12) **United States Patent**
Gniadek et al.

(10) **Patent No.: US 11,391,895 B2**
(45) **Date of Patent: Jul. 19, 2022**

(54) **OPTICAL FIBER CONNECTOR WITH CHANGEABLE POLARITY**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **17/366,489**

(22) Filed: **Jul. 2, 2021**

(65) **Prior Publication Data**

US 2021/0405303 A1 Dec. 30, 2021

Related U.S. Application Data

(63) Continuation of application No. 17/161,556, filed on Jan. 28, 2021, which is a continuation of application No. 16/707,532, filed on Dec. 9, 2019, now Pat. No. 11,079,557, which is a continuation of application No. 15/601,308, filed on May 22, 2017, now Pat. No. 10,539,750, which is a continuation of application

(Continued)

(51) **Int. Cl.**
G02B 6/38 (2006.01)

(52) **U.S. Cl.**
CPC ***G02B 6/3895*** (2013.01); ***G02B 6/3831*** (2013.01); ***G02B 6/3885*** (2013.01); *G02B 6/3825* (2013.01); *G02B 6/3893* (2013.01)

(58) **Field of Classification Search**
CPC .. G02B 6/3895; G02B 6/3831; G02B 6/3885; G02B 6/3825; G02B 6/3893
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,150,790	A	4/1979	Potter
4,327,964	A	5/1982	Haesly et al.
4,478,473	A	10/1984	Frear

(Continued)

FOREIGN PATENT DOCUMENTS

CA	2495693	C	1/2013
CN	2836038	Y	11/2006

(Continued)

OTHER PUBLICATIONS

“Fiber Optic Interconnect Solutions, Tactical Fiber Optic Connectors, Cables and Termini” 2006, Glenair, Inc., Glendale, California, wvvw.mps-electronics.de/fileadmin/files/MPS-E/Produkte/Katalog/Glenair/KatalogGlenair-LWL1110.pdf.

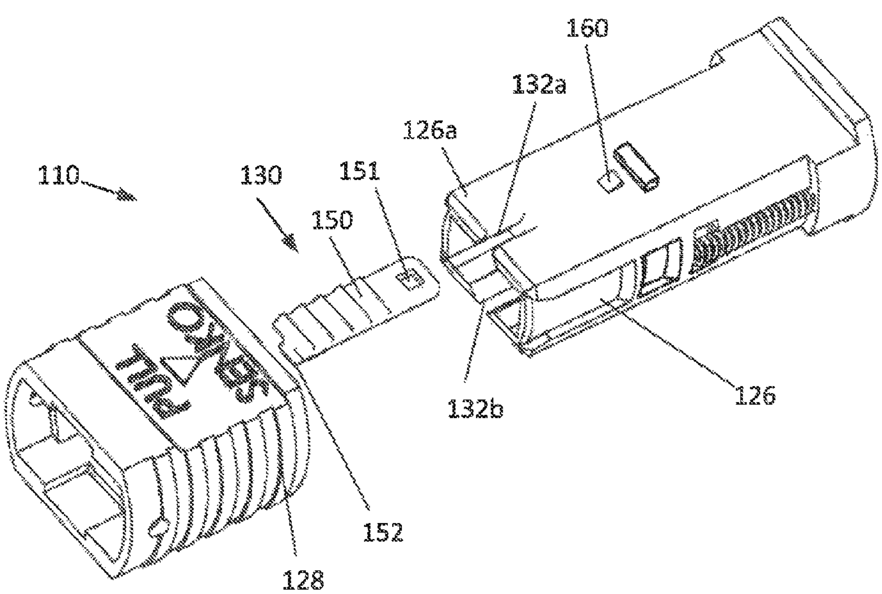
(Continued)

Primary Examiner — John Bedtelyon

(57) **ABSTRACT**

A multi-fiber, fiber optic connector may include a reversible keying arrangement for determining the orientation for plugging the connector into an adapter to thereby allow for a change in polarity of the connection to be made on site. The connector housing may be configured to engage with a removable key that may be engaged with the housing in at least two different locations to provide the plug-in orientation, or the housing may have slidably displaceable keys movable between multiple positions on the housing.

26 Claims, 17 Drawing Sheets



Related U.S. Application Data

No. 14/637,314, filed on Mar. 3, 2015, now Pat. No. 9,658,409.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,762,388 A 8/1988 Tanaka et al.
4,764,129 A 8/1988 Jones et al.
4,840,451 A 6/1989 Sampson et al.
4,872,736 A 10/1989 Myers et al.
4,979,792 A 12/1990 Weber et al.
5,041,025 A 8/1991 Haitmanek
D323,143 S 1/1992 Ohkura et al.
5,212,752 A 5/1993 Stephenson et al.
5,265,181 A 11/1993 Chang
5,289,554 A 2/1994 Cubukciyan et al.
5,317,663 A 5/1994 Beard et al.
5,335,301 A 8/1994 Newman et al.
5,348,487 A 9/1994 Marazzi et al.
5,444,806 A 8/1995 De Marchi et al.
5,481,634 A 1/1996 Anderson et al.
5,506,922 A 4/1996 Grois et al.
5,521,997 A 5/1996 Rovenolt et al.
5,570,445 A 10/1996 Chou et al.
5,588,079 A 12/1996 Tanabe et al.
5,684,903 A 11/1997 Kyomasu et al.
5,687,268 A 11/1997 Stephenson et al.
5,781,681 A 7/1998 Manning
5,937,130 A 8/1999 Amberg et al.
5,956,444 A 9/1999 Duda et al.
5,971,626 A 10/1999 Knodell et al.
6,041,155 A 3/2000 Anderson et al.
6,049,040 A 4/2000 Biles et al.
6,134,370 A 10/2000 Childers et al.
6,178,283 B1 1/2001 Weigel
RE37,080 E 3/2001 Stephenson et al.
6,206,577 B1 3/2001 Hall et al.
6,206,581 B1 3/2001 Driscoll et al.
6,227,717 B1 5/2001 Ott et al.
6,238,104 B1 5/2001 Yamakawa et al.
6,247,849 B1 6/2001 Liu
6,461,054 B1 10/2002 Iwase
6,471,412 B1 10/2002 Belenkiy et al.
6,478,472 B1 11/2002 Anderson et al.
6,551,117 B2 4/2003 Poplawski et al.
6,579,014 B2 6/2003 Melton et al.
6,634,801 B1 10/2003 Waldron et al.
6,648,520 B2 11/2003 Mcdonald et al.
6,682,228 B2 1/2004 Rathnam et al.
6,685,362 B2 2/2004 Burkholder et al.
6,695,486 B1 2/2004 Falkenberg
6,854,894 B1 2/2005 Yunker et al.
6,872,039 B2 3/2005 Baus et al.
6,935,789 B2 8/2005 Gross, III et al.
7,090,406 B2 8/2006 Melton et al.
7,090,407 B2 8/2006 Melton et al.
7,091,421 B2 8/2006 Kukita et al.
7,111,990 B2 9/2006 Melton et al.
7,113,679 B2 9/2006 Melton et al.
D533,504 S 12/2006 Lee
D534,124 S 12/2006 Taguchi
7,150,567 B1 12/2006 Luther et al.
7,153,041 B2 12/2006 Mine et al.
7,198,409 B2 4/2007 Smith et al.
7,207,724 B2 4/2007 Gurreri
D543,146 S 5/2007 Chen et al.
7,258,493 B2 8/2007 Milette
7,281,859 B2 10/2007 Mudd et al.
D558,675 S 1/2008 Chien et al.
7,315,682 B1 1/2008 En Lin et al.
7,325,976 B2 2/2008 Gurreri et al.
7,325,980 B2 2/2008 Pepe
7,329,137 B2 2/2008 Martin et al.
7,331,718 B2 2/2008 Yazaki et al.
7,354,291 B2 4/2008 Caveney et al.
7,371,082 B2 5/2008 Zimmel et al.
7,387,447 B2 6/2008 Mudd et al.
7,390,203 B2 6/2008 Murano et al.
D572,661 S 7/2008 En Lin et al.
7,431,604 B2 10/2008 Waters et al.
7,463,803 B2 12/2008 Cody et al.
7,465,180 B2 12/2008 Kusuda et al.
7,510,335 B1 3/2009 Su et al.
7,513,695 B1 4/2009 Lin et al.
7,561,775 B2 7/2009 Lin et al.
7,591,595 B2 9/2009 Lu et al.
7,594,766 B1 9/2009 Sasser et al.
7,641,398 B2 1/2010 O'Riorden et al.
7,695,199 B2 4/2010 Teo et al.
7,699,533 B2 4/2010 Milette
7,824,113 B2 11/2010 Wong et al.
7,837,395 B2 11/2010 Lin et al.
D641,708 S 7/2011 Yamauchi
8,186,890 B2 5/2012 Lu
8,192,091 B2 6/2012 Hsu et al.
8,202,009 B2 6/2012 Lin et al.
8,251,733 B2 8/2012 Wu
8,267,595 B2 9/2012 Lin et al.
8,270,796 B2 9/2012 Nhep
8,408,815 B2 4/2013 Lin et al.
8,465,317 B2 6/2013 Gniadek et al.
8,636,424 B2 1/2014 Kuffel et al.
8,651,749 B2 2/2014 Jnior et al.
8,770,863 B2 7/2014 Cooke et al.
9,829,645 B2 11/2017 Good et al.
2003/0053787 A1 3/2003 Lee
2004/0052473 A1 3/2004 Seo et al.
2004/0136657 A1 7/2004 Ngo
2004/0141693 A1 7/2004 Szilagyi et al.
2004/0161958 A1 8/2004 Togami et al.
2004/0234209 A1 11/2004 Cox et al.
2005/0111796 A1 5/2005 Matasek et al.
2005/0141817 A1 6/2005 Yazaki et al.
2006/0089049 A1 4/2006 Sedor
2006/0127025 A1 6/2006 Haberman
2006/0269194 A1 11/2006 Luther et al.
2006/0274411 A1 12/2006 Yamauchi
2007/0028409 A1 2/2007 Yamada
2007/0079854 A1 4/2007 You
2007/0098329 A1 5/2007 Shimoji et al.
2007/0149062 A1 6/2007 Long
2007/0230874 A1 10/2007 Lin
2007/0232115 A1 10/2007 Burke et al.
2007/0243749 A1 10/2007 Wu
2008/0008430 A1 1/2008 Kewitsch
2008/0044137 A1 2/2008 Luther et al.
2008/0069501 A1 3/2008 Mudd et al.
2008/0101757 A1 5/2008 Lin et al.
2008/0226237 A1 9/2008 O'Riorden et al.
2008/0267566 A1 10/2008 En Lin
2009/0022457 A1 1/2009 De Jong et al.
2009/0028507 A1 1/2009 Jones et al.
2009/0196555 A1 8/2009 Lin et al.
2009/0214162 A1 8/2009 O'Riorden et al.
2009/0220197 A1 9/2009 Gniadek et al.
2010/0034502 A1 2/2010 Lu et al.
2010/0092136 A1 4/2010 Nhep
2010/0247041 A1 9/2010 Szilagyi
2010/0322561 A1 12/2010 Lin et al.
2011/0044588 A1 2/2011 Larson et al.
2011/0131801 A1 6/2011 Nelson et al.
2011/0177710 A1 7/2011 Tobey
2012/0099822 A1* 4/2012 Kuffel G02B 6/383 385/78
2012/0189260 A1 7/2012 Kowalczyk et al.
2012/0269485 A1 10/2012 Haley et al.
2012/0301080 A1 11/2012 Gniadek
2013/0071067 A1 3/2013 Lin
2013/0089995 A1 4/2013 Gniadek et al.
2013/0094816 A1 4/2013 Lin et al.
2013/0121653 A1 5/2013 Shitama et al.
2013/0183012 A1 7/2013 Cabanne Lopez et al.
2013/0322825 A1 12/2013 Cooke et al.
2014/0016901 A1 1/2014 Lambourn et al.
2014/0023322 A1 1/2014 Gniadek

(56) **References Cited**

U.S. PATENT DOCUMENTS

2014/0050446	A1	2/2014	Chang
2014/0133808	A1	5/2014	Hill et al.
2014/0334780	A1	11/2014	Nguyen et al.
2014/0348477	A1	11/2014	Chang
2015/0003785	A1	1/2015	Raven et al.
2015/0378113	A1	12/2015	Good et al.

FOREIGN PATENT DOCUMENTS

CN	201383588	Y	1/2010
CN	202600189	U	12/2012
DE	202006011910	U1	4/2007
DE	102006019335	A1	10/2007
EP	1074868	A1	2/2001
EP	1211537	A2	6/2002
EP	1245980	A2	10/2002
EP	1566674	A1	8/2005
GB	2111240	A	6/1983
JP	2009229545	A	10/2009
JP	2009276493	A	11/2009
TW	200821653	A	5/2008
WO	2001079904		10/2001
WO	2004027485	A1	4/2004
WO	2008112986	A1	9/2008
WO	2009135787	A1	11/2009
WO	2010024851	A2	3/2010
WO	2012136702	A1	10/2012
WO	2012162385	A1	11/2012
WO	2013052070	A1	4/2013
WO	2014028527	A2	2/2014
WO	2014182351	A1	11/2014

OTHER PUBLICATIONS

"Fiber Optic Products Catalog" Nov. 2007, Tyco Electronics Corporation, Harrisburg, Pennsylvania, www.ampnetconnect.com/documents/Fiber/020Optice/020Catalog/0201107.pd f.

International Search Report and Written Opinion dated Aug. 21, 2008 for PCT/US2008/057023.

International Search Report and Written Opinion dated Apr. 27, 2012 for PCT/US2011/058799.

International Search Report and Written Opinion dated Aug. 27, 2012 for PCT/US2012/039126.

International Search Report and Written Opinion dated Aug. 29, 2014 for PCT/US2014/041500.

International Search Report and Written Opinion dated Jan. 16, 2014 for PCT/US2013/54784.

International Search Report and Written Opinion dated May 14, 2014 for PCT/US2014/012137.

International Search Report and Written Opinion dated Aug. 22, 2016 from corresponding International Application go. PCT/US15/59458, International Filing Date Nov. 6, 2015.

Extended European Search Report in related Application No. 15884159.3 dated Sep. 3, 2018, 8 pages.

Office Action issued for Taiwanese Patent Application No. 104140112 dated Oct. 8, 2019, 11 pages.

International Preliminary Report on Patentability dated Sep. 14, 2017 from related International Application No. 3CT/US2015/059458, International Filing Date Nov. 6, 2015.

Fiberoptic Connectors and Assemblies Catalog 2009, Huber & Suhner Fiber Optics, Herisau, Switzerland, www.ioogle.co.in/url?sa=t&source=web&cd=63&ved=OCCMQ9ACODw&url=http%3A%2P/02Fwww.hubersuhner.com%2Fwrite rtn binary_pdr/o3Fbinaryid%3D8DBC7DE2EB72D315%26binarytype%3D484 DKA363AEB7E&ei=ZvcvTujWH4ntrAfH-dXZCg&usg=AFQJCNE1MdC-4avewRJU6IDVc WYbrOQQ.

European Search Report and Written Opinion dated Feb. 19, 2015 for EP 14168005.

European Search Report and Written Opinion dated Mar. 3, 2015 for EP 14187661.

* cited by examiner

FIG. 1

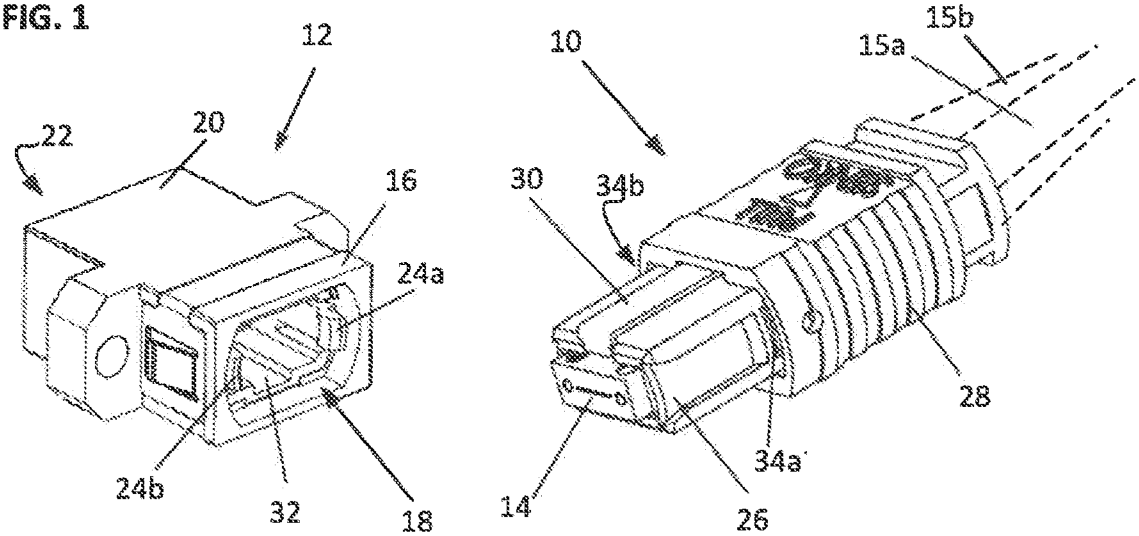


FIG. 2A

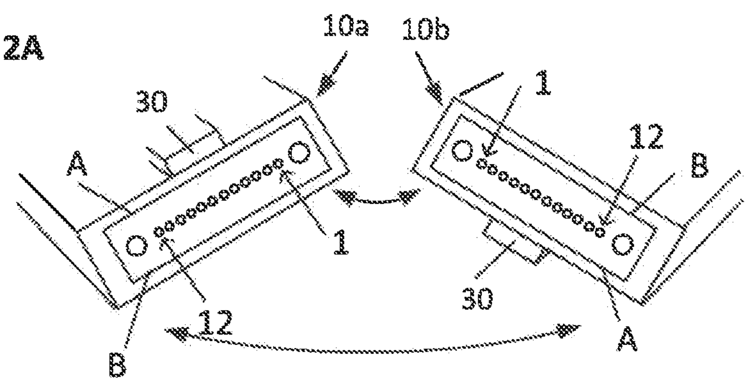


FIG. 2B

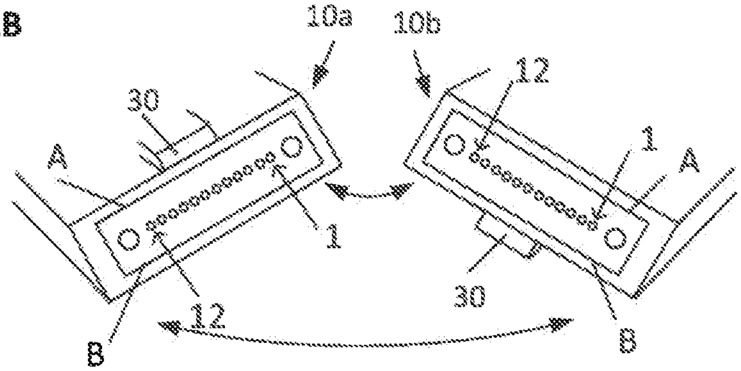
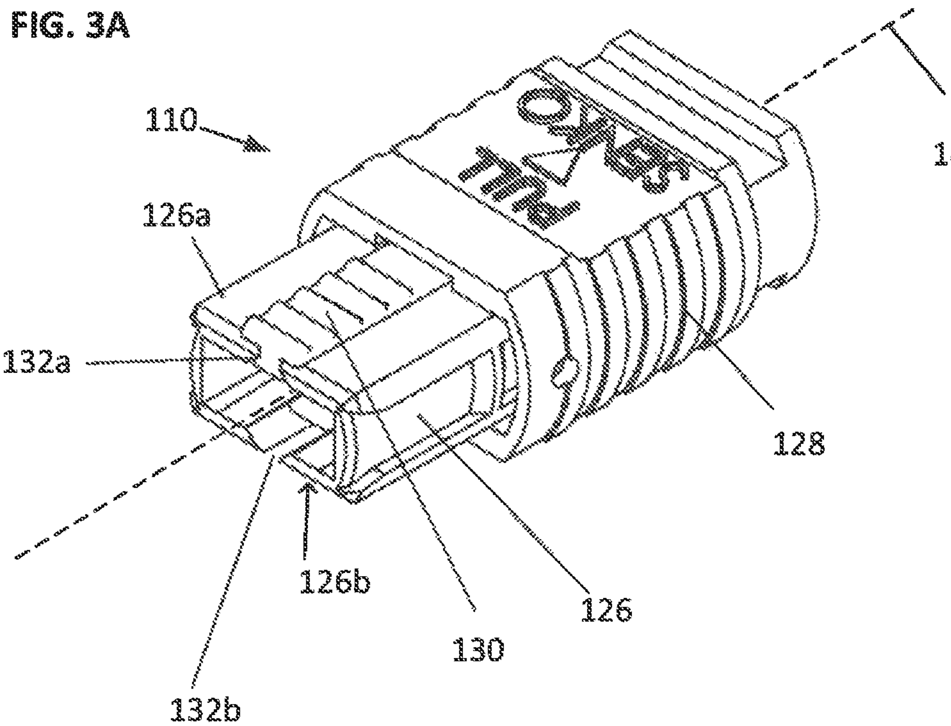


FIG. 3A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132a
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126
132b
PULL
SENKO

FIG. 3B

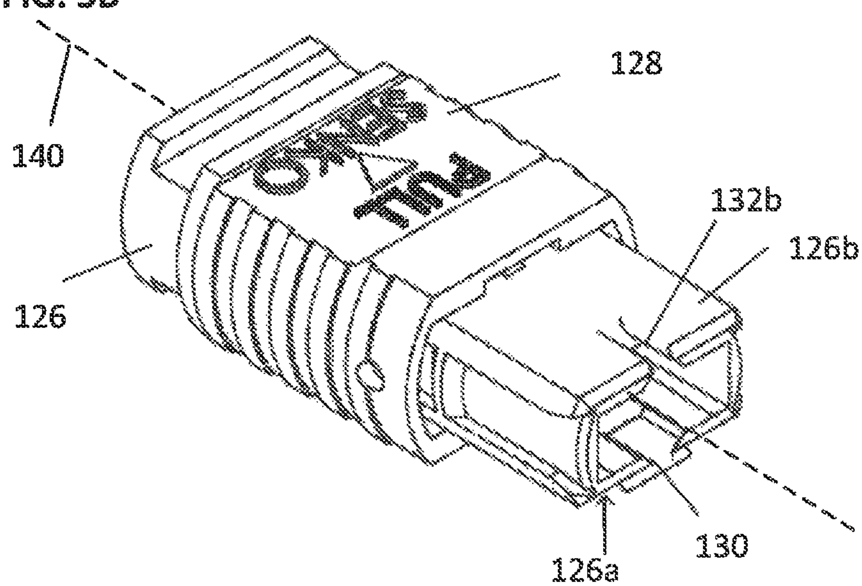
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FIG. 4

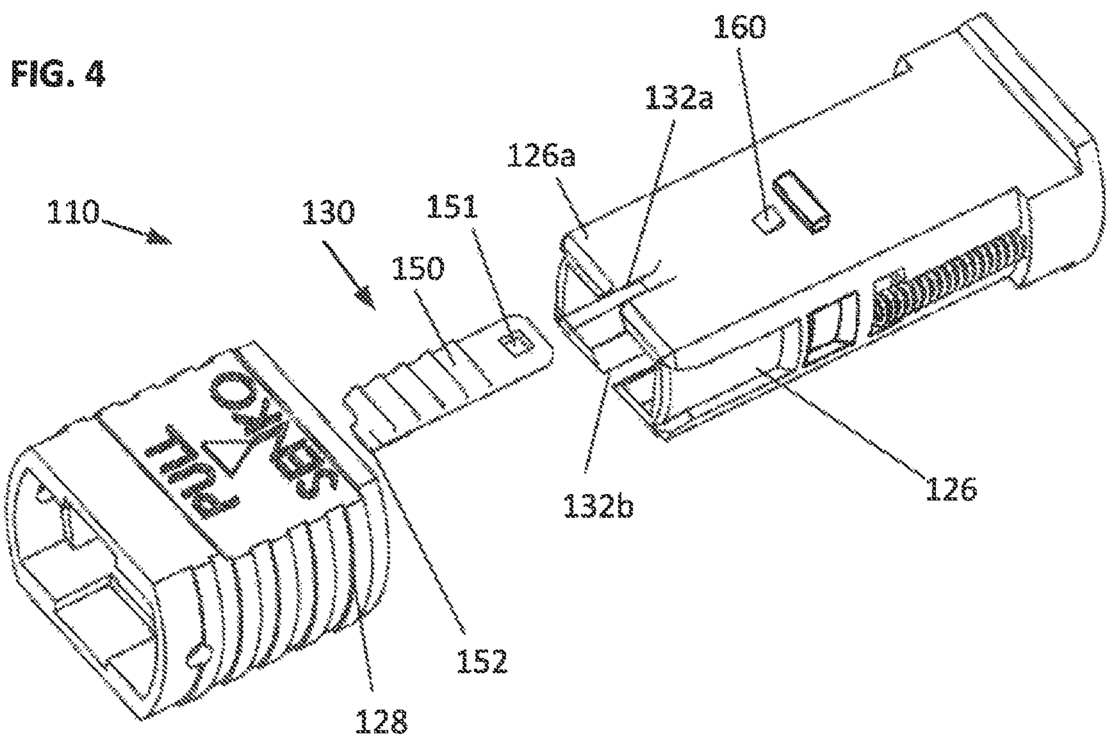
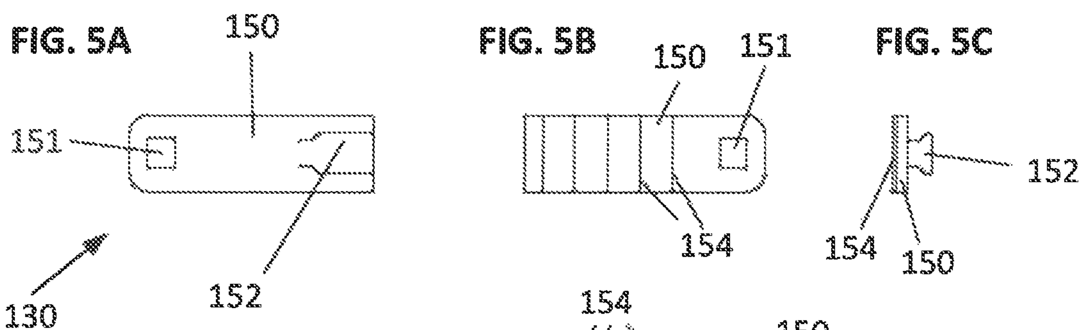


FIG. 5A
FIG. 5B
FIG. 5C



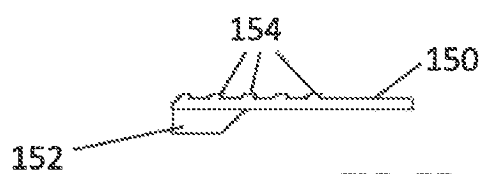


FIG. 5D

FIG. 6A FIG. 6B

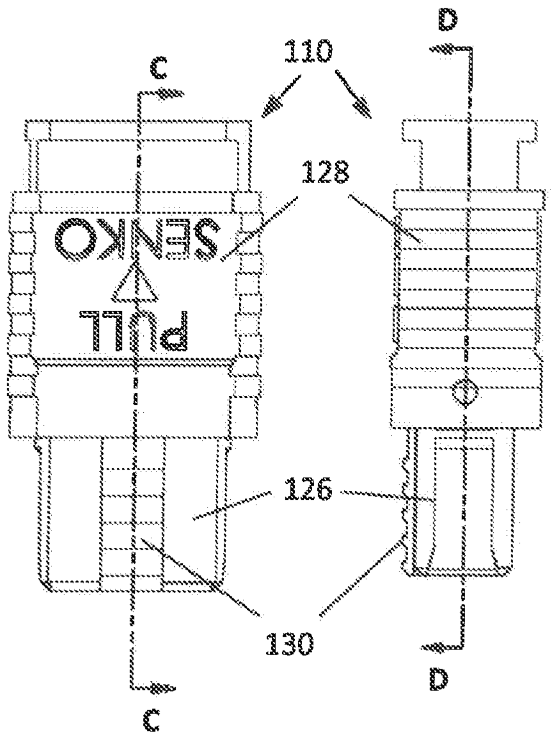
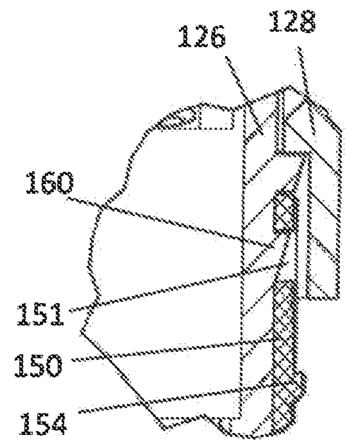
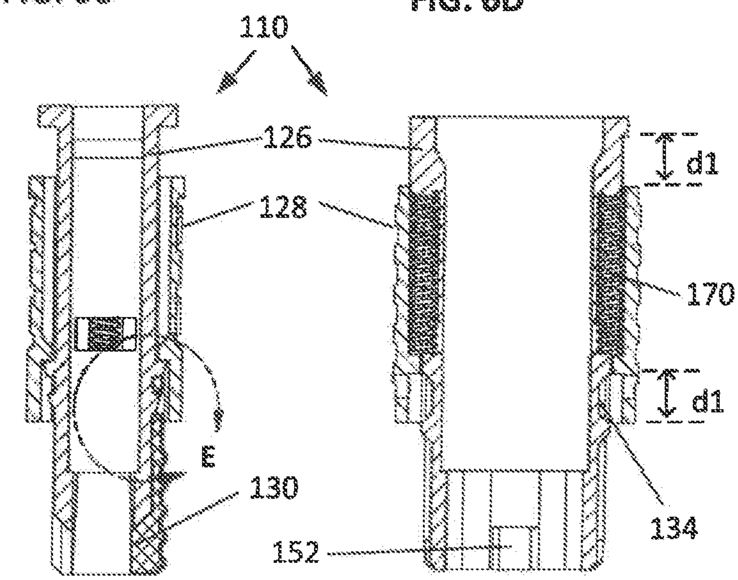


FIG. 6E



Detail E

FIG. 6C FIG. 6D



Section C-C Section D-D

FIG. 7

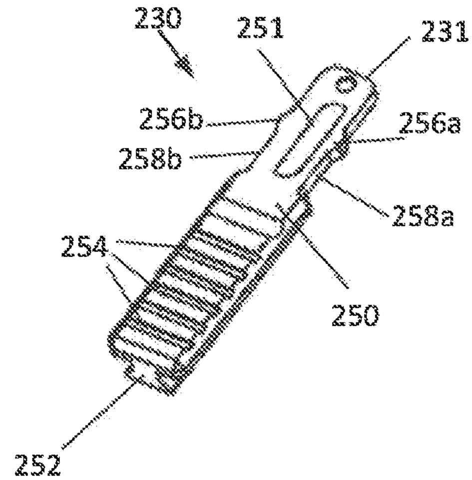


FIG. 8

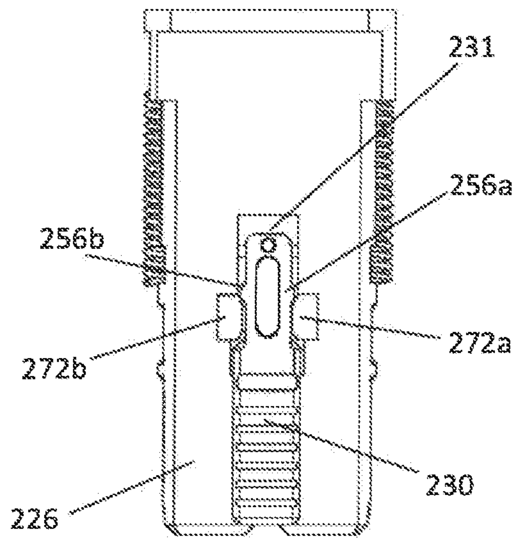


FIG. 9A

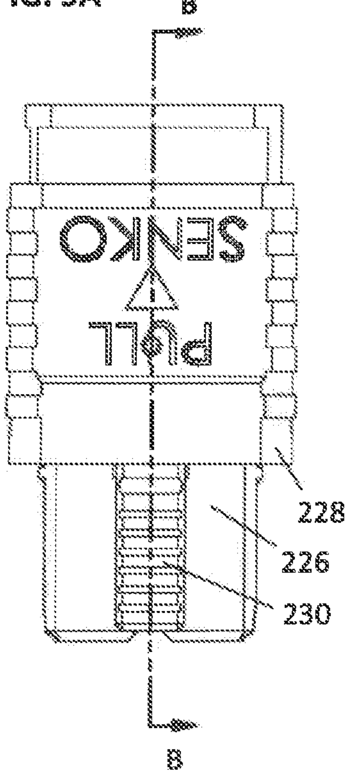
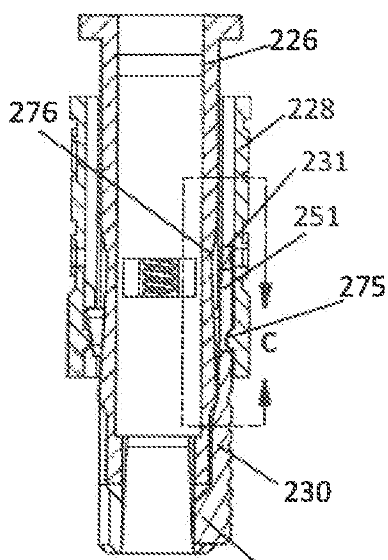
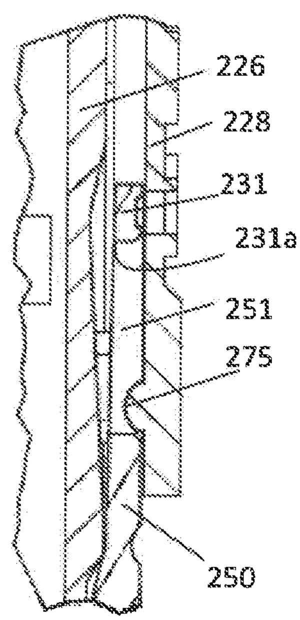


FIG. 9B



Section B-B

FIG. 9C



Detail C

FIG. 10B

FIG. 10A

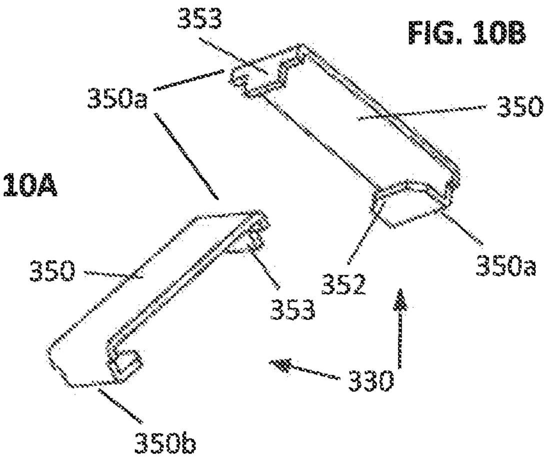


FIG. 11A

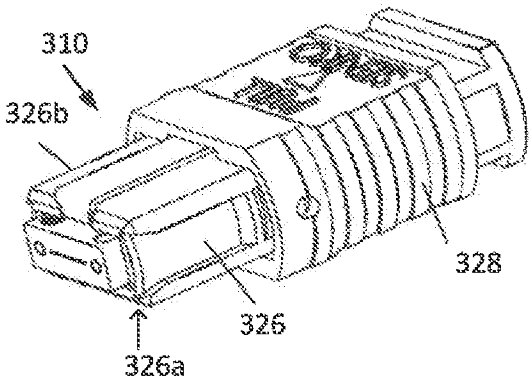


FIG. 11B

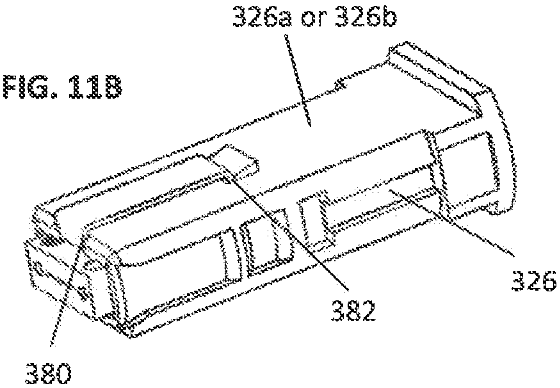


FIG. 11C

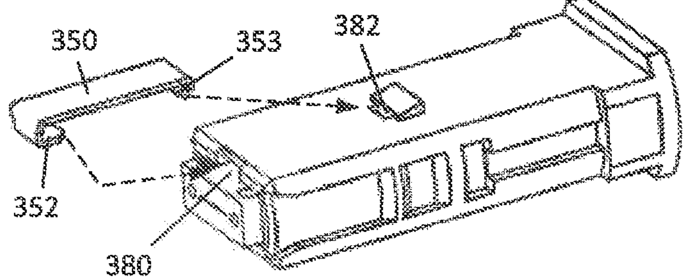


FIG. 12A

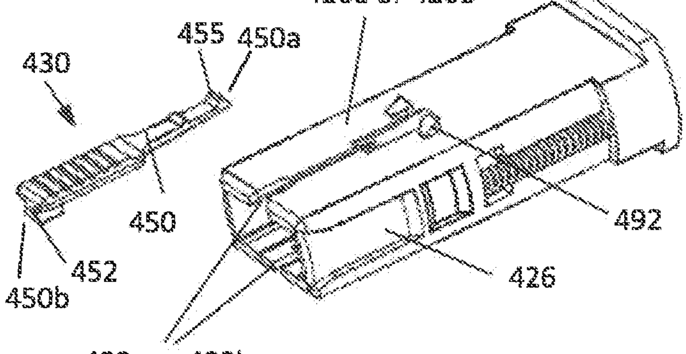


FIG. 12B

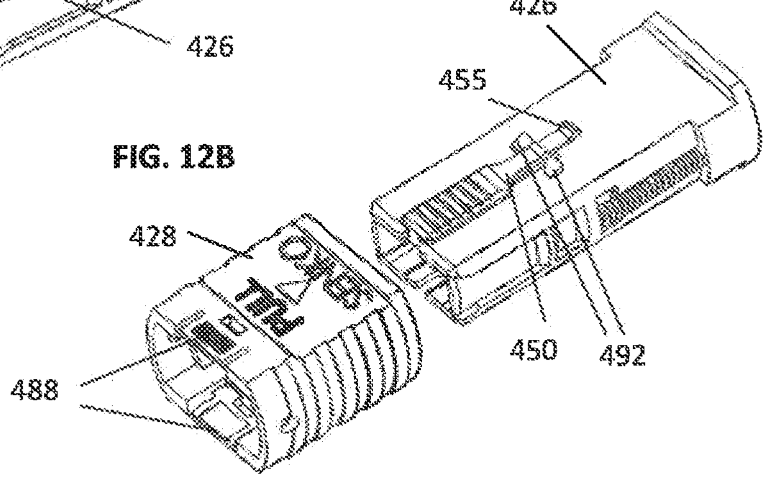


FIG. 13A

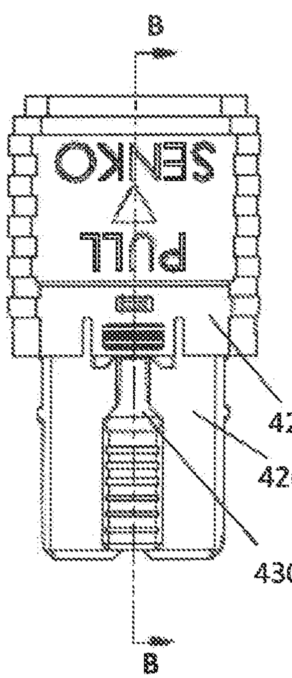
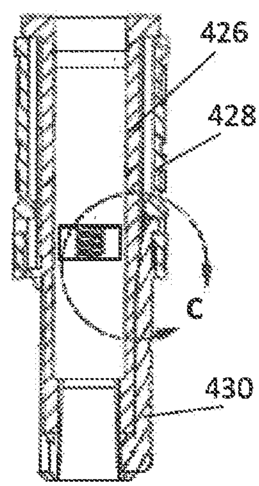
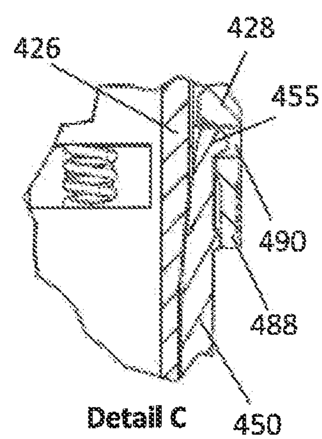


FIG. 13B



Section B-B

FIG. 13C



Detail C

FIG. 14A

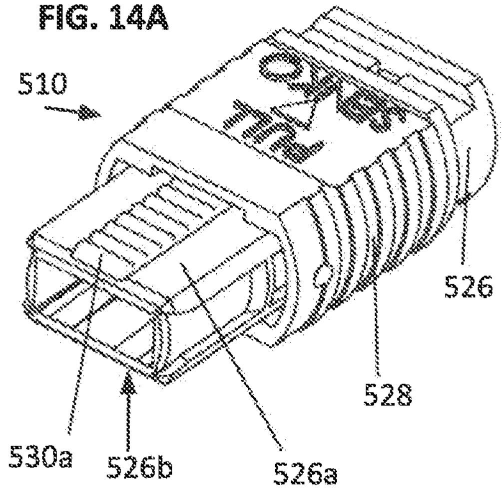


FIG. 14B

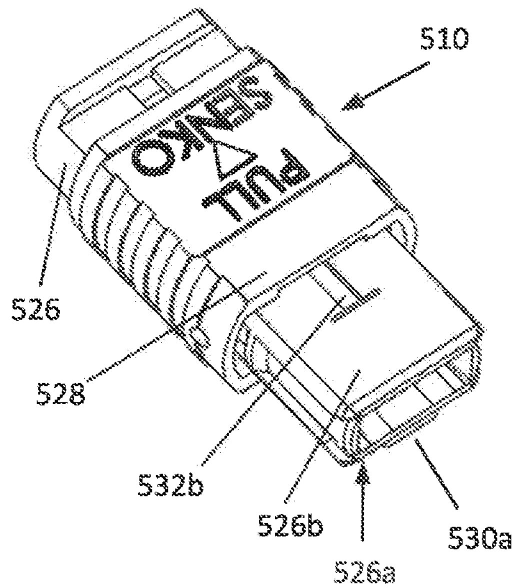


FIG. 15A

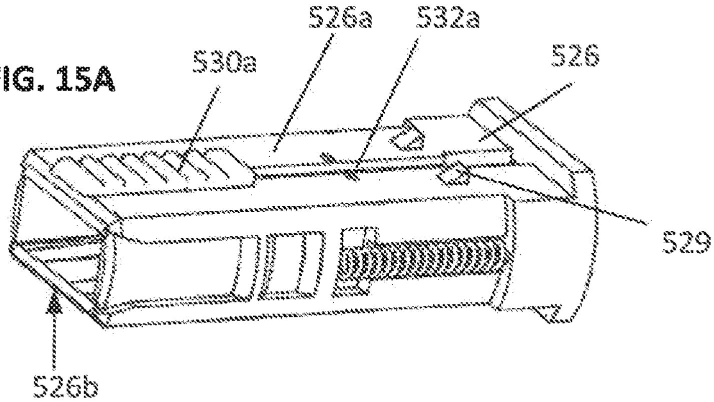


FIG. 15B

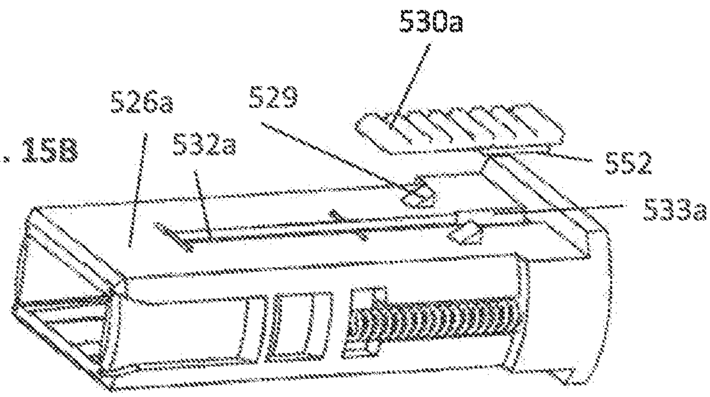


FIG. 16A

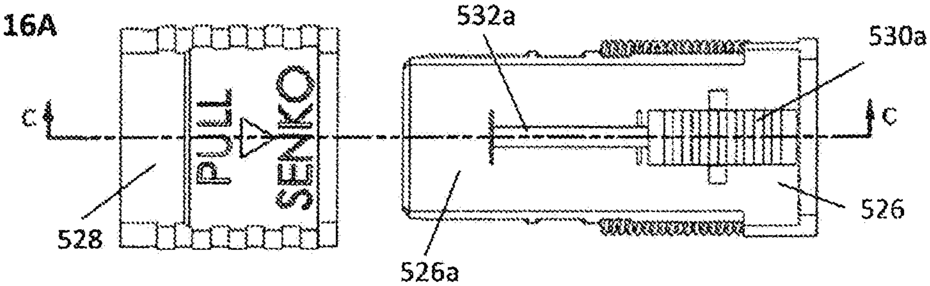


FIG. 16B

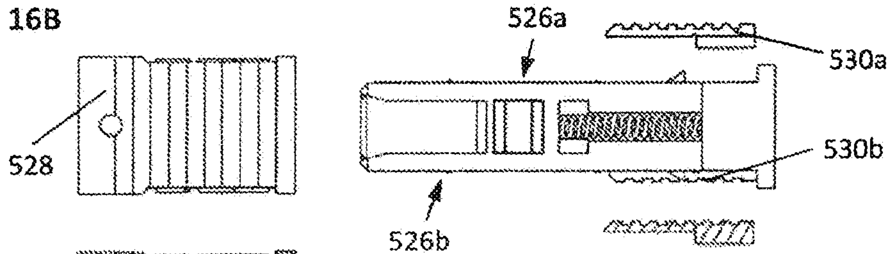


FIG. 16C

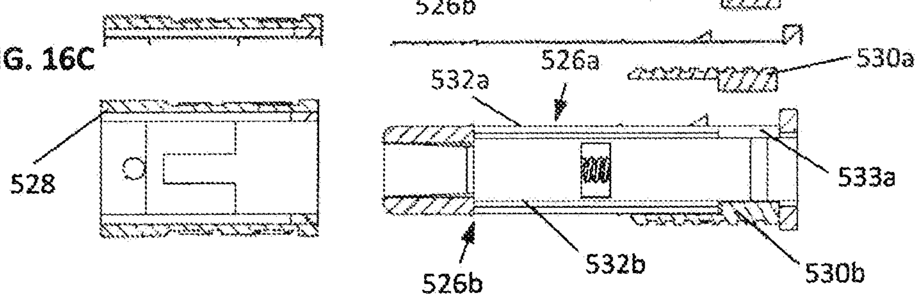


FIG. 17A

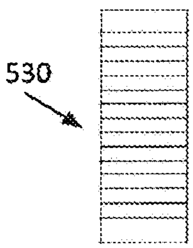


FIG. 17B

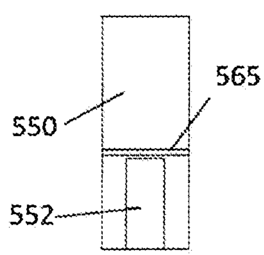


FIG. 17C

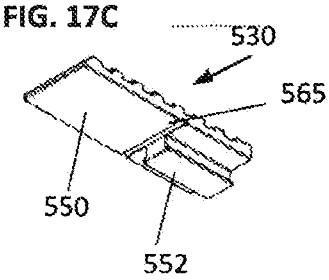


FIG. 17D

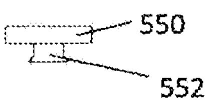


FIG. 17E

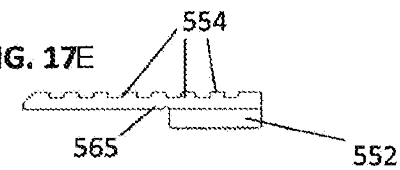


FIG. 18A

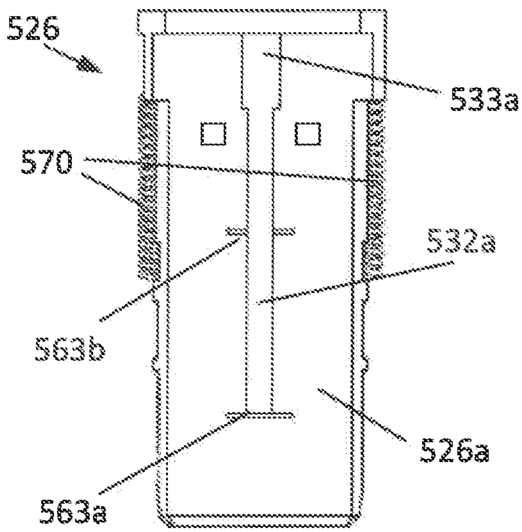


FIG. 18B

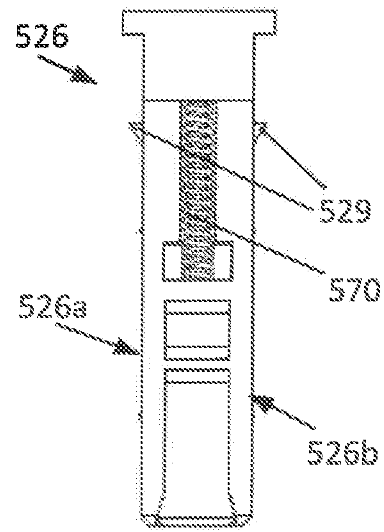


FIG. 18C

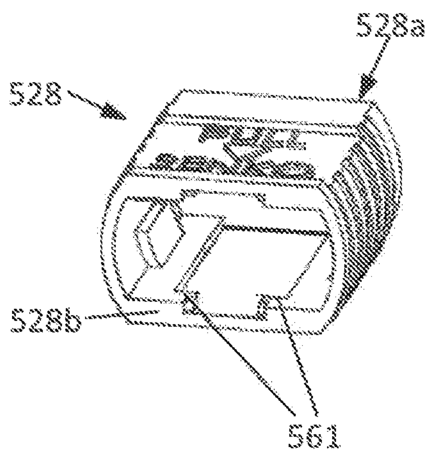
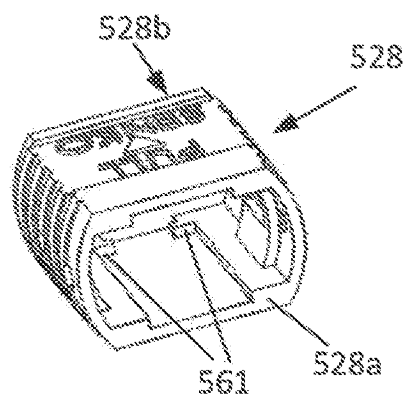


FIG. 18D



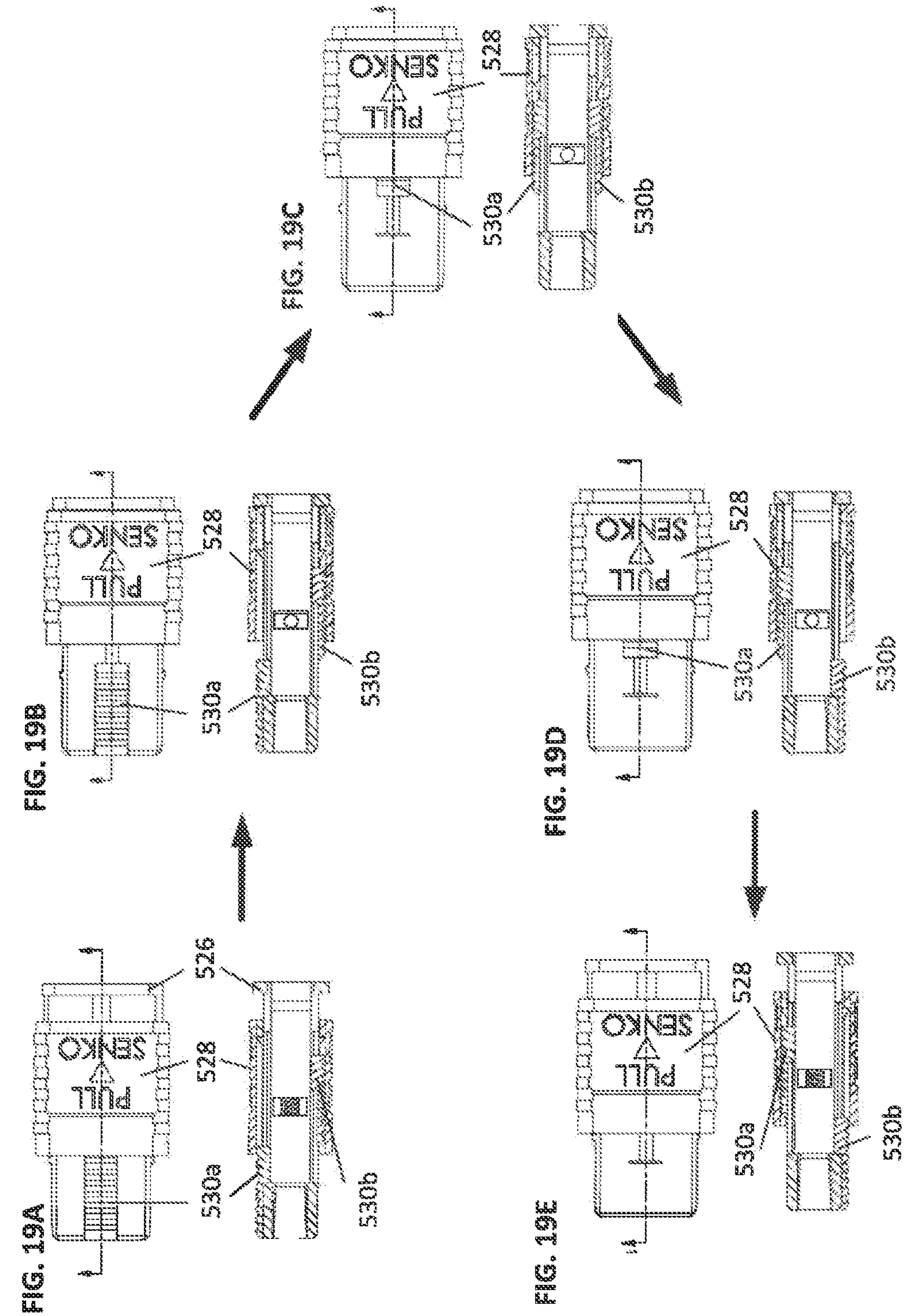


FIG. 19A
FIG. 19B
FIG. 19C
FIG. 19D
FIG. 19E
SENKO
PULL
526
528
530a
530b

FIG. 20B

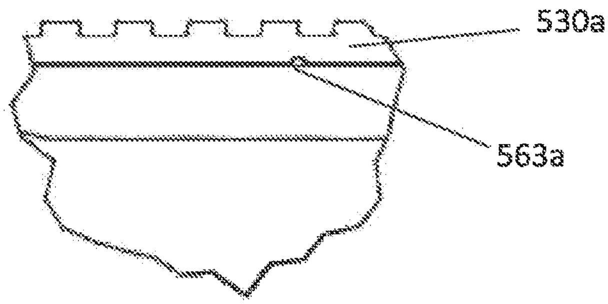


FIG. 20A

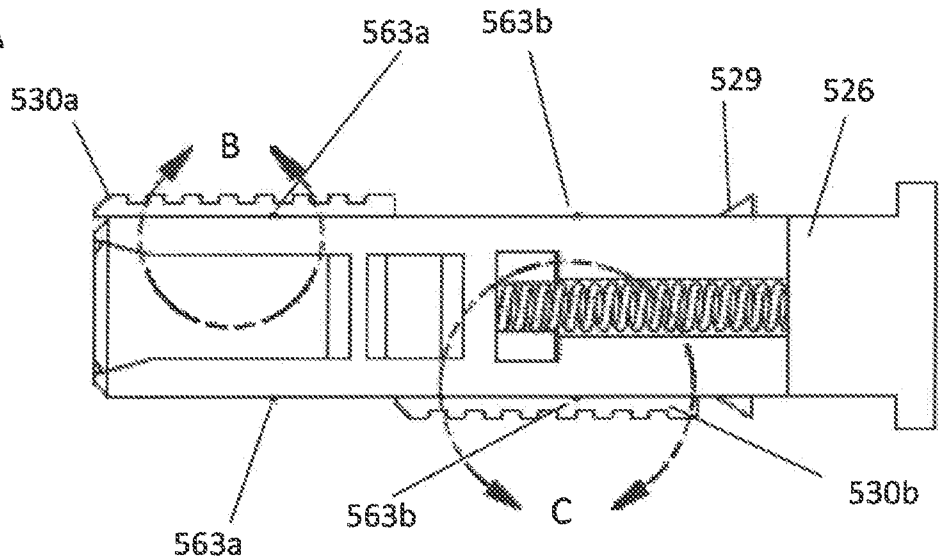


FIG. 20C

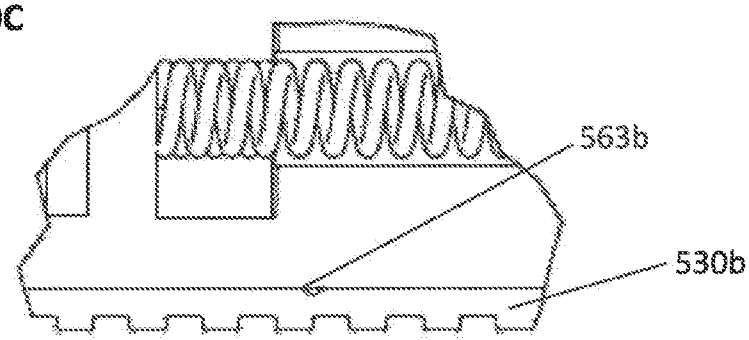


FIG. 21A

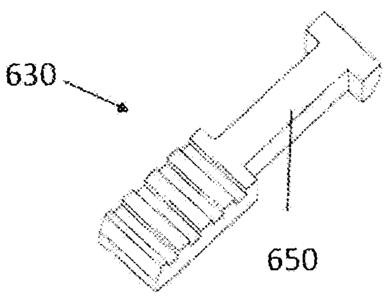


FIG. 21B

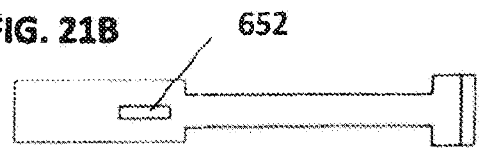


FIG. 21C

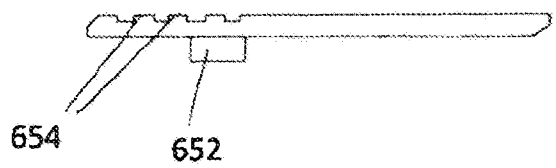


FIG. 22

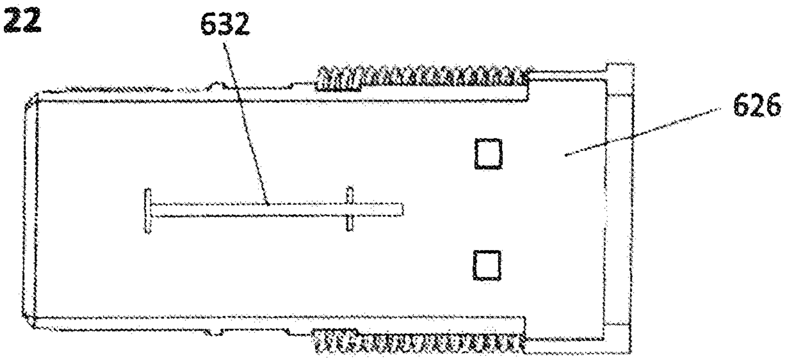


FIG. 23A

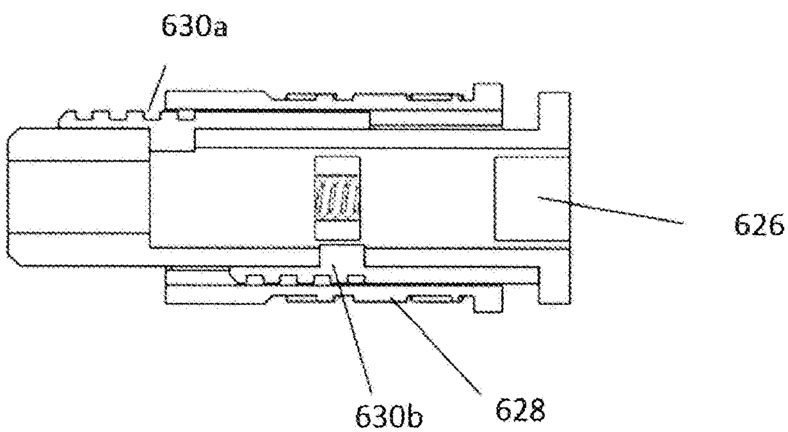


FIG. 23B

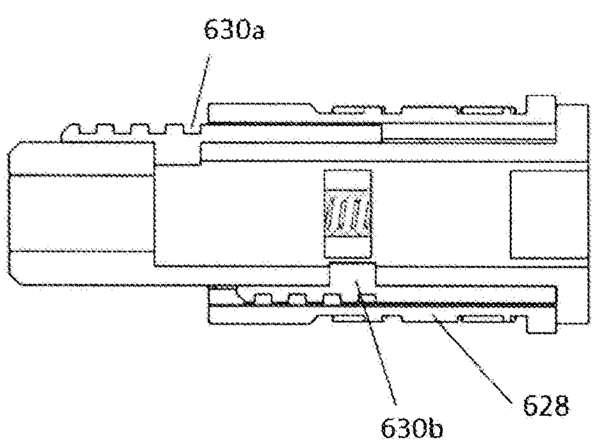


FIG. 23C

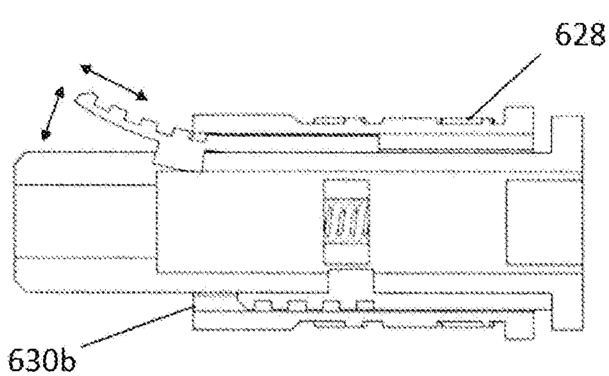


FIG. 24

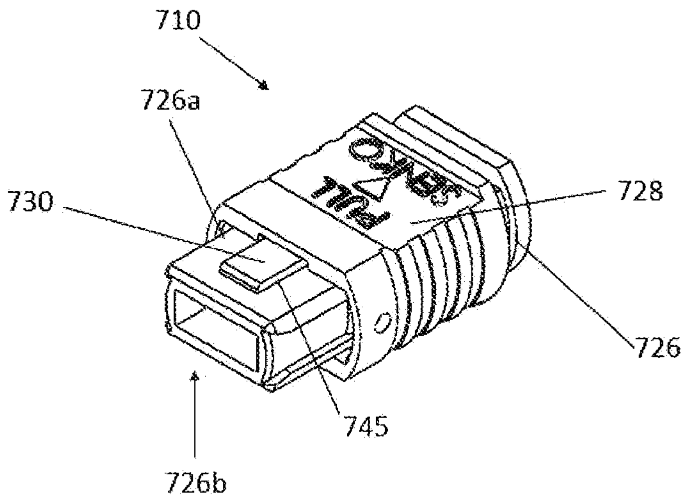


FIG. 25

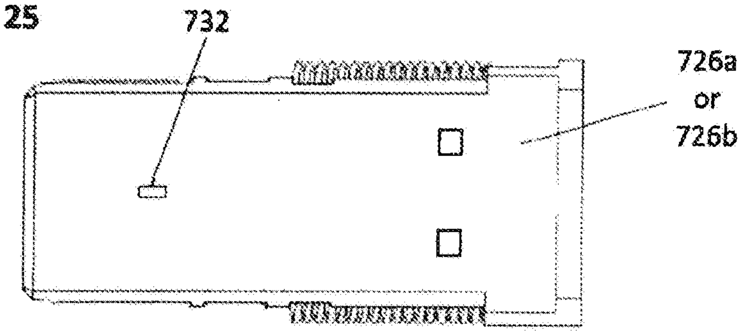


FIG. 26A

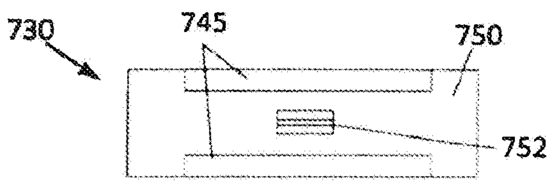
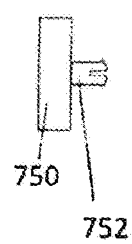


FIG. 26D

FIG. 26C



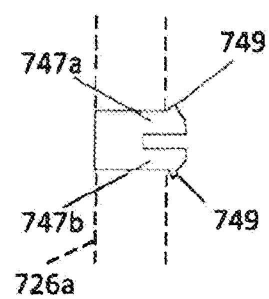


FIG. 26B

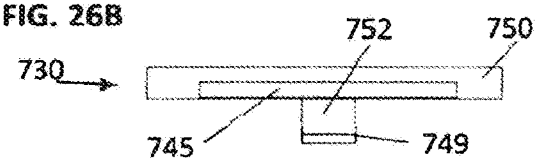


FIG. 27

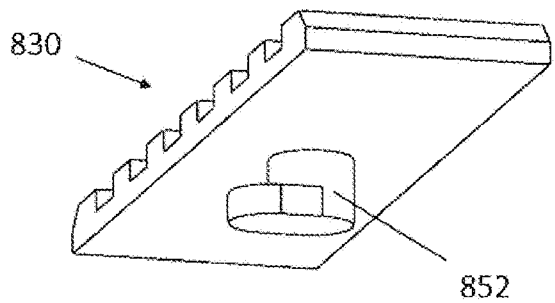


FIG. 28B

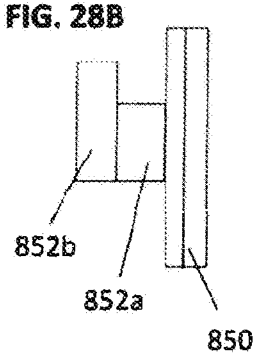


FIG. 28A

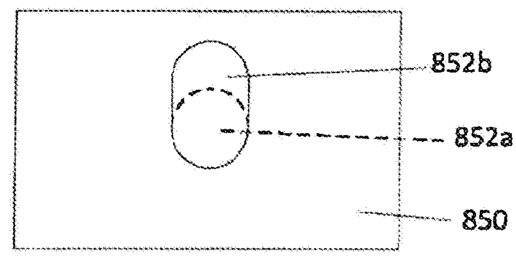


FIG. 28C

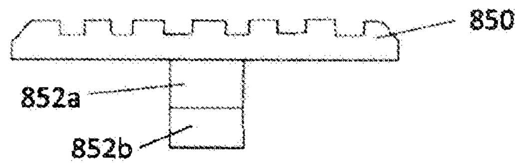


FIG. 29

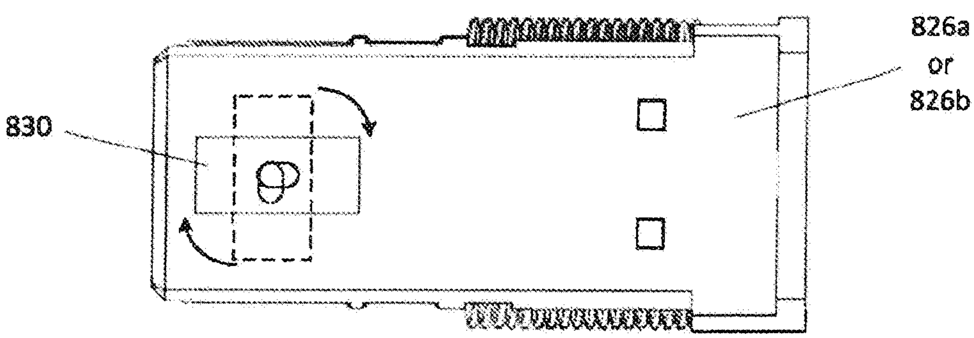


FIG. 30A

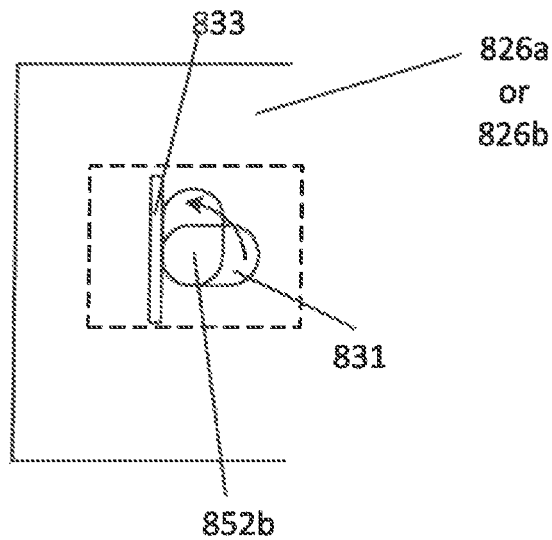
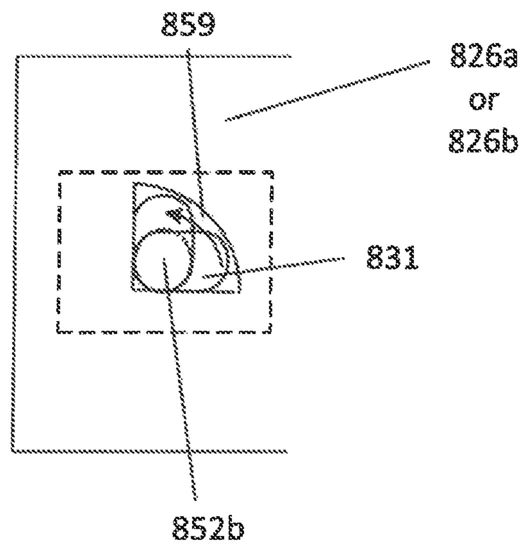


FIG. 30B



OPTICAL FIBER CONNECTOR WITH CHANGEABLE POLARITY

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 16/707,532 filed on Dec. 9, 2019 which is a continuation of U.S. patent application Ser. No. 15/601,308 filed on May 22, 2017, now U.S. Pat. No. 10,539,750 issued Jan. 21, 2020, which is a continuation of U.S. patent application Ser. No. 14/637,314, filed Mar. 3, 2015, now U.S. Pat. No. 9,658,409 issued on May 23, 2017, and all the contents of the above patent applications are incorporated by reference in their entirety as if fully set forth herein. The title of the patents above is “Optical Fiber With Changeable Polarity”.

BACKGROUND

Demand for bandwidth by enterprises and individual consumers continues to experience exponential growth. To meet this demand efficiently and economically, data centers have to achieve ultra-high density cabling with low loss budgets. Fiber optics have become the standard cabling medium used by data centers to meet the growing needs for data volume and transmission speeds.

Individual optical fibers are extremely small. For example, even with protective coatings, optical fibers may be only about 250 microns in diameter (only about 4 times the diameter of a human hair). As such, hundreds of fibers can be installed in cables that will take up relatively little space. For connections between cables, however, the fibers are terminated with connectors. Multiple fibers may be arranged within a single connector. For example, multi-fiber connectors such as those using multi-fiber push-on/pull-off (MPO) technology may contain and connect 12 or 24 fibers. Connectors, such as MPO type connectors, generally include a housing portion that contains a ferrule that terminates the ends of the fibers. Ferrules are generally used to retain the ends of the optical fibers for connecting the optical fibers. One type of optical ferrule that may be used with MPO type connectors is an MT (Mechanically Transferable) ferrule.

Typically, MPO connectors are joined together to connect the optical transmission path of one fiber optic cable to another fiber optic cable or device, and the connection may be made by inserting the MPO connectors in an MPO adapter. An adapter generally includes a housing, or portion of a housing, having at least one port which is configured to receive and hold a connector to facilitate the optical connection of the connector ferrule with the ferrule of another connector or other device. Adapters may be used to facilitate connections contained within a chassis. The term “chassis” as used herein broadly refers to a containment structure for housing electrical components or switching components.

As a result of the use of pre-terminated fiber assemblies, the issue of maintaining polarity in parallel fiber-optic links is becoming increasingly important. Described simply, polarity maintains proper continuity between transmitters and receivers. In order to make sure that connectors are mated correctly with an adapter, the connector and adapter typically include fixed keying features that permit the connector to be mated with the adapter in generally only one mating configuration. While this has the advantage of preventing a connection that has the wrong polarity, it also can make it difficult to change the polarity of the connection on site.

Therefore, there remains a need for multi-fiber, fiber optic connectors that have the flexibility of easily changing the polarity of the connector on site.

SUMMARY

So that the polarity of a multi-fiber, fiber optic connector may be changed, a housing of the connector may be configured to include a removable key that may be positioned at alternate locations on the housing. To change the polarity, the key may be moved from one location to another.

A multi-fiber fiber optic connector includes a ferrule having a plurality of optical fibers supported therein, and a housing disposed around at least a portion of the ferrule. The housing has a first end for being inserted into a fiber optic adapter, a second end disposed opposite the first end, and at least a first wall portion extending from the first end towards the second end and a second wall portion opposite the first wall portion and extending from the first end towards the second end, wherein each of the first wall portion and the second wall portion have an internal surface disposed towards the ferrule and an external surface disposed outwardly away from the ferrule. The housing defines a longitudinal axis in a direction from the first end to the second end, a transverse axis orthogonal to the longitudinal axis, and a vertical centerline through the first and second wall portions. The connector also includes a key configured to be removably attached to either the first wall portion to define a first keyed configuration for insertion of the first end into the adapter in only a first orientation to define a first polarity with respect to the adapter, or the second wall portion to define a second keyed configuration for insertion of the first end into the adapter in only a second orientation to define a second polarity with respect to the adapter, wherein the second polarity is opposite to the first polarity. The key includes a first end configured for engaging with the housing adjacent the first housing end to prevent movement of the first key end with respect to the housing in at least a direction laterally away from the housing when removably attached to either the first wall portion or the second wall portion, and a second end disposed longitudinally away from the first end and configured for being removably attached to the housing at a second location of the housing spaced longitudinally from the first end of the housing towards the second end of the housing to prevent movement of the key with respect to the housing in at least a longitudinal direction along the housing when removably attached to either the first wall portion or the second wall portion.

In an embodiment, a housing for a fiber optic connector includes a first end for being inserted into a fiber optic adapter, and a second end disposed opposite the first end, and the housing defines a longitudinal direction from the first end to the second end, and a transverse direction orthogonal to the longitudinal direction. The housing also includes at least a first wall portion extending from the first end towards the second end and a second wall portion opposite the first wall portion and extending from the first end towards the second end, wherein each of the first wall portion and the second wall portion have an external surface disposed outwardly away from the ferrule. The housing also includes a key configured to be removably attached to either the first wall portion to define a first keyed configuration for insertion of the first end into the adapter in only a first orientation to define a first configuration with respect to the adapter, or the second wall portion to define a second keyed configuration for insertion of the first end into the adapter in only a second orientation to define a second configuration

with respect to the adapter. The key includes one of a snap-in fastener and a twist lock fastener configured for engaging with either the first wall portion or the second wall portion, and each of the first wall portion and the second wall portion comprises an opening configured for receiving the snap-in fastener or the twist in fastener to releasably retain the key with either the first wall portion or the second wall portion.

In an embodiment, a method is provided for switching the polarity configuration between a multi-fiber fiber optic connector and a corresponding adapter configured for receiving the connector. The connector has a connector housing comprising a first end for being inserted into the adapter, a second end disposed opposite the first end, and at least first and second movably displaceable keys displaceable along the housing between a first position adjacent the first end and a second position disposed towards the second end. One of the first and second keys may be in its first position and the other of the first and second keys may be in its second position to provide a first polarity for the fiber optic connector. The method includes slidingly displacing the first key from its corresponding first or second position to the other of the first and second positions, and slidingly displacing the second key from its corresponding first or second position to the other of the first and second positions, to provide a second opposite polarity for the fiber optic connector.

BRIEF DESCRIPTION OF THE FIGURES

FIG. **1** depicts perspective views of an MPO connector and adapter according to an embodiment.

FIGS. **2**A and **2**B depict mating/polarity configurations of MPO connectors according to an embodiment.

FIGS. **3**A and **3**B are representative top and bottom perspective views of a fiber optic connector housing with a detachable key for changing the polarity of the connector according to an embodiment.

FIG. **4** is a perspective view of a partially disassembled fiber optic connector housing according to the embodiment of FIGS. **3**A and **3**B.

FIGS. **5**A-**5**D are bottom, top, end and side views of a key according to the embodiment of FIGS. **3**A and **3**B.

FIGS. **6**A-**6**E are face, side, cross-sectional and detail views of the fiber optic connector housing according to the embodiment of FIGS. **3**A and **3**B.

FIG. **7** is a perspective view of an alternative key according to an embodiment.

FIG. **8** shows the key of FIG. **7** positioned on a connector housing according to an embodiment.

FIGS. **9**A-**9**C are face, cross-sectional and detailed views of a connector of the embodiment of FIG. **8**.

FIGS. **10**A and **10**B are different perspective views of an alternative key according to embodiment.

FIGS. **11**A-**11**C are various views of a connector with the key of FIGS. **10**A and **10**B according to an embodiment.

FIGS. **12**A and **12**B are different perspective views of an alternative key according to an embodiment.

FIGS. **13**A-**13**C are various views of a connector with the key of FIGS. **12**A and **12**B according to an embodiment.

FIGS. **14**A and **14**B are perspective views of a connector with movable keys according to an embodiment.

FIGS. **15**A and **15**B are views of components of the connector of FIGS. **14**A, **14**B with the outer housing removed according to an embodiment.

FIGS. **16**A-**16**C show top, side and cross-sectional views of the connector or FIG. **14**A, **14**B according to an embodiment.

FIGS. **17**A-**17**E are various views of the moveable key of FIGS. **14**A, **14**B according to an embodiment.

FIGS. **18**A-**18**D show views of the inner and outer housing components of the connector of FIGS. **14**A, **14**B according to an embodiment.

FIGS. **19**A-**19**E show sequential views (top and cross-sectional) of the process of switching the polarity of the connector of FIGS. **14**A, **14**B according to an embodiment.

FIGS. **20**A-**20**C show side and detailed views of the connector of FIGS. **14**A, **14**B according to an embodiment.

FIGS. **21**A-**21**C are views of an alternative movable key according to an embodiment.

FIG. **22** provides a top view of an inner housing for the key of FIGS. **21**A-**21**C according to an embodiment.

FIGS. **23**A-**23**C show cross-sectional views of a connector assembly with the keys of FIGS. **21**A-**21**C according to an embodiment.

FIG. **24** is a perspective view of a connector having a 'snap-in' key according to an embodiment.

FIG. **25** is a top view of the inner housing of the connector of FIG. **24** according to an embodiment.

FIGS. **26**A-**26**D show bottom, side, end and detailed views of a snap-in key according to an embodiment.

FIG. **27** is a perspective view of an 'twist-lock' insertable key according to an embodiment.

FIGS. **28**A-**28**C are bottom, end and side views of the key of FIG. **27** according to an embodiment.

FIG. **29** is a top view of the inner housing of a connector for the key of FIG. **27** according to an embodiment.

FIGS. **30**A and **30**B show representative views of an internal side of a housing wall for engaging with the key of FIG. **27** according to an embodiment.

DETAILED DESCRIPTION

As used herein, the term "optical fiber" is intended to apply to all types of single mode and multi-mode light waveguides, including one or more bare optical fibers, coated optical fibers, loose-tube optical fibers, tight-buffered optical fibers, ribbonized optical fibers, bend performance optical fibers, bend insensitive optical fibers, nanostructured optical fibers or any other expedient for transmitting light signals. A multi-fiber optic cable includes a plurality of the optical fibers. Such cables have a variety of names depending on their particular usage, and may be considered as "trunk cables" or "trunks" when connected to fiber optic modules used to form connections to jumper cables using a select polarity.

For connection of cables together or with other fiber optic devices, the terminal ends of a cable may include a connector. A connector may include a housing structure configured to interact with and connect with an adapter. An adapter, in a simple form, may include two aligned ports for aligning fiber optic connectors therein to align and connect optical fibers end-to-end. As described herein, the connectors and adapters may be considered multi-fiber connectors and multi-fiber adapters.

While the following description is directed towards MPO adapters and MPO connectors with MT optical ferrules, the embodiments described may be applicable to other adapters, connectors and ferrule types as well. An embodiment of an MPO connector **10** and adapter **12** are generally represented in FIG. **1**. A first end of the connector **10** may include a ferrule **14** that may be a multi-fiber ferrule as shown. In addition, the connector **10** may have attached thereto, a fiber optic cable **15***a* and cable boot **15***b* (shown only schematically) that may extend from a second end of the connector.

An adapter **12** may include a first end **16** having a first plug-in port **18** for receiving the ferrule end of an optical fiber connector **10** therein, and may include a second end **16** having an additional plug-in port **22** (not visible) for receiving an additional MPO optical fiber connector, or other type of fiber optic device therein.

For retention of an MPO connector **10** within each of the ports **18**, **22** the ports may be provided internally with a connector clip that may be formed by the two resilient tabs **24***a*, **24***b* configured to be displaceable outwardly for insertion and removal of a connector **10** into or out of the ports **18**, **22**, and return to essentially their original position to engage and retain a connector in the ports. Adapters **12** may be configured to be mounted on a chassis panel, and may include mounting flanges **26***a*, **26***b* to mount the adapter via screws, for example.

A connector **10** may include an inner housing **26** that may surround the ferrule **14**. In the embodiment depicted, ferrule **14** is of the female type—a pairing connector may have a male-type ferrule with two guide pins that fit into the receiving holes of the female ferrule. A connector **10** may also include an outer housing member **28** that may be slidably disposed about the inner housing **26** adjacent the second end of the connector **10**. To provide for a predetermined alignment of the fiber optic cables within the adapter **12**, the inner housing may include an alignment key **30** that is configured to fit within keying slot **32** of the adapter. For example, in the embodiment depicted, one of the connector **10** or adapter **12** will need to be rotated about its axis 180° to align the key **30** with the slot **32**. Inner housing **26** may slide into port **18** until tabs **24***a*, **24***b* engage into slots **34***a*, **34***b* of the inner housing. The outer housing **28** may be moved towards the second end to allow the tabs **24***a*, **24***b* to engage into slots **34***a*, **34***b*, and to retain the tabs in the slots, the outer housing may be slid back towards the first end and over the tabs. The outer housing **28** may be biased towards the first end via springs (shown for example in FIG. **6**D) or alternative types of biasing devices.

FIGS. **2**A and **2**B represent the two different modes of connection alignment to provide for the two different modes of polarity. FIG. **2**A may be indicated as representing what may be termed a 'normal' polarity wherein fiber No. 1 of the connector **10***a* may mate with fiber No. 1 of connector **10***b*, and similarly, fiber No. 12 of the connector **10***a* may mate with fiber No. 12 of the connector **10***b*. For this type of alignment, the key **30** may be disposed adjacent side A of the ferrule, and the adapter may be keyed accordingly, with the slots **32** (FIG. **1**) in correspondingly opposed surfaces within the adapter **12**. To reverse the polarity of the connection between connectors **10***a*, **10***b*, as shown in FIG. **2**B, the key position of the key **30** of connector **10***b* would need to be changed to the opposite surface for reversed alignment in an adapter **12**, fiber No. 1 of the connector **10***a* may mate with fiber No. 12 of connector **10***b*, and similarly, fiber No. 12 of the connector **10***a* may mate with fiber No. 1 of the connector **10***b*. Alternatively, the key **30** of the connector **10***a* could be changed, or in a further embodiment, a different type of adapter may be used, wherein the slots **32** may be aligned on the same internal surface within the adapter **12**.

Since an adapter **12** may already be permanently mounted on a surface, and may have a cable plugged into a back side thereof, an embodiment wherein the location of key **30** may be changed would provide for a quick, onsite polarity change. An embodiment of a connector **110** having a detachable key **130** is represented in FIG. **3**. For clarity, the ferrule and any cable and cabling components are omitted. The connector may include an inner housing **126** and an outer housing **128**. The inner housing may have a top side wall **126***a* and a bottom side wall **126***b* that may be disposed opposite one another, or rotationally, 180° from one another about a central longitudinal axis **140**. The designation top and bottom are used for reference only as per the orientation shown, and could alternatively be interchanged. In an embodiment, each of the side walls **126***a* and **126***b* may be similar, or essentially the same, and each side wall may include a corresponding slot **132***a* and **132***b* that is configured for receiving the key **130**. At least a portion of the key **130** may be configured to be removably insertable into either of the slots **132***a* and **132***b*. The key **130** may be configured in conjunction with the walls **126***a* and **126***b* to be removably attached with either the top wall **126***a* or the bottom wall **126***b*. In an embodiment, when key **130** is disposed with the top wall **126***a*, the connector **110** may be configured to define a first keyed configuration for insertion of the first end of the connector into an adapter in only a first orientation to define a first polarity with respect to the adapter. Alternatively, when key **130** is disposed with the bottom wall **126***b*, the connector **110** may be configured to define a second keyed configuration for insertion of the first end into the adapter in only a second orientation to define a second polarity with respect to the adapter. As discussed previously, the second polarity may be considered to be opposite to the first polarity.

FIG. **4** shows a partially disassembled view of the connector **110** of FIGS. **3**A and **3**B. In an embodiment, as shown in greater detail in FIGS. **5**A-**5**D, the key **130** may include a body portion **150** that may include a slot or hole **151** at a first end of the key, and a guide rail **152** at a second end of the key. The guide rail **152** may be configured to fit within either of the slots **132***a*, **132***b* to guide longitudinal movement of the key **130** into a slot, and also prevent side-to-side (lateral) movement of the key once inserted in the slot. The guide rail **152** and slots **132***a*, **132***b* may also be configured with respect to one another to prevent the key from moving out of the slot in a direction transverse to the longitudinal axis. In an embodiment, the width of the slots **132***a*, **132***b* may widen in a direction from the external surfaces of the housing to the internal surface. The guide rail **152** may be correspondingly configured, as shown in FIG. **5**C to have a narrower width adjacent the body **150** and widen in a direction extending away from the base. With such a configuration the key **130** may essentially be prevented from being lifted upwardly away from the housing **126** once inserted in a slot **132***a* or **132***b*, while also being prevented from moving laterally on the housing.

To engage the key **130** longitudinally with respect to the housing **126**, the housing may include a projection **160** over which the key body **150** may be inserted to engage the projection within the hole **151**. The projection **160** may be tapered outwardly away from the housing in at least the insertion direction to facilitate movement of the key body **150** up and over the projection. To facilitate removal of a key **130**, once engaged with the projection **160**, the key body may include at least one gripping ridge **154**, or alternatively a plurality of ridges (as shown) disposed along the body **150**. The ridges may be configured to be engaged, for example with a fingernail, to pull the key from the housing **126**.

Additional details of the connector housing **110** may be seen in the views represented by FIGS. **6**A-**6**F. FIGS. **6**A and **6**B show representative face and side views of the connector **110** with the key **130** installed. FIG. **6**C is a cross-sectional view along line C-C in FIG. **6**A, and FIG. **6**D is a cross-sectional view along line D-D in FIG. **6**B. As mentioned previously with regard to FIG. **1**, the outer housing **128** may be slidably disposed about the inner housing **126** and a spring **170** may be provided to bias the outer housing forwardly, or towards the first, or insertion end of the inner housing as represented in FIG. **6**D. Tabs **129**, as shown in detail in FIG. **6**E, may be configured to limit forward movement of the outer housing **128** along the inner housing **126**.

The outer housing **128** may be moved rearwardly on the inner housing by a distance d**1**. Movement of the outer housing over the distance d**1** provides access to the slots **134** for engagement into the slots of adaptor tabs (such as tabs **24***a*, **24***b* in FIG. **1**) for engagement of the connector **110** within an adapter. Similarly, the outer housing **128** may be displaced by the distance d**1** to release the adapter tabs for removal of the connector **110** from the adapter. FIG. **6**E shows a detailed view of the interconnection between the key body **150** and hole **151** with the projection **160** of the inner housing **126**. As shown in FIG. **6**E, the second end of the body **150** may fit between the inner housing **126** and outer housing **128**. As such, in an embodiment, the outer housing **128** may be displaced by the distance d**1** to provide clearance for the key to be inserted onto the inner housing **126**. When the outer housing **128** is biased forwardly as shown, the key body **150** may be prevented from being released from the projection **160**. To remove the key **130**, the outer housing **128** may be slid rearwardly by the distance d**1** to provide clearance for lifting of the key body **150** outwardly away from around the projection **160** as shown in FIG. **6**F.

An alternative embodiment of a removable key **230** is depicted in FIG. **7**. In the embodiment of FIG. **7**, the guide rail **252** may essentially be similar to the guide rail **152** as discussed above. Alternatively, the guide rail **152** may have an alternative configuration. The gripping surface may include at least one groove **254** that may function in essentially the same manner as the ridges **154** as discussed above, that is, to provide a surface that may be readily engaged to slide the key **230** from the inner housing **226**. In an embodiment, the key **230** may have a solid key body **250** at the first end **231**, or alternatively, as shown, may include an elongated slot **251** that may provide various functions as set forth further herebelow.

In an embodiment as represented in FIGS. **7** and **8**, the configuration for releasably retaining the key **230** with the inner housing **226** may include lateral tabs **256***a*, **256***b* at the first, or insertion end **231** of the key body **250**. The lateral tabs **256***a*, **256***b* may be configured to define corresponding lateral recesses **258***a*, **258***b*. The top or bottom surface **226**, in addition to having slots for receiving the guide rail **252** (not shown, but essentially similar to slots **132***a*, **132***b* in FIG. **4**), may include projections **272***a*, **272***b* configured to straddle the key body **250** wherein the width between the projections may be substantially the same as the width of the key body between the lateral recesses **258***a*, **258***b*.

The key **230** may be engaged with the inner housing **226** by insertion of the first key end **231** between the projections **272***a*, **272***b*. By including a slot **251** between the lateral tabs **256***a*, **256***b* at the first end **231**, the tabs may more easily be deflected inwardly to allow for the tabs to pass between the projections **272***a*, **272***b*. Alternatively, if a slot **251** is not included, some polymeric materials of which the key may be constructed, may be resilient sufficiently to allow for inward compression of the tabs **256***a*, **256***b* to permit the tabs to move past the projections **272***a*, **272***b*. Once past the projections **272***a*, **272***b*, the tabs **256***a*, **256***b* may again push outwardly and retain the key **230** in engagement with the inner housing **226**, at least in the longitudinal direction of insertion of the key.

The thickness of the body **250** at the first end **231** may essentially be the same as the space defined between the inner housing **226** and an outer housing **228** (FIGS. **9**A-**9**C) so that the key **230** cannot be lifted away from the inner housing when the outer housing is in place, ensuring that removal of the key **230** must be done by longitudinal displacement of the key from between the projections **272***a*, **272***b*.

FIGS. **9**A-**9**C show an alternative embodiment of an outer housing **228**. In conjunction with the key **230** having a slot **251**, the inside of the outer housing may include a guide **275** that is configured to fit within the elongated slot for movement within the slot upon movement of the outer housing longitudinally along the inner housing **226**. In an embodiment, the guide **275** could also provide an additional stop for hindering longitudinal withdrawal of the key **230** from between the inner housing **226** and outer housing **228**. When the outer housing **228** is in its forward biased position as shown, the thickness of the key body **250** may be essentially the same as the distance between the inner and outer housings. As such, upon an initial movement of the key **230** in a longitudinally downward in the figure, the slot **251** would move along the guide **275** until the inner surface **231***a* of the first end **231** would contact the guide, thereby hindering further outward movement of the key.

So that the first end **231** of the key **230** may pass into the space between the inner housing **226** and outer housing **228**, the inner housing may include a recess **276** that has a depth into the housing that is sufficient to permit the first end to pass between the guide **275** and the inner housing. In an embodiment as represented in FIGS. **9**B and **9**C, the deepest part of the recess **276** may be located at a position along the inner housing **226** that corresponds to a location at which the guide **275** might be located upon displacement of the outer housing **228** towards the back end of the inner housing. As such, when the outer housing **228** is biased forward into its normal use position, the key **230** will not pass between the guide **275** and the inner body **226**. The key **230** may only pass when the outer housing **228** is first displaced towards the back end of the inner housing **226**.

In the various embodiments disclosed herein, the keys and housing components, may be formed of rigid polymers or metals, for example. In general, any type of substantially rigid material may be used. The material should have a rigidity sufficient to retain the necessary engagement between the key and the housing so that the key remains in place except when a force is applied to remove the key.

Another embodiment of a key **330** is shown in FIGS. **10**A and **101**B. The key **330** may, for example, be a formed metal band or rigid polymer. The key **330** may include a longitudinal body **350** having a first end **350***a* and a second end **350***b*. A connector **310** in conjunction with a key **330** is represented in FIGS. **11**A-**11**C. At the front end **327**, each of the sidewalls **326***a* and **326***b* may include a recess or notch **280** that is configured to receive the second end of the key **330** therein. The second end **350***b* may be hooked, or U-shaped to provide a bent flange **352** configured to fit around the front end **327** of the inner housing **326**. Such a configuration of a hook and notch may prevent lateral movement of the key **330** on the sidewalls **326***a* and **326***b*, and may prevent movement transversely away from the housing, or a lifting off from the housing via the second end.

The first end **350***a* of the key **330** may include a tab **353** that extends substantially orthogonally from the body **350**.

As represented in FIGS. **11**B and **11**C, the inner housing may have a recess, slot or hole **382** configured for receiving the tab **353** therein. Once tab **353** is engaged within the slot **382**, longitudinal movement of the key **330** may be inhibited. As shown in FIG. **11**A, outer housing **328** may prevent the first end **350***a* of the key **330** from being lifted away from the inner housing **326**, so that when the outer housing is biased into its forward position, the key **330** is essentially locked in place on the housing.

Outer housing **328** may be displaced rearwardly for installation and removal of the key **330**. For installation, the outer housing **328** may be displaced rearwardly against the bias of springs (not shown, but discussed previously). The flange **352** may be aligned with the notch **380** and the key may be slid longitudinally into place with the flange in the notch to align the tab **353** with the slot **382**. Tab **353** may be pushed into the slot **382** and the outer housing **328** may be released to move forwardly to cover the first end **350***a* of the key **330** and hold the key in place. This procedure may be reversed for removal of the key **330**. Outer housing **328** may be displaced rearwardly, tab **353** may be lifted out of the slot **382**, and the key may be slid longitudinally off of the inner housing **326**.

In an alternative embodiment, as represented in FIGS. **12**A, **12**B and **13**A-**13**C, a key **430** may be configured to releasably connect with the outer housing **428**. The key **430** may include a longitudinal body portion **450** and a guide rail **452** on the second end **450***b*. The guide rail **452** may be configured to engage in a slot **432***a*, **432***b* of the inner housing **426** in a manner as described earlier with regard to FIGS. **6**A-**6**E. In an embodiment, instead of a hole at the insertion end, the body **450** may include a projection **455** that extends away from the body. To engage with the projection **455**, as shown in detail in FIG. **13**C, the outer housing **428** may include a receptacle **490** into which the projection may extend when the outer housing is in place around the inner housing **426**.

Similar to earlier embodiments, the second end **450***b* of the key **430** may be retained in the slots **432***a*, **432***b* in the lateral and transverse directions by the configuration of the guide rail **452**. The second end **450***b* may essentially be movable in only the longitudinal direction upon insertion or removal of the key **430**. When inserted, the first end **450***a* of the key **430** may be held in place from lateral movement by a pair of projections **492** extending from the inner housing and defining a space therebetween that is essentially the same as the width of the body portion **450**. The outer housing **428** may include depressible tabs **488** that, when pressed down, press downwardly on the first end **450***a* to release the projection **455** from engagement in the receptacle **490**.

In an alternative embodiment, as shown in FIGS. **14**A, **14**B, **15**A, **15**B, **16**A, **16**B and **16**C, instead of a single key that may be alternatively placed in conjunction with each face of the top or bottom sidewalls of the connector, a connector **510** may be configured so that each sidewall **526***a*, **526***b* includes a corresponding displaceable key **530***a*, **530***b*. Similar to previous embodiments, the connector **510** may include an inner housing **526** with a longitudinally displaceable outer housing **528** disposed about the inner housing. Each sidewall **526***a*, **526***b* may include a longitudinal slot **532***a*, **532***b* that extends forwardly from the rear end of the inner housing **526**, and as discussed further below, the keys are movably disposable along the lengths of the slots. Depending on the desired polarity, one of the keys **530***a* or **530***b* may be positioned forwardly in the slots **532***a*, **532***b*, while the other is positioned out of the way, or hidden under the outer housing. In an embodiment, the width of the slots **532***a*, **532***b* may widen in a direction from the external surfaces of the housing to the internal surface.

As shown in FIGS. **17**A-**17**E, each key **530** may include a key body **550** and a projecting guide rail **552**, similar to the key **130** as previously discussed with reference to FIGS. **5**A-**5**D. Projecting rails **552** may have a narrower width adjacent the body **550** and either widen in a direction extending away from the body, or have a base portion disposed away from the body that has a width greater than the width adjacent the body. Slots **532***a*, **532***b* may include an enlarged entry port **533***a*, **533***b* that has a width sufficient to allow for passage of the guide rail **552** therethrough. FIG. **16**B shows the key **530***a* disposed over the slot **532***a* with the guide rail **552** over the entry port **533***a*, and the key **530***b* disposed within the slot **532***b*. Once inserted through the entry ports, the keys **530***a*, **530***b* may be displaceable longitudinally along the slots **532***a*, **532***b*, and once moved forwardly from the entry ports may not be lifted out of the slots in a direction transverse to the longitudinal direction of the slots due to the configuration of the guide rail with the greater width disposed away from the body.

FIGS. **18**A-**18**D depict the inner housing **526** and outer housing **528**. In an embodiment, the inner housing **526** may include stops **529** configured to limit the forward movement of the outer housing **528** under bias of the springs **570**. The outer housing may have a front end **528***a* for being disposed towards the front end of the inner housing **526** when disposed on the inner housing, and a rear end **528***b* disposed opposite the front end. The outer housing **528** may include internal stops **561**, that may be disposed adjacent the rear end **528***b*, and configured for engaging with the stops **529** of the inner housing **526**. A forward facing surface of the stops **529** may be sloped angularly upwards towards the rear of the inner housing so that the outer housing can be forced over the stops when the outer housing is slid onto the inner housing from the front end of the inner housing.

FIGS. **19**A-**19**E represent the operation of the displaceable keys **530***a*, **530***b* in relation to the displaceable outer housing **528** and inner housing **526**. FIG. **19**A represents a connector configured with a first polarity with key **530***a* in a forward 'active' position and key **530***b* in a hidden 'inactive' position. To change the polarity, the outer housing **528** may be displaced rearwardly on the inner housing **526** as shown in FIG. **19**B. After displacing the outer housing **528**, key **530** will be partially exposed. Key **530***a* may be slid rearwardly out of its 'active' position into its 'inactive' position and, as shown in FIG. **19**C, both keys may be in their 'inactive' position. Key **530***b* may be slid forwardly out of its 'inactive' hidden position into its 'active' position as shown in FIG. **19**D, and the outer housing **528** may be released to return to its forward position as represented in FIG. **19**E.

While the above-described sequence represents one mode of switching the polarities, the sequence of movements may be altered. For example, key **530***b* may be moved forwardly prior to moving key **530***a* rearwardly. To hold the keys **530***a*, **530***b* in the forward, or rearward position, the outer housing and/or keys may include a stop/retention configuration. In an embodiment as represented in FIGS. **20**A-**20**C, (see also FIG. **18**A) the exterior surfaces of walls **526***a*, **526***b* may include a ridge **563***a* positioned corresponding to the forward position of a key, and a ridge **563***b* positioned corresponding to a rearward position of a key. The keys **530***a*, **530***b*, as represented in FIGS. **17**A-**17**E may include a corresponding slot **565** (FIGS. **17**B, **17**C, **17**E) for engaging with either of the ridges **563***a* or **563***b* depending on the location of the key. Each key **530***a*, **530***b* may therefore be moveable longitudinally over the ridges and when the slots engage with a ridge, the frictional engagement between the keys and the housing will increase and a person working with the connector will be able to feel when engagement occurs. Once engaged, an additional amount of force would then be needed to move the keys from their engaged positions. Alternative configurations of engagement features may also be provided. As an example, as previously discussed with reference to FIGS. **7** and **8**, lateral projections and recesses, similar to projections **256***a* and recesses **258***a* may be provided on the sides of a key **530***a*, **530***b* and the housing surface could include a projection such as projections **272***a*, so that a similar engagement as previously described may be provided for positioning of the keys on the inner housing. Alternatively, the features could be reversed wherein the housing may include slots and the keys may include corresponding ridges.

In a variation of the displaceable key, a key **630** could be configured as depicted in FIG. **21**. In an embodiment, the key **630** may have a longer body **650** so that more than half of the length of the body, for example about ⅗ to about ⅔ of the key body, will be covered by the outer housing **628**, as depicted in FIG. **23**A, when the outer housing is in its rest, or forward position. With this type of configuration, the guide rail **652** may be configured as a 'fin-like' projection extending from the body **650**. As depicted in FIG. **22**, a longitudinal slot **632** on the inner housing **626** may be configured for receipt of the rail **652** therein. Similar to the previously described embodiments, each of the top and bottom surfaces of the inner housing **626** may essentially be identical.

Since at least, for example, about ⅗ of the length of the key **630** may be disposed between the inner housing and the outer housing, the outer housing will essentially prevent lateral movement of the key away from the inner housing **626** when the outer housing is in its forward position as represented, for example by key **630***a* in FIG. **23**A in its forward, or 'active' position. In this position of the outer housing **628**, the key **630***b* will essentially be hidden in its rearward, or 'inactive' position. The guide rail **652** may therefore not require any widening at its end away from the body as was previously described for guide rail **552**.

As in previous embodiments, the outer housing **628** may be displaceable rearwardly to a position as represented in FIG. **23**B. In this embodiment, for example, only ⅓ to ⅖ of the 'active' key may then be covered by the outer housing. In this position of the outer housing **628** the 'inactive' key **630***b* may be exposed for engaging the key to pull the key forward, if desired. The 'active' key **630***a* may by pushed rearwardly into its 'inactive' position, and by changing the position of both keys, the polarity of the connector may be changed. Alternatively, as represented in FIG. **23**C, when the outer housing **628** is in its rearward position, the keys **630***a* and/or **630***b* may be removed from the connector or inserted into position on the connector, as a flexibility of the material of the key may provide sufficient clearance for the fin **652** to be lifted out of its corresponding slot **632**, so that a key may be pulled form or inserted into the connector.

In a further embodiment, as represented in FIGS. **24-26**C, a connector **710** may include a snap-in key **730**. Each of top or bottom walls **726***a* or **726***b* of the inner housing **726** may essentially be identical and include a slot **732** for receiving a snap-in projection of the key **730**. The key **730** may include a key body portion **750** and a projecting engagement member **752** that is configured to fit into the slot **732** and retain the key **730** in engagement with the inner body **726**. The engagement member **752** may be configured as a 'snap-in' type connector, wherein the engagement member may compress to fit through the slot **732** and then expand to retain member within the slot. In general, any type of 'snap-in' configuration may be usable.

In an embodiment as shown, the engagement member **752** may include first and second leg portions **747***a* and **747***b* separated by a slot that allows for the leg portions to be resiliently displaced towards one another for passage into and through the slot **732**. Once through the slot **732** the leg portions **747***a*, **747***b* may return to their natural position. One or both of the leg portions **747***a*, **747***b* may include a catch **749** that projects outwardly from the leg portions to give the engagement member a width which is greater than a width of the slot **732**. As represented in FIG. **26**D, with an inner housing wall depicted in outline, when the leg portions **747***a*, **747***b* pass through the slot **732** in the inner housing wall and return to their normal positions, the catches can engage the inside surface of the housing wall to thereby provide a retention force against removing the key **730** from the inner housing **726**.

The key body **750** may include recessed notches **745** along the longitudinal sides thereof to facilitate removal of the key **730** from the slot **732**. The notches **745** may be configured to provide space for insertion of a tool, such as a small screwdriver, or even a fingernail, under the body **750** to apply a lifting force and pry the key **730** upwardly away from the inner housing **726**. To prevent rotation of a key **730** on the inner housing **726**, the engagement member **752** and slot **732** may have a length dimension (in a longitudinal direction of the key, or housing) that is at least twice as long as a width dimension transverse to the length dimension.

As an alternative to the 'snap-in' configuration, as represented in FIGS. **27** and **28**A-**28**C, a key **830** may be configured with a twist-lock connector **852**. The key **830** may include a connector **852** that extends away from the bottom surface of a body portion **850** of the key. The connector **852** may include a shaft portion **852***a* that extends from the body portion **850** and an arm portion **852***b* that extends away from the shaft portion. In an embodiment, the arm portion **852***b* may extend from the shaft portion **852***a* to only one side of the shaft as shown. Alternatively, the arm portion **852***b* and shaft portion **852***a* may be configured with a "T" configuration and the arm portion may extend bilaterally away from the shaft portion in opposite directions (not shown). The top and bottom walls **826***a* and **826***b* may include a corresponding passage **831** having a size and shape configured for passage of the arm portion **826***b* therethrough. The shaft portion **852***a* may have length extending from the body portion **850** so that the length may be substantially the same as the thickness of a wall portion of the top and bottom walls **826***a* and **826***b* at least in the vicinity of the passage **831**. The arm portion **852***b*, may thereby engage with an inner surface of the top or bottom walls **826***a* and **826***b* after being inserted through the passage **831** and then rotated about the shaft **852***a* as represented in FIG. **29**.

As shown in FIG. **29**, the key **830** may be attached to either of the top or bottom walls **826***a* and **826***b* by aligning the key as represented by the dashed key outline (longitudinal axis of the key transverse to the longitudinal axis of the connector), inserting the arm portion **826***b* through the opening **831** and rotating the key by about 90° to the 'locked-in' key position as represented by the solid key outline (longitudinal axis of the key aligned with the longitudinal axis of the connector). Once rotated, the arm portion **826***b* as indicated by the dotted outline will no longer be aligned with the passage **831** and will be engaged with an interior surface of the top or bottom surfaces **826***a* and **826***b* to thereby prevent a lifting or removal of the key **830** away from the top or bottom walls.

To change the polarity of the connector, the key **830** may be rotated back to its transverse position (dashed line), lifted from the top or bottom walls **826***a*, **826***b*, and reinstalled on the opposite surface. To limit rotational movement of the key **830**, the interior side of the walls may include a stop member **833**, shown in FIG. **30**A, which, upon rotation of the key about 90°, is engaged by the arm portion **826***b* to block further rotation. The stop member may be provided by a thickening of the wall, a projection from the wall, or alternatively, the arm may rotate within a depression **859** extending into the wall from the interior towards the exterior, and which depression may have the shape of a quarter, or half of a circle, so that the sides of the depression may provide rotational stops.

In addition to, or as an alternative to the stop **833**, in a manner similar to the embodiments of FIGS. **18**A and **20**A, a ridge **863** may be provided on the exterior surface of the top and bottom walls **826***a* and **826***b*, and the bottom surface of the key body **850** may include a corresponding slot **855** for engaging with the ridge upon rotation of the key **830** into its locked-in position. The ridge/slot configuration may also be configured to provide resistance to minimize inadvertent rotation of a key on the surfaces once a key is 'lock-in'. If a stop **833** is not provided, the ridge/slot configuration would also provide a user a noticeable engagement to indicate a proper alignment of the key on the housing.

In an alternative embodiment (not shown) the shaft **852***a* may be threaded with at least one circumferential thread and the opening **831** may include a matching thread and rotation of the shaft within the opening may thread the key into and out of the wall in a manner as would be represented by a nut and bolt engagement.

Various parts, components or configurations described with respect to any one embodiment above may also be adapted to any others of the embodiments provided.

This disclosure is not limited to the particular systems, devices and methods described, as these may vary. The terminology used in the description is for the purpose of describing the particular versions or embodiments only, and is not intended to limit the scope.

In the above detailed description, reference is made to the accompanying drawings, which form a part hereof. In the drawings, similar symbols typically identify similar components, unless context dictates otherwise. The illustrative embodiments described in the detailed description, drawings, and claims are not meant to be limiting. Other embodiments may be used, and other changes may be made, without departing from the spirit or scope of the subject matter presented herein. It will be readily understood that the aspects of the present disclosure, as generally described herein, and illustrated in the figures, can be arranged, substituted, combined, separated, and designed in a wide variety of different configurations, all of which are explicitly contemplated herein.

The present disclosure is not to be limited in terms of the particular embodiments described in this application, which are intended as illustrations of various aspects. Many modifications and variations can be made without departing from its spirit and scope, as will be apparent to those skilled in the art. Functionally equivalent methods and apparatuses within the scope of the disclosure, in addition to those enumerated herein, will be apparent to those skilled in the art from the foregoing descriptions. Such modifications and variations are intended to fall within the scope of the appended claims. The present disclosure is to be limited only by the terms of the appended claims, along with the full scope of equivalents to which such claims are entitled. It is to be understood that this disclosure is not limited to particular methods, reagents, compounds, compositions or biological systems, which can, of course, vary. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to be limiting.

As used in this document, the singular forms "a," "an," and "the" include plural references unless the context clearly dictates otherwise. Unless defined otherwise, all technical and scientific terms used herein have the same meanings as commonly understood by one of ordinary skill in the art. Nothing in this disclosure is to be construed as an admission that the embodiments described in this disclosure are not entitled to antedate such disclosure by virtue of prior invention. As used in this document, the term "comprising" means "including, but not limited to."

While various compositions, methods, and devices are described in terms of "comprising" various components or steps (interpreted as meaning "including, but not limited to"), the compositions, methods, and devices can also "consist essentially of" or "consist of" the various components and steps, and such terminology should be interpreted as defining essentially closed-member groups.

With respect to the use of substantially any plural and/or singular terms herein, those having skill in the art can translate from the plural to the singular and/or from the singular to the plural as is appropriate to the context and/or application. The various singular/plural permutations may be expressly set forth herein for sake of clarity.

It will be understood by those within the art that, in general, terms used herein, and especially in the appended claims (e.g., bodies of the appended claims) are generally intended as "open" terms (e.g., the term "including" should be interpreted as "including but not limited to," the term "having" should be interpreted as "having at least," the term "includes" should be interpreted as "includes but is not limited to," etc.). It will be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present. For example, as an aid to understanding, the following appended claims may contain usage of the introductory phrases "at least one" and "one or more" to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles "a" or "an" limits any particular claim containing such introduced claim recitation to embodiments containing only one such recitation, even when the same claim includes the introductory phrases "one or more" or "at least one" and indefinite articles such as "a" or "an" (e.g., "a" and/or "an" should be interpreted to mean "at least one" or "one or more"); the same holds true for the use of definite articles used to introduce claim recitations. In addition, even if a specific number of an introduced claim recitation is explicitly recited, those skilled in the art will recognize that such recitation should be interpreted to mean at least the recited number (e.g., the bare recitation of "two recitations," without other modifiers, means at least two recitations, or two or more recitations). Furthermore, in those instances where a convention analogous to "at least one of A, B, and C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., "a system having at least one of A, B, and

C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). In those instances where a convention analogous to "at least one of A, B, or C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., "a system having at least one of A, B, or C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). It will be further understood by those within the art that virtually any disjunctive word and/or phrase presenting two or more alternative terms, whether in the description, claims, or drawings, should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms. For example, the phrase "A or B" will be understood to include the possibilities of "A" or "B" or "A and B."

In addition, where features or aspects of the disclosure are described in terms of Markush groups, those skilled in the art will recognize that the disclosure is also thereby described in terms of any individual member or subgroup of members of the Markush group.

As will be understood by one skilled in the art, for any and all purposes, such as in terms of providing a written description, all ranges disclosed herein also encompass any and all possible subranges and combinations of subranges thereof. Any listed range can be easily recognized as sufficiently describing and enabling the same range being broken down into at least equal halves, thirds, quarters, fifths, tenths, etc. As a non-limiting example, each range discussed herein can be readily broken down into a lower third, middle third and upper third, etc. As will also be understood by one skilled in the art all language such as "up to," "at least," and the like include the number recited and refer to ranges which can be subsequently broken down into subranges as discussed above. Finally, as will be understood by one skilled in the art, a range includes each individual member. Thus, for example, a group having 1-3 cells refers to groups having 1, 2, or 3 cells. Similarly, a group having 1-5 cells refers to groups having 1, 2, 3, 4, or 5 cells, and so forth.

Various of the above-disclosed and other features and functions, or alternatives thereof, may be combined into many other different systems or applications. Various presently unforeseen or unanticipated alternatives, modifications, variations or improvements therein may be subsequently made by those skilled in the art, each of which is also intended to be encompassed by the disclosed embodiments.

What is claimed is:

1. A fiber optic connector comprising:

a connector housing having a longitudinal axis and comprising an exterior portion extending circumferentially about a space with respect to the longitudinal axis, the exterior portion including first and second exterior walls on opposite sides of the longitudinal axis, the connector housing being configured to receive a plurality of optical fibers in the space between the first and second exterior walls, the first exterior wall comprising a first elongate groove along the longitudinal axis and the second exterior wall comprising a second elongate groove along the longitudinal axis; and

a polarity change element comprising a key portion and a tongue, the tongue being configured to be slidably received in a selected one of each of the first elongate groove and the second elongate groove to selectively and releasably position the polarity change element on a corresponding one of the first exterior wall and the second exterior wall such that the key portion is externally positioned on the respective one of the first exterior wall and the second exterior wall,

wherein positioning the polarity change element on the first exterior wall such that the key portion is externally positioned on the first exterior wall configures the fiber optic connector in a first polarity configuration and positioning the polarity change element on the second exterior wall such that the key portion is externally positioned on the second exterior wall configures the fiber optic connector in a second polarity configuration; and

wherein the fiber optic connector is configured to be plugged into a mating receptacle with the connector housing in a first rotational orientation about the longitudinal axis when the fiber optic connector is in the first polarity configuration and the fiber optic connector is configured to be plugged into the mating receptacle with the connector housing in a second rotational orientation about the longitudinal axis when the fiber optic connector is in the second polarity configuration, the second rotational orientation being offset from the first rotational orientation about the axis by 180°;

wherein the polarity change element comprises opposing lateral tabs defining a first width and the connector housing includes a first pair of projections adjacent the first elongate groove and a second pair of projections adjacent the second elongate groove, the first pair of projections separated by a first opening having a second width and the second pair of projections separated by a second opening having the second width, the first width being greater than the second width;

wherein the fiber optic connector is configured so that:

as the tongue is slidably received in the first elongate groove to position the polarity change element on the first exterior wall to configure the fiber optic connector is in the first polarity configuration, the opposing lateral tabs pass through the first opening in a first longitudinal direction, and

when the fiber optic connector is in the first polarity configuration, the opposing lateral tabs are configured to engage the first pair of projections when the polarity change element is urged in a second longitudinal direction opposite the first longitudinal direction in relation to the connector housing to resist withdrawal of the tongue from the first elongate groove, whereby the opposing lateral tabs and the second pair of projections releasably retain the polarity change element on the first exterior wall; and

wherein the fiber optic connector is further configured so that:

as the tongue is slidably received in the second elongate groove to position the polarity change element on the second exterior wall to configure the fiber optic connector is in second first polarity configuration, the opposing lateral tabs pass through the second opening in the first longitudinal direction, and

when the fiber optic connector is in the second polarity configuration, the opposing lateral tabs are configured to engage the second pair of projections when the polarity change element is urged in the second longitudinal direction in relation to the connector housing to resist withdrawal of the tongue from the first elongate groove, whereby the opposing lateral tabs and the second pair of projections releasably retain the polarity change element on the second exterior wall.

2. The fiber optic connector as set forth in claim **1**, wherein each of the first elongate groove and the second elongate groove has an open axial end.

3. The fiber optic connector as set forth in claim **2**, wherein the tongue is configured to be received in each of the first elongate groove and the second elongate groove by insertion along the longitudinal axis into the respective open axial end.

4. The fiber optic connector as set forth in claim **3**, wherein the connector housing comprises a housing front end portion configured to be plugged into the receptacle and a housing rear end portion spaced apart from the housing front end portion along the longitudinal axis in a rear direction, wherein the polarity change element has an element front end portion and an element rear end portion spaced apart from the element front end portion in the rear direction.

5. The fiber optic connector as set forth in claim **4**, wherein the element front end portion defines at least a portion of the key.

6. The fiber optic connector as set forth in claim **1**, wherein the opposing lateral tabs are spaced apart from at least a portion of the tongue in the rear direction.

7. The fiber optic connector as set forth in claim **1**, wherein the connector housing comprises a housing front end portion configured to be plugged into the receptacle and a housing rear end portion spaced apart from the housing front end portion along the longitudinal axis in a rear direction, wherein the polarity change element has an element front end portion and an element rear end portion spaced apart from the element front end portion in the rear direction.

8. The fiber optic connector as set forth in claim **7**, wherein the element front end portion defines at least a portion of the key.

9. A fiber optic connector comprising:

a connector housing having a longitudinal axis and comprising an exterior portion extending circumferentially about a space with respect to the longitudinal axis, the exterior portion including first and second exterior walls on opposite sides of the longitudinal axis, the connector housing being configured to receive a plurality of optical fibers in the space between the first and second exterior walls, the first exterior wall comprising a first elongate groove along the longitudinal axis and the second exterior wall comprising a second elongate groove along the longitudinal axis; and

a polarity change element comprising a key portion and a tongue, the tongue being configured to be slidably received in a selected one of each of the first elongate groove and the second elongate groove to selectively and releasably position the polarity change element on a corresponding one of the first exterior wall and the second exterior wall such that the key portion is externally positioned on the respective one of the first exterior wall and the second exterior wall,

wherein positioning the polarity change element on the first exterior wall such that the key portion is externally positioned on the first exterior wall configures the fiber optic connector in a first polarity configuration and positioning the polarity change element on the second exterior wall such that the key portion is externally positioned on the second exterior wall configures the fiber optic connector in a second polarity configuration; and

wherein the fiber optic connector is configured to be plugged into a mating receptacle with the connector housing in a first rotational orientation about the longitudinal axis when the fiber optic connector is in the first polarity configuration and the fiber optic connector is configured to be plugged into the mating receptacle with the connector housing in a second rotational orientation about the longitudinal axis when the fiber optic connector is in the second polarity configuration, the second rotational orientation being offset from the first rotational orientation about the axis by 180°;

wherein when the fiber optic connector is in the first polarity configuration, the tongue is received in the first elongate groove and the second elongate groove is open; and

wherein when the fiber optic connector is in the second polarity the tongue is received in the second elongate groove and the first elongate groove is open.

10. The fiber optic connector as set forth in claim **9**, wherein each of the first elongate groove and the second elongate groove has an open axial end.

11. The fiber optic connector as set forth in claim **10**, wherein the tongue is configured to be received in each of the first elongate groove and the second elongate groove by insertion along the longitudinal axis into the respective open axial end.

12. The fiber optic connector as set forth in claim **11**, wherein the connector housing comprises a housing front end portion configured to be plugged into the receptacle and a housing rear end portion spaced apart from the housing front end portion along the longitudinal axis in a rear direction, wherein the polarity change element has an element front end portion and an element rear end portion spaced apart from the element front end portion in the rear direction.

13. The fiber optic connector as set forth in claim **12**, wherein the element front end portion defines at least a portion of the key.

14. The fiber optic connector as set forth in claim **13**, wherein the polarity change element comprises a retainer configured to engage the connector housing to releasably retain the polarity change element on each of the first exterior wall and the second exterior wall, the retainer being spaced apart from the element front end portion in the rear direction.

15. The fiber optic connector as set forth in claim **14**, wherein the connector housing comprises a protrusion on each of the first exterior wall and the second exterior wall, the retainer being configured to engage the protrusion on each of the first exterior wall and the second exterior wall.

16. The fiber optic connector as set forth in claim **14**, wherein the retainer is spaced apart from at least a portion of the tongue in the rear direction.

17. The fiber optic connector as set forth in claim **12**, wherein the polarity change element comprises a retainer configured to engage the connector housing to releasably retain the polarity change element on each of the first exterior wall and the second exterior wall, the retainer being spaced apart from the element front end portion in the rear direction.

18. The fiber optic connector as set forth in claim **17**, wherein the retainer is spaced apart from at least a portion of the tongue in the rear direction.

19. The fiber optic connector as set forth in claim **9**, wherein the connector housing comprises a housing front end portion configured to be plugged into the receptacle and a housing rear end portion spaced apart from the housing front end portion along the longitudinal axis in a rear direction, wherein the polarity change element has an element front end portion and an element rear end portion spaced apart from the element front end portion in the rear direction.

20. The fiber optic connector as set forth in claim **19**, wherein the element front end portion defines at least a portion of the key.

21. The fiber optic connector as set forth in claim **19**, wherein the polarity change element comprises a retainer configured to engage the connector housing to releasably retain the polarity change element on each of the first exterior wall and the second exterior wall, the retainer being spaced apart from the element front end portion in the rear direction.

22. The fiber optic connector as set forth in claim **21**, wherein the connector housing comprises a protrusion on each of the first exterior wall and the second exterior wall, the retainer being configured to engage the protrusion on each of the first exterior wall and the second exterior wall.

23. The fiber optic connector as set forth in claim **21**, wherein the retainer is spaced apart from at least a portion of the tongue in the rear direction.

24. The fiber optic connector as set forth in claim **21**, wherein the polarity change element consists of a single piece of material which forms the key portion, the tongue, and the retainer.

25. The fiber optic connector as set forth in claim **9**, wherein the polarity change element comprises opposing lateral tabs defining a first width and the connector housing includes a first pair of projections adjacent the first elongate groove and a second pair of projections adjacent the second elongate groove, the first pair of projections separated by a first opening having a second width and the second pair of

projections separated by a second opening having the second width, the first width being greater than the second width.

26. The fiber optic connector as set forth claim **25**, wherein the fiber optic connector is configured so that:

as the tongue is slidably received in the first elongate groove to position the polarity change element on the first exterior wall to configure the fiber optic connector is in the first polarity configuration, the opposing lateral tabs pass through the first opening in a first longitudinal direction, and

when the fiber optic connector is in the first polarity configuration, the opposing lateral tabs are configured to engage the first pair of projections when the polarity change element is urged in a second longitudinal direction opposite the first longitudinal direction in relation to the connector housing to resist withdrawal of the tongue from the first elongate groove, whereby the opposing lateral tabs and the second pair of projections releasably retain the polarity change element on the first exterior wall; and

wherein the fiber optic connector is further configured so that:

as the tongue is slidably received in the second elongate groove to position the polarity change element on the second exterior wall to configure the fiber optic connector is in second first polarity configuration, the opposing lateral tabs pass through the second opening in the first longitudinal direction, and

when the fiber optic connector is in the second polarity configuration, the opposing lateral tabs are configured to engage the second pair of projections when the polarity change element is urged in the second longitudinal direction in relation to the connector housing to resist withdrawal of the tongue from the first elongate groove, whereby the opposing lateral tabs and the second pair of projections releasably retain the polarity change element on the second exterior wall.

* * * * *

EXHIBIT J

US011435535B2

(12) **United States Patent**
Chang et al.

(10) **Patent No.: US 11,435,535 B2**
(45) **Date of Patent: Sep. 6, 2022**

(54) **BEHIND THE WALL OPTICAL CONNECTOR WITH REDUCED COMPONENTS**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **17/464,117**

(22) Filed: **Sep. 1, 2021**

(65) **Prior Publication Data**

US 2021/0396941 A1 Dec. 23, 2021

Related U.S. Application Data

(63) Continuation of application No. 17/221,561, filed on Apr. 2, 2021, which is a continuation of application No. 16/448,030, filed on Jun. 21, 2019, now Pat. No. 10,989,884, which is a continuation of application No. 15/926,263, filed on Mar. 20, 2018, now Pat. No. 10,359,583, which is a continuation of application No. 15/847,875, filed on Dec. 19, 2017, now Pat. No. 10,209,461.

(60) Provisional application No. 62/482,790, filed on Apr. 7, 2017.

(51) **Int. Cl.**
G02B 6/38 (2006.01)

(52) **U.S. Cl.**
CPC ***G02B 6/3898*** (2013.01); ***G02B 6/3825*** (2013.01); ***G02B 6/3874*** (2013.01); ***G02B 6/3887*** (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,312,564	A	1/1982	Cefarelli et al.
4,327,964	A	5/1982	Haesly et al.
4,478,473	A	10/1984	Frear
4,762,388	A	8/1988	Tanaka et al.

(Continued)

FOREIGN PATENT DOCUMENTS

CA	2495693	A1	4/2004
CN	2836038	Y	11/2006

(Continued)

OTHER PUBLICATIONS

"Fiber Optic Products Catalog" Nov. 2007, Tyco Electronics Corporation, Harrisburg, Pennsylvania, www.ampnetconnect.com.

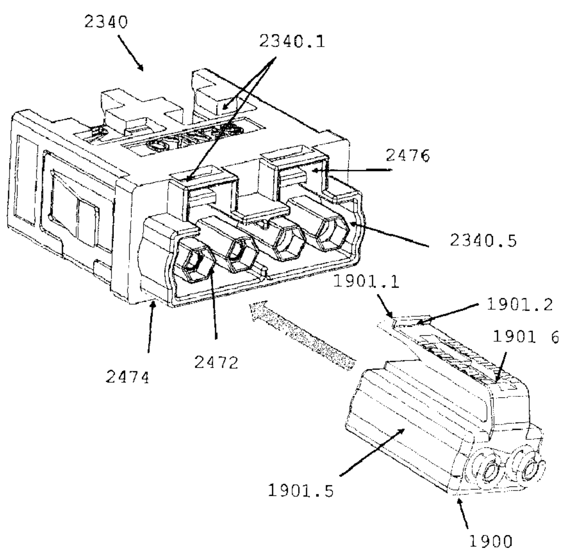
(Continued)

Primary Examiner — Omar R Rojas

(57) **ABSTRACT**

A behind-the-wall optical connector an outer housing configured to be inserted into an adapter with a corresponding inner surface, a ferrule included in an annular collar to mate with a corresponding projection at an adapter opening, and a latch attached to one side of housing configured to lock the connecter into an adapter opening. The latch is further configured with a locking channel and guide to accept a pull tab with a catch at one end, the pull tab releases the connector from the adapter opening when the tab is pulled rearward or away from the adapter.

19 Claims, 35 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

4,764,129 A 8/1988 Jones et al.
4,840,451 A 6/1989 Sampson et al.
4,872,736 A 10/1989 Myers et al.
4,979,792 A 12/1990 Weber et al.
5,041,025 A 8/1991 Haitmanek
D323,143 S 1/1992 Ohkura et al.
5,212,752 A 5/1993 Stephenson et al.
5,265,181 A 11/1993 Chang
5,289,554 A 2/1994 Cubukciyan et al.
5,317,663 A 5/1994 Beard et al.
5,335,301 A 8/1994 Newman et al.
5,348,487 A 9/1994 Marazzi et al.
5,414,790 A 5/1995 Lee et al.
5,444,806 A 8/1995 De Marchi et al.
5,481,634 A 1/1996 Anderson et al.
5,506,922 A 4/1996 Grois et al.
5,521,997 A 5/1996 Rovenolt et al.
5,570,445 A 10/1996 Chou et al.
5,588,079 A 12/1996 Tanabe et al.
5,684,903 A 11/1997 Kyomasu et al.
5,687,268 A 11/1997 Stephenson et al.
5,719,977 A * 2/1998 Lampert G02B 6/3831 385/60
5,781,681 A 7/1998 Manning
5,937,130 A 8/1999 Amberg et al.
5,956,444 A 9/1999 Duda et al.
5,971,626 A 10/1999 Knodell et al.
6,041,155 A 3/2000 Anderson et al.
6,049,040 A 4/2000 Biles et al.
6,134,370 A 10/2000 Childers et al.
6,178,283 B1 1/2001 Weigel
RE37,080 E 3/2001 Stephenson et al.
6,206,577 B1 3/2001 Hall et al.
6,206,581 B1 3/2001 Driscoll et al.
6,227,717 B1 5/2001 Ott et al.
6,238,104 B1 5/2001 Yamakawa et al.
6,247,849 B1 6/2001 Liu
6,371,657 B1 4/2002 Chen et al.
6,454,463 B1 9/2002 Halbach et al.
6,461,054 B1 10/2002 Iwase
6,471,412 B1 10/2002 Belenkiy et al.
6,478,472 B1 11/2002 Anderson et al.
6,551,117 B2 4/2003 Poplawski et al.
6,579,014 B2 6/2003 Melton et al.
6,634,801 B1 10/2003 Waldron et al.
6,648,520 B2 11/2003 Mcdonald et al.
6,682,228 B2 1/2004 Rathnam et al.
6,685,362 B2 2/2004 Burkholder et al.
6,695,486 B1 2/2004 Falkenberg
6,705,765 B2 3/2004 Lampert et al.
6,854,894 B1 2/2005 Yunker et al.
6,872,039 B2 3/2005 Baus et al.
6,935,789 B2 8/2005 Gross, III et al.
7,090,406 B2 8/2006 Melton et al.
7,090,407 B2 8/2006 Melton et al.
7,091,421 B2 8/2006 Kukita et al.
7,111,990 B2 9/2006 Melton et al.
7,113,679 B2 9/2006 Melton et al.
D533,504 S 12/2006 Lee
D534,124 S 12/2006 Taguchi
7,150,567 B1 12/2006 Luther et al.
7,153,041 B2 12/2006 Mine et al.
7,198,409 B2 4/2007 Smith et al.
7,207,724 B2 4/2007 Gurreri
D543,146 S 5/2007 Chen et al.
7,258,493 B2 8/2007 Milette
7,281,859 B2 10/2007 Mudd et al.
D558,675 S 1/2008 Chien et al.
7,315,682 B1 1/2008 En Lin et al.
7,325,976 B2 2/2008 Gurreri et al.
7,325,980 B2 2/2008 Pepe
7,329,137 B2 2/2008 Martin et al.
7,331,718 B2 2/2008 Yazaki et al.
7,354,291 B2 4/2008 Caveney et al.
7,371,082 B2 5/2008 Zimmel et al.
7,387,447 B2 6/2008 Mudd et al.
7,390,203 B2 6/2008 Murano et al.
D572,661 S 7/2008 En Lin et al.
7,431,604 B2 10/2008 Waters et al.
7,463,803 B2 12/2008 Cody et al.
7,465,180 B2 12/2008 Kusuda et al.
7,510,335 B1 3/2009 Su et al.
7,513,695 B1 4/2009 Lin et al.
7,561,775 B2 7/2009 Lin et al.
7,591,595 B2 9/2009 Lu et al.
7,594,766 B1 9/2009 Sasser et al.
7,641,398 B2 1/2010 O'Riorden et al.
7,695,199 B2 4/2010 Teo et al.
7,699,533 B2 4/2010 Milette
7,824,113 B2 11/2010 Wong et al.
7,837,395 B2 11/2010 Lin et al.
7,903,922 B2 3/2011 Momotsu et al.
D641,708 S 7/2011 Yamauchi
8,186,890 B2 5/2012 Lu
8,192,091 B2 6/2012 Hsu et al.
8,202,009 B2 6/2012 Lin et al.
8,251,733 B2 8/2012 Wu
8,267,595 B2 9/2012 Lin et al.
8,270,796 B2 9/2012 Nhep
8,317,408 B2 * 11/2012 Nakagawa G02B 6/3877 385/78
8,408,815 B2 4/2013 Lin et al.
8,465,317 B2 6/2013 Gniadek et al.
8,636,424 B2 1/2014 Kuffel et al.
8,651,749 B2 2/2014 Dainese Jnior et al.
8,770,863 B2 7/2014 Cooke et al.
9,188,747 B2 11/2015 Gniadek
9,411,110 B2 8/2016 Barnette, Jr. et al.
9,494,744 B2 11/2016 De Jong
9,548,557 B2 1/2017 Liu
9,551,842 B2 1/2017 Theuerkorn
9,568,686 B2 2/2017 Fewkes et al.
9,581,768 B1 2/2017 Baca et al.
9,684,313 B2 6/2017 Chajec
9,726,830 B1 8/2017 Gniadek
10,401,574 B2 * 9/2019 Gurreri G02B 6/3893
2003/0053787 A1 3/2003 Lee
2003/0095754 A1 5/2003 Matsumoto et al.
2004/0052473 A1 3/2004 Seo et al.
2004/0136657 A1 7/2004 Ngo
2004/0141693 A1 7/2004 Szilagyi et al.
2004/0161958 A1 8/2004 Togami et al.
2004/0165832 A1 8/2004 Bates, III et al.
2004/0234209 A1 11/2004 Cox et al.
2005/0111796 A1 5/2005 Matasek et al.
2005/0141817 A1 6/2005 Yazaki et al.
2006/0089049 A1 4/2006 Sedor
2006/0127025 A1 6/2006 Haberman
2006/0269194 A1 11/2006 Luther et al.
2006/0274411 A1 12/2006 Yamauchi
2007/0028409 A1 2/2007 Yamada
2007/0079854 A1 4/2007 You
2007/0098329 A1 5/2007 Shimoji et al.
2007/0149062 A1 6/2007 Long et al.
2007/0230874 A1 10/2007 Lin
2007/0232115 A1 10/2007 Burke et al.
2007/0243749 A1 10/2007 Wu
2008/0008430 A1 1/2008 Kewitsch
2008/0044137 A1 2/2008 Luther et al.
2008/0069501 A1 3/2008 Mudd et al.
2008/0101757 A1 5/2008 Lin et al.
2008/0226237 A1 9/2008 O'Riorden et al.
2008/0267566 A1 10/2008 En Lin
2009/0022457 A1 1/2009 De Jong et al.
2009/0028507 A1 1/2009 Jones et al.
2009/0092360 A1 4/2009 Lin et al.
2009/0188106 A1 7/2009 Wang et al.
2009/0196555 A1 8/2009 Lin et al.
2009/0214162 A1 8/2009 O'Riorden et al.
2009/0220197 A1 9/2009 Gniadek et al.
2009/0290938 A1 11/2009 Asaoka et al.
2010/0034502 A1 2/2010 Lu et al.
2010/0247041 A1 9/2010 Szilagyi
2010/0322561 A1 12/2010 Lin et al.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2011/0044588 A1 2/2011 Larson et al.
2011/0131801 A1 6/2011 Nelson et al.
2011/0177710 A1 7/2011 Tobey
2012/0099822 A1 4/2012 Kuffel et al.
2012/0189260 A1 7/2012 Kowalczyk et al.
2012/0269485 A1 10/2012 Haley et al.
2012/0301080 A1 11/2012 Gniadek
2013/0071067 A1 3/2013 Lin
2013/0089995 A1 4/2013 Gniadek et al.
2013/0094816 A1 4/2013 Lin et al.
2013/0121653 A1 5/2013 Shitama et al.
2013/0183012 A1 7/2013 Cabanne Lopez et al.
2013/0259429 A1 10/2013 Czosnowski et al.
2013/0322825 A1 12/2013 Cooke et al.
2014/0016901 A1 1/2014 Lambourn et al.
2014/0023322 A1 1/2014 Gniadek
2014/0050446 A1 2/2014 Chang
2014/0133808 A1 5/2014 Hill et al.
2014/0219621 A1 8/2014 Barnette, Jr. et al.
2014/0226946 A1 8/2014 Cooke et al.
2014/0241678 A1 8/2014 Bringuier et al.
2014/0241688 A1 8/2014 Isenhour et al.
2014/0334780 A1 11/2014 Nguyen et al.
2014/0348477 A1 11/2014 Chang
2015/0301294 A1 10/2015 Chang et al.
2015/0331201 A1 11/2015 Takano et al.
2015/0355417 A1 12/2015 Takano et al.
2015/0378113 A1 12/2015 Good et al.
2016/0116685 A1 4/2016 Wong et al.
2016/0131849 A1 5/2016 Takano et al.
2016/0172852 A1 6/2016 Tamura et al.
2016/0195682 A1 7/2016 Takano et al.
2016/0266326 A1 9/2016 Gniadek
2016/0291262 A1 10/2016 Chang et al.
2016/0320572 A1 11/2016 Gniadek
2016/0322750 A1 11/2016 Plamondon et al.
2017/0003458 A1 1/2017 Gniadek

FOREIGN PATENT DOCUMENTS

CN 101091131 A 12/2007
CN 201383588 Y 1/2010
CN 102016669 A 4/2011
CN 202600189 U 12/2012
DE 202006011910 U1 4/2007
DE 102006019335 A1 10/2007
EP 1074868 A1 2/2001
EP 1211537 A2 6/2002
EP 1245980 A2 10/2002
EP 1566674 A1 8/2005
GB 2111240 A 6/1983
JP 2009229545 A 10/2009
JP 2009276493 A 11/2009
TW 200821653 A 5/2008
WO 2001/79904 A2 10/2001
WO 2004027485 A1 4/2004
WO 2008112986 A1 9/2008
WO 2009135787 A1 11/2009
WO 2010024851 A2 3/2010
WO 2012136702 A1 10/2012
WO 2012162385 A1 11/2012
WO 2014182351 A1 11/2014
WO 2015191024 A1 12/2015
WO 2016148741 A1 9/2016

OTHER PUBLICATIONS

International Search Report and Written Opinion dated Apr. 27, 2012 for PCT/US2011/058799.
International Preliminary Report on Patentability dated Aug. 22, 2016 from related International Application No. PCT/US2015/059458, International Filing Date Nov. 6, 2015.
Non-Final Office Action, U.S. Appl. No. 15/882,343, dated Nov. 19, 2018, pp. 12.
"Fiber Optic Connectors and Assemblies Catalog" 2009, Huber & Suhner Fiver Optics, Herisau, Switzerland, www.hubersuhner.com.
International Search Report and Written Opinion dated Jan. 16, 2014 for PCT/US2013/54784.
"Fiber Optic Interconnect Solutions, Tactical Fiber Optical Connectors, Cables and Termini" 2006, Glenair, Inc., Glendale, California, www.mps-electronics.de.
International Search Report (ISR) WO2008112986 dated Sep. 15, 2009.
International Search Report and Written Opinion dated Aug. 27, 2012 for PCT/US2012/039126.
Chinese Examiner's Report for Application No. 201810180319.5 dated Dec. 30, 2020, 8 pages, China (Summary translation attached).
International Search Report and Written Opinion dated May 14, 2014 for PCT/US2014/012137.
International Search Report and Written Opinion dated Oct. 9, 2014 for PCT/US2014/041500.
International Search Report and Written Opinion dated Aug. 21, 2008 for PCT/US2008/057023.
European Search Report and Written Opinion dated Mar. 3, 2015 for EP 14187661.
European Search Report and Written Opinion dated Feb. 19, 2015 for EP 14168005.
ISR WO2014028527ISR dated Feb. 20, 2014.
ISR WO2015US57610ISR dated Jan. 21, 2016.
Non-Final Office Action, U.S. Appl. No. 15/979,596, dated Dec. 11, 2018, pp. 10.
Non-Final Office Action, U.S. Appl. No. 15/926,263, dated Oct. 4, 2018, pp. 34.
Non-Final Office Action, U.S. Appl. No. 15/847,875, dated Jun. 1, 2018, pp. 9.

* cited by examiner

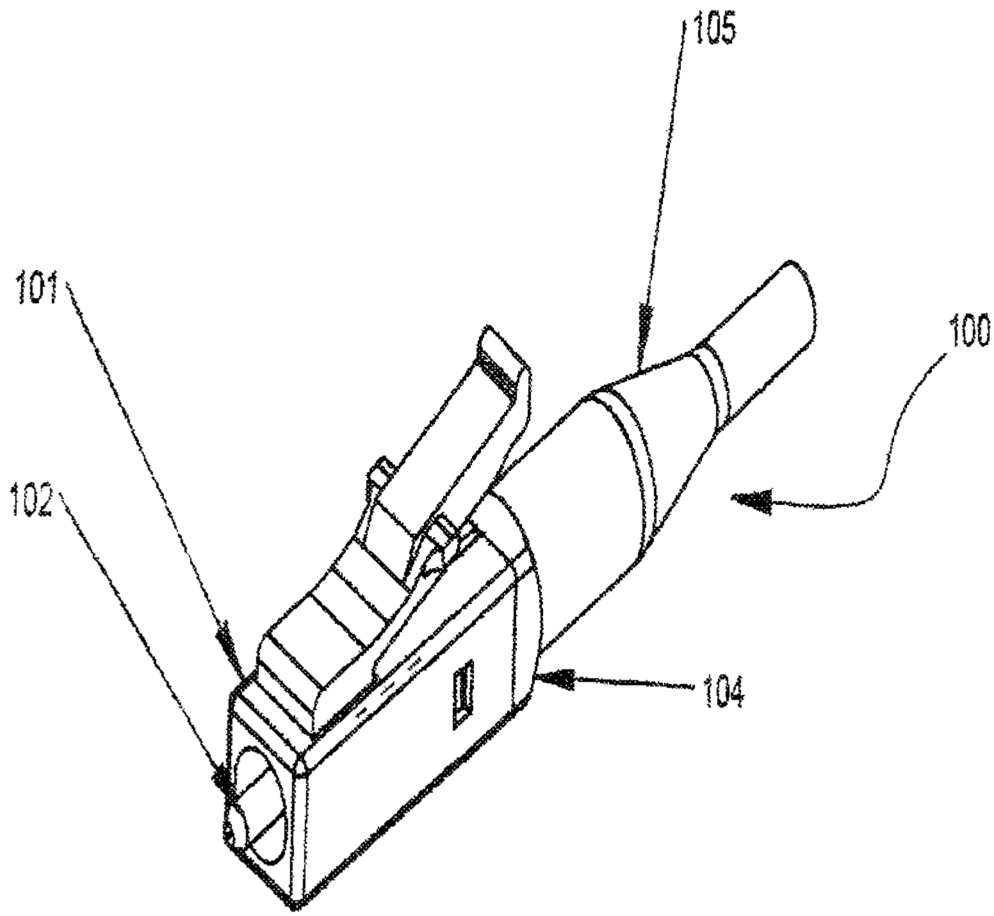


FIG. 1

Prior Art

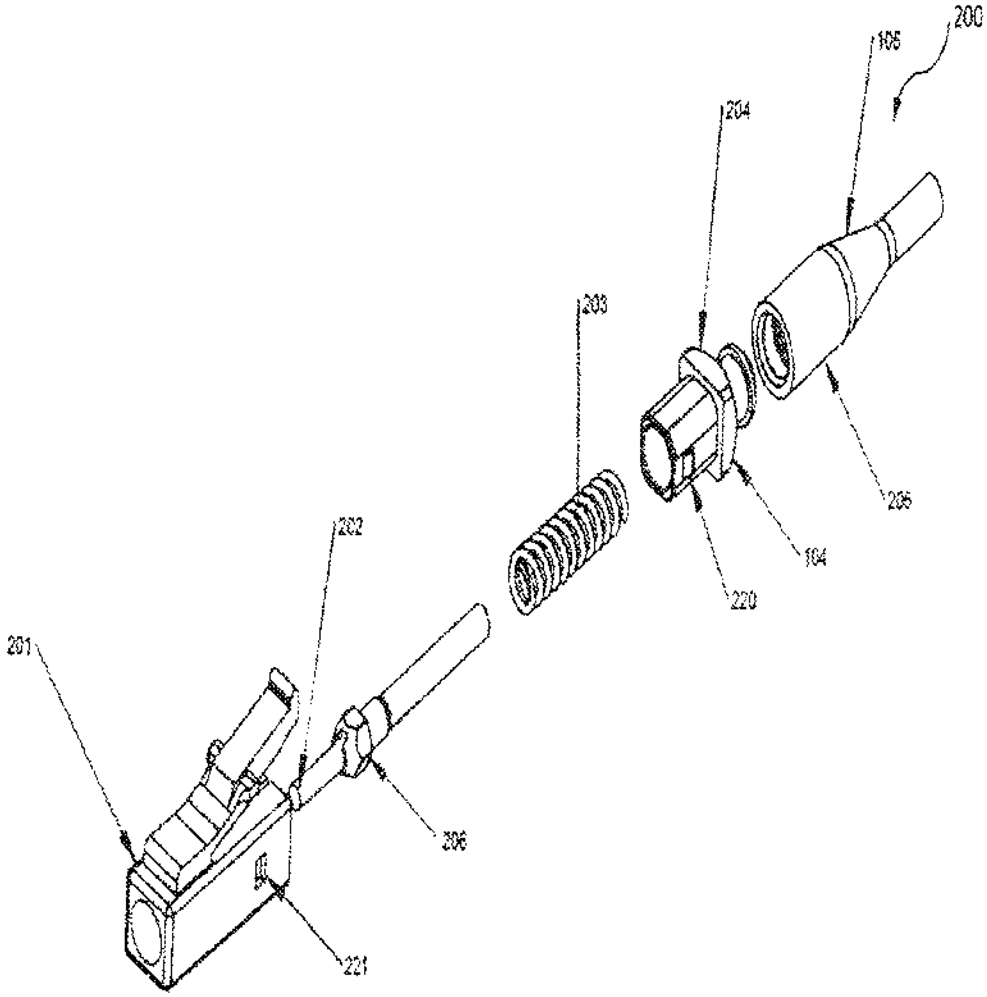


FIG. 2

Prior Art

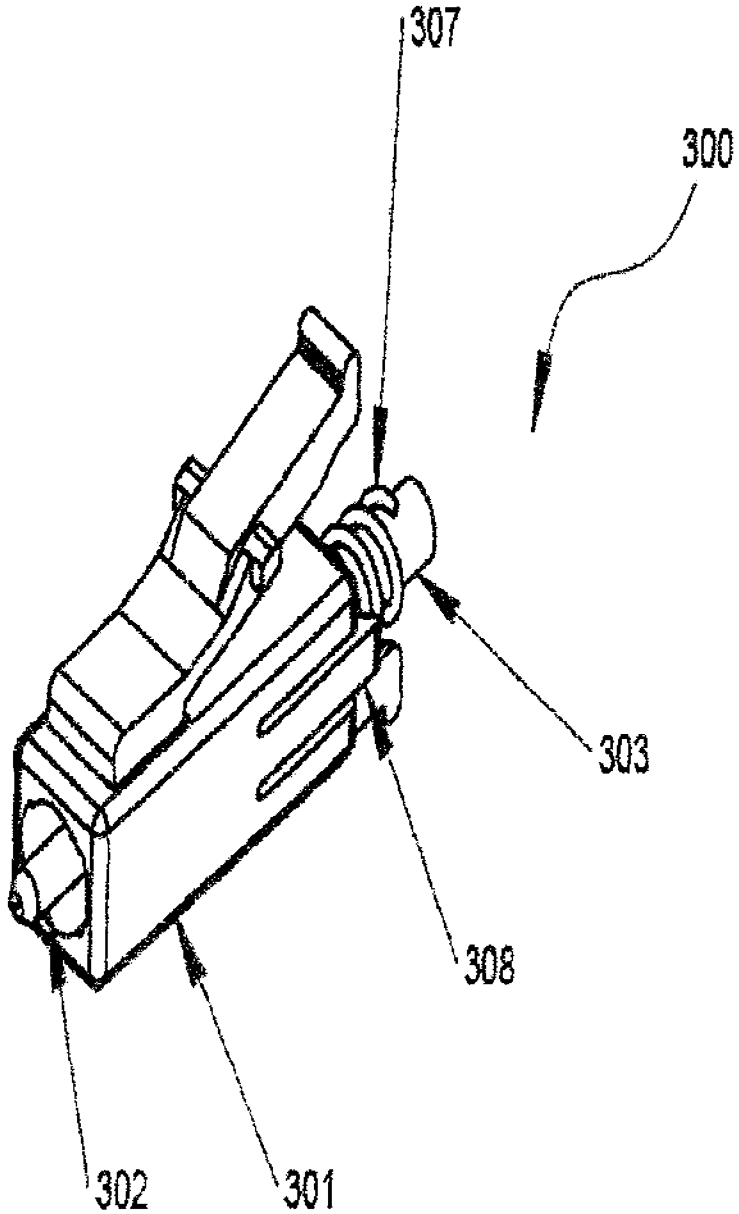


FIG. 3

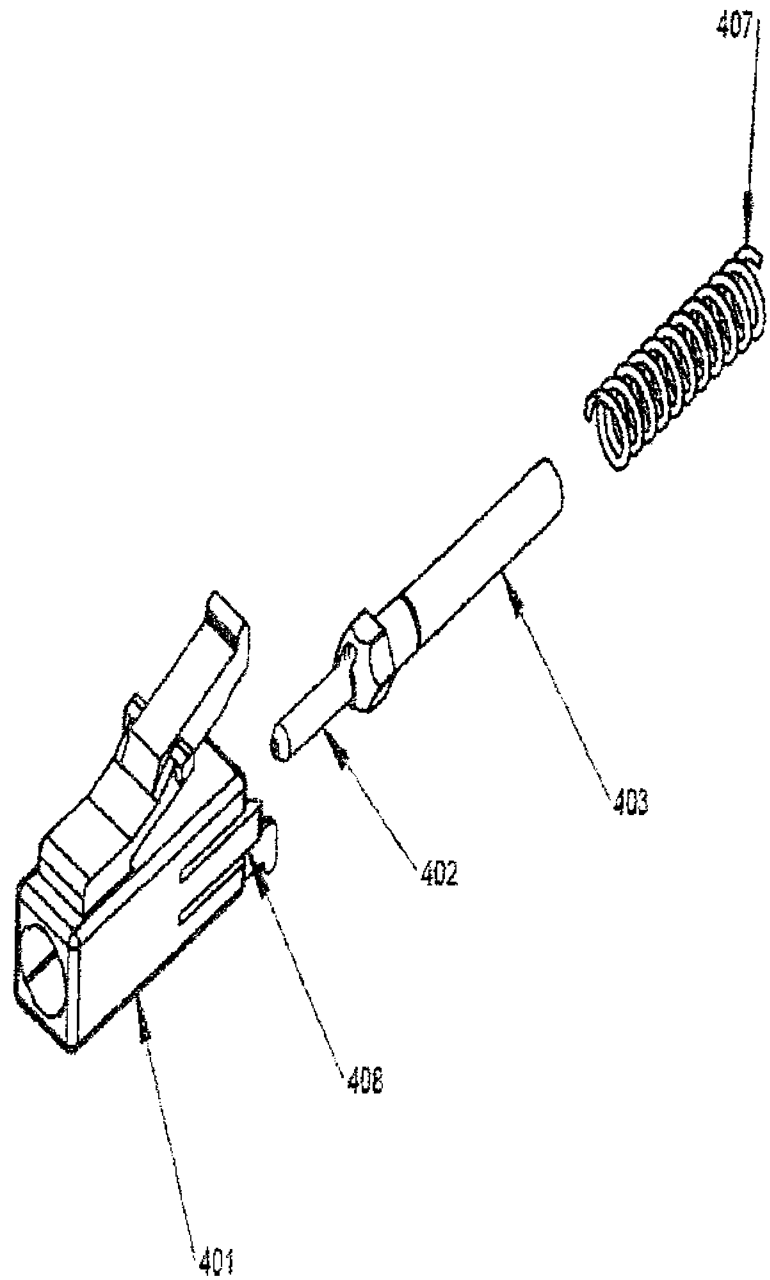


FIG. 4

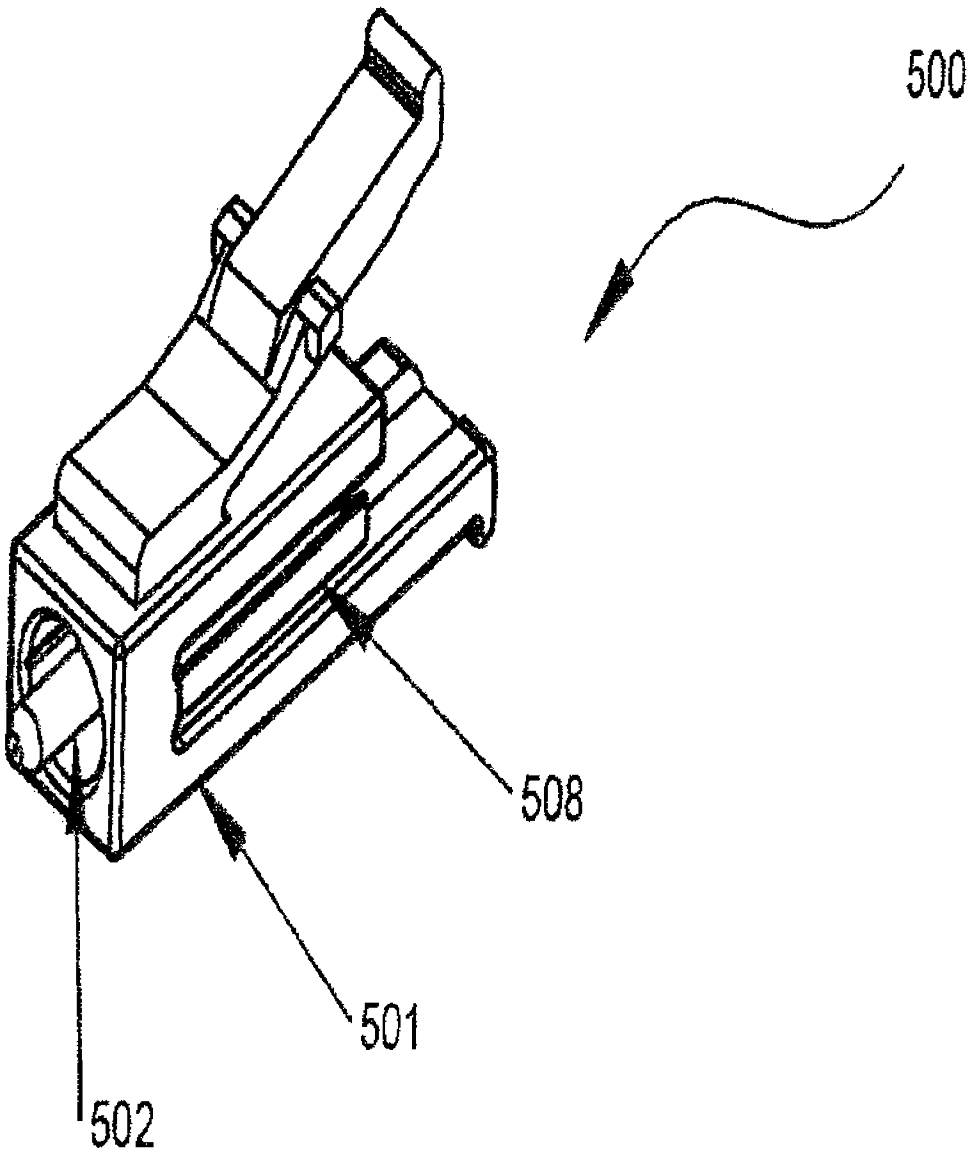


FIG. 5

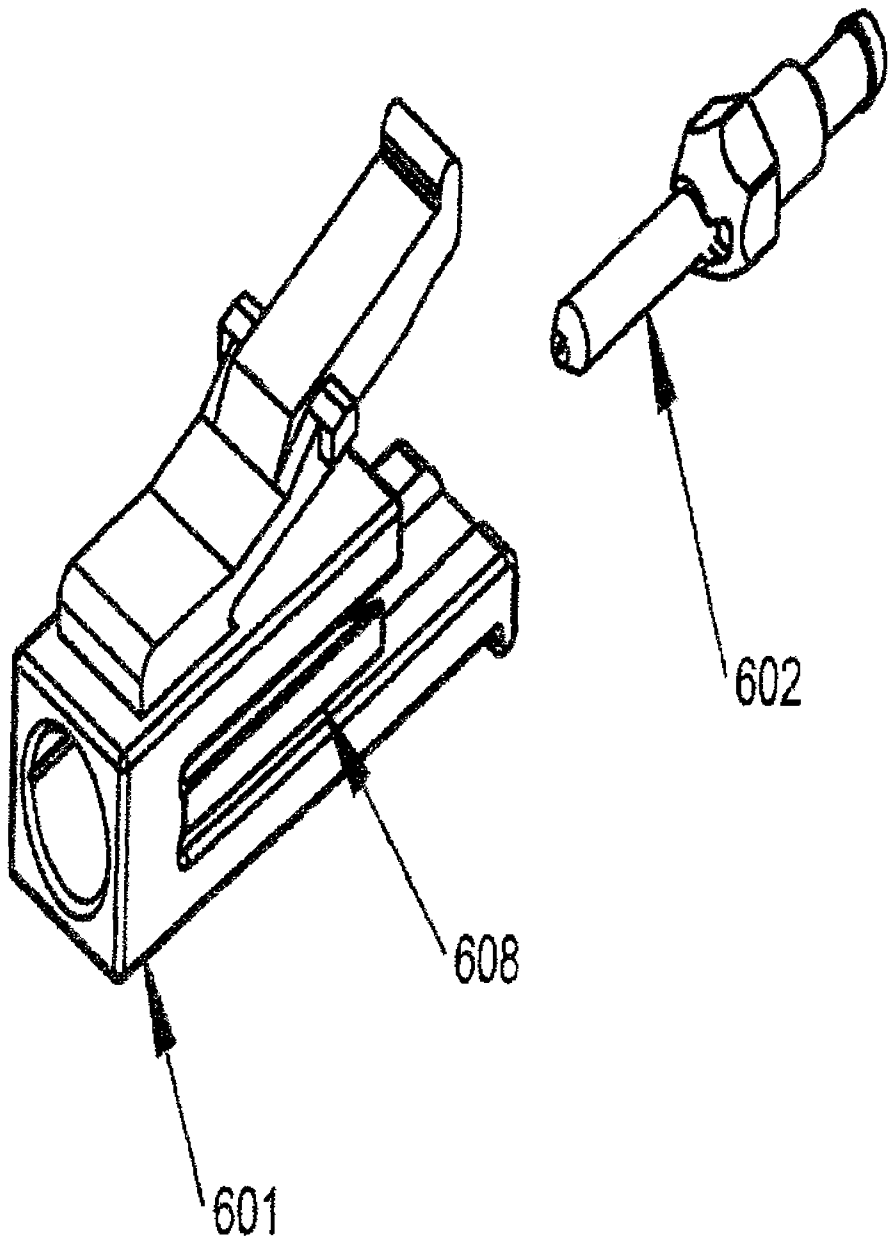


FIG. 6

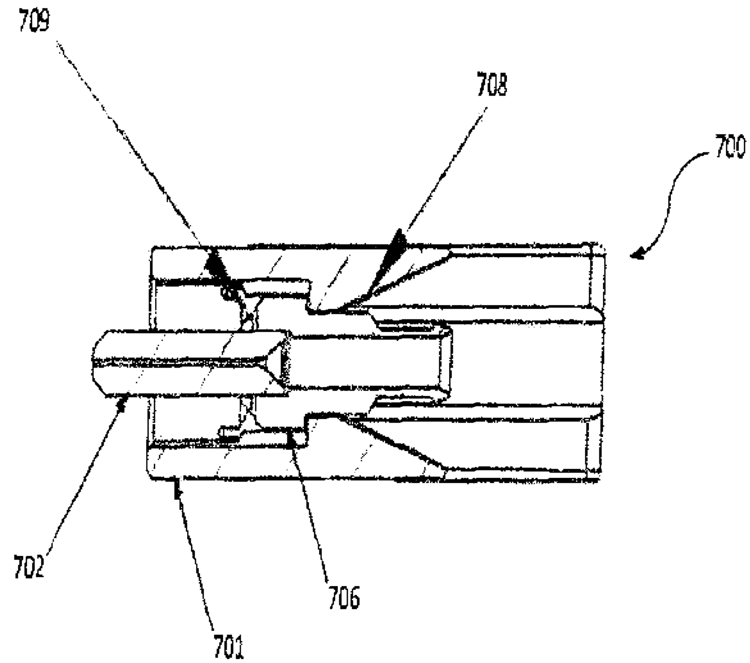


FIG. 7

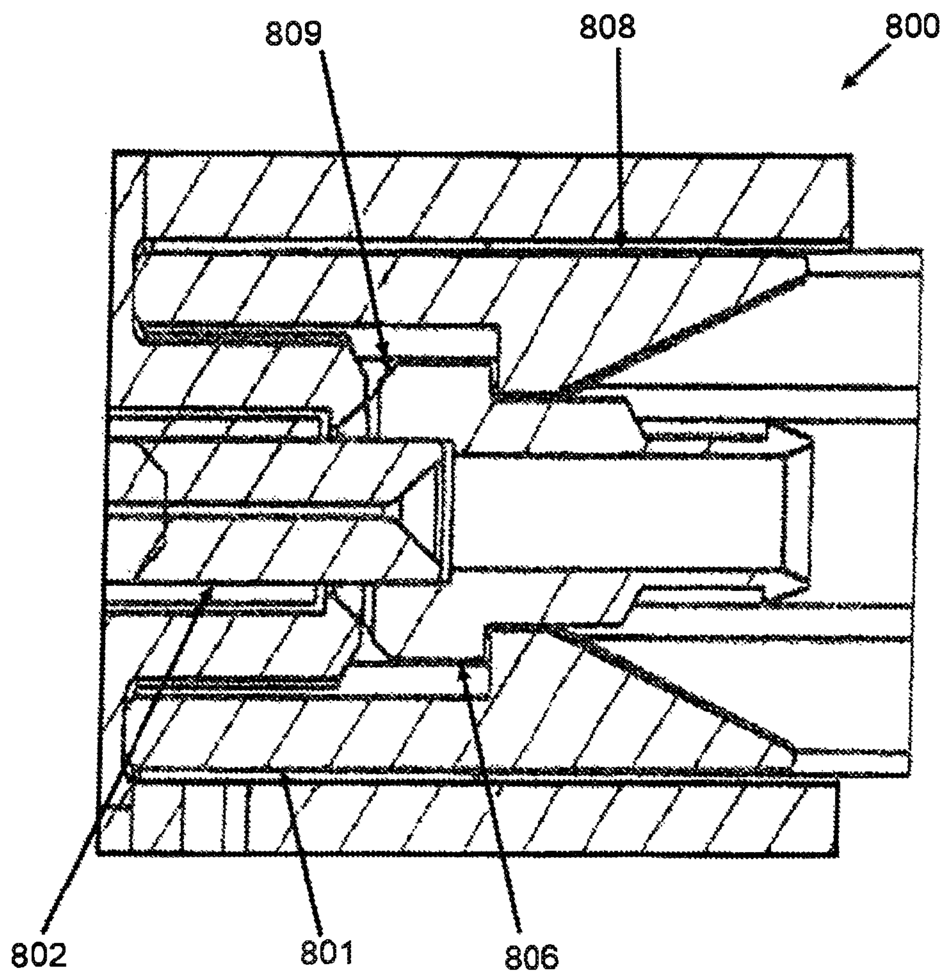


FIG. 8

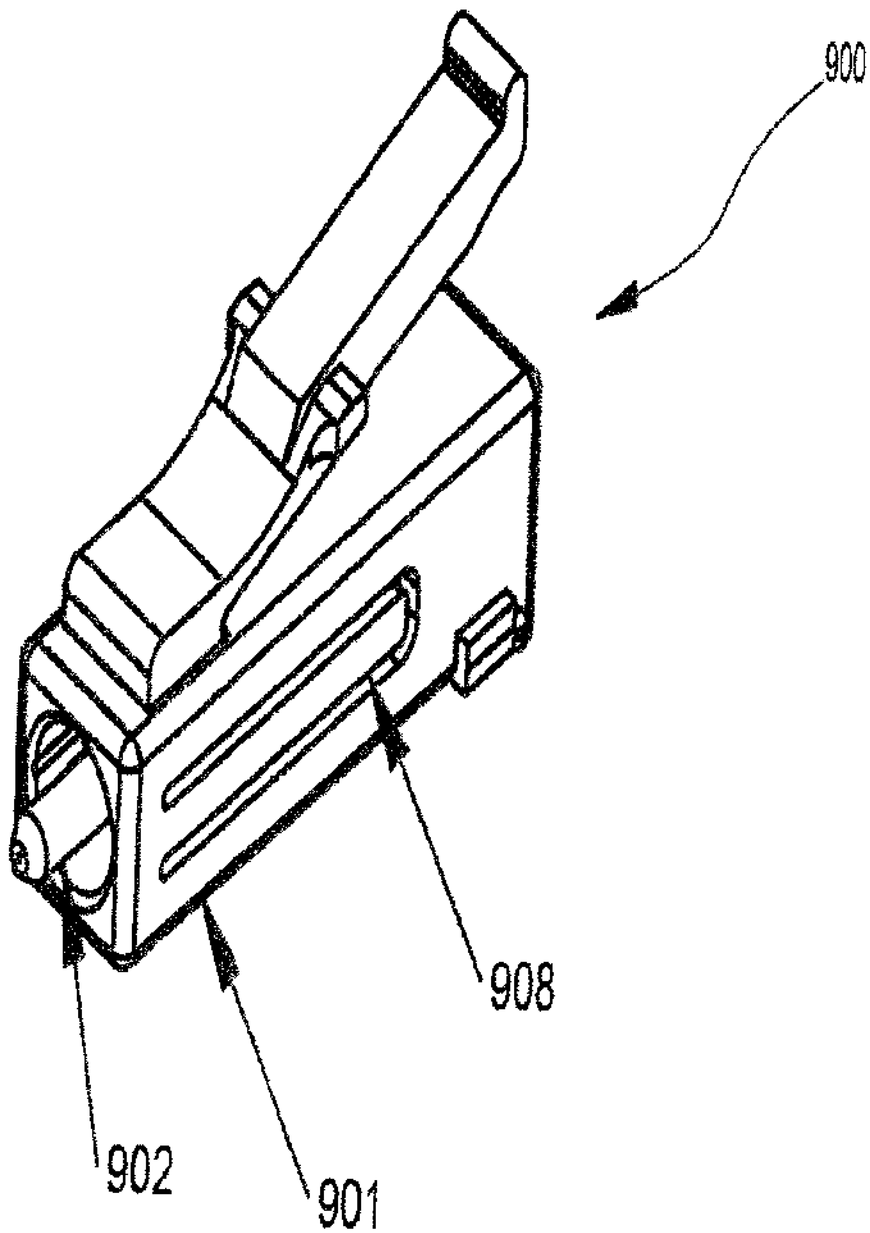


FIG. 9

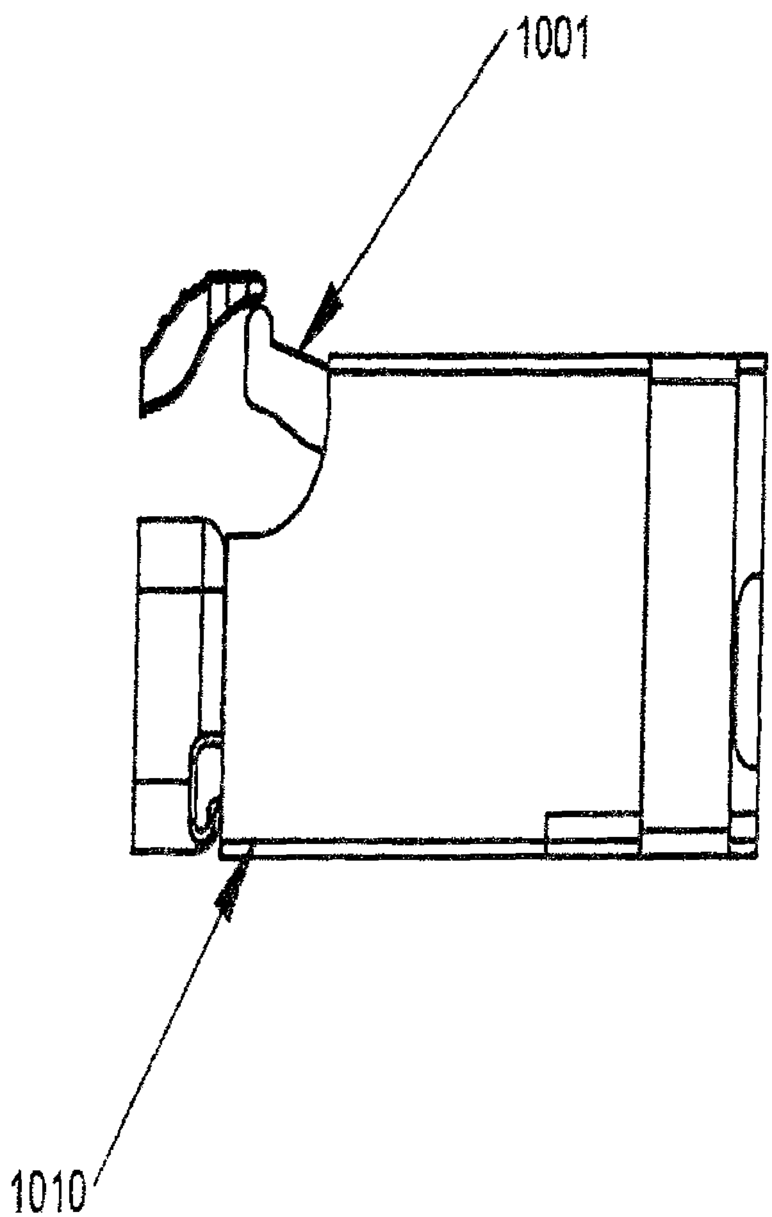


FIG. 10

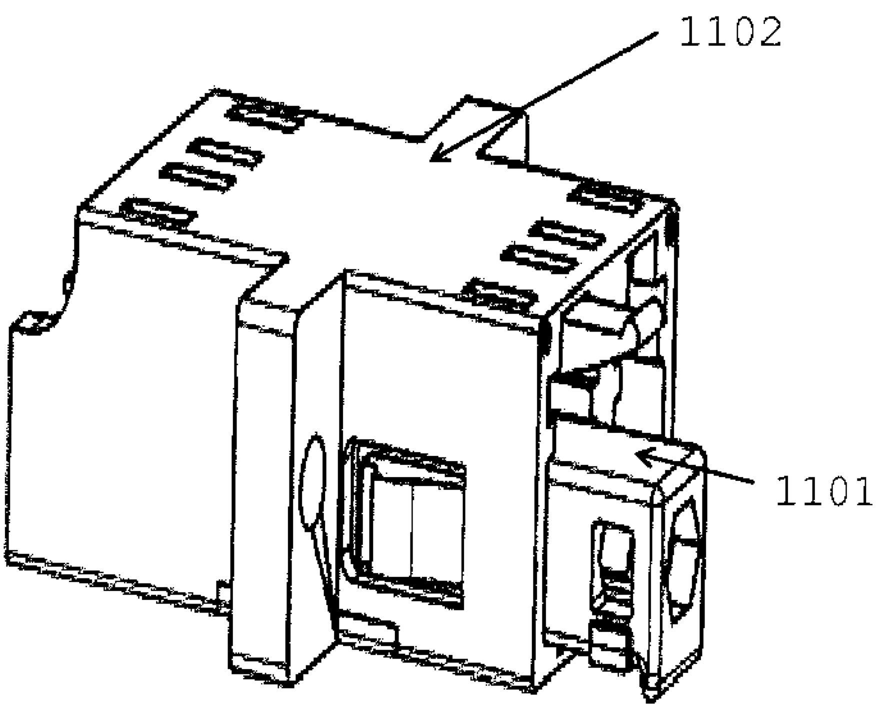


FIG. 11A

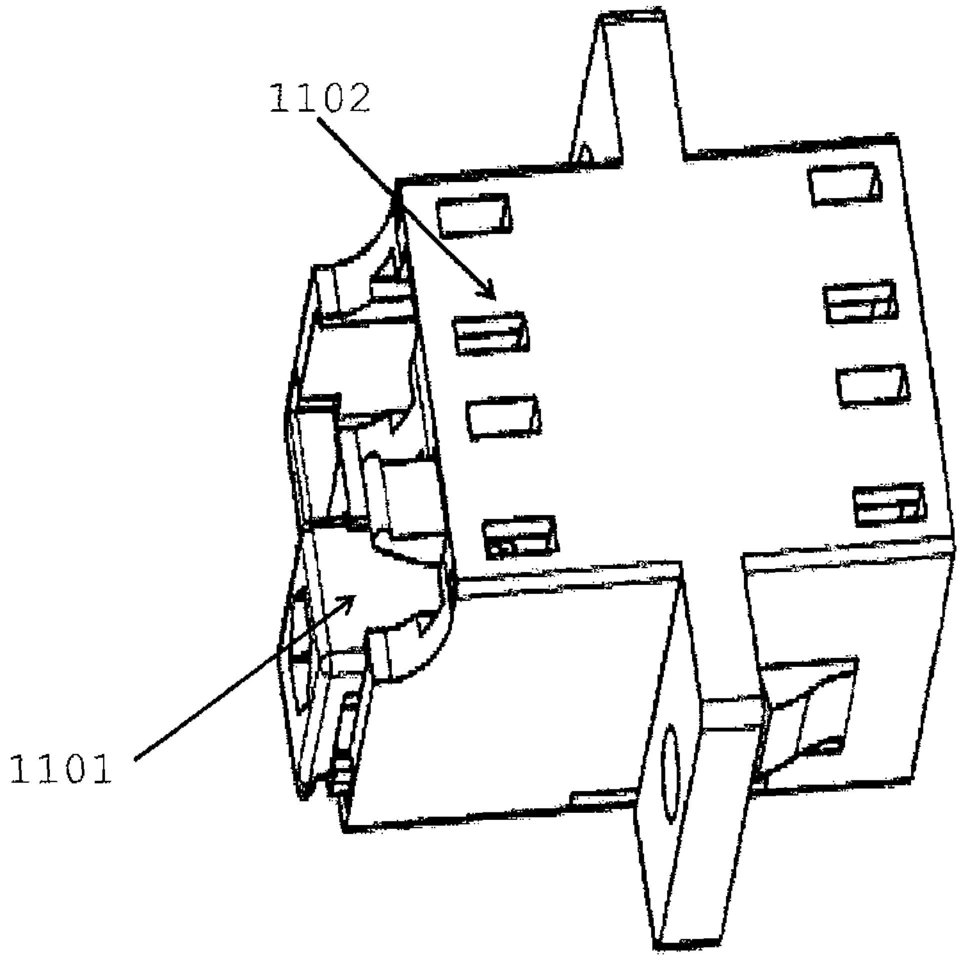


FIG. 11B

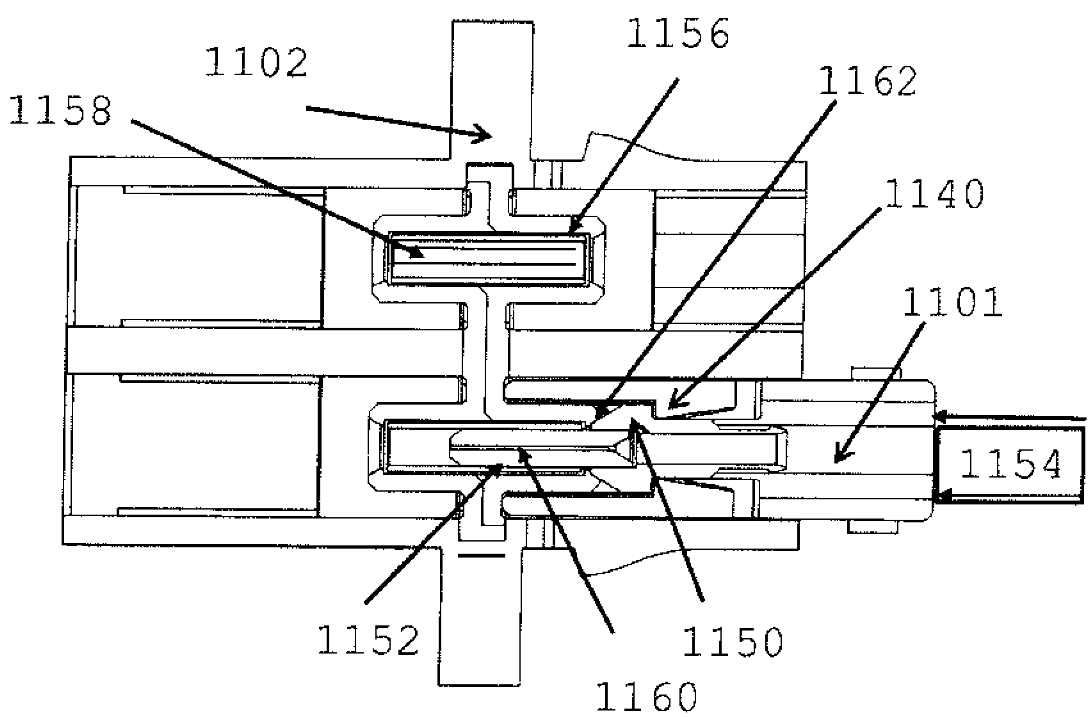


FIG. 11C

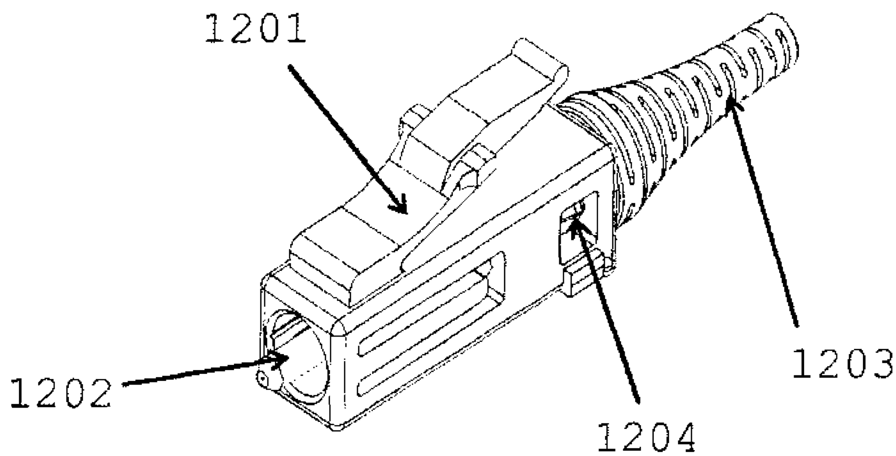


FIG. 12A

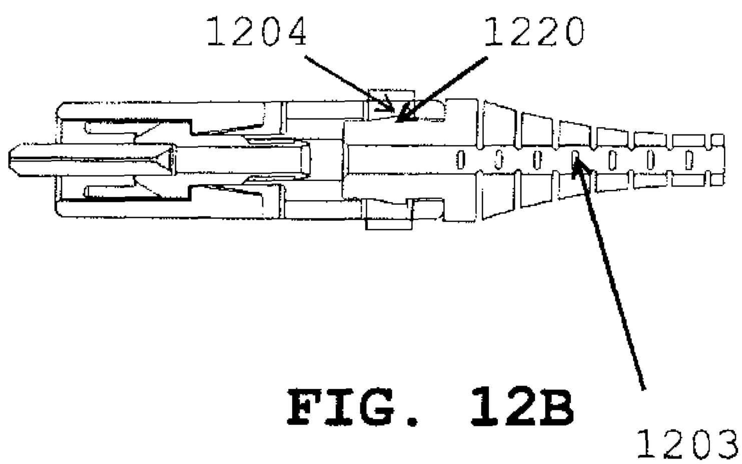


FIG. 12B

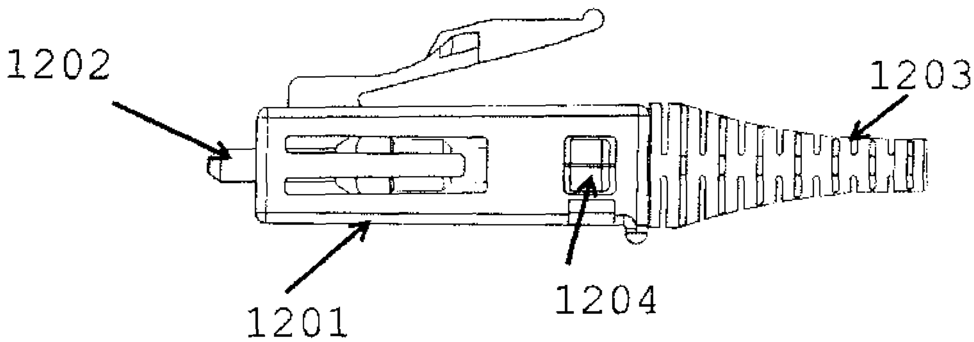


FIG. 12C

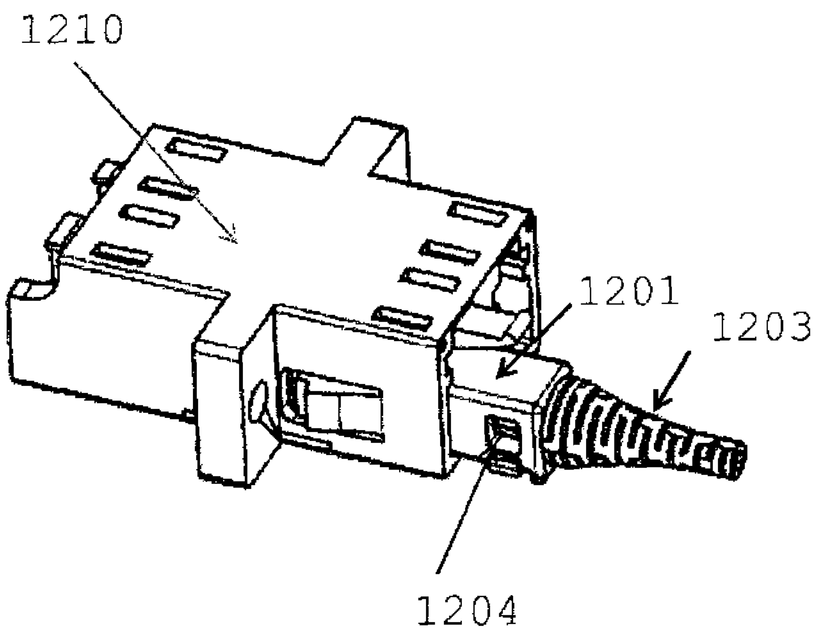


FIG. 12D

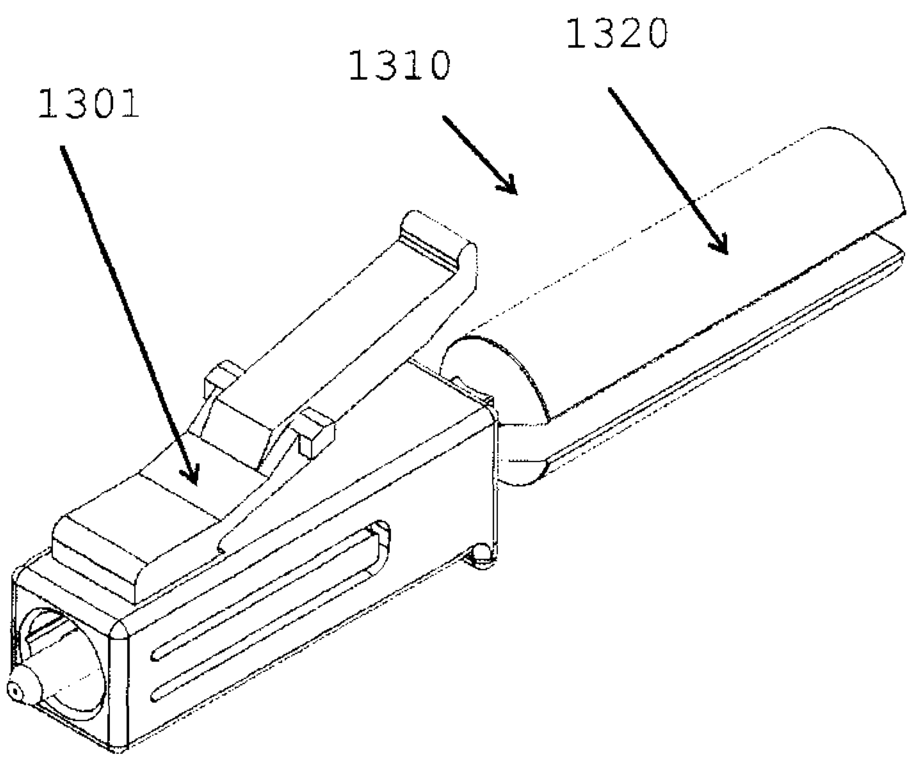


FIG. 13A

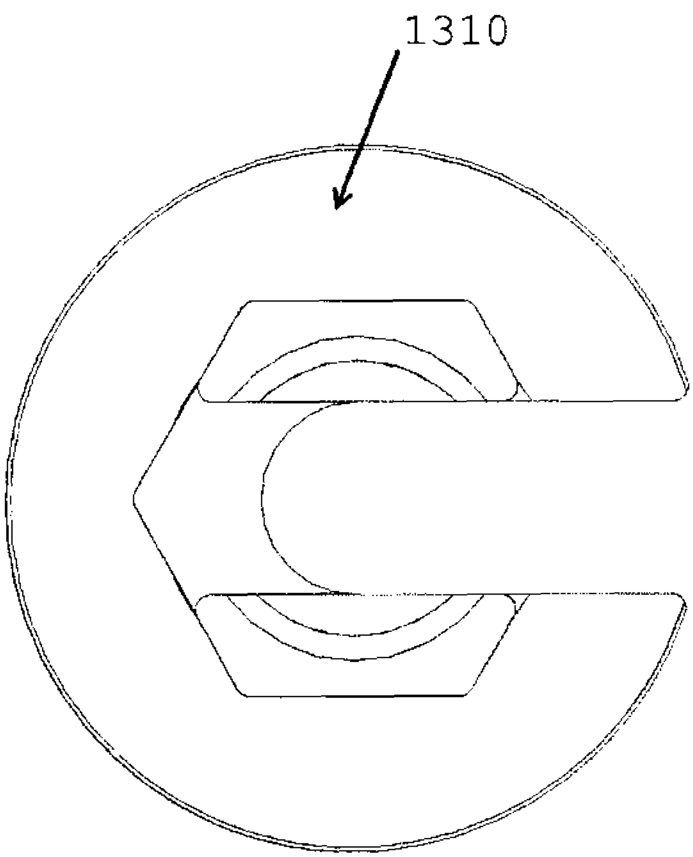


FIG. 13B

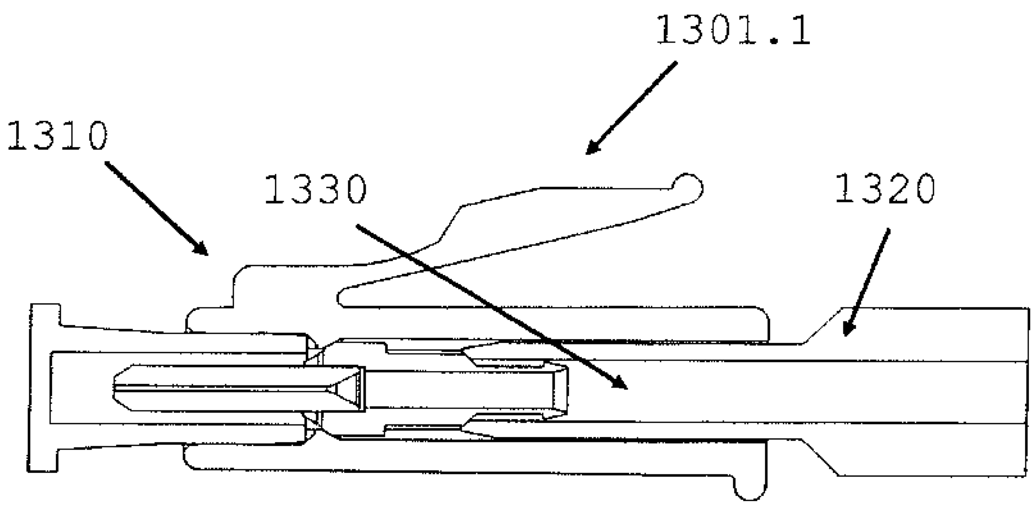


FIG. 13C

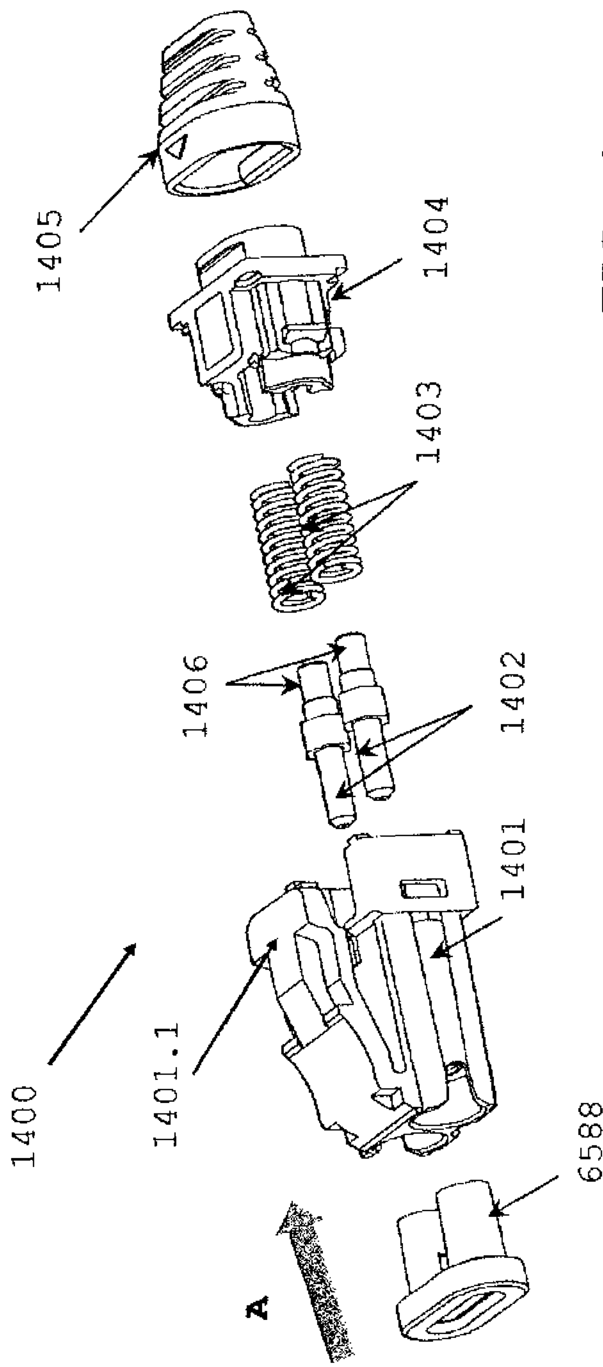


FIG. 14

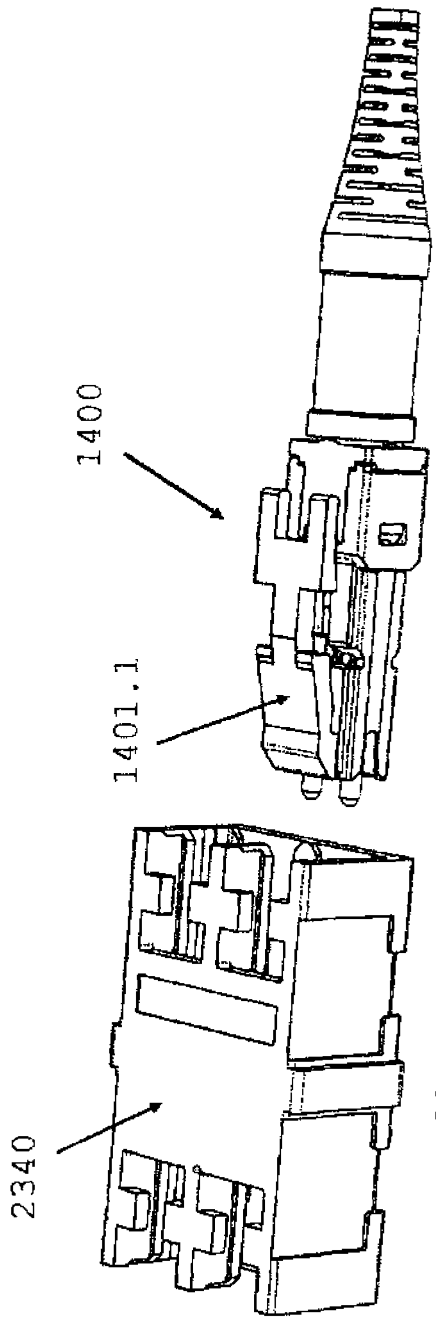


FIG. 15A

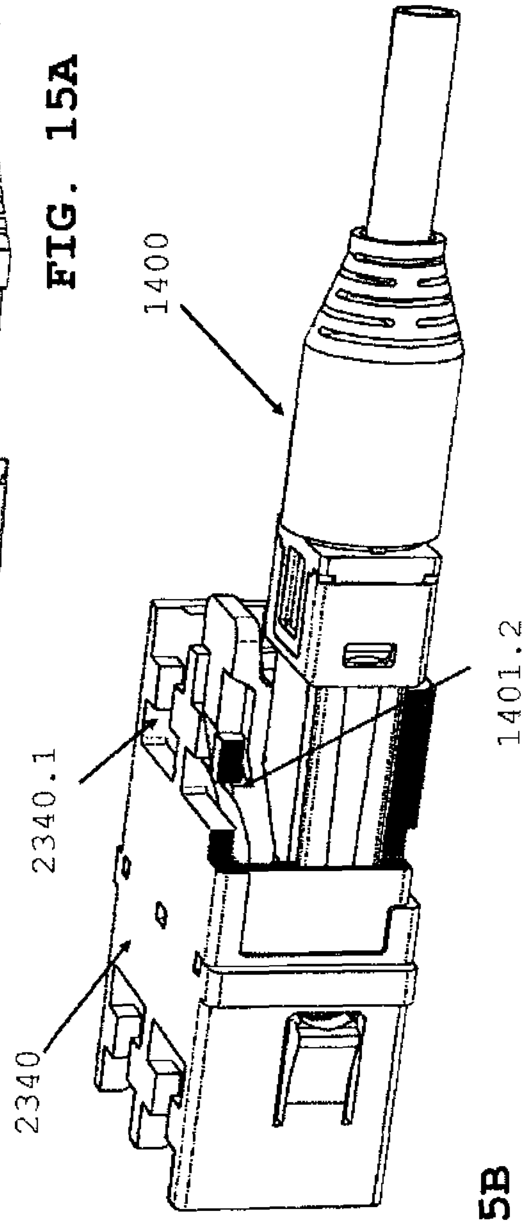


FIG. 15B

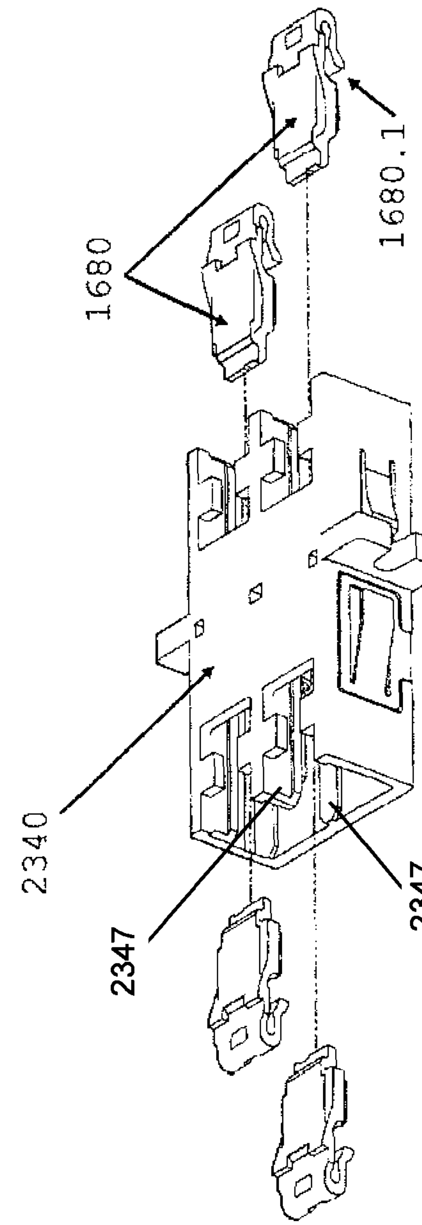


FIG. 16A

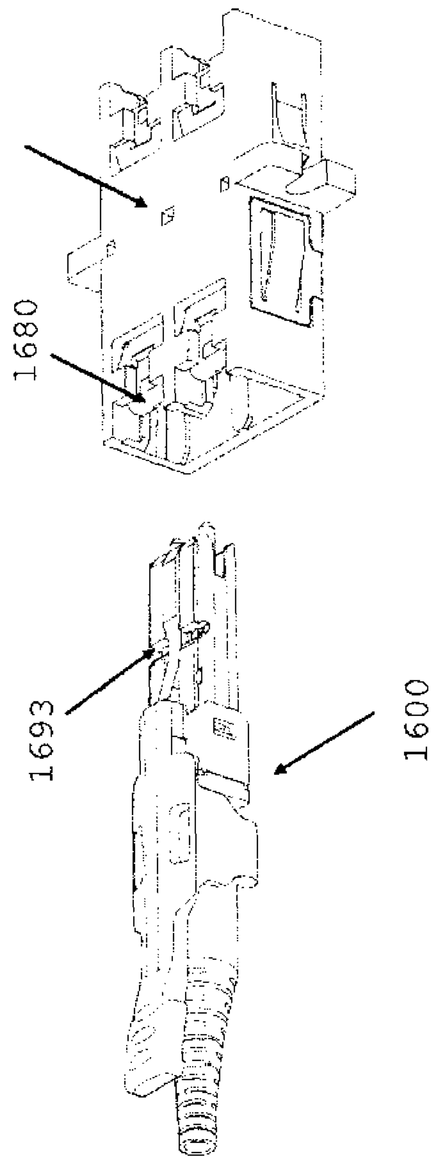


FIG. 16B

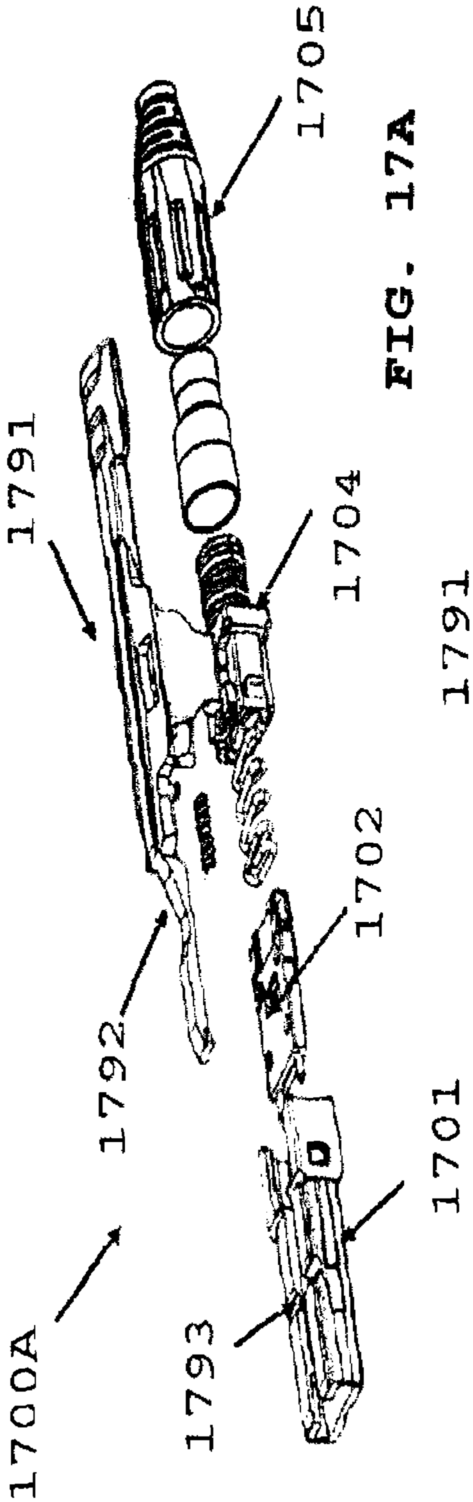


FIG. 17A

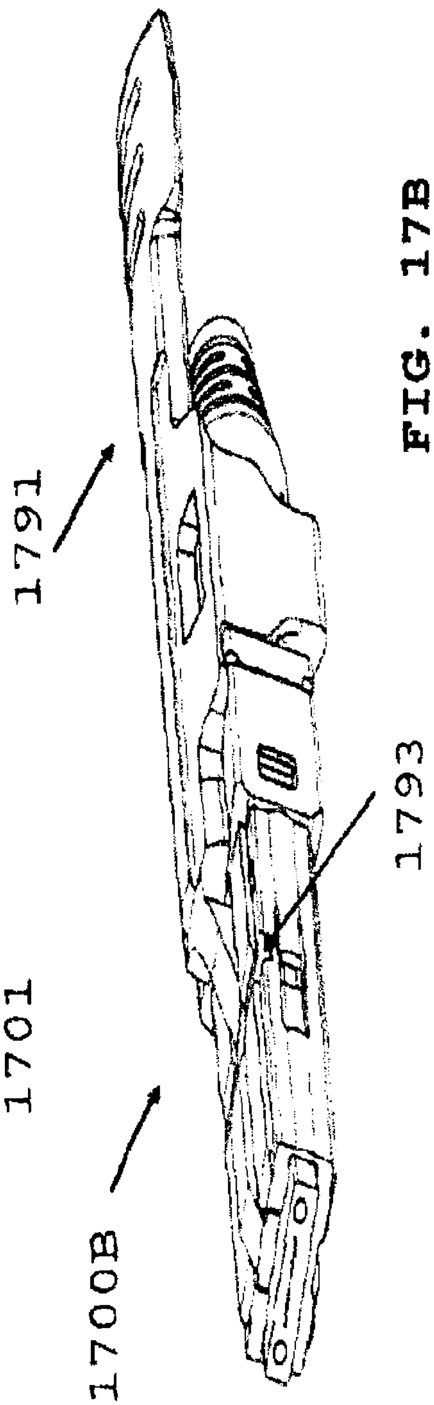


FIG. 17B

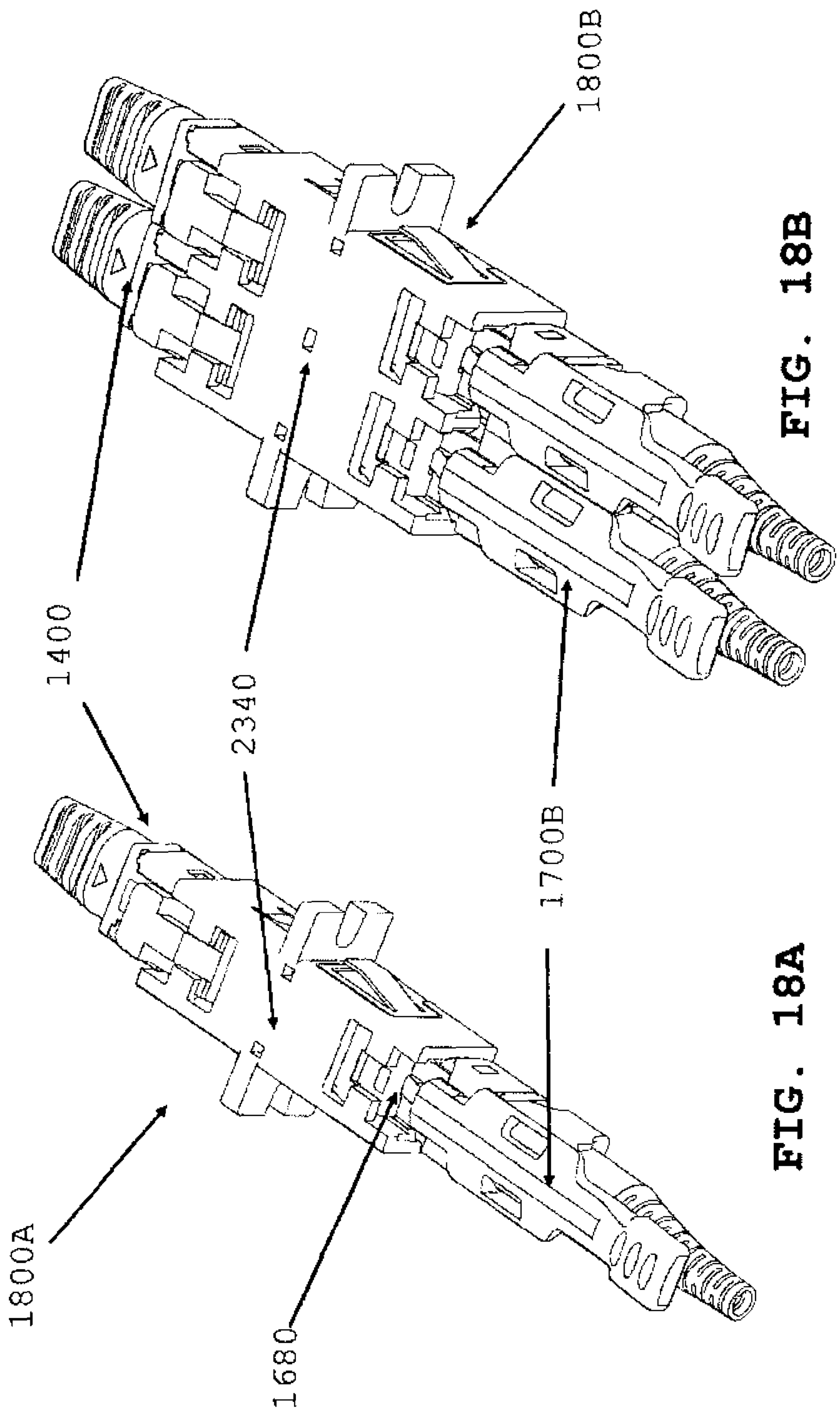


FIG. 18B

FIG. 18A

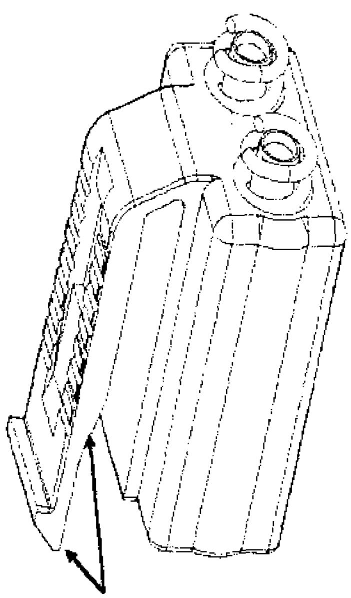


FIG. 19A

FIG. 19B

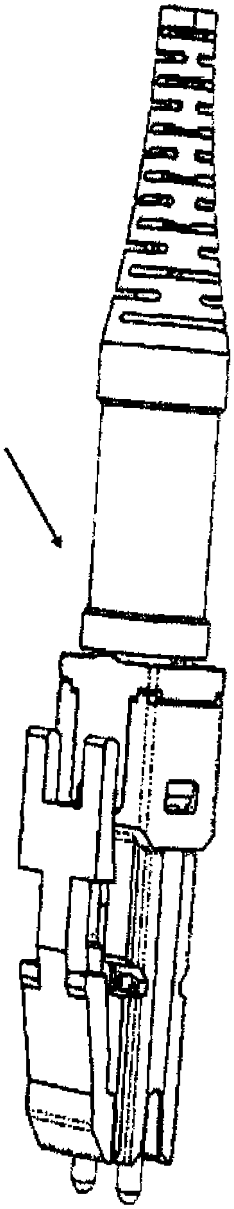


FIG. 19C

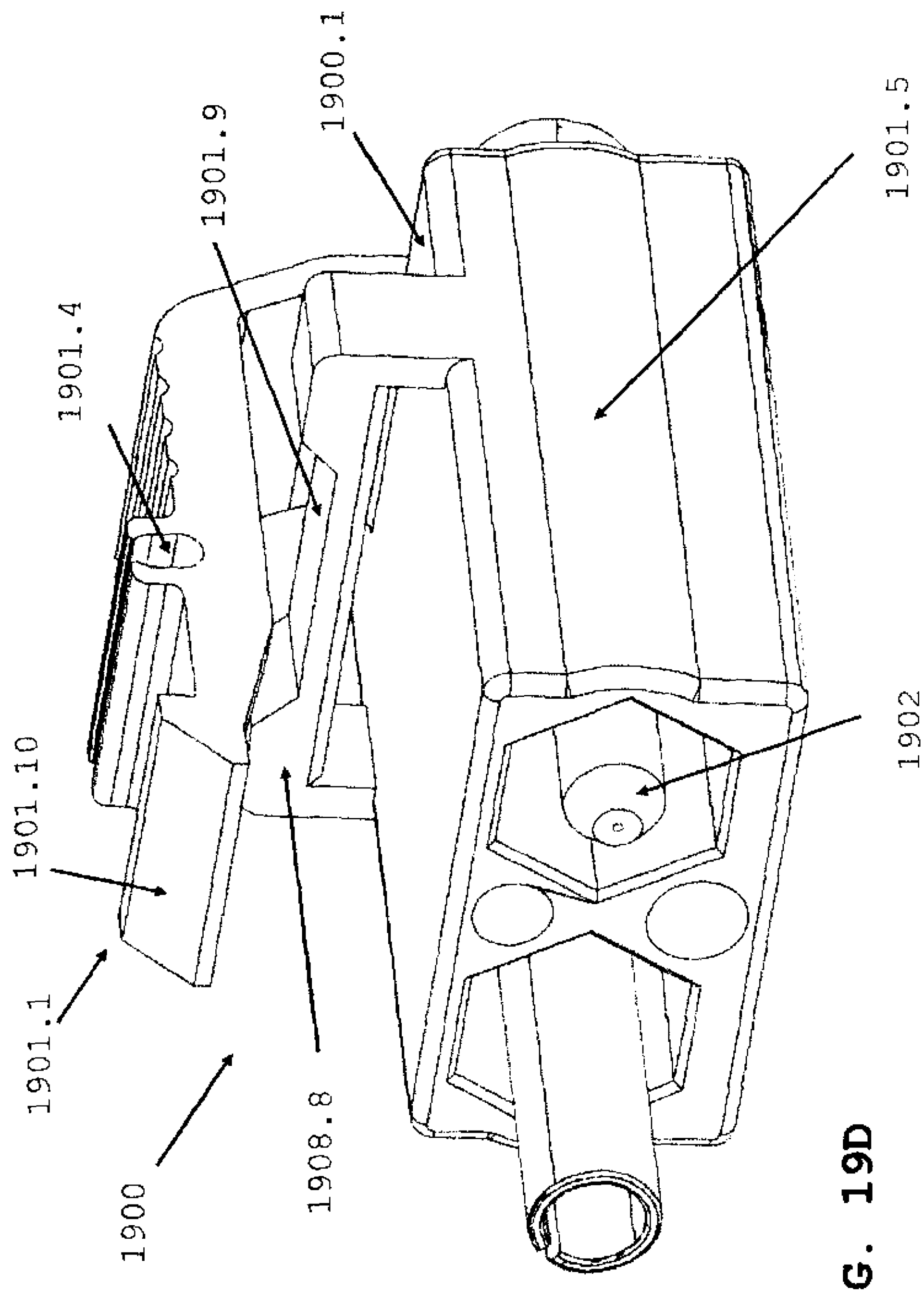


FIG. 19D

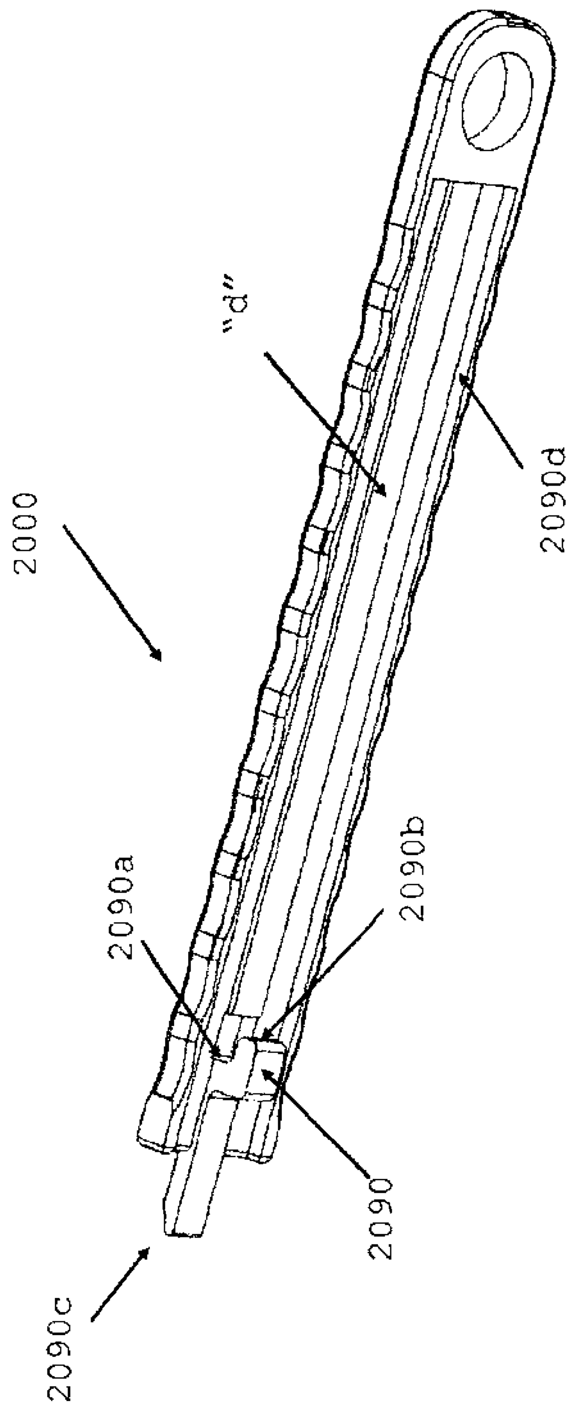


FIG. 20A

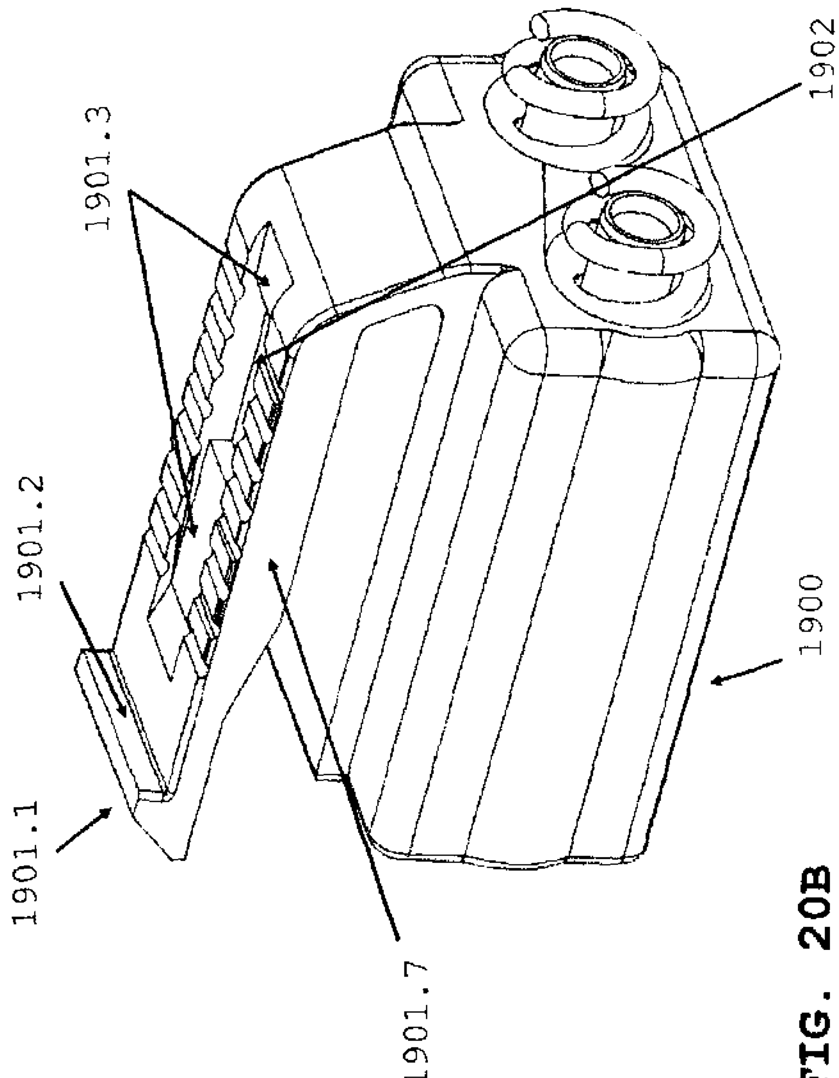


FIG. 20B

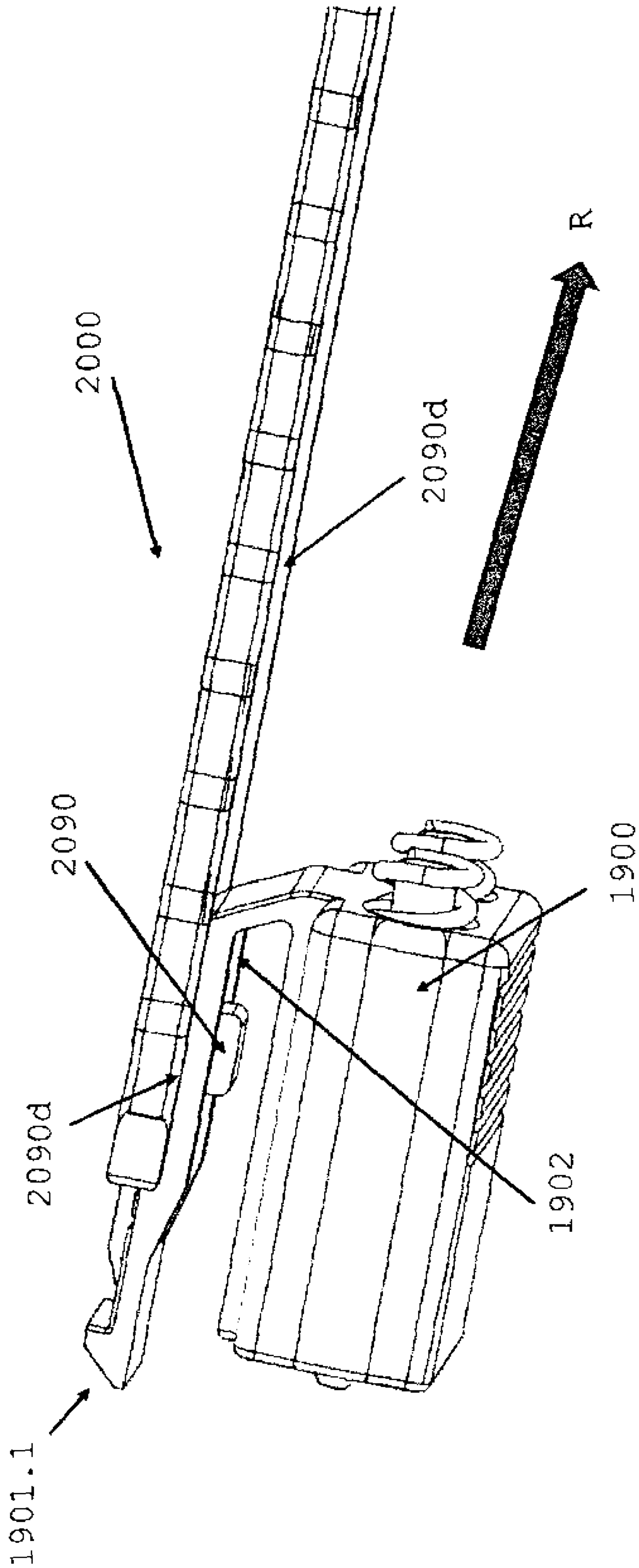


FIG. 21

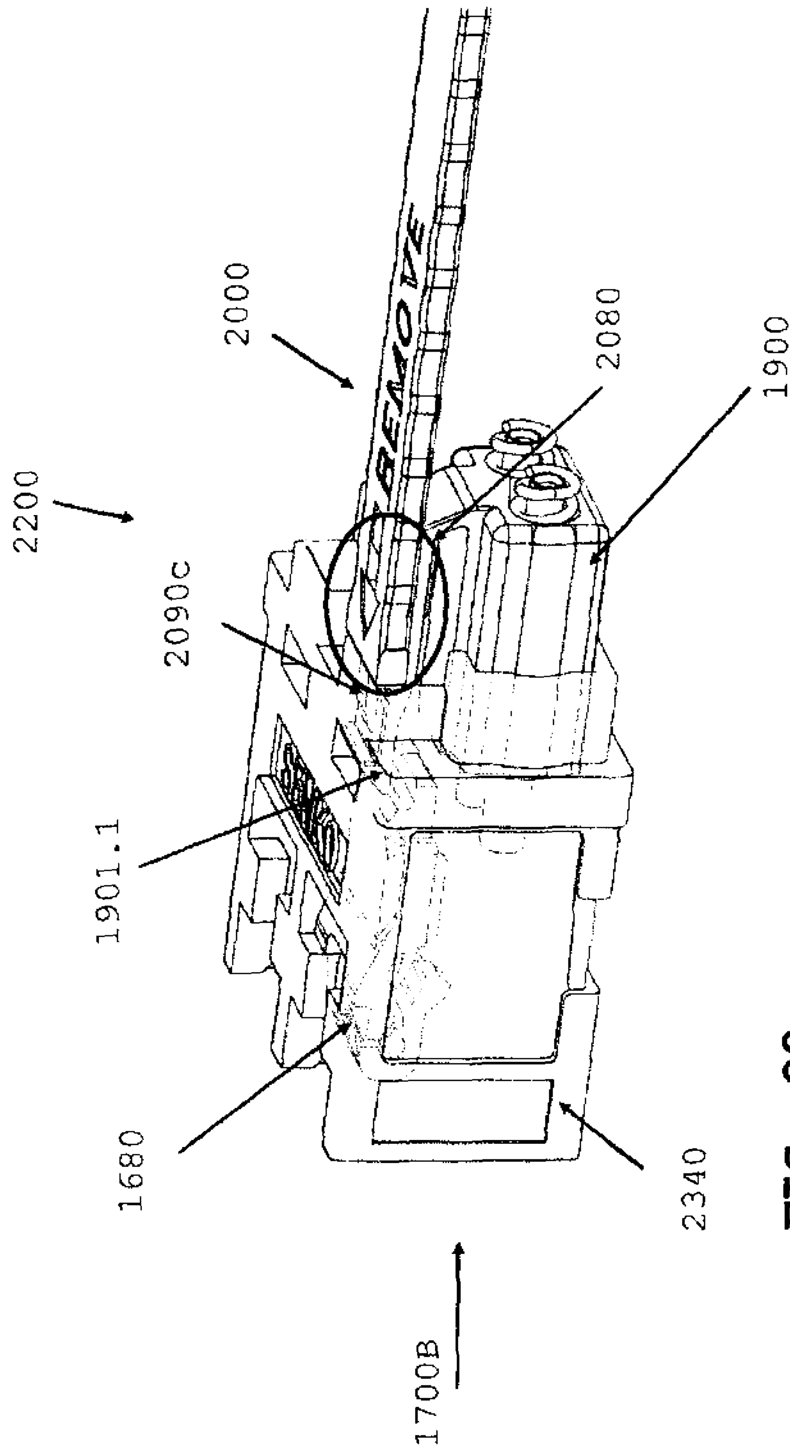


FIG. 22

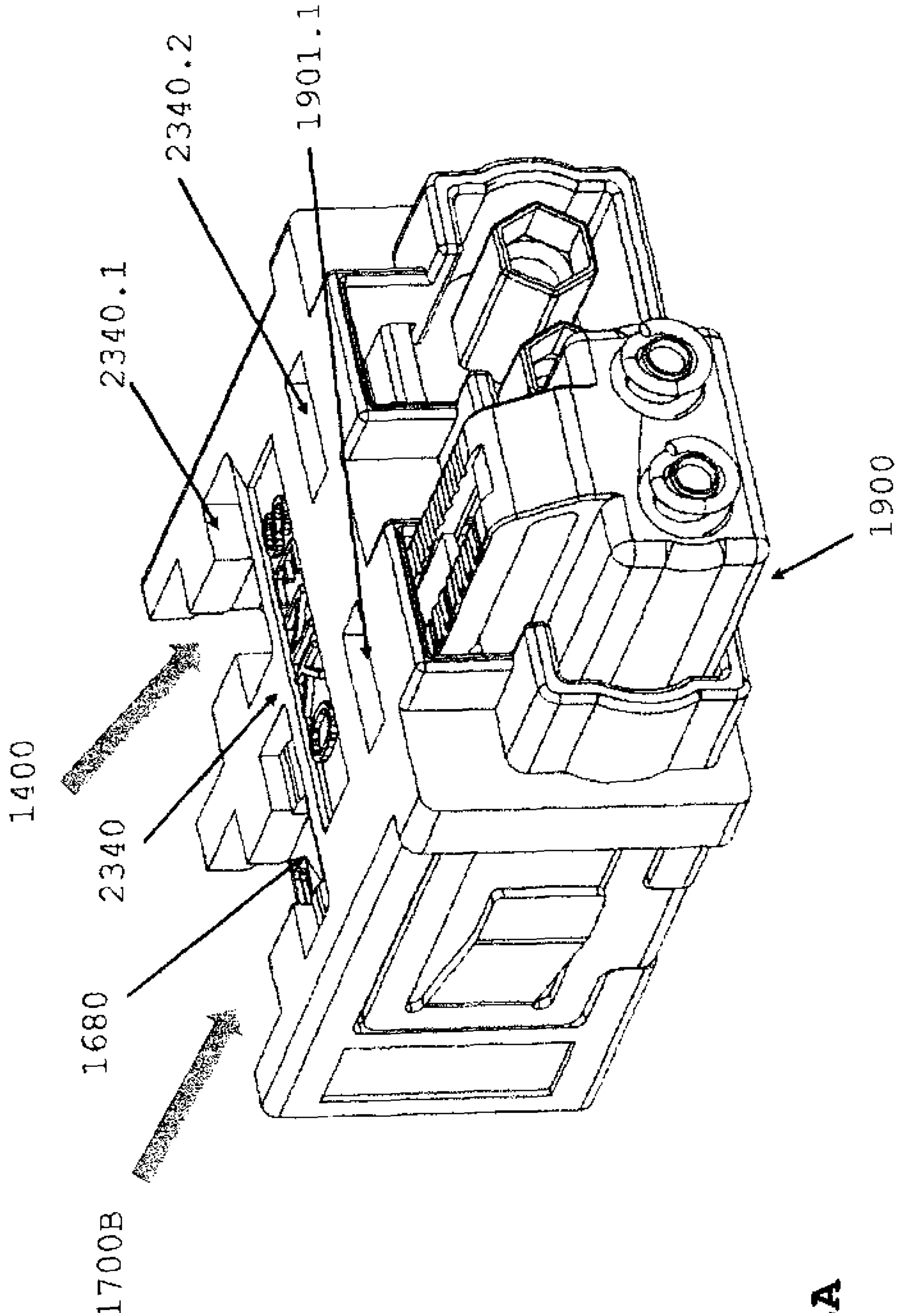


FIG. 23A

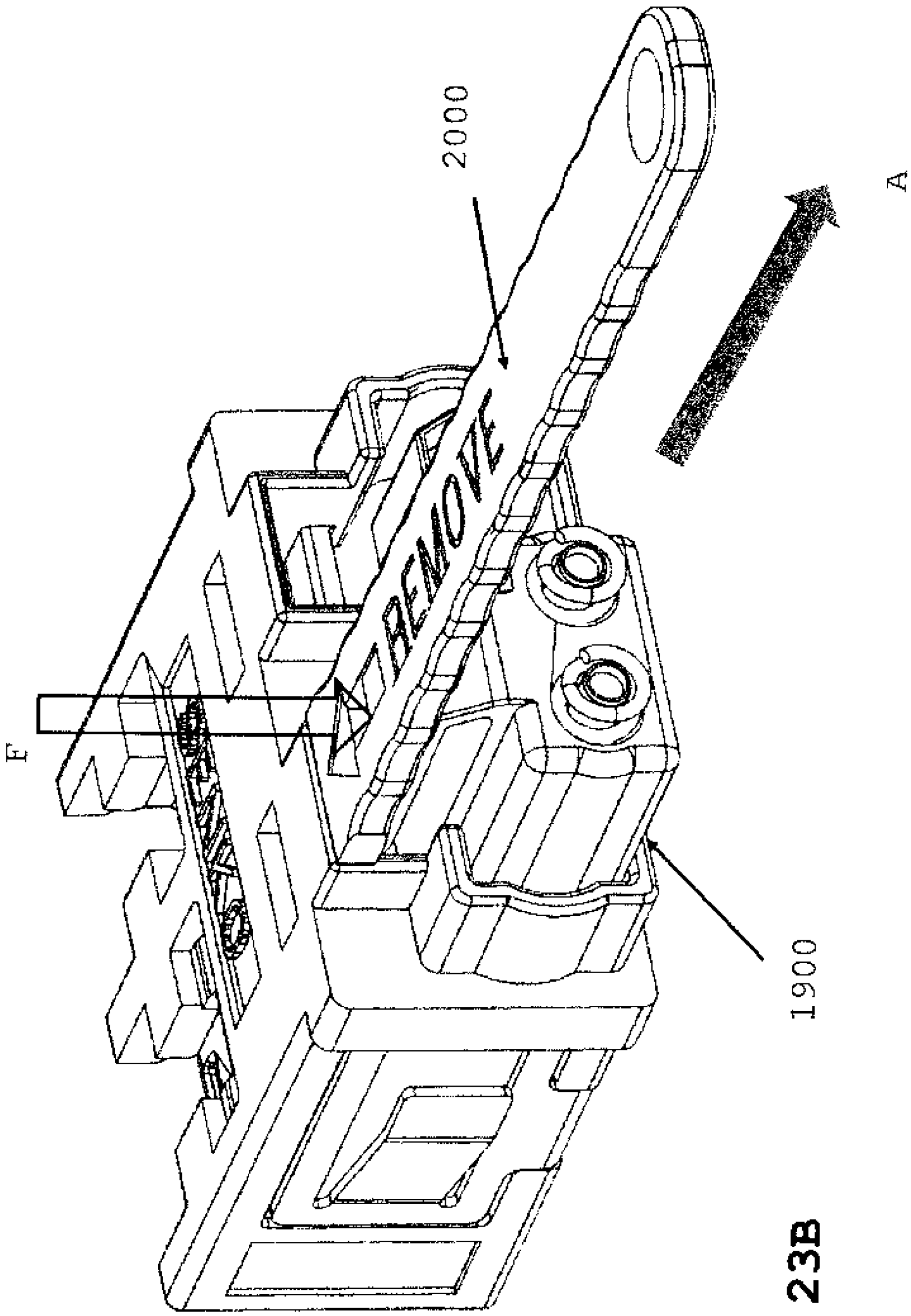
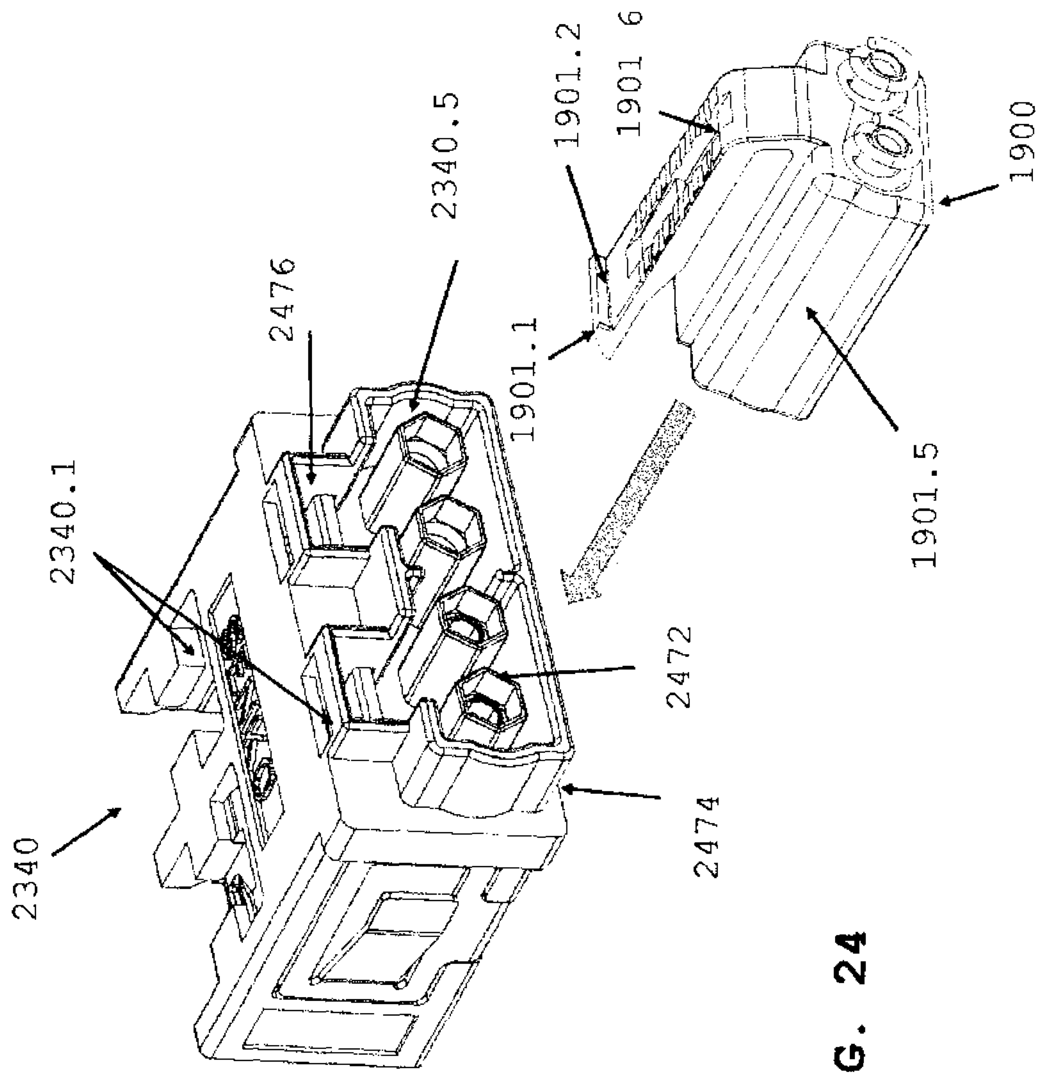


FIG. 23B


1901.2
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2340.5
2476
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2472
2474
2340

FIG. 24

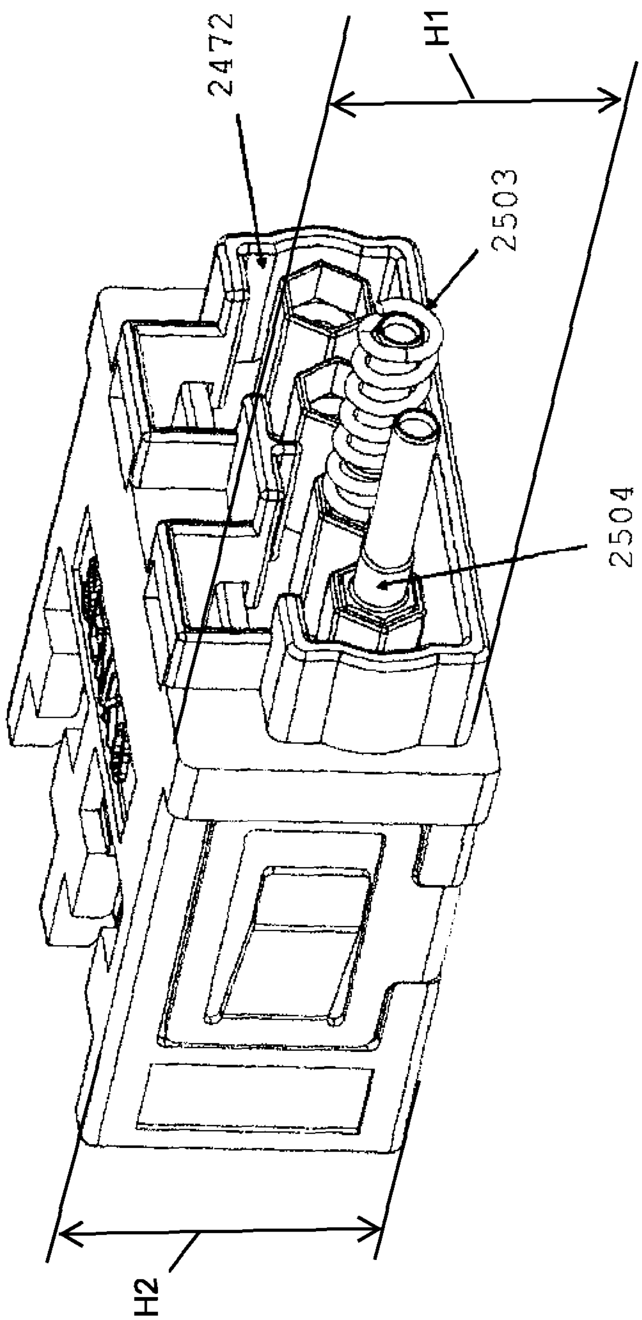

FIG. 25A

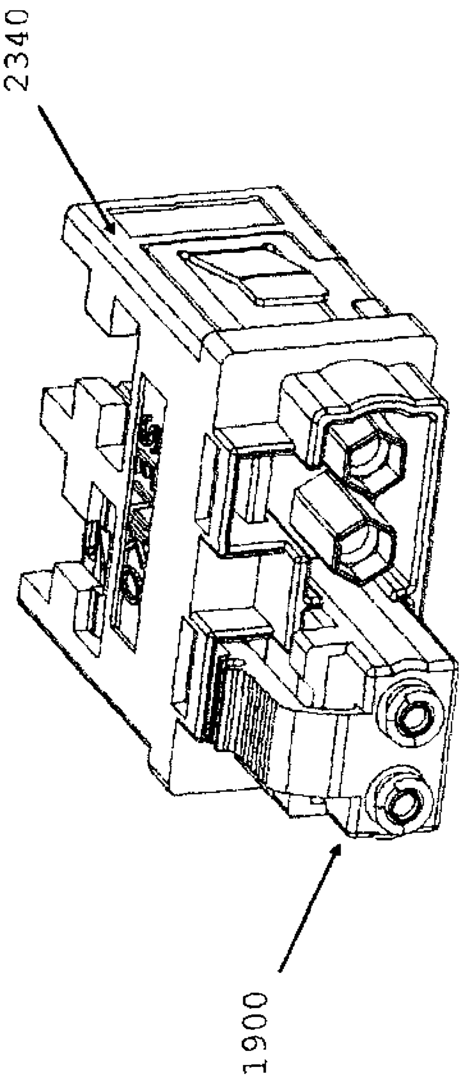

FIG. 25B

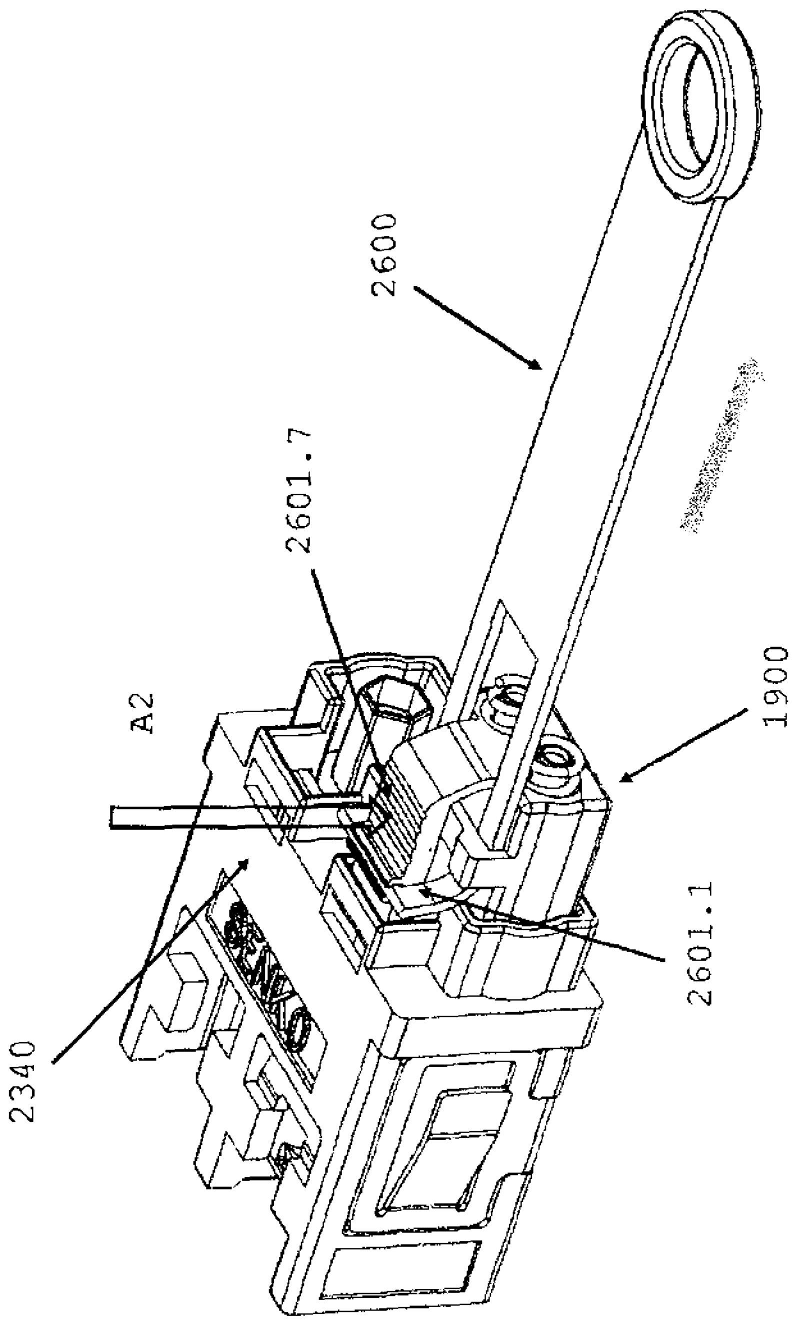

FIG. 26

BEHIND THE WALL OPTICAL CONNECTOR WITH REDUCED COMPONENTS

RELATED APPLICATIONS

This application is a continuation of U.S. Ser. No. 17/221,561 filed on Apr. 2, 2021 titled "BEHIND THE WALL OPTICAL CONNECTOR WITH REDUCED COMPONENTS," which is a continuation of U.S. Ser. No. 16/448,030 filed on Jun. 21, 2019, titled "BEHIND THE WALL OPTICAL CONNECTOR WITH REDUCED COMPONENTS", which is a continuation of U.S. Ser. No. 15/926,263 filed on Mar. 20, 2018, titled "BEHIND THE WALL OPTICAL CONNECTOR WITH REDUCED COMPONENTS", which is a continuation in part of U.S. Ser. No. 15/847,875 filed on Dec. 19, 2017, titled "BEHIND THE WALL OPTICAL CONNECTOR WITH REDUCED COMPONENTS", claiming priority under 35 U.S.C. sec. 119(e) to U.S. Ser. No. 62/482,790 filed on Apr. 7, 2017 titled "BEHIND THE WALL OPTICAL CONNECTOR WITH REDUCED COMPONENTS", all of which are hereby incorporated by reference in their entirety.

BACKGROUND

The present disclosure field of invention relates generally to fiber optic connectors having a release. More specifically, the present disclosure relates to narrow width adapters and connectors, such as narrow pitch distance Lucent Connector (LC) duplex adapters and narrow width multi-fiber connectors.

The prevalence of the Internet has led to unprecedented growth in communication networks. Consumer demand for service and increased competition has caused network providers to continuously find ways to improve quality of service while reducing cost. Certain solutions have included deployment of high-density interconnect panels. High-density interconnect panels may be designed to consolidate the increasing volume of interconnections necessary to support the fast-growing networks into a compacted form factor, thereby increasing quality of service and decreasing costs such as floor space and support overhead. However, the deployment of high-density interconnect panels is still advancing.

In communication networks, such as data centers and switching networks, numerous interconnections between mating connectors may be compacted into high-density panels. Panel and connector producers may optimize for such high densities by shrinking the connector size and/or the spacing between adjacent connectors on the panel. Thus, generally, more connectors are used in a high density array. As the numbers of connectors in a switching network increases, the associated cost of creating the switching network similarly increases. Generally, the construction of connectors includes the use of various components. The manufacturing process used to make these connectors and the components used to build them can greatly affect their cost per unit.

With high density switching networks and large data centers using thousands of these connectors, the cost per unit can have an extreme impact on the overall cost of designing and implementing a data center. Thus, if a new lower cost connector (e.g., a lower cost behind-the-wall (BTW) connector) could be developed, it could have a profound effect on the cost of building out a data center.

SUMMARY OF INVENTION

The present invention is directed to low-profile, reduced sized connector used in fiber optic networks. The connector is inserted into an adapter or transceiver receptacle to mate with an opposing fiber optic connector of the same type, or different configuration or electronics that convert the light signal over the fiber optic into an electrical signal, or vice versa.

The behind-the-wall connector has an outer housing shaped to be received in an adapter opening similarly configured to help align the connector before the connector is secured in the adapter. The connector has a release or latch with a recess that secures the connector in the adapter via an opening in the adapter housing. The connector release is integrated at one end of the connector housing, and extends beyond a second end. The second end of the release latches into the adapter opening.

In another embodiment, the release accepts a pull tab that removes the connector from the adapter housing. The pull tab snaps onto the release and is aligned with the release through a guide on the release that allows the pull tab to slidably move rearward to release the connector from the adapter.

In another embodiment a removal tool can be used to release the connector from the adapter housing. The removal tool is inserted onto the release via a protrusion that is placed through an opening in the release. The tool has an alignment tab that engages a corresponding channel on the release to guide the protrusion into the opening and help ensure the tool does not get jammed into the adapter port. The protrusion has a stop that engages a surface within the opening of the release.

In another embodiment, the adapter has a shroud at a first end that receives the second end of the BTW connector, the shroud inner surface is configured to engage an outer surface of the connector, and ferrule alignment sleeves are configured to engage corresponding ferrule opening with a ferrule therein, to connect the BTW connector with an opposing connector in the adapter.

Additional features and advantages of the invention will be set forth in the detailed description below, and in part apparent to those skilled in the art of the invention. It is understood that foregoing summary, drawings and detailed description are intended to provide a framework or overview for understanding the scope of the invention claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of a typical behind-the-wall connector.

FIG. **2** is an exploded perspective view of a typical behind-the-wall connector.

FIG. **3** is a perspective view of an embodiment of a redesigned behind-the-wall connector including a tension spring.

FIG. **4** is an exploded perspective view of an embodiment of a redesigned behind-the-wall connector including a tension spring.

FIG. **5** is a perspective view of an embodiment of a redesigned behind-the-wall connector without a tension spring.

FIG. **6** is an exploded perspective view of an embodiment of a redesigned behind-the-wall connector without a tension spring.

FIG. **7** is a detailed cross-sectional view of an embodiment of a redesigned behind-the wall connector without a tension spring.

FIG. **8** is a zoomed-in detailed cross-sectional view of an embodiment of a redesigned behind-the wall connector without a tension spring.

FIG. **9** is a perspective view of another embodiment of a redesigned behind-the-wall connector without a tension spring.

FIG. **10** is an illustrative embodiment of a connector within an adapter housing.

FIGS. **11**A and **11**B are illustrative embodiments of connectors within junior and senior sides of an adapter housing, respectively; FIG. **11**C is a cross-sectional view of a connector within an adapter housing.

FIGS. **12**A, **12**B, **12**C, and **12**D show embodiments of a connector with an optional boot according to a further embodiment.

FIGS. **13**A and **13**C depict an optical connector with a connector insertion tool; FIG. **13**B depicts a cross-section of the insertion tool.

FIG. **14** is an exploded view of a connector according to an embodiment of the invention.

FIG. **15**A is a perspective view of an adapter and an assembled connector of FIG. **14** just prior to insertion into an adapter.

FIG. **15**B is a cross-section view of an adapter with the connector of FIG. **14** inserted and latched in an adapter.

FIG. **16**A is an exploded view of the adapter in FIG. **15**A with a plural of hooks prior to insertion into an adapter.

FIG. **16**B is a perspective view of a connector according to an embodiment of the present invention prior to insertion into the adapter of FIG. **16**A with a plural of hooks inserted into an adapter.

FIG. **17**A is an exploded view of a connector according to an embodiment of the present invention.

FIG. **17**B is a view of the assembled connector of FIG. **17**A.

FIG. **18**A is a perspective view of the connector of FIG. **17**B inserted into a simplex adapter at a first end, according to the adapter of FIG. **15**A and the connector of FIG. **17**B inserted into the adapter at a second end.

FIG. **18**B is a perspective view of the adapter of FIG. **15**A, the adapter is configured as a duplex port adapter with a pair of connectors of FIG. **17**B or FIG. **16**B inserted into a first end of the adapter and a pair of connectors of FIG. **14** assembled and inserted into a second end of the adapter.

FIG. **19**A is a perspective view of a behind-the-wall connector.

FIG. **19**B is a perspective view of a pull tab connector.

FIG. **19**C is a perspective view of a bend latch connector.

FIG. **19**D is a perspective view of a behind-the-wall connector at a proximal end.

FIG. **20**A is a perspective view of a removal tool.

FIG. **20**B is a perspective view of the behind-the-wall connector.

FIG. **21** is a perspective view from the bottom of the removal tool of FIG. **20**A attached to the behind-the-wall connector of FIG. **20**B.

FIG. **22** is a transparent view of the connector assembly of FIG. **21** inserted into the adapter of FIG. **16**A on a first side, with a hook inserted therein on the opposing side of the behind-the-wall connector on a second side.

FIG. **23**A is a perspective view of the behind-the-wall connector of FIG. **20**B latched into an adapter.

FIG. **23**B is a perspective view of connector and adapter assembly of FIG. **23**A with the removal tool of FIG. **20**A attached to the behind-the-wall connector as shown by arrow "I".

FIG. **24** is a perspective view of the behind-the-wall connector prior to insertion into an adapter.

FIG. **25**A is a perspective view of the adapter of FIG. **24** with a ferrule flange and ferrule flange with a spring inserted on the flange.

FIG. **25**B is a perspective view of the connector and adapter system of FIG. **24** where the connector is inserted into the adapter.

FIG. **26** is a perspective view of a behind-the-wall connector with a pull tab attached to a connector latch for removal of the connector from an adapter.

DETAILED DESCRIPTION

This disclosure is not limited to the particular systems, devices and methods described, as these may vary. The terminology used in the description is for the purpose of describing the particular versions or embodiments only, and is not intended to limit the scope.

As used in this document, the singular forms "a," "an," and "the" include plural references unless the context clearly dictates otherwise. Unless defined otherwise, all technical and scientific terms used herein have the same meanings as commonly understood by one of ordinary skill in the art. Nothing in this disclosure is to be construed as an admission that the embodiments described in this disclosure are not entitled to antedate such disclosure by virtue of prior invention. As used in this document, the term "comprising" means "including, but not limited to."

The following terms shall have, for the purposes of this application, the respective meanings set forth below.

A "connector," as used herein, refers to a device and/or components thereof that connects a first module or cable to a second module or cable. The connector may be configured for fiber optic transmission or electrical signal transmission. The connector may be any suitable type now known or later developed, such as, for example, a ferrule connector (FC), a fiber distributed data interface (FDDI) connector, an LC connector, a mechanical transfer (MT) connector, a square connector (SC) connector, an SC duplex connector, a straight tip (ST) connector, or a behind-the-wall (BTW) connector. The connector may generally be defined by a connector housing body. In some embodiments, the housing body may incorporate any or all of the components described herein.

A "fiber optic cable" or an "optical cable" refers to a cable containing one or more optical fibers for conducting optical signals in beams of light. The optical fibers can be constructed from any suitable transparent material, including glass, fiberglass, and plastic. The cable can include a jacket or sheathing material surrounding the optical fibers. In addition, the cable can be connected to a connector on one end or on both ends of the cable.

Behind the wall connectors are important in today's crowded data centers. This connector is considered a small form factor or small footprint connector, that is, the overall length is reduced, compare, for example, FIG. **1** with FIGS. **3** and **5**. The size decrease is from the ferrule or distal end to the end of the boot or proximal end of the connector. In this invention, behind-the-wall literally means the connector is placed behind a wall or panel, and the panels are stored in the rack that extend from the floor to the ceiling, and the racks of panels, each containing numerous adapters, are positioned near another rack with little or no distance between the racks. As such, the removal of connector structure is needed to allow the racks to be placed very close together, without degrading the reliability of the connector. In this invention the extender cap **204** is removed along with other components.

In an embodiment of the present invention, the spring was removed, and instead of replacing with a back post (not shown), a resilient latch (**308**, **408**, **508**, **608**, **115**) was designed. In another embodiment the spring (**307**, **407**) is retained. The spring allows the ferrule flange to move more easily in response to stresses placed on the connector.

Other prior art connectors that remove the spring insert the ferrule from the front or distal end of the connector with an end cap or cover placed over the plug housing to hold the ferrule flange in place. The present invention inserts the ferrule flange and ferrule from the boot side or proximal end of the connector. This improves connector quality and operation because the pull force or the force one can exert on the connector when removing from the adapter is increased, and this reduces breakage when employing the resilient latch.

Various embodiments described herein generally provide a cost-reducing design for a fiber optic connector. In some embodiments, such as those discussed herein, various components of typically known connectors may be removed (e.g., an extender cap, a spring, a boot, etc.). Various embodiments may comprise different structure types for the connector, for example, some might be flexible, and others might be more rigid. Detailed examples of these connector types are shown in the figures, and discussed further herein.

FIG. **1** shows a perspective view of a standard behind-the-wall (BTW) connector **100**. Generally, and as shown, a BTW connector may comprise a plug frame **101**, a ferrule-flange **102**, an extender cap **104**, and a boot **105**. As shown in FIG. **2**, a BTW connector is comprised of various parts which are held together via mechanical interlock and/or spring tension. For example, as shown, a typical BTW connector may have a plug frame **201**. The plug frame **201** comprises the majority of the external area of the connector. The plug frame **201** has an opening at both ends to allow for the insertion of additional components. One such component is the ferrule-flange **202**, which is usually also accompanied by a flange tube **203**. The ferrule-flange **202** is generally designed with an extended collar **206**, which is designed to restrict the ferrule-flanges movement through the plug frame **201**. Stated differently, the extended collar **206** keeps the ferrule **202** from falling completely through the plug frame **201** and out the front opening.

The BTW connector may also comprise a spring **203**, which generally goes around at least a portion of the flange tube and/or the ferrule-flange **202** when combined. The spring **203** applies a tension to the ferrule-flange **202** to prevent it from protruding out of the plug frame **201** in order to maintain a good connection. However, the spring **203** may also provide some cushion so as to not break the ferrule **202** if improperly aligned. The spring **203** is then capped using an extender cap **204**. The extender cap **204** has a fastening mechanism **220**, which is designed to interlock with a cutout **221** in the plug frame **201**. Finally, a boot **205** is placed over the extender cap **204**.

Thus, a large number of components are required to build a typical BTW connector. Removing some of these components or replacing them with similar but less complex analogues can reduce the cost of a connector. Accordingly, some embodiments may, as shown in FIG. **3** remove various components. FIG. **3** shows a BTW connector **300**, which comprises a plug frame **301**, a ferrule flange **302**, a flange tube **303**, and a spring **307**. In some embodiments, and as shown in FIG. **3**, the plug frame **301** may comprise a latching member **308**. The latching member **308** may be flexibly rigid such that it can be moved via a tool or human pressure, but is rigid enough to hold the ferrule flange **302** in place in conjunction with the spring **307**. Additionally or alternatively, some embodiments may consist essentially of a plug frame **301**, a ferrule flange **302**, a flange tube **303**, a spring **307**, and a latching member **308**.

Specifically, in some embodiments, the latching member **308** may have a hook or protrusion (not shown) which may hook or latch onto one or more portions of the spring **307**. Thus, as shown, the latching member **308** can hold the spring **307** in a fixed position, allowing the spring to exert horizontal pressure or tension onto the ferrule **302** ensuring proper placement of the ferrule.

FIG. **4** shows an exploded view of an embodiment comprising a plug frame **401**, a ferrule flange **402**, a flange tube **403**, a spring, **407**, and a latching member **408**. Thus, some embodiments (e.g., the embodiments shown in FIGS. **3** and **4**) may remove various components (e.g., the extender cap and boot) from the design. Removing these parts, reducing the cost of the connector, while also maintaining proper functionality is advantageous in almost any data center setting.

Referring now to FIG. **5**, an example embodiment is shown having fewer components for connector design **500**. As shown, the illustrative embodiment merely includes a plug frame **501** and a ferrule-flange **502**. This embodiment is achievable as a result of the configuration of the latching member **508**, and its relative position on the plug frame **501**. Accordingly, some embodiments may consist essentially of a plug frame **501** and a ferrule flange **502**.

FIG. **6** shows an exploded view of the connector design. As is clear from FIGS. **5** and **6**, not only have the extender cap and boot been removed, but the spring and flange tube have been removed as well. This arrangement results from the latching member **608** of the plug frame **601** being designed in a manner to take advantage of the standard shape of the ferrule-flange **602**. The exact interaction may be better understood with reference to FIG. **7**.

As shown in FIG. **7**, the ferrule-flange **702** is inside the plug frame **701**. In some embodiments, the plug frame **701** may comprise one or more front stops **709**. These front stops **709** prevent the ferrule-flange **702** from falling out the front opening of the plug frame **701**. In addition, and as shown, the latching member **708** is closed around the extended collar **706** of the ferrule-flange **702**. This interlocking system prevents the ferrule-flange from falling or being pushed (e.g., when making a connection) out of the back of the plug frame **701**. As discussed herein, the latching member(s) **708** are flexible or elastic in nature, and thus can be moved using a tool, or a user. By moving the latching member **708** away from the side of the ferrule-flange **702** (e.g., applying outward pressure on the latching member to disengage it from the ferrule), the ferrule-flange may be removed via the rear opening of the plug frame **701**.

FIG. **8** illustrates a zoomed-in and more detailed view of an embodiment of a BTW connector **800** similar to that of FIG. **7**. As shown, the ferrule-flange **802** is within the plug frame **801**, and held in place primarily by opposing forces placed upon the extended collar **806** of the ferrule. These opposing forces are applied via the front stop **809** acting upon the front of the extended collar **806** and the latching member **808** acting upon the back of the extended collar.

Referring to FIG. **9**, an alternative embodiment of a connector system **900** is shown. As shown in FIG. **9**, the plug frame **901** is larger and more robust that some other connectors discussed and illustrated herein. However, the ferrule-flange **902** is still held in place via means similar to those discussed in FIGS. **3**-**8**. In this non-limiting example, the plug frame **901** comprises a latching member **908** which may interact with various connector components. For example, the latching member **908** may, as discussed herein, latch onto a portion of a spring thus imparting some lateral force upon the ferrule-flange **902**. In addition or alternatively, the latching member **908** may latch or interact with the extended collar (not pictured) to apply a force to keep the ferrule-flange **902** within the plug frame **901**. Some embodiments may consist essentially of a plug frame **901**, a ferrule flange **902**, and a latching member **908**. In addition or alternatively, some embodiments may consist essentially of a plug frame **901** and a ferrule flange **902**, a flange tube (not shown), a spring **907** (not shown), and a latching member **908**.

Referring now to FIG. **10**, in some embodiments, the plug frame **1001** may be placed in an adaptor **1010**. In some embodiments, in which the plug frame **1001** is within the adapter **1010**, the latching member (not pictured) may not be pushed out because the walls of the adapter prevent it. Such embodiments impart additional strength to the connector specifically the plug frame **1001**.

Referring now to FIGS. **11**A-C, additional views of an optical connector **1101** inserted into an adapter **1102** are depicted. In FIG. **11**A, the connector **1101** is positioned in the junior side of the adapter **1102**. In FIG. **11**B, the connector **1101** is positioned in the senior side of the adapter **1102**. Both connectors have a ferrule **1152** that upon insertion into either adapter side, engages an opening **1158** of a resilient member **1156** (FIG. **11**C). The resilient member **1156** is configured to expand and secure the ferrule **1152**, while aligning the ferrule **1152**.

FIG. **11**C shows a typical resilient member **1156**, which, in an embodiment, may be fabricated from zirconia or a high strength polymer. The resilient member **1156** has a length, inner diameter and outer diameter. When the connector **1101** is inserted into the adapter **1102**, the leading tip of the ferrule **1152** enters the resilient member **1156** opening **1158**, and the ferrule **1152** outer diameter being larger than the ferrule **1152** inner diameter, the ferrule **1152** expands the resilient member **1156** circumferentially. The engagement of the distal end of the annular collar **1150** is stopped at an outer surface **1162** of the resilient member **1156**. This helps ensure the annular collar **1150** is seated correctly, so when the resilient latch **1140** returns to its original or relaxed, unflexed position, the latch **1140** is seated just in front of the proximal side of the annular collar **1150**, and secures the ferrule flange (**402**, **602**) from being dislodged if unintentionally hit.

The expansion of the resilient member depends on the modulus of the resilient member **1156** material and a width of an optional cut (shown by the pair of solid lines **1159**) that runs lengthwise along the resilient member **1156**, in FIG. **11**C.

In the cross-sectional view of FIG. **11**C, it can clearly be seen that plug latch **1140** is positioned adjacent the exterior wall of the plug frame of connector **1101** (also shown at **608**). As such, the plug latch **1140** is constrained by adapter **1102** from flexing outward and releasing the annular ferrule collar **1150**. Thus, when the connector is inserted in the adapter, the constraint of the adapter prevents movement of the ferrule **1152** within the plug frame. This constraint further secures the ferrule **1152** within the resilient member **1156**.

A central bore **1154** receives the annular collar **1150**. The central bore **1154** is also shown in FIG. **11**A, where the inner dimensions of the bore **1154** match the outer dimensions of the extended collar **206** or annular ferrule collar **1150**. The annular ferrule collar **1150** is generally round or annular and can contain surface features to aid in placement in the plug frame. The ferrule collar **206** is shown in FIG. **2** with a hexagonal outer dimensional appearance. Other outer surface features may be used without departing from the scope of the invention. A typical purpose of these features is to aid in connector assembly.

Depending upon the application environment of the optical connectors of the various embodiments, that is, both embodiments with a spring and embodiments without a spring, it may be desirable to affix a boot to the optical connector to protect optical fibers positioned therein. This may be a consideration when forces that may be applied to the optical fibers could damage or break the fibers so that the extra protection that a boot provides may be desirable. As seen in FIGS. **12**A-**12**D, an optional boot **1203** may be affixed to the optical connector **1201**. As with previous embodiments, the optical connector **1201** includes a ferrule **1202**. To affix the boot to the connector, apertures **1204** are provided. As best seen in FIG. **12**B, engagement projections **1220** provided at the distal end of the boot **1203** are inserted into connector apertures **1204** to retain the boot in a position extending from the proximal end of the connector plug frame. In both the side view of FIG. **12**C and the adapter/connector assembly view of **12**D, apertures **1204** with engagement projections **1220** are clearly depicted.

To facilitate assembly of the ferrule within the plug frame, an insertion tool **1310** is provided as seen in the several views of FIGS. **13**A-**13**C. In FIG. **13**A, the handle **1320** of insertion tool **1310** is visible as the tool is inserted within optical connector **1301**. To accommodate optical fiber, insertion tool **1310** features a generally C-shaped cross-section as seen in FIG. **13**B, with various cross-sectional shapes along its length to receive the ferrule and the ferrule collar. As seen in FIG. **13**C, the distal end portion **1330** of the insertion tool **1310** features a reduced cross-section so that the tool may be inserted into the bore of connector **1301** to position the ferrule therein.

Referring to FIG. **14**, an exploded view of a connector according to the present invention shows a dust cap **1480** may be inserted into a front body **1401** at the proximal end, in the direction of the arrow "A". The dust cap prevents debris from contacting a ferrule that may interfere with a fiber optic signal. The front body **1401** further comprises a latch **1401**.**1**. The latch engages an inside surface of adapter **2340**, as shown in FIG. **15**B, to secure the connector **1400** in the adapter. The connector further comprises a pair a ferrules **1402**, ferrule flanges **1406**, ferrule spring **1403** and back-body **1404** with a boot **1405** covering the ferrules and back body attaching to the front body **1401** to form the connector **1400**. The connector **1400** is sometimes called a bend-latch connector wherein the latch **1401**.**1** bends down when inserted into an adapter. Once inserted, the latch snaps into the adapter housing opening as shown and described in FIG. **15**B.

Referring to FIG. **15**A, the connector **1400** with an alternative latch **1401**.**1** is shown prior to insertion into an adapter **2340**. Referring to FIG. **15**B, the connector **1400** is inserted into the adapter. A latch surface **1401**.**2** engages an adapter surface **2340**.**1** that secures the connector **1400** in the adapter **2340**.

Referring to FIG. **16**A, the adapter **2340** may accept a hook engagement device **1680**. Referring to FIG. **16**A, a hook surface **1680**.**1** locks into a widthwise groove **1693** on a front body **1701** of the connector **1600** as shown in FIG. **16**B, which secures the connector **1600** into the adapter. The connector **1600** is sometimes called a pull tab connector as shown by a pull tab **1791** (refer to FIG. **17**A) interacting with groove **1693** to unlock the connector (**1600**, **1700**) from the hook surface **1680.1** located within the adapter **2340**.

Referring to FIG. **17**A, an exploded view of a pull tab connector **1700**A further comprises a ferrule assembly **1702** called a multi-port optical ferrule or MPO ferrule. The connector **1700**A further comprises a widthwise groove **1793**, a front body **1701** that comprises the groove at a top surface, the ferrule assembly **1702**, a back-body **1704**, and boot **1705** is used to cover and secure the aforementioned components to the front body **1701**. This connector **1700**A further comprises a pull tab **1791** that comprises a ramp area **1792**. The ramp area unlocks the connector from the hook surface **1680.1** when the pull tab **1791** is pulled rearward away from the adapter. Referring to FIG. **17**B, the connector **1700**A is assembled **1700**B illustrating the widthwise groove **1793** and pull tab **1791**.

Referring to FIG. **18**A, a connector **1700**B and a connector **1400** are inserted into a simplex adapter **1800**A at opposing ends. The connector **1700**B, as described above engages and secures to a hook **1680** inserted into the adapter **2340**. Referring to FIG. **18**B, a pair of connectors **1700**B and connectors **1400** are inserted into a duplex adapter **1800**B at opposing ends. These connectors extend beyond the adapter because of the additional structure such as boot **1405** and pull tab **1791**. A connector **1700**B may be swapped with connector **1400** on the opposing side without departing from the scope of the present invention. The present invention behind-the-wall connector is substantially shorter than the connectors **1700**B or **1600** or **1400** as shown in FIGS. **19**A-**19**C.

Referring to FIG. **19**A, another embodiment of the behind-the-wall connector (**100**, **300**) is shown. Connector **1900** does not include a boot assembly (**105**, **205**). Connector **1900** comprises a latch **1901.1** that extends a predetermined distance "L" beyond the connector housing to ensure the connector **1900** mates within an adapter (not shown), while minimizing overall connector length exposed outside of adapter (not shown), as shown in FIG. **19**A as compared with FIGS. **19**B and **19**C. Like connector **900** of FIG. **9**, the boot assembly is excluded in the behind-the-wall connector **1900**. Comparing connector **1700**B as shown in FIG. **18**B, the connector **1900** is substantially shorter in length and more compact, even as compared with connector **1400** as shown in FIG. **19**C. Referring to FIG. **19**D, connector **1900** further comprises a housing **1900.1** with a mating surface **1901.5** configured to mate with an inner surface **2474.1** of a shroud **2474** (refer to FIG. **24**). The connector **1900** comprises a latch **1910.1** attached to one side of the housing **1901.1**. The latch further comprises a widthwise locking groove **1901.4** that accepts a catch **2601.1** of a pull tab **2600** (refer to FIG. **26**), a guide **1908.8** to slidably hold the pull tab in place, and guide recess **1909.9** accept a portion of the depressed latch structure during pull tab release of the connector from adapter. The locking groove **1901.4** is sized to snap in the catch upon depressing the catch into the groove, and removing the catch from the groove by prying the catch out of the groove. The latch **1901.1** further comprises a chamfer or inclined surface **1901.10** that engages a corresponding adapter surface upon insertion of connector into adapter (not shown). The surface **1901.10** pushes the latch downward upon contact with corresponding adapter structure for an essentially resistant free insertion.

Referring to FIG. **20**A, removal tool **2000** is configured to engage the connector **1900** via a protrusion **2090** configured to be inserted an opening **1902** (refer to FIG. **20**B). Pulling tool **2000** rearward in a direction "R" (FIG. **21**), depresses latch **1901.1** (refer to FIG. **20**B), which releases connector

1900 from adapter **2340** as shown in FIG. **23**A. Referring to FIG. **20**A, removal tool **2000** and its protrusion **2090** further comprise a cutout **2909***a* and a stop surface **2090***b*. The cutout **2090***a* engages a latch inner surface **1901.6** (refer to FIG. **24**), and pulling on the tool **2000** in a direction "A" of the arrow (refer to FIG. **23**B) will release the connector **1900** from the adapter **2340**. The stop surface adds strength to the removal tool when it engages the latch inner surface and the tool is pulled to release the connector **1900**.

Referring to FIG. **20**B, the connector **1900** comprises an opening **1902** configured to receive the protrusion **2090**, a channel **1901.3** configured to receive an alignment tab **2090***c* that helps ensure the tool **2000** does not get stuck in the adapter, and protrusion **2090** is configured to be received in opening **1902**. Referring to FIG. **21**, the protrusion **2090** is shown inserted into opening **1902** of the connector **1900**. Referring to FIG. **20**A, a projection **2090***d* runs lengthwise along underside or attachment side to a connector of the removal tool. The projection is on both inner sides and projects inward. This allows projection **2090***d* to engage a side face **1901.7** of the latch **1901**. The width of the projection opening defines a distance "d" between the projections **2090***d* (refer to FIG. **21**) and "d" is sized to engage a top surface of the latch **1901.1**. Projection **2090***b* captures the latch side face **1901.7** to secure tool **2000** and help prevent it from sliding widthwise across the latch and getting jammed in the adapter. This is also shown in FIG. **22** at **2280**. Returning to FIG. **21**, the tool **2000** is secured to latch **1901.1** by side projections **2090***d* and protrusion **2090** that extends through latch opening **1902**.

Referring to FIG. **22**, adapter **2340** comprises a connector **1900** inserted and latched into a first port, and an opposing adapter port or opening comprises connector **1900** with removal tool **2000** attached thereto. The projections **2090***d* are shown in the call out **2280** as further securing and stabilizing the tool **2000** to latch **1901.1**. The alignment tab **2090***c* is shown engaged in the channel **1901.3** to help ensure tool **2000** does not become jammed in the adapter. If the tool becomes jammed, the connector would be likely destroyed or damaged along with the adapter itself, upon dislodging the jammed tool. The opposing side of the adapter **2340** shows a hook **1680** in an adapter port. The hook **1680** can accept connector **1700**B and mate the fiber optic pathways contained in the ferrules of the connectors **1700**B and **1900** to form a signal path. Without departing from the scope of the invention, the hook **1680** can be removed and a connector **1400** can be secured and latched into the adapter port in place of connector **1700**B, and form the same signal path with the connector **1900**.

Referring to FIG. **23**A, connector **1900** is shown in a first port of a duplex adapter **2340**, with a hook **1680** in an opposing port to the connector **1900**. The adapter port with a hook can accept a connector **1700**B, and a connector **1400** can be inserted in an adjacent port that does not contain a hook **1680**. The adapter comprises an opening **2340.2** further comprising an adapter latching surface **2340.1** that engages a corresponding latch face **1901.2** (refer to FIG. **20**B) thereby securing connector **1900** into the adapter **2340**. Referring to FIG. **23**A, removal tool **2000** is not inserted onto connector **1900**. Referring to FIG. **23**B, the connector **1900** with a removal tool **2000** is inserted in a first port of duplex adapter. The adapter is also shown in FIG. **24**. Pulling on the tool **2000** in a direction "A" of the arrow would remove the connector **1900** from the adapter. Pulling on tool **2000** in direction "A" imparts a downward force "F" on latch **1901.1** separating latch face **1901.2** from within adapter opening **2340.2**.

Referring to FIG. **24**, an embodiment of an adapter comprises an outer shroud **2474**, a ferrule flange alignment sleeve **2472**, and a latch opening **2476**. The shroud **2474** further comprises an inner surface **2474.1**, a plural of walls **2474.2** and a channel **2474.5** configured to accept an outer housing of the connector **1900** and its mating surface **1901.5**. These features help ensure connector **1900** when inserted into an adapter port, in the direction of arrow "I", the connector **1900** is aligned so latch **1901.1** will secure into adapter opening **2340.2** (FIG. **23**A) and a latch face **1901.2** will engage and lock with a corresponding adapter latching surface **2340.1**.

Referring to FIG. **25**A, the adapter of FIG. **24** further comprises a ferrule flange **2506** inserted into the ferrule flange alignment sleeve holder **2472**, and further comprises a spring **2503** over ferrule flange (**1906**, **2504**) and alignment sleeve **1906.1**. The connector outer housing is not shown. FIG. **25**A shows that the adapter **2340** has a height H**1** at the first end of the adapter and a height H**2** at the second end of the adapter, and the height H**1** at the first end is less than the height H**2** at the second end. Referring to FIG. **25**B, the connector **1900** is fully inserted and latched into adapter **2340** where the outer surface of the connector **1900** housing engages with the inner surface **2474.1** of the shroud **2474**. FIG. **16**A shows that the adapter **2340** includes upper and lower longitudinal ribs **2347** between the non-behind-the-wall ports.

Referring to FIG. **26**, a pull tab **2600** is configured to attach to latch **1901.1** of connector **1900**. A proximal end of the pull tab **2600** further comprises a catch **2601.1** that engages a groove **2601.7** running widthwise on the latch top surface. As the pull tab **2600** is moved in a direction of arrow "**A1**", the catch forces the latch down in the direction of arrow "A**2**", and this releases the connector **1900** from the adapter **2340**.

The present disclosure is not to be limited in terms of the particular embodiments described in this application, which are intended as illustrations of various aspects. Many modifications and variations can be made without departing from its spirit and scope, as will be apparent to those skilled in the art. Functionally equivalent methods and apparatuses within the scope of the disclosure, in addition to those enumerated herein, will be apparent to those skilled in the art from the foregoing descriptions. Such modifications and variations are intended to fall within the scope of the appended claims. The present disclosure is to be limited only by the terms of the appended claims, along with the full scope of equivalents to which such claims are entitled. It is to be understood that this disclosure is not limited to particular methods, reagents, compounds, compositions or biological systems, which can, of course, vary. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to be limiting.

With respect to the use of substantially any plural and/or singular terms herein, those having skill in the art can translate from the plural to the singular and/or from the singular to the plural as is appropriate to the context and/or application. The various singular/plural permutations may be expressly set forth herein for sake of clarity.

It will be understood by those within the art that, in general, terms used herein, and especially in the appended claims (for example, bodies of the appended claims) are generally intended as "open" terms (for example, the term "including" should be interpreted as "including but not limited to," the term "having" should be interpreted as "having at least," the term "includes" should be interpreted as "includes but is not limited to," et cetera). While various compositions, methods, and devices are described in terms of "comprising" various components or steps (interpreted as meaning "including, but not limited to"), the compositions, methods, and devices can also "consist essentially of" or "consist of" the various components and steps, and such terminology should be interpreted as defining essentially closed-member groups. It will be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present. For example, as an aid to understanding, the following appended claims may contain usage of the introductory phrases "at least one" and "one or more" to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles "a" or "an" limits any particular claim containing such introduced claim recitation to embodiments containing only one such recitation, even when the same claim includes the introductory phrases "one or more" or "at least one" and indefinite articles such as "a" or "an" (for example, "a" and/or "an" should be interpreted to mean "at least one" or "one or more"); the same holds true for the use of definite articles used to introduce claim recitations. In addition, even if a specific number of an introduced claim recitation is explicitly recited, those skilled in the art will recognize that such recitation should be interpreted to mean at least the recited number (for example, the bare recitation of "two recitations," without other modifiers, means at least two recitations, or two or more recitations). Furthermore, in those instances where a convention analogous to "at least one of A, B, and C, et cetera" is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (for example, "a system having at least one of A, B, and C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, et cetera). In an instance where a convention analogous to "at least one of A, B, or C, et cetera" is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (for example, "a system having at least one of A, B, or C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, et cetera). It will be further understood by those within the art that virtually any disjunctive word and/or phrase presenting two or more alternative terms, whether in the description, claims, or drawings, should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms. For example, the phrase "A or B" will be understood to include the possibilities of "A" or "B" or "A and B."

In addition, where features or aspects of the disclosure are described in terms of Markush groups, those skilled in the art will recognize that the disclosure is also thereby described in terms of any individual member or subgroup of members of the Markush group.

As will be understood by one skilled in the art, for any and all purposes, such as in terms of providing a written description, all ranges disclosed herein also encompass any and all possible subranges and combinations of subranges thereof. Any listed range can be easily recognized as sufficiently describing and enabling the same range being broken down into at least equal halves, thirds, quarters, fifths, tenths, et cetera. As a non-limiting example, each range discussed herein can be readily broken down into a lower third, middle third and upper third, et cetera. As will also be understood by one skilled in the art all language such as "up to," "at least," and the like include the number recited and refer to ranges which can be subsequently broken down into sub-ranges as discussed above. Finally, as will be understood by one skilled in the art, a range includes each individual member. Thus, for example, a group having 1-3 cells refers to groups having 1, 2, or 3 cells. Similarly, a group having 1-5 cells refers to groups having 1, 2, 3, 4, or 5 cells, and so forth.

Various of the above-disclosed and other features and functions, or alternatives thereof, may be combined into many other different systems or applications. Various presently unforeseen or unanticipated alternatives, modifications, variations or improvements therein may be subsequently made by those skilled in the art, each of which is also intended to be encompassed by the disclosed embodiments.

The invention claimed is:

1. An adapter for optical connectors, the adapter comprising:

an adapter housing having a first end portion and an opposite second end portion spaced apart along a longitudinal axis, the adapter housing defining a plurality of behind-the-wall ports and a plurality of non-behind-the-wall ports aligned with corresponding behind-the-wall ports, each behind-the-wall port opening through the first end portion of the adapter housing and each non-behind-the-wall port opening through the opposite second end portion of the adapter housing; and

a plurality of ferrule alignment sleeves between each behind-the-wall port and the corresponding non-behind-the-wall port;

wherein the adapter housing is configured to receive a behind-the-wall optical connector in each behind-the-wall port and a non-behind-the-wall connector in each non-behind-the-wall port, each behind-the-wall connector and each non-behind-the-wall connector comprising a plurality of optical fiber ferrules, the plurality of ferrule alignment sleeves between each behind-the-wall port and the corresponding non-behind-the-wall port configured to receive the plurality of optical ferrules of the behind-the-wall optical connector received in the behind-the-wall port and the plurality of optical ferrules of the non-behind-the-wall connector in received in the non-behind-the-wall port;

wherein the adapter is configured to retain the behind-the-wall connector in the behind-the-wall port and the non-behind-the-wall connector in the non-behind-the-wall port such that an optical connection is made between the plurality of ferrules of the behind-the-wall connector and the plurality of ferrules of the non-behind-the-wall connector in the adapter housing;

wherein the adapter housing has an upper wall portion and an opposite lower wall portion, the upper wall portion defining a latch recess for each behind-the-wall port configured to latch with a depressible latch arm on a connector housing of the behind-the-wall connector received in the behind-the-wall port to retain the behind-the-wall connector in the behind-the-wall port.

2. The adapter as set forth in claim **1**, wherein the adapter is configured to retain the behind-the-wall connector in each behind-the-wall port and the non-behind-the-wall connector in each non-behind-the-wall port such that the plurality of optical fiber ferrules of the behind-the-wall connector engage the plurality of optical fiber ferrules of the non-behind-the-wall connector at an optical reference plane.

3. The adapter as set forth in claim **2**, wherein the optical reference plane is spaced apart from opposite second end portion of the adapter housing along the longitudinal axis by a greater distance than the optical reference plane is spaced apart from the first end portion along the longitudinal axis.

4. The adapter as set forth in claim **2**, wherein the adapter is configured to retain the behind-the-wall connector in each behind-the-wall port and the non-behind-the-wall connector in each non-behind-the-wall port such that a longitudinal distance from the optical reference plane to a distal end of the behind-the-wall connector is greater than a longitudinal distance from the optical reference plane to a distal end of the non-behind-the-wall connector.

5. The adapter as set forth in claim **1**, wherein each non-behind-the-wall port is configured to receive a portion of an elongate release of the non-behind-the-wall connector when the non-behind-the-wall connector is retained in the non-behind-the-wall port.

6. The adapter as set forth in claim **5**, wherein the adapter housing is configured such that the elongate release is slidable in the non-behind-the-wall port to unlatch the non-behind-the-wall connector from the adapter.

7. The adapter as set forth in claim **1**, wherein the adapter housing has a height extending from the lower wall portion to the upper wall portion.

8. The adapter as set forth in claim **7**, wherein the height of the adapter housing is less at the first end portion than at the second end portion.

9. The adapter as set forth in claim **7**, wherein the adapter housing has a width and the plurality of behind-the-wall ports and the plurality of non-behind-the-wall ports are spaced apart along the width.

10. The adapter as set forth in claim **9**, wherein the upper wall portion comprises an upper longitudinal rib adjacent the second end portion, the upper longitudinal rib projecting inwardly along the height toward the lower wall portion, wherein the lower wall portion comprises a lower longitudinal rib adjacent the second end portion, the lower longitudinal rib projecting inwardly along the height toward the upper wall portion.

11. The adapter as set forth in claim **10**, wherein the upper longitudinal rib and the lower longitudinal rib are located between two of the plurality of non-behind-the-wall ports along the width.

12. The adapter as set forth in claim **11**, wherein the upper longitudinal rib and the lower longitudinal rib are separated by a heightwise gap.

13. The adapter as set forth in claim **12**, wherein the upper longitudinal rib has a height and the lower longitudinal rib has a height less than the height of the upper longitudinal rib.

14. The adapter as set forth in claim **9**, wherein the plurality of ferrule alignment sleeves comprises a pair of ferrule alignment sleeves between each of the plurality of behind-the-wall ports and a corresponding non-behind-the-wall port.

15. A connection system comprising the adapter as set forth in claim **1** and a behind-the-wall connector.

16. The connection system as set forth in claim **15**, wherein the behind-the-wall connector comprises: first and second optical fiber ferrules; a duplex connector housing having a longitudinal axis and comprising an exterior portion at least partially surrounding the first and second optical fiber ferrules such that the exterior portion extends 360° about a space in which each of the first and second optical fiber ferrules are received; and a depressible latch arm disposed on the duplex connector housing.

17. The connection system as set forth in claim **16**, further comprising a non-behind-the-wall connector.

18. The connection system as set forth in claim **17**, wherein the non-behind-the-wall connector comprises: first and second optical fiber ferrules; a duplex connector housing having a longitudinal axis and comprising an exterior portion at least partially surrounding the first and second optical fiber ferrules such that the exterior portion extends 360° about a space in which each of the first and second optical fiber ferrules are received; and an elongate release slidable along the longitudinal axis to unlatch the non-behind-the-wall connector from the non-behind-the-wall port of the adapter.

19. The connection system as set forth in claim **17**, wherein the behind-the-wall connector has a length and the non-behind-the-wall connector has a length greater than the length of the behind-the-wall connector.

* * * * *

EXHIBIT K

US011585989B2

(12) **United States Patent**
Takano et al.

(10) **Patent No.: US 11,585,989 B2**
(45) **Date of Patent: *Feb. 21, 2023**

(54) **SMALL FORM FACTOR FIBER OPTIC CONNECTOR WITH MULTI-PURPOSE BOOT**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **17/342,988**

(22) Filed: **Jun. 9, 2021**

(65) **Prior Publication Data**

US 2021/0294045 A1 Sep. 23, 2021

Related U.S. Application Data

(60) Continuation of application No. 16/782,196, filed on Feb. 5, 2020, now Pat. No. 11,061,190, which is a

(Continued)

(51) **Int. Cl.**

G02B 6/38	(2006.01)
G02B 6/40	(2006.01)
G02B 6/42	(2006.01)

(52) **U.S. Cl.**

CPC ***G02B 6/38875*** (2021.05); ***G02B 6/387*** (2013.01); ***G02B 6/3825*** (2013.01);

(Continued)

(58) **Field of Classification Search**

CPC G02B 6/387; G02B 6/3821; G02B 6/3825; G02B 6/3831

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

681,132	A	8/1901	Norton
3,721,945	A	3/1973	Hults

(Continued)

FOREIGN PATENT DOCUMENTS

CA	2495693	A1	4/2004
CA	2495693	A1	4/2004

(Continued)

OTHER PUBLICATIONS

International Search Report and Written Opinion; Application No. PCT/US2018/042202, dated Dec. 7, 2018, pp. 17.

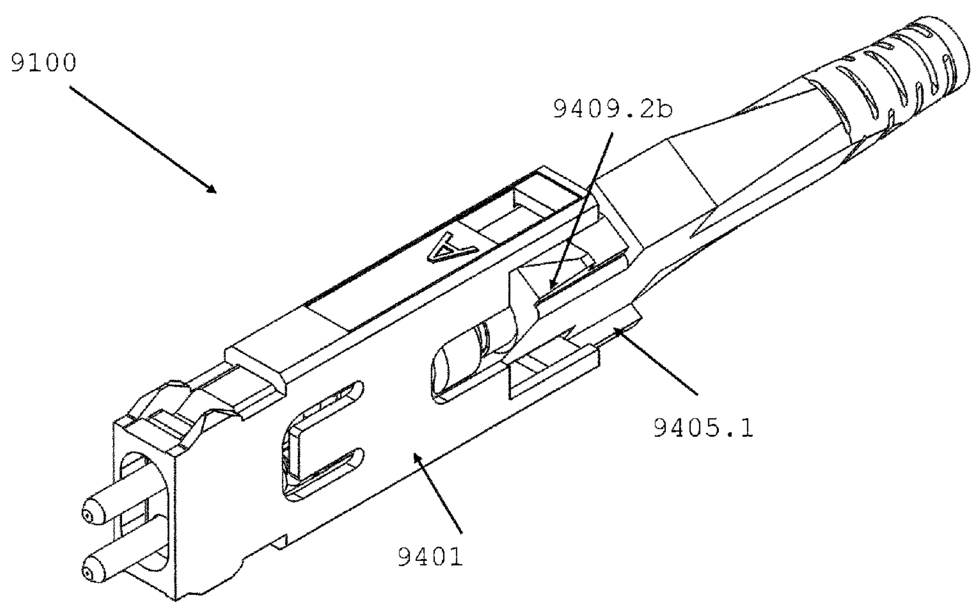
(Continued)

Primary Examiner — Eric Wong

(57) **ABSTRACT**

An optical connector holding two or more LC-type optical ferrules is provided. The optical connector includes an outer body, an inner front body accommodating the two or more LC-type optical ferrules, ferrule springs for urging the optical ferrules towards a mating connection, and a back body for supporting the ferrule springs. A removable inner front body for polarity change is disclosed. A multi-purpose rotatable boot assembly for polarity change is disclosed. The multi-purpose boot assembly can be pushed and pulled to insert and remove the micro connector from an adapter receptacle.

20 Claims, 32 Drawing Sheets



Related U.S. Application Data

division of application No. 16/368,828, filed on Mar. 28, 2019, now Pat. No. 10,705,300, and a continuation of application No. 16/103,555, filed on Aug. 14, 2018, now Pat. No. 10,718,911, which is a continuation-in-part of application No. 16/035,691, filed on Jul. 15, 2018, now Pat. No. 10,281,668.

(60) Provisional application No. 62/649,539, filed on Mar. 28, 2018, provisional application No. 62/588,276, filed on Nov. 17, 2017, provisional application No. 62/549,655, filed on Aug. 24, 2017, provisional application No. 62/532,710, filed on Jul. 14, 2017.

(52) **U.S. Cl.**
CPC ***G02B 6/3879*** (2013.01); ***G02B 6/3887*** (2013.01); ***G02B 6/3893*** (2013.01); ***G02B 6/403*** (2013.01); ***G02B 6/406*** (2013.01); ***G02B 6/4292*** (2013.01); *G02B 6/3821* (2013.01)

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,150,790 A 4/1979 Potter
4,240,695 A 12/1980 Evans
4,327,964 A 5/1982 Haesley et al.
4,478,473 A 10/1984 Frear
4,762,388 A 8/1988 Tanaka et al.
4,764,129 A 8/1988 Jones et al.
4,840,451 A 6/1989 Sampson et al.
4,872,736 A 10/1989 Myers et al.
4,979,792 A 12/1990 Weber
5,026,138 A 6/1991 Boudreau
5,031,981 A 7/1991 Peterson
5,011,025 A 8/1991 Haitmanek
5,041,025 A 8/1991 Haitmanek
5,073,045 A 12/1991 Abendschein
D323,143 S 1/1992 Ohkura et al.
5,101,463 A 3/1992 Cubukciyan
5,146,813 A 9/1992 Stanfill, Jr.
5,159,652 A 10/1992 Grassin D'Alphonse
5,212,752 A 5/1993 Stephenson et al.
5,265,181 A 11/1993 Chang
5,289,554 A 2/1994 Cubukciyan et al.
5,315,679 A 5/1994 Baldwin
5,317,663 A 5/1994 Beard et al.
5,321,784 A 6/1994 Cubukciyan et al.
5,335,301 A 8/1994 Newman et al.
5,348,487 A 9/1994 Marazzi et al.
5,418,875 A 5/1995 Nakano
5,444,806 A 8/1995 de Marchi et al.
5,481,634 A 4/1996 Anderson et al.
5,506,922 A 4/1996 Grois et al.
5,521,997 A 5/1996 Rovenolt et al.
5,570,445 A 10/1996 Chou et al.
5,588,079 A 12/1996 Tanabe et al.
5,602,951 A 2/1997 Shiota
5,684,903 A 11/1997 Kyomasu et al.
5,687,268 A 11/1997 Stephenson et al.
5,781,681 A 7/1998 Manning
5,845,036 A 12/1998 De Marchi
5,862,282 A 1/1999 Matsuura
5,915,987 A 6/1999 Reed
5,930,426 A 7/1999 Harting
5,937,130 A 8/1999 Amberg et al.
5,953,473 A 9/1999 Shimotsu
5,956,444 A 9/1999 Duda et al.
5,971,626 A 10/1999 Knodell et al.
6,041,155 A 3/2000 Anderson et al.
6,049,040 A 4/2000 Biles et al.
6,095,862 A 8/2000 Doye
6,134,370 A 10/2000 Childers et al.
6,178,283 B1 1/2001 Weigel
RE37,080 E 3/2001 Stephenson et al.
6,206,577 B1 3/2001 Hall, III et al.
6,206,581 B1 3/2001 Driscoll et al.
6,227,717 B1 5/2001 Ott et al.
6,238,104 B1 5/2001 Yamakawa et al.
6,240,228 B1 5/2001 Chen
6,247,849 B1 6/2001 Liu
6,250,817 B1 6/2001 Lampert et al.
6,276,840 B1 8/2001 Weiss
6,318,903 B1 11/2001 Andrews
6,364,537 B1 4/2002 Maynard
6,379,052 B1 4/2002 de Jong
6,422,759 B1 7/2002 Kevern
6,450,695 B1 9/2002 Matsumoto
6,461,054 B1 10/2002 Iwase
6,471,412 B1 10/2002 Belenkiy et al.
6,478,472 B1 11/2002 Anderson et al.
6,485,194 B1 11/2002 Shirakawa
6,527,450 B1 3/2003 Miyachi
6,530,696 B1 3/2003 Ueda
6,551,117 B2 4/2003 Poplawski et al.
6,565,262 B2 5/2003 Childers
6,572,276 B1 6/2003 Theis
6,579,014 B2 6/2003 Melton et al.
6,585,194 B1 7/2003 Brushwood
6,634,796 B2 10/2003 de Jong
6,634,801 B1 10/2003 Waldron et al.
6,648,520 B2 11/2003 McDonald et al.
6,668,113 B2 12/2003 Togami
6,682,228 B2 1/2004 Ralhnam et al.
6,685,362 B2 2/2004 Burkholder et al.
6,695,486 B1 2/2004 Falkenberg
6,811,321 B1 11/2004 Schmalzigaug et al.
6,817,272 B2 11/2004 Holland
6,854,894 B1 2/2005 Yunker et al.
6,869,227 B2 3/2005 Del Grosso
6,872,039 B2 3/2005 Baus et al.
6,935,789 B2 8/2005 Gross, III et al.
7,036,993 B2 5/2006 Luther
7,052,186 B1 5/2006 Bates
7,077,576 B2 7/2006 Luther
7,090,407 B2 8/2006 Melton et al.
7,091,421 B2 8/2006 Kukita et al.
7,111,990 B2 9/2006 Melton et al.
7,113,679 B2 9/2006 Melton et al.
D533,504 S 12/2006 Lee
D534,124 S 12/2006 Taguchi
7,150,567 B1 12/2006 Luther et al.
7,153,041 B2 12/2006 Mine et al.
7,198,409 B2 4/2007 Smith et al.
7,207,724 B2 4/2007 Gurreri
D543,146 S 5/2007 Chen et al.
7,258,493 B2 8/2007 Milette
7,261,472 B2 8/2007 Suzuki et al.
7,264,402 B2 9/2007 Theuerkorn
7,281,859 B2 10/2007 Mudd et al.
7,284,912 B2 10/2007 Suzuki et al.
D558,675 S 1/2008 Chien et al.
7,315,682 B1 1/2008 En Lin et al.
7,325,976 B2 2/2008 Gurreri et al.
7,325,980 B2 2/2008 Pepe
7,329,137 B2 2/2008 Martin et al.
7,347,634 B2 3/2008 Gunther et al.
7,354,291 B2 4/2008 Caveney et al.
7,331,718 B2 5/2008 Yazaki et al.
7,371,082 B2 5/2008 Zimmell et al.
7,387,447 B2 6/2008 Mudd et al.
7,390,203 B2 6/2008 Murano et al.
D572,661 S 7/2008 En Lin et al.
7,431,604 B2 10/2008 Waters et al.
7,463,803 B2 12/2008 Cody et al.
7,465,180 B2 12/2008 Kusuda et al.
7,473,124 B1 1/2009 Briant
7,510,335 B1 3/2009 Su et al.
7,513,695 B1 4/2009 Lin et al.
7,534,128 B2 5/2009 Caveney et al.
7,540,666 B2 6/2009 Luther
7,561,775 B2 7/2009 Lin et al.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,588,373	B1	9/2009	Sato
7,591,595	B2	9/2009	Lue et al.
7,594,766	B1	9/2009	Sasser et al.
7,641,398	B2	1/2010	O'Riorden et al.
7,695,199	B2	4/2010	Teo et al.
7,699,533	B2	4/2010	Milette
7,712,970	B1	5/2010	Lee
7,717,625	B2	5/2010	Margolin et al.
7,824,113	B2	11/2010	Wong et al.
7,837,395	B2	11/2010	Lin et al.
D641,708	S	7/2011	Tammauchi
8,083,450	B1	12/2011	Smith et al.
8,152,385	B2	4/2012	de Jong
8,186,890	B2	5/2012	Lu
8,192,091	B2	6/2012	Hsu et al.
8,202,009	B2	6/2012	Lin et al.
8,221,007	B2	7/2012	Peterhans
8,251,733	B2	8/2012	Wu
8,267,595	B2	9/2012	Lin et al.
8,270,796	B2	9/2012	Nhep
8,408,815	B2	4/2013	Lin et al.
8,414,196	B2	4/2013	Lu
8,465,317	B2	6/2013	Gniadek et al.
8,534,928	B2	9/2013	Cooke
8,550,728	B2	10/2013	Takahashi
8,556,645	B2	10/2013	Crain
8,559,781	B2	10/2013	Childers
8,622,634	B2	1/2014	Arnold
8,636,424	B2	1/2014	Kuffel et al.
8,651,749	B2	2/2014	Clovis et al.
8,676,022	B2	3/2014	Jones
8,678,670	B2	3/2014	Takahashi
8,727,638	B2	5/2014	Lee
8,757,894	B2	6/2014	Katoh
8,764,308	B2	7/2014	Irwin
8,770,863	B2	7/2014	Cooke et al.
8,869,661	B2	10/2014	Opstad
9,052,474	B2	6/2015	Jiang
9,063,296	B2	6/2015	Dong
9,250,399	B2	2/2016	Margolin et al.
9,250,402	B2	2/2016	Ishii et al.
9,310,569	B2	4/2016	Lee
9,366,829	B2	6/2016	Czosnowski
9,411,110	B2	8/2016	Barnette, Jr. et al.
9,448,370	B2	9/2016	Xue et al.
9,465,172	B2	10/2016	Shih
9,494,744	B2	11/2016	de Jong
9,548,557	B2	1/2017	Liu
9,551,842	B2	1/2017	Theuerkorn
9,557,495	B2	1/2017	Raven et al.
9,568,686	B2	2/2017	Fewkes et al.
9,581,768	B1	2/2017	Baca et al.
9,599,778	B2	3/2017	Wong et al.
9,658,409	B2	5/2017	Gniadek
9,678,283	B1	6/2017	Chang et al.
9,684,130	B2	6/2017	Veatch et al.
9,684,136	B2	6/2017	Cline et al.
9,684,313	B2	6/2017	Chajec
9,709,753	B1	8/2017	Chang et al.
9,778,425	B2	10/2017	Nguyen
9,829,644	B2	11/2017	Nguyen
9,829,645	B2	11/2017	Good
9,829,653	B1	11/2017	Nishiguchi
9,869,825	B2	1/2018	Bailey et al.
9,880,361	B2	1/2018	Childers
9,946,035	B2	4/2018	Gustafson
9,971,103	B2	5/2018	de Jong et al.
9,989,711	B2	6/2018	Ott et al.
10,031,296	B2	7/2018	Good
10,067,301	B2	9/2018	Murray
10,107,972	B1	10/2018	Gniadek et al.
10,114,180	B2	10/2018	Suzic
10,146,011	B2	12/2018	Nhep
10,281,668	B2	5/2019	Takano et al.
10,281,669	B2	5/2019	Takano et al.
2002/0168148	A1	11/2002	Gilliland
2002/0172467	A1	11/2002	Anderson et al.
2002/0191919	A1	12/2002	Nolan
2003/0053787	A1	3/2003	Lee
2003/0063862	A1	4/2003	Fillion
2003/0157825	A1	8/2003	Kane
2004/0052473	A1	3/2004	Seo
2004/0109646	A1	6/2004	Anderson
2004/0161958	A1	6/2004	Togami et al.
2004/0136657	A1	7/2004	Ngo
2004/0141693	A1	7/2004	Szilagyi et al.
2004/0234209	A1	11/2004	Cox et al.
2004/0247252	A1	12/2004	Ehrenreich
2005/0036744	A1	2/2005	Caveney et al.
2005/0111796	A1	5/2005	Matasek et al.
2005/0135755	A1	6/2005	Kiani et al.
2005/0141817	A1	6/2005	Yazaki et al.
2006/0013539	A1	1/2006	Thaler
2006/0076061	A1	4/2006	Bush
2006/0089049	A1	4/2006	Sedor
2006/0127025	A1	6/2006	Haberman
2006/0153503	A1	7/2006	Suzuki
2006/0160429	A1	7/2006	Dawiedczyk et al.
2006/0193562	A1	8/2006	Theuerkorn
2006/0269194	A1	11/2006	Luther et al.
2006/0274411	A1	12/2006	Yamauchi
2007/0025665	A1	2/2007	Dean
2007/0028409	A1	2/2007	Yamada
2007/0079854	A1	4/2007	You
2007/0098329	A1	6/2007	Shimoji et al.
2007/0149028	A1	6/2007	Yu et al.
2007/0149062	A1	6/2007	Long et al.
2007/0230874	A1	10/2007	Lin
2007/0232115	A1	10/2007	Burke et al.
2007/0243749	A1	10/2007	Wu
2008/0008430	A1	1/2008	Kewitsch
2008/0013896	A1	1/2008	Salzberg et al.
2008/0044137	A1	2/2008	Luther et al.
2008/0056647	A1	3/2008	Margolin et al.
2008/0064334	A1	3/2008	Hamadi
2008/0069501	A1	3/2008	Mudd et al.
2008/0101757	A1	5/2008	Lin et al.
2008/0226237	A1	9/2008	O'Rioreden et al.
2008/0267566	A1	10/2008	En Lin
2009/0028507	A1	1/2009	Jones et al.
2009/0047818	A1	2/2009	Irwin et al.
2009/0092360	A1	4/2009	Lin et al.
2009/0176401	A1	7/2009	Gu
2009/0196555	A1	8/2009	Lin et al.
2009/0214162	A1	8/2009	O'Riorden et al.
2009/0220197	A1	9/2009	Gniadek
2009/0220200	A1	9/2009	Wong et al.
2009/0222457	A1	9/2009	Gallant
2009/0290839	A1	11/2009	En Lin
2009/0290938	A1	11/2009	Asaoka
2010/0034502	A1	2/2010	Lu et al.
2010/0054668	A1	3/2010	Nelson
2010/0061069	A1	3/2010	Cole
2010/0092136	A1	4/2010	Nhep
2010/0220961	A1	9/2010	de Jong et al.
2010/0247041	A1	9/2010	Szilagyi
2010/0284656	A1	11/2010	Morra
2010/0322561	A1	12/2010	Lin et al.
2011/0044588	A1	2/2011	Larson et al.
2011/0058773	A1	3/2011	Peterhans
2011/0131801	A1	6/2011	Nelson et al.
2011/0155810	A1	6/2011	Taniguichi
2011/0177710	A1	7/2011	Tobey
2011/0239220	A1	9/2011	Gibson
2012/0099822	A1	4/2012	Kuffel et al.
2012/0155810	A1	6/2012	Nakagawa
2012/0189260	A1	7/2012	Kowalczyk et al.
2012/0237177	A1	9/2012	Minota
2012/0269485	A1	10/2012	Haley et al.
2012/0301080	A1	11/2012	Gniadek
2012/0308183	A1	12/2012	Irwin
2012/0328248	A1	12/2012	Larson
2013/0019423	A1	1/2013	Srutkowski
2013/0071067	A1	3/2013	Lin

(56) **References Cited**

U.S. PATENT DOCUMENTS

2013/0089995	A1	4/2013	Gniadek et al.
2013/0094816	A1	4/2013	Lin et al.
2013/0101258	A1	4/2013	Hikosaka
2013/0121653	A1	5/2013	Shitama et al.
2013/0170797	A1	7/2013	Ott
2013/0183012	A1	7/2013	Lopez et al.
2013/0216185	A1	8/2013	Klavuhn
2013/0259429	A1	10/2013	Czosnowski et al.
2013/0308915	A1	11/2013	Buff
2013/0322825	A1	12/2013	Cooke et al.
2014/0016901	A1	1/2014	Lamboum et al.
2014/0023322	A1	1/2014	Gniadek
2014/0050446	A1	2/2014	Chang
2014/0056562	A1	2/2014	Limbert
2014/0133808	A1	5/2014	Hill et al.
2014/0169727	A1	6/2014	Veatch et al.
2014/0219621	A1	8/2014	Barnette, Jr. et al.
2014/0226946	A1	8/2014	Cooke et al.
2014/0241644	A1	8/2014	Kang
2014/0241678	A1	8/2014	Bringuier et al.
2014/0241688	A1	8/2014	Isenhour et al.
2014/0334780	A1	11/2014	Nguyen et al.
2014/0348477	A1	11/2014	Chang
2015/0003788	A1	1/2015	Chen
2015/0378841	A1	1/2015	Chen
2015/0111417	A1	4/2015	Vanderwoud
2015/0177463	A1	6/2015	Lee
2015/0198766	A1	7/2015	Takahashi
2015/0212282	A1	7/2015	Lin
2015/0241644	A1	8/2015	Lee
2015/0301294	A1	10/2015	Chang et al.
2015/0331201	A1	11/2015	Takano et al.
2015/0355417	A1	12/2015	Takano et al.
2015/0370021	A1	12/2015	Chan
2015/0378113	A1	12/2015	Good et al.
2016/0131849	A1	5/2016	Takano et al.
2016/0139343	A1	5/2016	Dean, Jr. et al.
2016/0161681	A1	6/2016	Banal, Jr. et al.
2016/0172852	A1	6/2016	Tamura
2016/0178852	A1	6/2016	Takano
2016/0195682	A1	6/2016	Takano
2016/0291262	A1	6/2016	Chang et al.
2016/0231512	A1	8/2016	Seki
2016/0259135	A1	9/2016	Gniadek et al.
2016/0266326	A1	9/2016	Gniadek
2016/0320572	A1	11/2016	Gniadek
2016/0349458	A1	12/2016	Murray
2016/0370545	A1	12/2016	Jiang
2017/0003458	A1	1/2017	Gniadek
2017/0205587	A1	7/2017	Chang et al.
2017/0205590	A1	7/2017	Bailey
2017/0205591	A1	7/2017	Takano et al.
2017/0212313	A1	7/2017	Elenabaas
2017/0212316	A1	7/2017	Takano
2017/0254961	A1	9/2017	Kamada et al.
2017/0276275	A1	9/2017	Beemer et al.
2017/0276887	A1	9/2017	Allen
2017/0277059	A1	9/2017	Miura et al.
2017/0343740	A1	11/2017	Nguyen
2018/0128988	A1	5/2018	Chang
2018/0156982	A1*	6/2018	Lu G02B 6/3885
2018/0156988	A1	6/2018	Gniadek
2018/0172923	A1	6/2018	Bauco
2018/0252872	A1	9/2018	Chen
2018/0341069	A1	11/2018	Takano
2019/0064447	A1	2/2019	Chang et al.
2019/0204513	A1	7/2019	Davidson et al.
2021/0263238	A1*	8/2021	Tseng G02B 6/3869

FOREIGN PATENT DOCUMENTS

CN	2836038	Y	11/2006
CN	2836038	Y	11/2006
CN	201383588	Y	1/2010
CN	201383588	Y	1/2010
CN	2026500189	U	12/2013
CN	106997078		8/2017
DE	19507669	A1	9/1996
DE	202006011910	U1	3/2007
DE	102006019335	U1	10/2007
EP	1074868	A1	2/2001
EP	1074868	A1	7/2001
EP	1211537	A2	6/2002
EP	1211537	A3	6/2002
EP	1245980	A1	10/2002
EP	1566674	A2	8/2005
GB	2111240	A	6/1983
JP	2000089059	A	3/2000
JP	03752331	B2	3/2006
JP	2009229545	A	10/2009
JP	2009276493	A	11/2009
JP	04377820	B2	12/2009
JP	2011027876	A	2/2011
JP	2012053375	A	3/2012
KR	20040028409	A	4/2006
KR	2009005382	A	1/2009
KR	200905382	U	6/2009
KR	1371686	B1	3/2014
TW	200821653	A	5/2008
WO	200179904	A2	10/2001
WO	WO2001079904	A2	10/2001
WO	2004027485	A1	4/2004
WO	WO2006007120	A1	1/2006
WO	2008112986	A1	9/2008
WO	2009135787	A1	11/2009
WO	2010024851	A2	3/2010
WO	2012136702	A1	10/2012
WO	2012162385	A1	11/2012
WO	WO2012162385	A1	11/2012
WO	2014028527	A1	2/2014
WO	2014182351	A1	11/2014
WO	WO2015103783	A1	7/2015
WO	2015191024	A1	12/2015
WO	2016019993	A1	2/2016
WO	2016148741	A1	9/2016
WO	WO2019126333	A1	6/2019

OTHER PUBLICATIONS

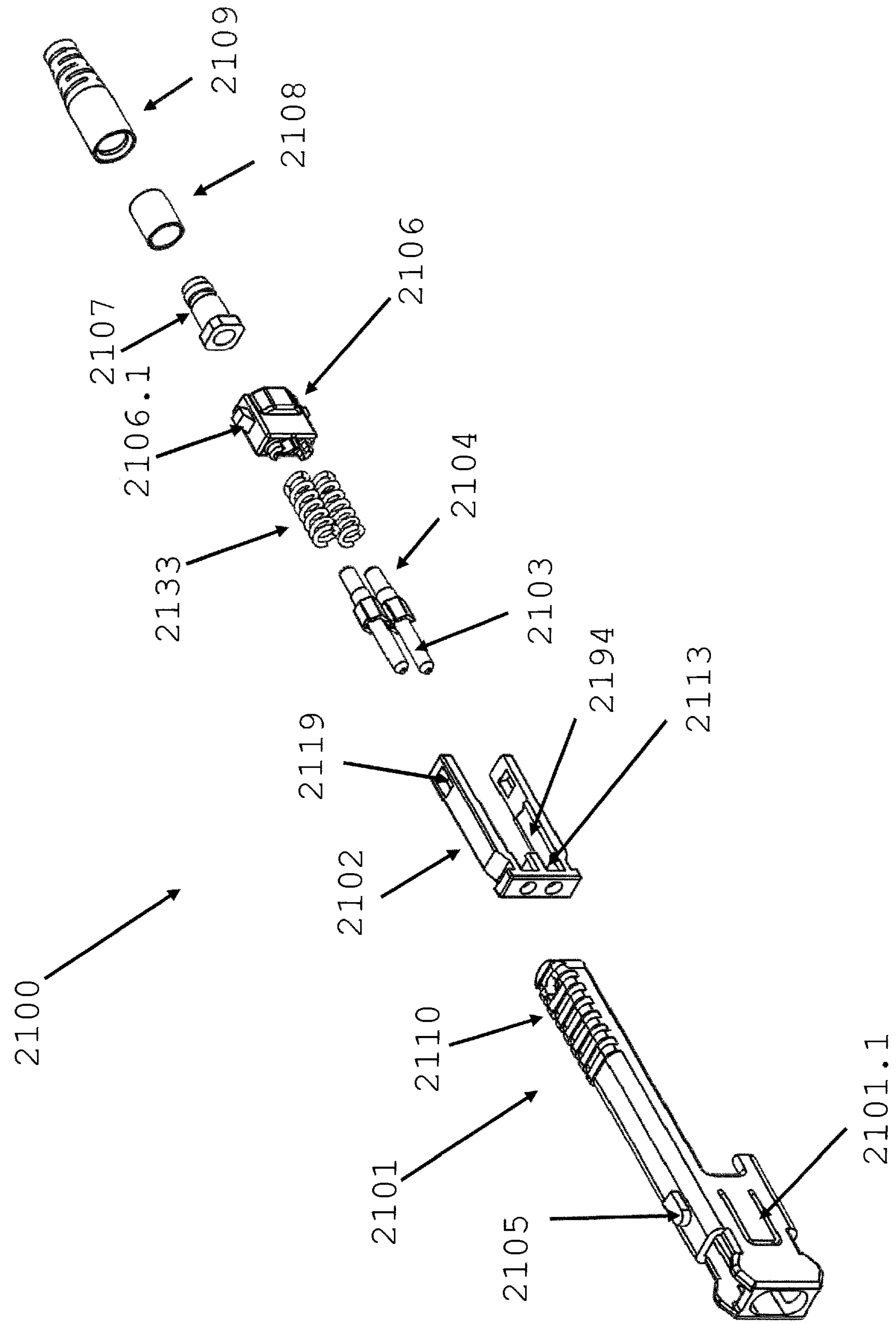
International Search Report and Written Opinion, Application No. PCT/US2019/013861, dated Apr. 8, 2019, pp. 15.
Fiber Optic Connectors Tutorial, 2018, pp. 20.
Fiber Optic Glossary, Feb. 29, 2016, pp. 93.
"Fiber Optic Interconnect Solutions, Tactical Fiber Optical Connectors, Cables and Termini" 2006, Glenair, Inc., Glendale, California, www.mps-electronics.de, pp. 232.
"Fiber Optic Products Catalog" Nov. 2007, Tyco Electronics Corporation, Harrisburg, Pennsylvania, www.ampnetconnect.com, pp. 204.
"Fiber Optic Connectors and Assemblies Catalog" 2009, Huber & Suhner Fiver Optics, Herisau, Switzerland, www.hubersuhner.com, pp. 104.
PCT/US2018/062406 International Search Report dated Mar. 18, 2019.
PCT/US2018/062406 The written Opinion dated Mar. 18, 2019.
PCT/US2018/062405 International Search Report dated Apr. 3, 2019.
PCT/US2018/062405 The written Opinion dated Apr. 3, 2019.
PCT/IB2018/056133 Written Opinion dated Jan. 3, 2019.
PCY/IB/056133 Search Report dated Jan. 3, 2019.
Final Office Action, U.S. Appl. No. 16/035,691, dated Feb. 11, 2019, pp. 8.
Non-Final Office Action, U.S. Appl. No. 16/035,695, dated Sep. 28, 2018, pp. 7.
International Search Report and Written Opinion, Application No. PCT/US/2018/042202, pp. 17, dated Dec. 7, 2018.
International Search Report and Written Opinion, Application No. PCT/US19/24718, dated Jun. 26, 2019, pp. 7.
ISR for PCT/US2019/013861, Apr. 8, 2019, 3 pages.
WO for PCT/US2019/013861, Apr. 8, 2019, 11 pages.

(56) **References Cited**

OTHER PUBLICATIONS

International Search Report and Written Opinion for Application No. PCT/US2018/62406 dated Mar. 18, 2019, 12, pages, United States.
International Search Report and Written Opinion for Application No. PCT/US2019/40700 dated Sep. 27, 2019, 12, pages, United States.
International Search Report and Written Opinion for Application No. PCT/US2019/50895 dated Jan. 6, 2020, 12, pages, United States.
International Search Report and Written Opinion for Application No. PCT/US2019/50909 dated Dec. 17, 2019, 11, pages, United States.
International Search Report and Written Opinion for Application No. PCT/US2019/56564 dated Jan. 14, 2020, 14, pages, United States.
International Search Report and Written Opinion, Application No. PCT/US19/46397, dated Nov. 12, 2019, pp. 6.
International Search Report; PCT/US2018/042202 filed Jul. 16, 2018; Applicant: Senko Advanced Components, Inc.
International Preliminary Report on Patentability for PCT/US2019/022940 dated Oct. 1, 2020, 11 pages.
Extended European Search Report and Written Opinion, Application No. 18832246.5, dated Mar. 15, 2021, pp. 6.

* cited by examiner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2101
2105

FIG. 1.

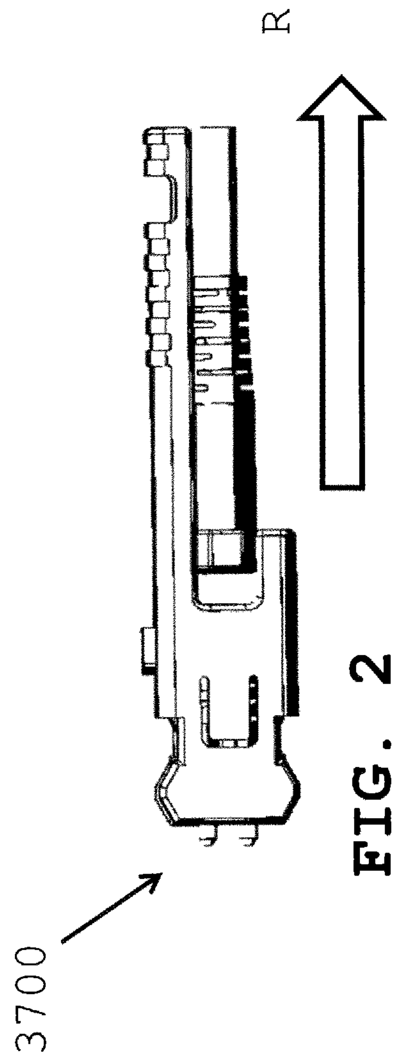
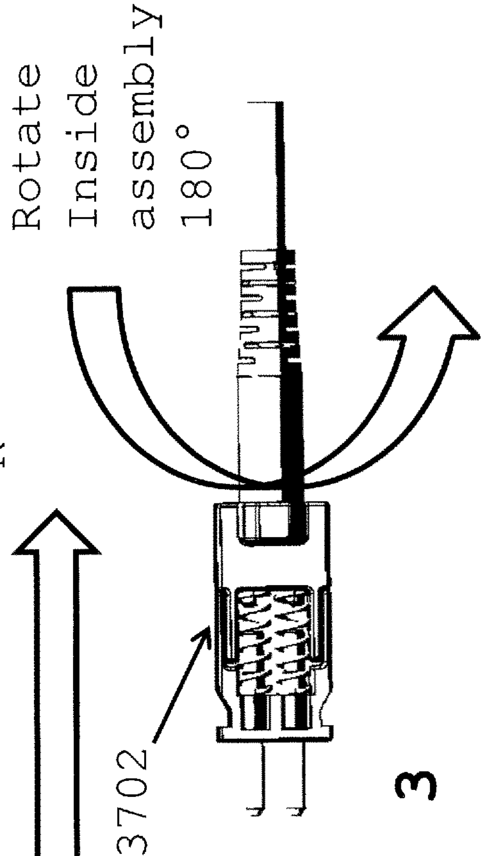


FIG. 2



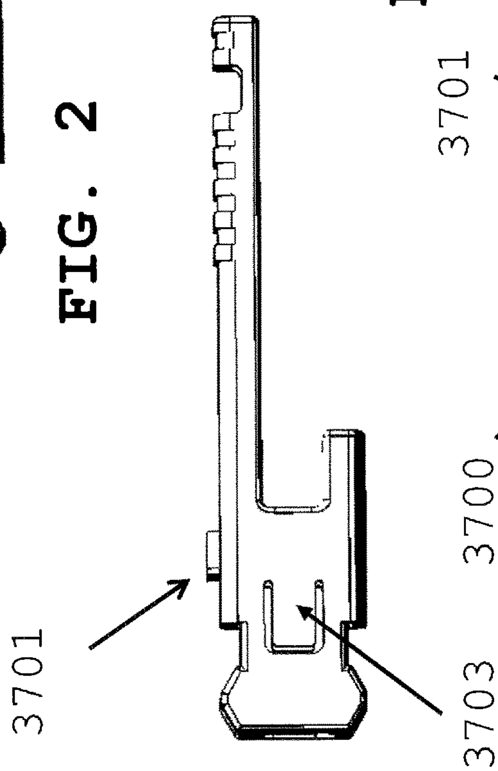


FIG. 3

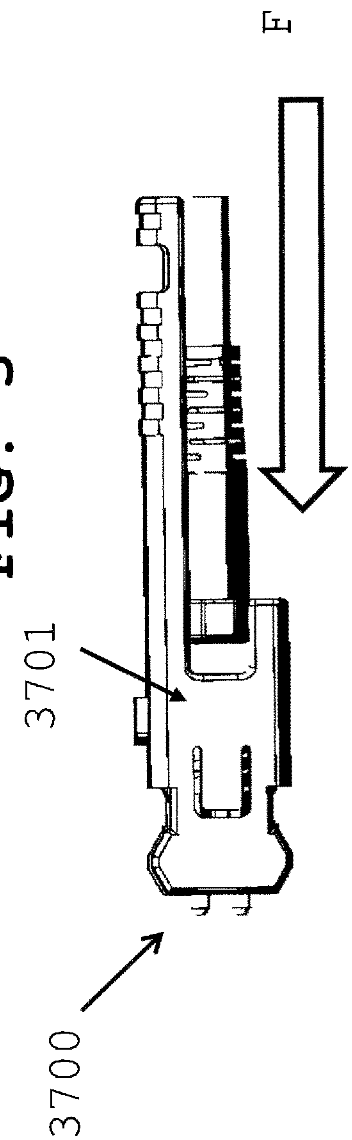


FIG. 4

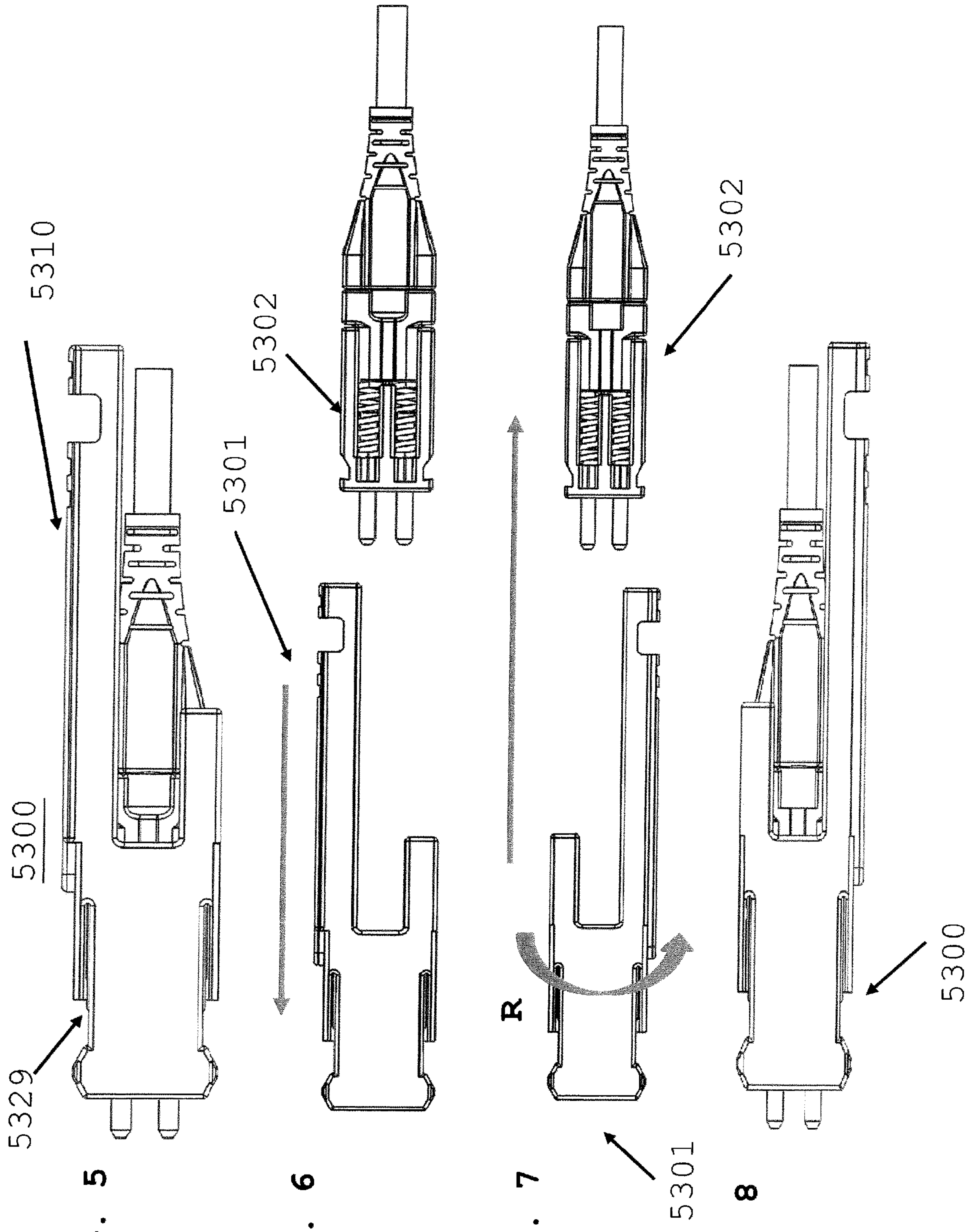


FIG. 5

FIG. 6

FIG. 7

FIG. 8

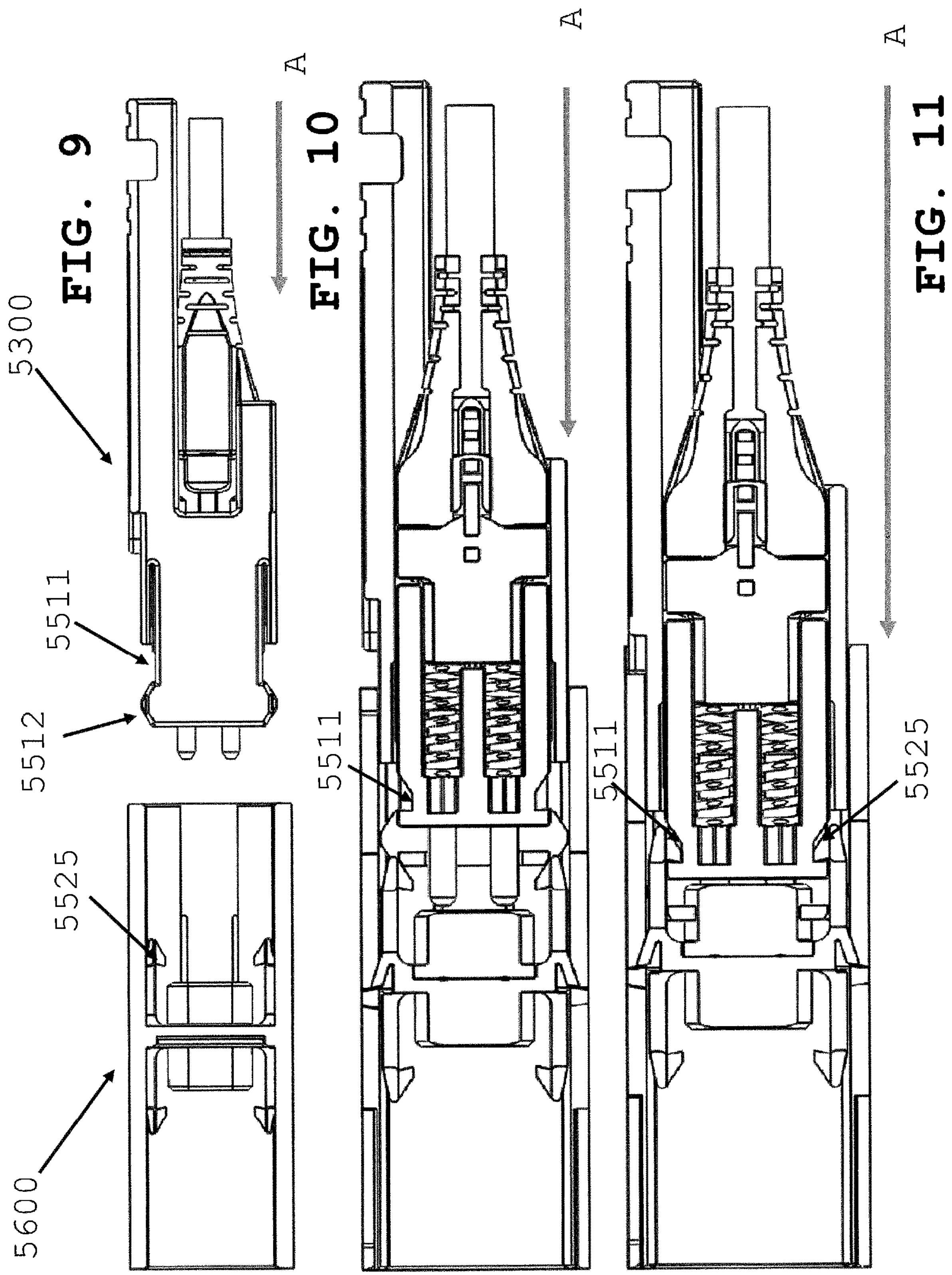

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FIG. 10
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FIG. 11
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5525
A

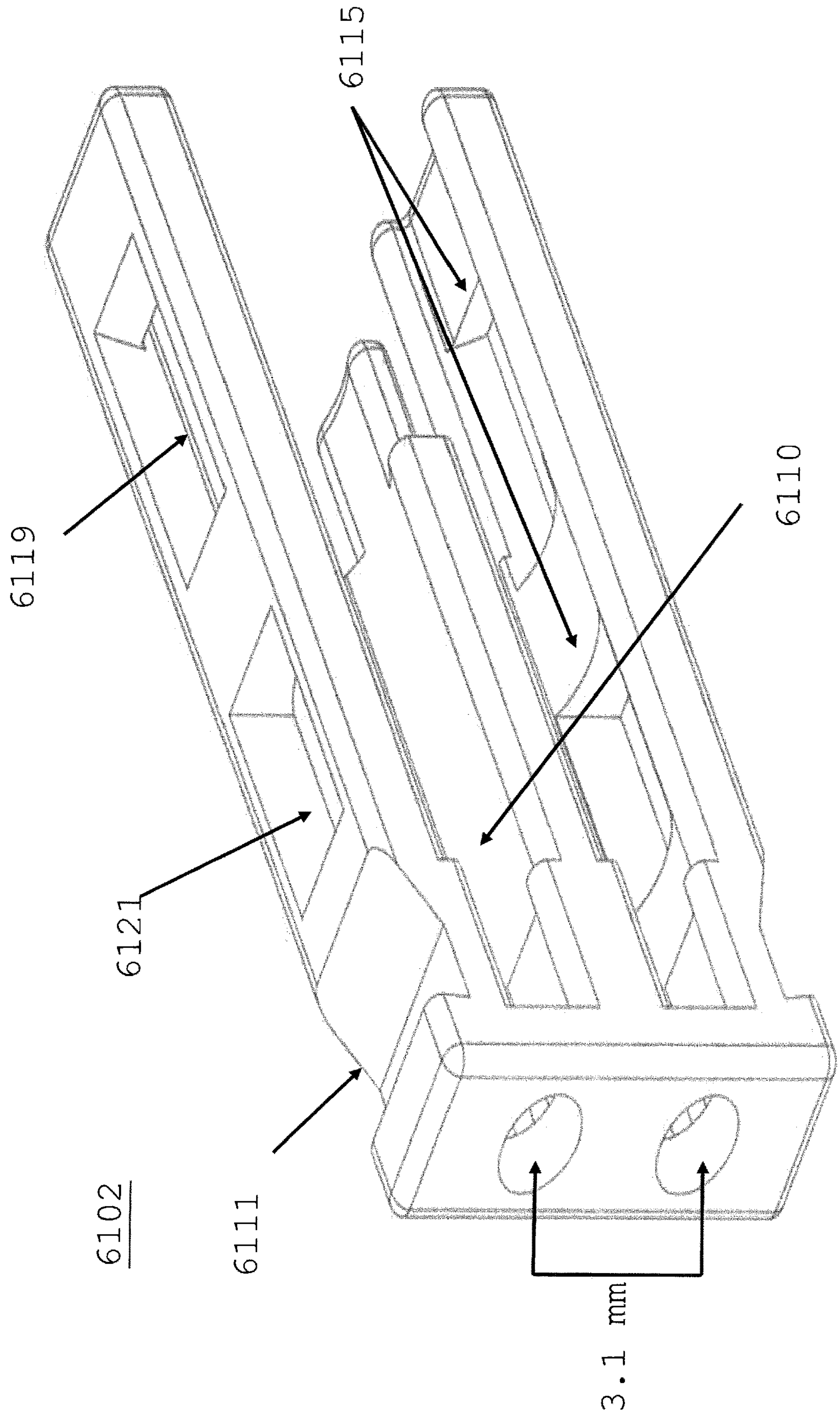


FIG. 12

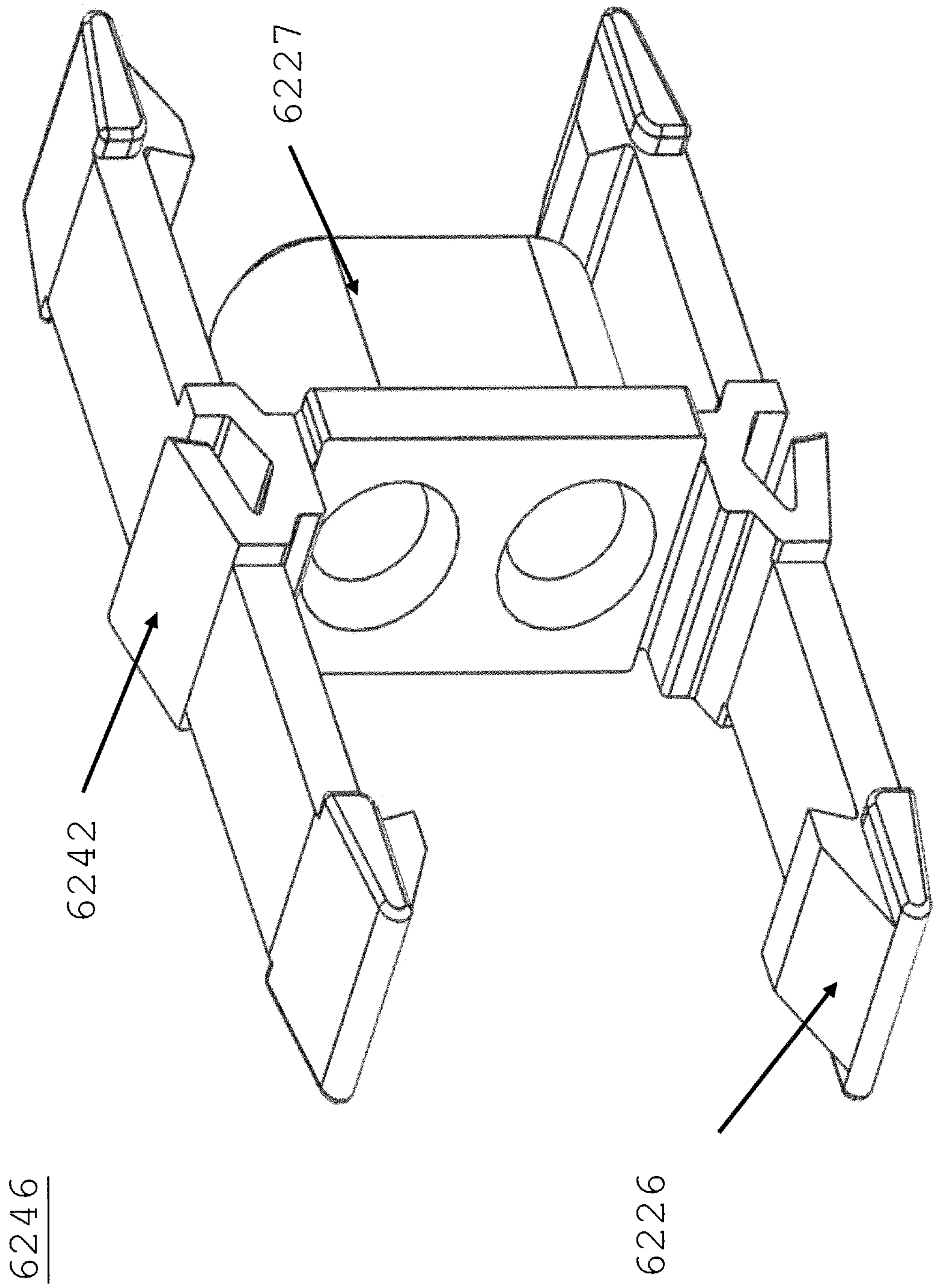


FIG. 13

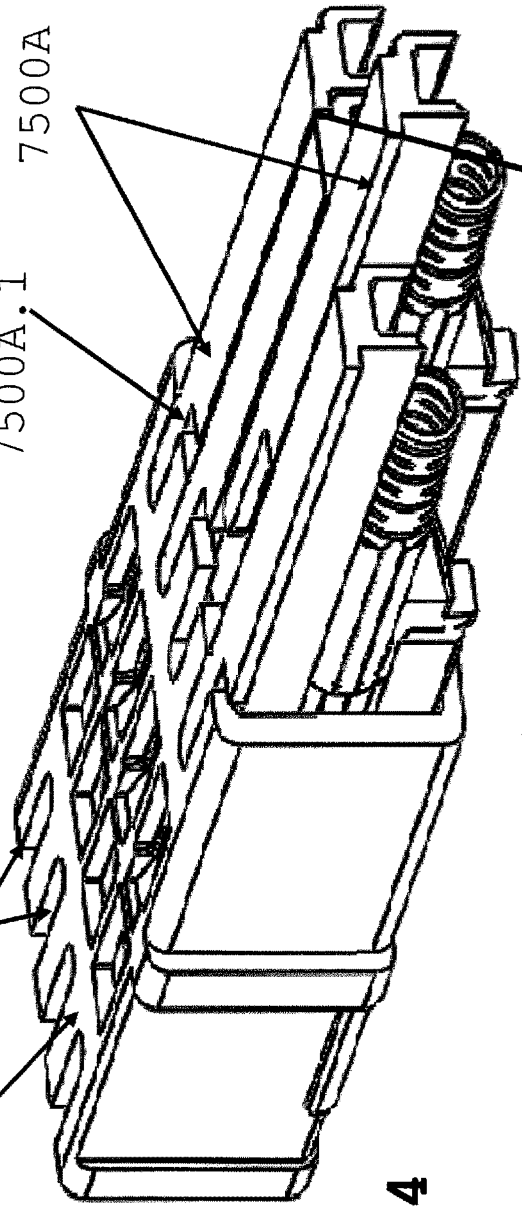


FIG. 14

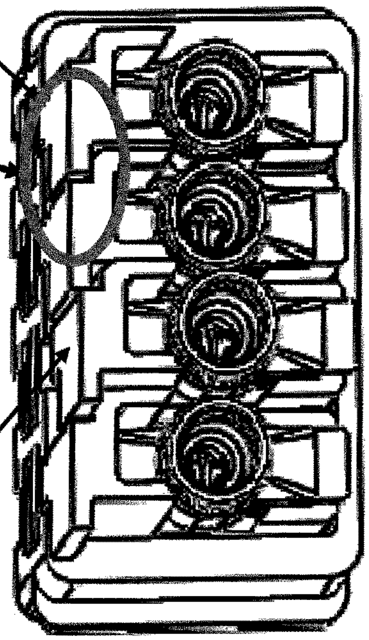


FIG. 15

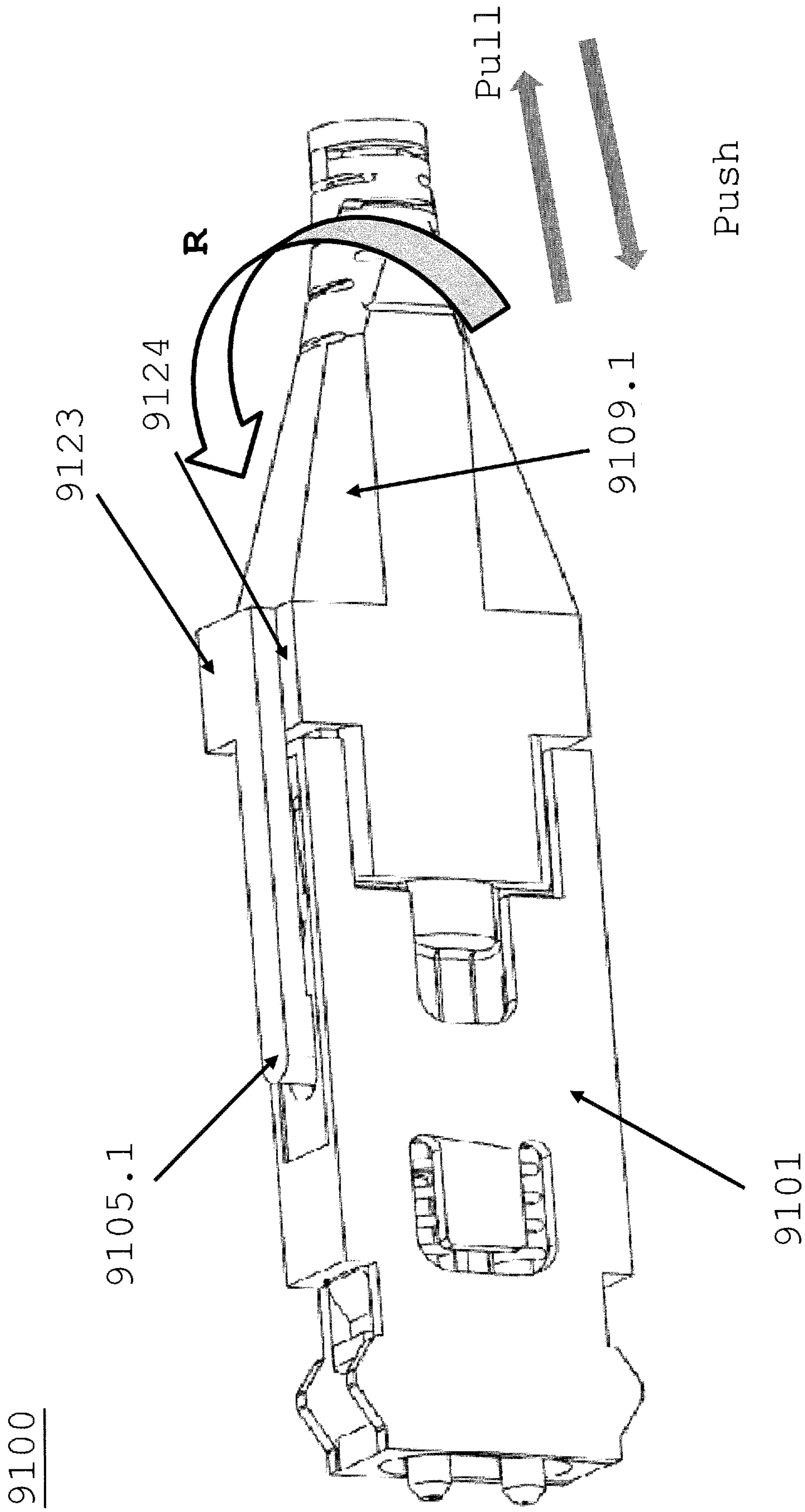


FIG. 16

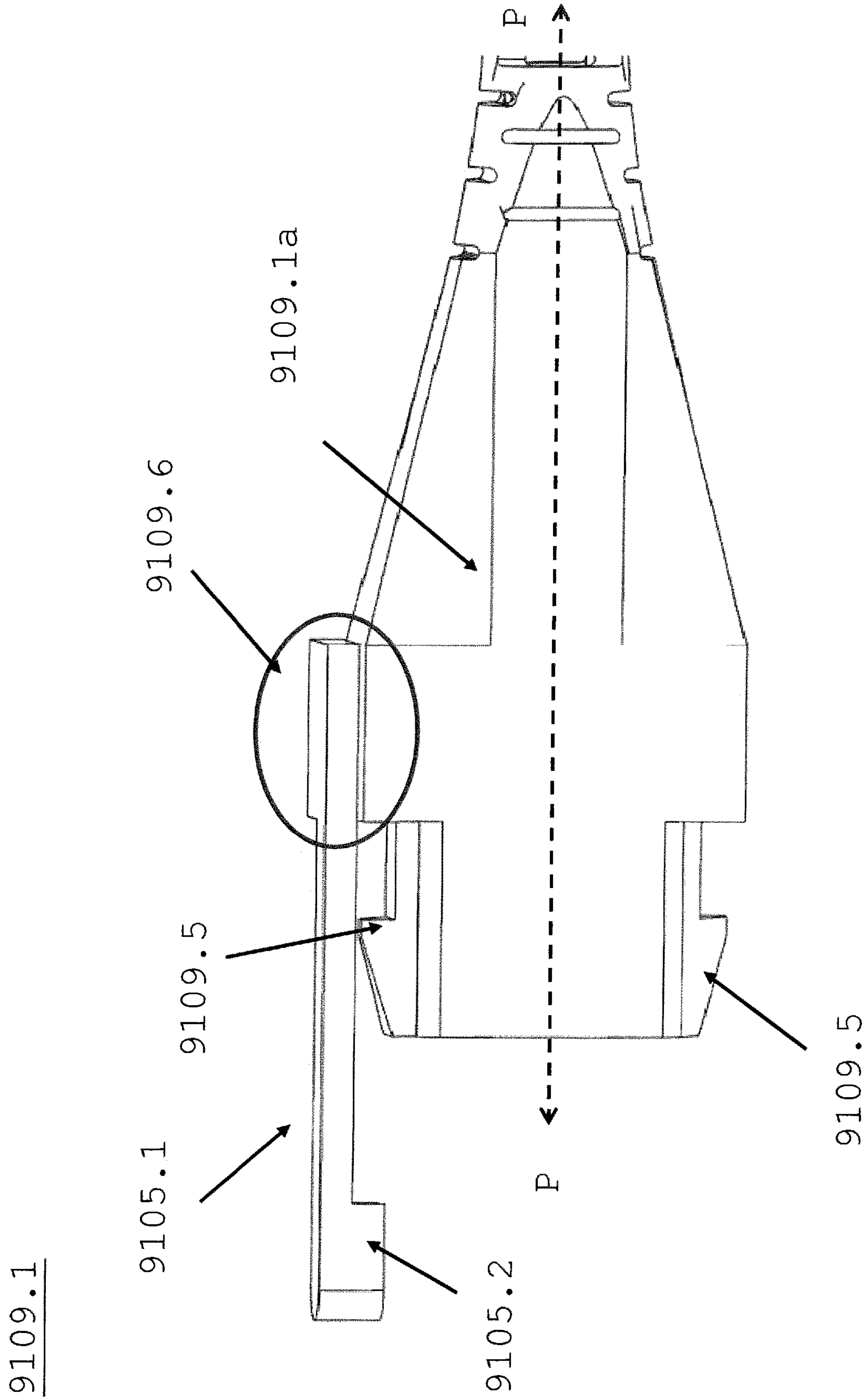
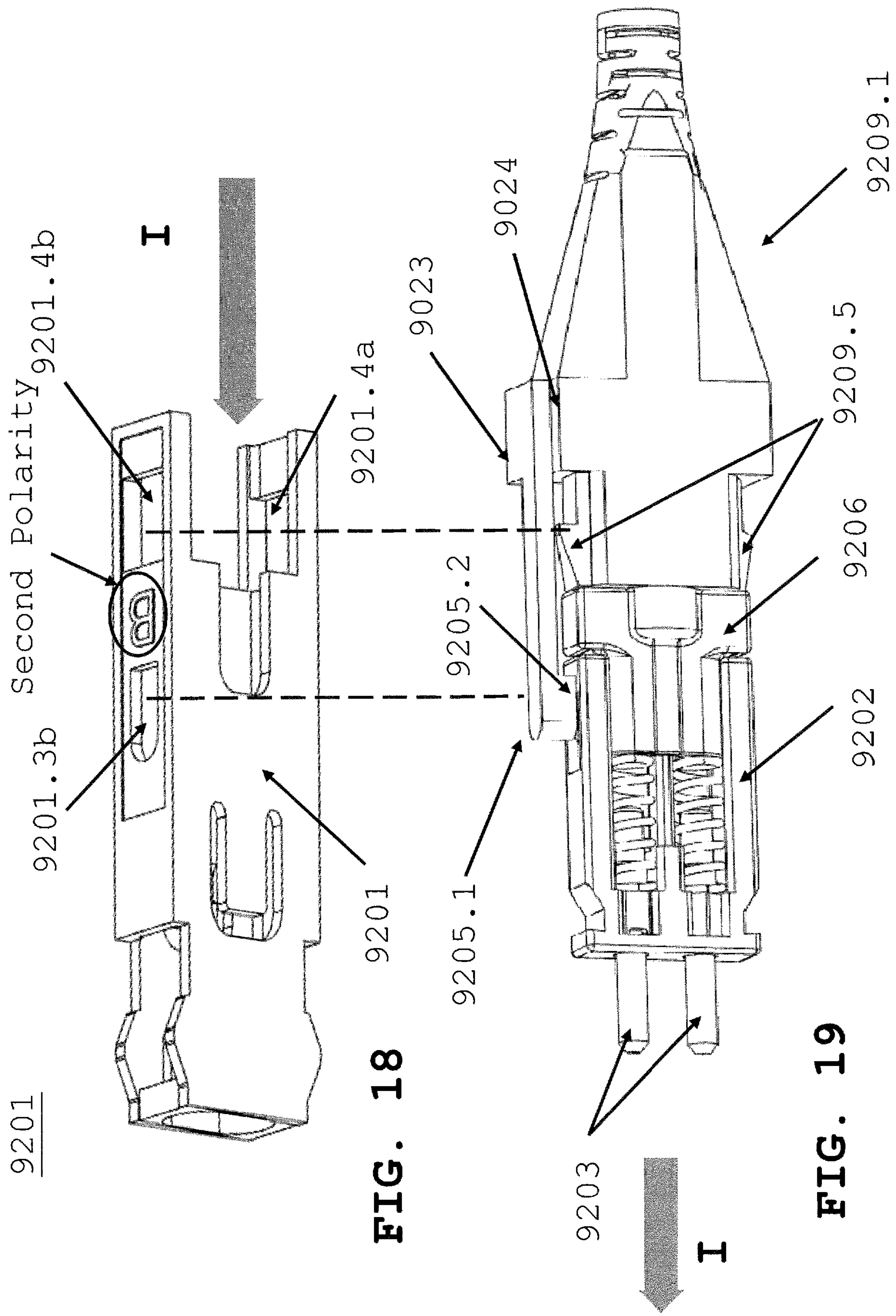


FIG. 17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9201.4a
9201
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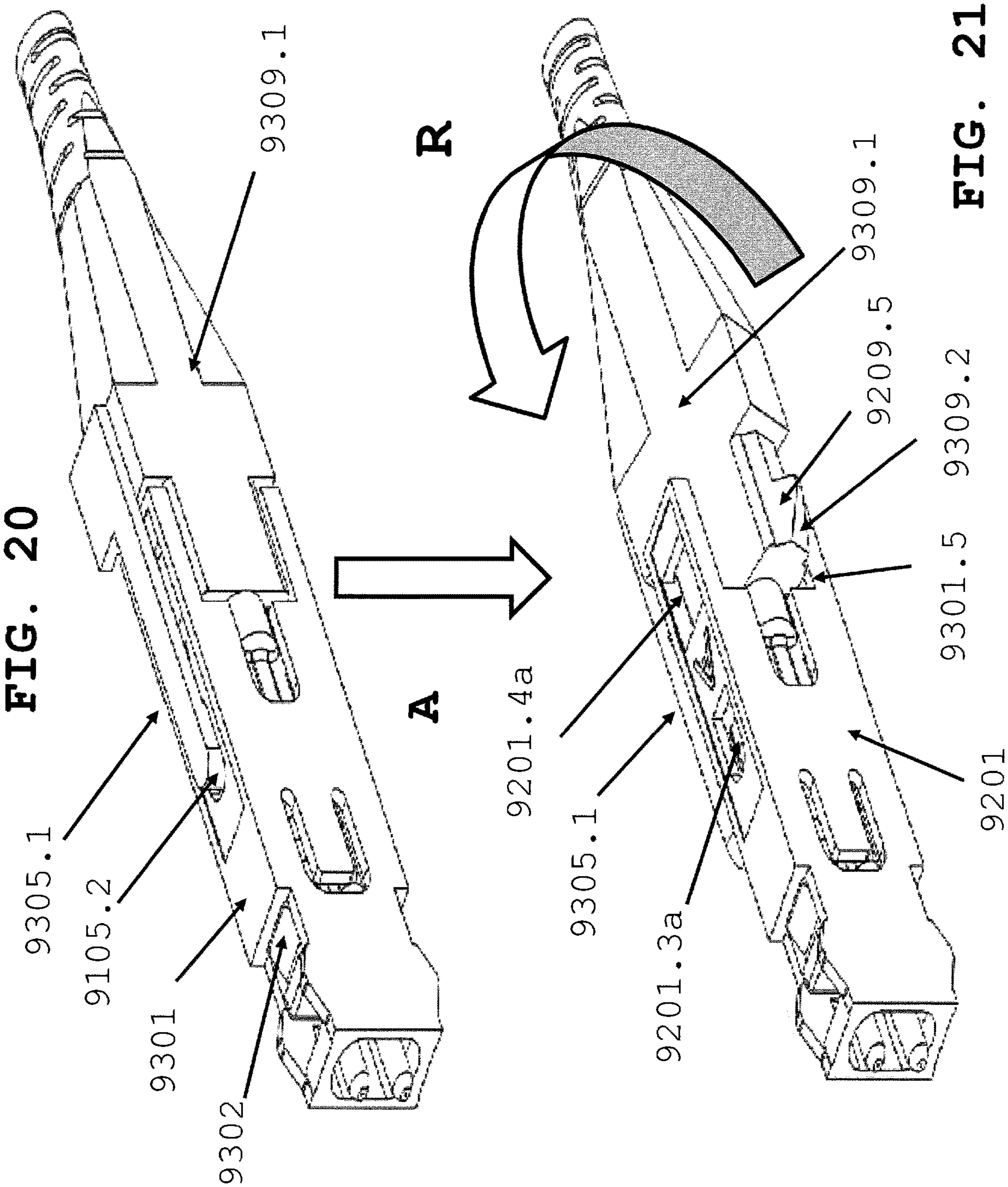
9205.2
9205.1
9209.1
9209.5
9206
9202
9203
I

FIG. 18

FIG. 19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9305.1
9105.2
9301
9302
A
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9309.1
9209.5
9309.2
9301.5
9201.4a
9305.1
9201.3a
9201

FIG. 20

FIG. 21

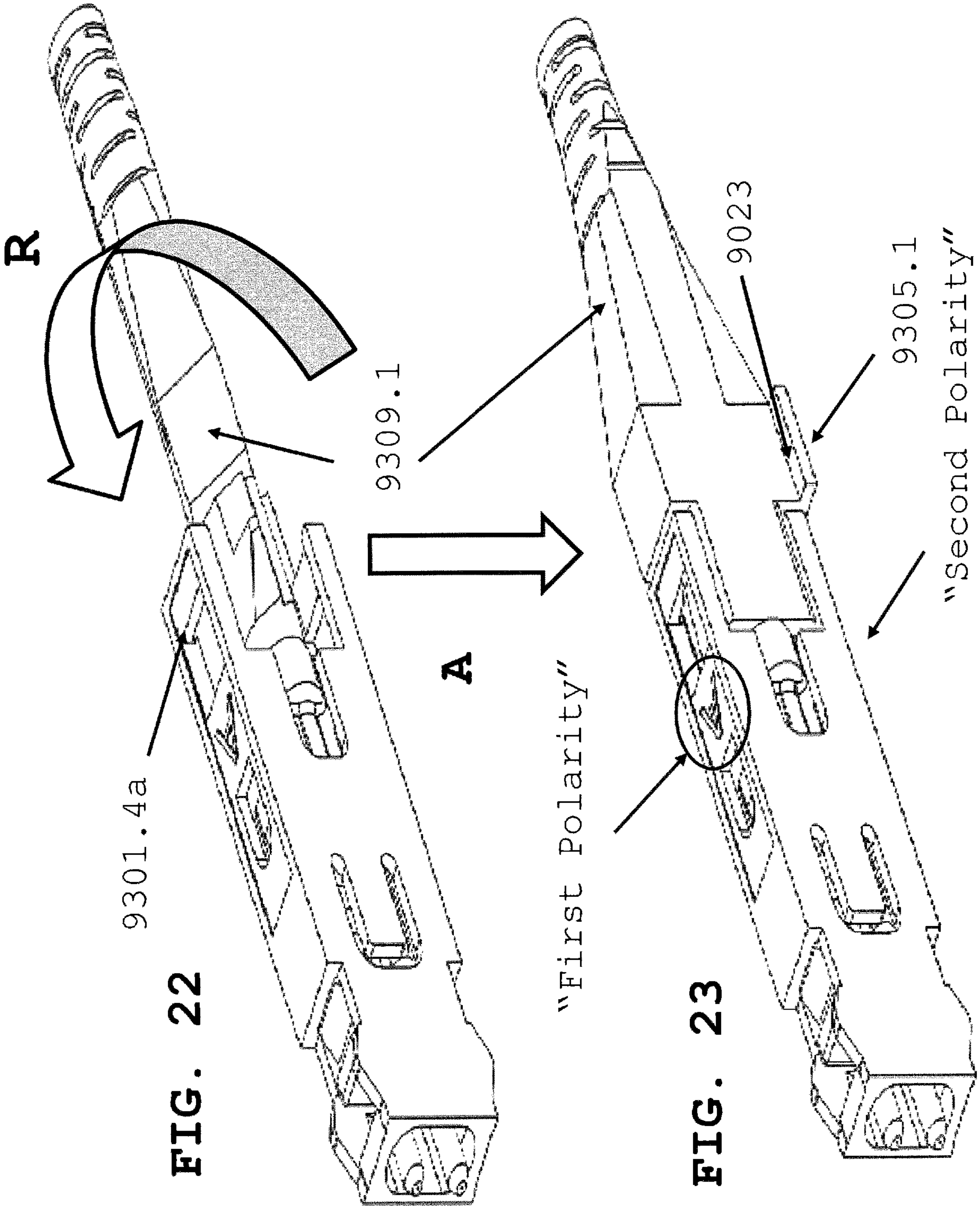


FIG. 22

FIG. 23

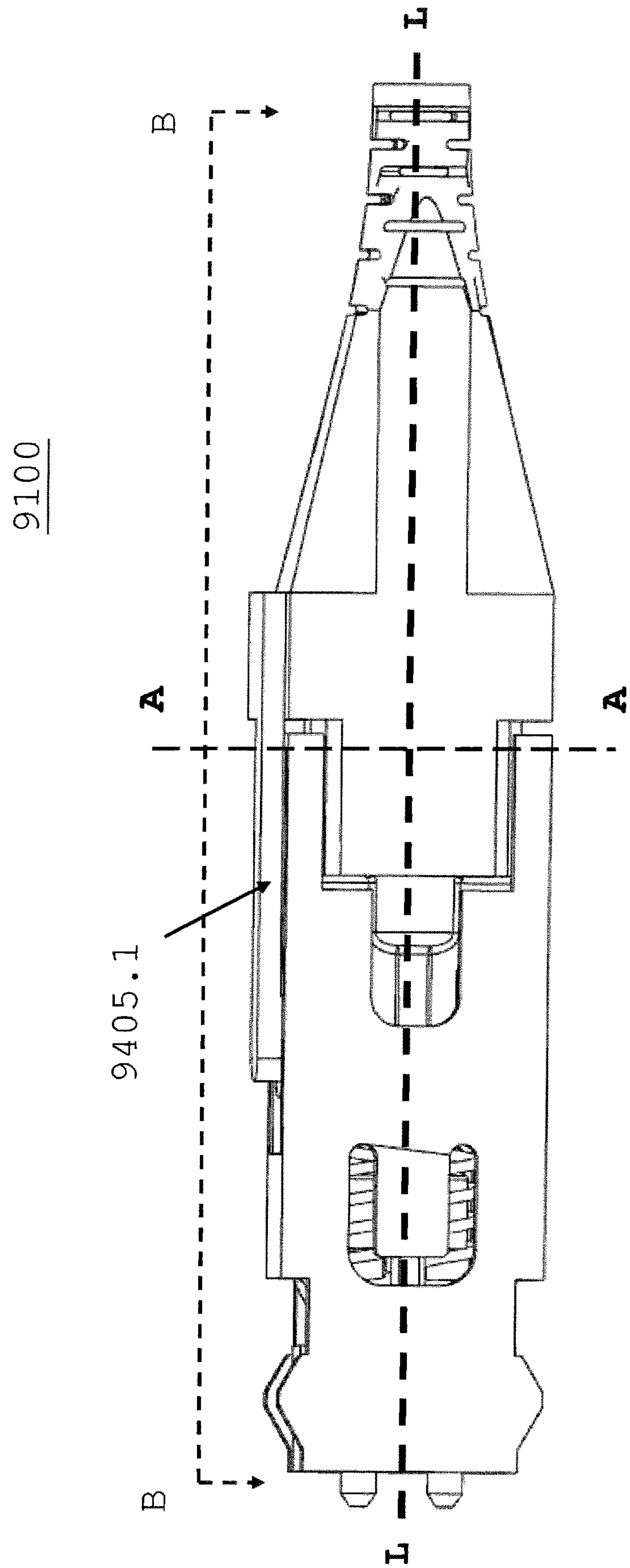
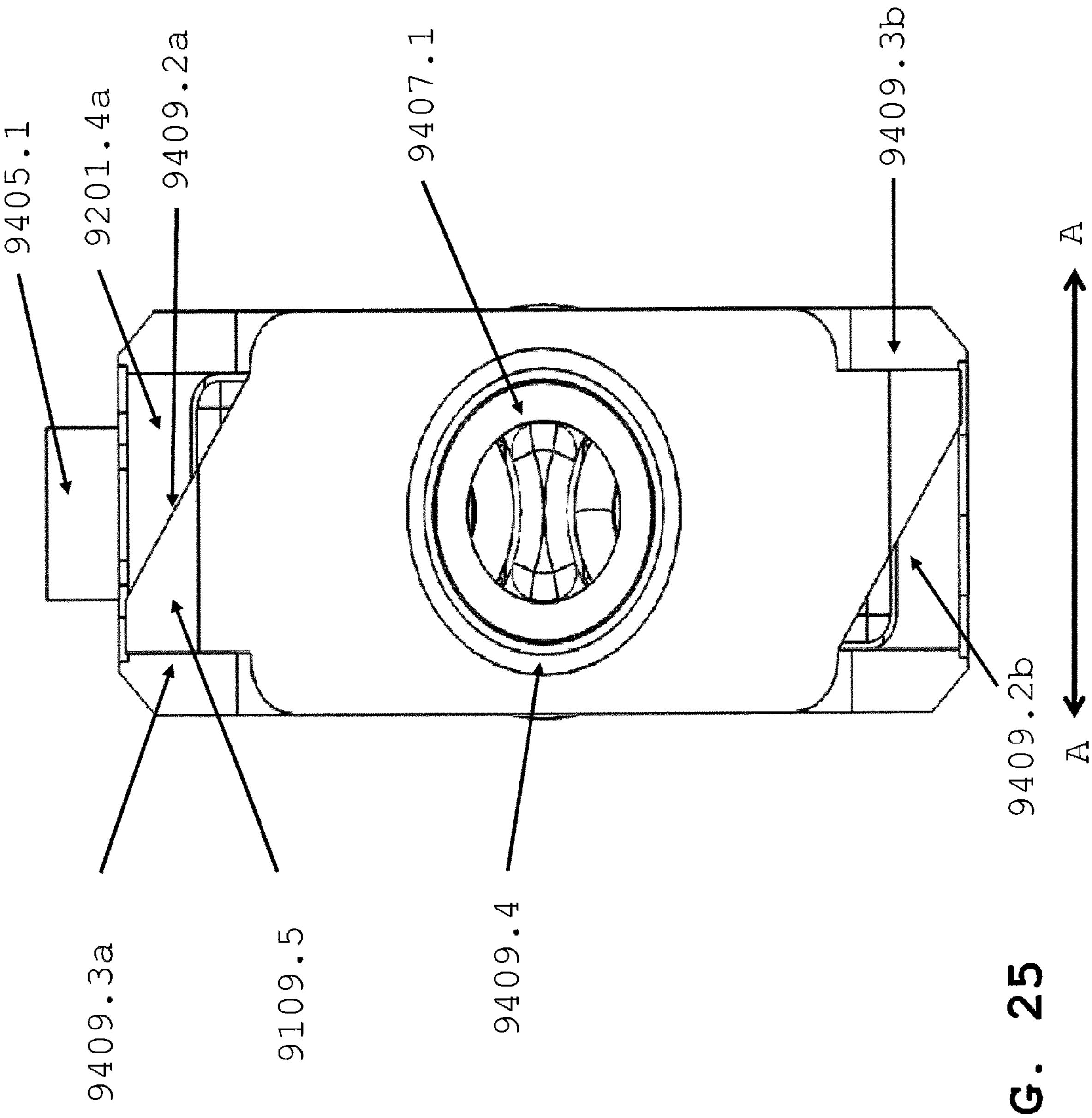


FIG. 24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9409.2b
9409.3a
9109.5
9409.4

FIG. 25

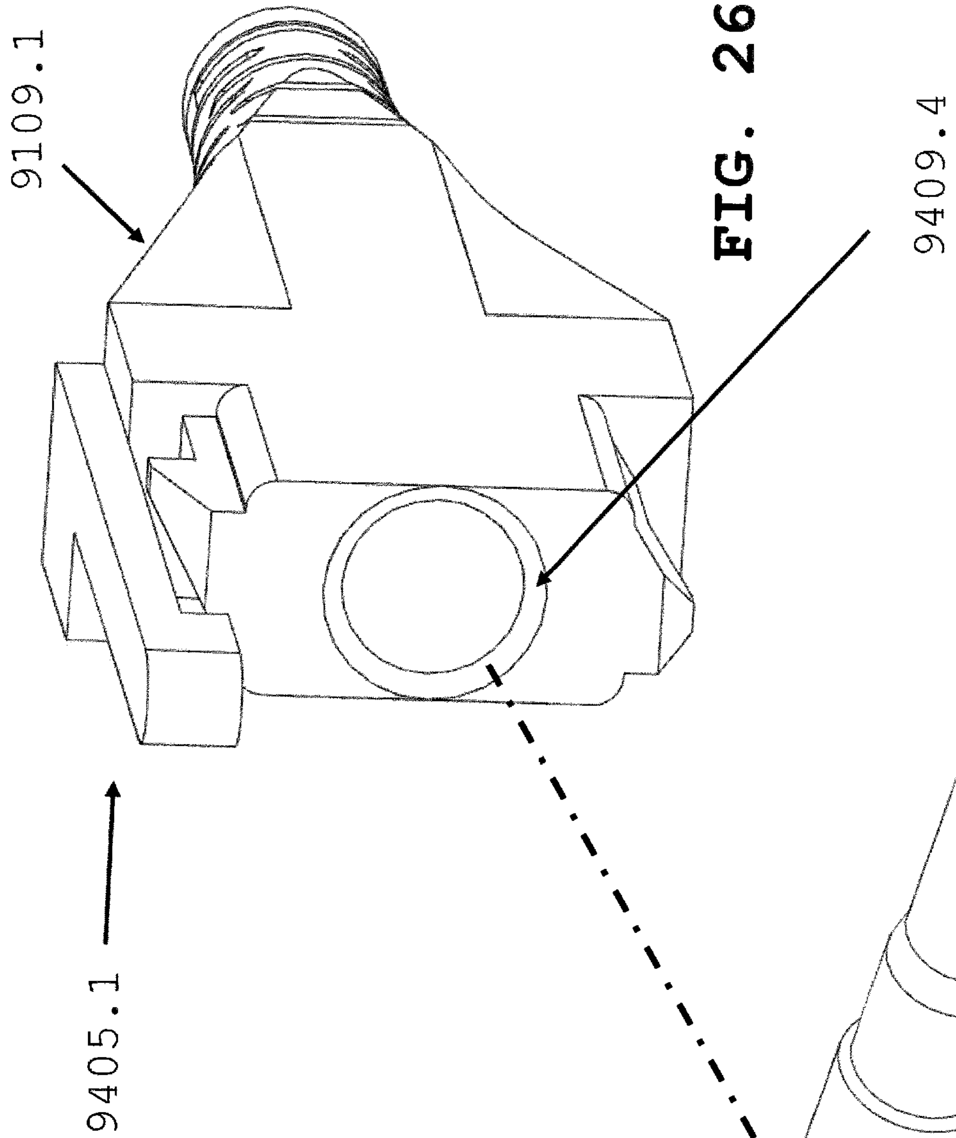


FIG. 26

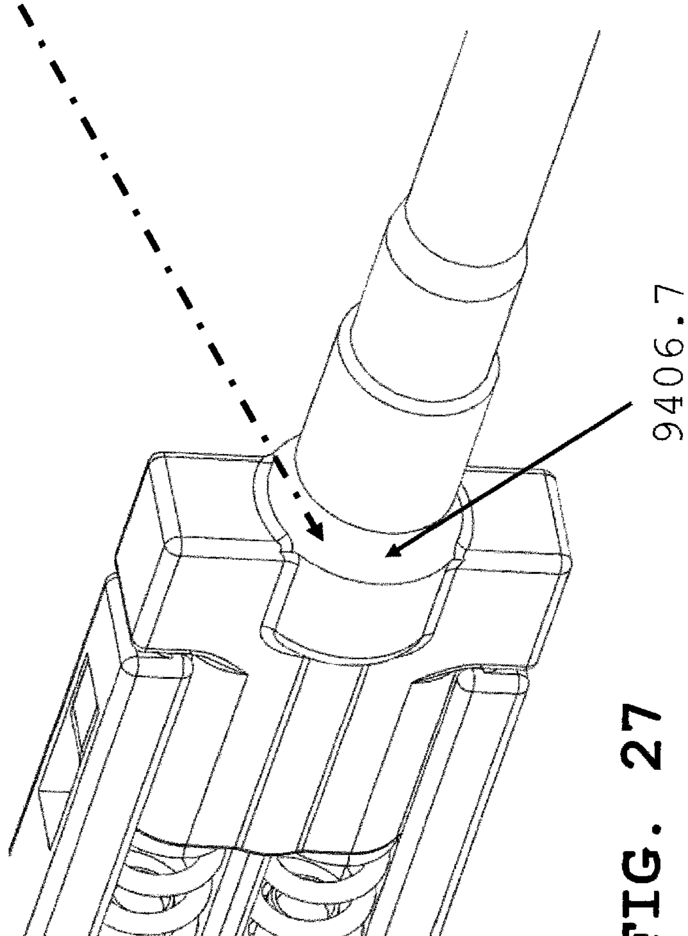


FIG. 27

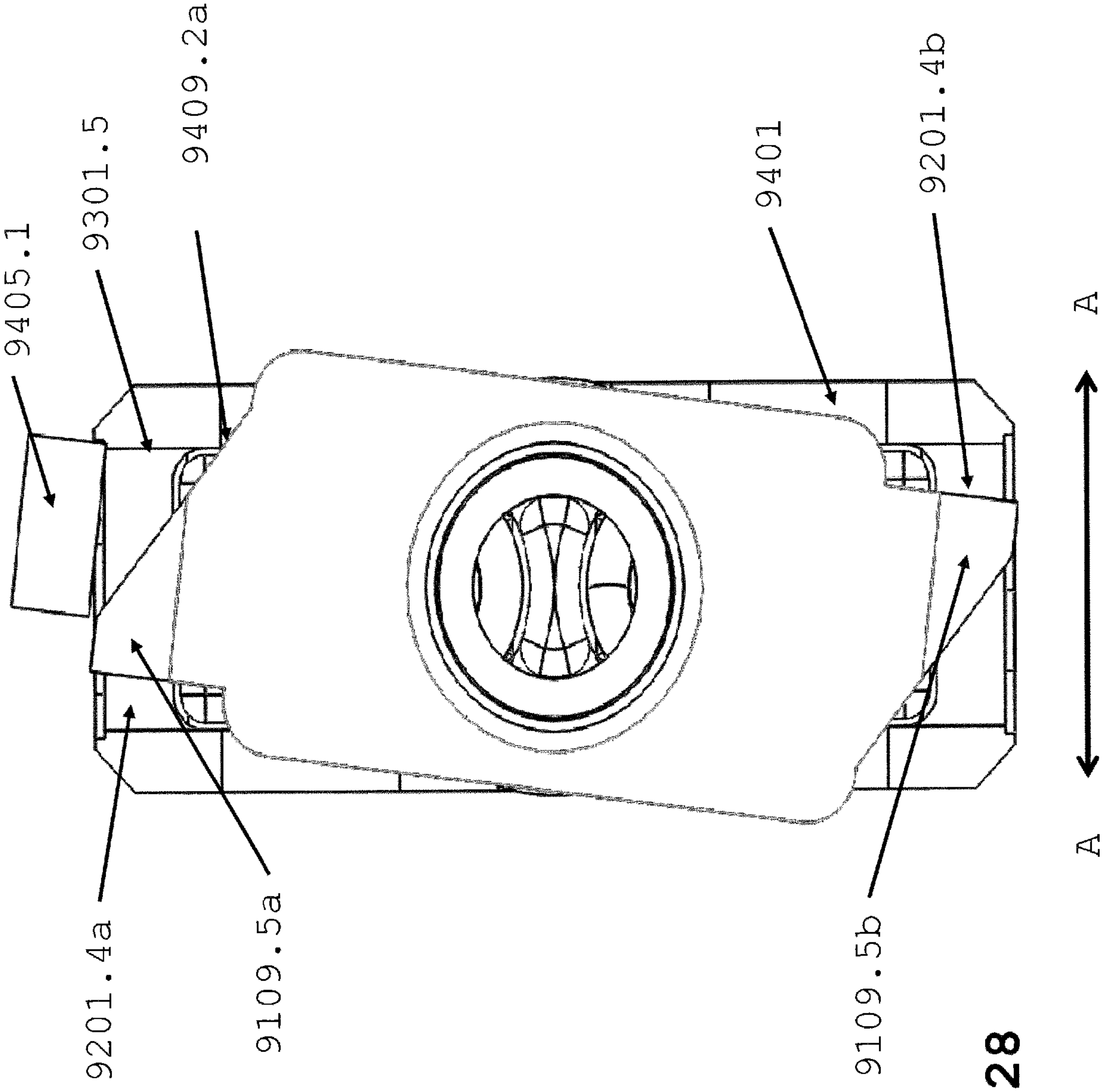


FIG. 28

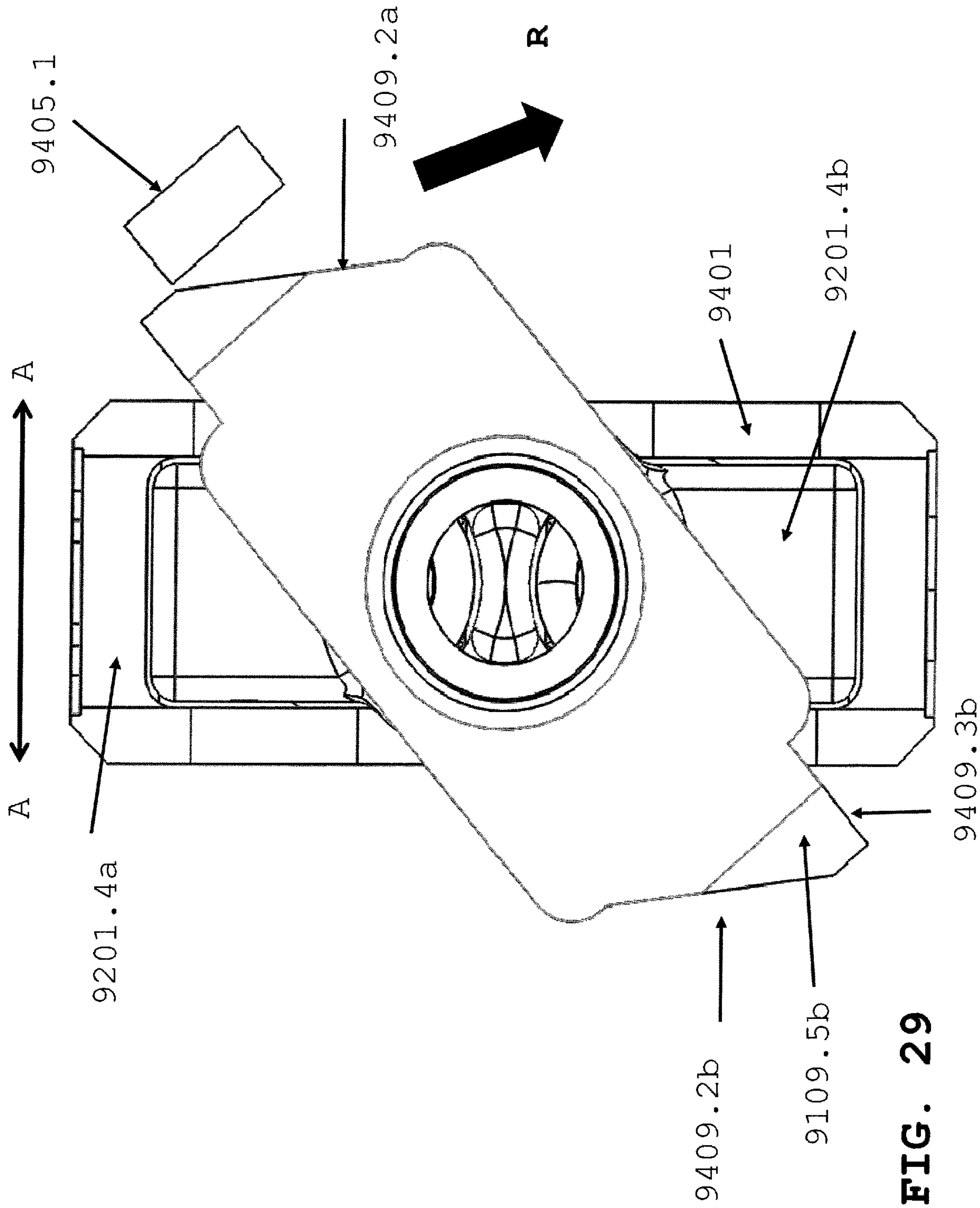


FIG. 29

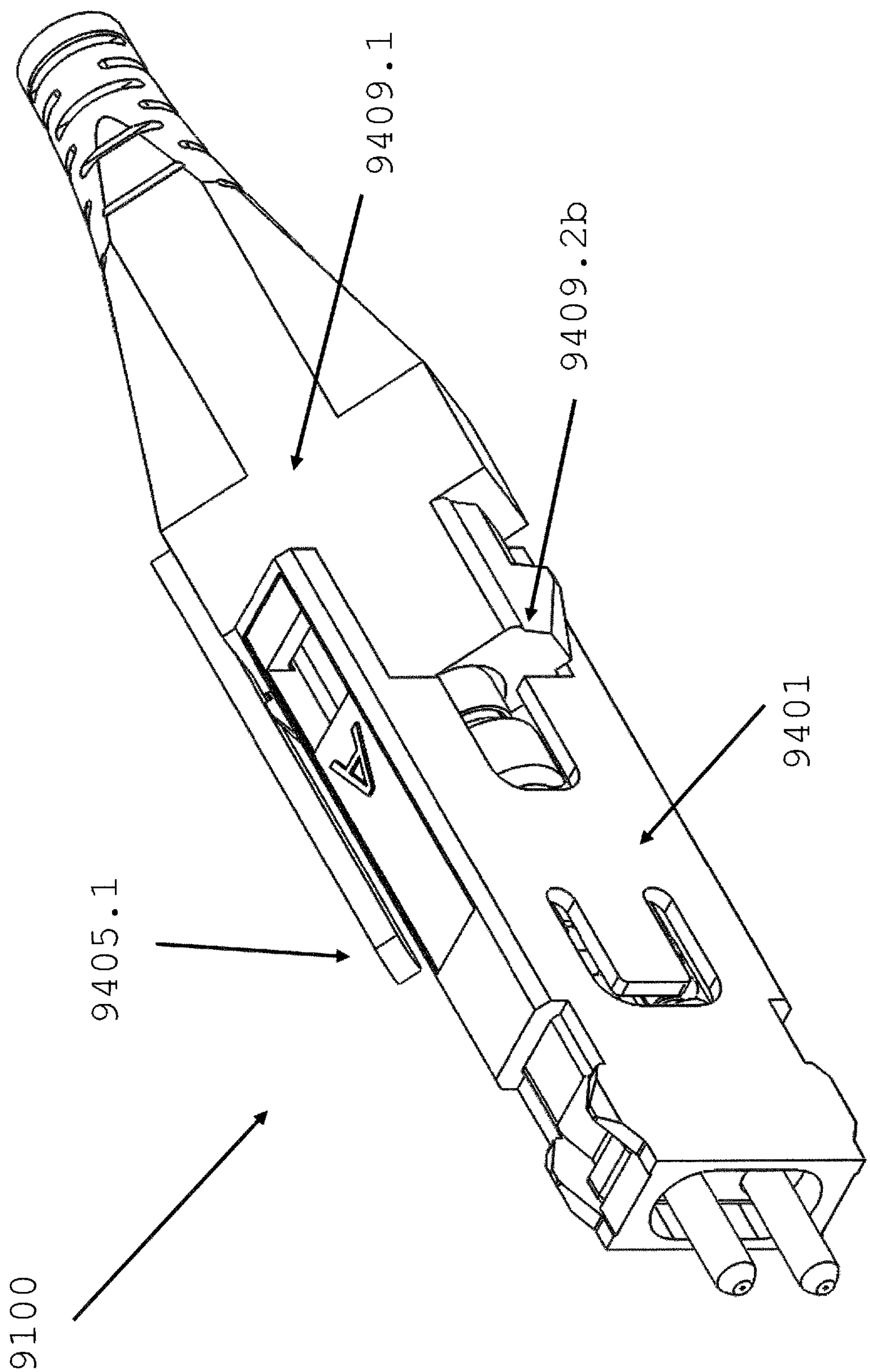


FIG. 30

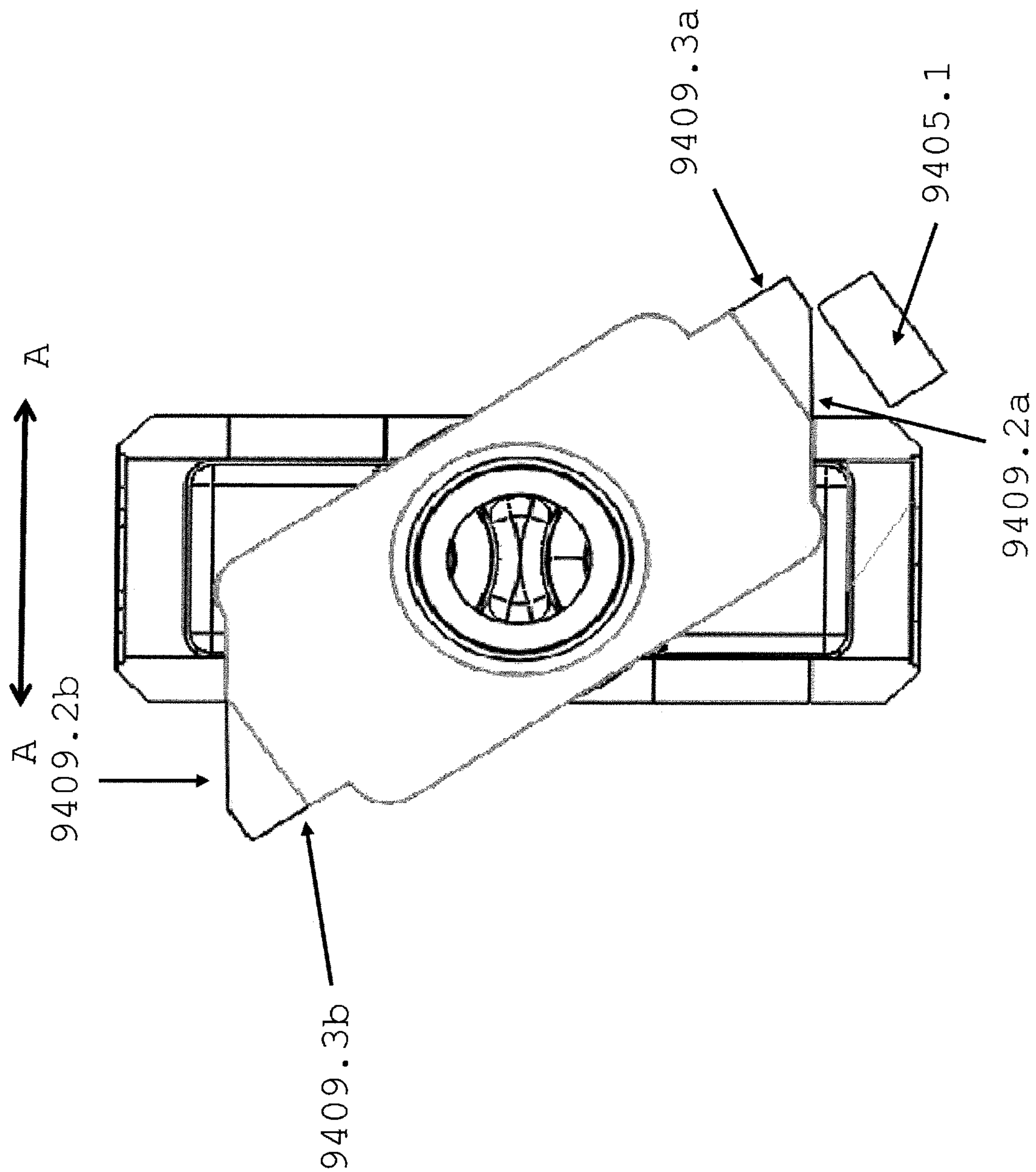


FIG. 31

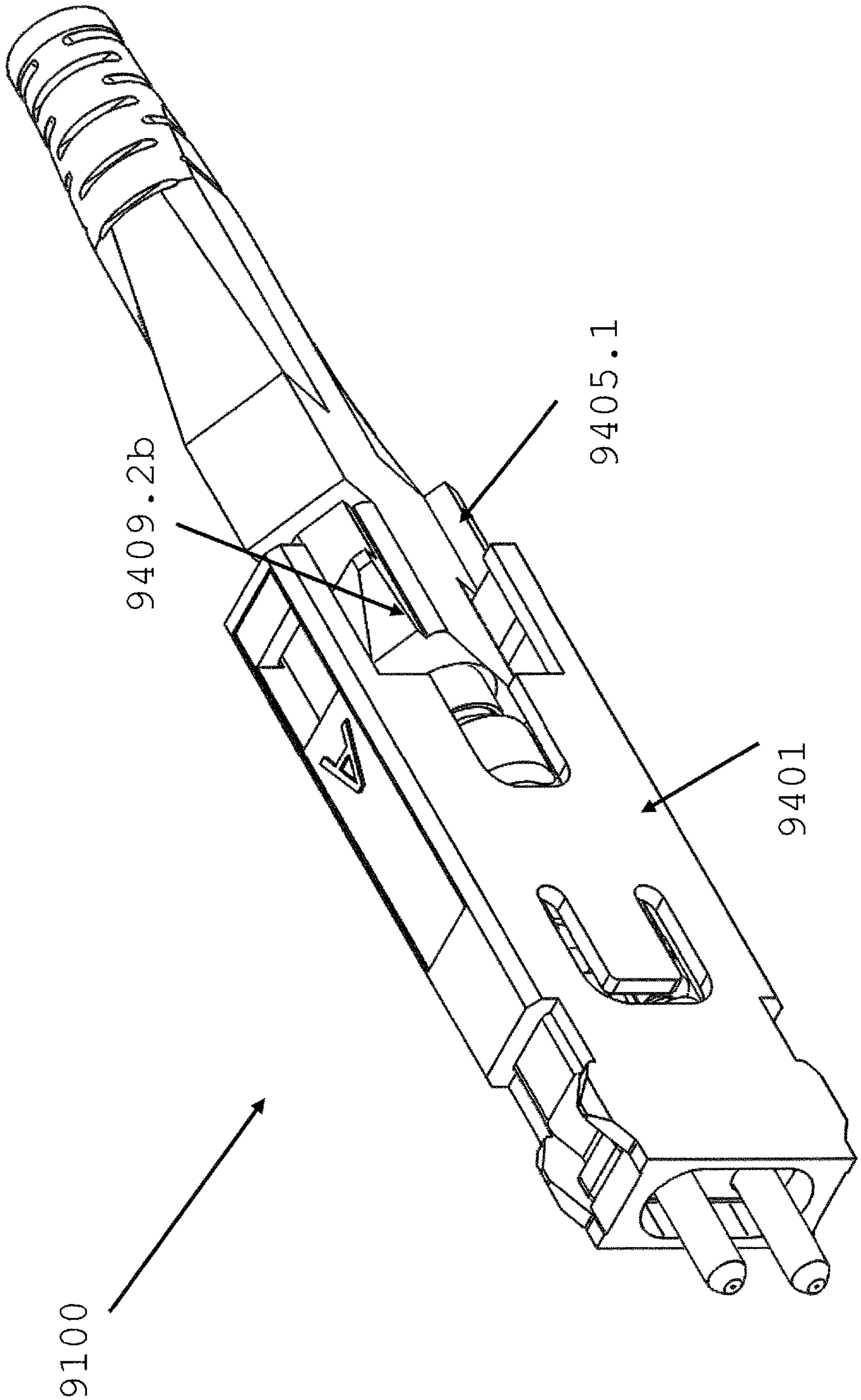


FIG. 32

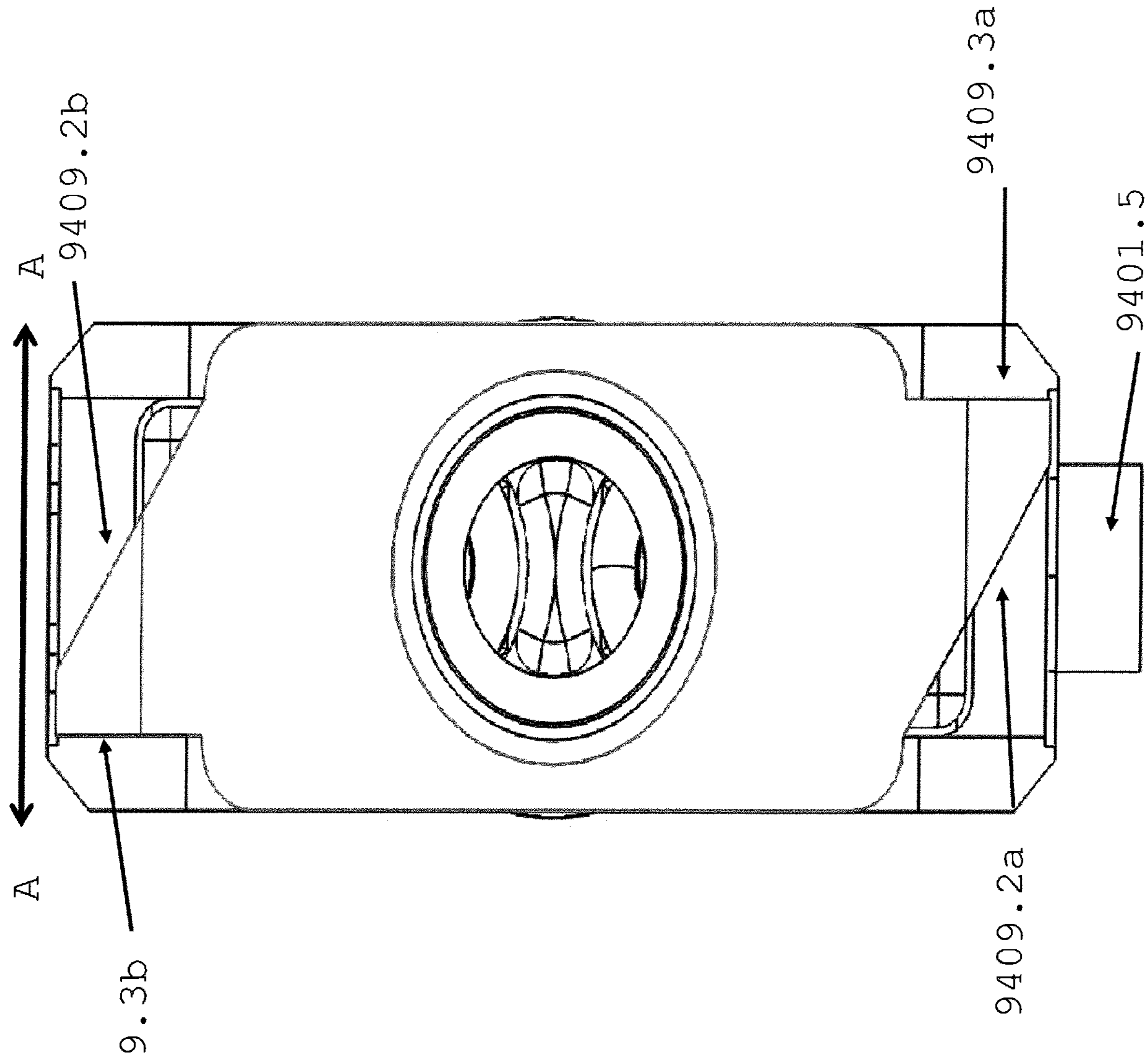
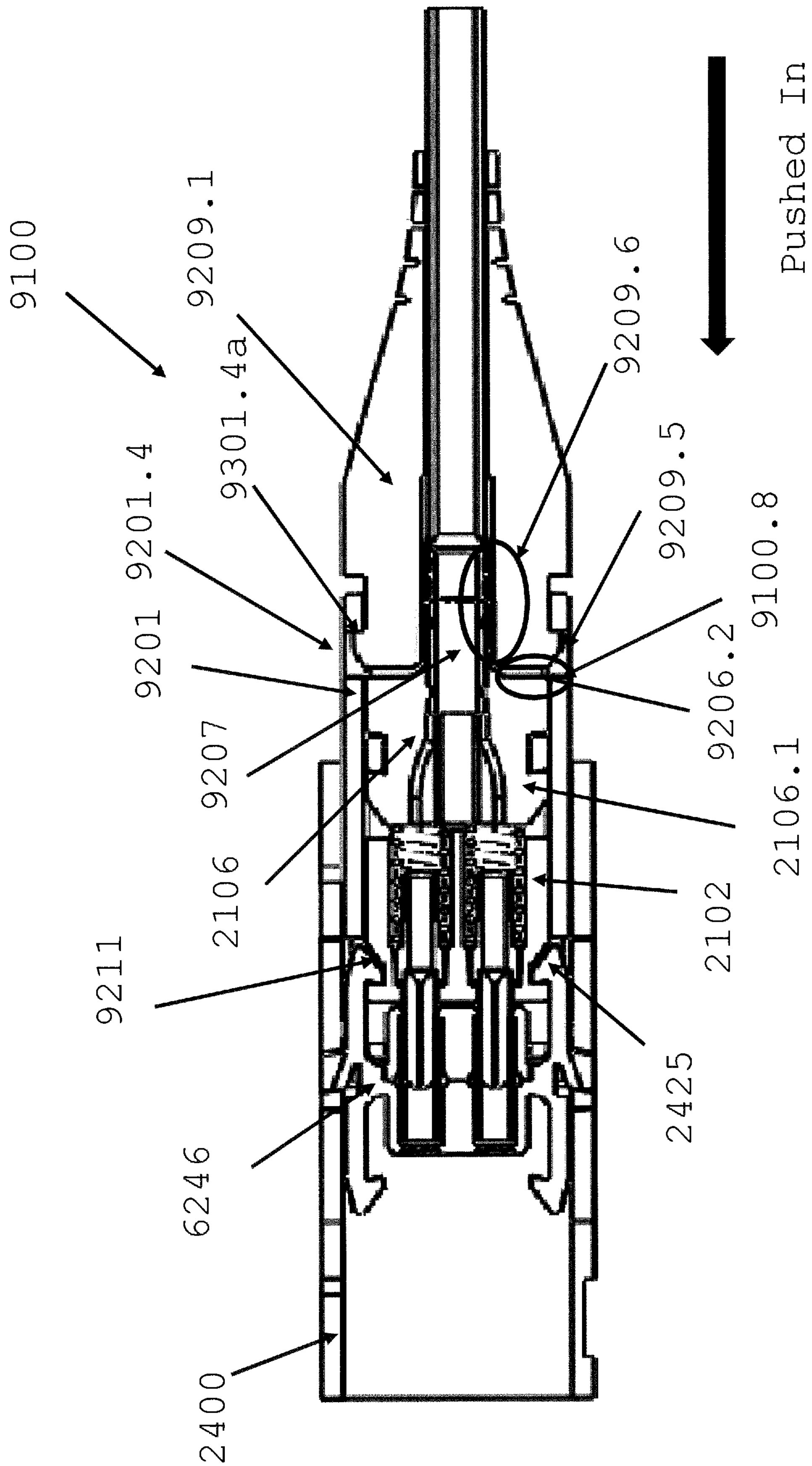


FIG. 33



9100
9209.1
9301.4a
9201.4
9201
9207
2106
9211
6246
2400
9209.6
9209.5
9100.8
9206.2
2106.1
2102
2425
Pushed In

FIG. 34

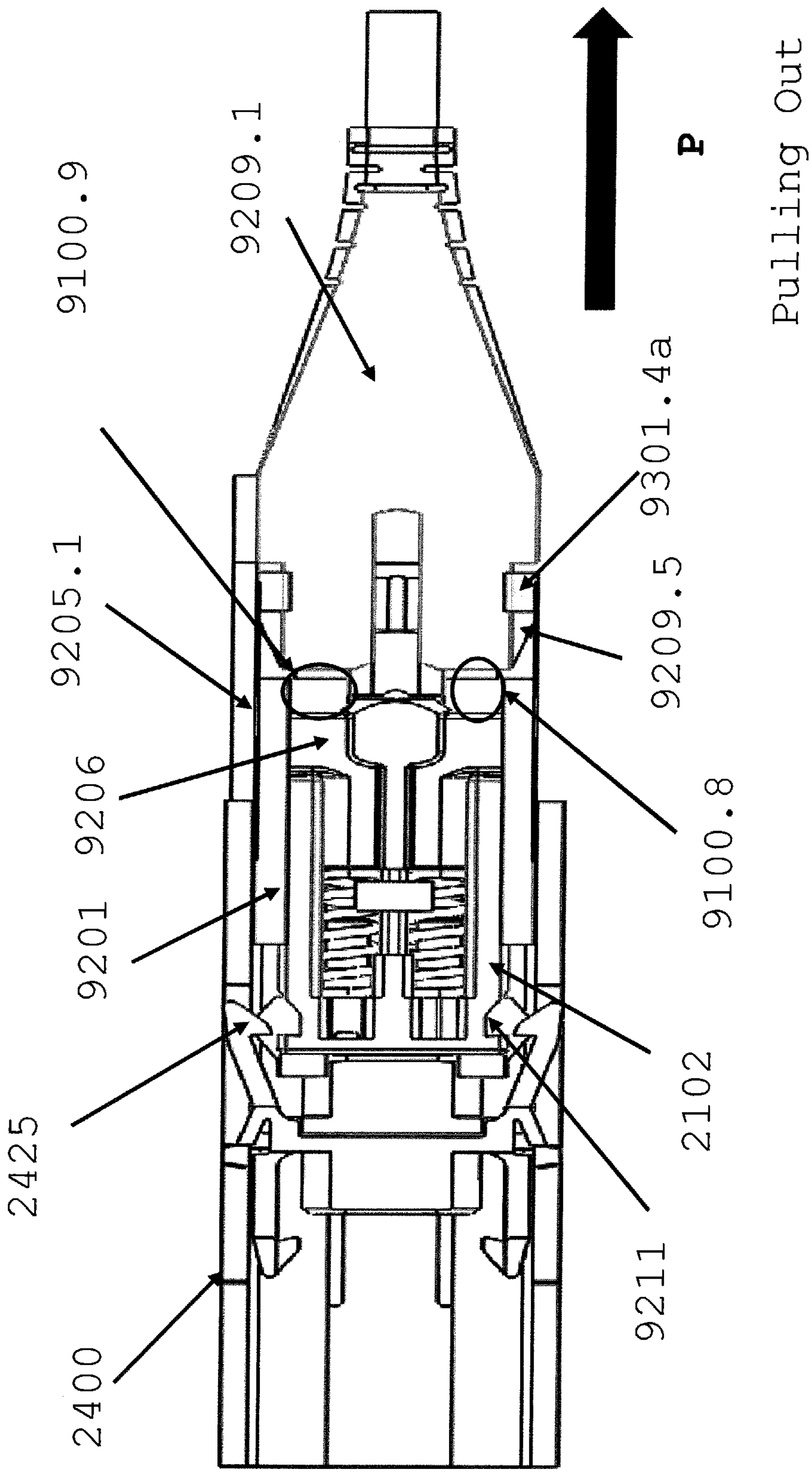

9100.9
9209.1
P
Pulling Out
9301.4a
9205.1
9209.5
9206
9100.8
9201
2102
2425
9211
2400

FIG. 35

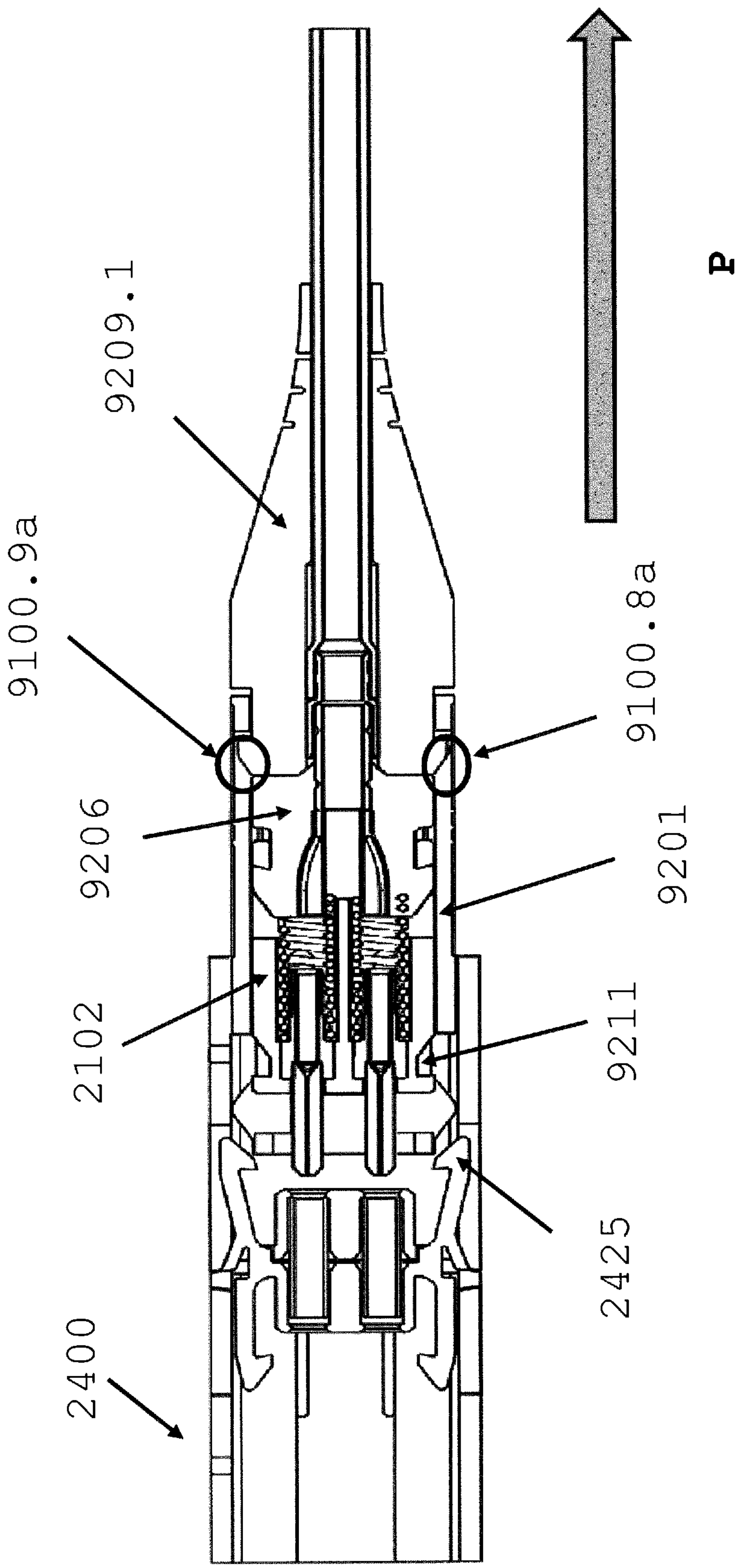


FIG. 36

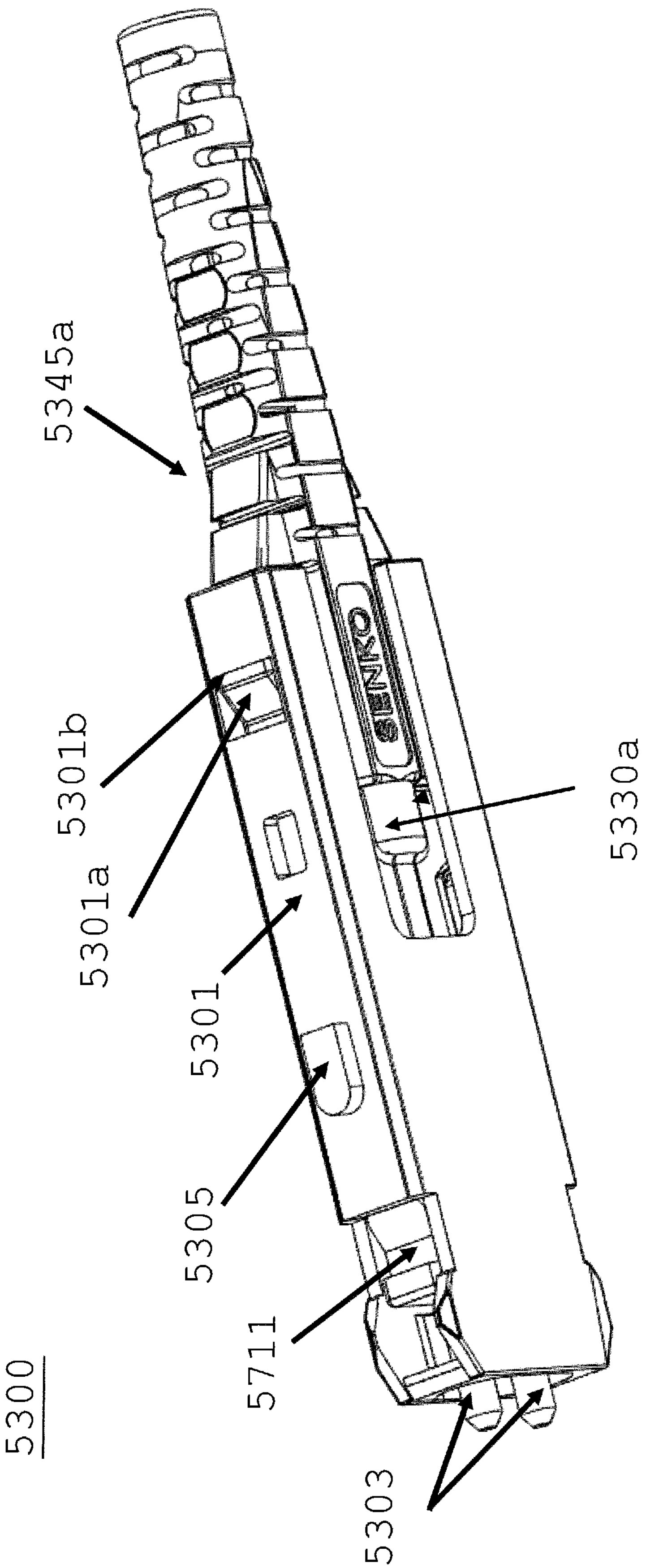


FIG. 37

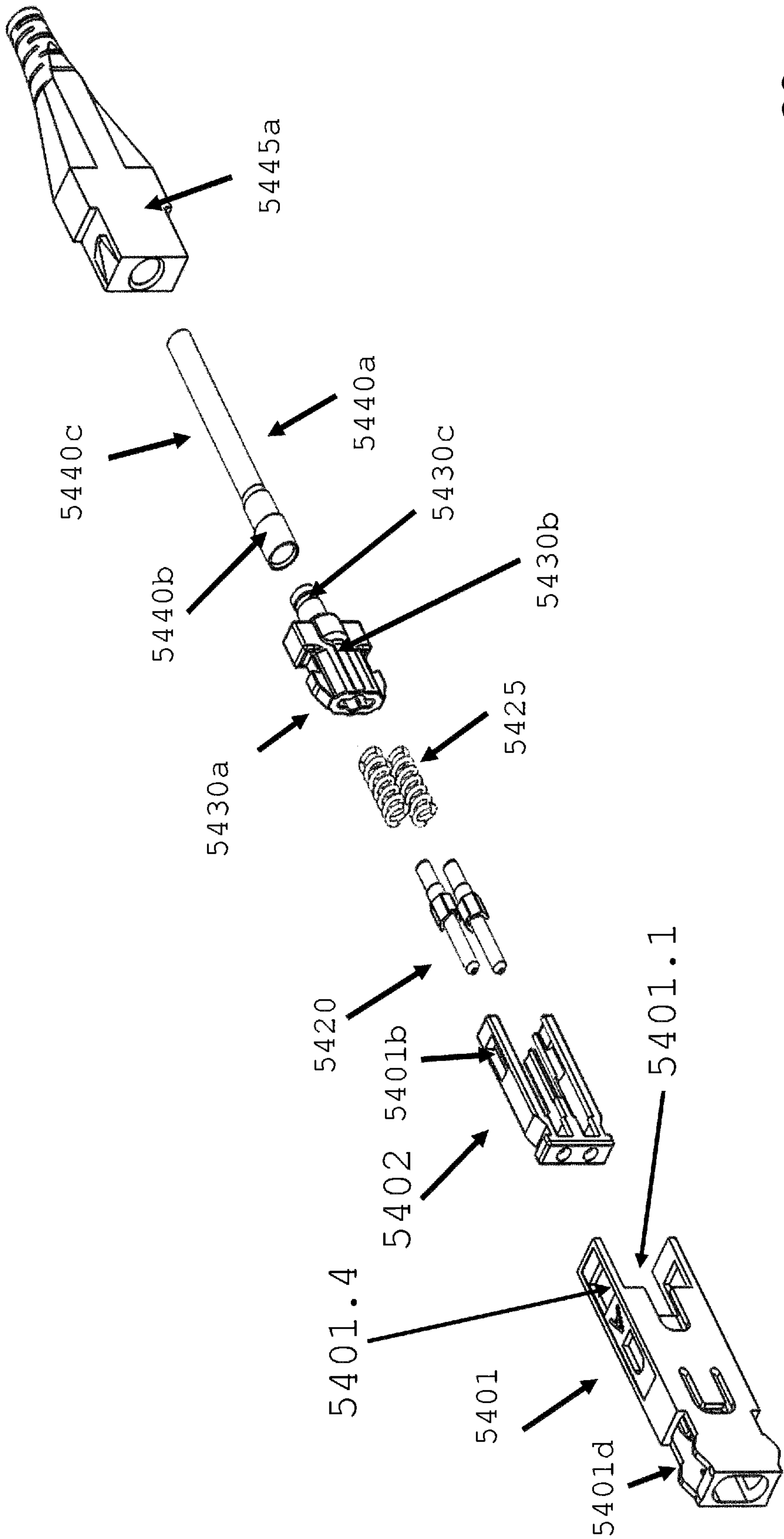

5445a
5440c
5440a
5430c
5440b
5430b
5430a
5425
5420
5401b
5401.1
5402
5401.4
5401
5401d

FIG. 38

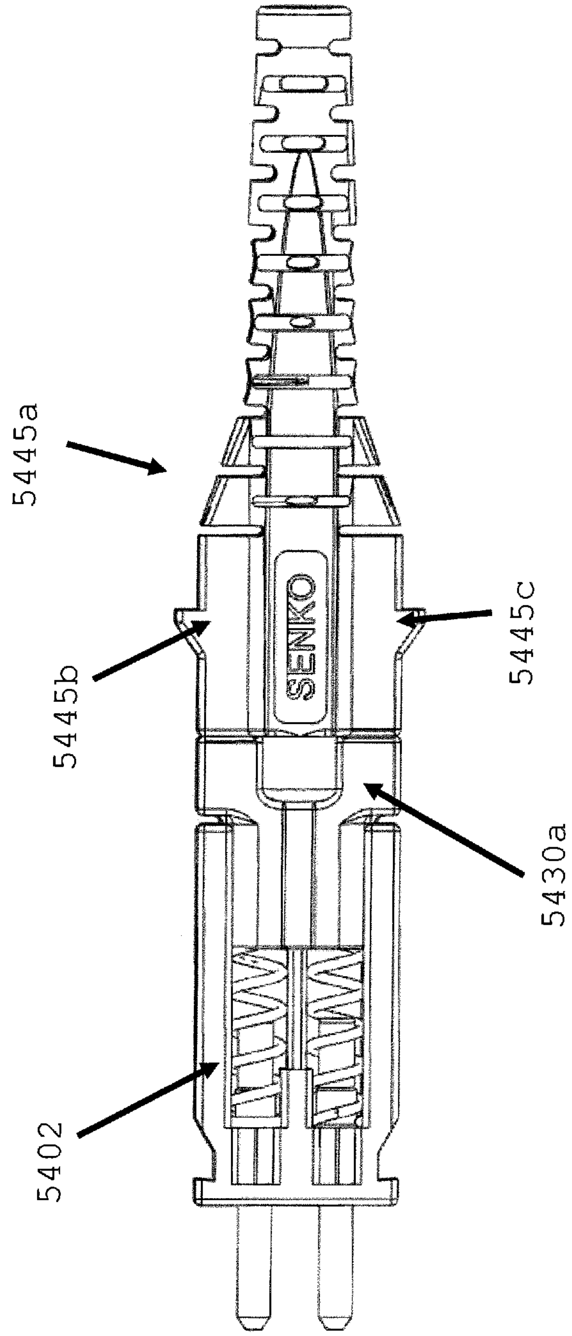


FIG. 39

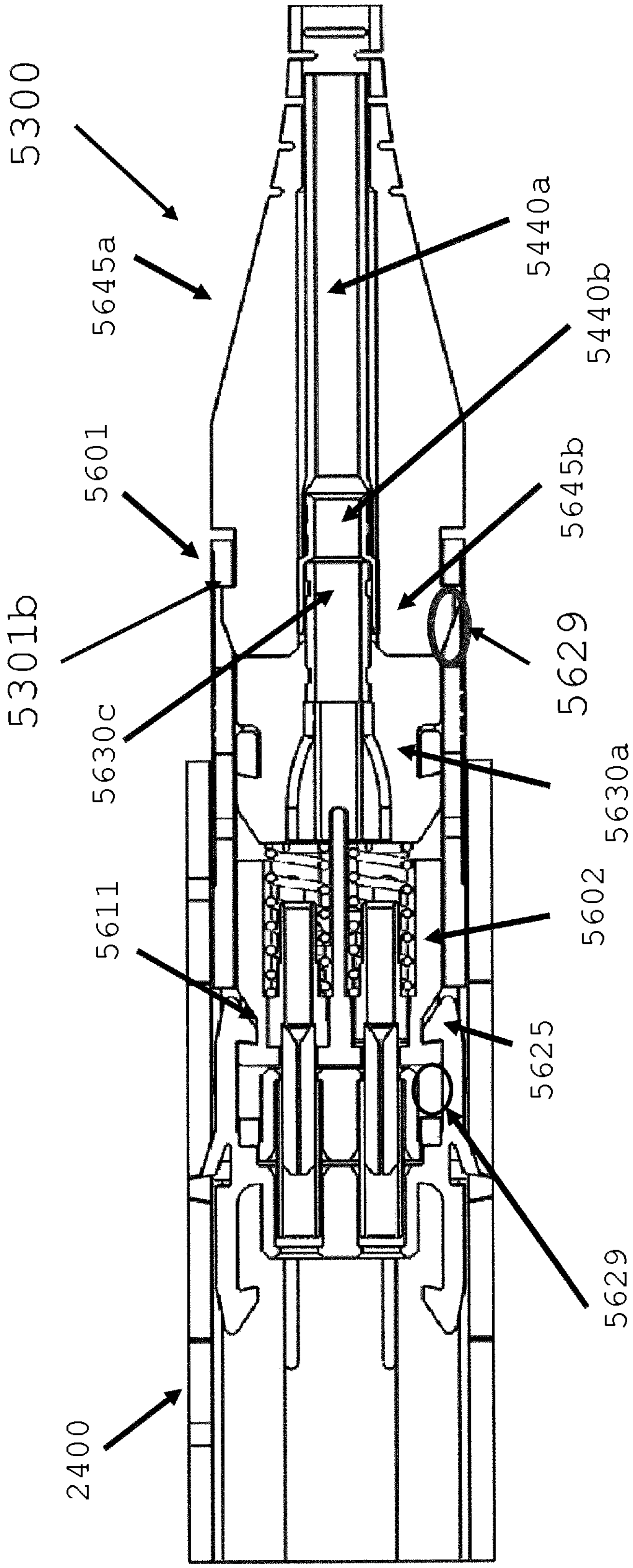

5300
5645a
5440a
5440b
5601
5645b
5301b
5629
5630c
5630a
5602
5611
5625
5629
2400

FIG. 40

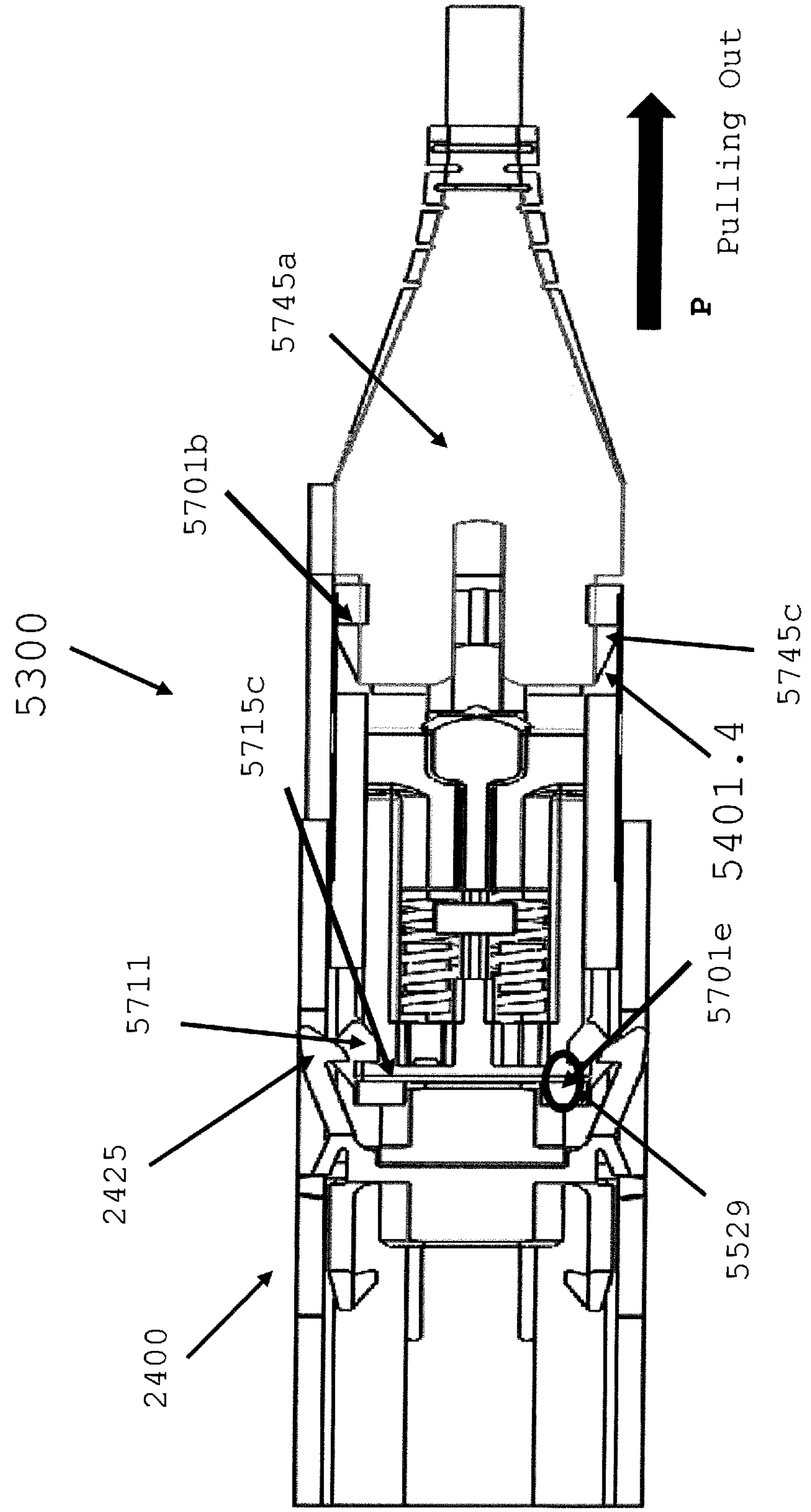

Pulling Out
P
5745a
5701b
5300
5715c
5745c
5401.4
5701e
5711
2425
5529
2400

FIG. 41

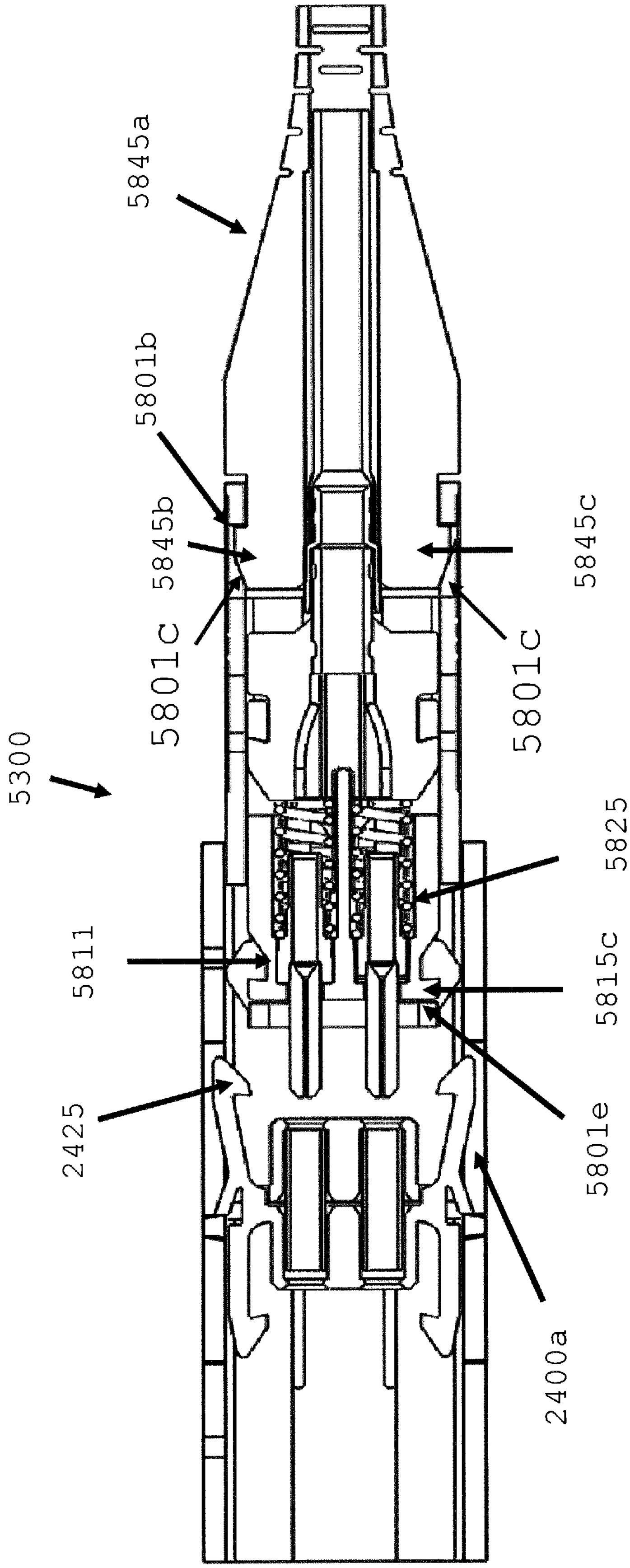

5845a
5801b
5845b
5845c
5801c
5801c
5300
5825
5811
5815c
2425
5801e
2400a

FIG. 42

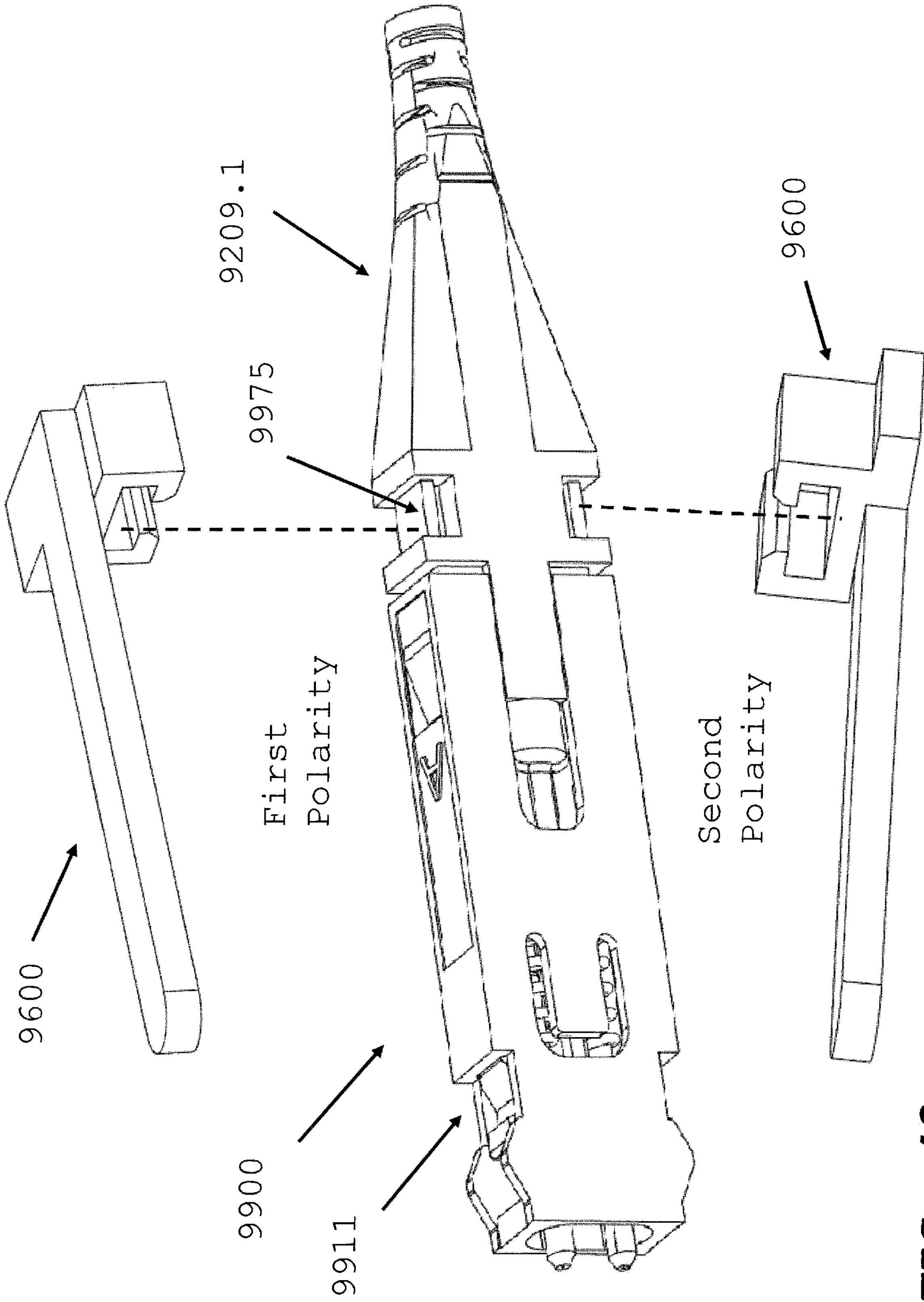

9209.1
9975
9600
9600
First Polarity
Second Polarity
9900
9911

FIG. 43

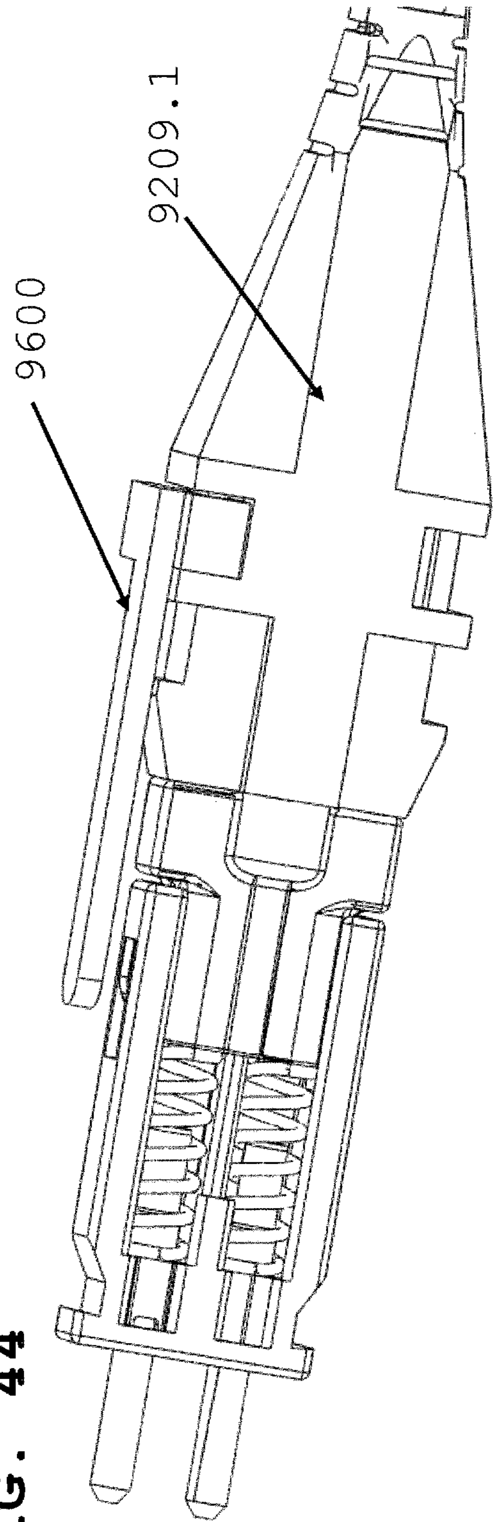


FIG. 44

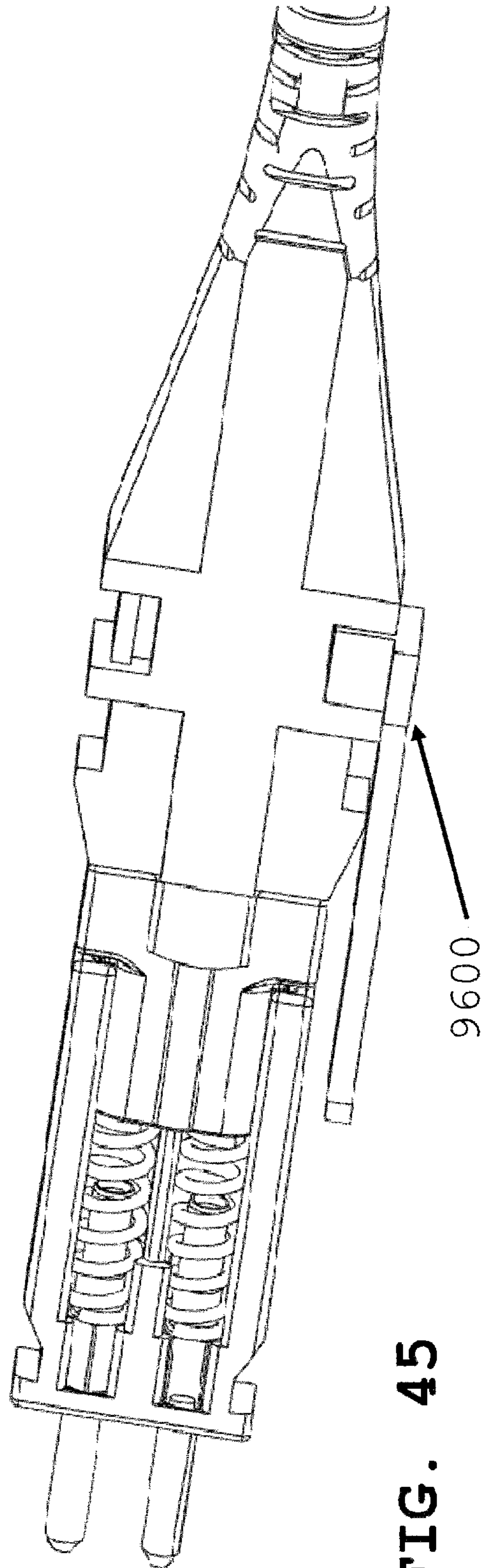


FIG. 45

SMALL FORM FACTOR FIBER OPTIC CONNECTOR WITH MULTI-PURPOSE BOOT

RELATED APPLICATIONS

This application is a divisional under 35 USC 121 that claims priority to U.S. patent application Ser. No. 16/782,196, titled "Small Form Factor Fiber Optic Connector with Multi-Purpose Boot Assembly", filed on Feb. 5, 2020, which claims priority to U.S. application Ser. No. 16/368,828, titled "Small Factor Fiber Optic Connector with Multi-Purpose Boot", filed on Mar. 28, 2018, which claims priority to U.S. Patent Application 62/649,539 titled "Micro Connector with Multi-Purpose Boot", filed on Mar. 28, 2018; and further claims priority to U.S. Patent with Ser. No. 16/103,555 filed on Aug. 14, 2018 entitled "Ultra-Small Form Factor Optical Connectors Using A Push-Pull Boot Receptacle Release", which is a continuation in-part of U.S. patent application Ser. No. 16/035,691 filed Jul. 15, 2018, entitled "Ultra-Small Factor Optical Connectors", which claims priority from U.S. Provisional Application Ser. No. 62/588,276 filed Nov. 17, 2017; U.S. Provisional Application Ser. No. 62/549,655 filed Aug. 24, 2017; and U.S. Provisional Application Ser. No. 62/532,710 filed Jul. 14, 2017 all of the above applications are incorporated by reference in this non-provisional patent application.

FIELD OF THE INVENTION

The present disclosure relates generally to ultra-small form factor optical connectors, termed "micro optical connectors," and related connections within adapters and optical transceivers.

BACKGROUND

The prevalence of the Internet has led to unprecedented growth in communication networks. Consumer demand for service and increased competition has caused network providers to continuously find ways to improve quality of service while reducing cost.

Certain solutions have included deployment of high-density interconnect panels. High-density interconnect panels may be designed to consolidate the increasing volume of interconnections necessary to support the fast-growing networks into a compacted form factor, thereby increasing quality of service and decreasing costs such as floor space and support overhead. However, room for improvement in the area of data centers, specifically as it relates to fiber optic connects, still exists. For example, manufacturers of connectors and adapters are always looking to reduce the size of the devices, while increasing ease of deployment, robustness, and modifiability after deployment. In particular, more optical connectors may need to be accommodated in the same footprint previously used for a smaller number of connectors in order to provide backward compatibility with existing data center equipment. For example, one current footprint is known as the small form-factor pluggable transceiver footprint (SFP). This footprint currently accommodates two LC-type ferrule optical connections. However, it may be desirable to accommodate four optical connections (two duplex connections of transmit/receive) within the same footprint. Another current footprint is the quad small form-factor pluggable (QSFP) transceiver footprint. This footprint currently accommodates four LC-type ferrule optical connections. However, it may be desirable to accommodate eight optical connections of LC-type ferrules (four duplex connections of transmit/receive) within the same footprint.

In communication networks, such as data centers and switching networks, numerous interconnections between mating connectors may be compacted into high-density panels. Panel and connector producers may optimize for such high densities by shrinking the connector size and/or the spacing between adjacent connectors on the panel. While both approaches may be effective to increase the panel connector density, shrinking the connector size and/or spacing may also increase the support cost and diminish the quality of service.

In a high-density panel configuration, adjacent connectors and cable assemblies may obstruct access to the individual release mechanisms. Such physical obstructions may impede the ability of an operator to minimize the stresses applied to the cables and the connectors. For example, these stresses may be applied when the user reaches into a dense group of connectors and pushes aside surrounding optical fibers and connectors to access an individual connector release mechanism with his/her thumb and forefinger. Overstressing the cables and connectors may produce latent defects, compromise the integrity and/or reliability of the terminations, and potentially cause serious disruptions to network performance.

While an operator may attempt to use a tool, such as a screwdriver, to reach into a dense group of connectors and activate a release mechanism, adjacent cables and connectors may obstruct the operator's line of sight, making it difficult to guide the tool to the release mechanism without pushing aside the adjacent cables. Moreover, even when the operator has a clear line of sight, guiding the tool to the release mechanism may be a time-consuming process. Thus, using a tool may not be effective at reducing support time and increasing the quality of service.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an exploded view of a micro optical connector improved according to disclosed embodiments of push/pull and polarity change in present invention.

FIGS. **2-4** depict a technique polarity changing of the micro connector of FIG. **1**

FIGS. **5-8** depict polarity changing according to an another embodiment of the present invention of a micro-connector.

FIG. **9-11** depict inserting the micro-connector of FIG. **1** into an adapter.

FIG. **12** is a perspective view of a front body according to an embodiment of the present invention.

FIG. **13** is a perspective view of another embodiment of an adapter hook and alignment assembly.

FIG. **14** is a perspective view of micro connectors of FIG. **1** inserted into an adapter.

FIG. **15** is a perspective rear view of a group of micro connectors of FIG. **14**.

FIG. **16** is a perspective view of a micro connector with multi-purpose push/pull—rotatable boot (FIG. **17**) for insert/removal of connector from adapter and for polarity change.

FIG. **17** is a perspective view of multi-purpose rotatable boot assembly with an alignment and offset key releasable attached to the boot assembly.

FIG. **18** is a perspective view of an outer housing of the micro connector of FIG. **16**.

FIG. **19** is a perspective view of front body and boot removed from FIG. **18** outer housing.

FIG. **20** is a perspective view of the micro connector in a first polarity position.

FIG. **21** is a perspective view of the connector of FIG. **20** being rotated in direction "R" to a second polarity.

FIG. **22** depicts micro connector of FIG. **20** being rotated further to the second polarity.

FIG. **23** depicts micro connector of FIG. **20** in the second polarity.

FIG. **24** is side view of micro connector of FIG. **16** with a cross section cut "A-A".

FIG. **25** is a view along cross section cut "A-A" of the micro connector of FIG. **16** in a first polarity position.

FIG. **26** is an end view of the boot assembly illustrating an opening for fiber optic cabling.

FIG. **27** is a perspective view of end of a back body, with fiber optic cabling.

FIG. **28** is perspective view along cross section "A-A" at a start of boot rotation to change a micro connector from a first polarity to a second polarity.

FIG. **29** is perspective view along cross section "A-A" in furtherance of boot rotation to change the micro connector from a first polarity to a second polarity.

FIG. **30** is a perspective view of the micro connector in furtherance of boot rotation.

FIG. **31** is a perspective view along cross section "A-A" just prior to completion to a second polarity of the micro connector.

FIG. **32** is a perspective view of the micro connector just prior to completion to a second polarity.

FIG. **33** is a perspective view along cross section "A-A" of micro connector FIG. **16** in a second polarity position.

FIG. **34** is a perspective view along a longitudinal cross section of a micro connector of FIG. **16**, latched into an adapter receptacle with multi-purpose rotatable boot assembly biased forward or pushed in.

FIG. **35** is a perspective view of FIG. **34** as multi-purpose rotatable boot assembly is partially pulled in direction "P".

FIG. **36** is a perspective view of FIG. **34** as multi-purpose rotatable boot assembly (FIG. **17**) is release from adapter hook but still under influence of pulling force "P".

FIG. **37** is perspective view of a micro connector with another push/pull release embodiment incorporated therein.

FIG. **38** is an exploded view of FIG. **37** connector.

FIG. **39** is a side perspective inner view of a micro connector of FIG. **37** without an outer housing.

FIG. **40** is a cross-section view of connector of FIG. **37** latched into a receptacle.

FIG. **41** is a cross-section view of connector of FIG. **37** partial removed using push/pull release boot according to the present invention.

FIG. **42** is a cross-section view of connector of FIG. **37** released from an adapter receptacle.

FIG. **43** is an exploded view of another embodiment of a micro connector with a releasably attached clip defining a first and a second polarity.

FIG. **44** is an assembly view of the micro connector of FIG. **43** in a first polarity.

FIG. **45** is an assembled view of the micro connector of FIG. **43** in a second polarity.

DETAILED DESCRIPTION

The following terms shall have, for the purposes of this application, the respective meanings set forth below.

A connector, as used herein, refers to a device and/or components thereof that connects a first module or cable to a second module or cable. The connector maybe configured for fiber optic transmission or electrical signal transmission. The connector may be any suitable type now known or later developed, such as, for example, a ferrule connector (FC), a fiber distributed data interface (FDDI) connector, an LC connector, a mechanical transfer (MT) connector, a square connector (SC) connector, an SC duplex connector, or a straight tip (ST) connector. The connector maybe generally defined by a connector housing body. In some embodiments, the housing body may incorporate any or all of the components described herein.

A "fiber optic cable" or an "optical cable" refers to a cable containing one or more optical fibers for conducting optical signals in beams of light. The optical fibers can be constructed from any suikeyle transparent material, including glass, fiberglass, and plastic. The cable can include a jacket or sheathing material surrounding the optical fibers. In addition, the cable can be connected to a connector on one end or on both ends of the cable.

Various embodiments described herein generally provide a remote release mechanism such that a user can remove cable assembly connectors that are closely spaced together on a high density panel without damaging surrounding connectors, accidentally disconnecting surrounding connectors, disrupting transmissions through surrounding connectors, and/or the like. Various embodiments also provide narrow pitch LC duplex connectors and narrow width multi-fiber connectors, for use, for example, with future narrow pitch LC SFPs and future narrow width SFPs. The remote release mechanisms allow use of the narrow pitch LC duplex connectors and narrow width multi-fiber connectors in dense arrays of narrow pitch LC SFPs and narrow width multi-fiber SFPs.

FIG. **1** depicts an embodiment of micro optical connector **2100**, shown in exploded view. Micro optical connector **2100** may include outer housing **2101**, front body **2102**, one or more ferrules **2103**, one or more ferrule flanges **2104**, one or more springs **2133**, back body **2106**, the latter has a wing **2106.1** on the top and bottom of the body, the wing **2106.1** is secured within an opening **2119** at a distal end of front body **2102**, back post **2107**, crimp ring **2108**, and boot **2109**. Front body **2102** side walls are open not closed, a channel **2194** for aligning ferrule flanges **2104**, and an alignment sleeve opening **2113** to accept ferrule **2103**. Outer housing **2101** may include a longitudinal bore for accommodating front body **2102** and ferrule **2103**, springs **2133** and back body **2106**, connector alignment key **2105** used during interconnection, connector flap **2101.1** and an optional pull key **2110** to facilitate removal of connector **2100** when connected in a dense array of optical connectors. Optionally, the ferrules may be LC-type ferrules having an outer diameter of 1.25 mm. Connector flap **2101.1** secures front body **2102** within outer housing **2101**. Alignment key **2105** is also used as blocking structure to indicated connector polarity orientation as disclosed herein. Polarity is determined by the ferrules **9203** (Refer to FIG. **19**), where a first ferrule is for Tx or transmit and a second ferrule is for Rx or receive. As known in the art, a mismatch of ferrules **9203** with opposing ferrules secured in an opposing adapter port, the signal would be lost. Alignment key performs a dual function, when the boot assembly is rotated, the alignment key is repositioned, so upon insertion into an adapter, the connector can be blocked by the key. This in effect disallows the user to insert the connector within the adapter receptacle, thus, preventing a mismatch of signal between opposing connectors across an adapter interface. As disclosed below, starting at FIG. **18** an additional aid may be markings located on the connector housing, indicating "A" or "B" polarity of the connector ferrules after rotating the boot.

As depicted FIGS. **2-4**, FIG. **2** micro connector **3700** includes an assembled front body **3702** that may be removed from outer housing **3701**, rotated 180° as indicated by the arrow (FIG. **3**), and re-inserted into the outer housing (FIG. **4**). This allows for a change in the polarity of the connector by removing and rotating front body **3702**, and therefore the ferrules can be switched quickly and easily without unnecessarily risking the delicate fiber cables and ferrules. Referring to FIG. **2**, micro connector **3700** is fully assembled. To remove front body **3702** to change connector polarity, as shown in FIG. **3**, one or more flex key **3703** are lifted outward to release front body **3702** for removal in rearward in the direction of the arrow "R". Referring to FIG. **4**, to complete the polarity change, after rotating front body **3702** by 180 degrees as shown in FIG. **3**, front body **3702** is inserted into the outer housing in the direction of arrow "F".

FIG. **5** depicts the operation of the polarity change mechanism using outer housing **5301** (refer to FIG. **6**), where pull key **5310** is integrated with the outer housing. In FIG. **5**, micro connector **5300** is fully assembled. The user inserts a tool in access slot **5329** and lifts off outer housing **5301**, instead of flexible keys **3703** (refer to FIG. **3**). Front body **5302** is removed with the boot and cable attached as shown in FIG. **6**. Turning to FIG. **7**, the outer housing **5301** is rotated 180 degrees, as shown by the arrow "R", and placed back over front body **5302** in the direction of the second arrow as shown. The reversed polarity micro connector **5300** is shown fully assembled in FIG. **8**.

Referring to FIG. **9**, micro connector **5300** is shown just prior to insertion into adapter **5600**. Connector **5300** is partially inserted in FIG. **10**, wherein connector hook (or adapter hook) **5525** has not yet been seated in the connector recess **5511**, and FIG. **11** depicts hook **5525** seated in recess **5511**, in direction of arrow "A".

Referring to FIG. **12**, front body **6102** has two cutouts **6119** and **6121** and an extended middle wall **6110**. Cutout **6121** engages the outer housing hooks (not shown) that replaces flex key **3703** to secure the outer housing to the front body. Cutout **6121** secures the polarity change key **5310**. Cutout **6119** secures back post **2106** to front body **6102** via back post front body hook **2106.1** (refer to FIG. **2**). The material is saved at back post **2106** overmolding, by not using the flex key, and this saved material to reinforce the middle wall to better help support the ferrule springs from bending and thus help prevent distorting the ferrules. This reduced material also allowed a reduction in the connector size contribution to a 3.1 mm ferrule to ferrule pitch as shown in FIG. **12**. This distortion can increase insertion loss. Connector recess **6111** is located at the proximal end of front body **6102**, and the recess engages and locks with connector hook **5525**. Referring to FIG. **13**, adapter hook **6246** added chamfers (**6242**, **6226**) to adapter (connector) hook surfaces to improve installation of the connector into the adapter when connector ramps **5512** engage adapter (connector hook) **5525** Refer to FIG. **5**). Adapter hook assembly has an alignment sleeve holder **6227** that accepts one or more ferrules from the micro connector, and aligns the ferrules **9203** with opposing ferrules of a second micro connector (not shown).

FIG. **14** illustrates a group of micro connectors **7500**A inserted into an adapter **5700**. Adapter **5700** has plural of slots **5700***a* configured to accept an alignment key **7500**A.**1** proximal on the alignment and offset key (**7500**A, **9105.1**)

Alignment key, and alignment and offset key is defined as a protrusion adjacent to a side of the connector housing.

FIG. **15** depicts alignment and offset key **7500**B with the group of micro connectors **7500**A of FIG. **14**. Alignment/offset key **7500**B adds stability and reduces misalignment during insertion when key **7500**B acts as a support between connectors as shown. Key **7500**B also helps determine polarity of the micro connector, as described herein.

Referring to FIGS. **16-17**, FIG. **16** depicts micro connector **9100** with an alignment and offset key **9105.1** having an offset portion **9123**. Offset portion **9123** engages a top surface of a side bar ledge **9124** for aligning connector **9100** into a multi-receptacle adapter next to another micro connector. Side bar ledge **9124** is located further back or nearer a distal end of a connector (e.g. closer to the cable) where side bar ledge **9124** is part of a multi-purpose rotatable boot **9109.1**. Micro connector **9100** outer housing **9101** is secured to boot **9100.1** via boot hooks **9109.5** (FIG. **17**) that engages second slot **9201.4***a* and **9201.4***b* in connector housing **9201** (as shown in FIG. **18**), when in polarity status "B" or status "A", as depicted on outside of micro connector housing. Multi-purpose boot is rotatable in the direction of arrow "R".

Referring to FIG. **17**, multi-purpose rotatable boot **9109.1** comprises releasably attached alignment and offset key **9105.1**, releasable at release point **9109.6**, also refer to FIG. **43**. Alignment and offset key **2105** may be fixed on connector outer housing, as shown in FIG. **1** or at alignment key **5305** disclosed in FIG. **37**. The alignment key may have not offset portion as disclosed in FIG. **1** and FIG. **37**, without departing from the scope of the invention, that the boot assembly is rotatable as disclosed in FIGS. **26-27** and FIGS. **25-33** and FIGS. **43-45**. It is the key protruding from the connector housing that is determines polarity upon rotation of the boot assembly as disclosed herein. Alignment key (**2105**, **9405.1**, **5305**, **9600**) or similar structure protruding from the outer connector housing repositioned by the rotating boot assembly and the key interaction with adapter structure that determines polarity as described herein. Referring to FIG. **17**, key **9105.1** has a securing protrusion **9105.2** at a proximal end that engages first slot **9201.3***b* in connector housing **9201** (refer to FIG. **18**) to further secure multi-purpose rotatable boot assembly **9109.1** to front body **9202** or outer housing **9201**. Multi-purpose rotatable boot assembly **9109.1** comprises a body **9109.1***a* with a passageway along line P-P for passing a fiber optic cable (refer to FIG. **26** and FIG. **27**) to the ferrules to complete the signal path.

Referring to FIG. **18**, outer housing **9201** is shown in a Second Polarity orientation "B" comprising corresponding first slot **9201.3***b* and second slot **9201.4***b*. Multi-purpose rotatable boot assembly **9209.1** (FIG. **19**) is inserted at a distal end of connector housing **9201** shown in the direction of arrow "I". Second slot **9201.4***a* corresponds to polarity position "A".

Referring to FIG. **19**, multi-purpose rotatable boot assembly **9209.1** comprises alignment and offset key **9205.1**, as described herein boot hook **9209.5**, side bar ledge **9024** that is configured (as described herein) to engage back body **9206**, front body **9202** and plural of ferrules **9203**. Side bar ledge **9024** accepts offset key **9023** of a second connector when two connectors are inserted into an adapter. This allows connectors to be inserted side by side into an adapter more easily, without jamming. The proximal end (or ferrules **9203** end) of assembly **9209.1** is inserted into a distal end of the outer housing **9201** (FIG. **18**) in the direction of arrow "I". Upon insertion, the outer housing **9201** engages with multi-purpose rotatable boot assembly **9209.1** as shown by the dotted lines between first slot **9201.3***b* and second slot **9201.4***b*, engaging securing protrusion **9205.2** on alignment and offset key **9205.1** and boot wing **9209.5**. The wing and securing protrusion are received second slot and first slot described in FIG. **18** outer housing.

Referring to FIG. **20**, front body **9302** and boot assembly **9309.1** are assembled in micro connector housing **9301** with alignment and offset key **9305.1** in a first polarity position.

Referring to FIG. **21**, multi-purpose rotatable boot assembly **9309.1** is rotated in direction "R" to convert from a first polarity "A" (refer to FIG. **20**) to Second Polarity "B" (refer to FIG. **23**), with alignment and offset key **9305.1** 180 degrees or opposite the first polarity position as depicted in FIG. **20**, to Second Polarity position "B". Boot rotation key **9305.1** may be sized as disclosed in FIG. **1**. Boot hook **9209.5** further comprises chamfer **9309.2**. Chamfer **9309.2** engages wall **9301.5** of connector outer housing and chamfer **9309.2** lifts boot hook **9209.5** out of a distal end of connector housing **9301** and is freed from second slot **9201.4***b*, and securing protrusion **9105.2** (refer to FIG. **17** and shown in FIG. **20**) lifts out of first slot **9201.3***b* thereby allowing the boot assembly to rotate as shown in the direction "R", FIG. **21**. Chamfer **9309.2** may engage wall **9301.5** using an angle or chamfer cut opposite current chamfer **9309.2** to allow for rotation in the opposite direction of FIG. **21**. Rotation of boot assembly **9309.1** changes connector **9100** from a first polarity "A", as depicted in FIG. **20**, to Second Polarity "B", as depicted in FIG. **19** (without connector housing) and FIG. **32**. Boot assembly may be rotated in a clockwise direction, without departing from the scope of the invention.

Referring to FIG. **22**, further rotation of boot assembly **9309.1** results in a change to a second polarity as shown in FIG. **23**, with alignment and offset key secured within polarity "B" first slot **9201.3***b*.

Referring to FIG. **23**, side bar ledge **9023** (as well as alignment key **9305.1**) is in Second Polarity position or "B" polarity, and when the micro connector is inserted into an adapter (not shown), the micro connector is oriented with key **9305.1** in an opposite position to FIG. **20**, so key may be blocked by corresponding adapter structure (not shown). If micro connector **9100** is blocked by adapter structure this means the micro connector is not in the correct polarity orientation to make a fiber to fiber connection via an adapter to an opposing fiber optic connector or transceiver as is known in the art. After rotation, the ferrules are reversed the top ferrule is now the bottom ferrule, and this results in a second polarity configuration. The second polarity being different from the first polarity, that is, Rx receive signal is now Tx transmit signal path and vice versa. Alignment and offset key **9405.1** has been switch from a First Polarity "A" to Second Polarity "B".

FIG. **24** is the micro connector **9100** with a cross section along "A-A" line as shown in FIGS. **25** through **33** further illustrating polarity change using multi-purpose rotatable boot assembly **9209.1**. Longitudinal cross section is provided along line "B-B" in various drawings of this application. "L-L" is the longitudinal axis of the connectors in the present invention.

Referring to FIG. **25**, a front view of the cross-section cut "A-A" of the micro connector of FIG. **24** (also FIG. **16**) further comprises an opening through which fiber cabling (not shown) travels, and crimp ring surface **9407.1** that is further surrounded by inner round **9409.4**. Referring to FIG. **26**, inner round **9409.4** engages a back post surface **9406.7** formed as an outer round shown at FIG. **27**, as the assembly **9209.1** is rotated. Inner round and outer round form mating surfaces that can freely rotate thereby allowing multi-purpose boot assembly to be rotated about fiber optic connector housing. Referring back to FIG. **25**, boot hook **9109.5** further comprises first chamfer **9409.2***a* and first stopping wall **9409.3***a*, and second chamfer **9409.2***b* and second stopping wall **9409.3***b*, in a first polarity position. Boot hooks **9109.5** rotate between second slot **9201.4***a* and second slot **9201.4***b* during polarity change. Second slot **9201.4***a* corresponds to the connector being in a "A" polarity position. Likewise, second slot **9201.4***b* corresponds to the connector being in "B" polarity configuration. Securing protrusion **9405.1** resides in first slot **9201.3***a* for "A" polarity, and then resides in first slot **9201.3***b* for "B" polarity after boot release **9309.1** rotation.

Referring to FIG. **28**, rotating of the boot assembly is started and chamfer **9409.2***a* engages connector housing wall **9301.5** and begins to lift first boot wing **9109.5***a* out of second slot **9201.4***a*. Likewise, a second boot wing **9109.5***b* is rotating out of second slot **9201.4***b*.

Referring to FIG. **29** upon further rotation in direction "R", securing protrusion **9105.2** (refer to FIG. **20**) on alignment and offset key **9405.1** is lifted out of first slot **9201.3***a* (refer to FIG. **20** and FIG. **21**), and boot wing **9109.5***a* is lifted out of second slot **9201.4***a* at a top surface and upon 180 degree rotation, securing protrusion **9105.2** (refer to FIG. **20**) is accepted into first slot **9201.4***b* at a bottom surface of the outer housing **9401**. Boot wing **9109.5***b* moves out of second slot **9201.4***b*.

Referring to FIG. **30**, the rotation of boot assembly **9409.1** is shown as it exits the outer housing **9401** of connector **9100**. Chamfer **9409.2***b* exits first from this view. Alignment and offset key **9405.1** is moving around the outer housing body in a counter-clockwise direction, in this view to a Second Polarity position "B".

Referring to FIG. **31**, alignment and offset key **9405.1** is almost in a second polarity position as shown, with chamfer **9409.2***b* in an opposite orientation to itself in FIG. **25**. Referring to FIG. **32**, connector **9100** shows chamfer **9409.2***b* in the opposite position to that of FIG. **30**, indicating the connector is close to its second polarity configuration with alignment and offset key **9405.1** at bottom surface of outer housing **9401**. FIG. **33** depicts connector **9100** along cross section "A-A" in its second polarity position, with chamfer **9409.2***b* in second slot **9401.4***a* at the top surface of outer housing **9401**. Polarity key **9405.1** is at the bottom surface of outer housing **9401** indicating the connector is in a second polarity configuration.

Referring to FIG. **34** a micro connector **9100** is shown along cross section "B-B" (refer to FIG. **24**) in a latched position within a receptacle of adapter **2400**. During rotation of the multi-purpose rotatable boot assembly **9209.1**, boot wing **9209.5** operates as described above in FIGS. **25-33**. This is accomplished by gap **9209.6** between boot assembly **9209.1** that allows "free-wheeling" about crimp ring **9207** as inner round **9409.4** engages back post face surface **9406.7** as described in FIGS. **26-27**. Rotating boot assembly while connector is in a latched position within adapter, boot assembly wing **9209.5** facing surface is in contact with facing surface **9206.2** of back post **2106**, as shown at interface **9100.8**. Still referring to FIG. **34**, boot wing **9209.5** face engages and releaseably locks with corresponding surface **9301.4***a* of second slot **9201.4** of outer housing **9201**, FIG. **18** and FIG. **21**. Micro connector **9100** is latched and unlatched in an adapter **2400** receptacle using push/pull boot assembly or push/pull key as described in FIGS. **9-11**, or FIGS. **34-36**, or FIGS. **37-42**. Adapter hook **2425** is seated in connector recess **9211** located in front body **9202**. In this position, boot assembly **9209.1** is up against back body **2106** as shown at interface **9100.8**, as shown by direction of arrow "Pushed In".

Referring to FIG. **35**, boot assembly **9209.1** is being pulled rearward in the direction of "P". Boot assembly **9209.1** is pulled a release distance "d" to interface **9100.8**, **9100.9** to unlatch connector from adapter interface. At the same time, adapter hook **2425** is being lifted out connector recess **9211** as micro connector **9100** is removed from adapter **2400** receptacle. Boot assembly **9209.1** moves a distance "d" because boot wing **9209.5** engages outer housing face **9301.4***a*, and pulls outer housing **9201** rearward. Outer housing **9201** is pulled rearward connector **9100** is released from this the amount of separation between the distal end of the back body and proximal end of boot assembly **9209.1**. This distance matches channel distance, FIG. **36**, **9100.9***a*, **9100.8***a* in which boot hooks slide upon pulling connector from adapter using rotatable boot assembly. Hooks **2425** lift out of recess **9211** located at a proximal end of front body **2102**, when boot assembly **9209.1** is pulled rearward at least this distance.

Referring to FIG. **36**, once boot assembly **9209.1** is fully pulled in direction of "P", connector **9100** is released from within adapter **2400**. Adapter hook **2425** is completely out of connector recess **9211**, and maximum pulling distance. Once the pull force, "P", is release from boot **9209.1**, interface distance **9100.8** returns to that of FIG. **34**, upon release of pull force "P", on boot assembly **9209.1**.

FIG. **37** depicts connector **5300** with push/pull boot assembly **5345***a* at its distal end receiving a fiber cable with a plural of fiber strands therein, and a proximal end configured to connect and secure to back body assembly **5330***a* secured with outer housing **5301**. Outer housing **5301** has alignment key **5305**, further has opening **5301***a* with stop face **5301***b* that boot wings (**5445***b*, **5445***c*) (refer to FIG. **38**) engage when boot assembly **5345***a* is pulled in a distal direction fully to release connector **5300** from a receptacle as shown in FIG. **41**, when hook **5425** is removed from recess **5711**. Ferrules **5303** provide the Tx, Rx information light signals.

FIG. **38** depicts an exploded view of connector **5300** of FIG. **37**. Boot assembly **5445***a* accepts crimp ring assembly **5440***a* having protective tube **5440***c* covering fiber strands and crimp ring **5440***b* secured to back post **5430***c* of back body assembly **5430***a* including back body **5430***b*. A pair of springs **5425** are placed over a corresponding ferrule assembly **5420** comprising a ferrule and ferrule flange. The ferrule assembly and springs are held within front body **5402** by back body assembly **5430***a*, as described for connector **2100**. Front body **5402** is inserted into distal opening **5401.1** of outer housing **5401** with boot assembly wing **5430***a* secured within a distal opening **5415***b* of front body and wing is secured through opening **5401.4** of outer housing securing outer housing, front body and back body together when assembled with push/pull boot, as depicted in FIG. **37**.

FIG. **39** depicts connector of FIG. **37** without its outer housing **5301**, in an assembled configuration. Boot assembly **5445***a* is secured on back post **5430***c* of back body **5430***a* via crimp ring **5440***a*, as described in FIG. **38**. Wings (**5445***b*, **5445***c*) secure FIG. **39** assembly within outer housing **5301**, and during release of connector **5300** from a receptacle, wings (**5445***b*, **5445***c*) pull back outer housing a specific distance "d", which releases adapter/receptacle hook or latch **5625** that is seated in recess **5611** (refer to FIG. **40**), while connector **5300** is secured within receptacle **2400**. Front body **5402** is secured to connector housing **5401** with back body **5430***a* secured to a distal end of front body **5402**, as described in FIG. **1** and elsewhere in this disclosure.

FIG. **40** depicts connector **5300** secured within receptacle **2400** of FIG. **24**. Receptacle hook or latch **5625** rests in connector recess **5611** formed within front body **5601**, at its proximal end. A gap of distance "d" **5629** limits travel of front body **5601** as boot release wing **5645***b* engages stop face **5301***b* of outer housing **5601**. This "d" travel removes hook **5625** from connector recess **5611** thereby unlatching or releasing connector from adapter **2400**. Crimp ring **5440***b* is shown secured to back post **5630***c*. Back body **5630***a* is secured within front body **5402** at distal openings **5401***b* (FIG. **38**).

FIG. **41** depicts connector **5300** being removed or pulled out of receptacle **2400** in direction "P". Hook or latch **2425** within receptacle housing lifts out of recess **5711** along front body ramp **5401***d* (FIG. **38**), as boot assembly **5745***a* is being pulled rearward or in a distal direction. Gap **5529** is closed as shown in FIG. **41**. Inner face of connector housing **5715***c* is flush with front face of front body **5701***e*, which stops travel of boot assembly and is configured to ensure adapter latch or hook **2425** is displaced from recess **5711** to release connector from receptacle, as shown in FIG. **42**. Boot wing **5745***c* is secured at a distal end within second slot or opening **5401.4** within connector housing **5401**.

FIG. **42** depicts connector **5300** removed from receptacle **2400** using boot assembly **5845***a*. In this embodiment, wings (**5845***b*, **5845***c*) are flush with outer housing wall **5801***b*. Wings (**5845***b*, **5845***c*) move within gap or opening **5801***c* within connector housing outer wall, as boot **5845***a* is pulled rearward to release connector from adapter **2400** as shown. Spring **5825** biases forward front body face **5815***c* to be flush with front body face **5801***e*, when pull force is released from boot assembly. Hook or latch **2425** is displaced from recess **5811**, and hook resides in adapter housing gap **2400***a* within outer housing of receptacle **2400**. This reduces the overall dimensions of the adapter to accept more connectors.

Referring to FIG. **43**, another embodiment of a polarity change is disclosed using alignment and offset key **9600**. Alignment and offset key **9600** is releasably attached to boot clip surface **9975** as shown by the dotted line. Attaching key **9600** to a first side of the boot **9209.1**, connector **9100** is in first polarity configuration, and attaching key **9600** to a second side, connector **9100** is in a second polarity configuration. Referring to FIG. **44**, a first polarity configuration is assembled key **9600** is attached to boot **9209.1** of connector **9100**. Referring to FIG. **45**, a second polarity configuration is assembled with key **9600** is attached to the opposite side of boot **9209.1**.

In the above detailed description, reference is made to the accompanying drawings, which form a part hereof. In the drawings, similar symbols typically identify similar components, unless context dictates otherwise. Other embodiments may be used, and other changes may be made, without departing from the spirit or scope of the subject matter presented herein.

It will be understood by those within the art that, in general, terms used herein, and especially in the appended claims (for example, bodies of the appended claims) are generally intended as "open" terms (for example, the term "including" should be interpreted as "including but not limited to," the term "having" should be interpreted as "having at least," the term "includes" should be interpreted as "includes but is not limited to," et cetera). For example, as an aid to understanding, the following appended claims may contain usage of the introductory phrases "at least one" and "one or more" to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles "a" or "an" limits any particular claim containing such introduced claim recitation to embodiments containing only one such recitation, even when the same claim includes the introductory phrases "one or more" or "at least one" and indefinite articles such as "a" or "an" (for example, "a" and/or "an" should be interpreted to mean "at least one" or "one or more").

The invention claimed is:

1. An optical fiber connector comprising:

a front body configured to hold first and second ferrules;

a back body having a proximal end portion and a distal end portion spaced apart along a longitudinal axis, the proximal end portion of the back body configured to couple to the front body, the back body defining a back body passageway extending from the distal end portion through the proximal end portion; and

a rotatable boot assembly having a proximal end portion and a distal end portion spaced apart along the longitudinal axis, the rotatable boot assembly comprising a main body and a strain relief sleeve extending longitudinally from the main body to the distal end portion of the rotatable boot assembly, the rotatable boot assembly comprising a boot passageway extending from the distal end portion through the main body, the rotatable boot assembly configured to be disposed on the back body such that the cable boot member is slidable along the longitudinal axis relative to the back body for releasing the optical fiber connector from an adapter, the optical fiber connector being configured to terminate a fiber optic cable such that a jacket of the cable is received in the strain relief sleeve in the boot passageway, the boot passageway and the back body passageway configured to align for passing first and second fibers from the fiber optic cable to the front body to complete a signal path to the first and second ferrules within the front body; the main body being configured to releasably secure the multi-purpose rotatable boot assembly against rotation relative to the back body, and the rotatable boot assembly further comprising an elongate arm extending longitudinally from the main body in a proximal direction along the longitudinal axis, the elongate arm being configured for selectively setting the optical fiber connector to each of a first polarity and a second polarity.

2. The optical fiber connector according to claim **1**, wherein the elongate arm is an alignment key.

3. The optical fiber connector according to claim **2**, wherein the alignment key aligns the proximal end of the optical fiber connector into the adapter.

4. The optical fiber connector according to claim **2**, wherein the alignment key further comprises an offset key, the offset key stabilizes the distal ends of the fiber optic connector and the second fiber optic connector.

5. The optical fiber connector according to claim **1**, wherein the main body further comprises first and second boot hooks configured to releasably couple the multi-purpose rotatable boot assembly to the back body.

6. The optical fiber connector according to claim **5**, wherein the first and second boot hooks are spaced apart on diametrically opposite sides of the longitudinal axis.

7. The optical fiber connector according to claim **5**, wherein when the rotatable boot assembly is disposed on the back body, the first and second boot hooks are spaced apart on diametrically opposite sides of the back body passageway and radially overlap the back body passageway relative to the longitudinal axis.

8. The optical fiber connector according to claim **5**, wherein the first and second boot hooks are releasable to allow the rotatable boot assembly to rotate on the fiber optic cable 180° about the longitudinal axis from a first polarity position in which the elongate arm sets the optical fiber connector to the first polarity to a second polarity position in which the elongate arm sets the optical fiber connector to the second polarity.

9. The optical fiber connector according to claim **8**, wherein when the rotatable boot assembly is in the first polarity position, the first boot hook is on a first side of the back post and the second boot hook is on a second side of the back post; and wherein when the boot assembly is in the second polarity position, the first boot hook is on the second side of the back post and the second boot hook is on the first side of the back post.

10. The optical fiber connector according to claim **8**, wherein the elongate arm is connected to the main body to rotate with the main body as the rotatable boot assembly rotates between the first polarity position and the second polarity position.

11. The optical fiber connector according to claim **5**, wherein the first boot hook and the elongate arm are radially spaced apart from the longitudinal axis in a first direction and the second boot hook is radially spaced apart from the longitudinal axis in a second direction opposite the first direction.

12. The optical fiber connector according to claim **1**, wherein the rotatable boot assembly is configured to rotate on the fiber optic cable 180° about the longitudinal axis from a first polarity position in which the elongate arm sets the optical fiber connector to the first polarity to a second polarity position in which the elongate arm sets the optical fiber connector to the second polarity.

13. The optical fiber connector according to claim **12**, wherein the elongate arm is connected to the main body to rotate with the main body as the rotatable boot assembly rotates between the first polarity position and the second polarity position.

14. The optical fiber connector according to claim **13**, wherein the front body holds the first and second ferrules such that the first ferrule is radially spaced apart from the longitudinal axis in a first direction and the second ferrule is radially spaced apart from the longitudinal axis in a second direction opposite the first direction.

15. The optical fiber connector according to claim **14**, wherein when the rotatable boot assembly is in the first polarity position, the elongate arm is radially spaced apart from the longitudinal axis in the first direction; and wherein when the rotatable boot assembly is in the second polarity position, the elongate arm is radially spaced apart from the longitudinal axis in the second direction.

16. The optical fiber connector according to claim **14**, wherein the front body comprises a contiguous ferrule support wall extending transverse to the longitudinal axis and having a first end portion radially spaced apart from the longitudinal axis in the first direction and a second end portion radially spaced apart from the longitudinal axis in the second direction, the ferrule support wall defining a first ferrule opening radially spaced between the first end portion and the longitudinal axis and a second ferrule opening radially spaced between the longitudinal axis and the second end portion, the front body configured to receive the first ferrule in the first opening and the second ferrule in the second opening.

17. The optical fiber connector of claim **16**, wherein the front body further comprises a first elongate portion extending longitudinally from the first end portion of the ferrule support wall and a second elongate portion extending longitudinally from the second end portion of the ferrule support wall, the first and second elongate portions having distal end segments that define an undivided space between them that opens longitudinally through a distal end of the front body.

18. The optical fiber connector according to claim **17**, wherein the proximal end portion of the back body is configured to be received in the undivided space between the distal end segments of the first and second elongate portions.

19. The optical fiber connector according to claim **1**, wherein the back body passageway and the boot passageway form a single, undivided longitudinal passage through which the first and second fibers are passable from the cable to the first and second ferrules.

20. The optical fiber connector according to claim **1**, wherein the back body passageway comprises a distal segment along the back post, a proximal segment along the proximal end portion of the back body, and a transition segment between the distal segment and the proximal segment,

wherein the back body passageway has a first inner dimension along a first radial axis and a second inner dimension along a second radial axis perpendicular to the first radial axis,

wherein along the distal segment, the back body passageway is substantially circular such that the first inner dimension is about the same as the second inner dimension;

wherein along the proximal segment, the back body has a cross-sectional shape that is elongate along the first radial axis such that the first inner dimension is greater than the second inner dimension; and

wherein along the transition segment, as the back body passageway extends in the proximal direction along the longitudinal axis, the first inner dimension increases by a greater amount than the second inner dimension.

* * * * *

EXHIBIT L

US011774685B2

(12) **United States Patent**
Wong et al.

(10) **Patent No.: US 11,774,685 B2**
(45) **Date of Patent: Oct. 3, 2023**

(54) **ADAPTER FOR OPTICAL CONNECTORS**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **17/733,865**

(22) Filed: **Apr. 29, 2022**

(65) **Prior Publication Data**

US 2022/0252797 A1 Aug. 11, 2022

Related U.S. Application Data

(63) Continuation of application No. 17/375,856, filed on Jul. 14, 2021, now Pat. No. 11,333,836, which is a continuation of application No. 17/200,134, filed on Mar. 12, 2021, now Pat. No. 11,181,701, which is a continuation of application No. 16/297,607, filed on Mar. 9, 2019, now Pat. No. 10,976,505, which is a continuation of application No. PCT/US2018/016049, filed on Jan. 30, 2018.

(60) Provisional application No. 62/581,961, filed on Nov. 6, 2017, provisional application No. 62/546,920, filed on Aug. 17, 2017, provisional application No. 62/485,042, filed on Apr. 13, 2017, provisional application No. 62/463,898, filed on Feb. 27, 2017, provisional application No. 62/457,150, filed on Feb. 9, 2017, provisional application No. 62/452,147, filed on Jan. 30, 2017.

(51) **Int. Cl.**
G02B 6/38 (2006.01)

(52) **U.S. Cl.**
CPC ***G02B 6/3893*** (2013.01); ***G02B 6/3821*** (2013.01); ***G02B 6/3879*** (2013.01)

(58) **Field of Classification Search**
CPC ... G02B 6/3893; G02B 6/3821; G02B 6/3879
USPC 385/78
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,150,790 A 4/1979 Potter
4,327,964 A 8/1982 Haesley et al.
(Continued)

FOREIGN PATENT DOCUMENTS

CA 2495693 A1 4/2004
CN 2836038 Y 11/2006
(Continued)

OTHER PUBLICATIONS

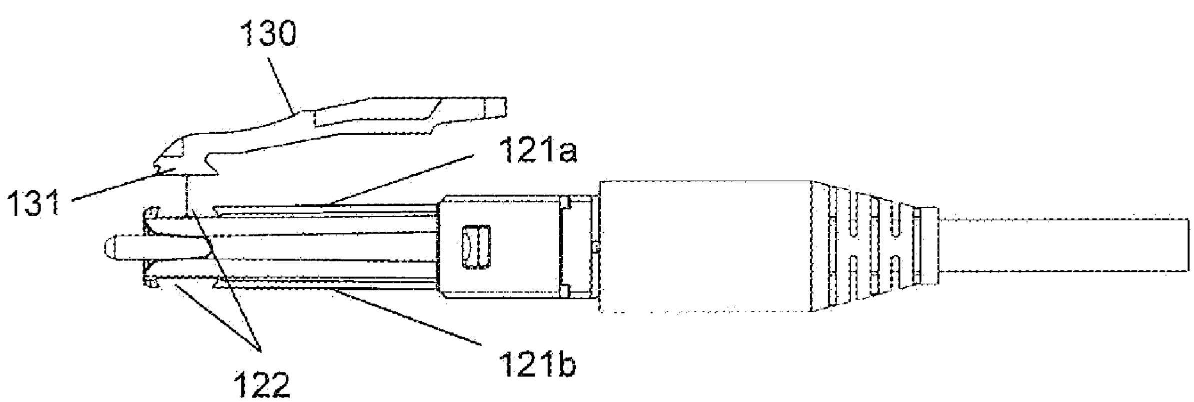
European Search Report and Written Opinion, dated Mar. 3, 2015 for EP 14187661.
(Continued)

Primary Examiner — Jerry M Blevins

(57) **ABSTRACT**

An optical fiber connector assembly comprises at least one connector having a latching arm for coupling to an adapter, and a remote release tab having a protrusion configured to cooperate with the adapter to depress said latching arm when the remote release tab is pulled relative to the adapter. The optical fiber connector assembly may further be configured to allow reversing its polarity.

18 Claims, 28 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

4,478,473 A 10/1984 Frear
4,762,388 A 8/1988 Tanaka et al.
4,764,129 A 8/1988 Jones et al.
4,840,451 A 6/1989 Sampson et al.
4,872,736 A 10/1989 Myers et al.
4,979,792 A 12/1990 Weber et al.
5,041,025 A 8/1991 Haitmanek
D323,143 S 1/1992 Ohkura et al.
5,212,752 A 5/1993 Stephenson et al.
5,265,181 A 11/1993 Chang
5,289,554 A 2/1994 Cubukciyan et al.
5,317,663 A 5/1994 Beard et al.
5,335,301 A 5/1994 Newman et al.
5,348,487 A 9/1994 Marazzi et al.
5,444,806 A 8/1995 deMarchi et al.
5,481,634 A 1/1996 Anderson et al.
5,506,922 A 4/1996 Grois et al.
5,521,997 A 5/1996 Rovenolt et al.
5,570,445 A 10/1996 Chou et al.
5,588,079 A 12/1996 Tanabe et al.
5,684,903 A 11/1997 Kyomasu et al.
5,687,268 A 11/1997 Stephenson et al.
5,781,681 A 7/1998 Manning
5,845,036 A 12/1998 De Marchi
5,937,130 A 8/1999 Amberg et al.
5,956,444 A 9/1999 Duda et al.
5,971,626 A 10/1999 Knodell et al.
6,041,155 A 3/2000 Anderson et al.
6,049,040 A 4/2000 Biles et al.
6,134,370 A 10/2000 Childers et al.
6,178,283 B1 1/2001 Weigel
RE37,080 E 3/2001 Stephenson et al.
6,206,577 B1 3/2001 Hall, III et al.
6,206,581 B1 3/2001 Driscoll et al.
6,227,717 B1 5/2001 Ott et al.
6,238,104 B1 5/2001 Yamakawa et al.
6,247,849 B1 6/2001 Liu
6,276,840 B1 8/2001 Weiss et al.
6,364,537 B1 4/2002 Maynard
6,371,657 B1 4/2002 Chen et al.
6,386,768 B1 5/2002 Yoon et al.
6,447,170 B1 9/2002 Takahashi et al.
6,461,054 B1 10/2002 Iwase
6,471,412 B1 10/2002 Belenkiy et al.
6,478,472 B1 11/2002 Anderson et al.
6,551,117 B2 4/2003 Poplawski et al.
6,579,014 B2 6/2003 Melton et al.
6,634,801 B1 10/2003 Waldron et al.
6,648,520 B2 11/2003 McDonald et al.
6,668,113 B2 12/2003 Togami et al.
6,682,228 B2 1/2004 Rathnam et al.
6,685,362 B2 2/2004 Burkholder et al.
6,695,486 B1 2/2004 Falkenberg
6,854,894 B1 2/2005 Yunker et al.
6,872,039 B2 3/2005 Baus et al.
6,935,789 B2 8/2005 Gross, III et al.
7,052,186 B1 5/2006 Bates
7,091,421 B2 5/2006 Kukita et al.
7,090,406 B2 8/2006 Melton et al.
7,090,407 B2 8/2006 Melton et al.
7,111,990 B2 9/2006 Melton et al.
7,113,679 B2 9/2006 Melton et al.
D533,504 S 12/2006 Lee
D534,124 S 12/2006 Taguchi
7,150,567 B1 12/2006 Luther et al.
7,153,041 B2 12/2006 Mine et al.
7,198,409 B2 4/2007 Smith et al.
7,207,724 B2 4/2007 Gurreri
D543,146 S 5/2007 Chen et al.
7,258,493 B2 8/2007 Milette
7,281,859 B2 10/2007 Mudd et al.
7,297,013 B2 11/2007 Caveney et al.
D558,675 S 1/2008 Chien et al.
7,315,682 B1 1/2008 En Lin et al.
7,325,976 B2 2/2008 Gurreri et al.
7,325,980 B2 2/2008 Pepe
7,329,137 B2 2/2008 Martin et al.
7,331,718 B2 2/2008 Yazaki et al.
7,354,291 B2 4/2008 Caveney et al.
7,371,082 B2 5/2008 Zimmel et al.
7,387,447 B2 6/2008 Mudd et al.
7,390,203 B2 6/2008 Murano et al.
D572,661 S 7/2008 En Lin et al.
7,431,604 B2 10/2008 Waters et al.
7,463,803 B2 12/2008 Cody et al.
7,465,180 B2 12/2008 Kusuda et al.
7,473,124 B1 1/2009 Briant et al.
7,507,103 B1 3/2009 Phillips et al.
7,510,335 B1 3/2009 Su et al.
7,513,695 B1 4/2009 Lin et al.
7,561,775 B2 7/2009 Lin et al.
7,591,595 B2 9/2009 Lu et al.
7,594,766 B1 9/2009 Sasser et al.
7,641,398 B2 1/2010 O'Riorden et al.
7,651,361 B2 1/2010 Henry et al.
7,695,199 B2 4/2010 Teo et al.
7,699,533 B2 4/2010 Milette
7,824,113 B2 11/2010 Wong et al.
7,837,395 B2 11/2010 Lin et al.
D641,708 S 7/2011 Yamauchi
8,083,450 B1 12/2011 Smith et al.
8,186,890 B2 5/2012 Lu
8,192,091 B2 6/2012 Hsu et al.
8,202,009 B2 6/2012 Lin et al.
8,251,733 B2 8/2012 Wu
8,267,595 B2 9/2012 Lin et al.
8,270,796 B2 9/2012 Nhep
8,408,815 B2 4/2013 Lin et al.
8,465,317 B2 6/2013 Gniadek et al.
8,556,645 B2 10/2013 Crain
8,636,424 B2 1/2014 Kuffel et al.
8,641,293 B2 2/2014 Lin
8,651,749 B2 2/2014 Dainese Junior et al.
8,770,863 B2 7/2014 Cooke et al.
8,998,505 B2 4/2015 Motofuji
9,028,270 B1 5/2015 Vanderwoud
9,411,110 B2 8/2016 Barnette et al.
9,494,744 B2 11/2016 de Jong
9,548,557 B2 1/2017 Liu
9,551,842 B2 1/2017 Theuerkorn
9,568,686 B2 2/2017 Fewkes et al.
9,568,689 B2 2/2017 Nguyen et al.
9,581,768 B1 2/2017 Baca et al.
9,684,313 B2 6/2017 Cline et al.
9,709,753 B1 7/2017 Chang et al.
10,185,099 B2 1/2019 Chang et al.
10,444,444 B2 10/2019 Ma et al.
11,385,415 B2 7/2022 Nguyen et al.
2001/0026661 A1 10/2001 de Jong et al.
2002/0172467 A1 11/2002 Anderson et al.
2003/0053787 A1 3/2003 Lee
2003/0063862 A1 4/2003 Fillion et al.
2003/0157825 A1 8/2003 Kane
2004/0052473 A1 3/2004 Seo et al.
2004/0062487 A1 4/2004 Mickievicz
2004/0136657 A1 7/2004 Ngo
2004/0141693 A1 7/2004 Szilagyi et al.
2004/0161958 A1 8/2004 Togami et al.
2004/0234209 A1 11/2004 Cox et al.
2005/0013753 A1 1/2005 Eaton et al.
2005/0111796 A1 5/2005 Matasek et al.
2005/0135752 A1* 6/2005 Kiani G02B 6/3895 385/55
2005/0141817 A1 6/2005 Yazaki et al.
2006/0089049 A1 4/2006 Sedor
2006/0127025 A1 6/2006 Haberman
2006/0140453 A1 6/2006 Abendschein et al.
2006/0160429 A1 7/2006 Dawiedczyk et al.
2006/0269194 A1 11/2006 Luther et al.
2006/0274411 A1 12/2006 Yamauchi
2007/0028409 A1 2/2007 Yamada
2007/0079854 A1 4/2007 You
2007/0098329 A1 5/2007 Shimoji et al.
2007/0149062 A1 6/2007 Long et al.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2007/0230874 A1 10/2007 Lin
2007/0232115 A1 10/2007 Burke et al.
2007/0243749 A1 10/2007 Wu
2008/0008430 A1 1/2008 Kewitsch
2008/0044137 A1 2/2008 Luther et al.
2008/0069501 A1 3/2008 Mudd et al.
2008/0101757 A1 5/2008 Lin et al.
2008/0226237 A1 9/2008 O'Riorden et al.
2008/0267566 A1 10/2008 Lin et al.
2009/0022457 A1 1/2009 De Jong et al.
2009/0028507 A1 1/2009 Jones et al.
2009/0092360 A1 4/2009 Lin et al.
2009/0196555 A1 8/2009 Lin et al.
2009/0214162 A1 8/2009 O'Riorden et al.
2009/0220197 A1 9/2009 Gniadek
2009/0232455 A1 9/2009 Nhep
2009/0290938 A1 11/2009 Lin et al.
2010/0034502 A1 2/2010 Lu et al.
2010/0239220 A1 9/2010 Lin et al.
2010/0247041 A1 9/2010 Szilagyi
2010/0322561 A1 12/2010 Lin et al.
2011/0044588 A1 2/2011 Larson et al.
2011/0045683 A1 2/2011 Foung
2011/0058773 A1 3/2011 Peterhans et al.
2011/0091159 A1 4/2011 de Jong et al.
2011/0131801 A1 6/2011 Nelson et al.
2011/0177710 A1 7/2011 Tobey
2011/0267742 A1 11/2011 Togami et al.
2012/0099822 A1 4/2012 Kuffel et al.
2012/0155810 A1 6/2012 Nakagawa
2012/0189260 A1 7/2012 Kowalczyk et al.
2012/0237177 A1 9/2012 Minota
2012/0269485 A1 10/2012 Haley et al.
2012/0301080 A1 11/2012 Gniadek
2013/0071067 A1 3/2013 Lin
2013/0089995 A1 4/2013 Gniadek et al.
2013/0094816 A1 4/2013 Lin et al.
2013/0121653 A1 5/2013 Shitama et al.
2013/0183012 A1 7/2013 Cabanne Lopez et al.
2013/0216188 A1 8/2013 Lin et al.
2013/0259429 A1 10/2013 Czosnowski et al.
2013/0322825 A1 12/2013 Cooke et al.
2014/0016901 A1 1/2014 Lambourn et al.
2014/0023322 A1 1/2014 Gniadek et al.
2014/0050446 A1 2/2014 Chang
2014/0133808 A1 5/2014 Hill et al.
2014/0219621 A1 8/2014 Barnette et al.
2014/0226946 A1 8/2014 Cook et al.
2014/0241678 A1 8/2014 Brinquier et al.
2014/0241688 A1 8/2014 Isenhour et al.
2014/0334780 A1 11/2014 Nguyen et al.
2014/0348477 A1 11/2014 Chang
2015/0111417 A1 4/2015 Vanderwoud
2015/0301294 A1 10/2015 Chang
2015/0355417 A1 10/2015 Takano
2015/0331201 A1 11/2015 Takano et al.
2015/0378113 A1 12/2015 Good et al.
2016/0116685 A1 4/2016 Wong et al.
2016/0172852 A1 6/2016 Takano
2016/0291262 A1 6/2016 Chang
2016/0195682 A1 7/2016 Takano
2016/0231512 A1 8/2016 Seki
2016/0259135 A1 9/2016 Gniadek et al.
2016/0266326 A1 9/2016 Gniadek
2016/0320572 A1 11/2016 Gniadek
2016/0131849 A1 12/2016 Takano
2016/0349458 A1 12/2016 Murray et al.
2017/0003458 A1 1/2017 Gniadek
2017/0205590 A1 7/2017 Bailey et al.

FOREIGN PATENT DOCUMENTS

CN 201383588 Y 1/2010
CN 202600189 U 12/2012
DE 202006011910 U1 4/2007
DE 102006019335 A1 10/2007
EP 1074868 A1 7/2001
EP 1211537 A2 6/2002
EP 1245980 A2 10/2002
EP 1566674 A1 8/2005
GB 2111240 A 6/1983
JP 2009229545 A 10/2009
JP 2009276493 A 11/2009
TW 200821653 A 5/2008
WO 2001/79904 A2 10/2001
WO 2004/027485 A1 4/2004
WO 2008/112986 A1 9/2008
WO 2009/135787 A1 11/2009
WO 2010/024851 A2 3/2010
WO 2012/136702 A1 10/2012
WO 2012/162385 A1 11/2012
WO 2014/028527 A1 2/2014
WO 2014/182351 A1 11/2014
WO 2015/191024 A1 12/2015
WO 2016/148741 A1 9/2016
WO 2017/127208 A1 7/2017

OTHER PUBLICATIONS

European Search Report and Written Opinion, dated Feb. 19, 2015 for EP 14168005.
"Fiber Optic Connectors and Assemblies Catalog" 2009, Huber & Suhner Fiver Optics, Herisau, Switzerland, www.hubersuhner.com.
"Fiber Optic Interconnect Solutions, Tactical Fiber Optical Connectors, Cables and Termini" 2006, Glenair, Inc., Glendale, California, www.mps-electronics.de.
"Fiber Optic Products Catalog" Nov. 2007, Tyco Electronics Corporation, Harrisburg, Pennsylvania, www.ampnetconnect.com.
International Search Report and Written Opinion, dated Apr. 27, 2012 for PCT/US2011/058799.
International Search Report and Written Opinion, dated Aug. 27, 2012 for PCT/US2012/039126.
International Search Report and Written Opinion, dated Jan. 16, 2014 for PCT/US2013/54784.
International Search Report and Written Opinion, dated Oct. 9, 2014 for PCT/US2014/041500.
International Search Report and Written Opinion, dated May 14, 2014 for PCT/US2014/012137.
International Search Report and Written Opinion, dated Aug. 21, 2008 for PCT/US2008/057023.
International Preliminary Report on Patentability dated Aug. 22, 2016 from related International Application No. PCT/US2015/059458, International Filing Date Nov. 6, 2015.
International Search Report, dated May 19, 2019 for PCT/US2016/028266.
International Search Report and Written Opinion, dated Feb. 20, 2014, WO2014028527.
International Search Report and Written Opinion, dated Jan. 21, 2016, WO2015US57610.
International Preliminary Report on Patentability, Application No. PCT/US2018/015733, dated Aug. 8, 2019, 9 pages.
Non-Final Office action, U.S. Appl. No. 15/882,343, dated Nov. 19, 2018, 12 pages.
International Search Report and Written Opinion for Application No. PCT/US2011/058799, dated Nov. 1, 2011.
International Search Report for Application No. PCT/US2012/039126, dated Aug. 27, 2012.
International Search Report for Application No. WO2008112986, dated Sep. 15, 2009.
International Search Report and Written Opinion for Application No. WO2012162385, dated Nov. 29, 2012.
International Search Report for Application No. WO2014028527, dated Jul. 16, 2015.
International Search Report for Application No. WO2015191024, dated Oct. 9, 2014.
International Search Report for Application No. WO2015US57610, dated Sep. 22, 2016.
International Search Report for Application No. WO2016176083, dated May 19, 2016.

(56) **References Cited**

OTHER PUBLICATIONS

International Search Report for Application No. WO2016148741, dated Sep. 22, 2016.
Re-Examination U.S. Appl. No. 90/014,456 of U.S. Pat. No. 10,191,230, filed Feb. 19, 2020, 191 pages.
Molex Incorporated, HBMT Motherboard Adapter, drawings, dated Oct. 31, 2005, 2 pages.

* cited by examiner

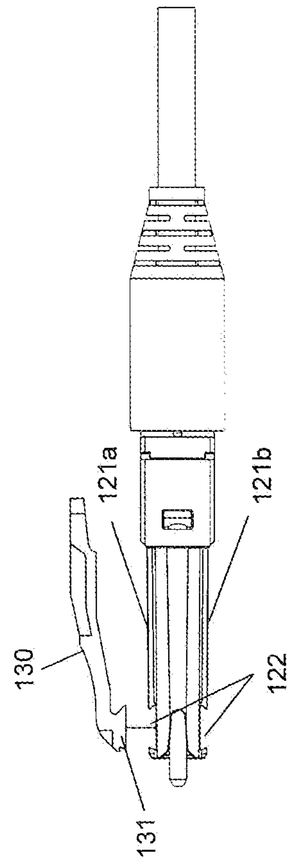


FIG. 1B

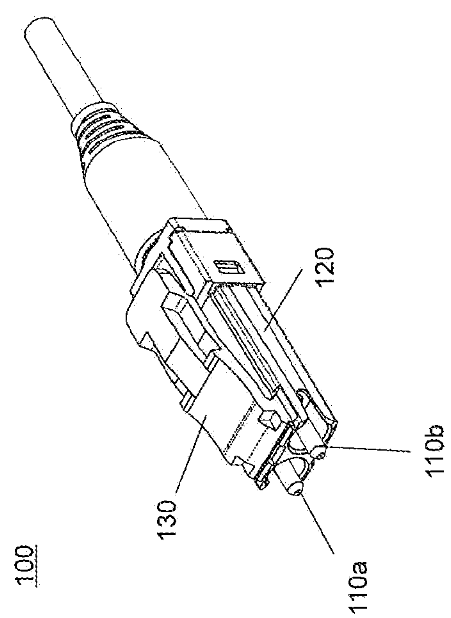


FIG. 1A

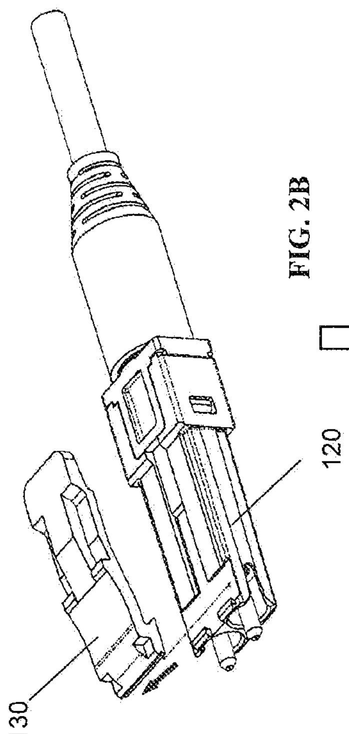


FIG. 2B

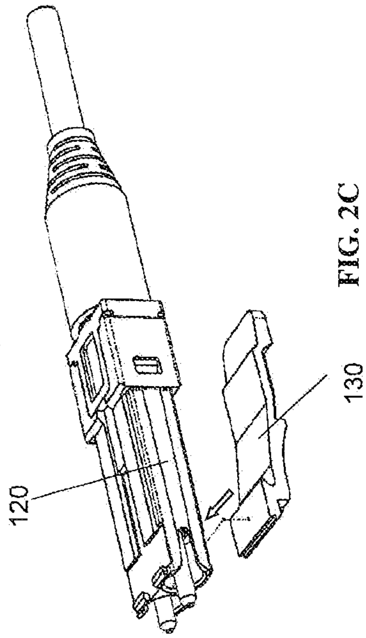


FIG. 2C

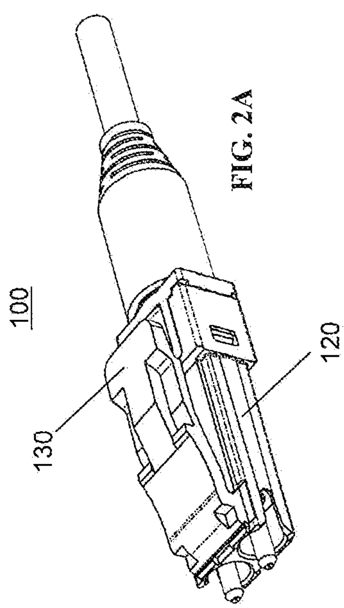


FIG. 2A

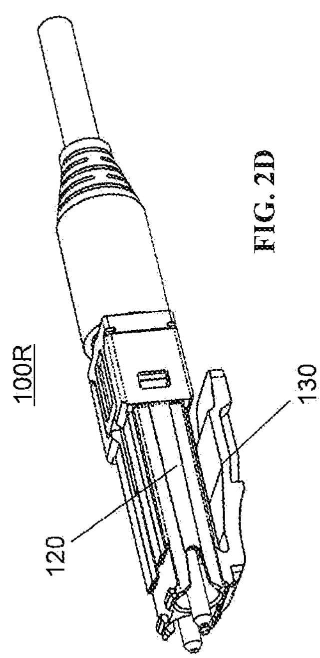


FIG. 2D

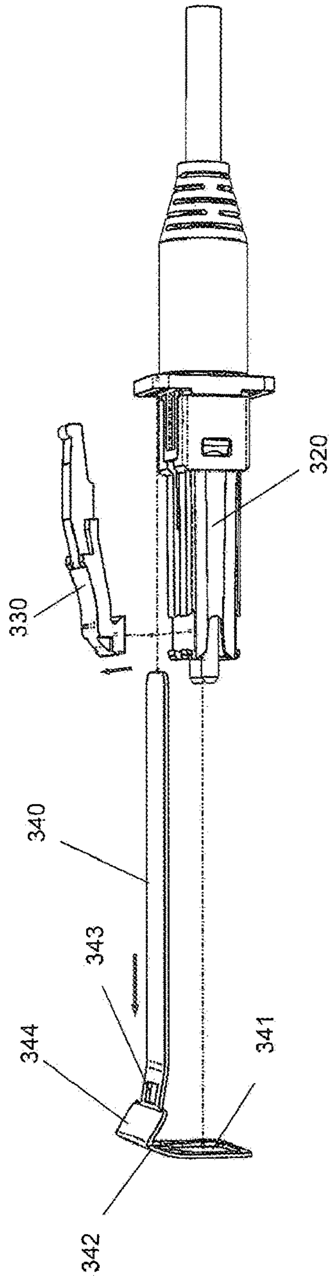


FIG. 3B

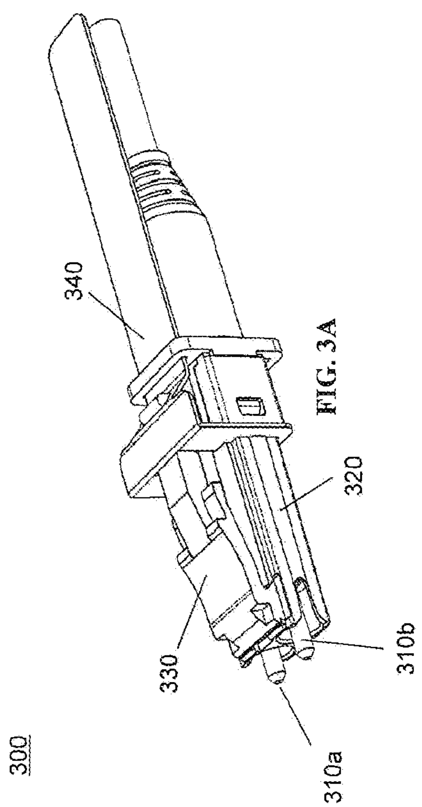


FIG. 3A

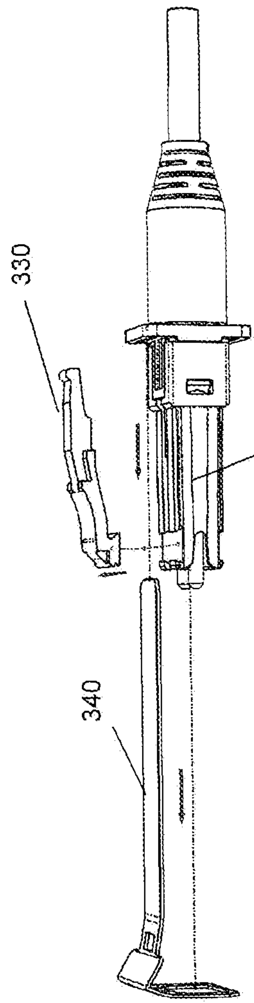


FIG. 4B

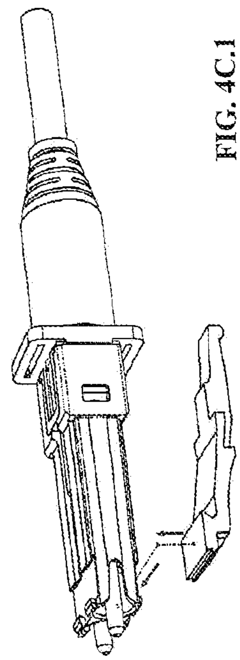


FIG. 4C.1

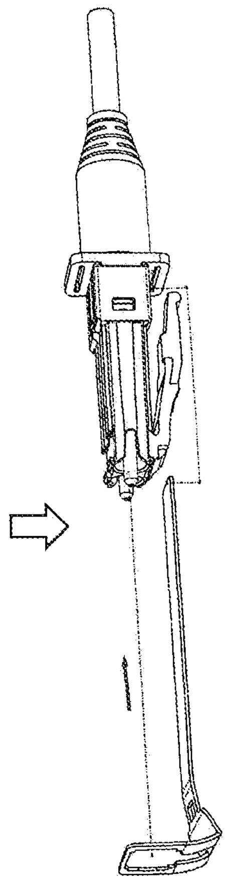


FIG. 4C.2

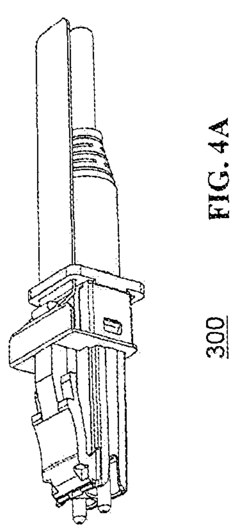


FIG. 4A

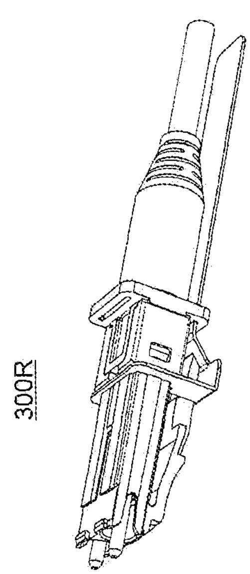


FIG. 4D

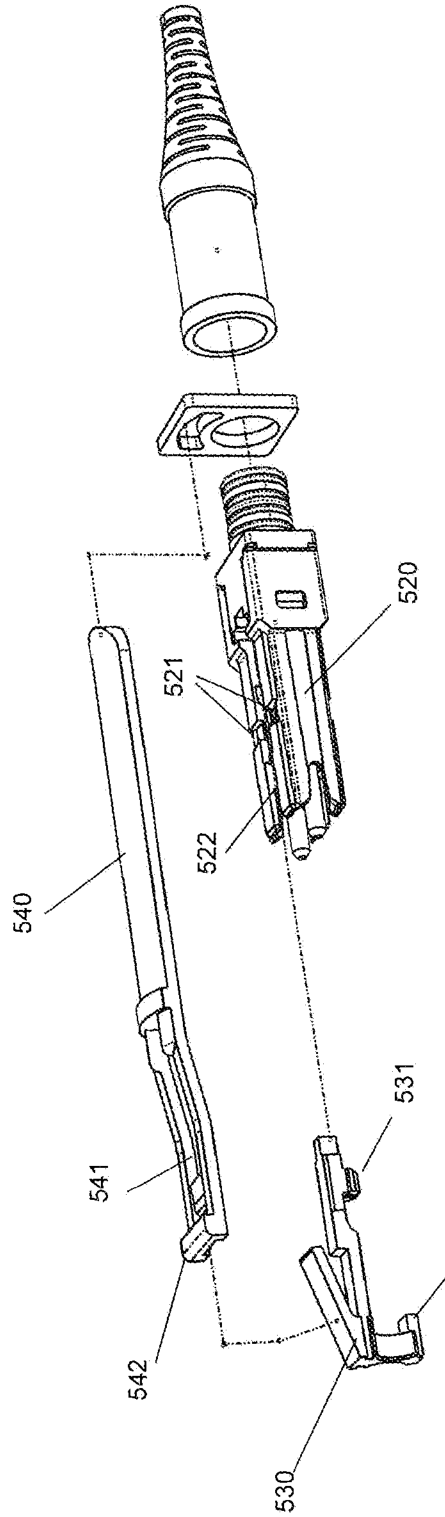


FIG. 5B

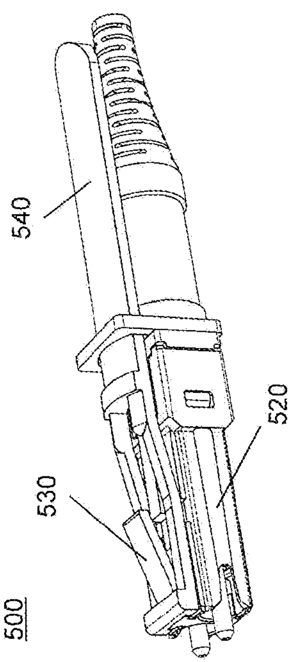


FIG. 5A

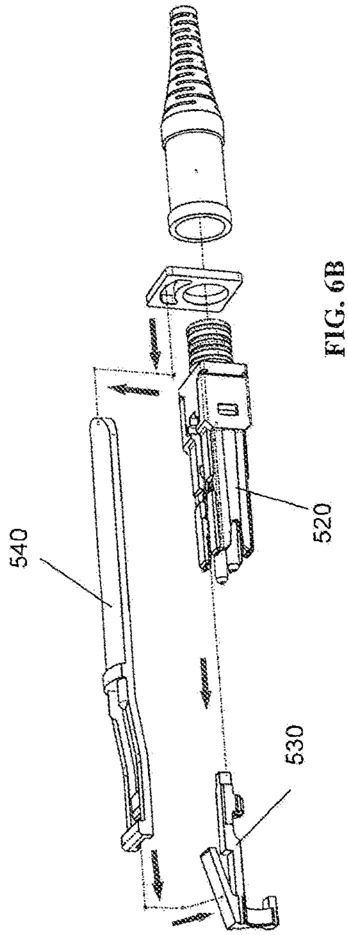


FIG. 6B

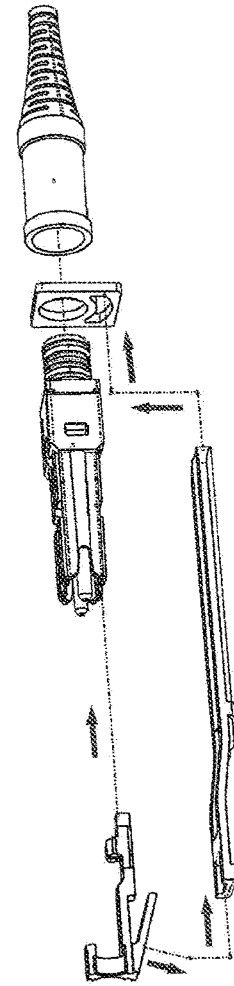


FIG. 6C

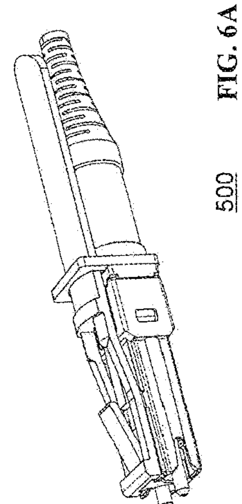


FIG. 6A

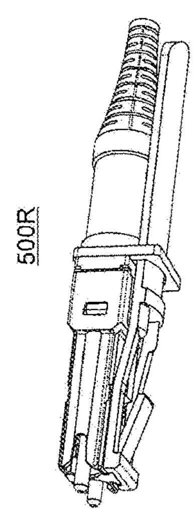


FIG. 6D

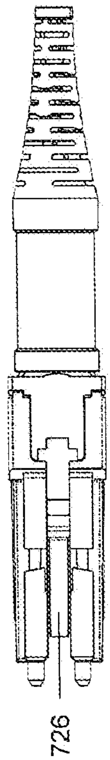


FIG. 7C

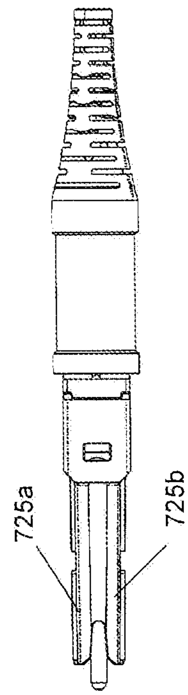


FIG. 7D

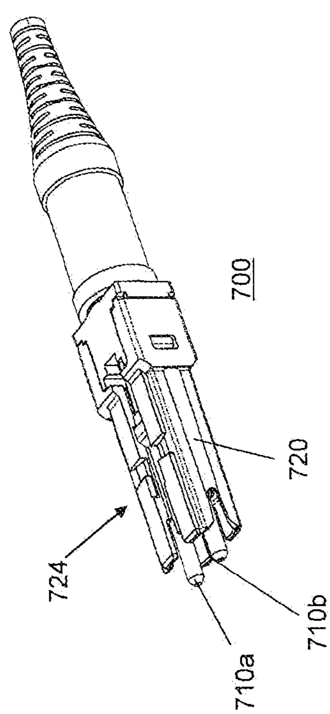


FIG. 7A

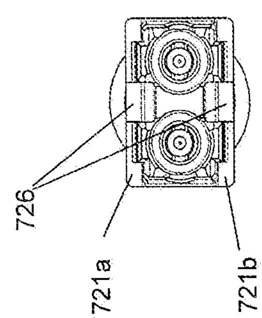


FIG. 7B

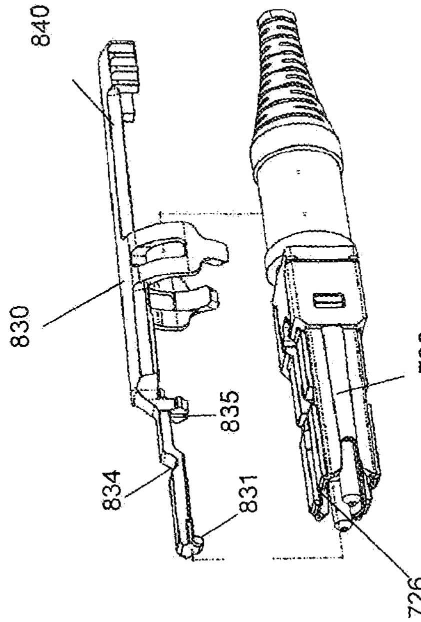


FIG. 8B.2

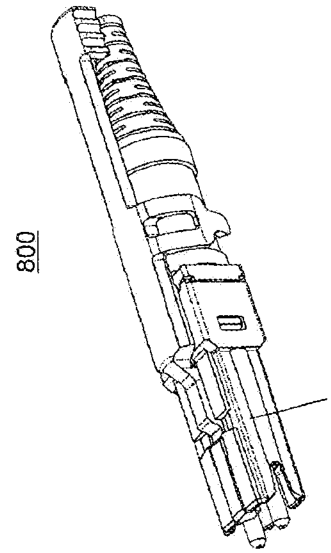


FIG. 8B.1

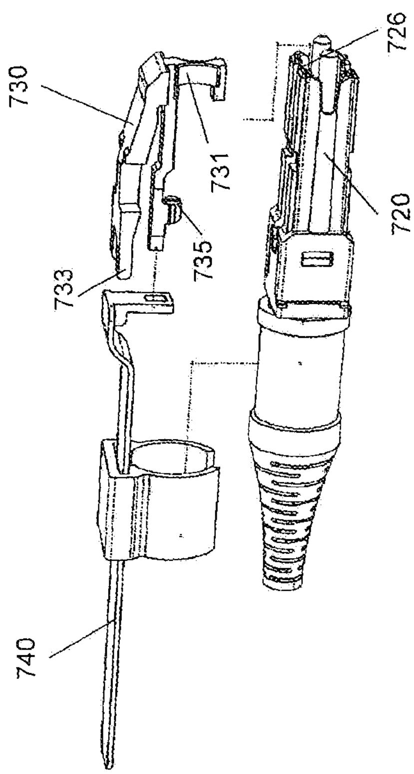


FIG. 8A.2

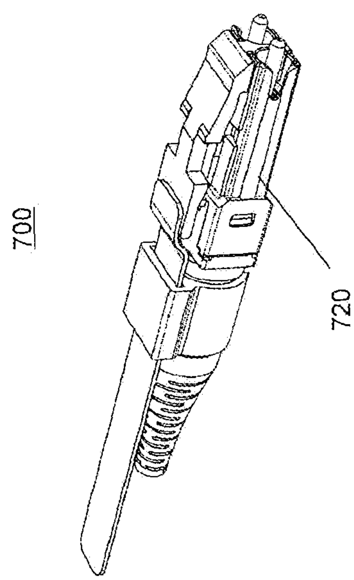


FIG. 8A.1

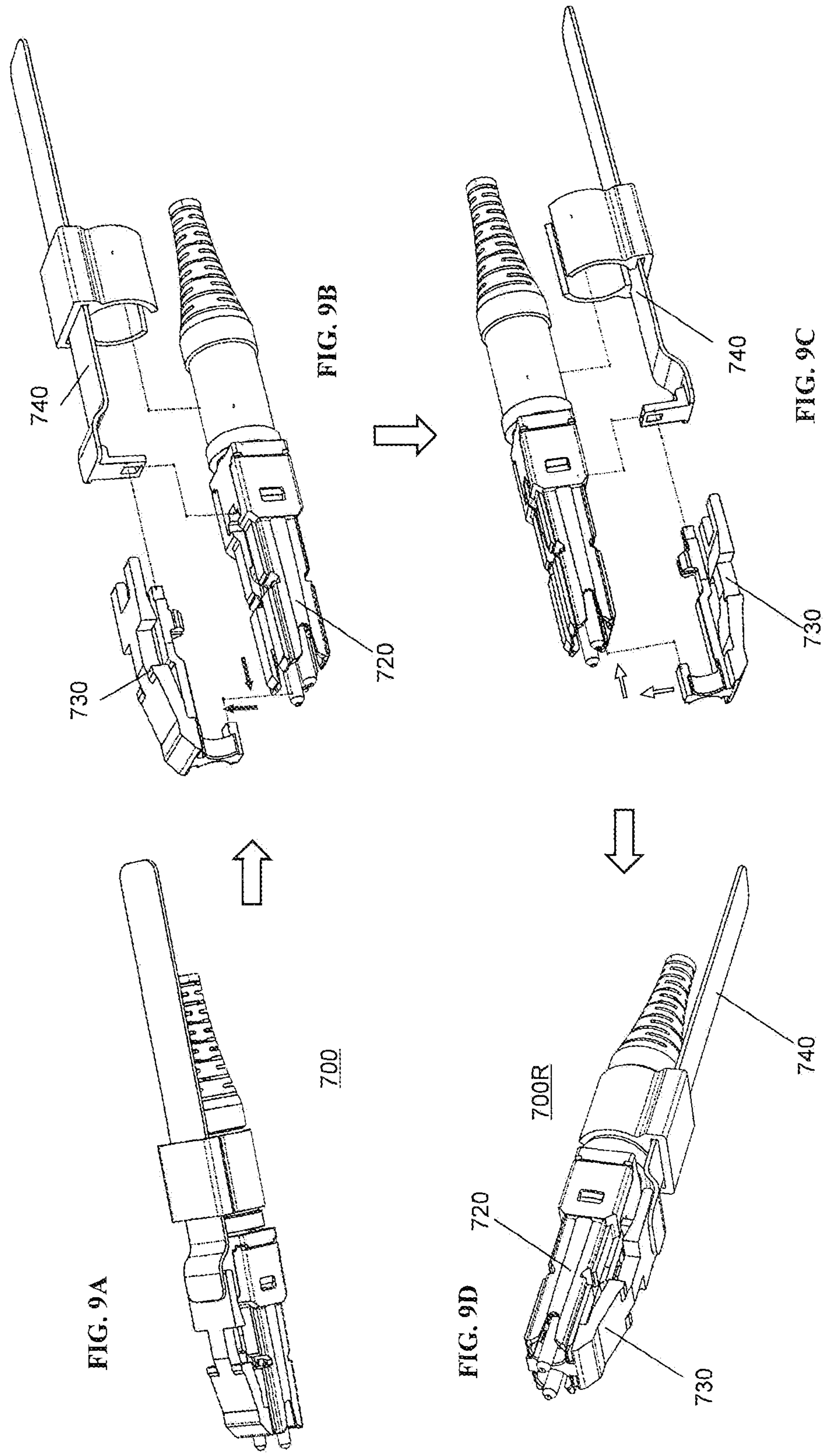


FIG. 9A

FIG. 9B

FIG. 9C

FIG. 9D

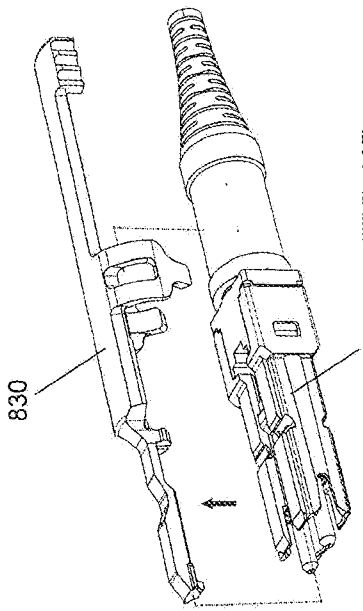


FIG. 10B

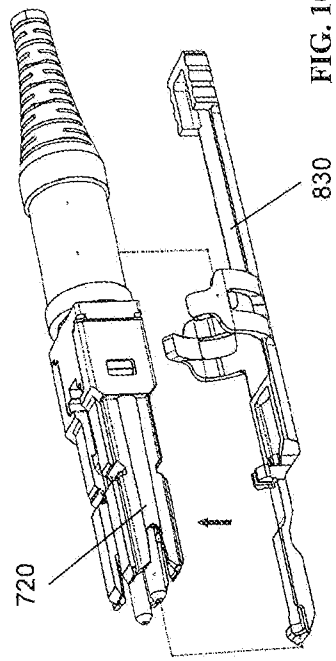


FIG. 10C

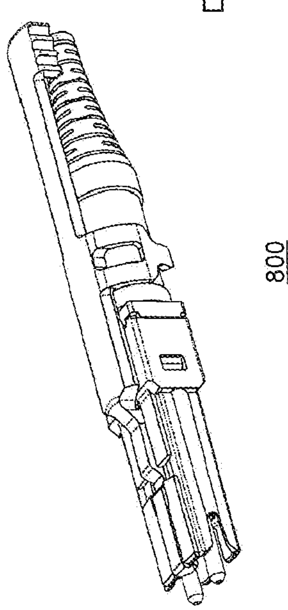


FIG. 10A

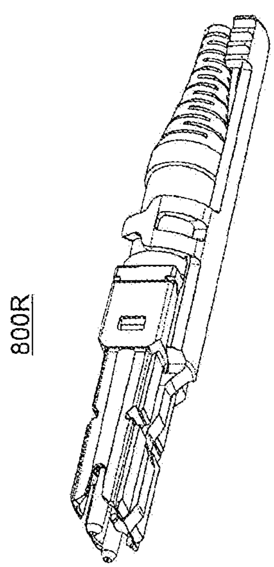


FIG. 10D

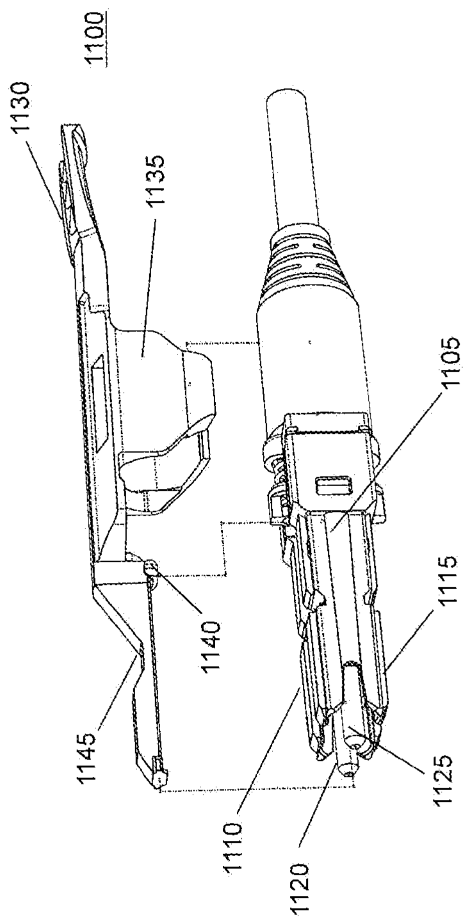


FIG. 11A

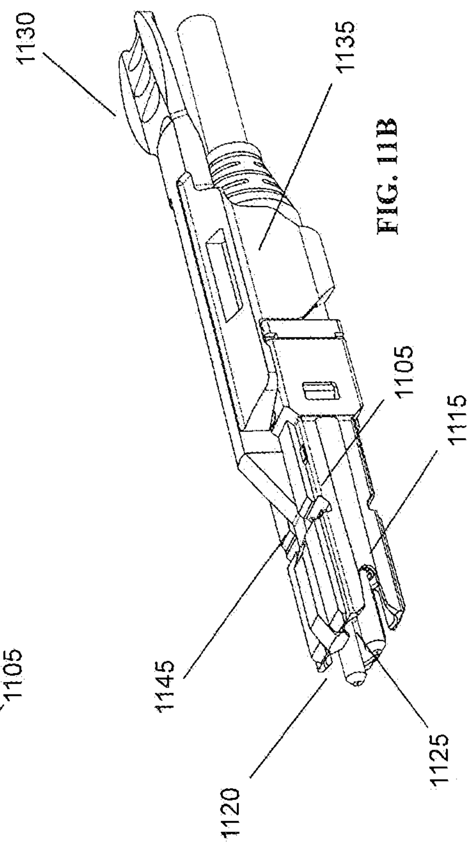


FIG. 11B

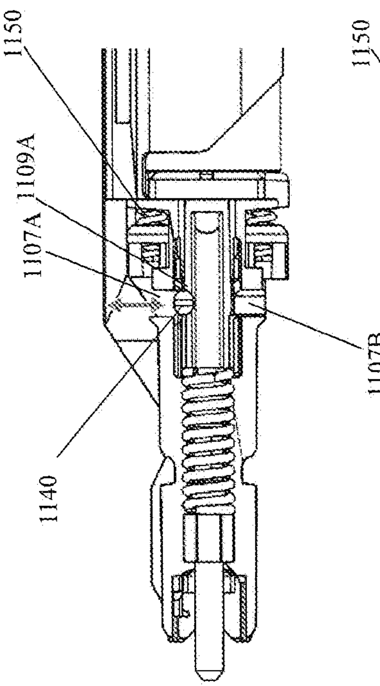


FIG. 12B

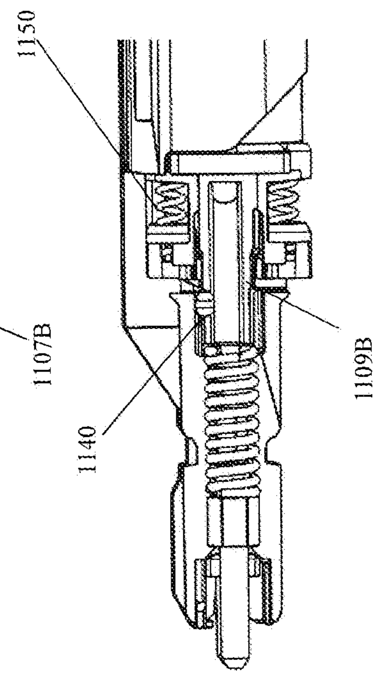


FIG. 12D

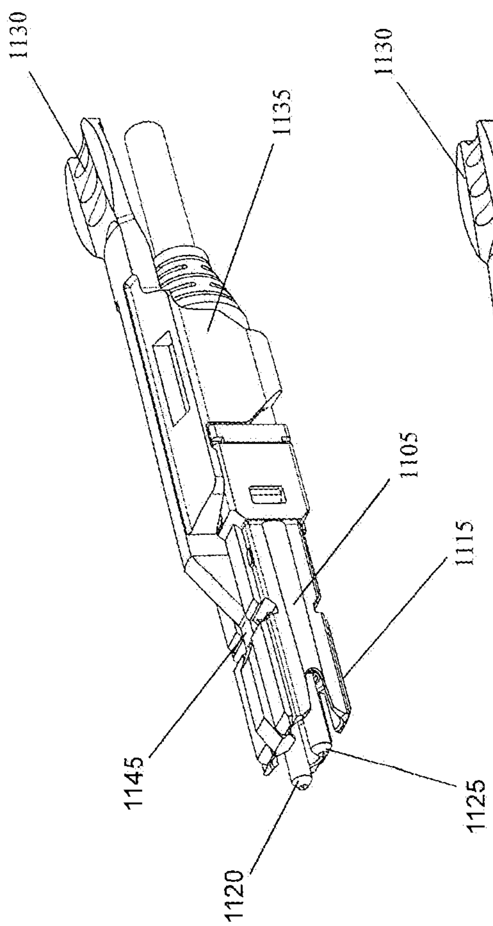


FIG. 12A

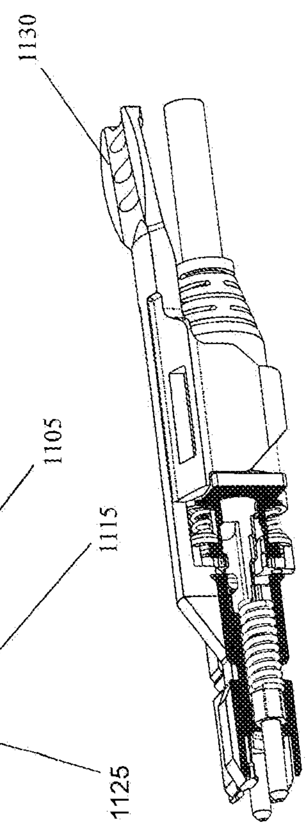


FIG. 12C

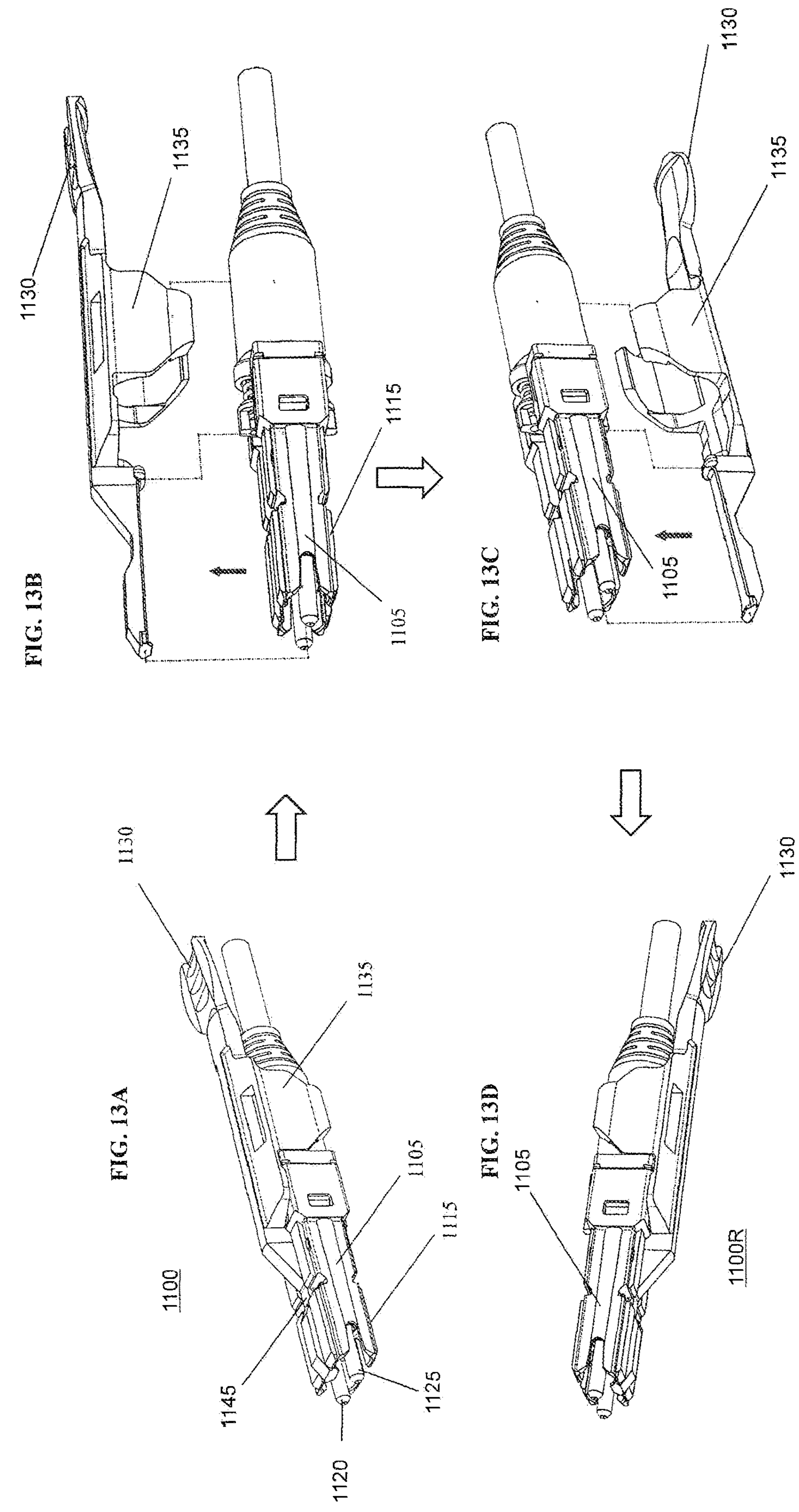


FIG. 13B

FIG. 13C

FIG. 13A

FIG. 13D

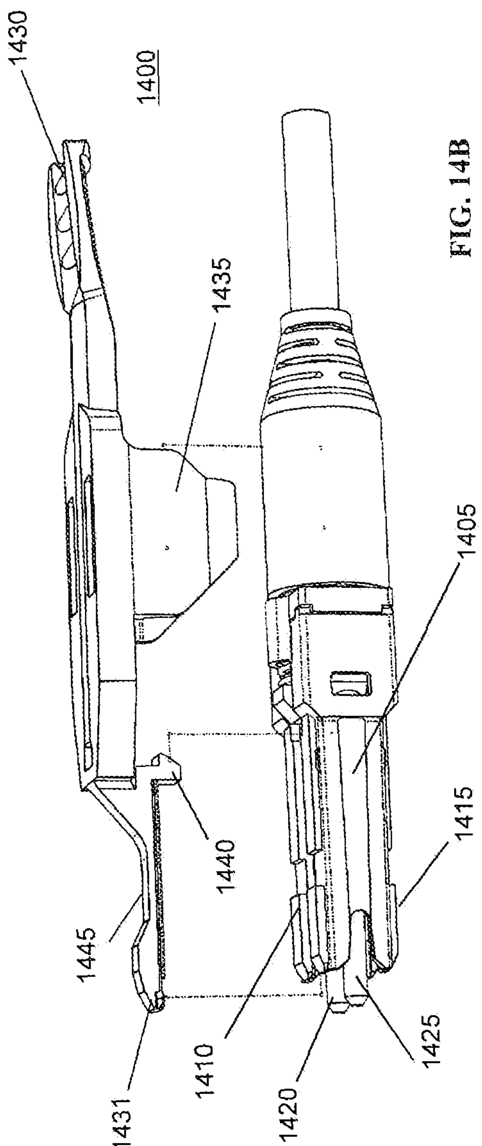


FIG. 14A

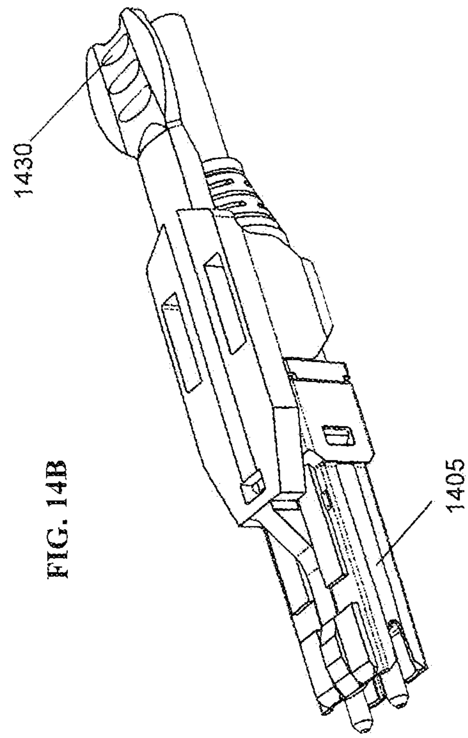


FIG. 14B

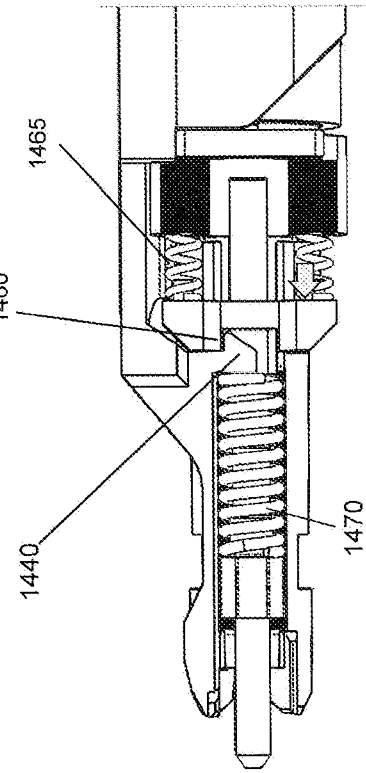


FIG. 15B

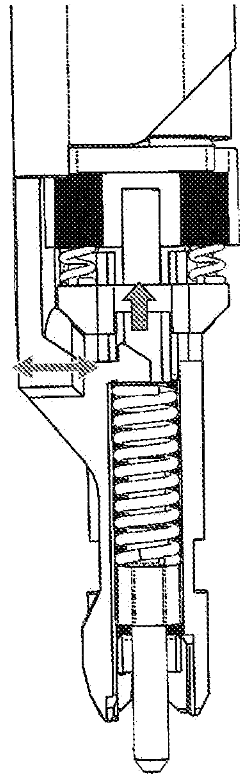


FIG. 15D

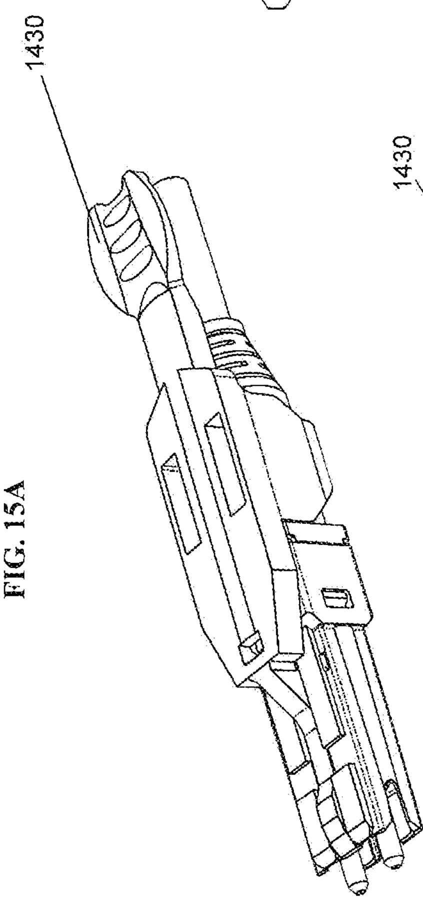


FIG. 15A

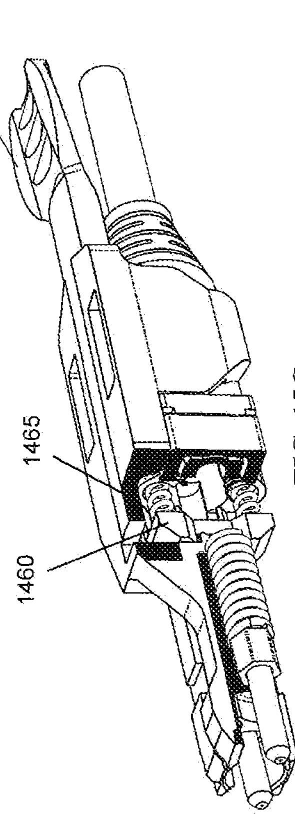


FIG. 15C

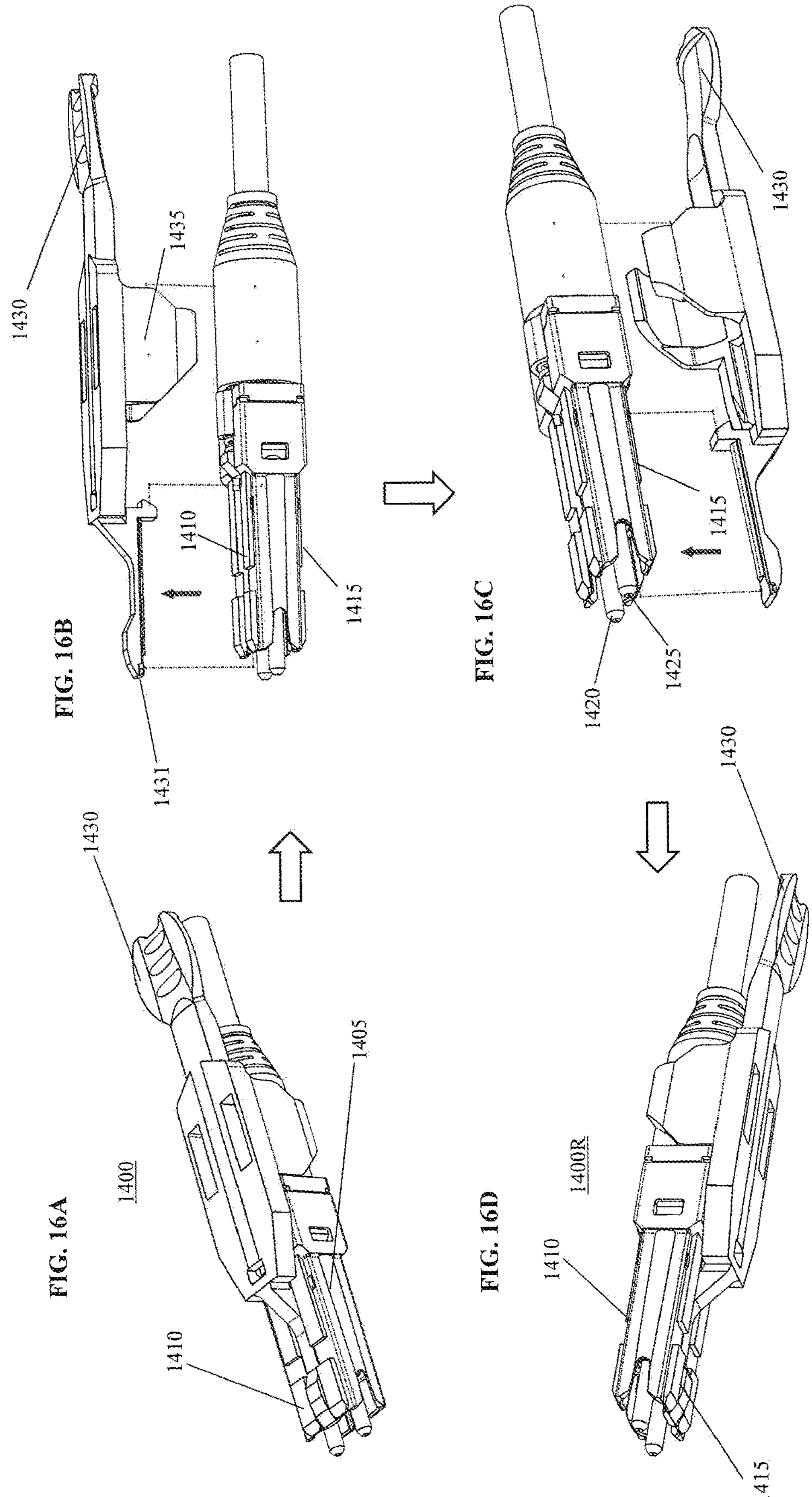


FIG. 16A

FIG. 16B

FIG. 16C

FIG. 16D

FIG 17B

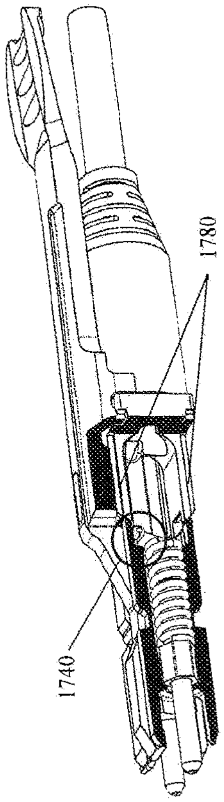


FIG 17C

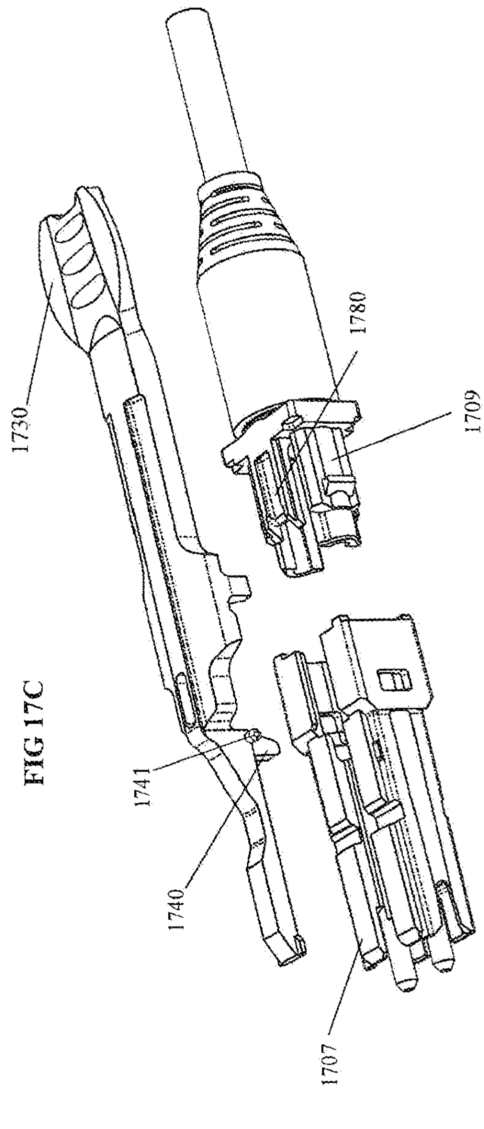
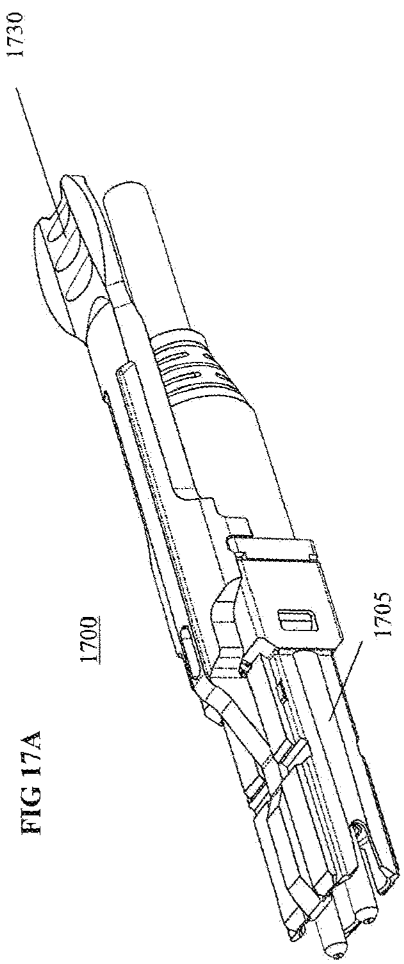


FIG 17A



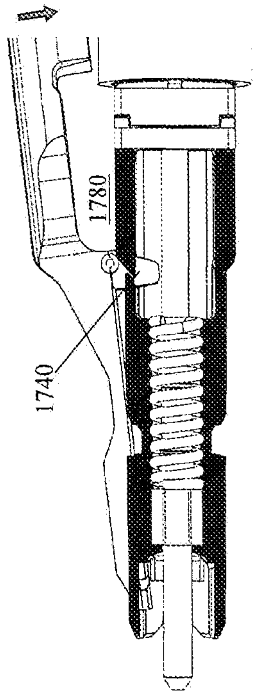


FIG 18B

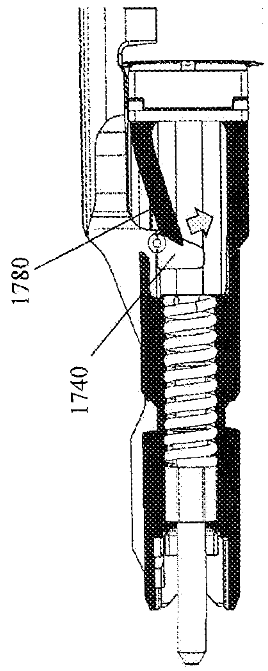


FIG. 18C

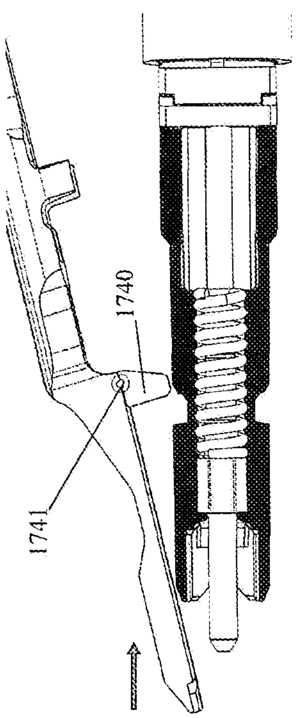


FIG. 18A

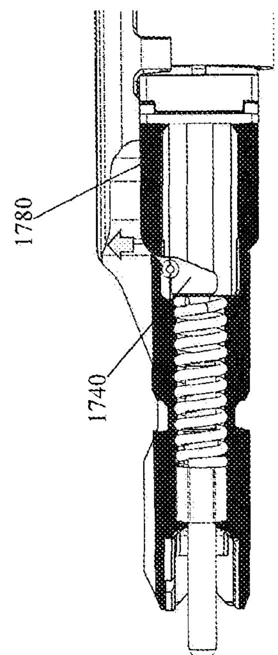


FIG. 18D

FIG. 19A

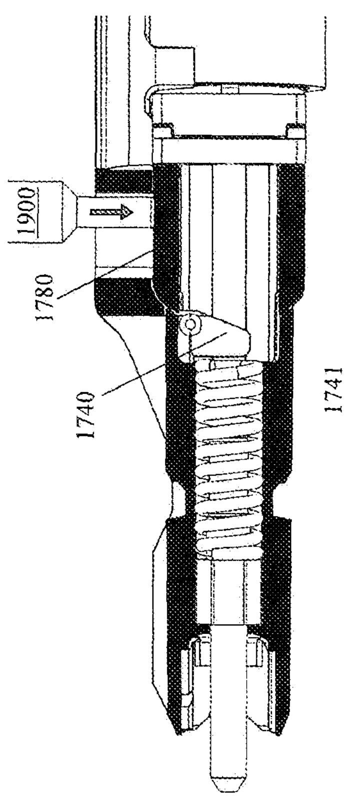
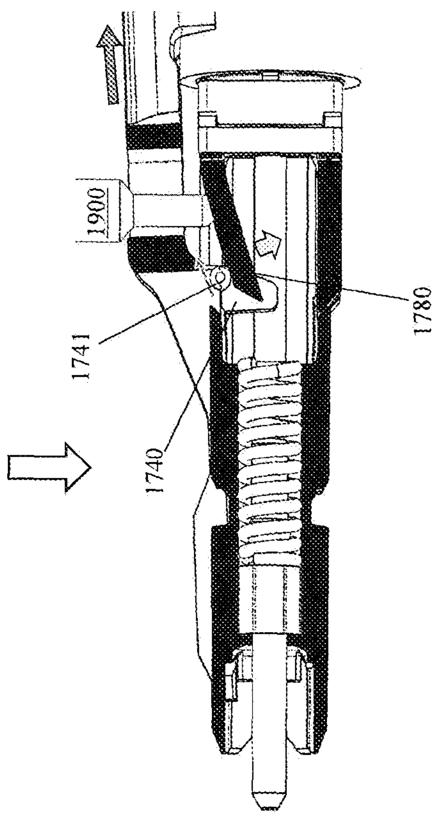


FIG. 19B



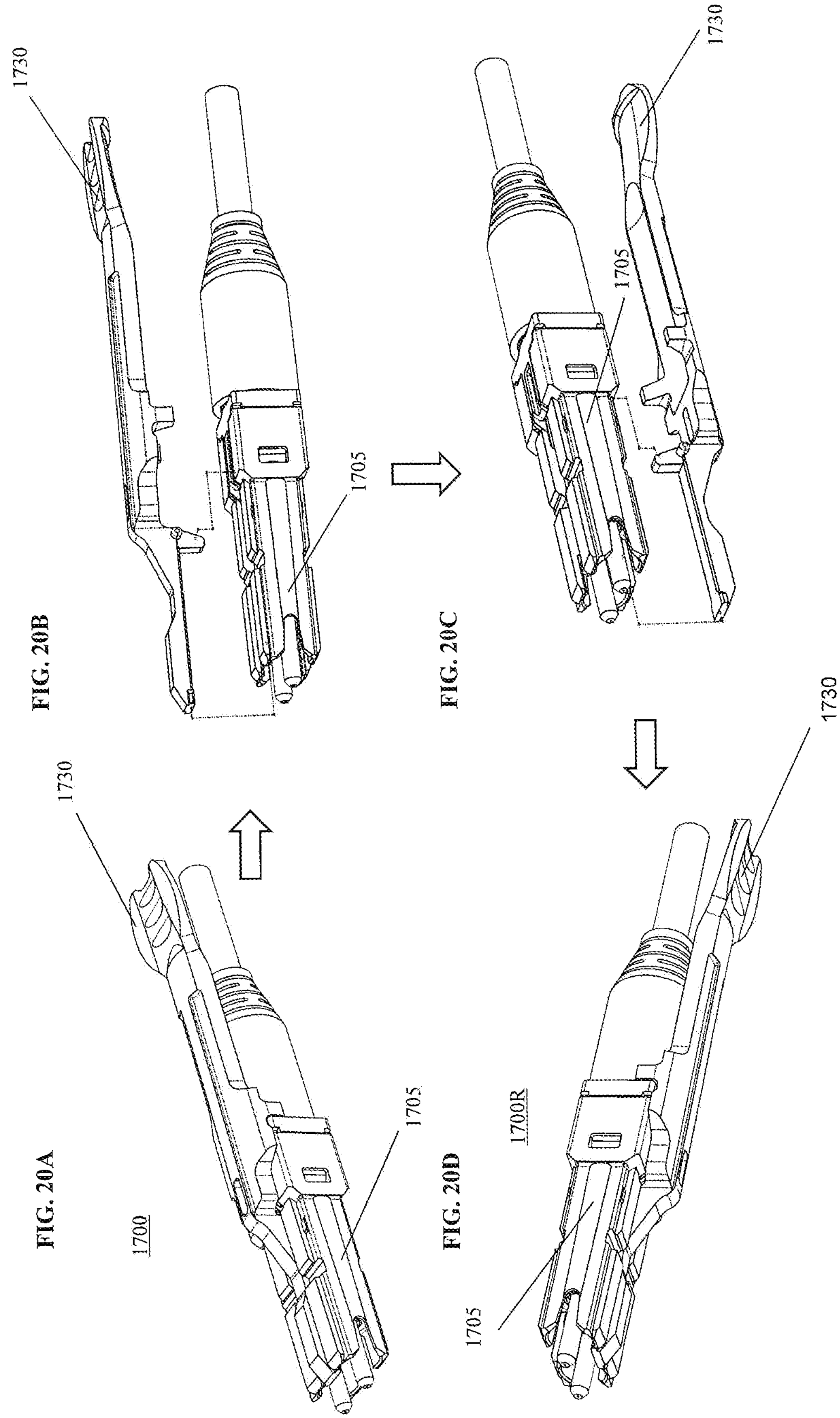


FIG. 20A

FIG. 20B

FIG. 20C

FIG. 20D

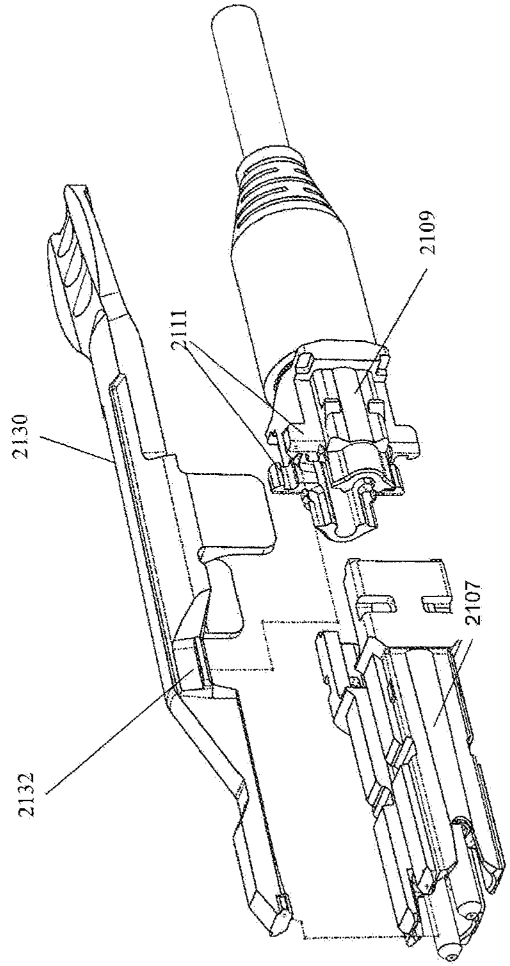


FIG. 21B

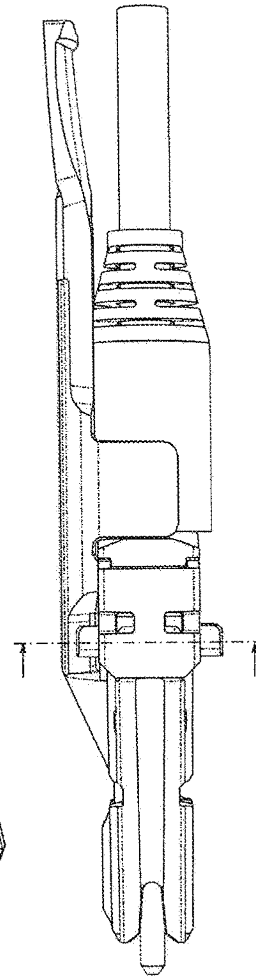


FIG. 21C

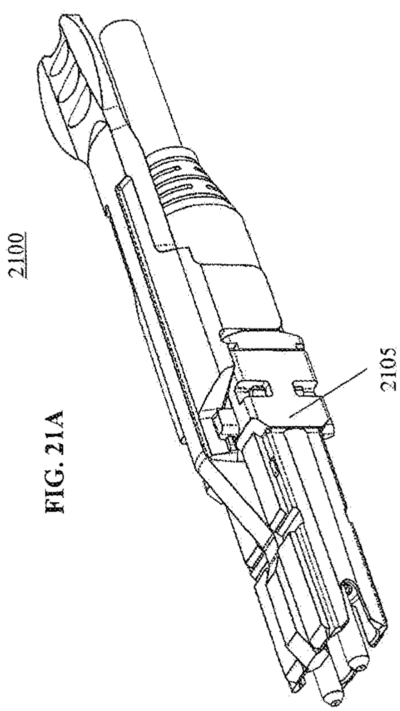


FIG. 21A

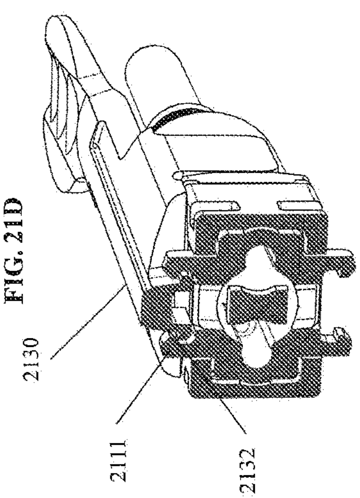


FIG. 21D

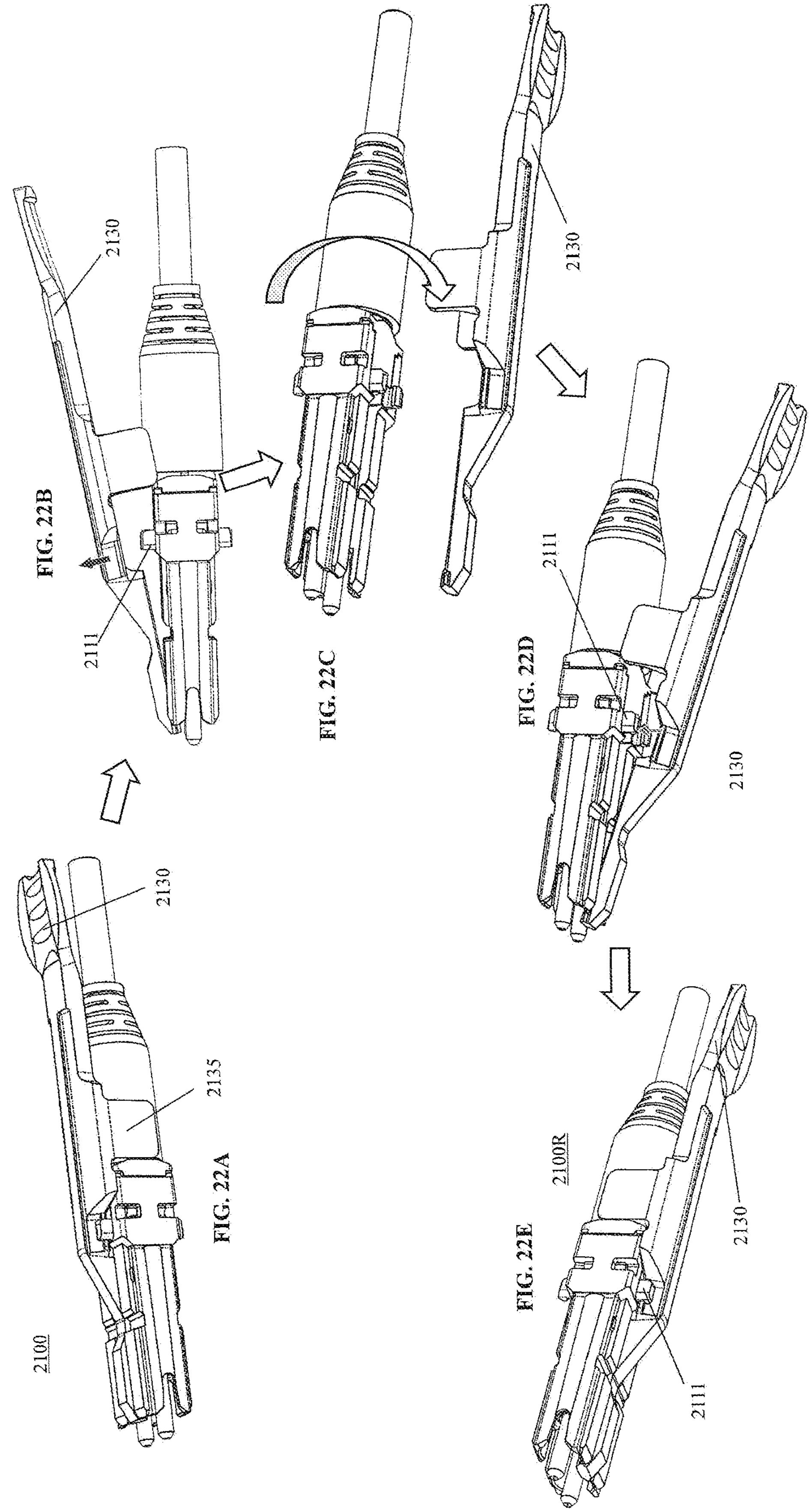


FIG. 22A
2100
2130
2135
FIG. 22B
2130
2111
FIG. 22C
2130
FIG. 22D
2111
2130
FIG. 22E
2100R
2130
2111

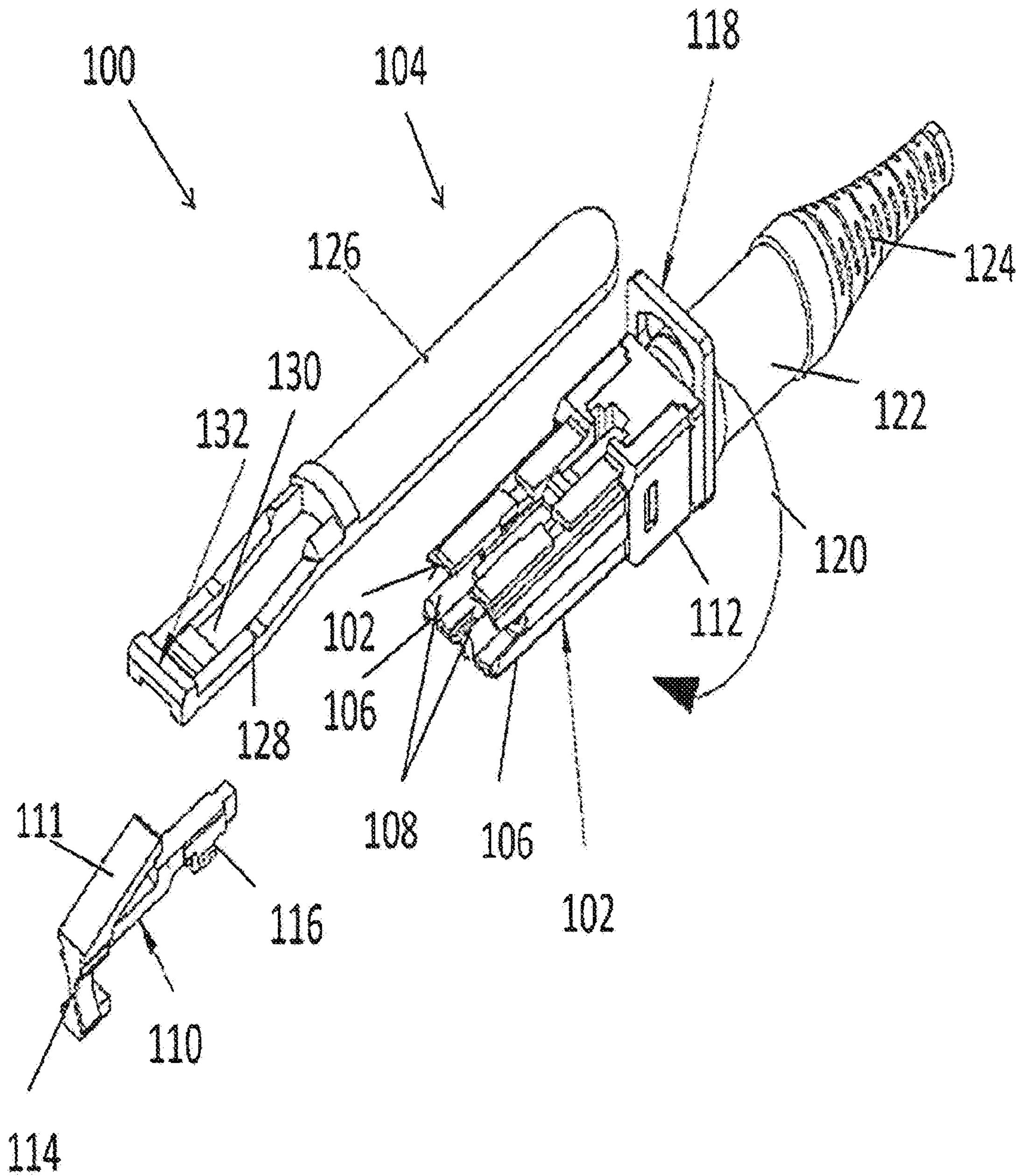

100
104
118
126
124
130
132
122
120
102
112
106
128
108
106
102
111
116
110
114

FIG. 23

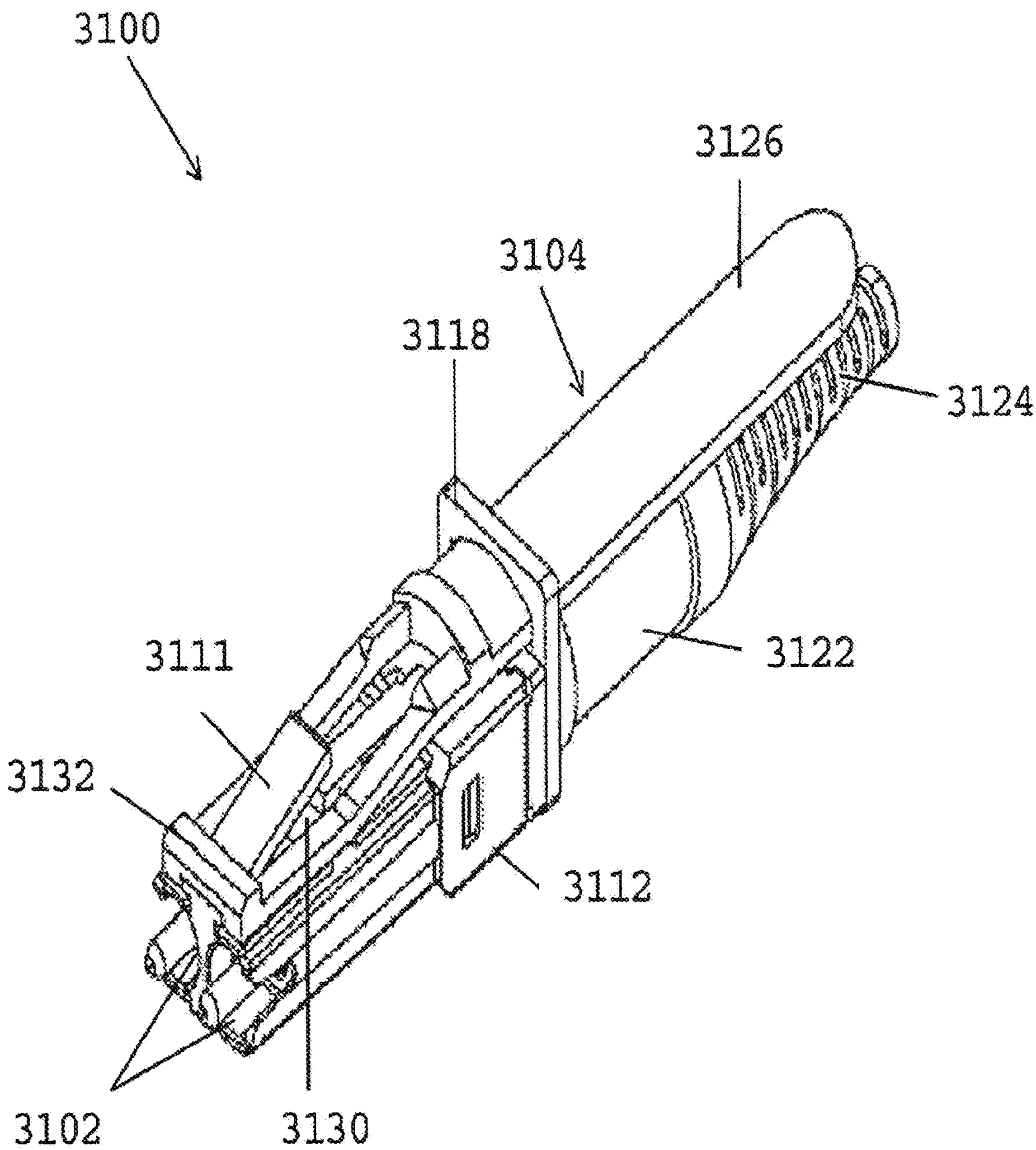


FIG. 24

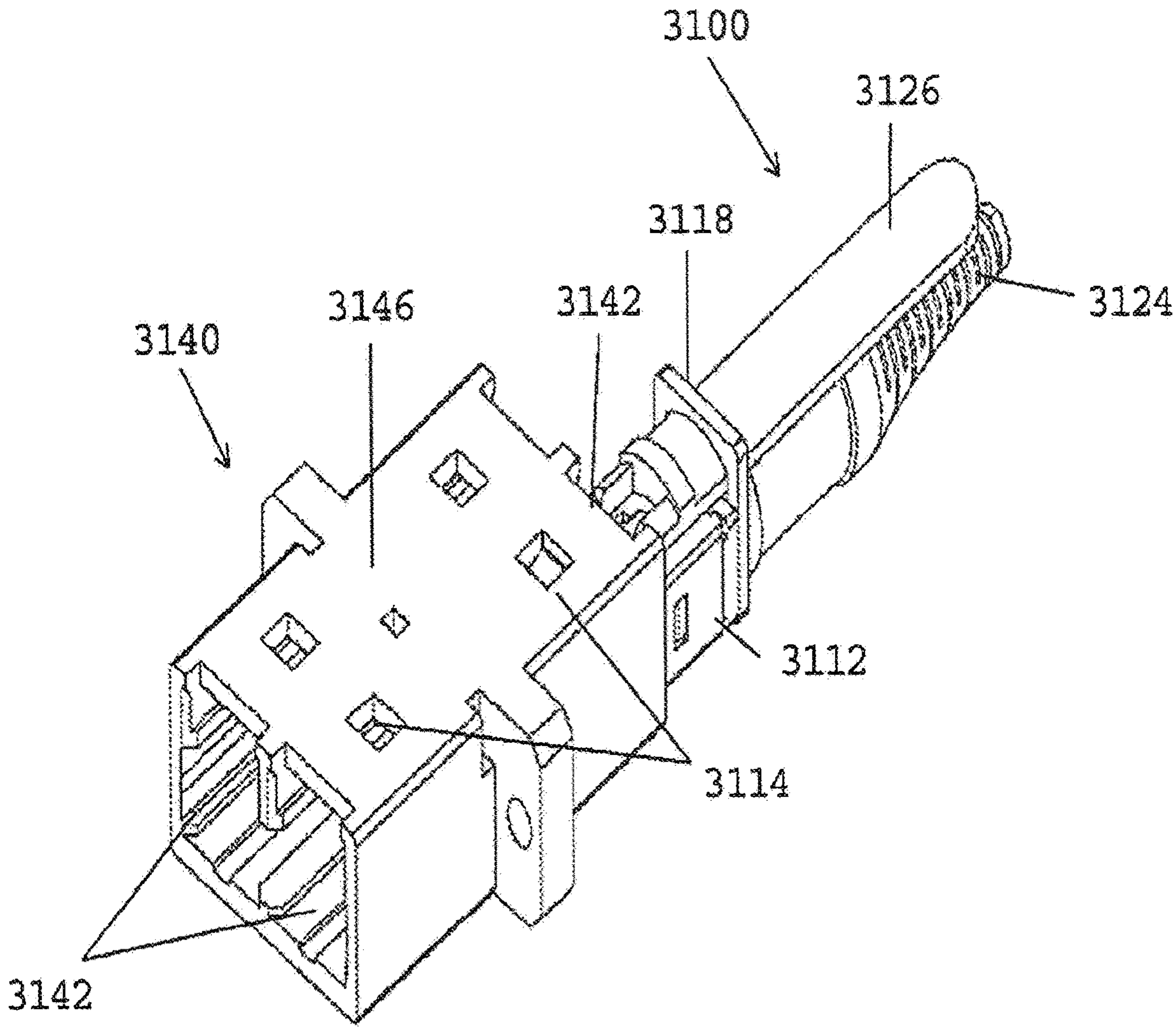


FIG. 25

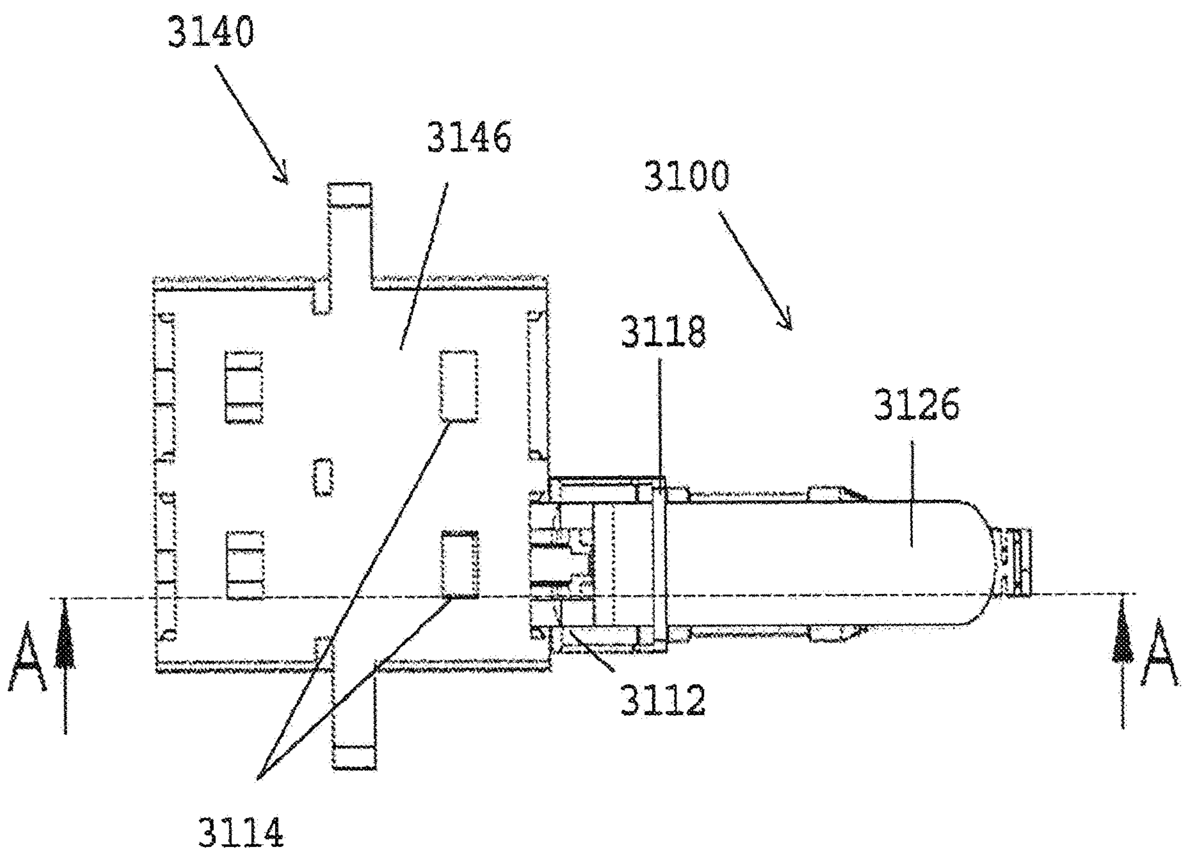


FIG. 26

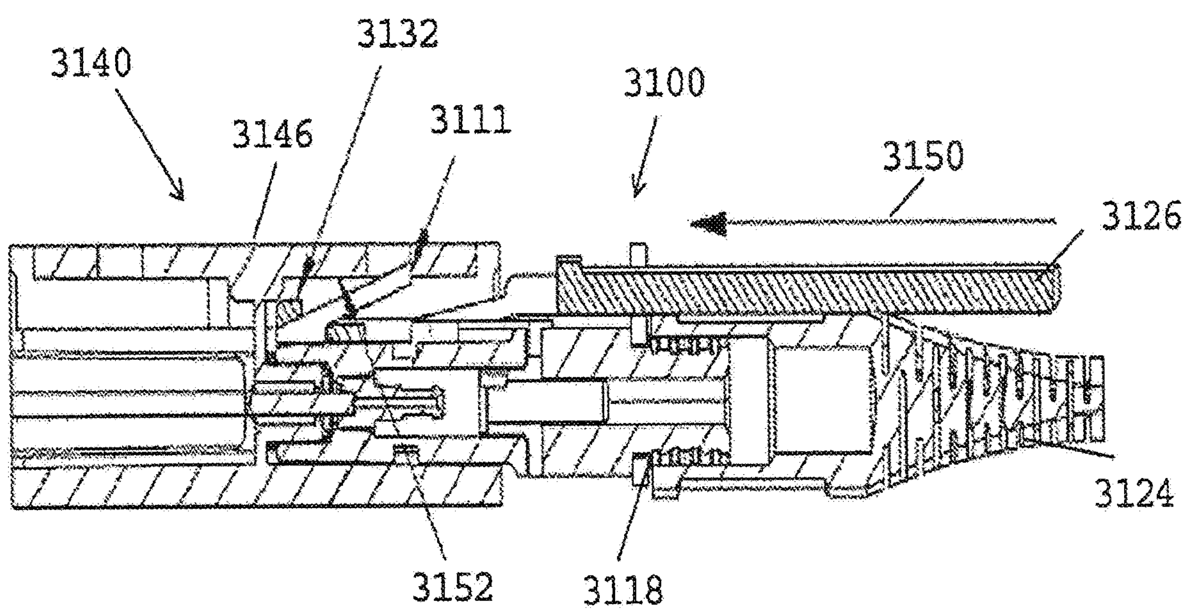


FIG. 27

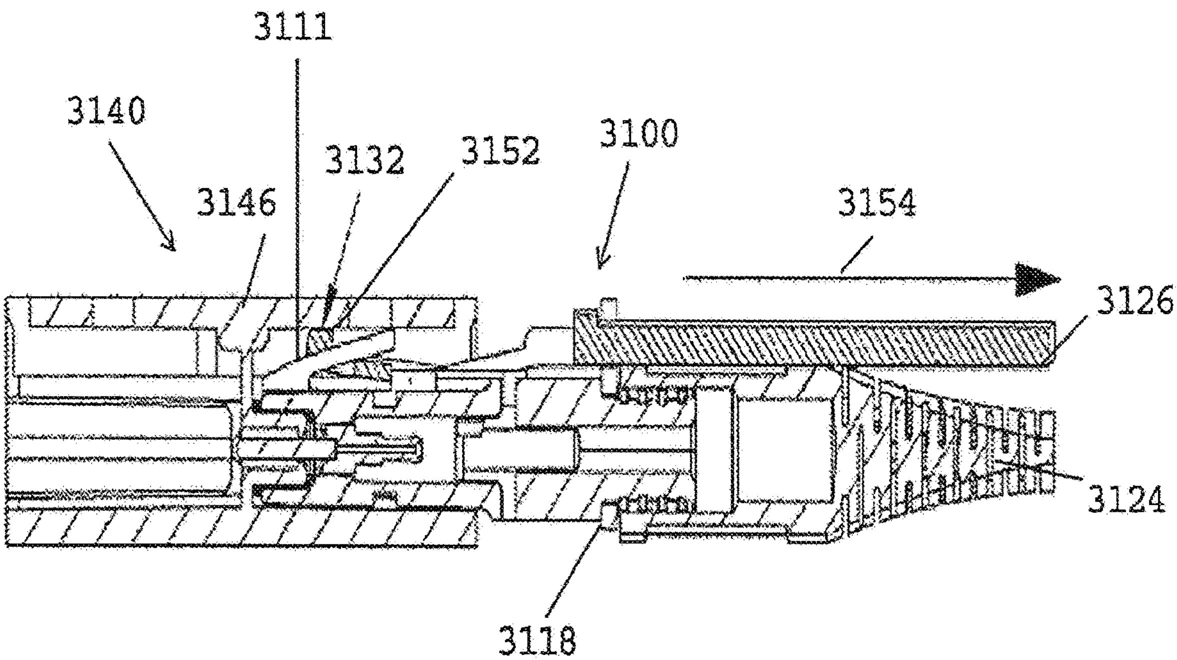


FIG. 28

ADAPTER FOR OPTICAL CONNECTORS

CROSS-REFERENCE TO RELATED PATENT APPLICATIONS

The present application is a continuation of U.S. Non-Provisional patent application Ser. No. 17/375,856, filed on Jul. 14, 2021, titled Adapter for Optical Connectors, which is a continuation of U.S. Non-Provisional patent application Ser. No. 17/200,134, filed on Mar. 12, 2021, titled Optical Connectors with Reversible Polarity, which is a continuation of U.S. Non-Provisional patent application Ser. No. 16/297,607, filed on Mar. 9, 2019, titled Optical Connectors with Reversible Polarity and Method of Use, which claims priority to PCT Application No. PCT/US2018/016049, filed Jan. 30, 2018, which claims priority to provisional applications: 62/452,147 filed Jan. 30, 2017, No. 62/457,150 filed Feb. 9, 2017, No. 62/463,898 filed Feb. 27, 2017, No. 62/463,901 filed Feb. 27, 2017, No. 62/485,042 filed Apr. 13, 2017, No. 62/546,920, filed Aug. 17, 2017, and No. 62/581,961 filed Nov. 6, 2017; all disclosures of the above are incorporated herein by reference in their entireties.

FIELD OF THE INVENTION

The present disclosure relates generally optical connectors with reversible polarity.

BACKGROUND

The prevalence of the Internet has led to unprecedented growth in communication networks. Consumer demand for service and increased competition has caused network providers to continuously find ways to improve quality of service while reducing cost.

Certain solutions have included deployment of high-density interconnect panels. High-density interconnect panels may be designed to consolidate the increasing volume of interconnections necessary to support the fast-growing networks into a compacted form factor, thereby increasing quality of service and decreasing costs such as floor space and support overhead. However, room for improvement in the area of data centers, specifically as it relates to fiber optic connections, still exists. For example, manufacturers of connectors are always looking to reduce the size of the devices, while increasing ease of deployment, robustness, and modifiability after deployment. In particular, more optical connectors may need to be accommodated in the same footprint previously used for a smaller number of connectors in order to provide backward compatibility with existing data center equipment. For example, one current footprint is known as the small form-factor pluggable footprint (SFP). This footprint currently accommodates two LC-type ferrule optical connections. However, it may be desirable to accommodate four optical connections (two duplex connections of transmit/receive) within the same footprint. Another current footprint is the quad small form-factor pluggable (QSFP) footprint. This footprint currently accommodates four LC-type ferrule optical connections. However, it may be desirable to accommodate eight optical connections of LC-type ferrules (four duplex connections of transmit/receive) within the same footprint.

In communication networks, such as data centers and switching networks, numerous interconnections between mating connectors may be compacted into high-density panels. Panel and connector producers may optimize for such high densities by shrinking the connector size and/or the spacing between adjacent connectors on the panel. While both approaches may be effective to increase the panel connector density, shrinking the connector size and/or spacing may also increase the support cost and diminish the quality of service.

In a high-density panel configuration, adjacent connectors and cable assemblies may obstruct access to the individual release mechanisms. Such physical obstructions may impede the ability of an operator to minimize the stresses applied to the cables and the connectors. For example, these stresses may be applied when the user reaches into a dense group of connectors and pushes aside surrounding optical fibers and connectors to access an individual connector release mechanism with his/her thumb and forefinger. Overstressing the cables and connectors may produce latent defects, compromise the integrity and/or reliability of the terminations, and potentially cause serious disruptions to network performance.

Accordingly, there is a need for smaller fiber optic connectors that will meet the needs of future developments in smaller SFPs and are reconfigurable for flexible deployment.

SUMMARY OF THE INVENTION

In a first aspect, the present disclosure provides a reversible polarity fiber optic connector including at least first and second optical ferrules and a connector housing at least partially surrounding the first and second optical ferrules. The housing has a first exterior wall positioned above the first and second optical ferrules and a second exterior wall positioned beneath the first and second optical ferrules. A latch coupling is positioned on each of the first and second exterior walls of the housing. A removable latch may engage either the first or second exterior wall latch coupling on the connector housing. Positioning the removable latch on the first exterior wall yields a fiber optic connector with a first polarity and positioning the removable latch on the second exterior wall yields a fiber optic connector with a second, opposite polarity.

In another aspect, the present disclosure provides a reversible polarity fiber optic connector with exchangeable arms for changing connector type. Thus, a common connector body may be formed into different connector types. The connector includes at least first and second optical ferrules and a common connector housing at least partially surrounding the first and second optical ferrules. The housing has a first exterior wall positioned above the first and second optical ferrules and a second exterior wall positioned beneath the first and second optical ferrules. A coupling surface is positioned on each of the first and second exterior walls of the common connector housing. To create a connector, a removable arm engages either the first or second exterior wall coupling surface; the removable arm includes either a latch or a latch recess depending upon the type of optical connector to be formed. Further, positioning the removable arm on the first exterior wall of the connector housing yields a fiber optic connector with a first polarity and positioning the removable arm on the second exterior surface of the housing yields a fiber optic connector with a second, opposite polarity.

In another aspect, the present disclosure provides a reversible polarity fiber optic connector with a push-pull tab. The connector includes at least first and second optical ferrules and has a connector housing at least partially surrounding the first and second optical ferrules. A first exterior wall is positioned above the first and second optical ferrules and a second exterior wall is positioned beneath the first and second optical ferrules. A first aperture is in the first exterior wall of the housing and a second aperture is in the second exterior wall of the housing. A removable push-pull tab includes a protrusion for positioning within either of the first or second apertures in the first and second exterior walls, respectively, of the connector housing. Positioning the removable push-pull tab with its protrusion within the first aperture yields a fiber optic connector with a first polarity and positioning the removable push-pull tab with its protrusion within the second aperture yields a fiber optic connector with a second, opposite polarity.

In yet another aspect, the present disclosure provides a reversible polarity fiber optic connector including at least first and second optical ferrules and a connector housing at least partially surrounding the first and second optical ferrules. A first exterior wall is positioned above the first and second optical ferrules and a second exterior wall is positioned beneath the first and second optical ferrules. A removable push-pull tab is provided. A first push-pull tab retainer is positioned on the first exterior wall and a second push-pull tab retainer is positioned on the second exterior wall. Positioning the removable push-pull tab in the retainer on the first exterior wall of the connector housing yields a fiber optic connector with a first polarity and positioning the removable push-pull tab in the retainer on the second exterior wall of the housing yields a fiber optic connector with a second, opposite polarity.

According to one aspect of the present disclosure, there is provided an optical fiber connector assembly comprising at least one connector, a latch arm for coupling to an adapter, and a remote release tab having a protrusion configured to cooperate with the adapter to depress said latch arm when the remote release tab is pulled relative to the adapter.

In some embodiments, the remote release tab may be coupled to the latch arm. The remote release tab may further comprise a window configured to receive the latch arm. In some embodiments, the remote release tab may be configured such that the protrusion slides along the latch arm when the remote release tab is pulled relative to the adapter. In some embodiments, the remote release tab may further be configured such that the protrusion interacts with an inner portion of the adapter to receive a downward force needed to depress said latch arm. In some embodiments, the inner portion of the adapter may be a fixed portion. In some embodiments, the protrusion may have a wedge shape. In various embodiments, the remote release tab may be configured such that the protrusion pushes down the latch arm substantially simultaneously as sliding along an inner portion of the adapter.

In some embodiments, the optical fiber connector assembly may further comprise a boot, and the remote release tab may be configured to extend over the boot.

In some embodiments, the optical fiber connector assembly may comprise a guide configured to receive the remote release tab. In various embodiments, the guide may be further configured to rotate to allow reversing a polarity of the optical fiber connector assembly.

Some embodiments of the optical fiber connector assembly may comprise a housing configured to receive the at least one connector. Some embodiments of the connector assembly may further comprise a latch arm assembly including the latch arm. The latch arm assembly may have a first portion configured to couple to the at least one connector and a second portion configured to engage the housing. In some embodiments of the connector assembly, the latch arm may be coupled to the at least one connector. In other embodiments, the at least one connector may include the latch arm as an integral structure.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**A is a perspective view of one embodiment of a reversible polarity fiber optic connector according to some aspects of the present disclosure;

FIG. **1**B is a side view of the reversible polarity fiber optic connector of FIG. **3**A with the removable latch being removed from the connector housing;

FIG. **2**A is a perspective view of the reversible polarity fiber optic connector of FIG. **1**A;

FIG. **2**B is an exploded view of a step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. **2**A;

FIG. **2**C is an exploded view of a next step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. **2**A;

FIG. **2**D is a perspective view of the fiber optic connector of FIG. **1**A with its polarity reversed;

FIG. **3**A is a perspective view of an embodiment of a reversible polarity fiber optic connector with a pull tab according to aspects of the present disclosure;

FIG. **3**B is an exploded view of the reversible polarity fiber optic connector of FIG. **3**A;

FIG. **4**A is a perspective view of the polarity of the reversible polarity fiber optic connector of FIG. **3**A;

FIG. **4**B is an exploded view of a step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. **4**A;

FIG. **4**C.**1** is an exploded view of positioning the latch in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. **4**A;

FIG. **4**C.**2** is an exploded view of attaching the removed components of FIG. **4**B in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. **4**A;

FIG. **4**D is a perspective view of the reversible polarity fiber optic connector of FIG. **4**A with its polarity reversed;

FIG. **5**A is a perspective view of another embodiment of a reversible polarity fiber optic connector with a pull tab according to aspects of the present disclosure;

FIG. **5**B is an exploded view of the reversible polarity fiber optic connector of FIG. **5**A;

FIG. **6**A is a perspective view of the polarity of the fiber optic connector of FIG. **5**A;

FIG. **6**B is an exploded view of a step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. **5**A;

FIG. **6**C is an exploded view of a next step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. **6**A;

FIG. **6**D is a perspective view of the reversible polarity fiber optic connector of FIG. **6**A with its polarity reversed;

FIG. **7**A is a perspective view of a common connector housing of a reversible polarity fiber optic connector with exchangeable arms for changing connector type in an embodiment according to aspects of the present disclosure;

FIG. **7**B is the front view of the common connector housing of FIG. **7**A;

FIG. **7**C is the top view of the common connector housing of FIG. **7**A;

FIG. **7**D is the side view of the common connector housing of FIG. **7**A;

FIG. **8**A.**1** shows how the common connector housing of FIG. **7**A is used to create a latch-type connector;

FIG. **8**A.**2** is an exploded view of FIG. **8**A.**1**;

FIG. **8**B.**1** shows how the common connector housing of FIG. **7**A is used to create a recess-type connector;

FIG. **8**B.**2** is an exploded view of FIG. **8**B.**1**;

FIG. **9**A is a perspective view of FIG. **8**A.**1** of the polarity of the latch-type fiber optic connector of FIG. **8**A.**1**;

FIG. **9**B is an exploded view of a step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. **8**A.**1**;

FIG. **9**C is an exploded view of a next step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. **8**A.**1**;

FIG. **9**D is a perspective view of the reversible polarity fiber optic connector of FIG. **8**A.**1** with its polarity reversed;

FIG. **10**A is a perspective view of FIG. **8**B.**1** of the polarity of the recess-type fiber optic connector of FIG. **8**B.**1**;

FIG. **10**B is an exploded view of a step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. **8**B.**1**;

FIG. **10**C is an exploded view of a next step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. **8**B.**1**;

FIG. **10**D is a perspective view of the reversible polarity fiber optic connector of FIG. **8**B.**1** with its polarity reversed;

FIGS. **11**A and **11**B respectively depict exploded and perspective views of a reversible polarity optical connector according to a further embodiment of the disclosure;

FIGS. **12**A-**12**D depict the operation of the reversible polarity optical connector of FIGS. **11**A and **11**B;

FIGS. **13**A-**13**D depict the process for changing the polarity of the optical connector of FIGS. **11**A and **11**B;

FIGS. **14**A and **14**B respectively depict exploded and perspective views of a reversible polarity optical connector according to a further embodiment of the disclosure;

FIGS. **15**A-**15**D depict the operation of the reversible polarity optical connector of FIGS. **14**A and **14**B;

FIGS. **16**A-**16**D depict the process for changing the polarity of the optical connector of FIGS. **14**A and **14**B;

FIGS. **17**A-**17**C respectively depict perspective, partial cross-section, and exploded views of a reversible polarity optical connector according to a further embodiment of the disclosure;

FIGS. **18**A-**18**D depict the assembly of the push-pull tab to the connector body of the connector of FIGS. **17**A-**17**C;

FIGS. **19**A-**19**B depict the removal of the push-pull tab from the connector body using a tool;

FIGS. **20**A-**20**D depict the process for changing the polarity of the optical connector of FIGS. **17**A-**17**C;

FIGS. **21**A-**21**D depict the process of changing polarity of an optical connector according to an embodiment of the invention;

FIGS. **22**A-**22**E depict the process for changing the polarity of an optical connector according to an embodiment of the invention;

FIG. **23** is a perspective view of a partially disassembled optical fiber connector assembly having a remote release tab according to aspects of the present disclosure;

FIG. **24** is a perspective view of the optical fiber connector assembly of FIG. **23** according to aspects of the present disclosure;

FIG. **25** is a perspective view of the optical fiber connector assembly of FIG. **23** coupled to an adapter according to aspects of the present disclosure;

FIG. **26** is a top view of the optical fiber connector assembly and adapter of FIG. **25** according to aspects of the present disclosure;

FIG. **27** is a cross-sectional view of the optical fiber connector assembly and adapter of FIG. **26** along section A-A, showing the remote release tab in a forward position according to aspects of the present disclosure; and

FIG. **28** is a cross-sectional view of the optical fiber connector assembly and adapter of FIG. **26** along section A-A, showing the remote release tab in a rearward position according to aspects of the present disclosure.

DETAILED DESCRIPTION

This disclosure is not limited to the particular systems, devices and methods described, as these may vary. The terminology used in the description is for the purpose of describing the particular versions or embodiments only, and is not intended to limit the scope.

As used in this document, the singular forms “a,” “an,” and “the” include plural references unless the context clearly dictates otherwise. Unless defined otherwise, all technical and scientific terms used herein have the same meanings as commonly understood by one of ordinary skill in the art. Nothing in this disclosure is to be construed as an admission that the embodiments described in this disclosure are not entitled to antedate such disclosure by virtue of prior invention. As used in this document, the term “comprising” means “including, but not limited to.”

The following terms shall have, for the purposes of this application, the respective meanings set forth below.

The connectors of the present disclosure may be configured for fiber optic transmission or electrical signal transmission. The connector may be any suitable type now known or later developed, such as, for example, a ferrule connector (FC), a fiber distributed data interface (FDDI) connector, an LC connector, a mechanical transfer (MT) connector, a square connector (SC) connector, an SC duplex connector, or a straight tip (ST) connector. The connector may generally be defined by a connector housing. In some embodiments, the housing may incorporate any or all of the components described herein.

Various embodiments described herein generally provide a remote release mechanism such that a user can remove cable assembly connectors that are closely spaced together without damaging surrounding connectors, accidentally disconnecting surrounding connectors, disrupting transmissions through surrounding connectors, and/or the like. Various embodiments also provide narrow pitch LC duplex connectors and narrow width multi-fiber connectors.

As discussed herein, current connectors may be improved by various means, such as, for example, reducing the footprint, increasing the structural strength, enabling polarity changes, etc. Various embodiments disclosed herein offer improvements over the current state of the art, as will be further discussed below.

In some embodiments, the fiber optic connector may be a narrow pitch duplex LC connector including two LC connectors. In some embodiments, such as that shown, the two LC connectors may comprise a single combined unit. In alternative embodiments, the LC connectors may be separate members, wherein an air gap exists between the two members, or wherein the two separate members are located adjacent and flush to each other (i.e., no air gap exists). In some embodiments, each of the LC connectors includes a respective ferrule and a respective extending member or modular arm. The connector may have a pitch of 4.8 mm, defined as the axis-to-axis distance between the central axes of the LC connectors. In other embodiments, the connector pitch may be less than that of the pitch of conventional connectors, for example less than 6.25 mm and less than about 5.25 mm. In some embodiments, the pitch may be about 4.8 mm or less.

In current designs, if a fiber optic connector, particularly a duplex connector, needs to have the ferrules rotated or swapped, for example, for exchanging transmit and receive optical fibers, it can be a time consuming and difficult process. Generally, if a duplex connector needs to be rotated, current systems require twisting the individual LC connector tips 180 degrees. However, this process also twists the fibers that enter the connector tip. Twisting the fiber at any stage of the connection can cause wear and/or damage to the delicate fibers. Thus, most systems involve an alternative solution, wherein the duplex connector is partially or completely disassembled in order to access the ferrules or fibers and manually relocate them within the duplex connector. However, swapping ferrules side to side is a delicate operation. In order to prevent damage to the internal fibers, great care must be taken. Thus, this operation usually requires specialized tools and preparation time to perform safely and accurately.

Therefore, embodiments as described herein, allow for easy, quick, and safe swapping of the left and right side ferrules in a connector. Thus, embodiments discussed herein allow for a change in polarity of the duplex connector without twisting the fibers or performing any complex disassembly of the duplex connector.

FIGS. **1**A and **1**B depict a fiber optic connector with reversible polarity according to one aspect of the present disclosure. As shown in FIG. **1**A, a reversible polarity fiber optic connector may include first and second optical ferrules **110***a* and **110***b* and a connector housing **120** at least partially surrounding the first and second optical ferrules. A removable latch **130** is depicted in FIG. **1**A in its assembled state and in FIG. **1**B removed from the connector housing **120**.

FIG. **1**B is a side view of the reversible polarity fiber optic connector of FIG. **1**A with the removable latch **130** being separated from the connector housing. As shown, the connector housing **120** may have a first exterior wall **121***a* positioned above the first and second optical ferrules and a second exterior wall **121***b* positioned beneath the first and second optical ferrules. A latch coupling **122** is positioned on each of the first and second exterior walls of the housing. The removable latch **130** may include a protrusion **131** for engaging the housing latch coupling **122**. In particular, the latch coupling **122** may include angled walls that interact with slanted edges of the protrusion **131** to prevent accidental disassembly of the latch **130**. Although the latch coupling **122** is depicted as a recess on the housing accommodating a latch protrusion, these elements may be reversed with the latch including a recess and the housing including a protrusion. Other mechanical coupling mechanisms may be used to interconnect the housing and the removable latch. For example, an embodiment may involve a coupling system wherein the removable latch is inserted into a recess in the connector housing and twisted (e.g., 90°, 180°, etc.) to secure the latch to the recess. Alternative coupling may use a more complex shape. For example, a u-shaped recess in the connector housing may engage a cooperatively-shaped projection in the latch that is inserted and fed through the u-shape until secure. It should thus be understood, that any system or method of coupling may be used to attach the removable latch to the connector housing, including various locations (e.g., sliding from the front, sides, back, bottom, top, etc.).

FIGS. **2**A-**2**D depict the process for changing the polarity of the fiber optic connector of FIG. **1**A from a first polarity, FIG. **2**A to a second, opposite polarity, FIG. **2**D. The removable latch **130** may be removed from the latch coupling on the first exterior wall of the connector housing, FIG. **2**B, positioned adjacent the second exterior wall on beneath the ferrules, FIG. **2**C, and then coupled with the latch coupling on the second exterior wall of the connector housing to yield a connector **100**R, FIG. **2**D, having the opposite polarity of connector **100**. In this manner, transmit and receive optical fibers may be reversed without necessitating any fiber twist or complex repositioning of the optical ferrules.

In typical embodiments, the latch of the connector housing is required to be flexible. Thus, when a latch and a connector housing (e.g., duplex connector) are built as one unified member (as is currently done), the fiber optic connector is built of a similar flexible or less rigid material. Building the connector housing out of a plastic or polymeric material, limits the amount of rigidity that it can have. Thus, as fiber optic connectors continue to reduce in size, the strength of the housing has been reduced. Therefore, it would be advantageous to build the connector housing out of a more robust material while still allowing the latch to remain flexible. In order to accomplish this, in some embodiments according to aspects of the present disclosure, the connector housing may be manufactured out of a very rigid or strong material (e.g., steel, graphene, carbon, metal alloys, or any material of suitable properties). Because the connector housing and the removable latch need only interlock with each other, the removable latch may still be made out of a more flexible material. Thus, the removable nature of the latch disclosed herein allow for a more robust and secure overall design when dealing with the shrinking footprint of fiber optic connectors.

FIG. **3**A is a perspective view of another embodiment of a reversible polarity fiber optic connector **300**. As shown, the reversible polarity fiber optic connector may further comprise a pull tab **340** for engaging a removable latch **330**. The pull tab **340** depresses the latch **330** as the tab is pulled in a direction away from the fiber optic ferrules.

FIG. **3**B is an exploded view of the reversible polarity fiber optic connector of FIG. **3**A. As shown, the pull tab **340** may comprise a first opening **341** and a second opening **344**. The first opening **341** is configured to allow the connector housing and the removable latch to pass through while the second opening is configured to accommodate the tip of the latch. The pull tab may further comprise a first deformable portion **342** and a second deformable portion **344**. In operation, the first deformable portion **342** cooperates with the second deformable portion **344** to depress the removable latch when the pull tab is pulled in a direction away from the ferrules.

FIGS. **4**A-**4**D depict the process for changing the polarity of the fiber optic connector **300** from a first polarity, FIG. **4**A to a second polarity **300**R, FIG. **4**D. The pull tab **340** may be disengaged from the connector housing **320** and the removable latch **330** on the first exterior wall of the connector housing, FIG. **2**B. The removable latch is then detached from the latch coupling on the first exterior wall of the connector housing, FIG. **4**C.**1**. Next, the removable latch is engaged with the latch coupling on the second exterior wall of the connector housing, beneath the ferrules, FIG. **4**C.**2**. Finally, the pull tab **340** is positioned surrounding the connector housing and engaging the removable latch tip, resulting in the assembled optical connector **300**R having polarity opposite to that of connector **300**, FIG. **4**D.

FIGS. **5**A and **5**B are a perspective view and exploded view, respectively, of another embodiment of a reversible polarity fiber optic connector **500**. The connector **500** includes a connector housing **520**, a latch **530**, and a pull tab **540**. On the first and second exterior walls of connector housing **520** are latch couplings that include a groove **522**. A recess **521** is also provided in the housing. The latch **530** includes a protrusion **531** that is received within groove **522**. The latch further includes a projection **532** that is received in the housing between the optical ferrules. The pull tab **540** includes an opening **541** for engaging the removable latch **530**. A front protrusion **542** is configured to depress the removable latch **530** when the pull tab is pulled in a direction away from the ferrule side of the optical connector.

FIGS. **6**A-**6**D depict the process for changing the polarity of the fiber optic connector **500** from a first polarity, FIG. **6**A to a second polarity, FIG. **6**D. The pull tab **540** is disengaged from the connector housing and the removable latch **530** on the first exterior wall of the connector housing, FIG. **6**B, and the removable latch is decoupled from the latch coupling on the first exterior wall of the connector housing. Then the removable latch may be coupled with the latch coupling on the second exterior wall of the connector housing, beneath the optical ferrules in FIG. **6**C, and the pull tab **540** is engaged with the connector housing and the removable latch on the second exterior wall of the connector housing to create reverse polarity connector **500**R, FIG. **6**D.

It is of interest within the optical connectivity industry to have multiple styles of optical connectors for multiple purposes and/or multiple implementation styles. Thus, in order to more easily provide flexibility, a solution is needed that allows for on-the-fly, in-the-field, or in manufacturing modification of the connector. The below embodiment provides a universal type fiber optic connector which has a unique housing design that allows for different latches or arms to be attached.

FIG. **7**A is a perspective view of a common connector housing **720** of a reversible polarity fiber optic connector **700** with exchangeable arms for changing connector type in an embodiment according to aspects of the present disclosure. As shown, the reversible polarity fiber optic connector may comprise first and second optical ferrules **710***a* and **710***b* and the common connector housing **720** at least partially surrounding the first and second optical ferrules.

FIGS. **7**B, **7**C and **7**D are the front view, top view and side view, respectively, of the common connector housing **720**. As shown, the common connector housing may have a first exterior wall **725**a positioned above the first and second optical ferrules and a second exterior wall **725**b positioned beneath the first and second optical ferrules. The connector housing **720** may further have a coupling surface **724** positioned on each of the first and second exterior walls and include a receiving track **726** in the coupling surface.

FIG. **8**A.**1** shows the common connector housing **720** used to create a latch-type connector **700** and FIG. **8**B.**1** shows the common connector housing **720** used to create a recess-type connector **800**. Both of connectors **700** and **800** include a removable arm **730** or **830** for engaging either of the first and second exterior wall coupling surfaces **724** on the connector housing, FIGS. **8**A.**2** and **8**B.**2** respectively. The removable arms **730** and **830** may each respectively include a projection **735** or **835** for engaging in the receiving track **726** of the coupling surface **724**, FIGS. **8**A.**2** and **8**B.**2** respectively. As with the previous embodiments, positioning the removable arm on the first exterior wall of the connector housing yields a fiber optic connector with a first polarity and positioning the removable arm on the second exterior surface of the housing yields a fiber optic connector with the opposite polarity.

Still referring to FIGS. **8**A.**2** and **8**B.**2** respectively the removable arms may include either a latch or a recess: removable arm **730** includes a latch **733** while removable arm **830** includes a recess **834**. Thus, a latch-type connector **700** is created through assembly of the removable latch arm to the common connector body **720** as shown in FIG. **8**A.**1** and a recess-type connector **800** is created through assembly of the removable recess arm to the common connector body **720** as shown in FIG. **8**B.**1**.

The fiber optic connector may further include a pull tab. When a removable arm with a latch **730** is positioned on the coupling surface of the common connector housing **720** to create a latch-type connector **700**, the pull tab **740** is a separate element from the removable arm, FIG. **8**A.**2**. When a removable arm includes a recess **830** is positioned on the coupling surface of the common connector housing **720** to create a recess-type connector **800**, the pull tab **840** is integrated with the removable arm, FIG. **8**B.**2**.

FIGS. **9**A-**9**D depict the process for changing the polarity of the latch-type fiber optic connector from a first polarity **700**, FIG. **9**A to a second polarity **700**R, FIG. **9**D. The sub-assembly of the removable arm **730** and the pull tab **740** may be decoupled from the coupling surface **724** of the first exterior wall of the connector housing, FIG. **9**B. Then the sub-assembly of the removable arm **730** and the pull tab **740** may be coupled with the coupling surface of the second exterior wall of the connector housing, FIG. **9**C, creating the opposite polarity connector **700**R.

FIGS. **10**A-**10**C depicts the process for changing the polarity of the recess-type fiber optic connector **800** from a first polarity, FIG. **10**A to a second polarity, FIG. **10**D. The removable arm **830** with a recess and a pull tab as an integral structure may be decoupled from the coupling surface **724** of the first exterior wall of the connector housing, FIG. **10**B. Then the removable arm may be coupled with the coupling surface **724** of the second exterior wall of the common connector housing **720**, FIG. **10**C to create opposite polarity optical connector **800**R, FIG. **10**D.

FIGS. **11**A and **11**B depict a further embodiment **1100** of the reversible polarity optical connectors of the present disclosure. In FIG. **11**A, a push-pull tab **1130** may interconnect with either a first exterior wall **1110** of housing **1105** or with a second exterior wall **1115** of housing **1105**. Ferrules **1120** and **1125** are at least partially surrounded by housing **1105** and may be LC connectors in an embodiment. As in previous embodiments, the push-pull tab may include a tab recess **1145**. Alternatively, push-pull tab **1130** may include a latch (not shown). Various features of the push-pull tab **1130** are provided to assist in affixing the push-pull tab to the first exterior wall **1110** or the second exterior wall **1115** of the housing **1105**. This includes push-pull tab clips **1135** that clip onto the optical connector, optionally in a boot region, and protrusion **1140** that fits within a first aperture, **1109**A, beneath the housing exterior wall **1110** or a second aperture, **1109**B, beneath housing exterior wall **1115** (to be discussed in more detail below), and projection **1131** for inserting into the housing between ferrules **1120** and **1125**. Each of these features is fully reversible such that the push-pull tab is easily removed and repositioned on the opposite exterior wall to change polarity of the connector.

As best seen in FIGS. **12**B and **12**D, push-pull tab protrusion **1140** may be inserted into first aperture **1109**A of housing **1105** through a first exterior housing aperture **1107**A. Alternatively, in the reverse-polarity configuration, the push-pull tab protrusion **1140** may be inserted into second housing aperture **1109**B through second exterior housing aperture **1107**B. When the push-pull tab **1130** is moved forward, the protrusion slides within the aperture **1109**A or **1109**B, as shown in FIG. **12**B. To maintain the push-pull tab in a forward-biased position, tab position spring **1150** is provided. During insertion or removal of the protrusion **1140**, tab position spring **1150** is compressed, depicted in FIG. **12**B. When the position spring **1150** is in its relaxed (uncompressed) position, FIGS. **12**C and **12**D, the protrusion **1140** is slid forward within the aperture **1109**A or **1109**B.

To change polarity of the optical connector **1100**, FIGS. **13**A-**13**D, the push-pull tab **1130** is removed by withdrawing the protrusion **1140** from the housing **1105** through exterior housing aperture **1107**A along with detaching clips **1135** and decoupling projection **1131**, thus releasing the push-pull tab from the first exterior housing wall **1110** (FIG. **13**B). The push-pull tab is moved toward second exterior housing wall **1115** and the protrusion **1140** is inserted into aperture **1109**B through exterior housing aperture **1107**B in FIG. **13**C. Projection **1131** is fitted between ferrules **1120** and **1125** and clips **1135** are affixed to the connector. The resultant connector **1100**R of **13**D is of opposite polarity to the connector **1100** of FIG. **13**A.

Various alternatives to the protrusion **1140** of optical connector **1100** may be used in the optical connectors of this disclosure. For example, the protrusion may be provided by the connector housing with receiving elements provided in the push-pull tab. Variations to the shape of the projection and apertures may be made without affecting the function of the reversible-polarity connector.

Another alternative embodiment is depicted in FIGS. **14**A and **14**B in which a hook-shaped protrusion **1440** is provided for engagement within the connector housing. As in the previous embodiment, the push-pull tab **1430** includes a tab recess **1445**, connector-attachment clips **1435** and projection **1431** for positioning between ferrules **1420** and **1425**. In FIG. **14**B, the push-pull tab **1430** is positioned on first exterior housing wall **1410** and has a first polarity. In this position, the hook-shaped protrusion **1440** engages a housing projection **1460**, held in a forward-biased position by push-pull tab position spring **1465**, as seen in FIGS. **15**B and **15**D. To release the protrusion **1440**, push-pull tab position spring **1465** is compressed in FIG. **15**C such that housing projection **1460** is retracted sufficiently to allow removal of protrusion **1440** through the housing **1405**, FIG. **15**D.

To change polarity of the optical connector **1400** from the first polarity of FIG. **16**A, the push-pull tab **1430** is removed by withdrawing the protrusion **1440** from the housing **1405** through the housing along with detaching clips **1435** and decoupling projection **1431**, thus releasing the push-pull tab from the first exterior housing wall **1110** (FIG. **16**B). The push-pull tab is moved toward second exterior housing wall **1415** and the protrusion **1440** is inserted into the housing **1405**. Projection **1431** is fitted between ferrules **1420** and **1425** and clips **1435** are affixed to the connector in FIG. **16**C. The resultant connector **1400**R of FIG. **16**D is of opposite polarity to the connector of FIG. **16**A.

Protrusions from a push-pull tab may be inserted into a housing via features other than a housing aperture. Such a connector is depicted in FIG. **17** and features a deformable housing region to allow entry of a push-pull tab protrusion during affixing of the push-pull tab to the connector housing.

As seen in FIG. **17**A, the connector **1700** includes a connector housing **1705** which may optionally include a back body housing portion **1709** for connecting with a housing front portion **1707** (FIG. **17**C). The back body housing portion **1709** includes a deformable region **1780**, seen in the partial cross-section of FIG. **17**B and the perspective view of FIG. **17**C. The push-pull tab **1730** includes a protrusion **1740** with a projection **1741** extending therefrom.

Turning to FIG. **18**, to affix the push-pull tab to the connector housing, the protrusion **1740** penetrates the deformable region **1780** (FIG. **18**B) causing the deformable region to yield and accept entry of the protrusion **1740** into the housing. As the projection **1741** enters the housing as depicted in FIG. **18**C, the deformable region **1780** returns to its original position (FIG. **18**D), securing the push-pull tab **1730** to the connector housing.

Removal of the push-pull tab **1730** is depicted in FIGS. **19**A and **19**B. A removal tool **1900**, which may be shaped similar to a small screwdriver, depresses deformable region **1780**, allowing projection **1741** to slide along an edge of the deformable region **1780**, followed by the protrusion **1740**, releasing the push-pull tab **1730**.

To change polarity of the optical connector **1700** from the first polarity of FIG. **20**A, the push-pull tab **1730** is removed in FIG. **20**B by using the removal tool technique depicted in FIGS. **19**A and **19**B. The push-pull tab is moved toward the second exterior housing wall and the protrusion **1740** is inserted into the housing **1705** through the deformable region **1780** in FIG. **20**C. The resultant connector **1700**R of FIG. **20**D is of opposite polarity to the connector of FIG. **20**A.

In another aspect of the disclosure, a retaining member may be provided in the connector housing to retain a push-pull tab. As seen in FIGS. **21**A-**21**D, a connector **2100** having a housing **2105** is provided with a housing front portion **2107** and a back portion **2109**. FIG. **21**A depicts an assembled connector **2100** with housing **2105**. FIG. **21**B depicts an exploded view of connector **2100** of FIG. **21**A. Push-pull tab **2130** has a receiving surface **2132**, which during use of connector **2100** provides a surface over which retainer **2111** can slide across during tab movement. Extending from the housing back portion is a retainer **2111** which may include a pair of retaining clips, as shown, or any other structure configured to retain the push-pull tab **2130**. FIG. **21**C depicts connector **2100** showing a section view cut given by the arrows and broken line near the proximal end of connector **2100**. Optionally, when the retainer **2111** includes clips, the clips may be hook-shaped as seen in the cross-sectional view of FIG. **21**D. As shown in FIG. **21**D, receiving surface **2132** may be a recess with a protrusion along the edge that engages the hook-shaped edge of the clips.

FIG. **22**A through FIG. **22**E depicts the operation of polarity change for connector **2100** of FIG. **21**A-FIG. **21**D. FIG. **22**A depicts connector **2100** with pull-push tab clips **2135** (opposing side not shown) engaged around connector. To operate connector **2100**, user can move push-pull tab **2130** forward or toward front of connector or backward or toward rear of connector, and as describe in FIG. **21** above tab moves along connector receiving surface **2123**. This engages or releases connector **2100** from a receptacle as is known in the art. To change the polarity of connector **2100** from the polarity depicted in FIG. **22**A to the second, opposite polarity of FIG. **22**E, the retainer **2111** is removed from receiving surface **2132**. Referring to FIG. **21**B, lifting push-pull tab **2130** in direction of up-arrow, separates retainer **2111** from receiving surface. As shown in FIG. **22**C, push-pull tab clips separate from the connector as the retainer is removed. Continuing with FIG. **22**C, push-pull tab **2130** is moved to the opposite housing exterior wall in FIG. **22**C. FIG. **22**D depicts receiving surface **2132** engages with the retainer **2111**. In FIG. **21**E the assembled connector **2100**R having the opposite polarity to the connector of FIG. **22**A is depicted, fully assembled. Retainer **2111** is in contact with receiving surface **2132**, and push-pull tab **2130** is secured to connector body, as shown in FIG. **22**E.

FIGS. **23-28**

The following terms shall have, for the purposes of this application, the respective meanings set forth below.

A connector, as used herein, refers to a device and/or components thereof that connects a first module or cable to a second module or cable. The connector may be configured for fiber optic transmission or electrical signal transmission. The connector may be any suitable type now known or later developed, for example, embodiments of multiple-fiber push-on/pull-off (MPO) connectors, such as the Senko mini MPO connector and the Senko MPO Plus connector. The connector may generally be defined by a connector housing body.

A "fiber optic cable" or an "optical cable" refers to a cable containing one or more optical fibers for conducting optical signals in beams of light. The optical fibers can be constructed from any suitable transparent material, including glass, fiberglass, and plastic. The cable can include a jacket or sheathing material surrounding the optical fibers. In addition, the cable can be connected to a connector on one end or on both ends of the cable.

Various embodiments provide single fiber and multi-fiber connectors having a remote release tab, also referred to as a pull tab or a push pull tab. Some embodiments may be configured to allow polarity changes.

The pull tab of a typical connector may interact solely with the profile of the connector latch arm to flex the latch arm downward the distance needed to allow the connector to become unlatched from within the adapter/coupler for removal. Alternatively, the pull tab of a connector may work to solely lift an adapter hook a required distance to allow the connector to become unlatched for removal.

Various embodiments of connectors disclosed herein include an outer main body with a unique un-latching system. Various embodiments described herein generally provide optical fiber connectors with remote release tabs configured to allow a user to easily remove or insert connectors into adapters or couplers, such as adapters disposed on a high density panel without damaging surrounding connectors, accidentally disconnecting surrounding connectors, disrupting transmissions through surrounding connectors, and/or the like.

Various embodiments of connectors disclosed herein include a remote release tab having a tip configured to interact with an inner portion of the top surface of an adapter or coupler to provide some of the downward force needed to unlatch the connector from the adapter or coupler. In some embodiments, the inner portion of the top surface of the adapter or coupler may be a fixed portion that does not move.

In some embodiments, the tip of the remote release tab may be a wedge shaped tip. The connector may have a latch arm and may be configured such that as the remote release tab is pulled back, the tip of the remote release tab slides upwards along the slope of the latch arm of the connector. At a certain distance of retraction of the remote release tab, the wedge shape comes in contact with an inner portion of the top surface of the adapter. Upon additional retraction of the remote release tab, the wedge shaped tip simultaneously begins to push down the connector latch arm while sliding along the inner portion of the top surface of the adapter. As the connector latch arm is depressed to a sufficient distance, it becomes unlatched from the adapter, and any additional pulling of the remote release tab results in removing the connector from the adapter.

Some embodiments, such as embodiments having multiple ferrules and embodiments having multiple fiber ferrule connectors, are further configured to allow reversing the polarity. For example, in some embodiments, a guide of the remote release tab may be configured to rotate about **180** degrees in order to reverse polarity.

FIG. **23** shows one embodiment of an optical fiber connector assembly **3100** having a plurality of connectors **3102** and a remote release tab **3104**. In this embodiment, the connector assembly **3100** has a plurality of connectors. In other embodiments, the connector assembly may have one or more connectors. Various embodiments may include connectors of different types than shown in FIG. **23**. Each connector **3102** has a respective connector housing **3106** and a respective ferrule **3108**.

The connector assembly **3100** further includes at least one flexible latch arm assembly **3110**. The latch arm assembly **3110** includes at least one flexible latch arm **3111**. The latch arm assembly **3110** is configured to couple to the connectors **3102**. In other embodiments, each of the connectors **3102** may include a respective latch arm. In some embodiments, the latch arm may be formed integrally with one or more connectors in the connector assembly.

The connector assembly **3100** further includes a housing **3112** configured to receive the connectors **3102**. The latch arm assembly **3110** includes a first portion **3114** configured to couple with the connectors **3102**, for example by coupling to the connector housings **3106**. The latch arm assembly **3110** also includes a second portion **3116** configured to be received by the housing **3112**. In other embodiments, the latch arm assembly **3110** may be configured differently than shown in FIG. **23** to allow coupling to the connector assembly **3100**.

The connector assembly **3100** further includes a guide **3118** configured to retain the remote release tab **3104**. The guide **3118** is further configured to be rotated about **180** degrees, as shown for example by the arrow **3120**, to reverse the polarity of the connector assembly **3100**. In one example, the guide **3118** may be coupled to at least one polarity key, and rotation of the guide allows changing the polarity key. In another example, the polarity key may rotate with the guide. In other embodiments, the connector assembly need not be configured to reverse the polarity, and the guide may merely be configured to receive the remote release tab. The connector assembly **3100** further includes a back post **3122** and a boot **3124**.

The remote release tab **3104** has a body **3126**. The body **3126** may extend over the boot **3124** to facilitate remotely releasing the connector assembly from an adapter. In various embodiments, the length of the remote release tab **3104** may be selected so as to extend beyond the boot **3124** of the connector assembly **3100**. For example, the length may be selected such that the handle of the remote release tab is located beyond the boot of the connector for easy access.

The body **3126** includes a coupling portion **3128** configured to couple to the connectors **3120**. For example, as shown in FIG. **23**, the coupling portion **3128** includes a window **3130** configured to receive at least a portion of the latch arm assembly **3110**. For example, the window **3130** may be configured to receive the flexible latch arm **3111** of the connectors **3102**.

The remote release tab **3104** further includes a protrusion **3132** at one end thereof. The protrusion **3132** is shaped as a wedge. In other embodiments, the protrusion **3132** may have different shapes and configurations. In various embodiments, the protrusion **3132** may be configured to slide along the latch arm **3111** of the latch arm assembly **3110** and further to interact with an adapter coupled to the connector assembly **3100**, as the remote release tab **3104** is pulled rearward, to decouple the connector assembly from the adapter, as described and illustrated further below in relation to FIGS. **27** and **28**.

In some embodiments, the remote release tab **3104** may be removable from the optical connector assembly **3100**. The remote release tab **3104** may also be re-installed by coupling to the connector assembly **3100**. For example, the guide **3118** may be configured to retain the remote release tab **3104**. The guide **3118** may further be configured to allow removing the remote release tab **3104** from the connector assembly **3100**.

In various embodiments, the remote release tab **3104** may have a single integral structure. In other embodiments, the remote release tab **3104** may comprise a plurality of pieces coupled together to form the remote release tab. For example, in some embodiments, the coupling portion **3128** and the protrusion **3132** may be formed integrally with the body **3126**. In other embodiments, the coupling portion **3128** or the protrusion **3132** may be separate pieces coupled to each other to form the remote release tab **3104**.

FIG. **24** shows a perspective view of the assembled connector assembly **3100**. As shown in FIG. **24**, the latch arm **3111** protrudes through the window **3130** of the remote release tab **3104**. The remote release tab **3104** is retained by the guide **3118** such that the protrusion **3132** is disposed at a front end of the connector assembly **3100** and may slide along the latch arm **3111** as the remote release tab **3104** is pulled rearward.

FIG. **25** shows the connector assembly **3100** coupled to an adapter **3140**. The adapter may have a plurality of channels **3142** configured to receive connectors, including for example the connector assembly **3100**. The adapter **3140** further comprises a plurality of openings **3144** configured to couple the connector assembly to the adapter. For example, the openings **3144** are configured to engage the latch arm **3111** of the connector assembly **3100** so as to retain the connector assembly **3100** within the adapter **3140**. As the remote release tab **3104** is pulled rearward, the protrusion **3132** of the remote release tab interacts with both the latch arm **3111** and the adapter **3140** to release the latch arm from an opening **3144**, thereby decoupling the connector assembly **3100** from the adapter. In one embodiment, the protrusion **3132** interacts with an inner portion of a top surface **3146** of the adapter **3140**.

FIG. **26** shows a top view of the adapter **3140** and the connector assembly **3100** of FIG. **25**. The latch arm assembly **3110** and the connectors **3102** are received through the channels **3142** of the adapter **3140**.

FIGS. **27** and **28** show a cross-sectional view of the adapter **3140** and the connector assembly **3100** of FIG. **26** along section A-A. FIG. **27** further illustrates the remote release tab **3104** in a forward position, as the connector assembly **3100** is pushed into the adapter **3140** in the direction of the arrow **3150**. As shown, the connector assembly **3100** is coupled to the adapter **3140** by the latch arm **3111** which engages the opening **3144** of the adapter **3140**. The opening **3144** is disposed in the top surface **3146** of the adapter **3140**. The protrusion **3132** of the remote release tab **3104** is disposed at a front end of the latch arm **3111**. The protrusion **3132** does not yet contact an inner portion **3152** of the top surface **3146**.

FIG. **28** further illustrates the remote release tab **3104** in a rearward position as it is being pulled in the direction of the arrow **3154** so as to pull the connector assembly **3100** out of the adapter **3140**. The protrusion **3132** of the remote release tab **3104** slides along the latch arm **3111** and contacts an inner portion **3152** of the top surface **3146** of the adapter **3140**. The protrusion **3132** continues to slide along the inner portion **3152** of the top surface **3146** as the remote release tab **3104** is pulled further. The protrusion **3132** simultaneously begins to push down the connector latch arm **3111** while sliding rearward along the inner portion **3152** of the top surface **3146** of the adapter **3140**. As the connector latch arm **3111** is depressed by the protrusion **3132**, the connector assembly **3100** becomes unlatched from the adapter **3140**, and any additional pulling of the remote release tab **3104** results in removing the connectors from the adapter.

In the above detailed description, reference is made to the accompanying drawings, which form a part hereof. In the drawings, similar symbols typically identify similar components, unless context dictates otherwise. The illustrative embodiments described in the detailed description, drawings, and claims are not meant to be limiting. Other embodiments may be used, and other changes may be made, without departing from the spirit or scope of the subject matter presented herein. It will be readily understood that the aspects of the present disclosure, as generally described herein, and illustrated in the Figures, can be arranged, substituted, combined, separated, and designed in a wide variety of different configurations, all of which are explicitly contemplated herein.

The present disclosure is not to be limited in terms of the particular embodiments described in this application, which are intended as illustrations of various aspects. Many modifications and variations can be made without departing from its spirit and scope, as will be apparent to those skilled in the art. Functionally equivalent methods and apparatuses within the scope of the disclosure, in addition to those enumerated herein, will be apparent to those skilled in the art from the foregoing descriptions. Such modifications and variations are intended to fall within the scope of the appended claims. The present disclosure is to be limited only by the terms of the appended claims, along with the full scope of equivalents to which such claims are entitled. It is to be understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to be limiting.

With respect to the use of substantially any plural and/or singular terms herein, those having skill in the art can translate from the plural to the singular and/or from the singular to the plural as is appropriate to the context and/or application. The various singular/plural permutations may be expressly set forth herein for sake of clarity.

It will be understood by those within the art that, in general, terms used herein, and especially in the appended claims (for example, bodies of the appended claims) are generally intended as "open" terms (for example, the term "including" should be interpreted as "including but not limited to," the term "having" should be interpreted as "having at least," the term "includes" should be interpreted as "includes but is not limited to," et cetera). While various compositions, methods, and devices are described in terms of "comprising" various components or steps (interpreted as meaning "including, but not limited to"), the compositions, methods, and devices can also "consist essentially of" or "consist of" the various components and steps, and such terminology should be interpreted as defining essentially closed-member groups. It will be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present. For example, as an aid to understanding, the following appended claims may contain usage of the introductory phrases "at least one" and "one or more" to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles "a" or "an" limits any particular claim containing such introduced claim recitation to embodiments containing only one such recitation, even when the same claim includes the introductory phrases "one or more" or "at least one" and indefinite articles such as "a" or "an" (for example, "a" and/or "an" should be interpreted to mean "at least one" or "one or more"); the same holds true for the use of definite articles used to introduce claim recitations. In addition, even if a specific number of an introduced claim recitation is explicitly recited, those skilled in the art will recognize that such recitation should be interpreted to mean at least the recited number (for example, the bare recitation of "two recitations," without other modifiers, means at least two recitations, or two or more recitations). Furthermore, in those instances where a convention analogous to "at least one of A, B, and C, et cetera" is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (for example, "a system having at least one of A, B, and C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, et cetera). In those instances where a convention analogous to "at least one of A, B, or C, et cetera" is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (for example, "a system having at least one of A, B, or C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, et cetera). It will be further understood by those within the art that virtually any disjunctive word and/or phrase presenting two or more alternative terms, whether in the description, claims, or drawings, should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms. For example, the phrase "A or B" will be understood to include the possibilities of "A" or "B" or "A and B."

In addition, where features or aspects of the disclosure are described in terms of Markush groups, those skilled in the art will recognize that the disclosure is also thereby described in terms of any individual member or subgroup of members of the Markush group.

As will be understood by one skilled in the art, for any and all purposes, such as in terms of providing a written description, all ranges disclosed herein also encompass any and all possible subranges and combinations of subranges thereof. Any listed range can be easily recognized as sufficiently describing and enabling the same range being broken down into at least equal halves, thirds, quarters, fifths, tenths, et cetera As a non-limiting example, each range discussed herein can be readily broken down into a lower third, middle third and upper third, et cetera As will also be understood by one skilled in the art all language such as "up to," "at least," and the like include the number recited and refer to ranges which can be subsequently broken down into subranges as discussed above. Finally, as will be understood by one skilled in the art, a range includes each individual member. Thus, for example, a group having 1-3 cells refers to groups having 1, 2, or 3 cells. Similarly, a group having 1-5 cells refers to groups having 1, 2, 3, 4, or 5 cells, and so forth.

Various of the above-disclosed and other features and functions, or alternatives thereof, may be combined into many other different systems or applications. Various presently unforeseen or unanticipated alternatives, modifications, variations or improvements therein may be subsequently made by those skilled in the art, each of which is also intended to be encompassed by the disclosed embodiments.

The invention claimed is:

1. An adapter for mating with a plurality of optical fiber connectors, each of the plurality of optical fiber connectors comprising a connector housing holding multiple optical fibers, a flexible latch arm having a front end and a rear end spaced apart rearward of the front end, and a remote release comprising a front section configured to slide rearward along the flexible latch arm to depress the flexible latch arm, the adapter comprising:

an outer housing having a first end portion and a second end portion spaced apart along a longitudinal axis and a first side wall and a second side wall spaced apart along a width, the outer housing defining a plurality of channels side-by-side along the width of the outer housing, each of the plurality of channels opening through the first end portion such that the plurality of optical fiber connectors can be inserted forward along the longitudinal axis into the plurality of channels through the first end portion to mate the adapter with the plurality of optical fiber connectors for making an optical connection to the optical fibers via the adapter, the outer housing comprising an upper wall and a lower wall spaced apart along a transverse axis perpendicular to the longitudinal axis, the upper wall defining a plurality of latch openings configured to latch with the flexible latch arms of the plurality of optical fiber connectors, the plurality of channels being configured to receive the plurality of optical fiber connectors such that the front sections of the remote releases are inside the plurality of channels forward of the plurality of latch openings when the plurality of latch openings latch with the flexible latch arms;

wherein the plurality of channels includes a first channel and a second channel;

wherein the plurality of latch openings includes a first latch opening aligned with the first channel and a second latch opening aligned with the second channel;

wherein the upper wall comprises a first longitudinal rib projecting inwardly along the transverse axis toward the lower wall and the lower wall comprises a second longitudinal rib projecting inwardly along the transverse axis toward the upper wall, the first longitudinal rib and the second longitudinal rib being aligned along the width of the outer housing and located between the first and second channels, the first longitudinal rib being spaced apart from the second longitudinal rib along the transverse axis by a transverse gap, the first channel being open to the second channel through the transverse gap.

2. The adapter as set forth in claim **1**, wherein each channel is configured to allow the front section of the remote release to slide rearward along the flexible latch arm within the channel to depress the flexible latch arm, wherein the upper wall of the outer housing is configured to unlatch from each flexible latch arm when the flexible latch arm is depressed, and wherein the lower wall is configured to slidably engage each connector housing without latching.

3. The adapter as set forth in claim **1**, wherein the first longitudinal rib has a first height along the transverse axis and the second longitudinal rib has a second height along the transverse axis, the first height being greater than the second height.

4. The adapter as set forth in claim **1**, wherein the adapter comprises a transverse wall extending between the upper wall and the lower wall at a location longitudinally spaced apart from the first end portion of the outer housing and wherein the transverse wall includes a socket configured to receive a ferrule of the optical fiber connector.

5. The adapter as set forth in claim **4**, wherein the optical fiber connector is a duplex connector comprising first and second cylindrical ferrules.

6. The adapter as set forth in claim **1**, wherein the optical fiber connector is a multifiber connector comprising a multi-fiber ferrule.

7. The adapter as set forth in claim **1**,

wherein the first longitudinal rib has a bottom edge extending in a bottom edge plane parallel to the longitudinal axis and the width of the outer housing,

wherein the adapter is configured to mate with the plurality of optical fiber connectors such that parts of the remote releases are received in the plurality of channels and any portion of the remote releases received in the channels is located above the bottom edge plane,

wherein the second longitudinal rib has a top edge extending in a top edge plane parallel to the longitudinal axis and the width of the outer housing,

wherein each of the plurality of channels has an upper portion above the bottom edge plane, a lower portion below the top edge plane, and a central portion between the bottom edge plane and the top edge plane,

wherein the central portion of each channel is wider than the upper portion and the lower portion thereof,

wherein the upper wall comprises top channel surfaces defining top ends of the plurality of channels,

wherein the top channel surfaces extend in a top plane parallel to the longitudinal axis and the width of the adapter,

wherein the top plane is spaced apart above the bottom edge plane,

wherein the top channel surfaces are configured to slidably engage the front sections of the remote releases as the optical fiber connectors are inserted into the plurality of channels,

wherein the lower wall comprises bottom channel surfaces defining bottom ends of the plurality of channels,

wherein the bottom channel surfaces extend in a bottom plane parallel to the longitudinal axis and the width of the adapter,

wherein the bottom plane is spaced apart below the top edge plane,

wherein the bottom channel surfaces are configured to slidably engage bottom walls of the connector housings as the plurality of optical fiber connectors are inserted into the plurality of channels,

wherein the bottom edge plane and the top plane are spaced apart by a first height and the top edge plane and the bottom plane are spaced apart by a second height, and

wherein the first height is greater than the second height so that the upper channel portions can accommodate the front sections of the remote releases as the plurality of optical fiber connectors are inserted into the plurality of channels.

8. The adapter as set forth in claim **7**, comprising a single piece forming the upper wall, the lower wall, the first side wall, the second side wall, the first alignment rib, the second alignment rib, and the transverse wall.

9. The adapter as set forth in claim **7**,

wherein the adapter comprises a transverse wall between the upper wall and the lower wall at a location longitudinally spaced apart from the first end portion of the outer housing,

wherein the upper portion and the lower portion of each of the plurality of channels has a length extending along the longitudinal axis from an outer end at the first end portion of the outer housing to an inner end adjacent the transverse wall,

wherein the transverse wall closes the inner end of the upper portion and the lower portion of each of the plurality of channels,

wherein the top channel surfaces extend longitudinally from the first end portion of the outer housing to the transverse wall, and

wherein the bottom channel surfaces extend longitudinally from the first end portion of the outer housing to the transverse wall.

10. The adapter as set forth in claim **1**,

wherein the first longitudinal rib has a bottom edge extending in a bottom edge plane parallel to the longitudinal axis and the width of the outer housing,

wherein the second longitudinal rib has a top edge extending in a top edge plane parallel to the longitudinal axis and the width of the outer housing,

wherein the adapter is configured to mate with the plurality of optical fiber connectors such that parts of the remote releases are received in the plurality of channels and such that any portion of the remote releases received in the channels is located above the top edge plane,

wherein each of the plurality of channels has an upper portion above the bottom edge plane, a lower portion below the top edge plane, and a central portion between the bottom edge plane and the top edge plane,

wherein the central portion of each channel is wider than the upper portion and the lower portion thereof,

wherein the upper wall comprises top channel surfaces defining top ends of the plurality of channels,

wherein the top channel surfaces extend in a top plane parallel to the longitudinal axis and the width of the adapter,

wherein the top plane is spaced apart above the bottom edge plane,

wherein the top channel surfaces are configured to slidably engage the front sections of the remote releases as the optical fiber connectors are inserted into the plurality of channels,

wherein the lower wall comprises bottom channel surfaces defining bottom ends of the plurality of channels,

wherein the bottom channel surfaces extend in a bottom plane parallel to the longitudinal axis and the width of the adapter,

wherein the bottom plane is spaced apart below the top edge plane,

wherein the bottom channel surfaces are configured to slidably engage bottom walls of the connector housings as the plurality of optical fiber connectors are inserted into the plurality of channels,

wherein the bottom edge plane and the top plane are spaced apart by a first height and the top edge plane and the bottom plane are spaced apart by a second height, and

wherein the first height is greater than the second height so that the upper channel portions can accommodate the front sections of the remote releases as the plurality of optical fiber connectors are inserted into the plurality of channels.

11. A connection system comprising:

the adapter as set forth in claim **1**; and

an optical fiber connector comprising a connector housing defining a single plug frame around multiple optical fibers, a flexible latch arm having a front end and a rear end spaced apart rearward of the front end, and a remote release comprising a front section configured to slide rearward along the flexible latch arm to depress the flexible latch arm, the optical fiber connector configured to be inserted into the first channel to mate with the adapter whereby the flexible latch arm latches with the first latch opening and the front section of the remote release is inside the first channel forward of the first latch opening.

12. The connection system as set forth in claim **11**,

wherein the connector housing has a first side wall, a second side wall, and a width extending from the first side wall to the second side wall, the connector housing having a top wall, a bottom wall, and a height extending from the top wall to the bottom wall,

wherein the optical fiber connector comprises a latch arm piece formed separately from the connector housing, the latch arm piece including the flexible latch arm and configured to be coupled to the connector housing,

wherein the latch arm piece includes a portion configured to be received in a recess on the top wall of the connector housing when the latch arm piece is coupled to the connector housing, the flexible latch arm extending upward from said portion,

wherein the remote release comprises a body formed separately from the connector housing and the latch arm piece and the body comprises a coupling portion configured to couple the remote release to the connector housing,

wherein the body includes a window to receive the flexible latch arm,

wherein the body is configured to couple to the top wall of the connector housing.

13. The connection system as set forth in claim **12**, wherein the coupling portion comprises rails on opposite sides of the window.

14. The connection system as set forth in claim **12**, wherein the body is narrower than the connector housing and located centrally on the connector housing such that the entire body is contained inside the width of the connector housing and does not protrude widthwise past the first and second side walls.

15. The connection system as set forth in claim **12**, wherein the second longitudinal rib has a top edge extending in a top edge plane parallel to the longitudinal axis and the width of the outer housing, wherein the body comprises a front portion configured to be received in the first channel beside the first longitudinal rib, the entire front portion of the body being above the top edge plane when the optical fiber connector is inserted into the first channel to mate with the adapter.

16. The connection system as set forth in claim **12**,

wherein the first longitudinal rib has a bottom edge extending in a bottom edge plane parallel to the longitudinal axis and the width of the outer housing,

wherein the second longitudinal rib has a top edge extending in a top edge plane parallel to the longitudinal axis and the width of the outer housing,

wherein each of the plurality of channels has an upper portion above the bottom edge plane, a lower portion below the top edge plane, and a central portion between the bottom edge plane and the top edge plane,

wherein the central portion of each channel is wider than the upper portion and the lower portion thereof,

wherein the upper wall comprises top channel surfaces defining top ends of the plurality of channels,

wherein the top channel surfaces extend in a top plane parallel to the longitudinal axis and the width of the adapter,

wherein the top plane is spaced apart above the bottom edge plane,

wherein the lower wall comprises bottom channel surfaces defining bottom ends of the plurality of channels,

wherein the bottom channel surfaces extend in a bottom plane parallel to the longitudinal axis and the width of the adapter,

wherein the bottom plane is spaced apart below the top edge plane,

wherein the bottom edge plane and the top plane are spaced apart by a first height and the top edge plane and the bottom plane are spaced apart by a second height, and

wherein the optical fiber connector comprises an upper connector portion including the flexible latch arm, the front section of the remote release, and an upper portion of the connector housing, a lower portion including a lower portion of the connector housing, and a central connector portion including a central portion of the connector housing where the multiple optical fibers are located,

wherein the central connector portion is wider than the upper connector portion and the lower connector portion, and

wherein the optical fiber connector is configured to be received in the first channel such that:

the upper connector portion is received in the upper channel portion of the first channel and latched to the upper wall of the adapter;

the lower connector portion is received in the lower channel portion of the first channel without latching;

the central connector portion is slidably received in the central channel portion of the first channel;

the front section of the remote release is received in the first channel beside the first longitudinal rib,

the front section of the remote release is received between the top wall of the connector and the top channel surface of the first channel,

the entire front section of the remote release is above the top edge plane,

a side region of the central connector portion is received in the transverse gap between the first longitudinal rib and the second longitudinal rib, and

the side region is exposed to the second channel through the transverse gap.

17. The connection system as set forth in claim **16**, wherein the body and the latch arm piece form a latching assembly, and wherein the latching assembly is narrower than the connector housing and located centrally on the connector housing such that the entire latching assembly is contained inside the width of the connector housing and does not protrude widthwise past the first and second side walls.

18. The connection system as set forth in claim **16**, wherein the upper connector portion has a first connector portion height corresponding to the first height and the lower connector portion has a second connector portion height corresponding to the second height, the first connector portion height being greater than the second connector portion height, wherein the transverse gap has a gap height greater than the first height, and wherein the central connector portion has a third connector portion height corresponding to the gap height, the third connector portion height greater than the first connector portion height.

* * * * *

EXHIBIT M

US011809006B2

(12) **United States Patent**
Takano et al.

(10) **Patent No.: US 11,809,006 B2**
(45) **Date of Patent: *Nov. 7, 2023**

(54) **ULTRA-SMALL FORM FACTOR OPTICAL CONNECTORS USED AS PART OF A RECONFIGURABLE OUTER HOUSING**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **18/078,744**

(22) Filed: **Dec. 9, 2022**

(65) **Prior Publication Data**

US 2023/0107570 A1 Apr. 6, 2023

Related U.S. Application Data

(63) Continuation of application No. 17/591,298, filed on Feb. 2, 2022, now Pat. No. 11,543,605, which is a (Continued)

(51) **Int. Cl.**

G02B 6/42	(2006.01)
G02B 6/38	(2006.01)

(52) **U.S. Cl.**
CPC ***G02B 6/4292*** (2013.01); ***G02B 6/387*** (2013.01); ***G02B 6/3825*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC G02B 6/42; G02B 6/4292; G02B 6/38; G02B 6/3825; G02B 6/3893
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

681,132	A	8/1901	Norton
3,721,945	A	3/1973	Hults

(Continued)

FOREIGN PATENT DOCUMENTS

CA	2495693 A1	4/2004	
CA	2495693 A1	4/2004	

(Continued)

OTHER PUBLICATIONS

International Search Report and Written Opinion; Application No. PCT/US2018/042202, dated Dec. 7, 2018, pp. 17.

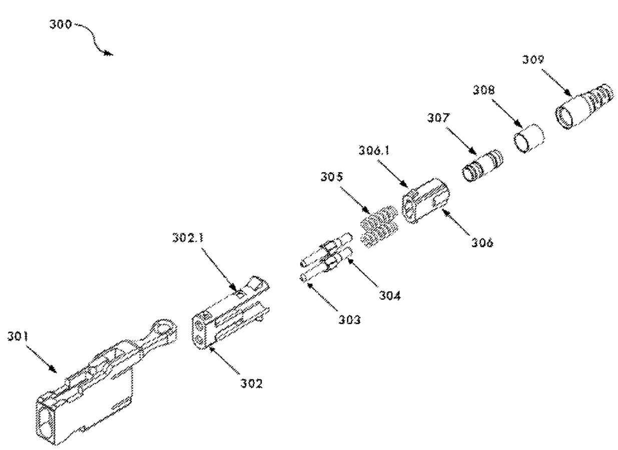
(Continued)

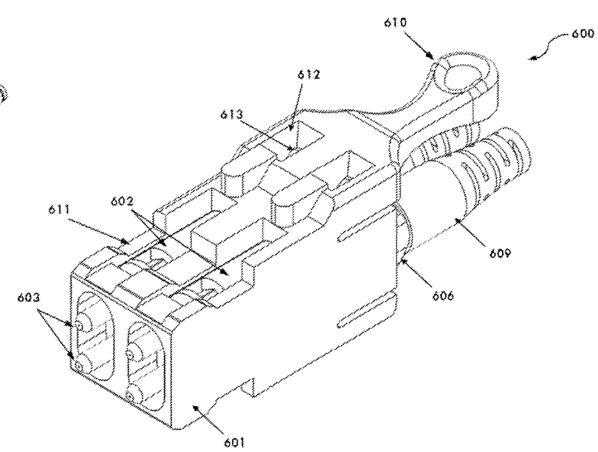
Primary Examiner — Tina M Wong

(57) **ABSTRACT**

An optical connector holding one or more optical ferrule assembly is provided. The optical connector includes an outer body, an inner front body accommodating the one or more optical ferrule assembly, ferrule springs for urging the optical ferrules towards a mating receptacle, and a back body for supporting the ferrule springs. The outer body and the inner front body are configured such that four optical ferrule assembly are accommodated in a small form-factor pluggable (SFP) transceiver footprint or eight optical ferrule assembly are accommodated in a quad small form-factor pluggable (QSFP) transceiver footprint. A receptacle can hold one or more connector inner bodies forming a single boot for all the optical fibers of the inner bodies.

31 Claims, 82 Drawing Sheets





Related U.S. Application Data

continuation of application No. 17/370,057, filed on Jul. 8, 2021, now Pat. No. 11,307,369, which is a continuation of application No. 17/327,197, filed on May 21, 2021, now Pat. No. 11,340,413, which is a continuation of application No. 17/090,855, filed on Nov. 5, 2020, now Pat. No. 11,487,067, which is a continuation of application No. 16/414,546, filed on May 16, 2019, now Pat. No. 10,859,778, which is a continuation of application No. 16/388,053, filed on Apr. 18, 2019, now Pat. No. 11,169,338, which is a continuation of application No. 16/035,691, filed on Jul. 15, 2018, now Pat. No. 10,281,668.

(60) Provisional application No. 62/588,276, filed on Nov. 17, 2017, provisional application No. 62/549,655, filed on Aug. 24, 2017, provisional application No. 62/532,710, filed on Jul. 14, 2017.

(52) **U.S. Cl.**
CPC ***G02B 6/3893*** (2013.01); *G02B 6/3873* (2013.01); *G02B 6/3878* (2013.01); *G02B 6/4228* (2013.01)

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,150,790 A 4/1979 Potter
4,240,695 A 12/1980 Evans
4,327,964 A 5/1982 Haesley et al.
4,478,473 A 10/1984 Frear
4,762,388 A 8/1988 Tanaka et al.
4,764,129 A 8/1988 Jones et al.
4,840,451 A 6/1989 Sampson et al.
4,872,736 A 10/1989 Myers et al.
4,979,792 A 12/1990 Weber
5,026,138 A 6/1991 Boudreau
5,031,981 A 7/1991 Peterson
5,011,025 A 8/1991 Haitmanek
5,041,025 A 8/1991 Haitmanek
5,073,045 A 12/1991 Abendschein
D323,143 S 1/1992 Ohkura et al.
5,101,463 A 3/1992 Cubukciyan
5,146,813 A 9/1992 Stanfill, Jr.
5,159,652 A 10/1992 Grassin D'Alphonse
5,212,752 A 5/1993 Stephenson et al.
5,265,181 A 11/1993 Chang
5,289,554 A 2/1994 Cubukciyan et al.
5,315,679 A 5/1994 Baldwin
5,317,663 A 5/1994 Beard et al.
5,321,784 A 6/1994 Cubukciyan et al.
5,335,301 A 8/1994 Newman et al.
5,348,487 A 9/1994 Marazzi et al.
5,418,875 A 5/1995 Nakano
5,444,806 A 8/1995 de Marchi et al.
5,481,634 A 4/1996 Anderson et al.
5,506,922 A 4/1996 Grois et al.
5,521,997 A 5/1996 Rovenolt et al.
5,570,445 A 10/1996 Chou et al.
5,588,079 A 12/1996 Tanabe et al.
5,602,951 A 2/1997 Shiota
5,684,903 A 11/1997 Kyomasu et al.
5,687,268 A 11/1997 Stephenson et al.
5,781,681 A 7/1998 Manning
5,845,036 A 12/1998 De Marchi
5,862,282 A 1/1999 Matsuura
5,915,987 A 6/1999 Reed
5,930,426 A 7/1999 Harting
5,937,130 A 8/1999 Amberg et al.
5,953,473 A 9/1999 Shimotsu
5,956,444 A 9/1999 Duda et al.
5,971,626 A 10/1999 Knodell et al.
6,041,155 A 3/2000 Anderson et al.
6,049,040 A 4/2000 Biles et al.
6,095,862 A 8/2000 Doye
6,134,370 A 10/2000 Childers et al.
6,178,283 B1 1/2001 Weigel
RE37,080 E 3/2001 Stephenson et al.
6,206,577 B1 3/2001 Hall, III et al.
6,206,581 B1 3/2001 Driscoll et al.
6,227,717 B1 5/2001 Ott et al.
6,238,104 B1 5/2001 Yamakawa et al.
6,240,228 B1 5/2001 Chen
6,247,849 B1 6/2001 Liu
6,250,817 B1 6/2001 Lampert et al.
6,276,840 B1 8/2001 Weiss
6,318,903 B1 11/2001 Andrews
6,364,537 B1 4/2002 Maynard
6,379,052 B1 4/2002 de Jong
6,422,759 B1 7/2002 Kevern
6,450,695 B1 9/2002 Matsumoto
6,461,054 B1 10/2002 Iwase
6,471,412 B1 10/2002 Belenkiy et al.
6,478,472 B1 11/2002 Anderson et al.
6,485,194 B1 11/2002 Shirakawa
6,527,450 B1 3/2003 Miyachi
6,530,696 B1 3/2003 Ueda
6,551,117 B2 4/2003 Poplawski et al.
6,565,262 B2 5/2003 Childers
6,572,276 B1 6/2003 Theis
6,579,014 B2 6/2003 IWelton et al.
6,585,194 B1 7/2003 Brushwood
6,634,796 B2 10/2003 de Jong
6,634,801 B1 10/2003 Waldron et al.
6,648,520 B2 11/2003 McDonald et al.
6,668,113 B2 12/2003 Togami
6,682,228 B2 1/2004 Ralhnam et al.
6,685,362 B2 2/2004 Burkholder et al.
6,695,486 B1 2/2004 Falkenberg
6,811,321 B1 11/2004 Schmalzigaug et al.
6,817,272 B2 11/2004 Holland
6,854,894 B1 2/2005 Yunker et al.
6,869,227 B2 3/2005 Del Grosso
6,872,039 B2 3/2005 Baus et al.
6,935,789 B2 8/2005 Gross, III et al.
7,036,993 B2 5/2006 Luther
7,052,186 B1 5/2006 Bates
7,077,576 B2 7/2006 Luther
7,090,407 B2 8/2006 Melton et al.
7,091,421 B2 8/2006 Kukita et al.
7,111,990 B2 9/2006 Melton et al.
7,113,679 B2 9/2006 Melton et al.
D533,504 S 12/2006 Lee
D534,124 S 12/2006 Taguchi
7,150,567 B1 12/2006 Luther et al.
7,153,041 B2 12/2006 Mine et al.
7,198,409 B2 4/2007 Smith et al.
7,207,724 B2 4/2007 Gurreri
D543,146 S 5/2007 Chen et al.
7,258,493 B2 8/2007 Milette
7,261,472 B2 8/2007 Suzuki et al.
7,264,402 B2 9/2007 Theuerkorn
7,281,859 B2 10/2007 Mudd et al.
7,284,912 B2 10/2007 Suzuki et al.
D558,675 S 1/2008 Chien et al.
7,315,682 B1 1/2008 En Lin et al.
7,325,976 B2 2/2008 Gurreri et al.
7,325,980 B2 2/2008 Pepe
7,329,137 B2 2/2008 Martin et al.
7,347,634 B2 3/2008 Gunther et al.
7,354,291 B2 4/2008 Caveney et al.
7,331,718 B2 5/2008 Yazaki et al.
7,371,082 B2 5/2008 Zimmel et al.
7,387,447 B2 6/2008 Mudd et al.
7,390,203 B2 6/2008 Murano et al.
D572,661 S 7/2008 En Lin et al.
7,431,604 B2 10/2008 Waters et al.
7,463,803 B2 12/2008 Cody et al.
7,465,180 B2 12/2008 Kusuda et al.
7,473,124 B1 1/2009 Briant
7,510,335 B1 3/2009 Su et al.
7,513,695 B1 4/2009 Lin et al.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,534,128 B2 5/2009 Caveney et al.
7,540,666 B2 6/2009 Luther
7,561,775 B2 7/2009 Lin et al.
7,588,373 B1 9/2009 Sato
7,591,595 B2 9/2009 Lue et al.
7,594,766 B1 9/2009 Sasser et al.
7,641,398 B2 1/2010 O'Riorden et al.
7,695,199 B2 4/2010 Teo et al.
7,699,533 B2 4/2010 Milette
7,712,970 B1 5/2010 Lee
7,717,625 B2 5/2010 Margolin
7,824,113 B2 11/2010 Wong et al.
7,837,395 B2 11/2010 Lin et al.
D641,708 S 7/2011 Tammauchi
8,083,450 B1 12/2011 Smith et al.
8,152,385 B2 4/2012 de Jong
8,186,890 B2 5/2012 Lu
8,192,091 B2 6/2012 Hsu et al.
8,202,009 B2 6/2012 Lin et al.
8,221,007 B2 7/2012 Peterhans
8,251,733 B2 8/2012 Wu
8,267,595 B2 9/2012 Lin et al.
8,270,796 B2 9/2012 Nhep
8,408,815 B2 4/2013 Lin et al.
8,414,196 B2 4/2013 Lu
8,465,317 B2 6/2013 Gniadek et al.
8,534,928 B2 9/2013 Cooke
8,550,728 B2 10/2013 Takahashi
8,556,645 B2 10/2013 Crain
8,559,781 B2 10/2013 Childers
8,622,634 B2 1/2014 Arnold
8,636,424 B2 1/2014 Kuffel et al.
8,651,749 B2 2/2014 Clovis et al.
8,676,022 B2 3/2014 Jones
8,678,670 B2 3/2014 Takahashi
8,727,638 B2 5/2014 Lee
8,757,894 B2 6/2014 Katoh
8,764,308 B2 7/2014 Irwin
8,770,863 B2 7/2014 Cooke et al.
8,869,661 B2 10/2014 Opstad
9,052,474 B2 6/2015 Jiang
9,063,296 B2 6/2015 Dong
9,250,399 B2 2/2016 Margolin et al.
9,250,402 B2 2/2016 Ishii et al.
9,310,569 B2 4/2016 Lee
9,366,829 B2 6/2016 Czosnowski
9,411,110 B2 8/2016 Barnette, Jr. et al.
9,448,370 B2 9/2016 Xue et al.
9,465,172 B2 10/2016 Shih
9,494,744 B2 11/2016 de Jong
9,548,557 B2 1/2017 Liu
9,551,842 B2 1/2017 Theuerkom
9,557,495 B2 1/2017 Raven et al.
9,568,686 B2 2/2017 Fewkes et al.
9,568,689 B2 2/2017 Nguyen et al.
9,581,768 B1 2/2017 Baca et al.
9,599,778 B2 3/2017 Wong et al.
9,658,409 B2 5/2017 Gniadek
9,678,283 B1 6/2017 Chang et al.
9,684,130 B2 6/2017 Veatch et al.
9,684,136 B2 6/2017 Cline et al.
9,684,313 B2 6/2017 Chajec
9,709,753 B1 8/2017 Chang et al.
9,778,425 B2 10/2017 Nguyen
9,829,644 B2 11/2017 Nguyen
9,829,645 B2 11/2017 Good
9,829,653 B1 11/2017 Nishiguchi
9,869,825 B2 1/2018 Bailey et al.
9,880,361 B2 1/2018 Childers
9,946,035 B2 4/2018 Gustafson
9,971,103 B2 5/2018 de Jong et al.
9,989,711 B2 6/2018 Ott et al.
10,031,296 B2 7/2018 Good
10,067,301 B2 9/2018 Murray
10,107,972 B1 10/2018 Gniadek et al.
10,114,180 B2 10/2018 Suzic
10,146,011 B2 12/2018 Nhep
10,281,668 B2 5/2019 Takano et al.
10,281,669 B2 5/2019 Takano et al.
10,859,778 B2 12/2020 Takano et al.
11,181,701 B2 11/2021 Wong et al.
11,307,369 B2 * 4/2022 Takano G02B 6/3825
11,340,413 B2 * 5/2022 Takano G02B 6/3825
11,543,605 B2 * 1/2023 Takano G02B 6/4292
2002/0168148 A1 11/2002 Gilliland
2002/0172467 A1 11/2002 Anderson et al.
2002/0191919 A1 12/2002 Nolan
2003/0053787 A1 3/2003 Lee
2003/0063862 A1 4/2003 Fillion
2003/0157825 A1 8/2003 Kane
2004/0052473 A1 3/2004 Seo
2004/0109646 A1 6/2004 Anderson
2004/0161958 A1 6/2004 Togami et al.
2004/0136657 A1 7/2004 Ngo
2004/0141693 A1 7/2004 Szilagyi et al.
2004/0234209 A1 11/2004 Cox et al.
2004/0247252 A1 12/2004 Ehrenreich
2005/0036744 A1 2/2005 Caveney et al.
2005/0111796 A1 5/2005 Matasek et al.
2005/0135755 A1 6/2005 Kiani et al.
2005/0141817 A1 6/2005 Yazaki et al.
2006/0013539 A1 1/2006 Thaler
2006/0076061 A1 4/2006 Bush
2006/0089049 A1 4/2006 Sedor
2006/0127025 A1 6/2006 Haberman
2006/0153503 A1 7/2006 Suzuki
2006/0160429 A1 7/2006 Dawiedczyk et al.
2006/0193562 A1 8/2006 Theuerkorn
2006/0269194 A1 11/2006 Luther et al.
2006/0274411 A1 12/2006 Yamauchi
2007/0025665 A1 2/2007 Dean
2007/0028409 A1 2/2007 Yamada
2007/0079854 A1 4/2007 You
2007/0098329 A1 6/2007 Shimoji et al.
2007/0149028 A1 6/2007 Yu et al.
2007/0149062 A1 6/2007 Long et al.
2007/0230874 A1 10/2007 Lin
2007/0232115 A1 10/2007 Burke et al.
2007/0243749 A1 10/2007 Wu
2008/0008430 A1 1/2008 Kewitsch
2008/0013896 A1 1/2008 Salzberg et al.
2008/0044137 A1 2/2008 Luther et al.
2008/0056647 A1 3/2008 Margolin et al.
2008/0064334 A1 3/2008 Hamadi
2008/0069501 A1 3/2008 Mudd et al.
2008/0101757 A1 5/2008 Lin et al.
2008/0226237 A1 9/2008 O'Riorden et al.
2008/0267566 A1 10/2008 En Lin
2009/0028507 A1 1/2009 Jones et al.
2009/0047818 A1 2/2009 Irwin et al.
2009/0092360 A1 4/2009 Lin et al.
2009/0176401 A1 7/2009 Gu
2009/0196555 A1 8/2009 Lin et al.
2009/0214162 A1 8/2009 O'Riorden et al.
2009/0220197 A1 9/2009 Gniadek
2009/0220200 A1 9/2009 Wong et al.
2009/0222457 A1 9/2009 Gallant
2009/0290839 A1 11/2009 En Lin
2009/0290938 A1 11/2009 Asaoka
2010/0034502 A1 2/2010 Lu et al.
2010/0054668 A1 3/2010 Nelson
2010/0061069 A1 3/2010 Cole
2010/0092136 A1 4/2010 Nhep
2010/0220961 A1 9/2010 de Jong et al.
2010/0247041 A1 9/2010 Szilagyi
2010/0284656 A1 11/2010 Morra
2010/0322561 A1 12/2010 Lin et al.
2011/0044588 A1 2/2011 Larson et al.
2011/0058773 A1 3/2011 Peterhans
2011/0131801 A1 6/2011 Nelson et al.
2011/0155810 A1 6/2011 Taniguichi
2011/0177710 A1 7/2011 Tobey
2011/0239220 A1 9/2011 Gibson
2012/0099822 A1 4/2012 Kuffel et al.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2012/0155810	A1	6/2012	Nakagawa
2012/0189260	A1	7/2012	Kowalczyk et al.
2012/0237177	A1	9/2012	Minota
2012/0269485	A1	10/2012	Haley et al.
2012/0301080	A1	11/2012	Gniadek
2012/0308183	A1	12/2012	Irwin
2012/0328248	A1	12/2012	Larson
2013/0019423	A1	1/2013	Srutkowski
2013/0071067	A1	3/2013	Lin
2013/0089995	A1	4/2013	Gniadek et al.
2013/0094816	A1	4/2013	Lin et al.
2013/0101258	A1	4/2013	Hikosaka
2013/0121653	A1	5/2013	Shitama et al.
2013/0170797	A1	7/2013	Ott
2013/0183012	A1	7/2013	Lopez et al.
2013/0216185	A1	8/2013	Klavuhn
2013/0259429	A1	10/2013	Czosnowski et al.
2013/0308915	A1	11/2013	Buff
2013/0322825	A1	12/2013	Cooke et al.
2014/0016901	A1	1/2014	Lamboum et al.
2014/0023322	A1	1/2014	Gniadek
2014/0050446	A1	2/2014	Chang
2014/0056562	A1	2/2014	Limbert
2014/0133808	A1	5/2014	Hill et al.
2014/0169727	A1	6/2014	Veatch et al.
2014/0219621	A1	8/2014	Barnette, Jr. et al.
2014/0226946	A1	8/2014	Cooke et al.
2014/0241644	A1	8/2014	Kang
2014/0241678	A1	8/2014	Bringuier et al.
2014/0241688	A1	8/2014	Isenhour et al.
2014/0334780	A1	11/2014	Nguyen et al.
2014/0348477	A1	11/2014	Chang
2015/0003788	A1	1/2015	Chen
2015/0111417	A1	4/2015	Vanderwoud
2015/0177463	A1	6/2015	Lee
2015/0198766	A1	7/2015	Takahashi
2015/0212282	A1	7/2015	Lin
2015/0241644	A1	8/2015	Lee
2015/0301294	A1	10/2015	Chang et al.
2015/0331201	A1	11/2015	Takano et al.
2015/0355417	A1	12/2015	Takano et al.
2015/0370021	A1	12/2015	Chan
2015/0378113	A1	12/2015	Good et al.
2016/0131849	A1	5/2016	Takano et al.
2016/0139343	A1	5/2016	Dean, Jr. et al.
2016/0161681	A1	6/2016	Banal, Jr. et al.
2016/0172852	A1	6/2016	Tamura
2016/0178852	A1	6/2016	Takano
2016/0195682	A1	7/2016	Takano
2016/0291262	A1	6/2016	Chang et al.
2016/0231512	A1	8/2016	Seki
2016/0259135	A1	9/2016	Gniadek et al.
2016/0266326	A1	9/2016	Gniadek
2016/0320572	A1	11/2016	Gniadek
2016/0349458	A1	12/2016	Murray
2016/0370545	A1	12/2016	Jiang
2017/0003458	A1	1/2017	Gniadek
2017/0205587	A1	7/2017	Chang et al.
2017/0205590	A1	7/2017	Bailey
2017/0205591	A1	7/2017	Takano et al.
2017/0212313	A1	7/2017	Elenabaas
2017/0212316	A1	7/2017	Takano
2017/0254961	A1	9/2017	Kamada et al.
2017/0276275	A1	9/2017	Beemer et al.
2017/0276887	A1	9/2017	Allen
2017/0277059	A1	9/2017	Miura et al.
2017/0343740	A1	11/2017	Nguyen
2018/0128988	A1	5/2018	Chang
2018/0156988	A1	6/2018	Gniadek
2018/0172923	A1	6/2018	Bauco
2018/0252872	A1	9/2018	Chen
2018/0341069	A1	11/2018	Takano
2019/0064447	A1	2/2019	Chang et al.
2019/0204513	A1	7/2019	Davidson et al.

FOREIGN PATENT DOCUMENTS

CN	2836038	Y	11/2006
CN	2836038	Y	11/2006
CN	201383588	Y	1/2010
CN	201383588	Y	1/2010
CN	2026500189	U	12/2013
DE	19507669	A1	9/1996
DE	202006011910	U1	3/2007
DE	102006019335	U1	10/2007
EP	1074868	A1	2/2001
EP	1074868	A1	7/2001
EP	1211537	A2	6/2002
EP	1211537	A3	6/2002
EP	1245980	A1	10/2002
EP	1566674	A2	8/2005
GB	2111240	A	6/1983
JP	2000089059	A	3/2000
JP	03752331	B2	3/2006
JP	2009229545	A	10/2009
JP	2009276493	A	11/2009
JP	04377820	B2	12/2009
JP	2011027876	A	2/2011
JP	2012053375	A	3/2012
KR	20040028409	A	4/2006
KR	2009005382	A	1/2009
KR	200905382	U	6/2009
KR	1371686	B1	3/2014
TW	200821653	A	5/2008
WO	200179904	A2	10/2001
WO	WO2001079904	A2	10/2001
WO	2004027485	A1	4/2004
WO	WO2006007120	A1	1/2006
WO	2008112986	A1	9/2008
WO	2009135787	A1	11/2009
WO	2010024851	A2	3/2010
WO	2012136702	A1	10/2012
WO	2012162385	A1	11/2012
WO	WO2012162385	A1	11/2012
WO	2014028527	A1	2/2014
WO	2014182351	A1	11/2014
WO	WO2015103783	A1	7/2015
WO	2015191024	A1	12/2015
WO	2016019993	A1	2/2016
WO	2016148741	A1	9/2016
WO	WO2017/127308	A1	7/2017
WO	WO2019126333	A1	6/2019

OTHER PUBLICATIONS

International Search Report and Written Opinion, Application No. PCT/US2019/013861, dated Apr. 8, 2019, pp. 15.

Fiber Optic Connectors Tutorial, 2018, pp. 20.

Fiber Optic Glossary, Feb. 29, 2016, pp. 93.

"Fiber Optic Interconnect Solutions, Tactical Fiber Optical Connectors, Cables and Termini" 2006, Glenair, Inc., Glendale, California, www.mps-electronics.de, pp. 232.

"Fiber Optic Products Catalog" Nov. 2007, Tyco Electronics Corporation, Harrisburg, Pennsylvania, www.ampnetconnect.com, pp. 204.

"Fiber Optic Connectors and Assemblies Catalog" 2009, Huber & Suhner Fiver Optics, Herisau, Switzerland, www.hubersuhner.com, pp. 104.

PCT/US2018/062406 International Search Report dated Mar. 18, 2019.

PCT/US2018/062406 The written Opinion dated Mar. 18, 2019.

PCT/US2018/062405 International Search Report dated Apr. 3, 2019.

PCT/US2018/062405 The written Opinion dated Apr. 3, 2019.

PCT/IB2018/056133 Written Opinion dated Jan. 3, 2019.

PCY/IB/056133 Search Report dated Jan. 3, 2019.

Final Office Action, U.S. Appl. No. 16/035,691, dated Feb. 11, 2019, pp. 8.

Non-Final Office Action, U.S. Appl. No. 16/035,695, dated Sep. 28, 2018, pp. 7.

(56) **References Cited**

OTHER PUBLICATIONS

International Search Report and Written Opinion, Application No. PCT/US/2018/042202, pp. 17, dated Dec. 7, 2018.
International Search Report and Written Opinion, Application No. PCT/US19/24718, dated Jun. 26, 2019, pp. 7.
ISR for PCT/US2019/013861, Apr. 8, 2019, 3 pages.
WO for PCT/US2019/013861, Apr. 8, 2019, 11 pages.
International Search Report and Written Opinion for Application No. PCT/US2018/62406 dated Mar. 18, 2019, 12, pages, United States.
International Search Report and Written Opinion for Application No. PCT/US2019/40700 dated Sep. 27, 2019, 12, pages, United States.
International Search Report and Written Opinion for Application No. PCT/US2019/50895 dated Jan. 6, 2020, 12, pages, United States.
International Search Report and Written Opinion for Application No. PCT/US2019/50909 dated Dec. 17, 2019, 11, pages, United States.
International Search Report and Written Opinion for Application No. PCT/US2019/56564 dated Jan. 14, 2020, 14, pages, United States.
International Search Report and Written Opinion, Application No. PCT/US19/46397, dated Nov. 12, 2019, pp. 6.
International Search Report; PCT/US2018/042202 filed Jul. 16, 2018; Applicant: Senko Advanced Components, Inc.
International Preliminary Report on Patentability for PCT/US2019/022940 dated Oct. 1, 2020, 11 pages.
Extended European Search Report and Written Opinion, Application No. 18832246.5, dated Mar. 15, 2021, pp. 6.
Photograph 1 of MXC Connector, US Conec, at least as early as Aug. 18, 2016, 1 page.
Photographs 2-4 of MXC Connector and Adapter, US Conec, publication date unknown, 2 pages.

* cited by examiner

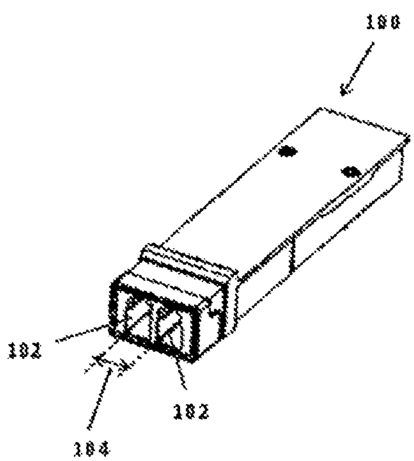


FIG. 1A
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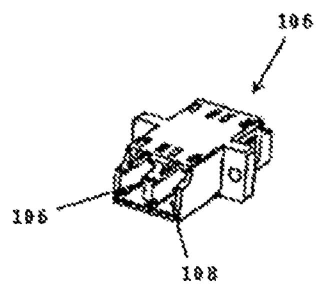

FIG. 1B
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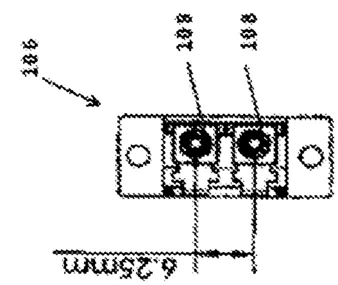

FIG. 1D
(Prior Art)

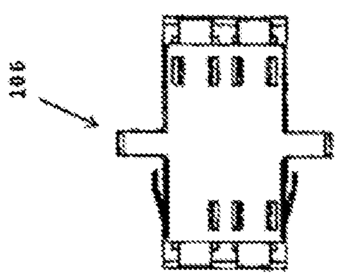

FIG. 1C
(Prior Art)

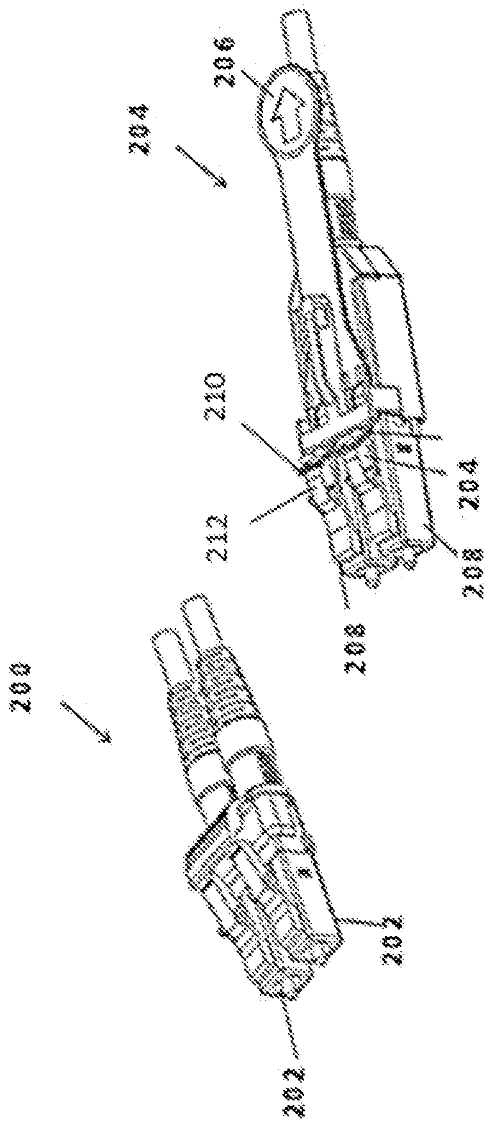

FIG. 2B
(Prior Art)

FIG. 2A
(Prior Art)

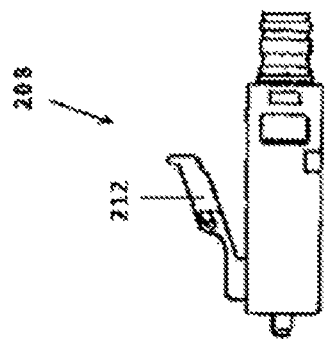

FIG. 2D
(Prior Art)

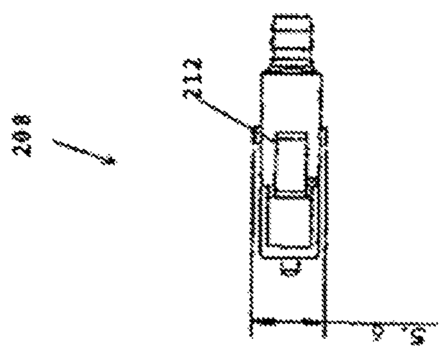

FIG. 2C
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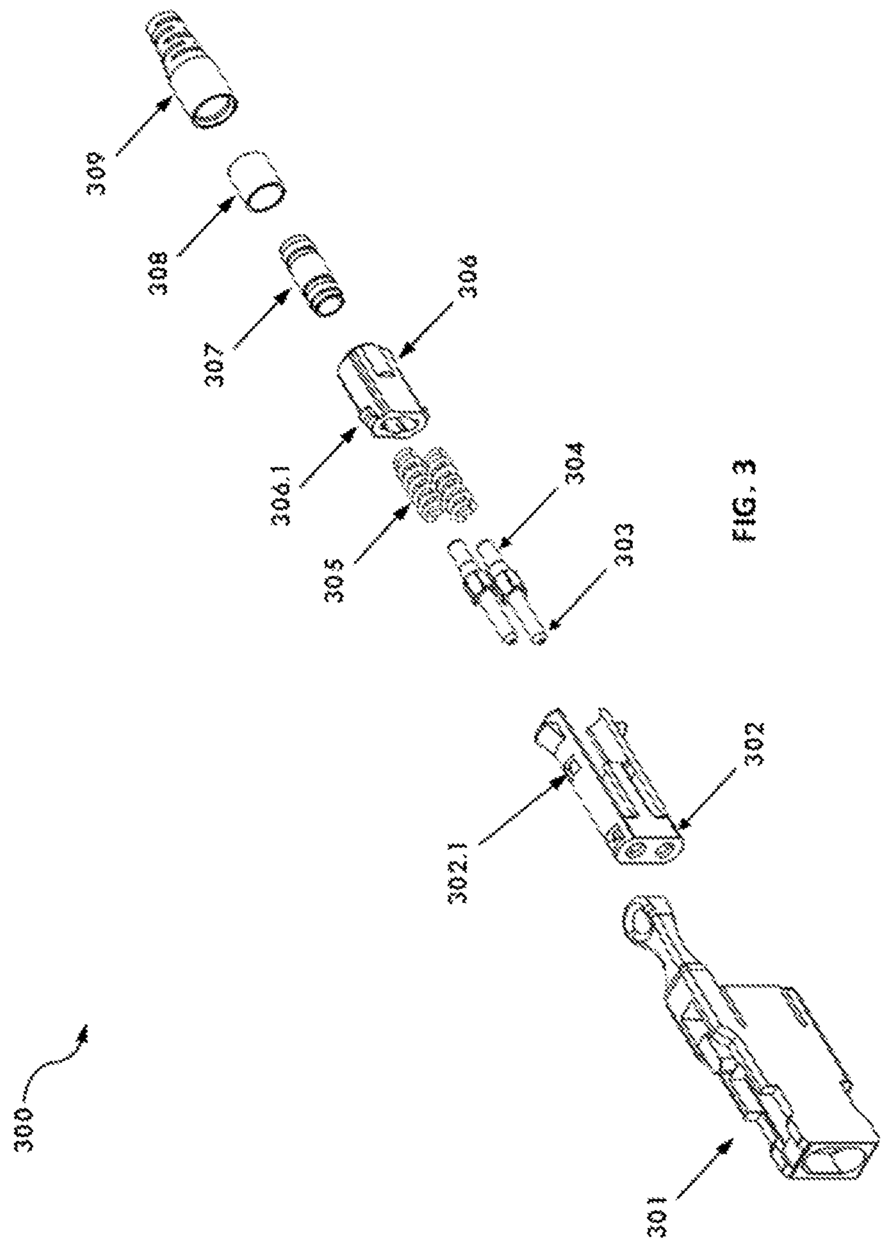

FIG. 3

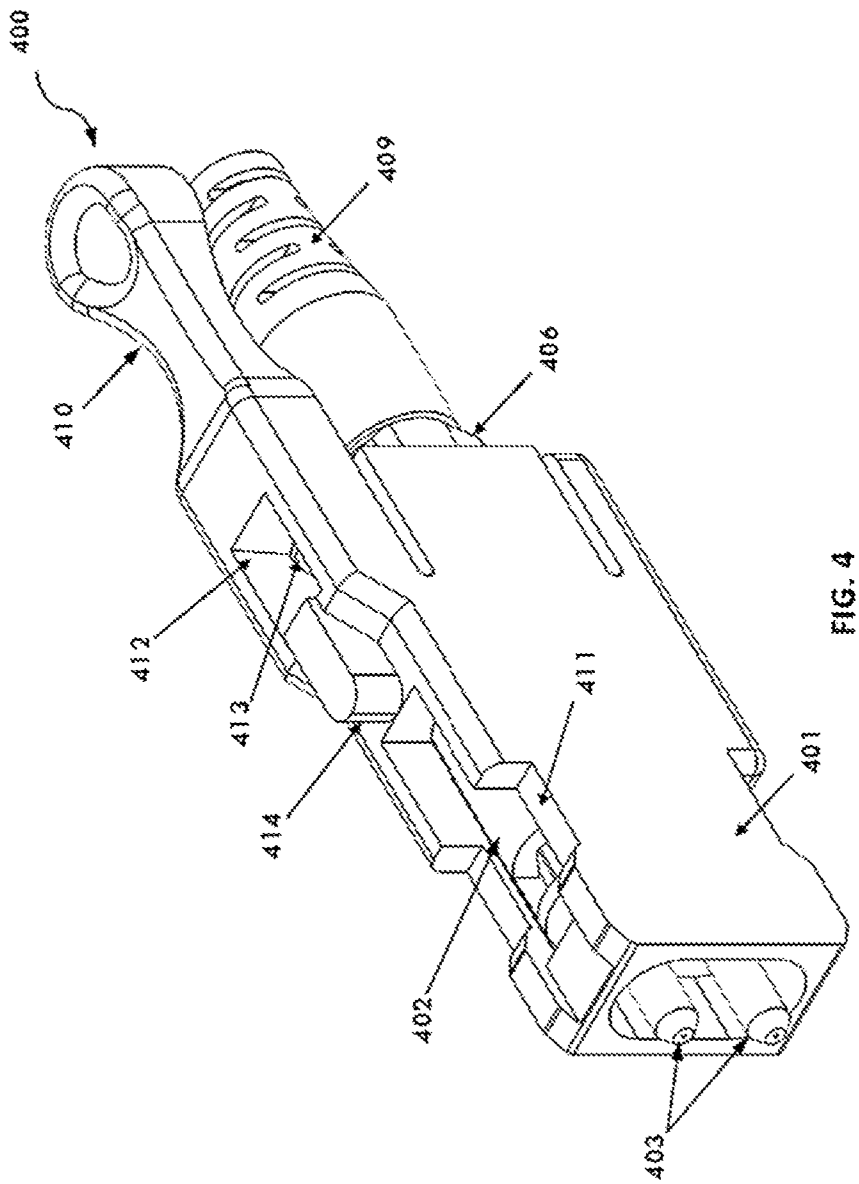

FIG. 4

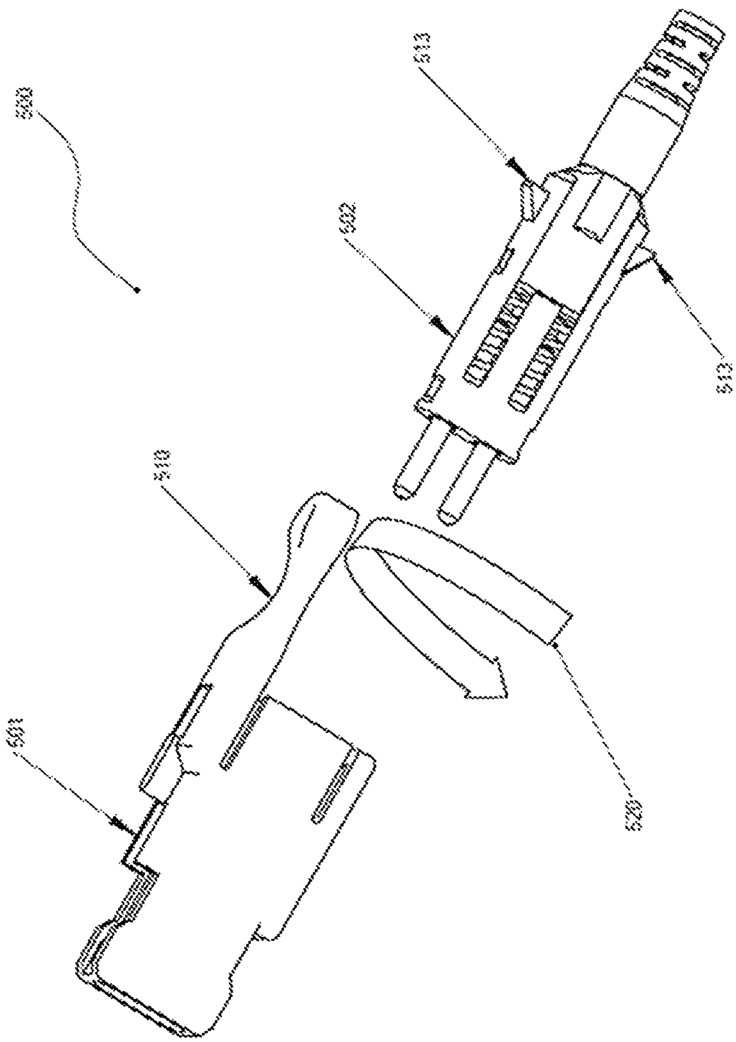

FIG. 5

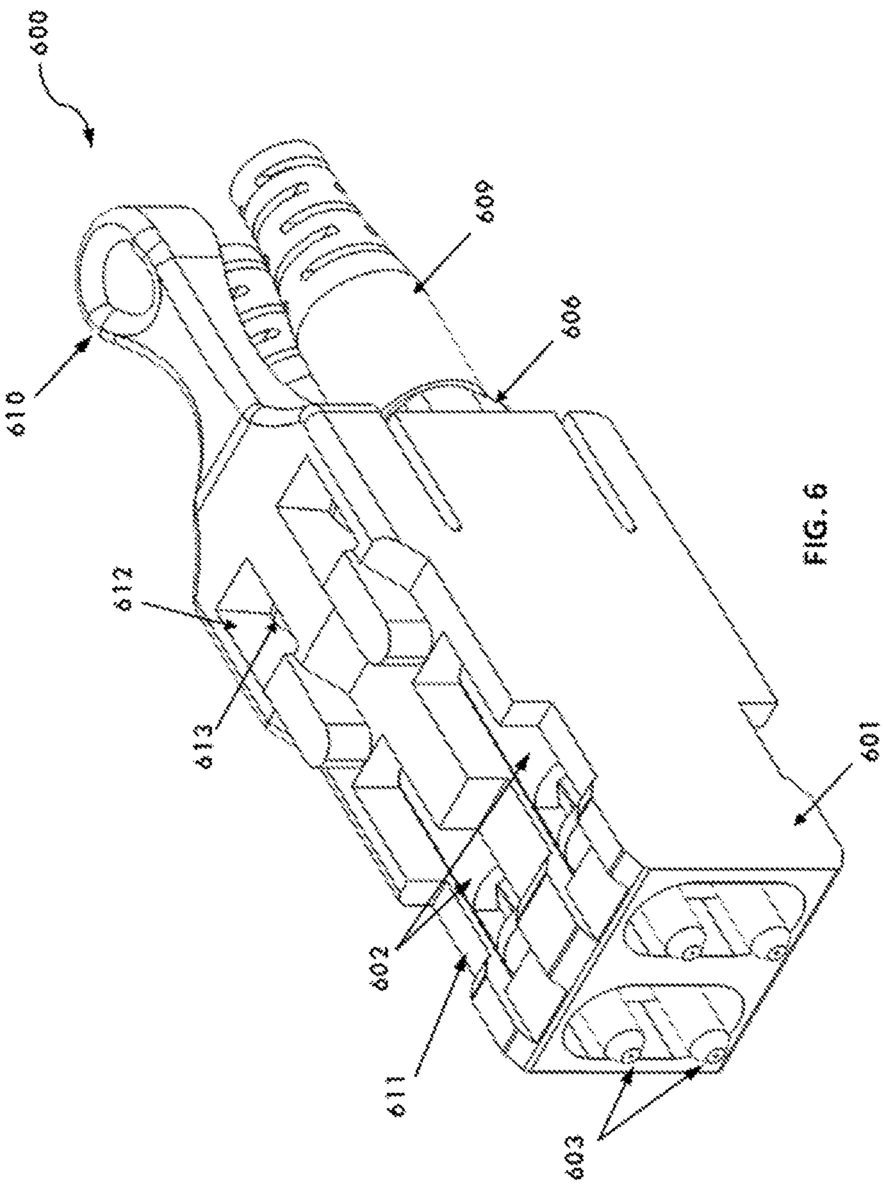

FIG. 6

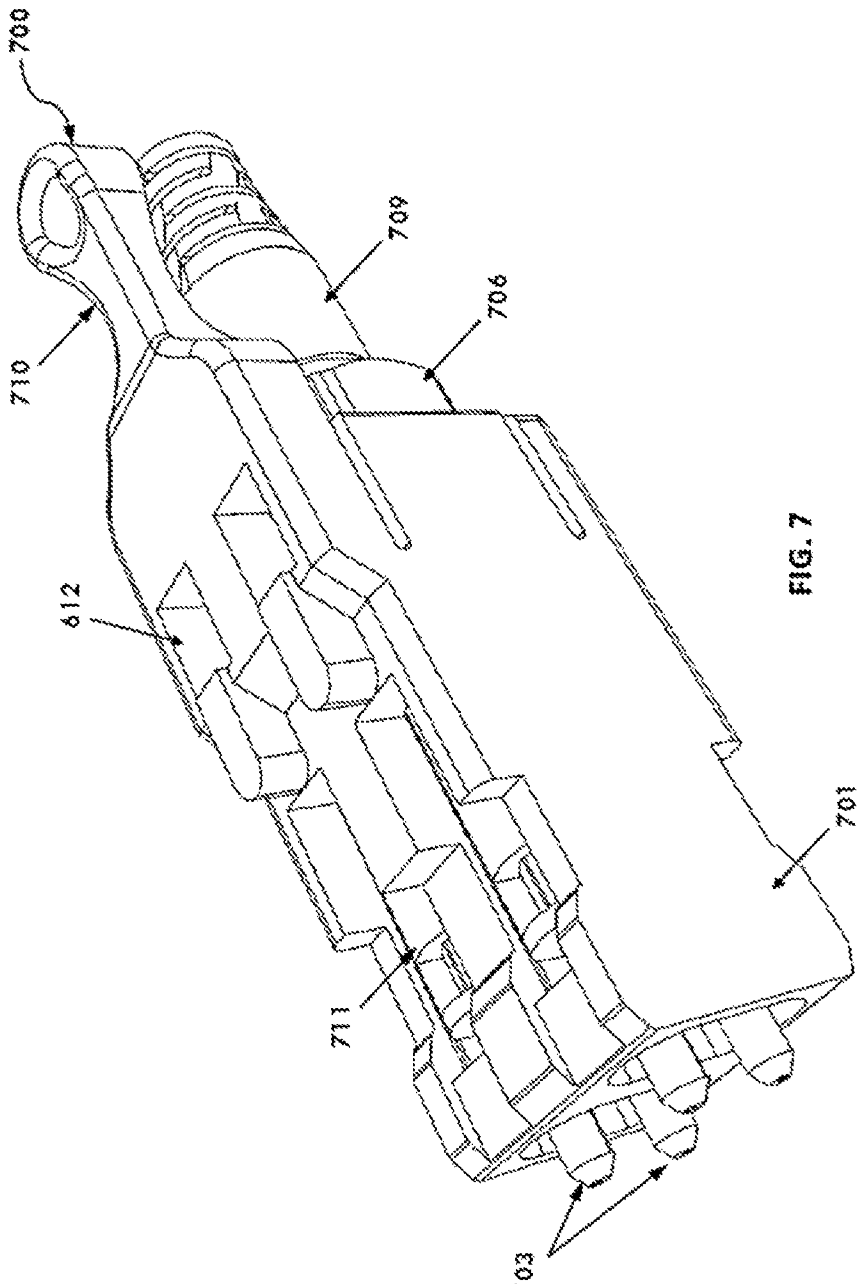

FIG. 7

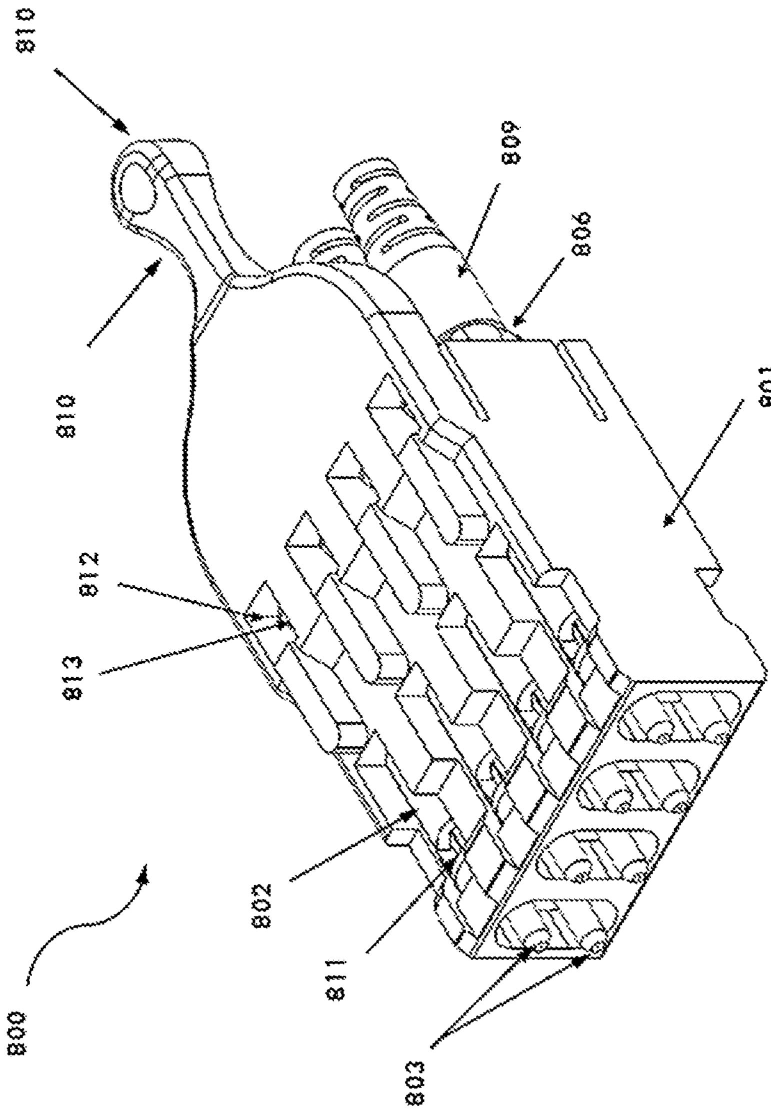

FIG. 8

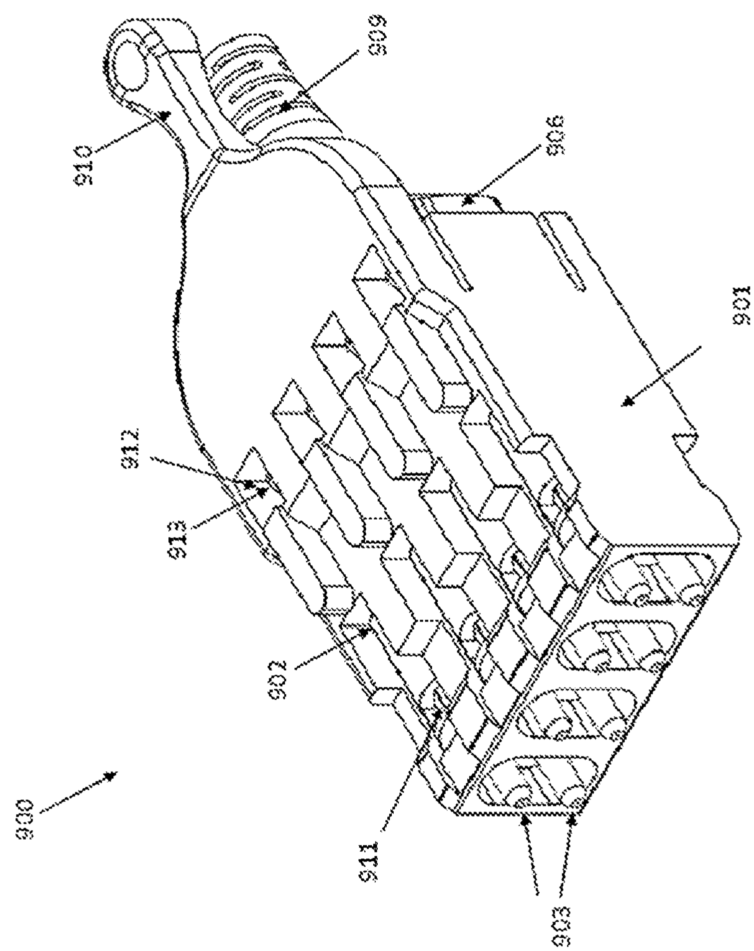

FIG. 9

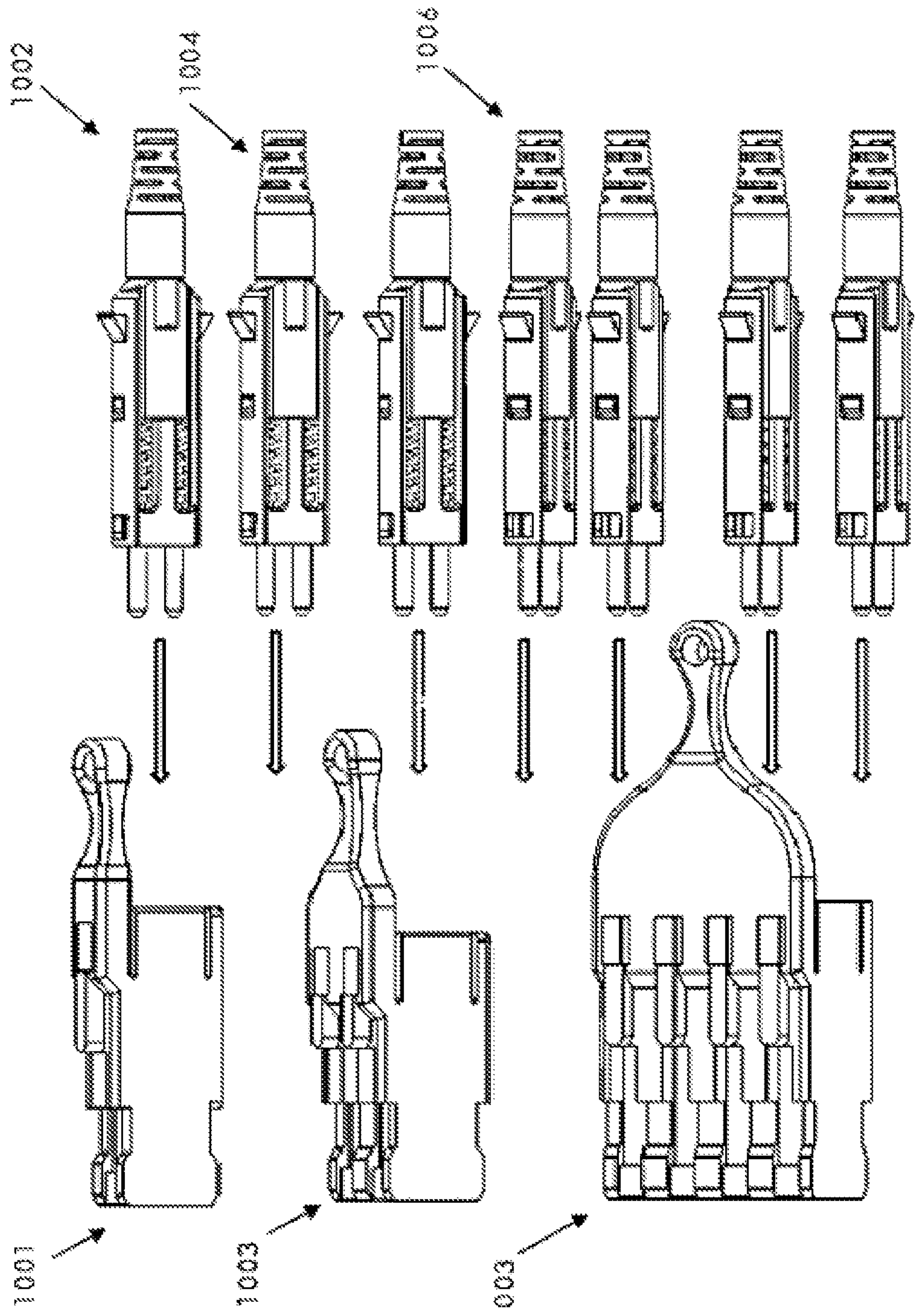

FIG. 10

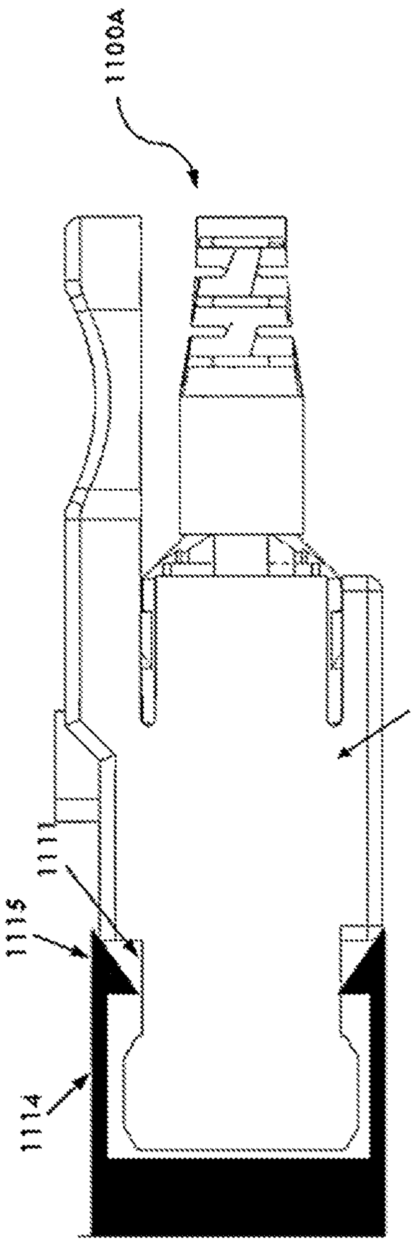

FIG. 11A

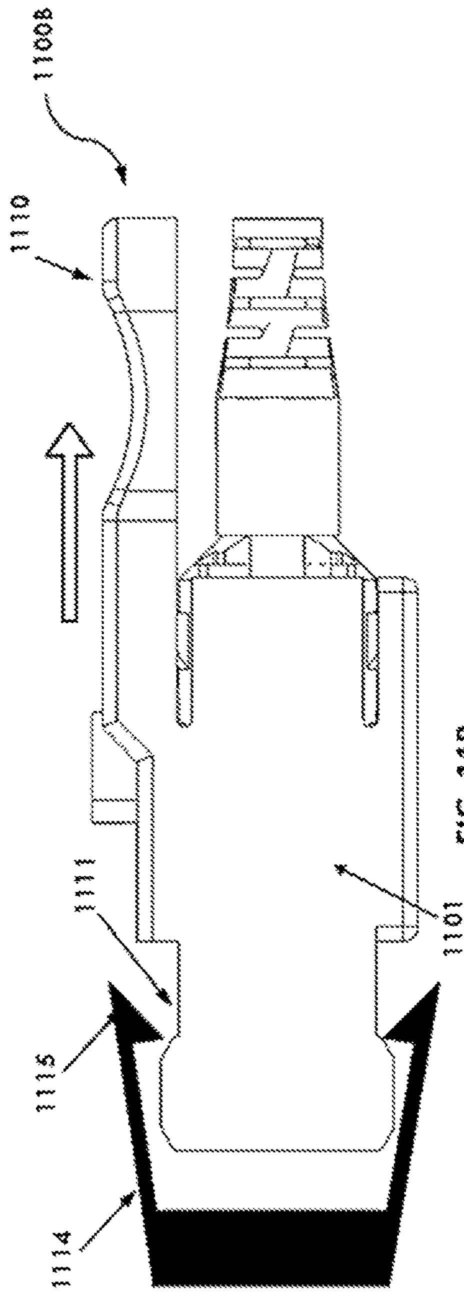

FIG. 11B

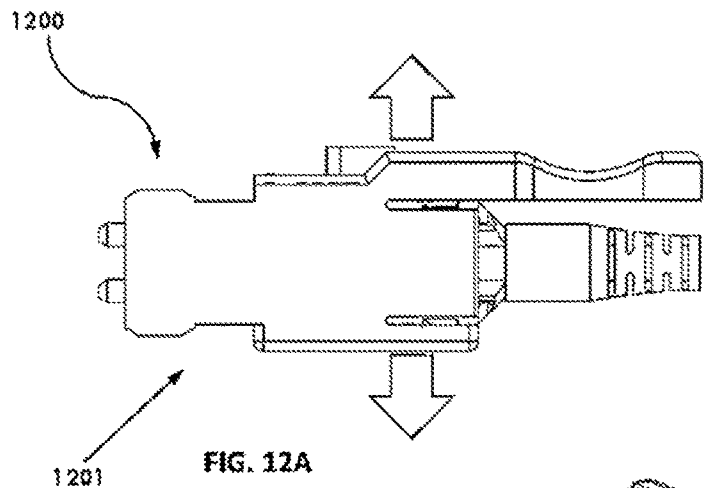

FIG. 12A

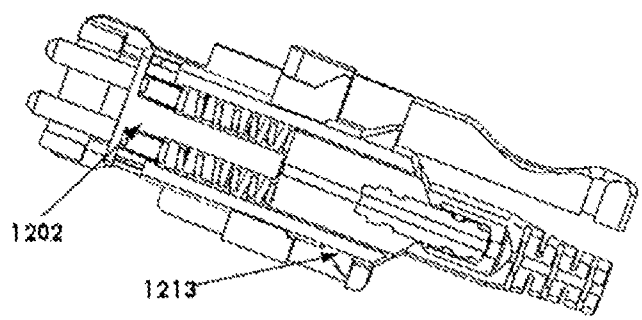

FIG. 12B

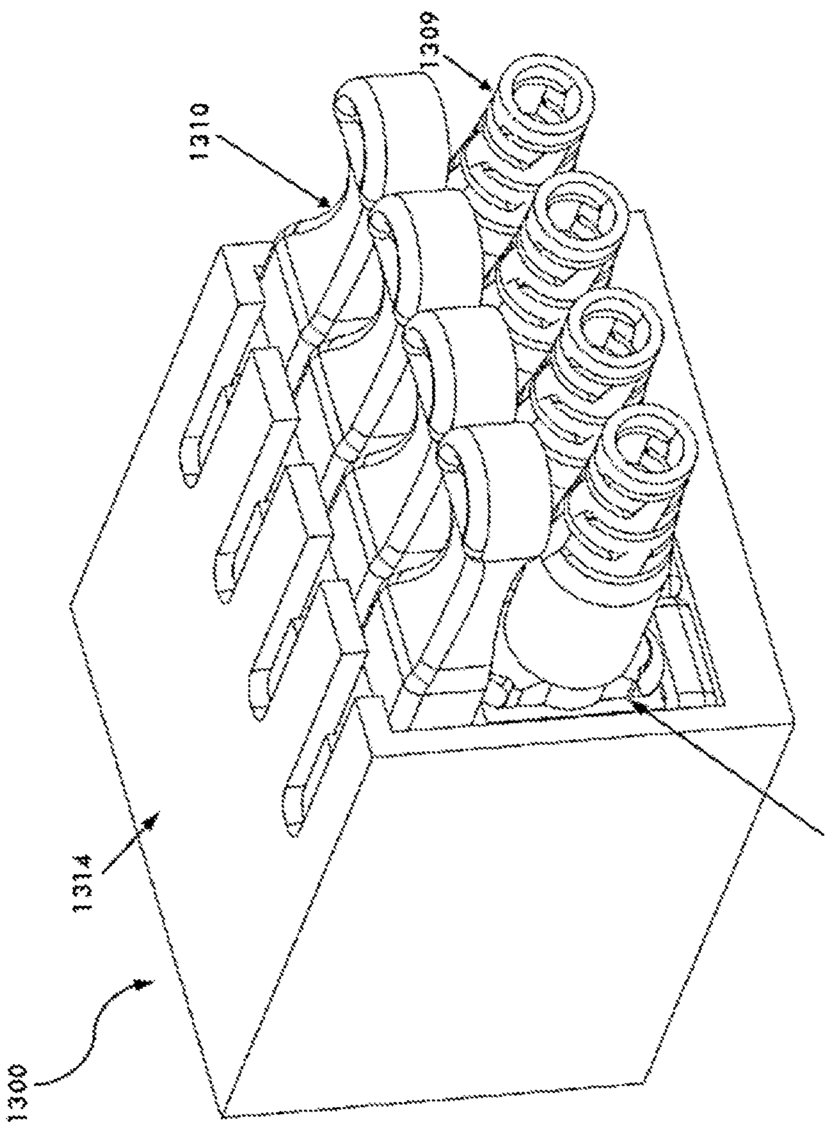

FIG. 13

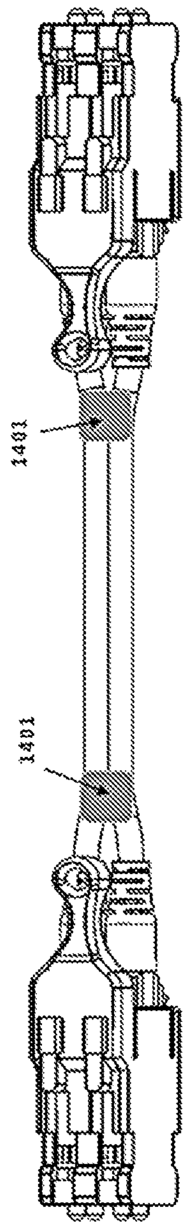

FIG. 14A

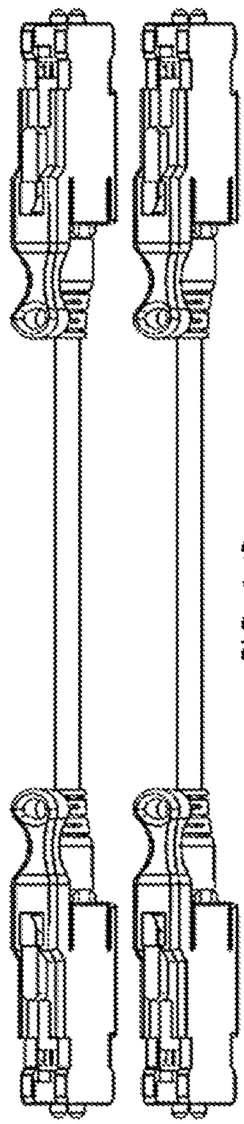

FIG. 14B

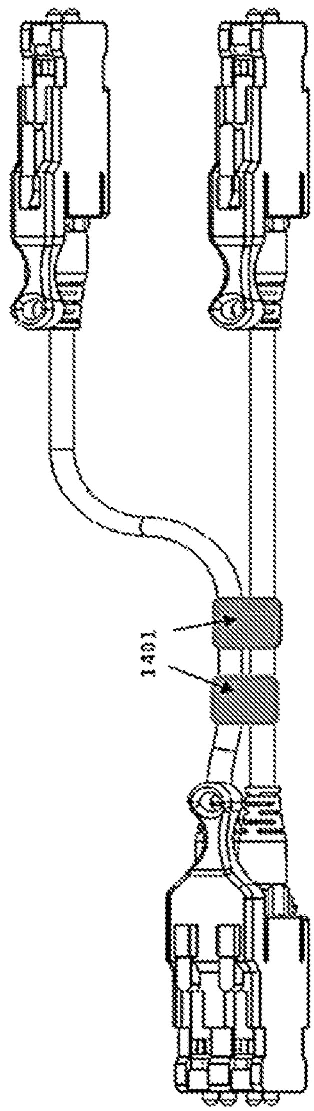

FIG. 14C

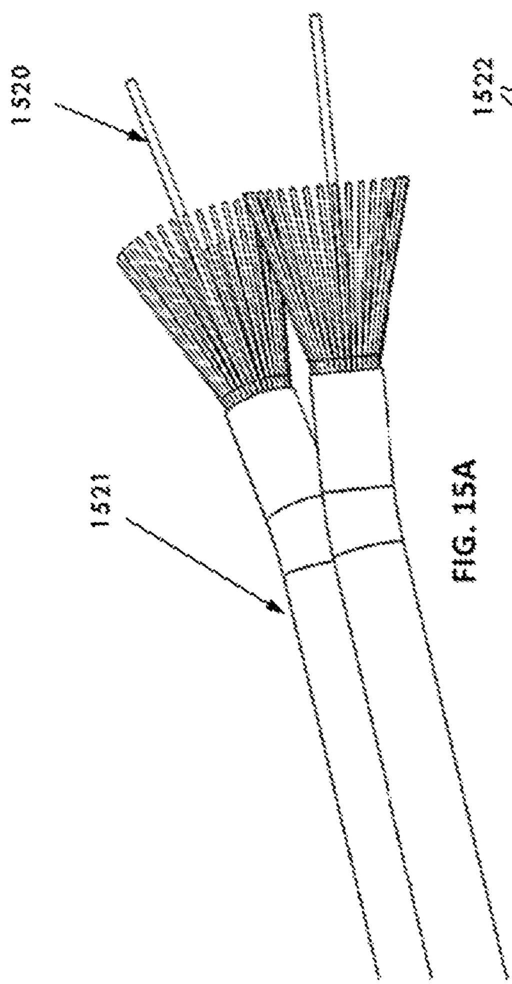

FIG. 15A

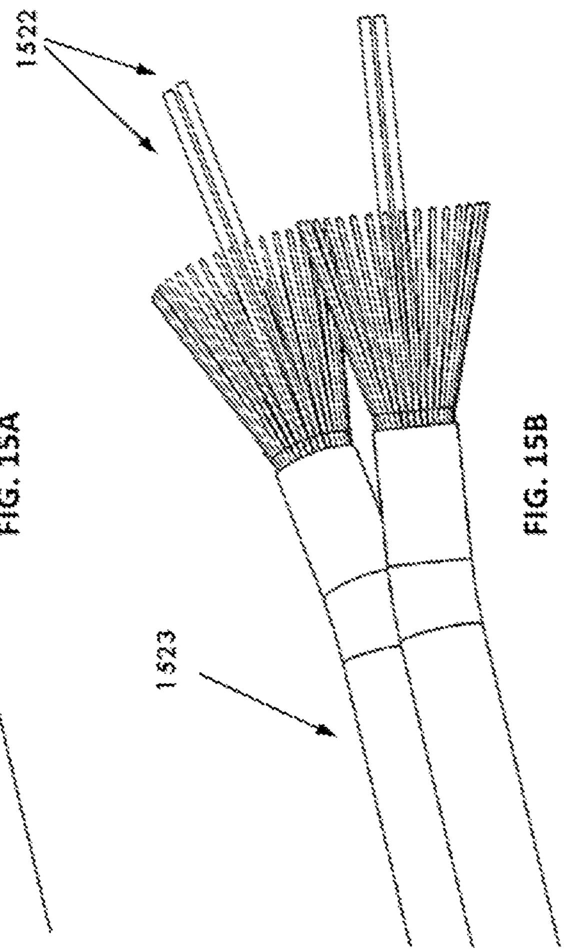

FIG. 15B

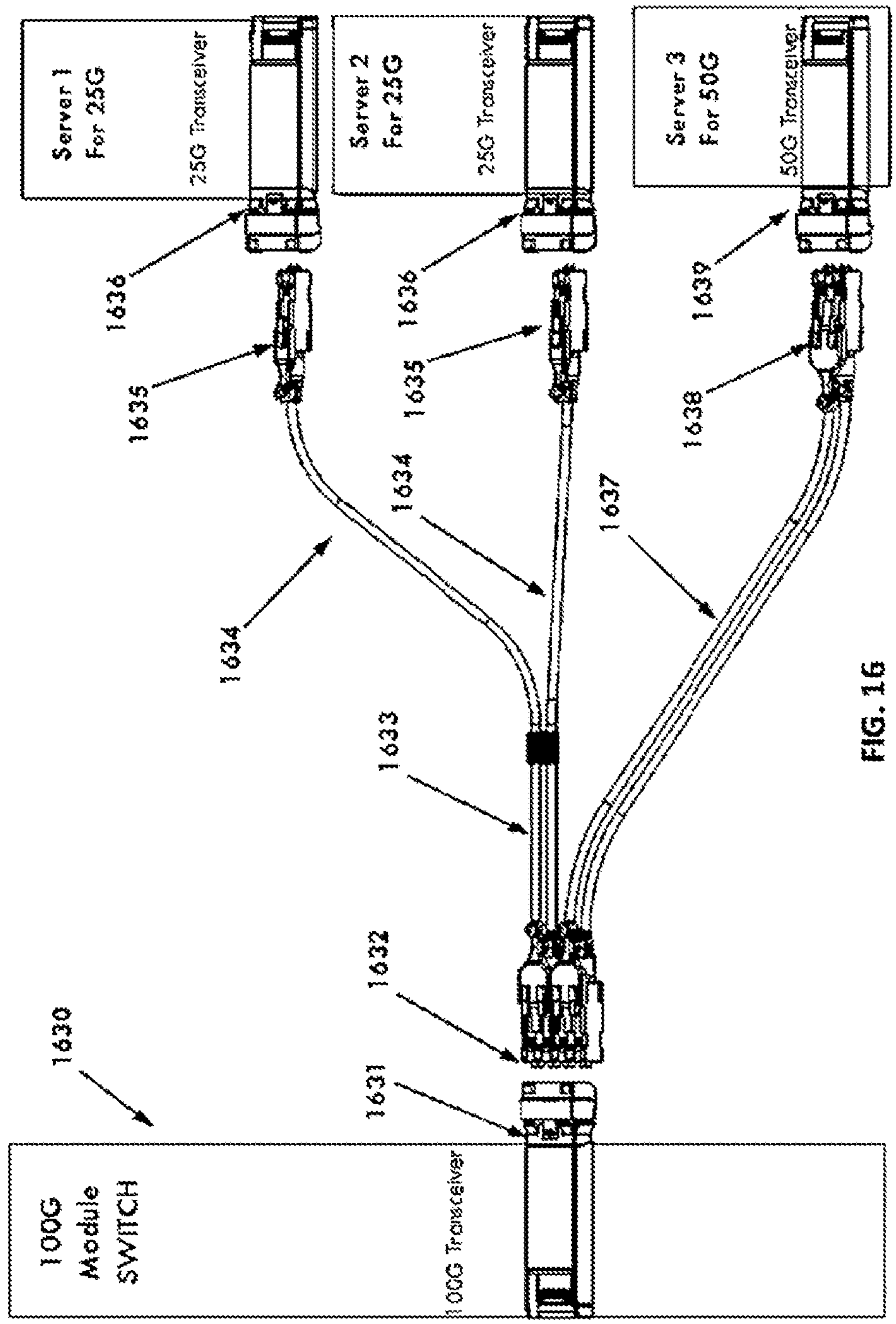
Server 1
For 25G
25G Transceiver
Server 2
For 25G
25G Transceiver
Server 3
For 50G
50G Transceiver
100G
Module
SWITCH
100G Transceiver
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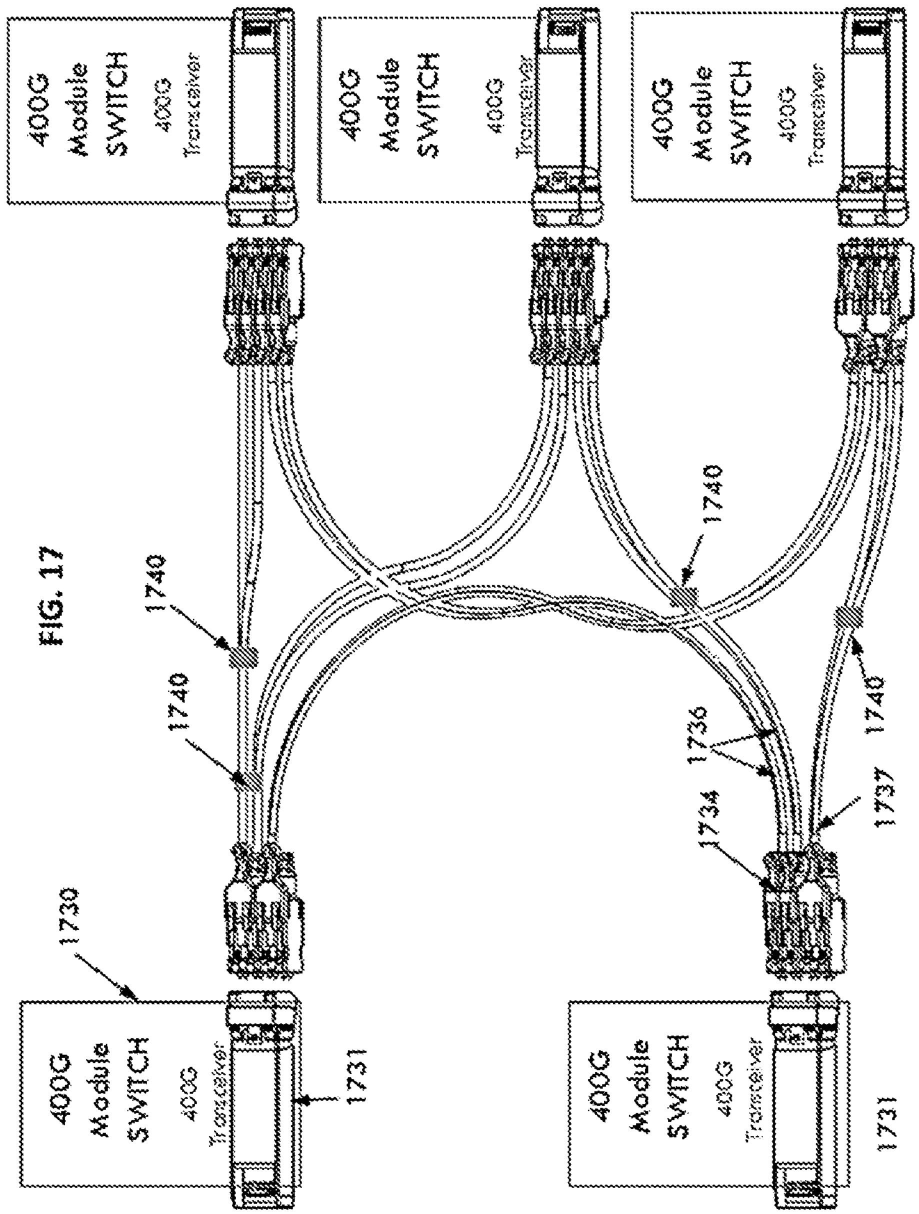
FIG. 16


400G Module SWITCH
400G Transceiver
400G Module SWITCH
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400G Module SWITCH
400G Transceiver
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400G Transceiver
400G Module SWITCH
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FIG. 17

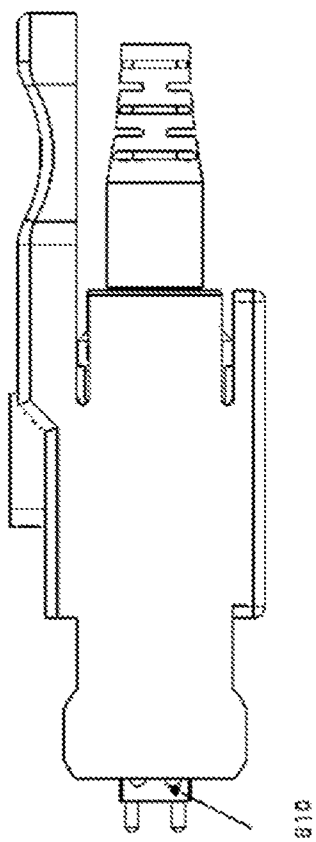

FIG. 18A

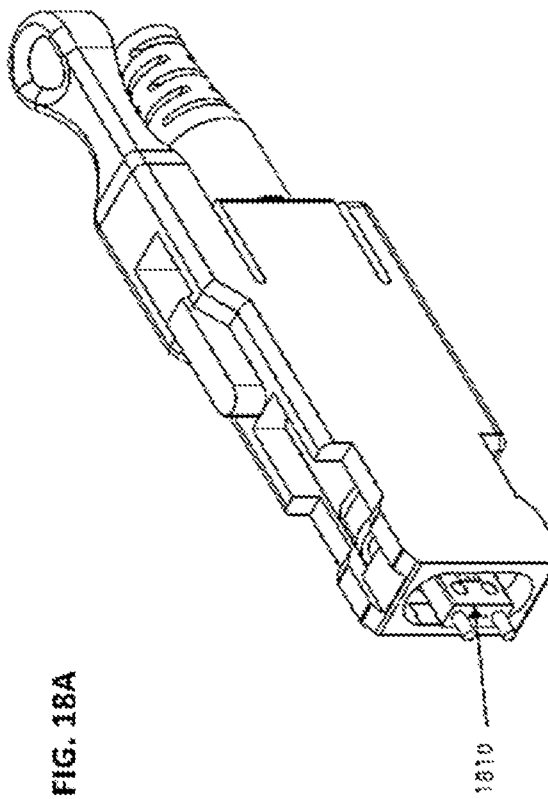

FIG. 18B

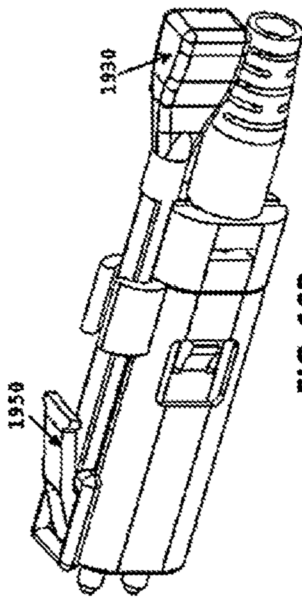

FIG. 19B

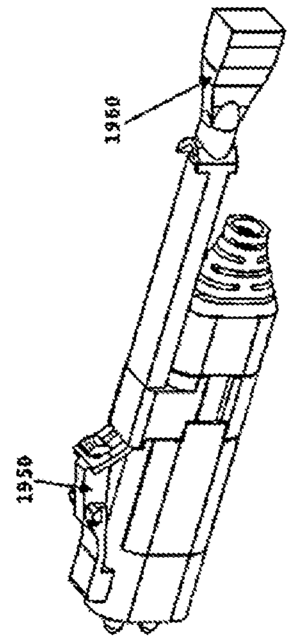

FIG. 19D

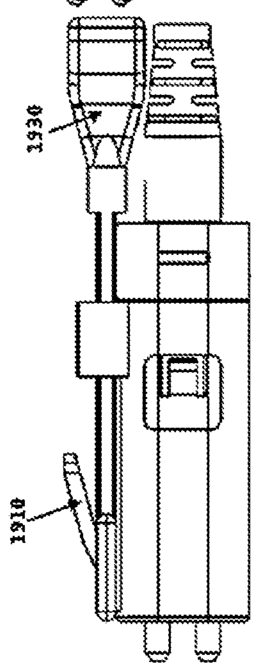

FIG. 19A

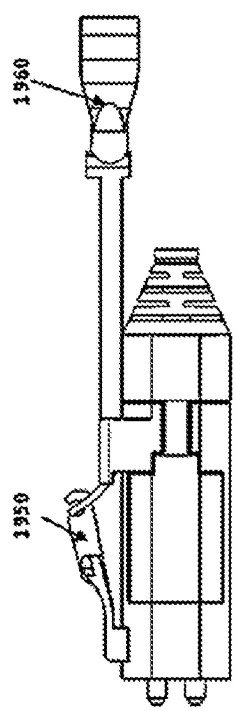

FIG. 19C

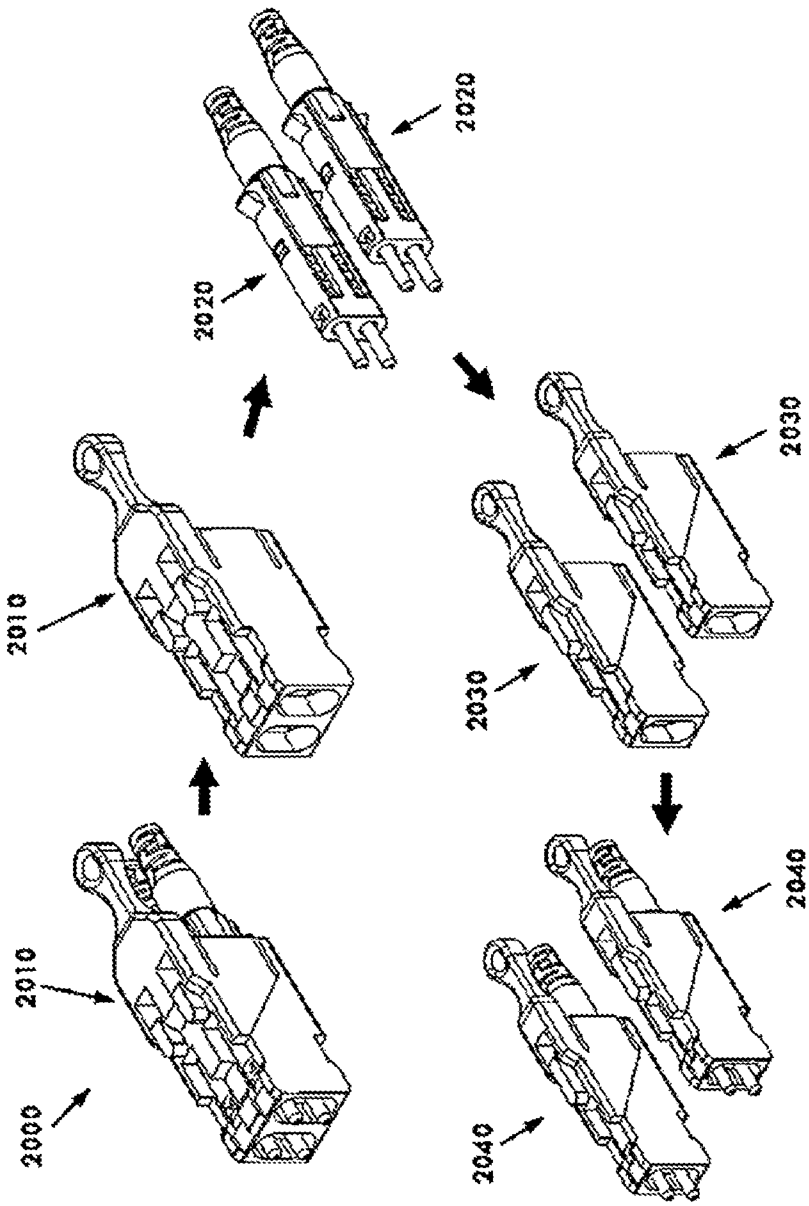

FIG. 20

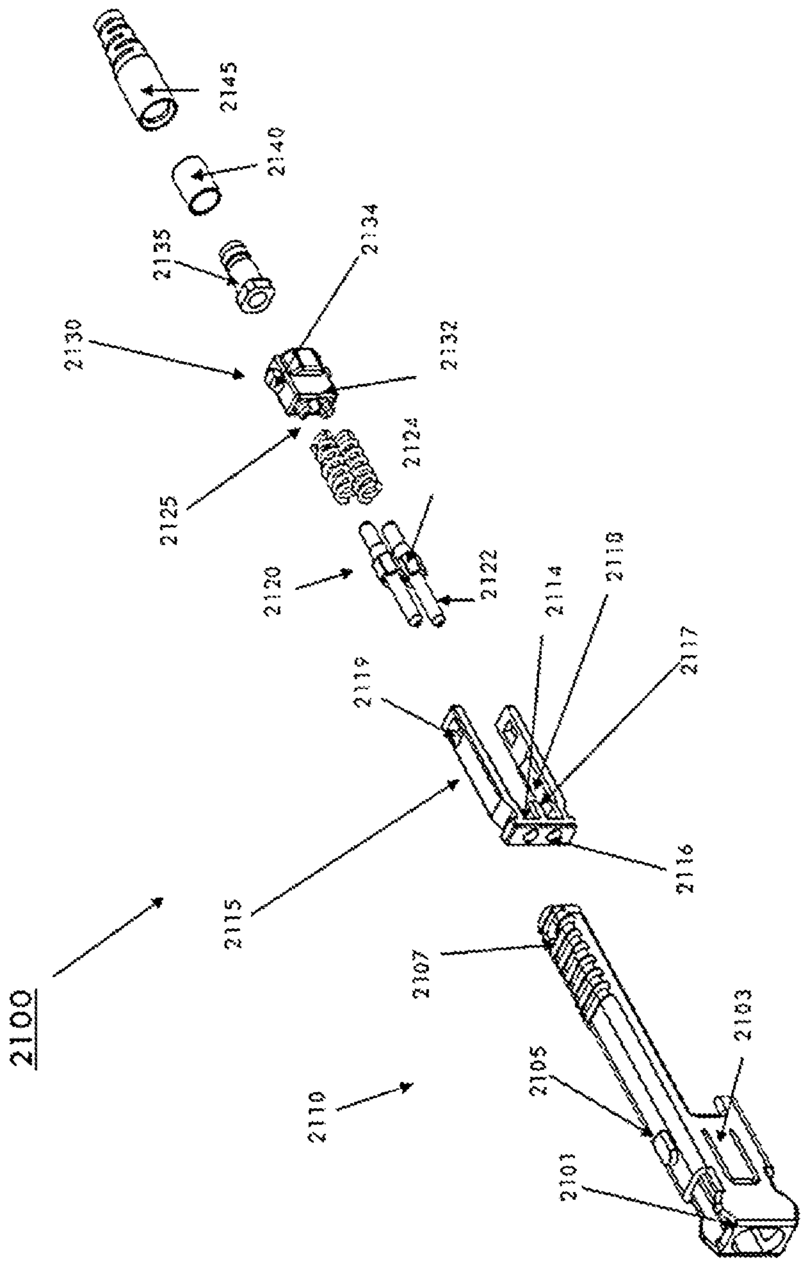
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FIG. 21A

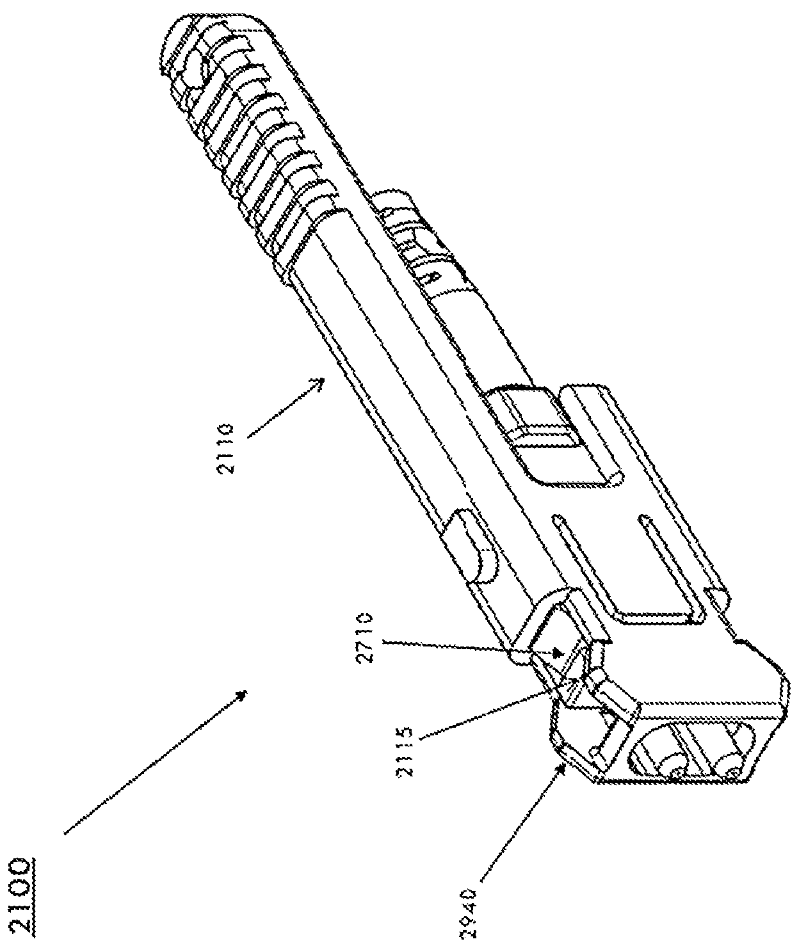

FIG. 21B

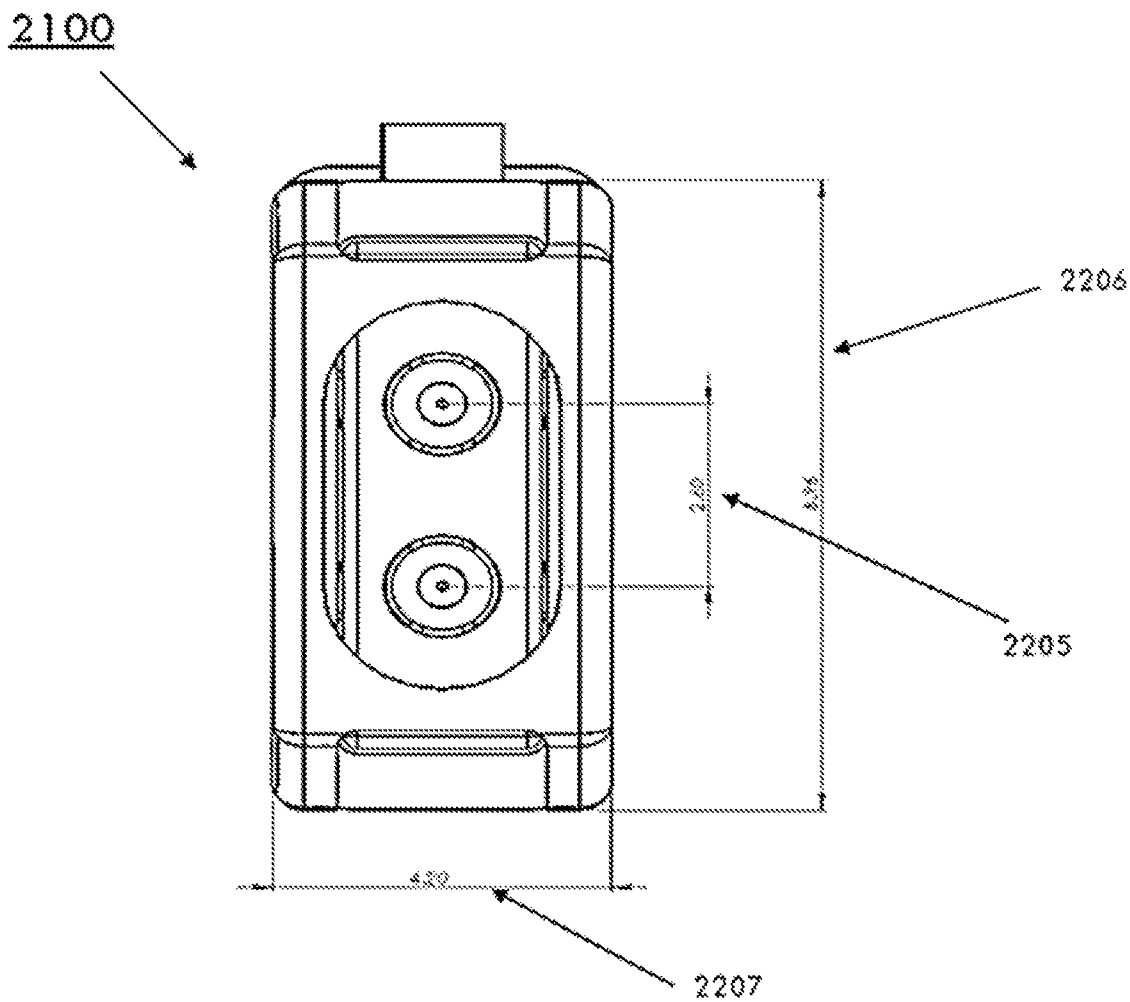

FIG. 22

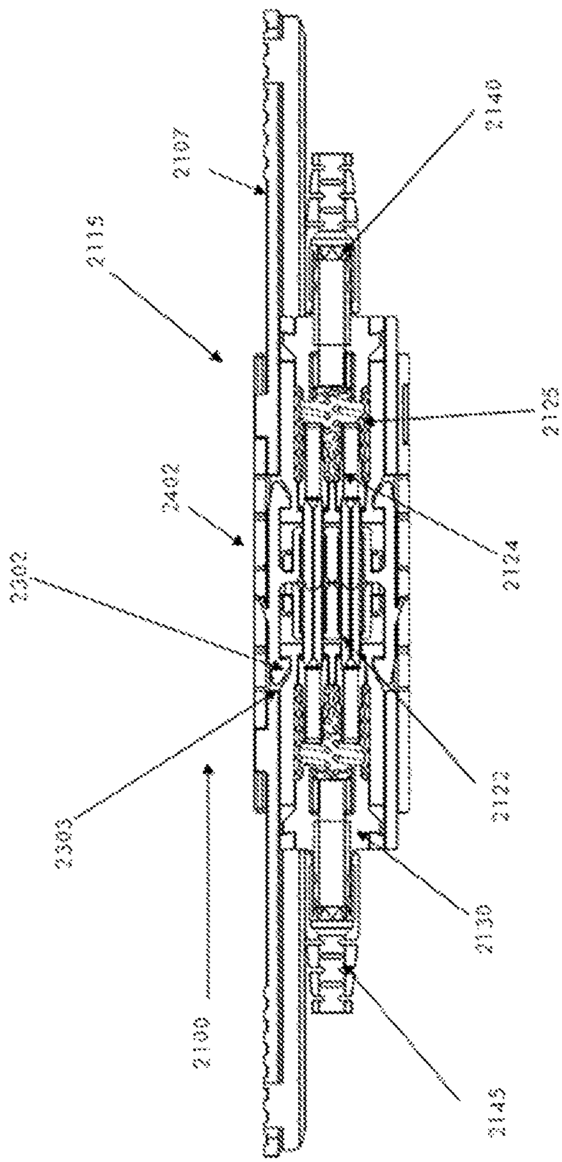

FIG. 23A

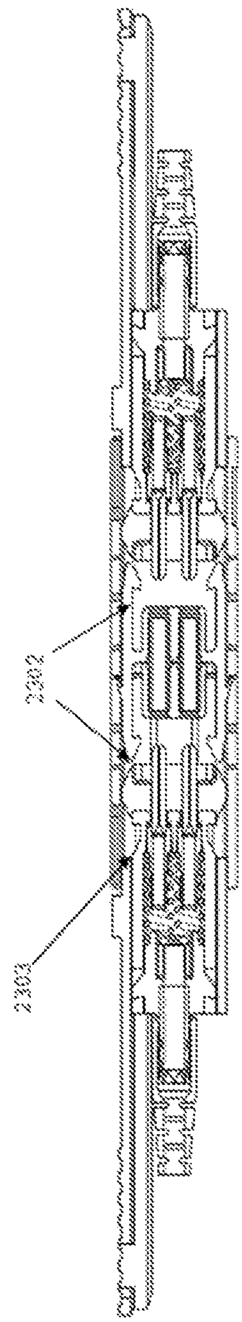

FIG. 23B

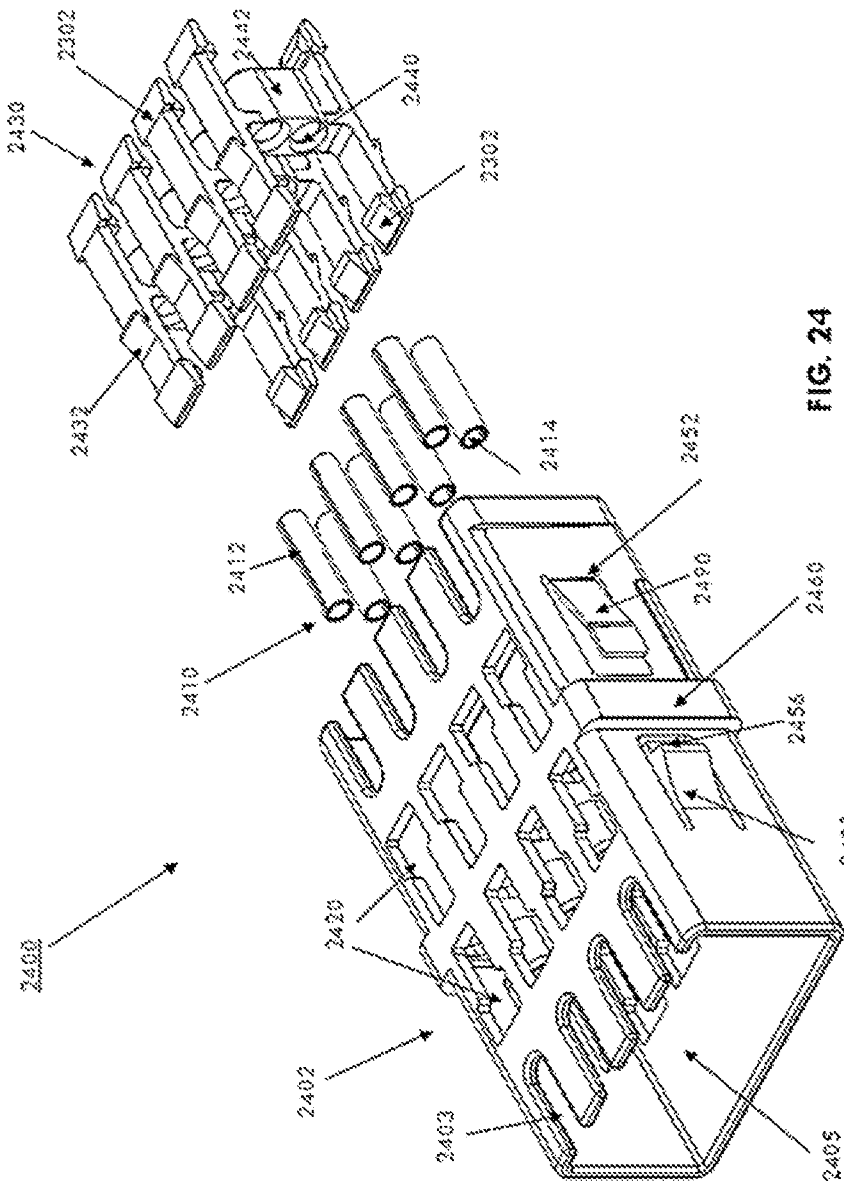
2302
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FIG. 24

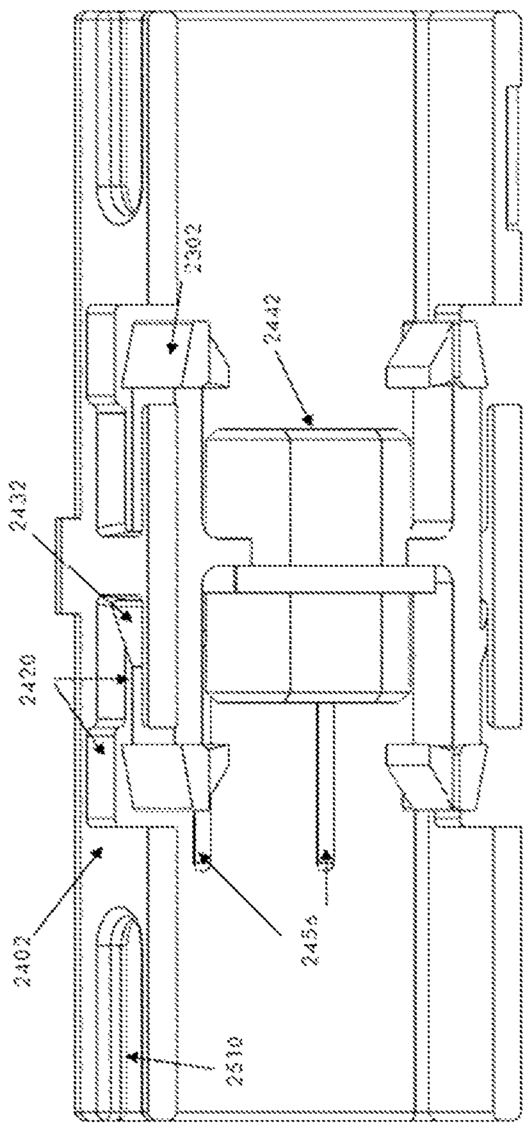

FIG. 25A

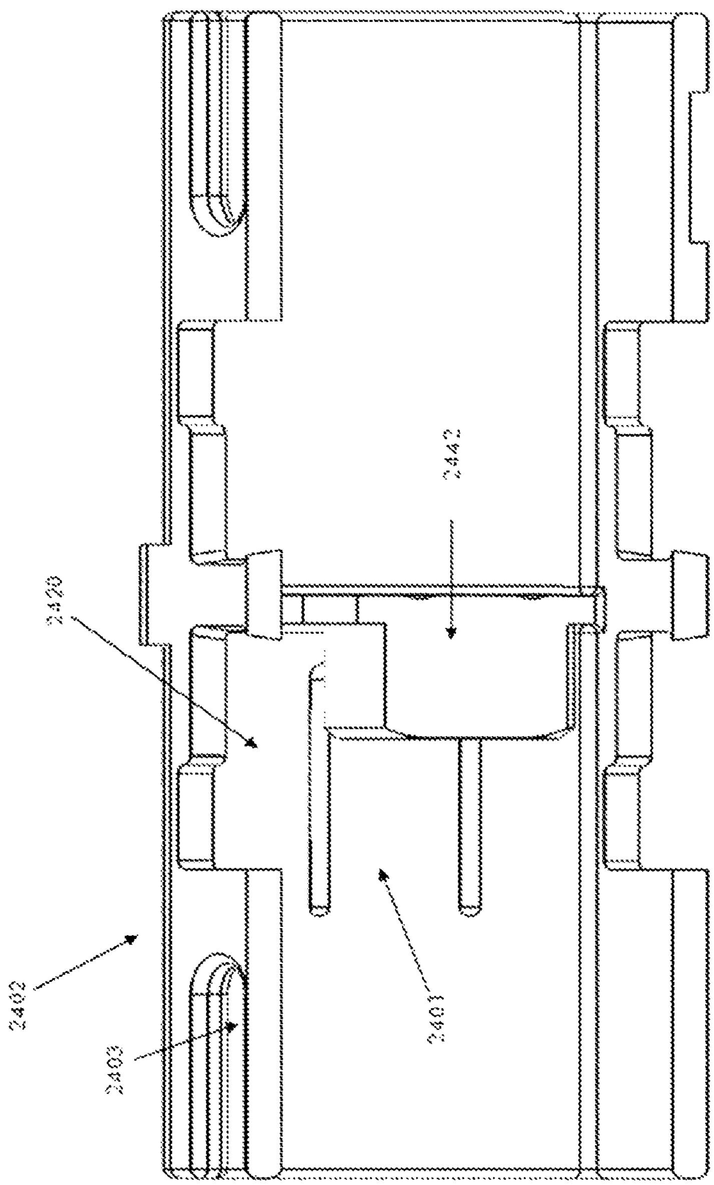

FIG. 25B

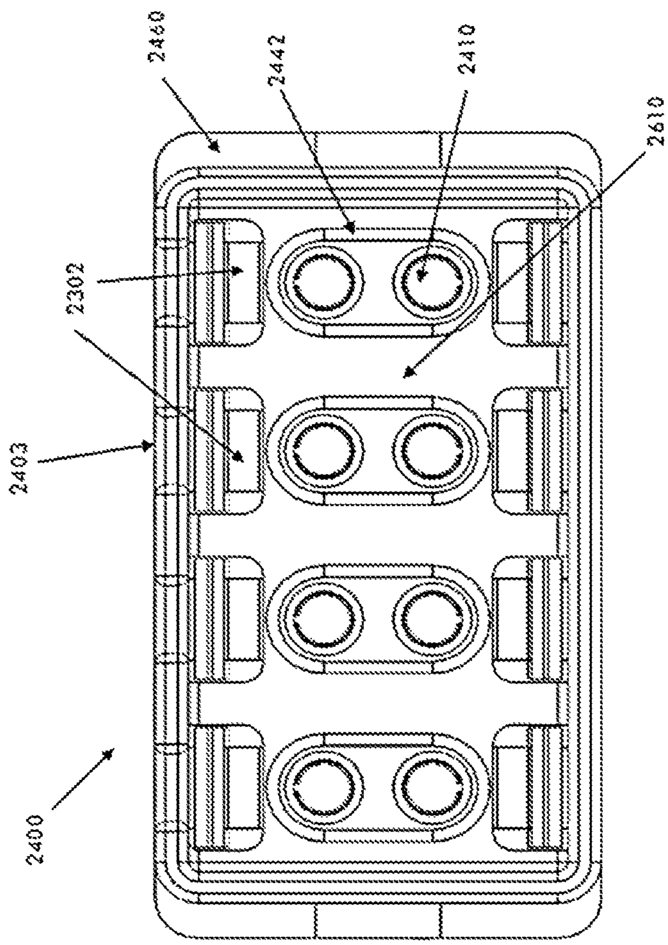

FIG. 26

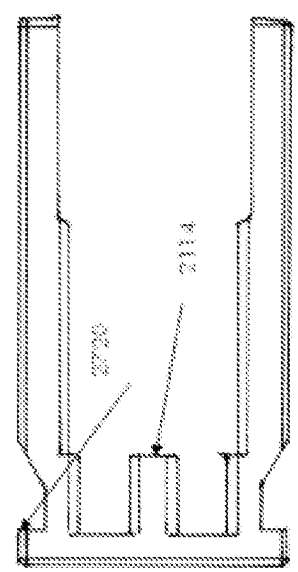

FIG. 27B

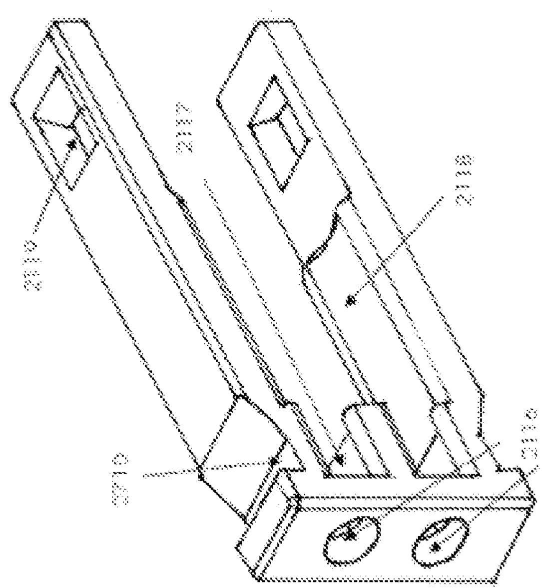

FIG. 27A

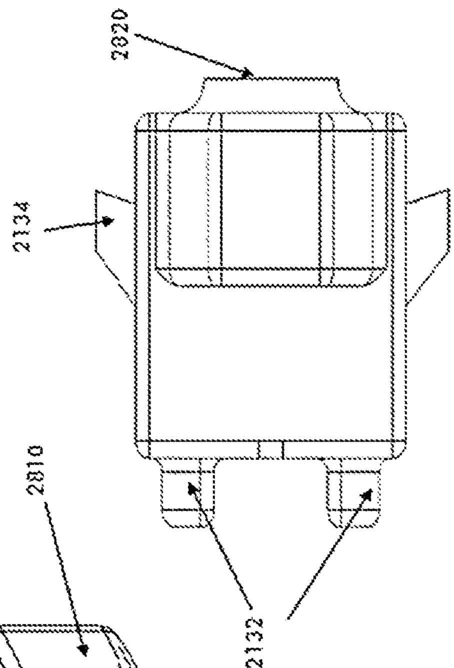

FIG. 28B

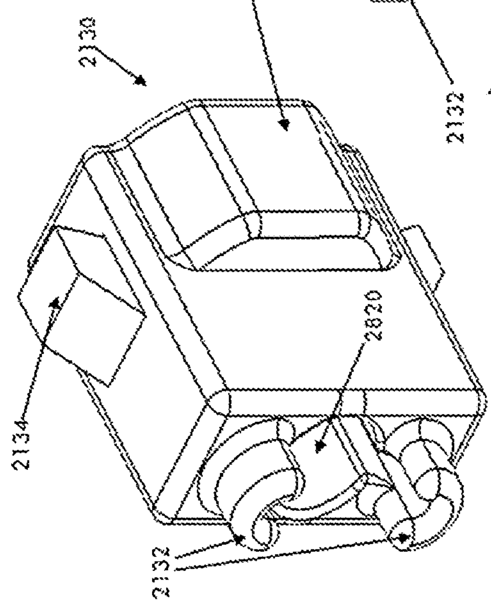

FIG. 28A

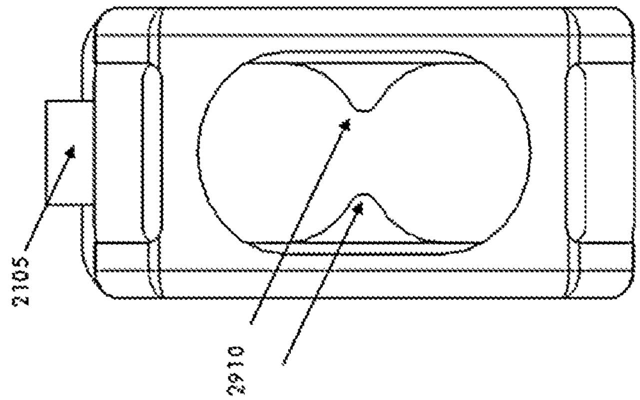

FIG. 29B

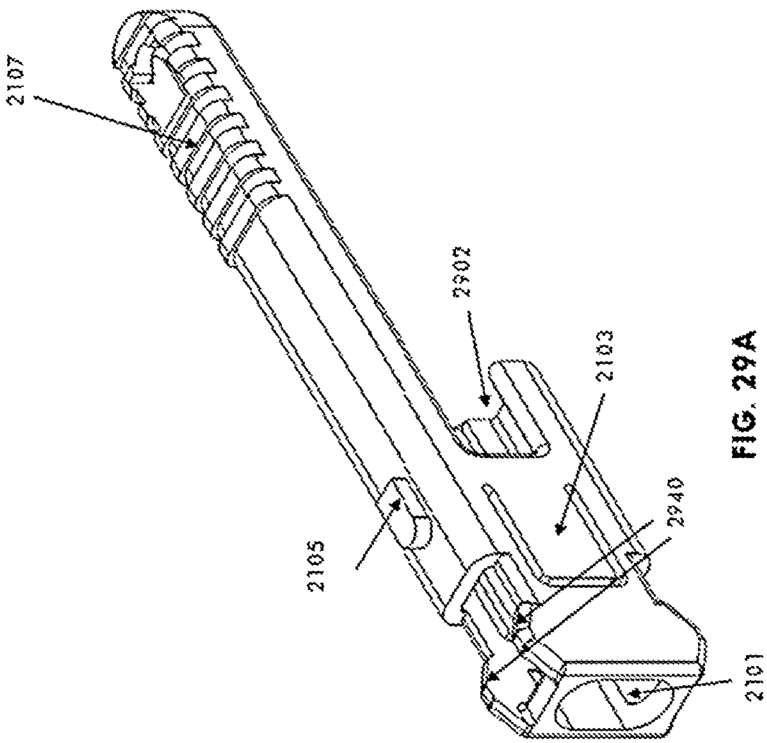

FIG. 29A

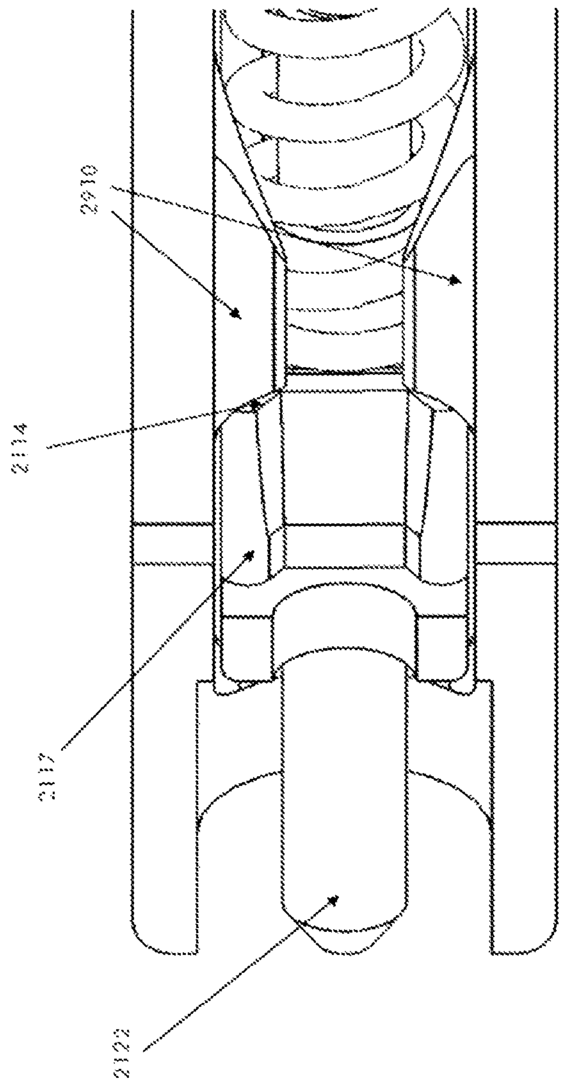

FIG. 29C

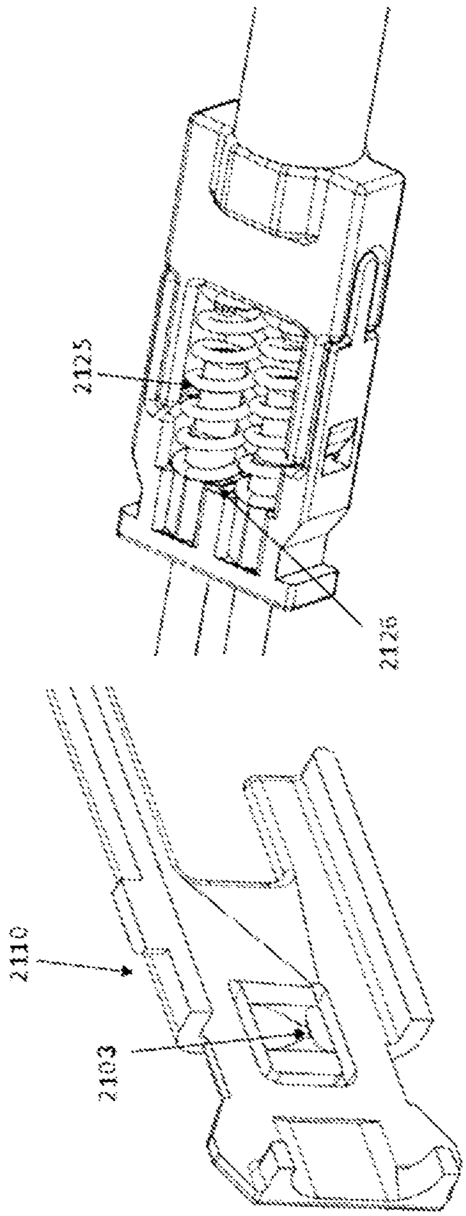

FIG. 29D

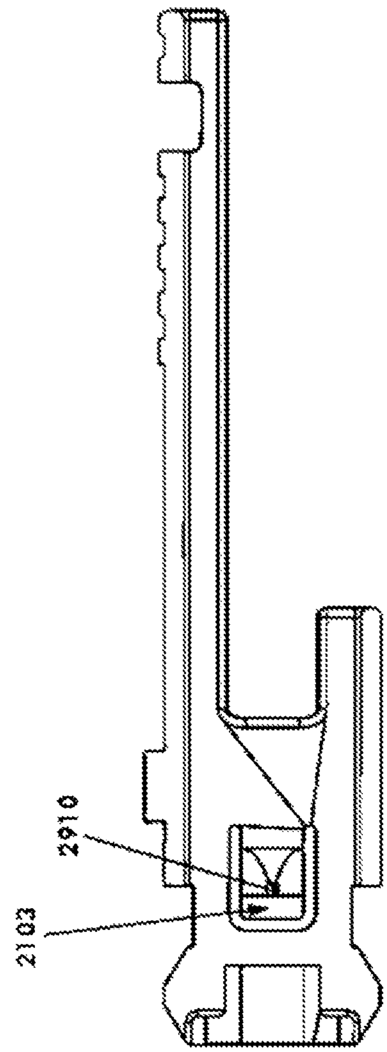

FIG. 29E

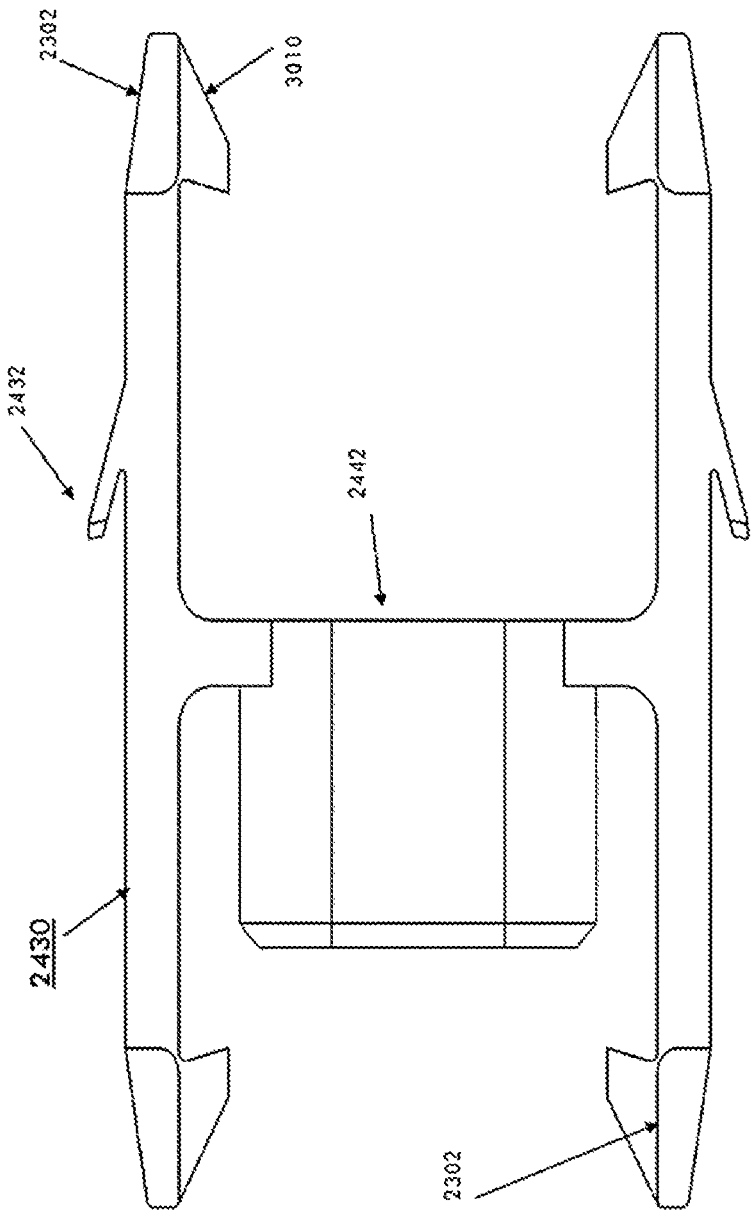

FIG. 30

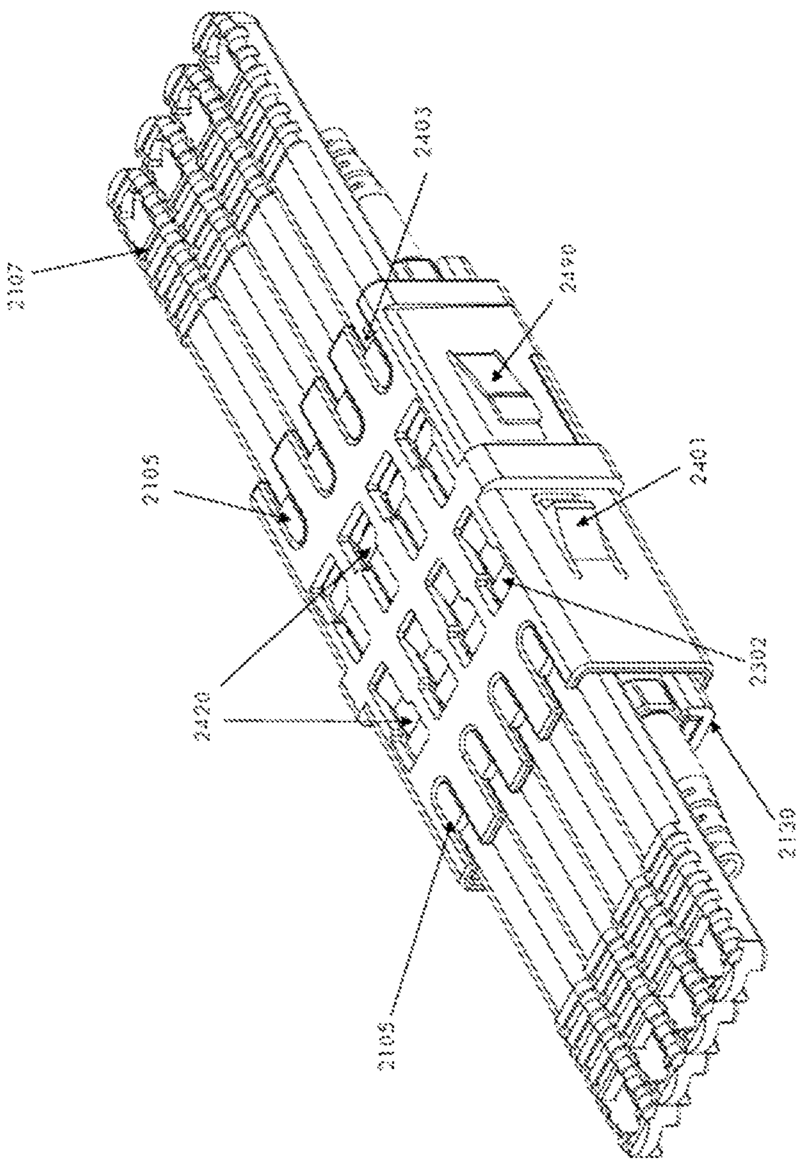

FIG. 31

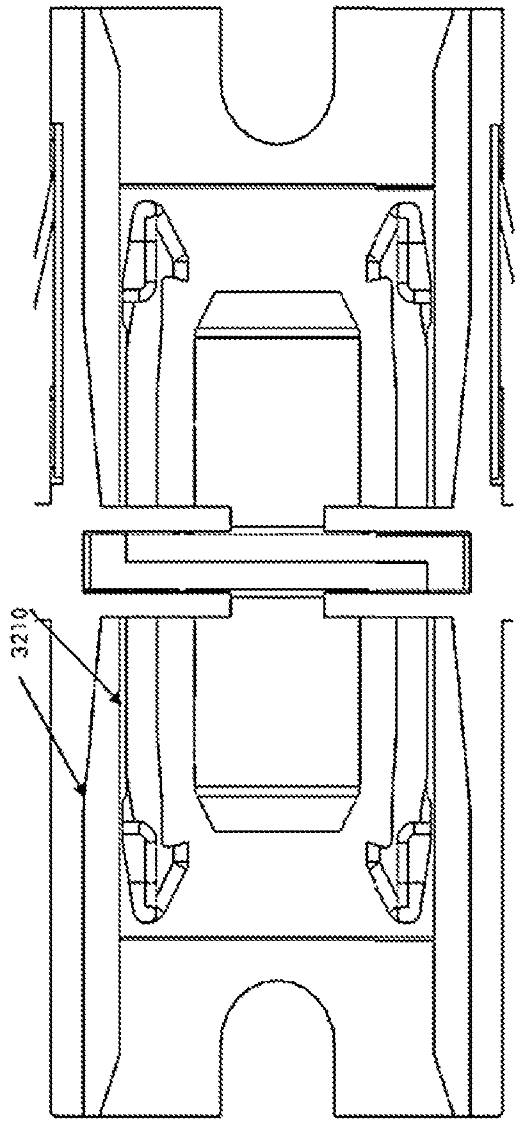

FIG. 32A

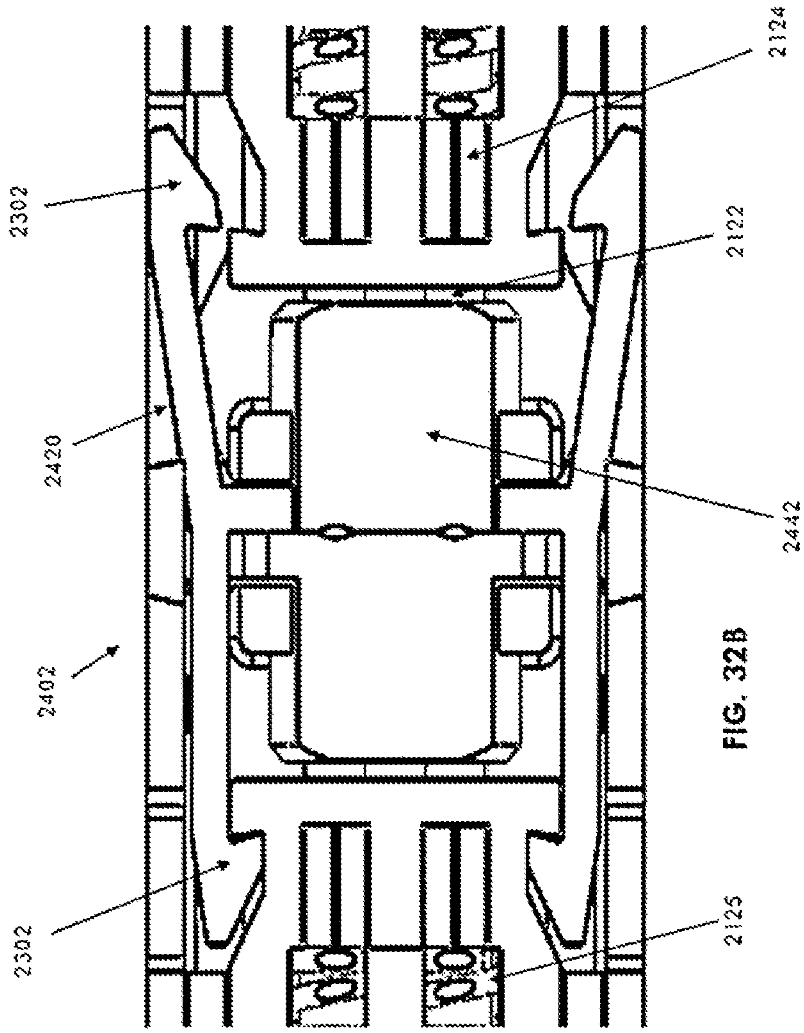

FIG. 32B

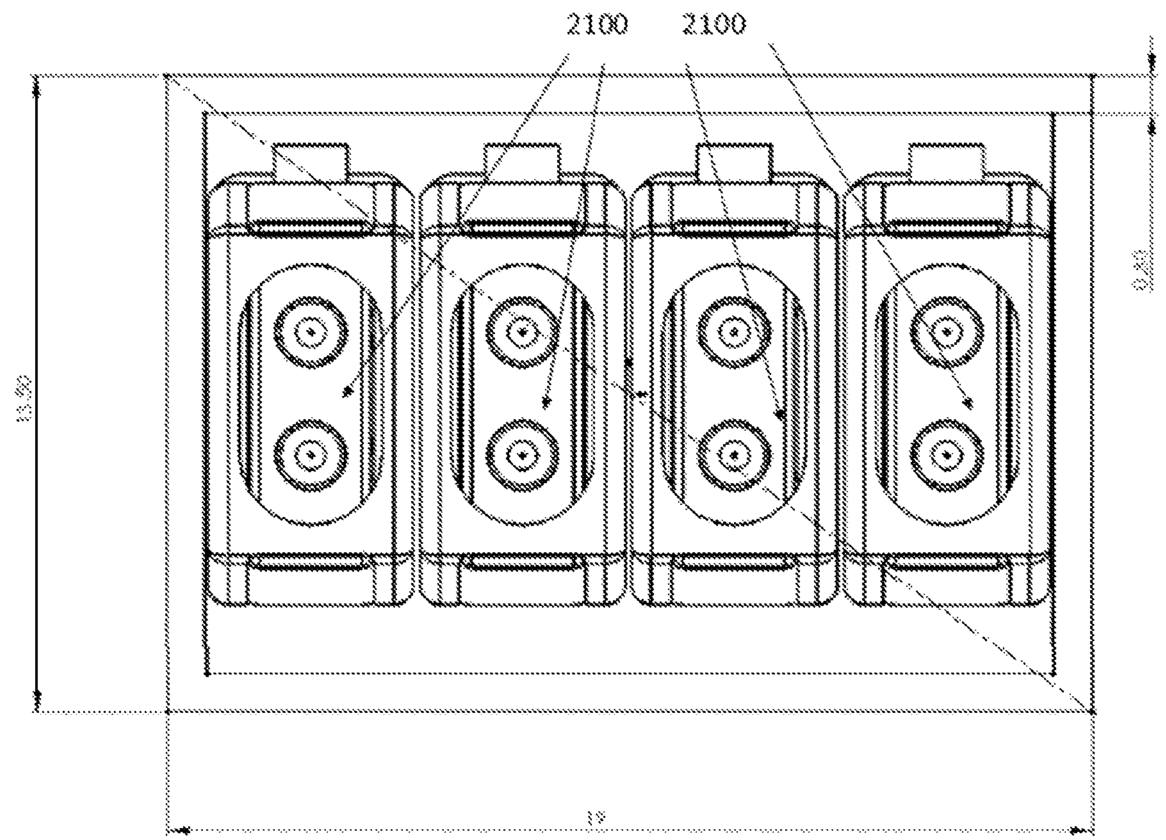

FIG. 33A

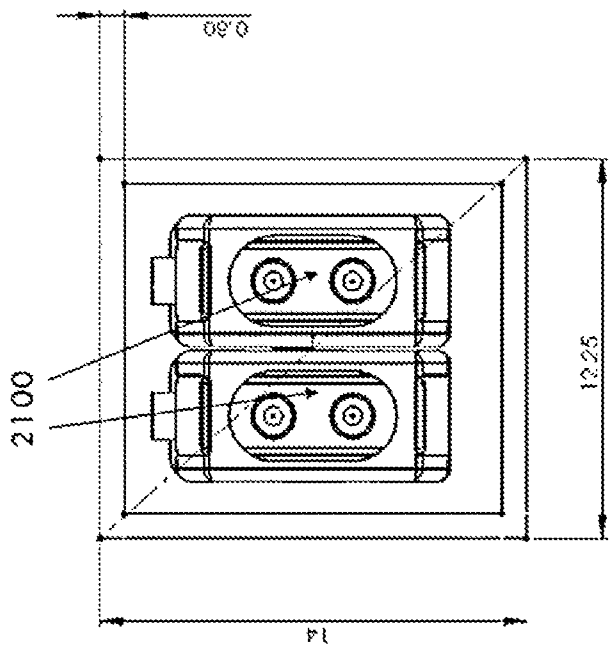

FIG. 33B

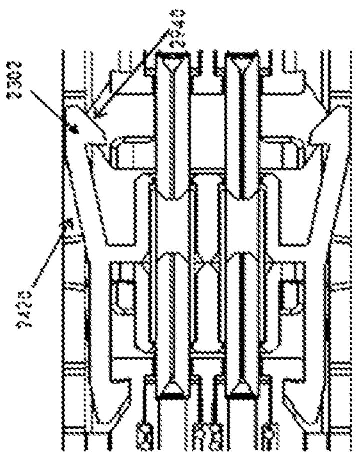

FIG. 34B

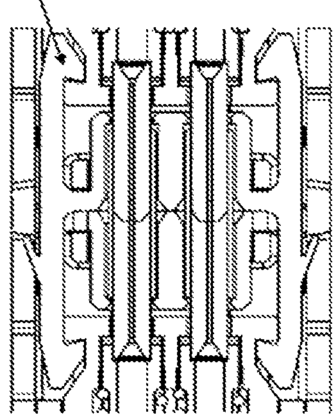

FIG. 34C

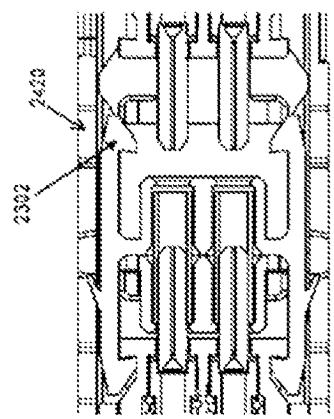

FIG. 34A

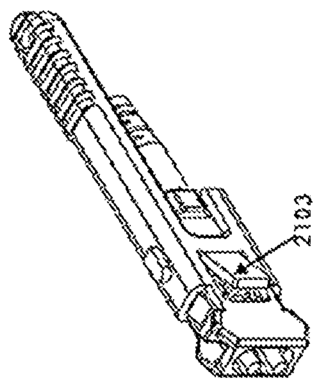

FIG. 35B

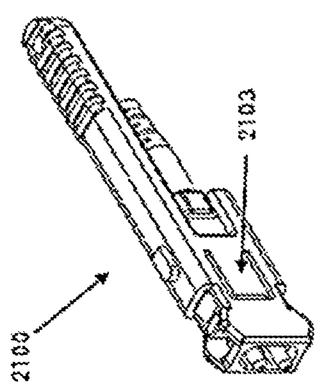

FIG. 35A

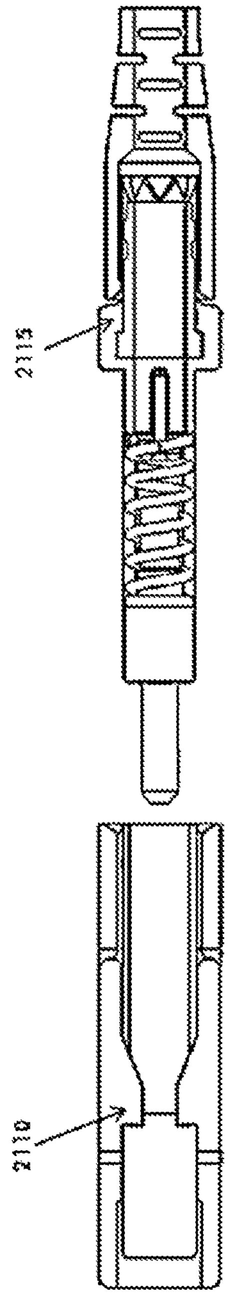

FIG. 35C

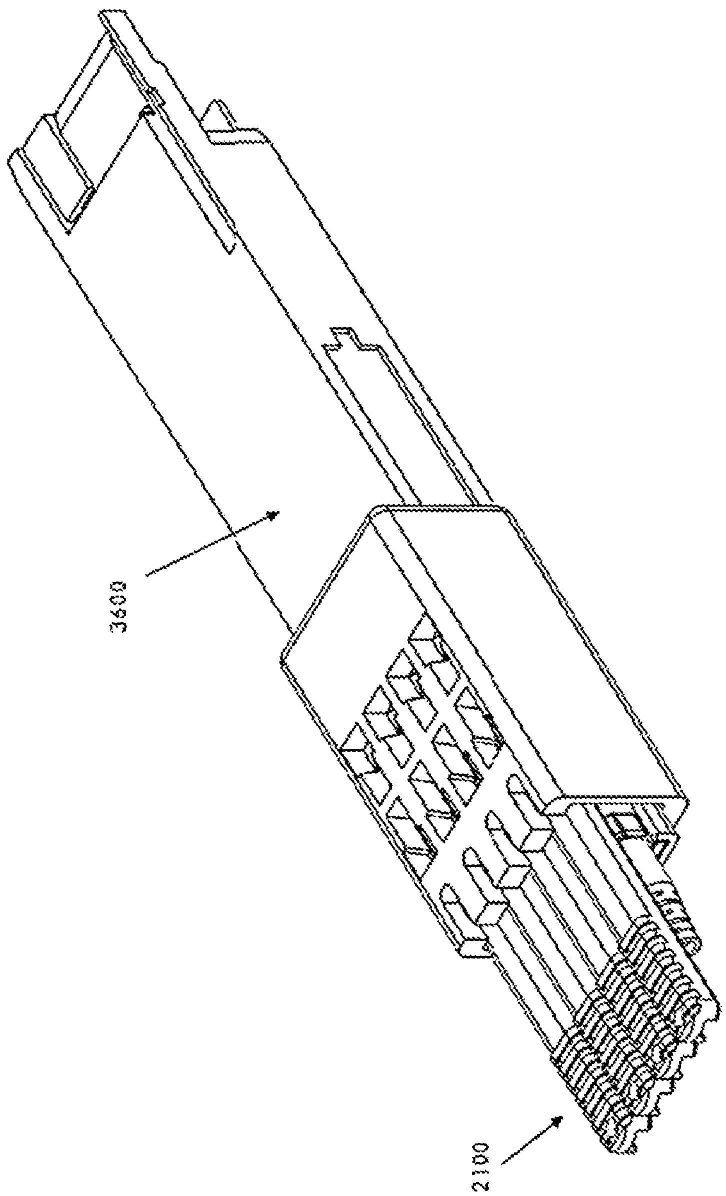

FIG. 36A

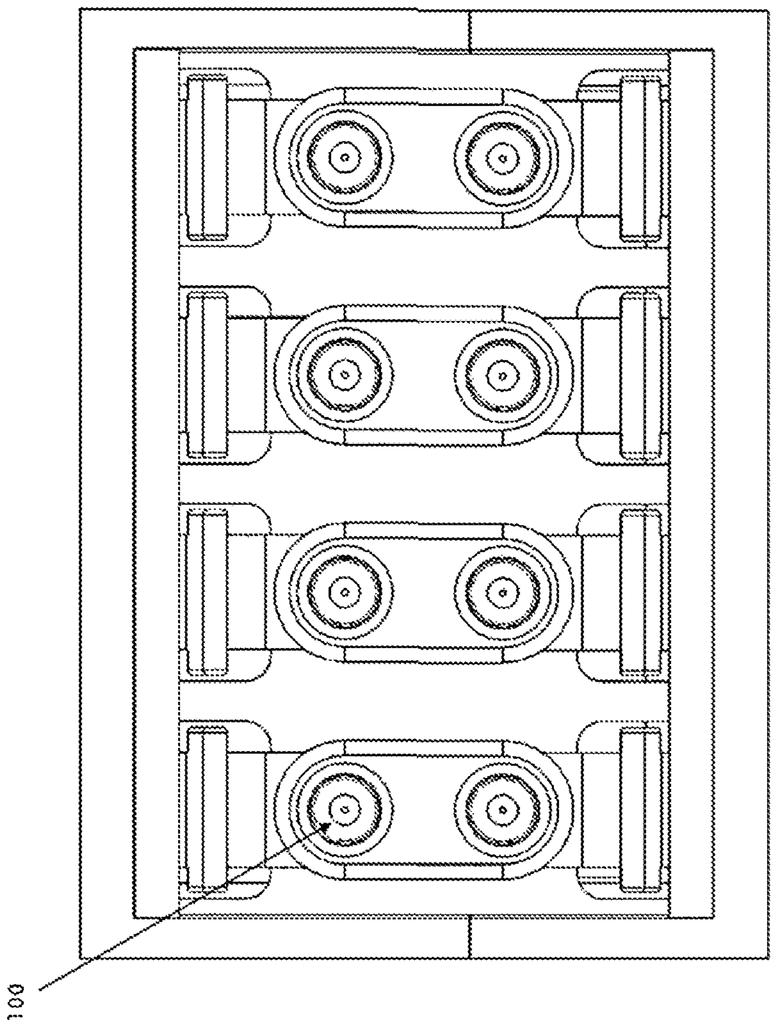

FIG. 36B

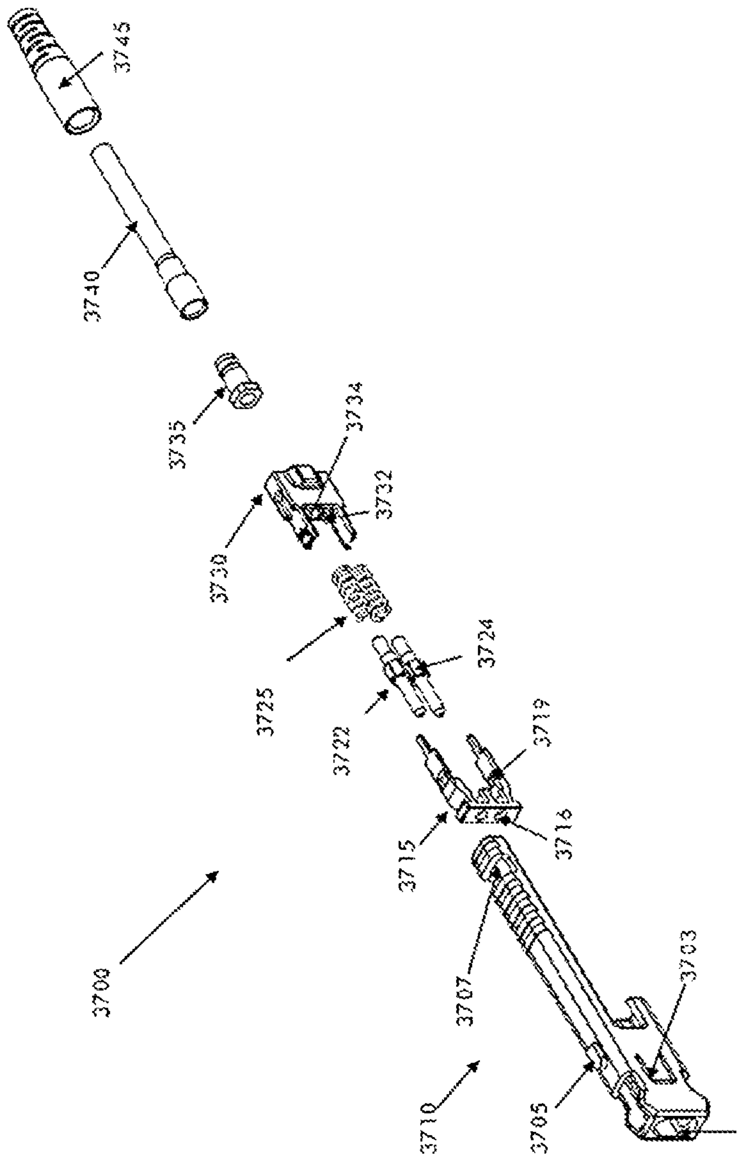
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FIG. 37

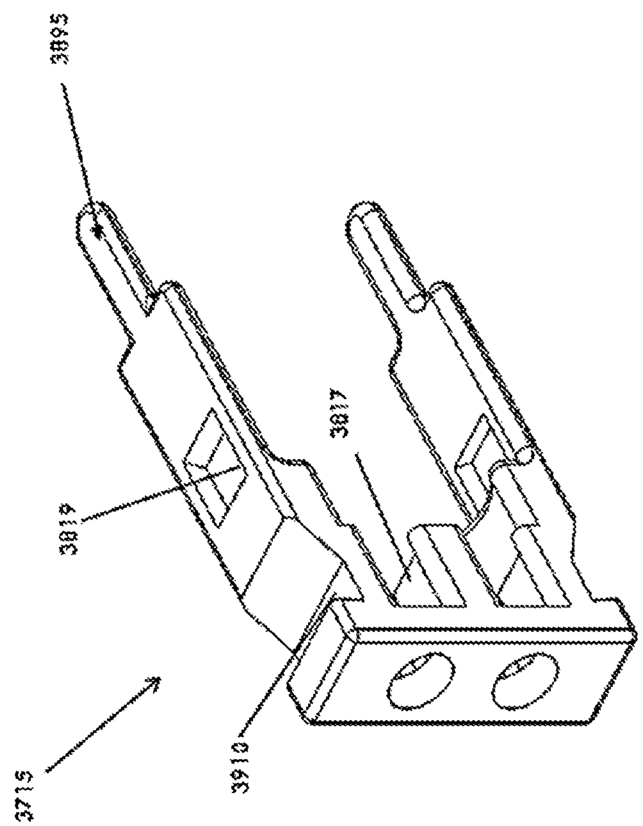

FIG. 38

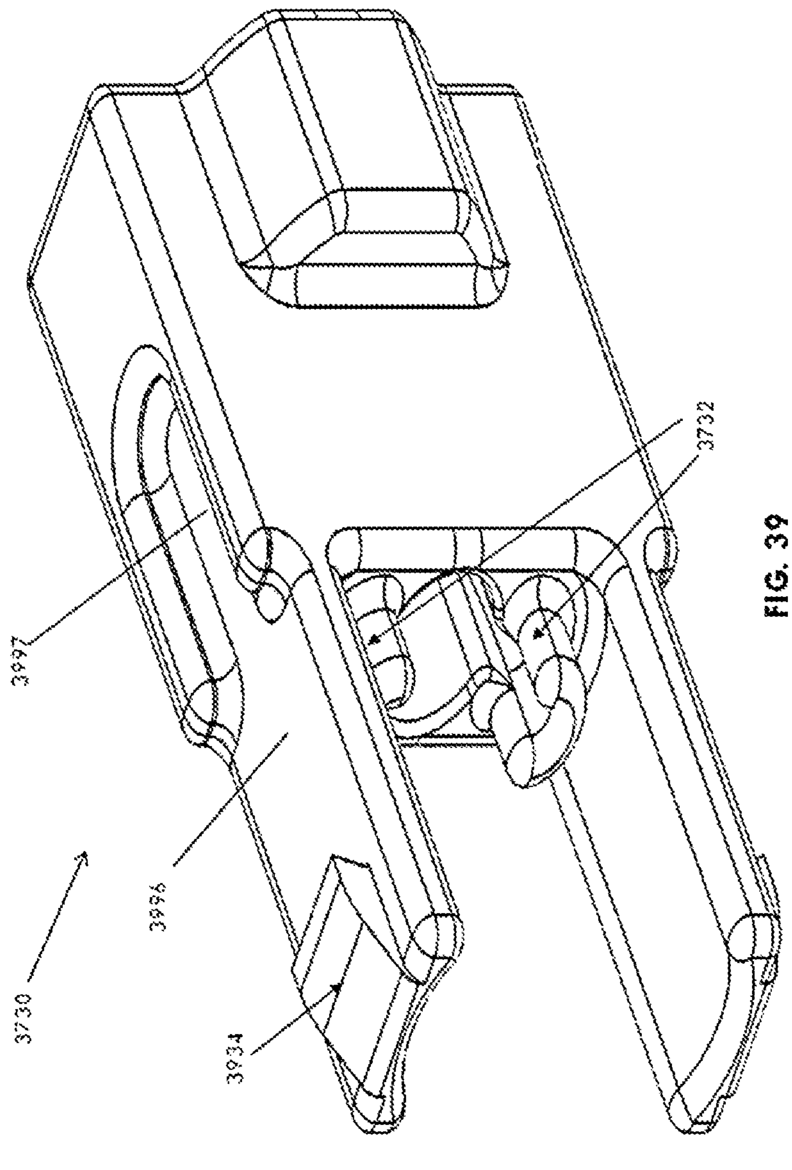

FIG. 39

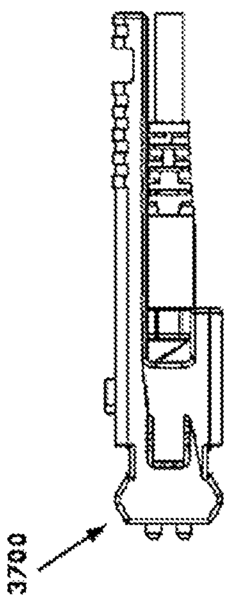

FIG. 40A

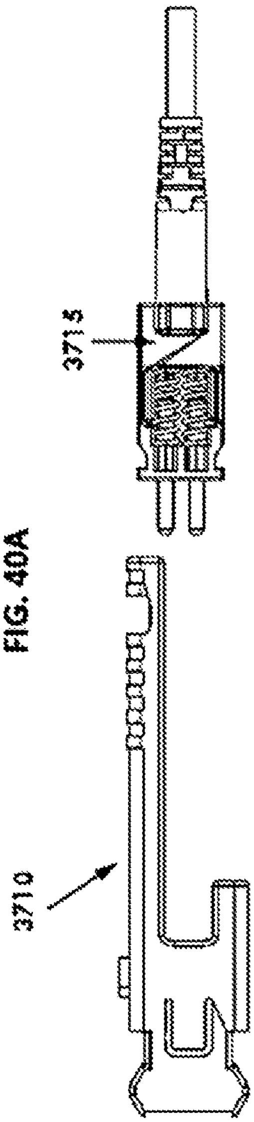

FIG. 40B

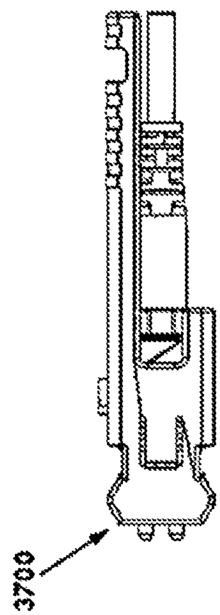

FIG. 40C

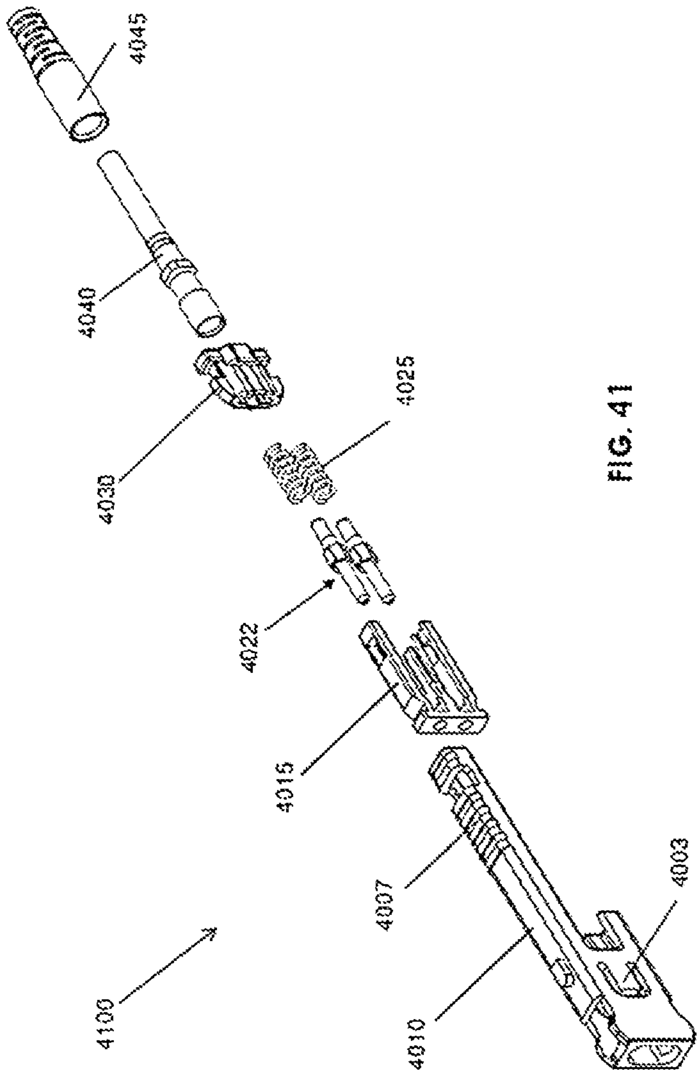

FIG. 41

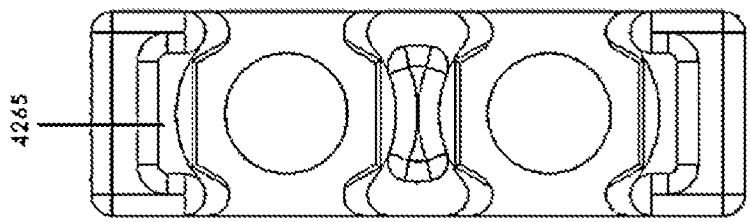

FIG. 42B

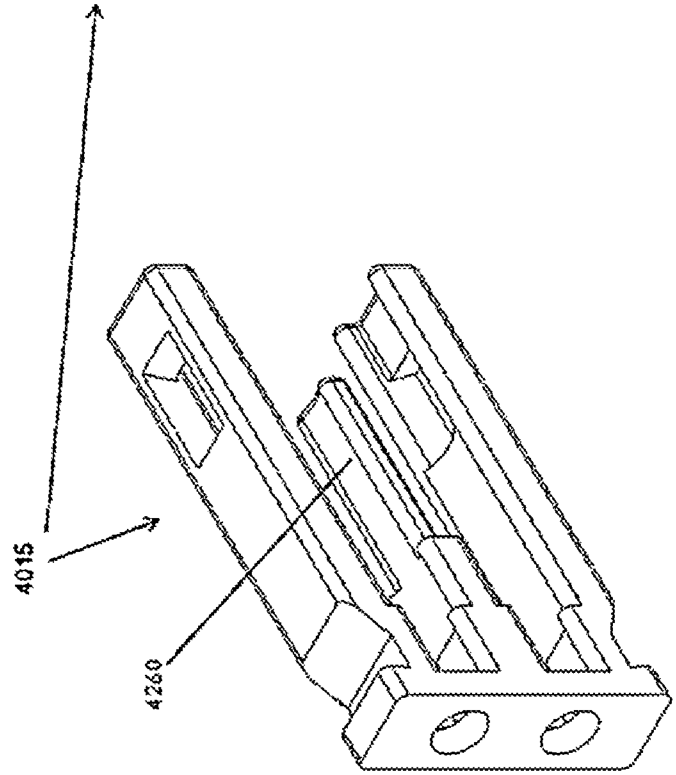

FIG. 42A

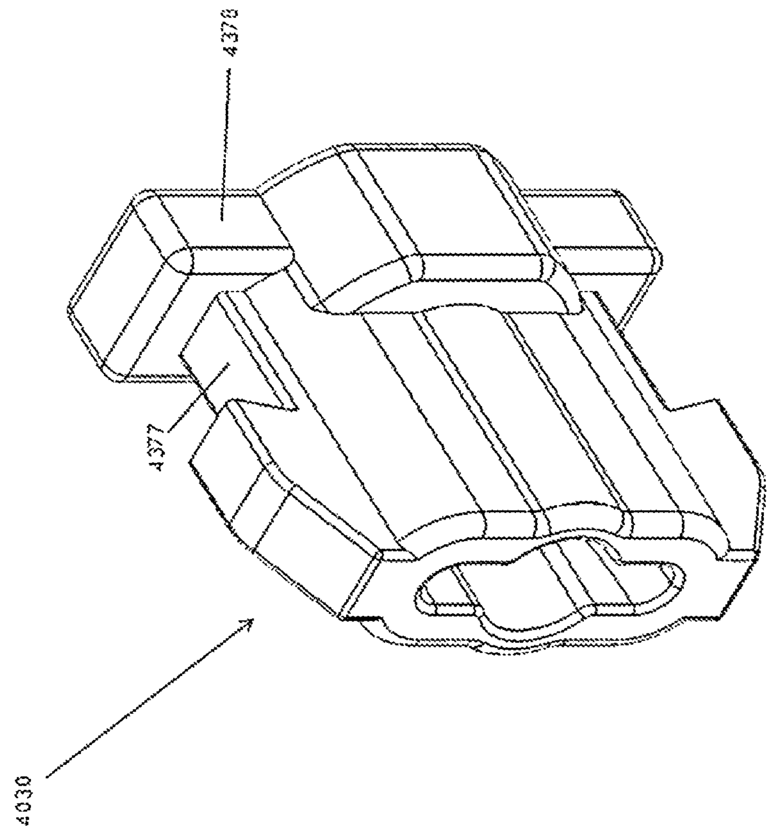

FIG. 43

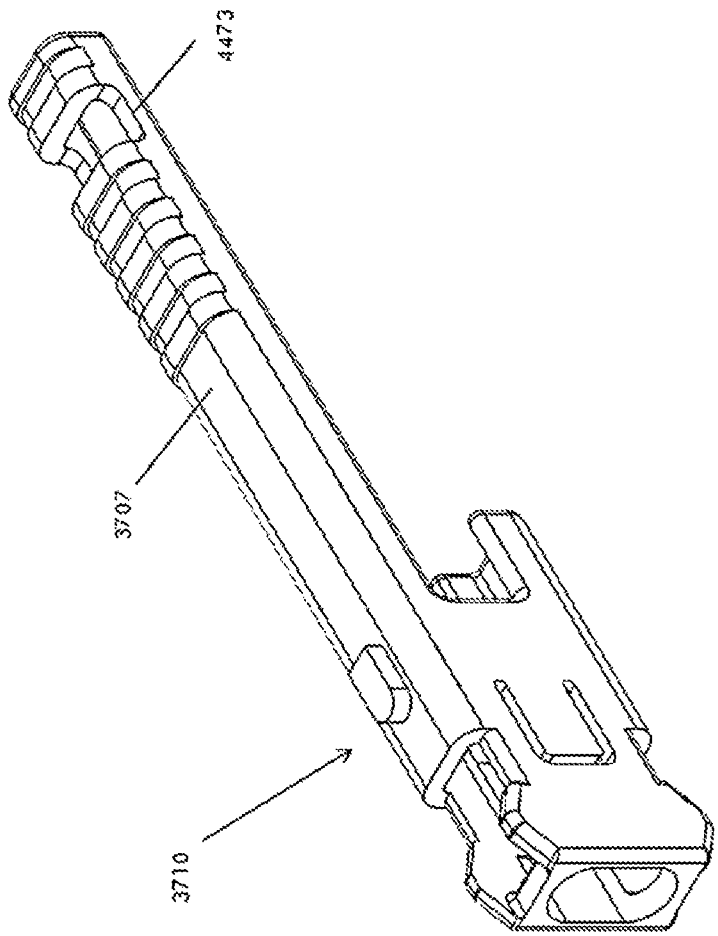

FIG. 44A

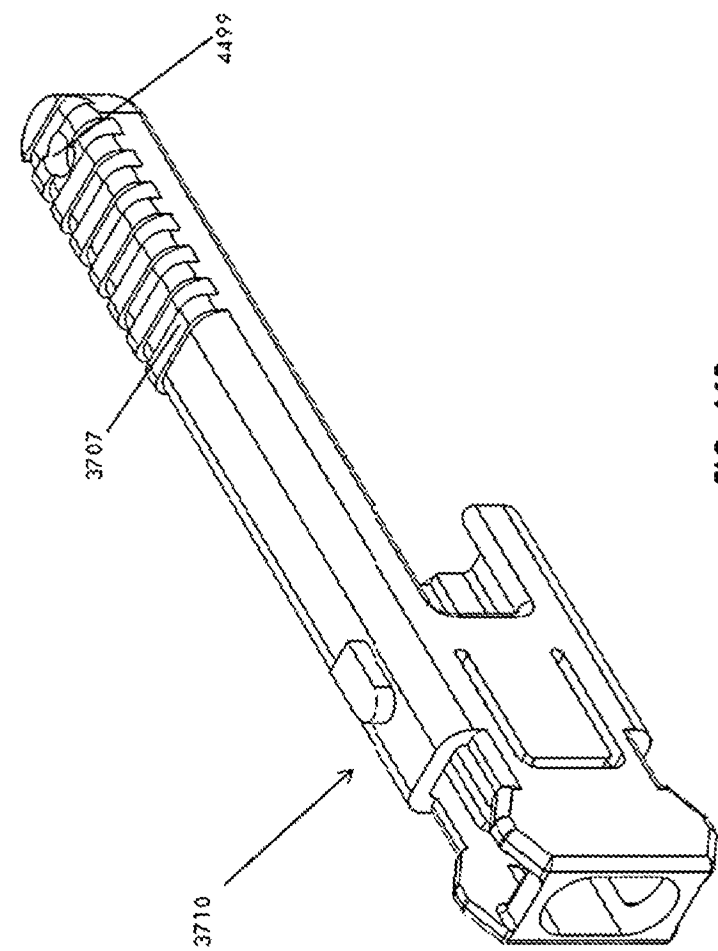

FIG. 44B

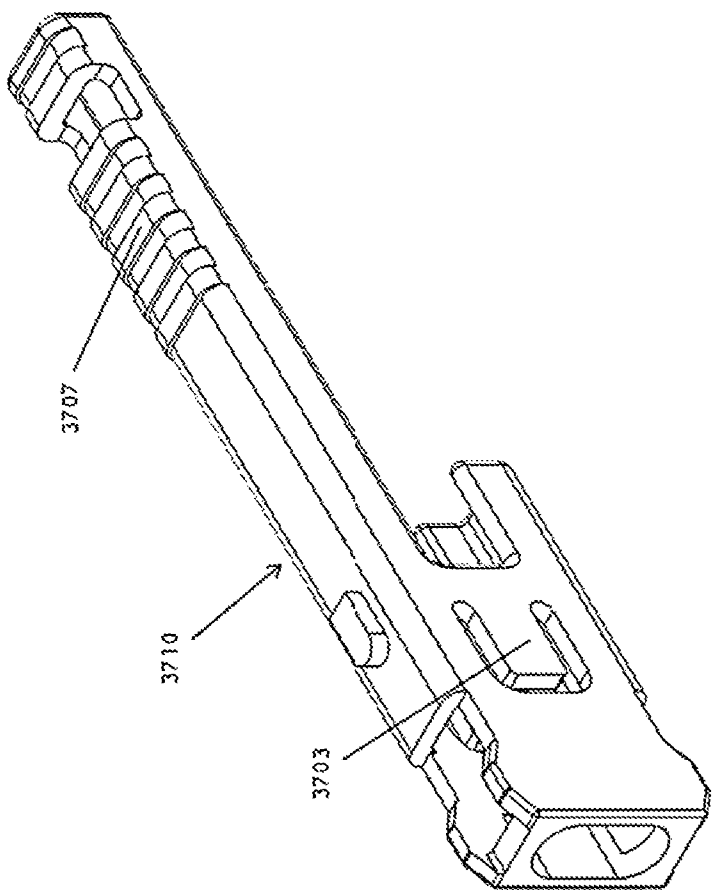

FIG. 44C

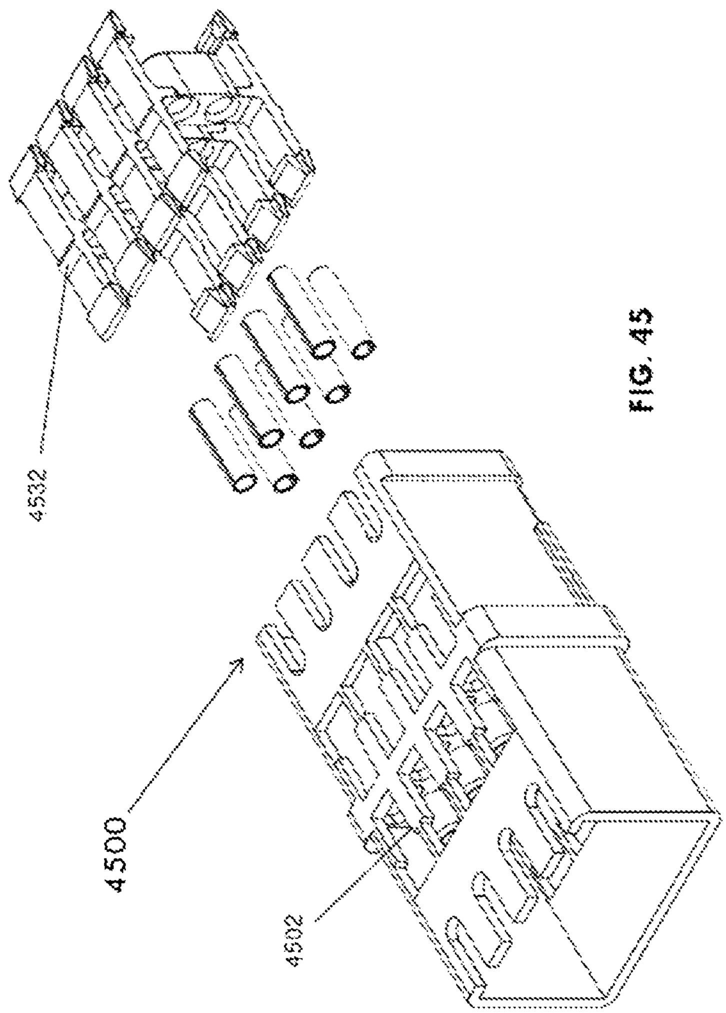

FIG. 45

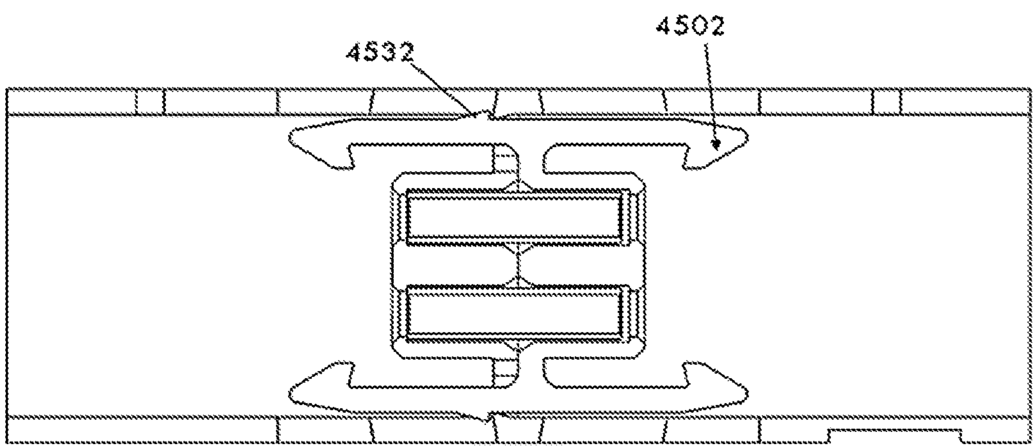

FIG. 46

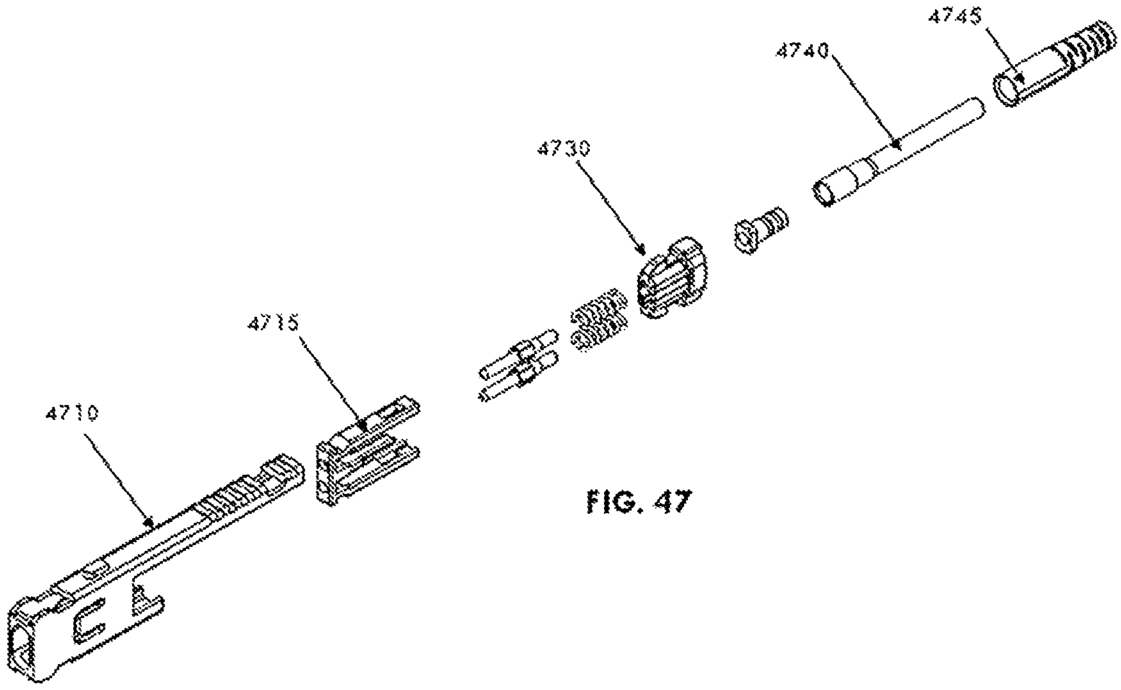

FIG. 47

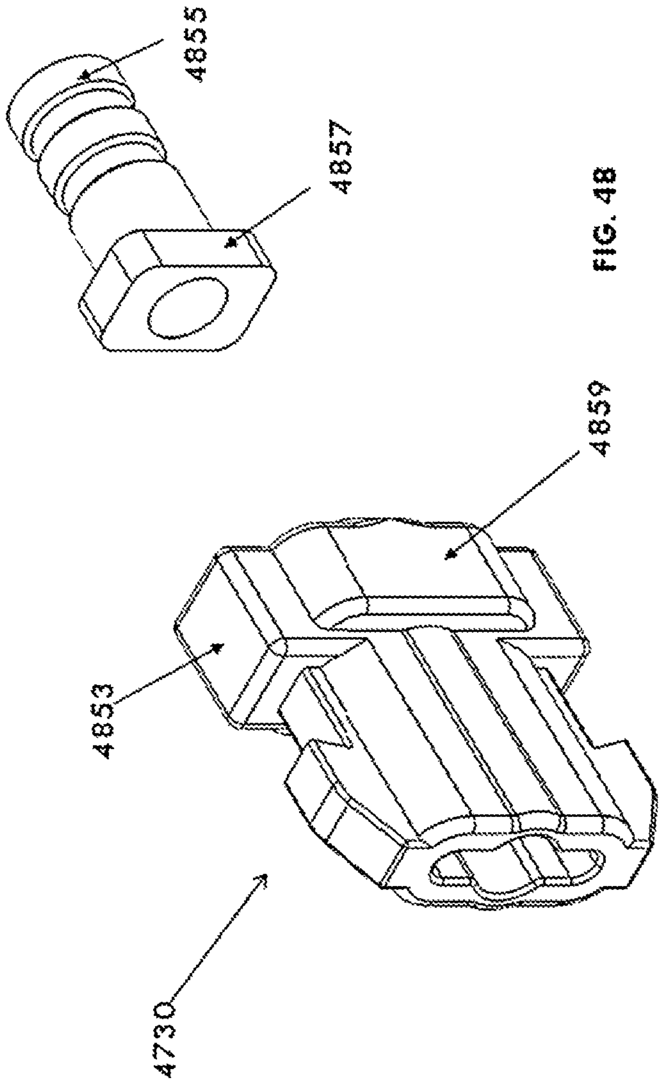

FIG. 4B

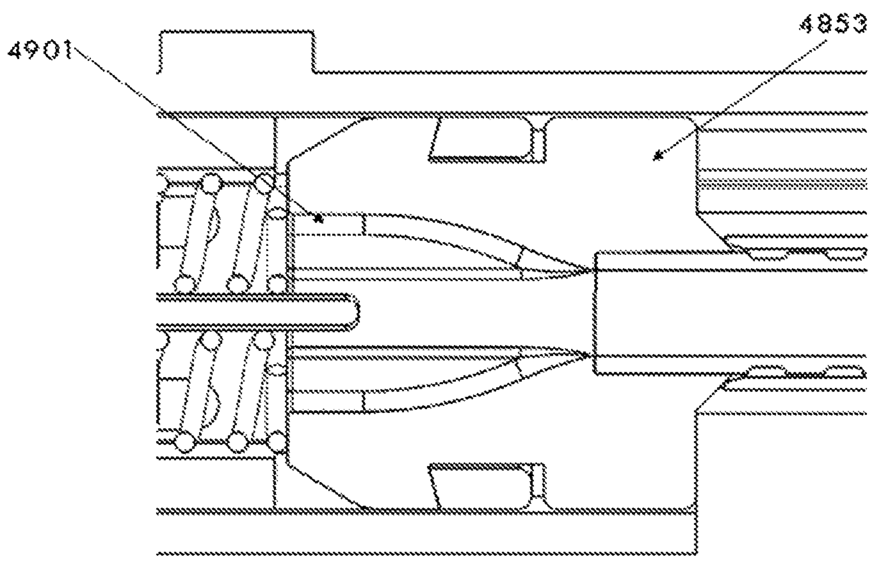

FIG. 49

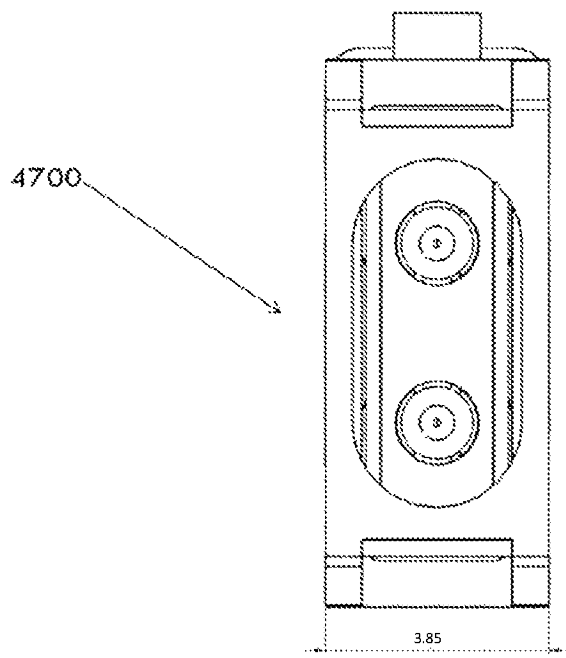

FIG. 50

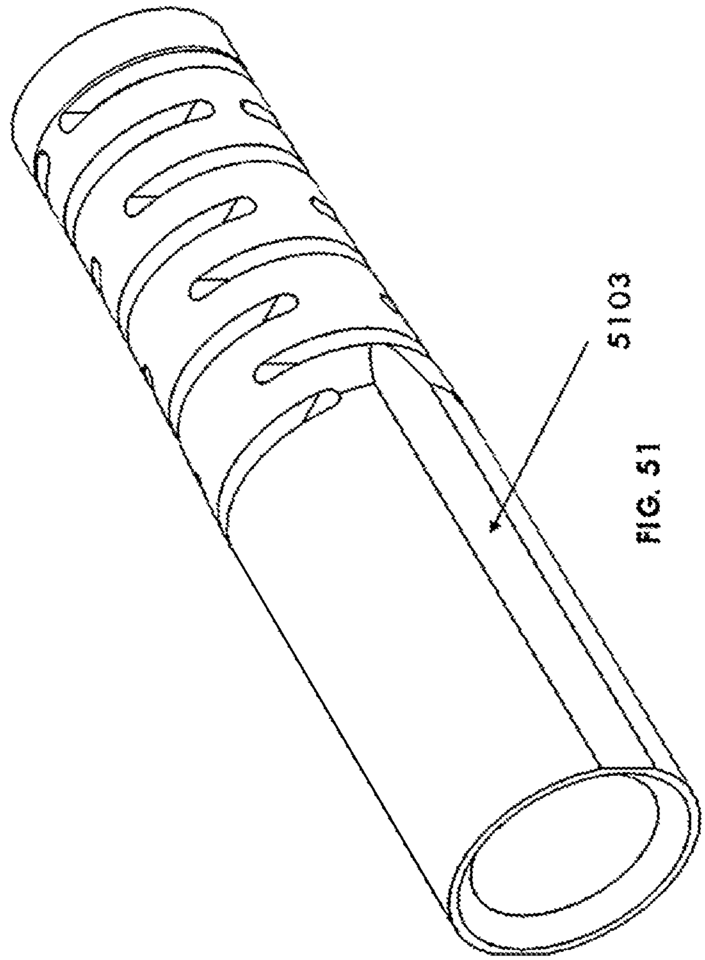

FIG. 51

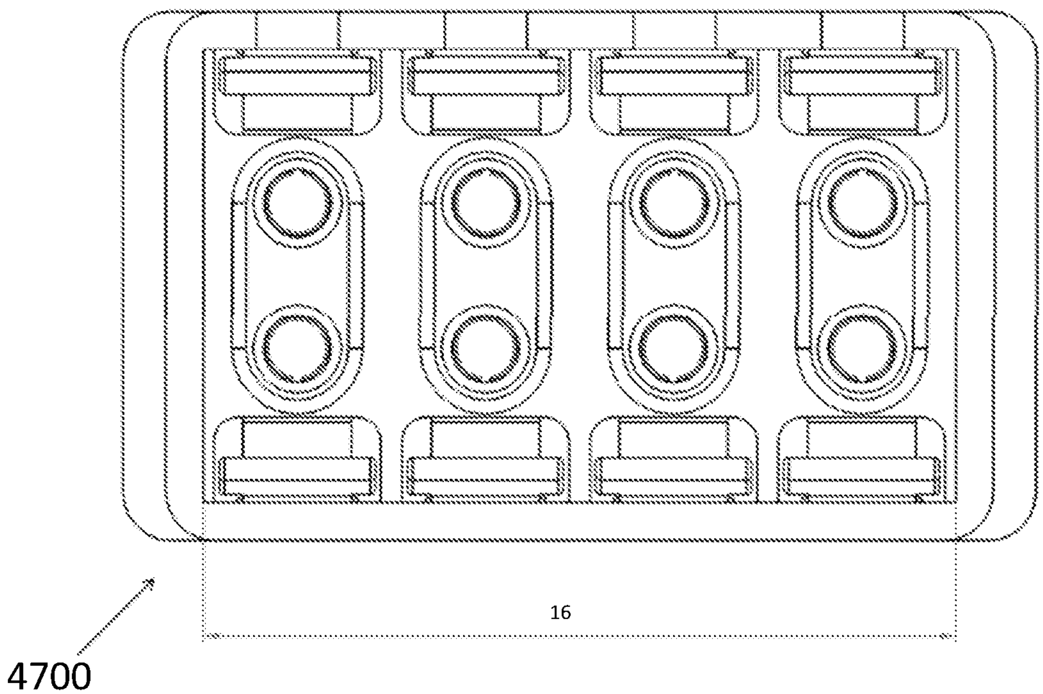

FIG. 52

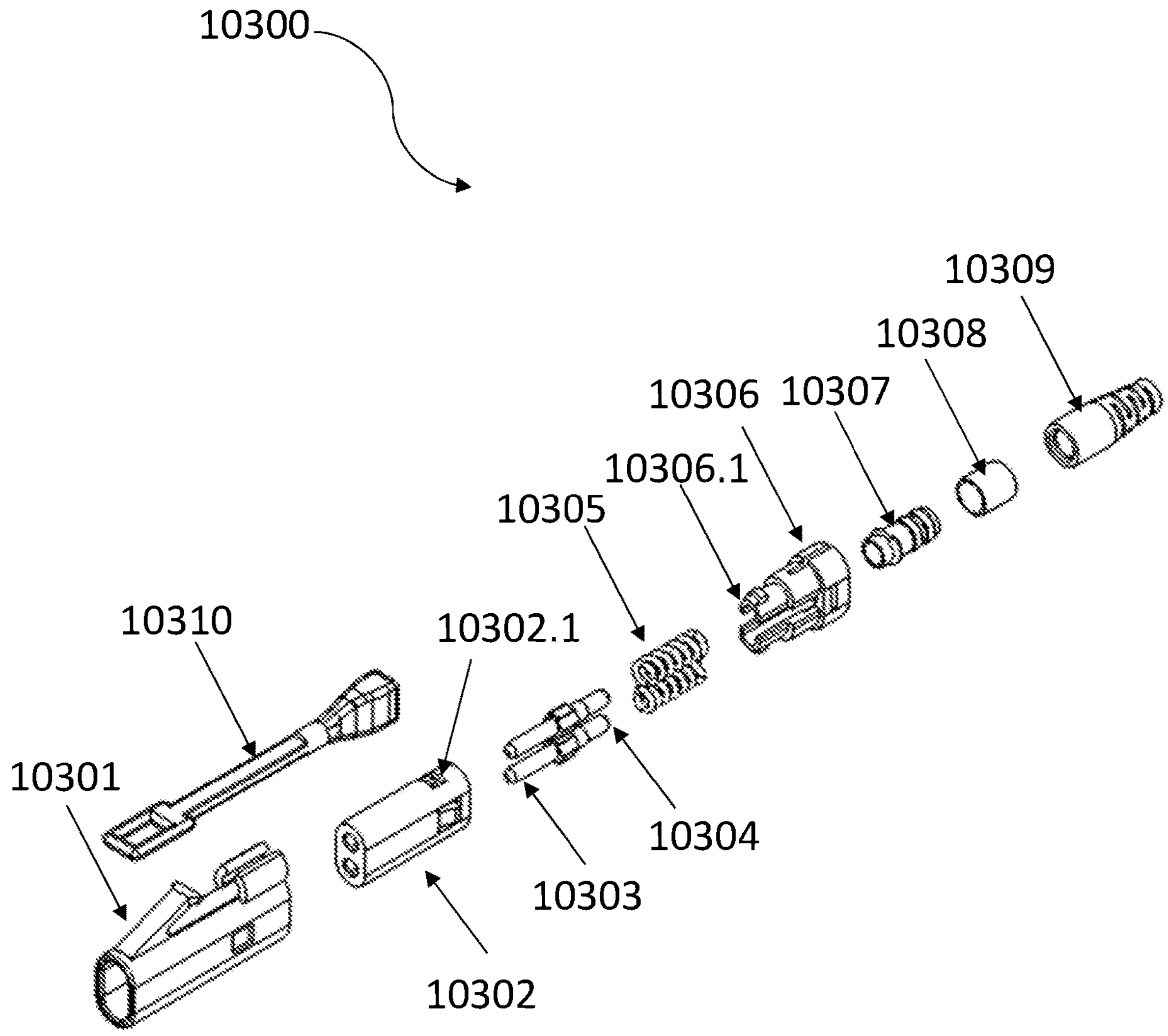
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FIG.53

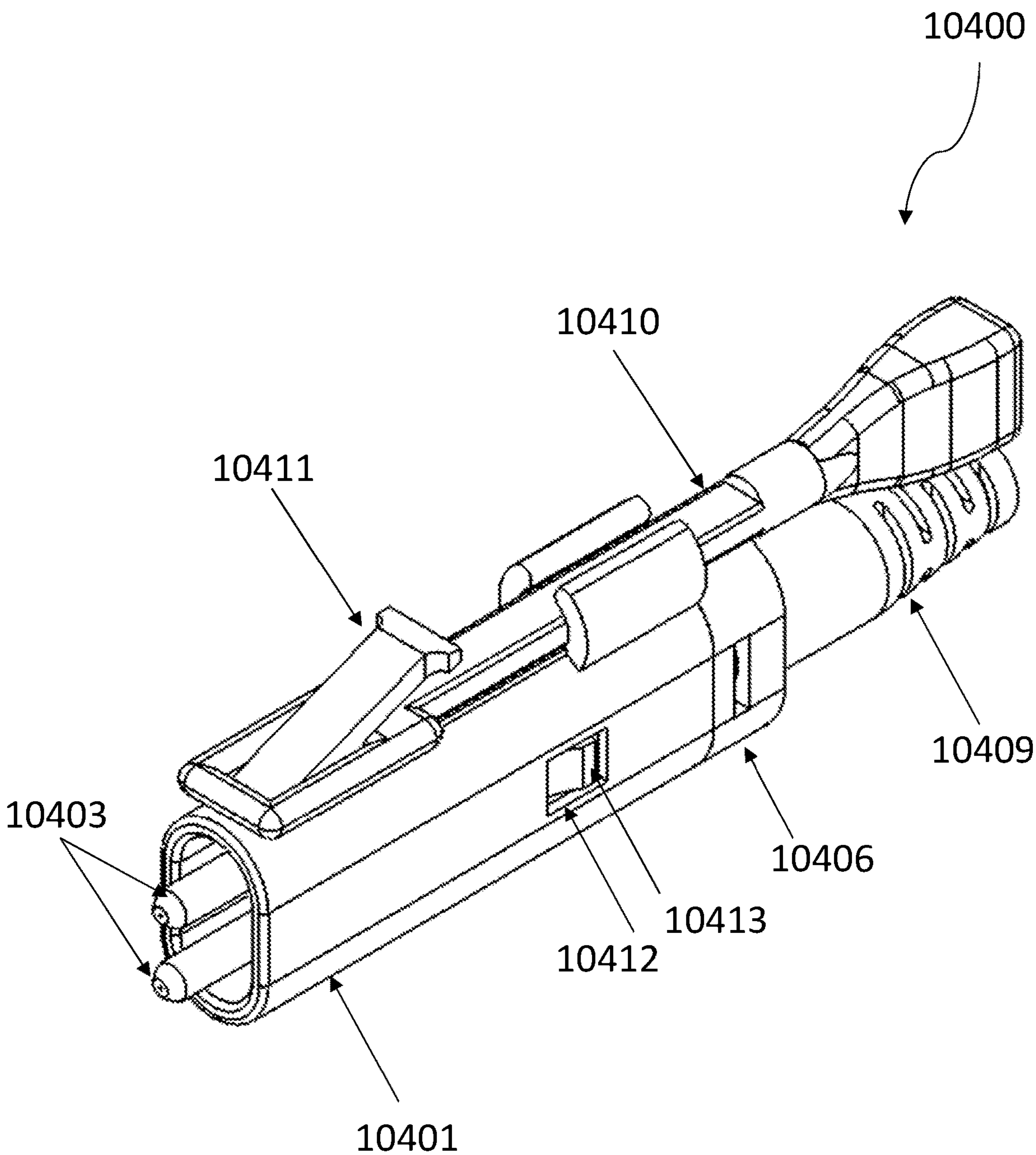


FIG.54

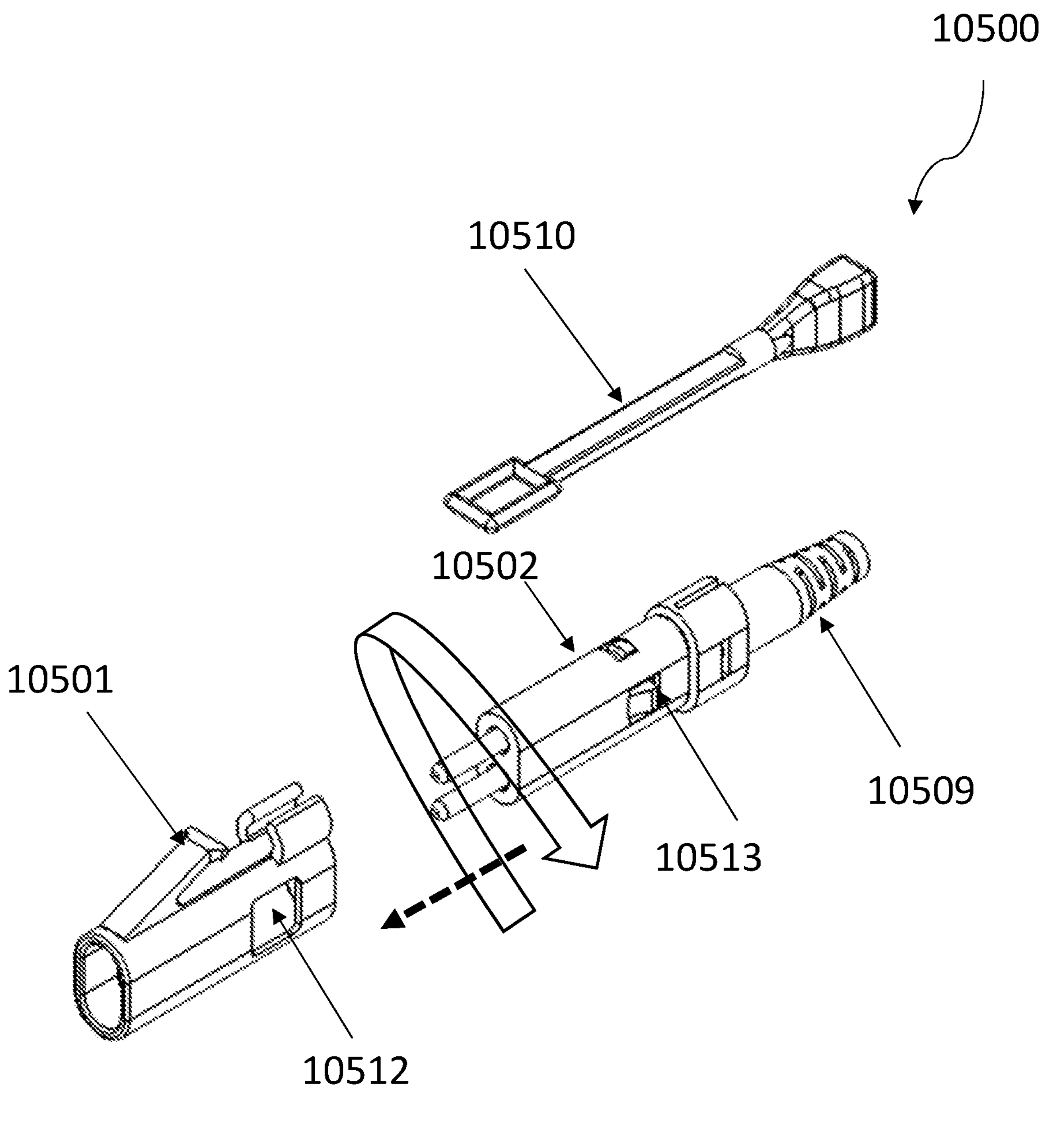


FIG.55

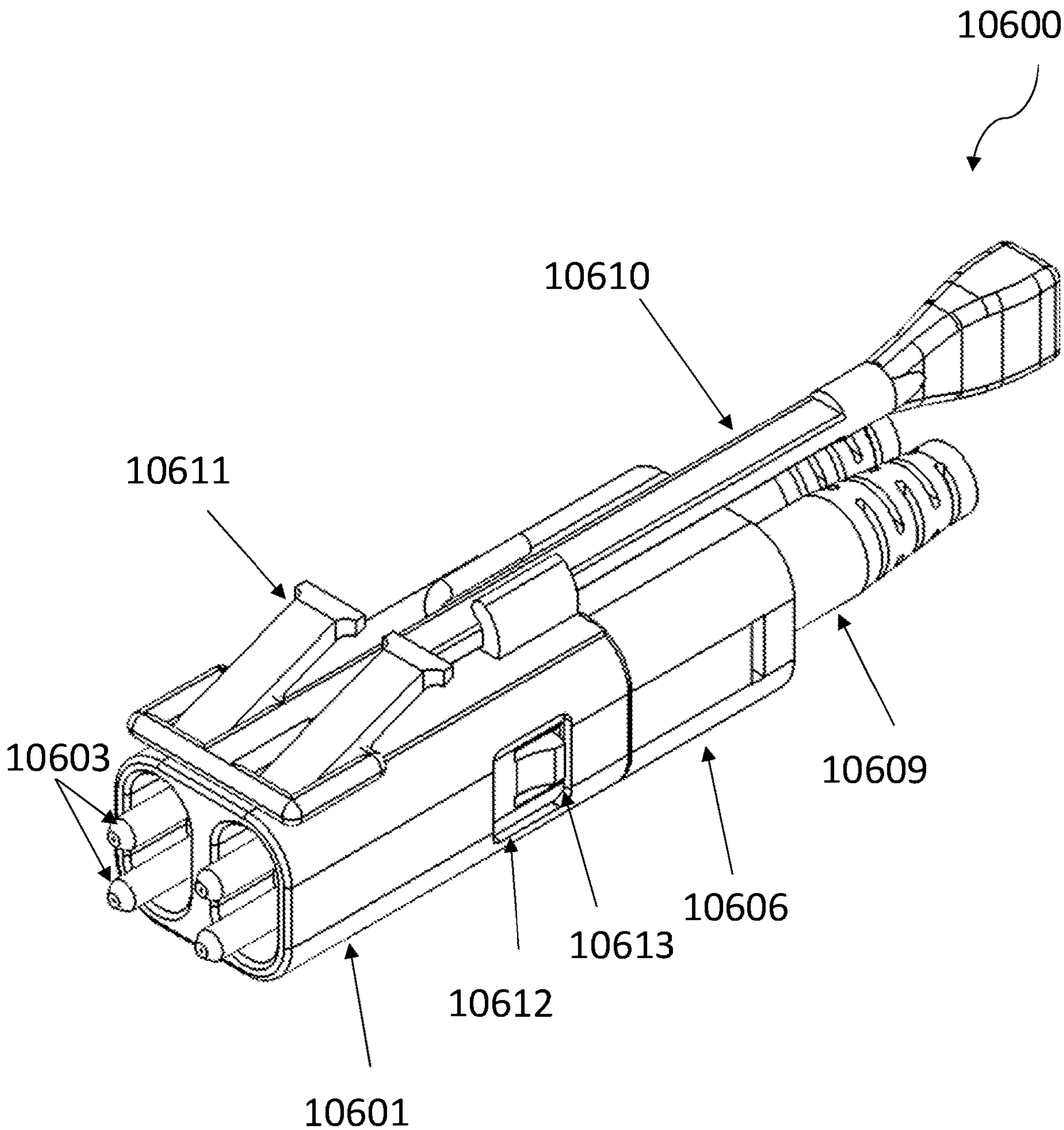


FIG.56

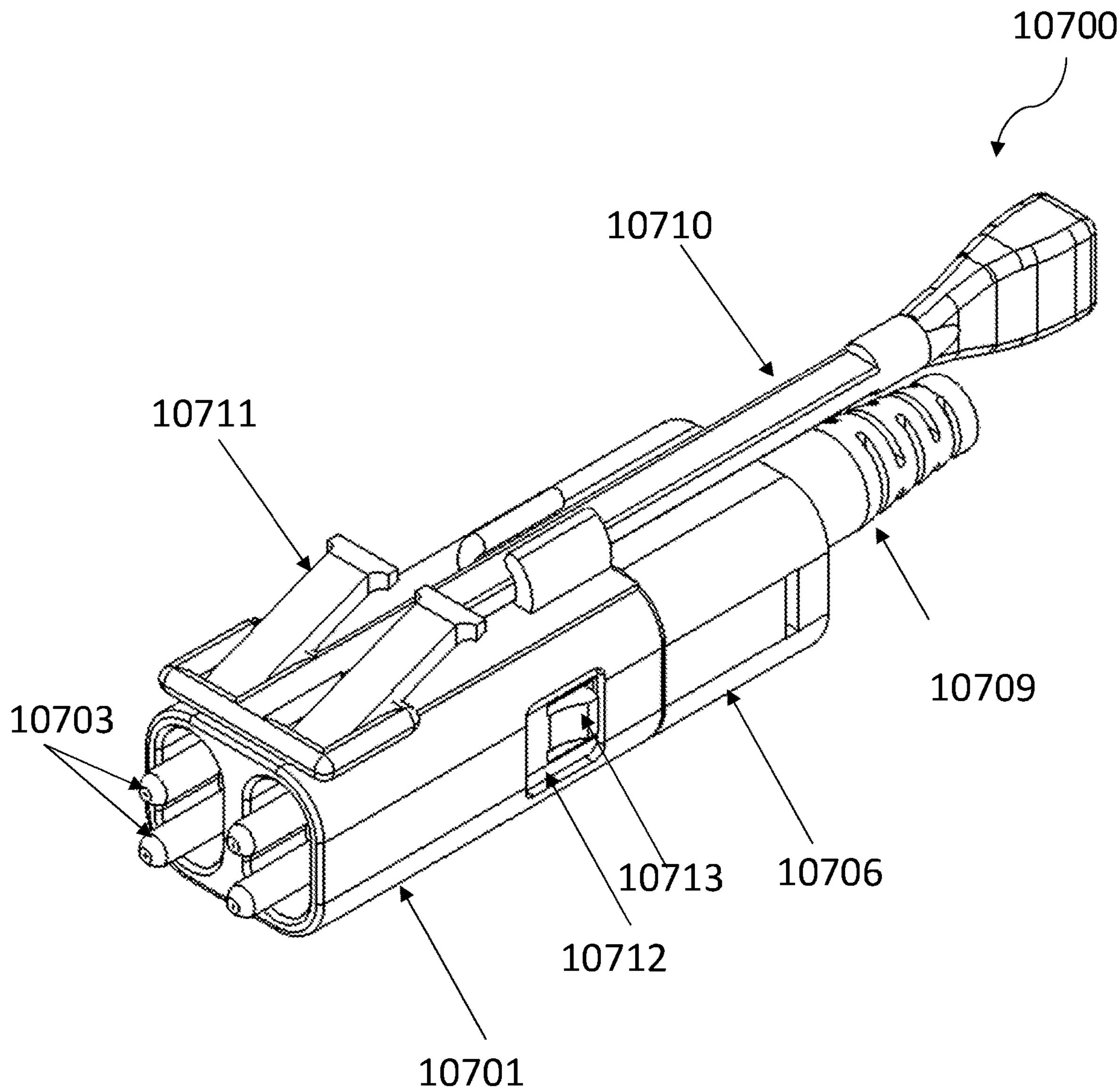


FIG.57

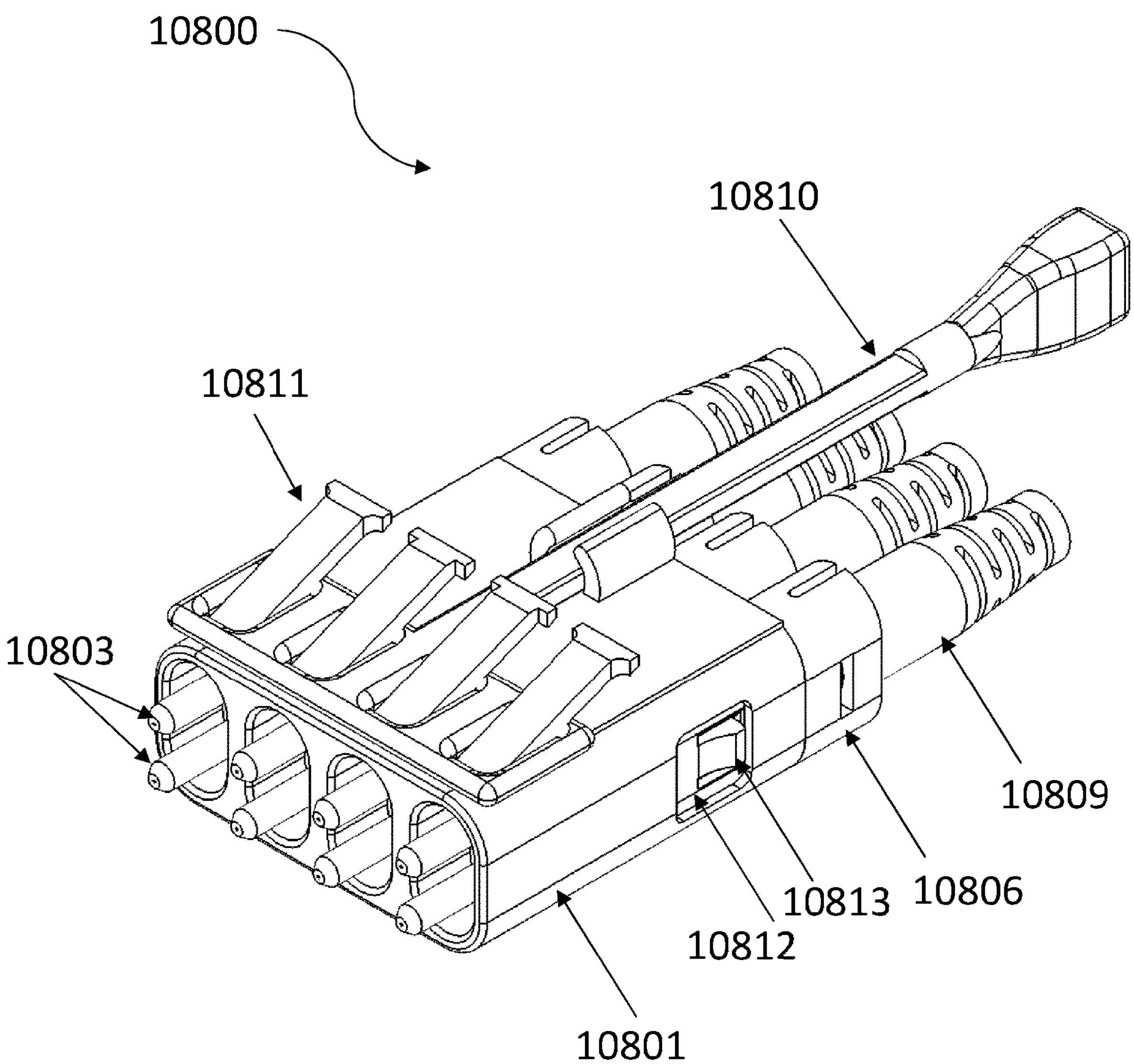


FIG.58

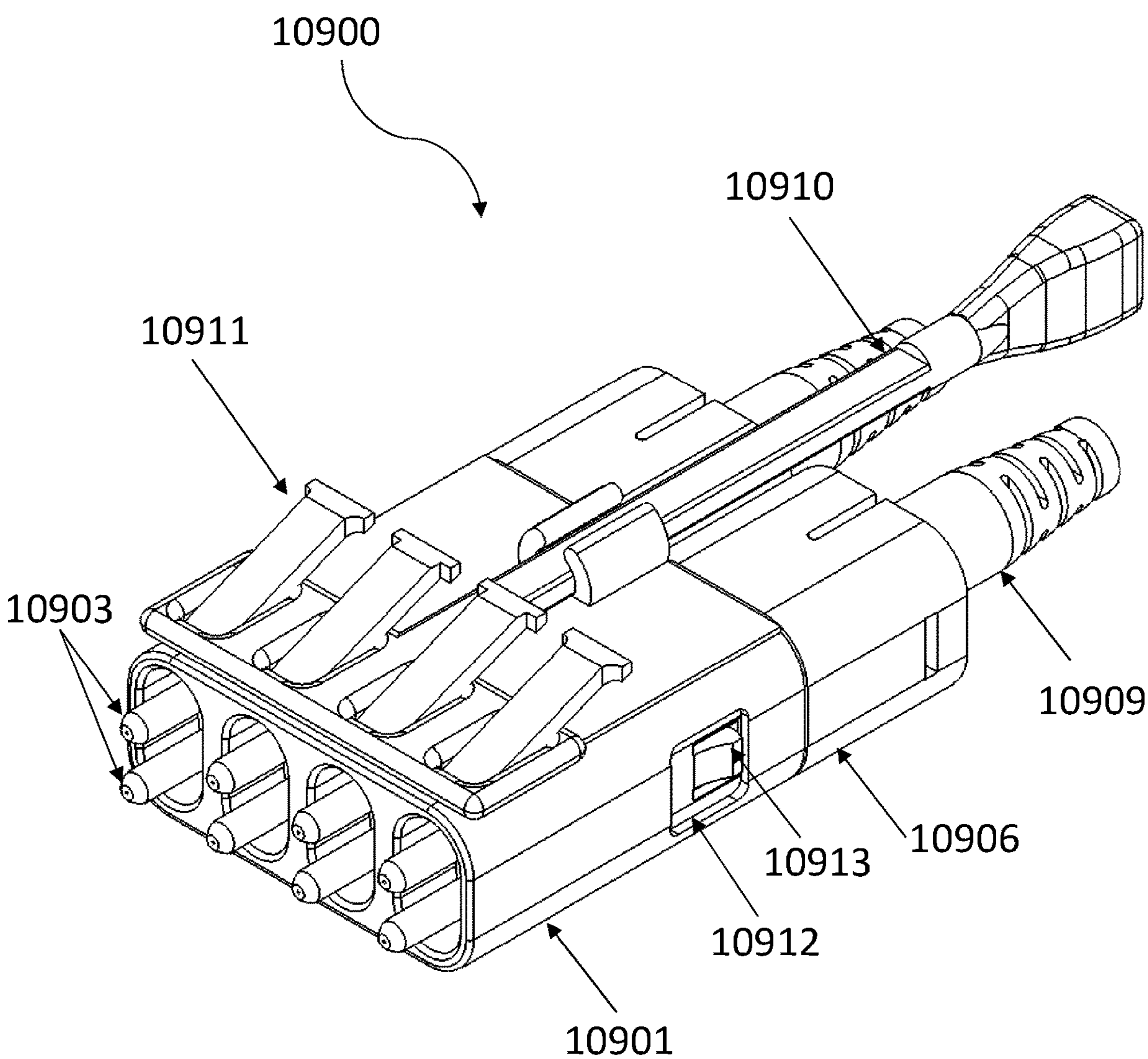


FIG.59

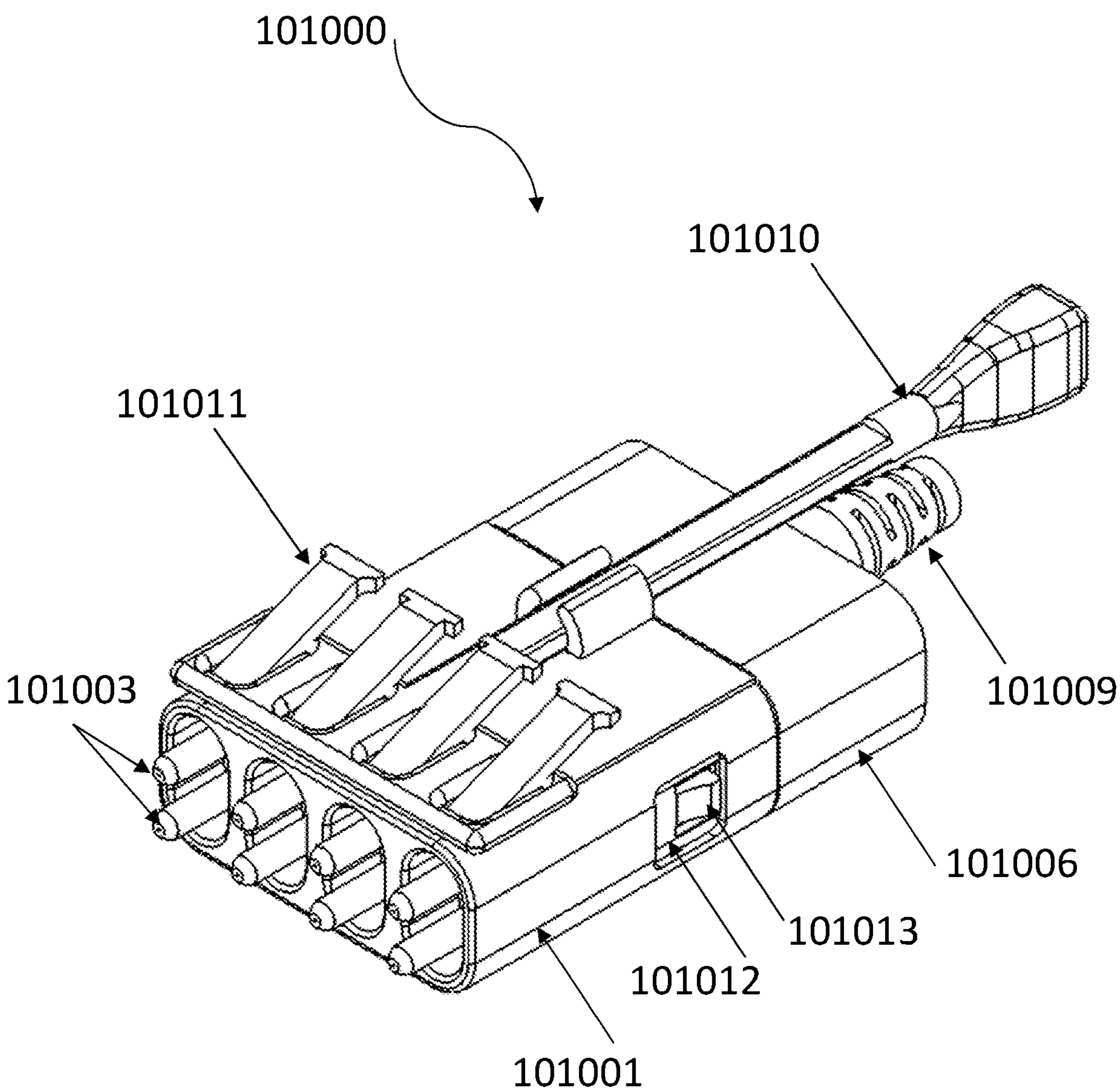

101000
101010
101011
101003
101009
101006
101013
101012
101001

FIG.60

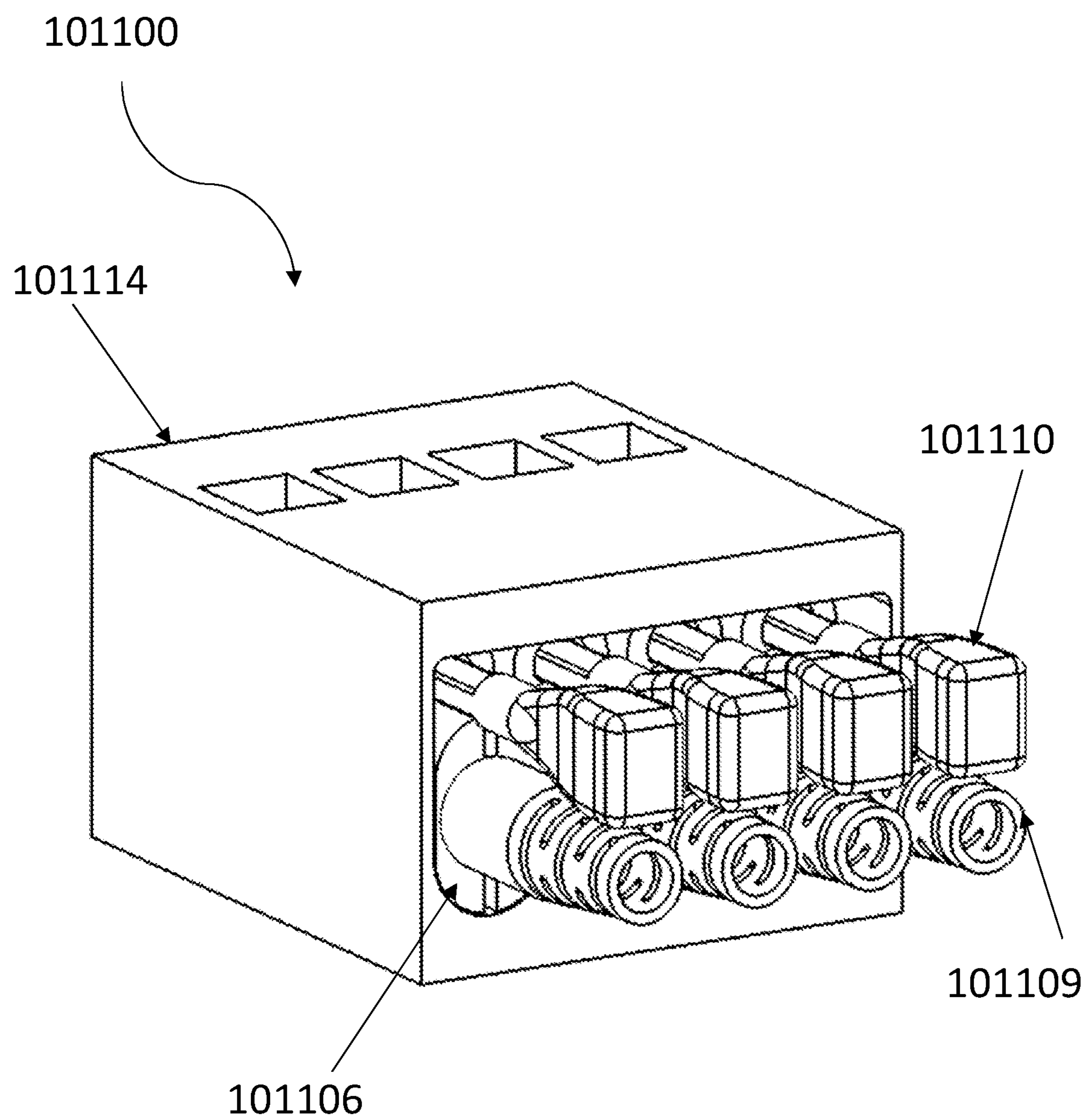


FIG.61

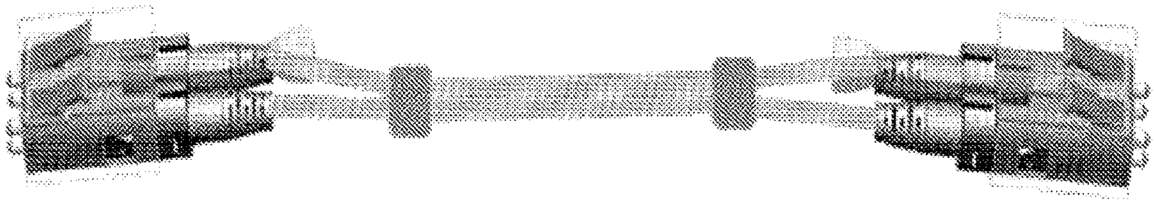


FIG. 62A

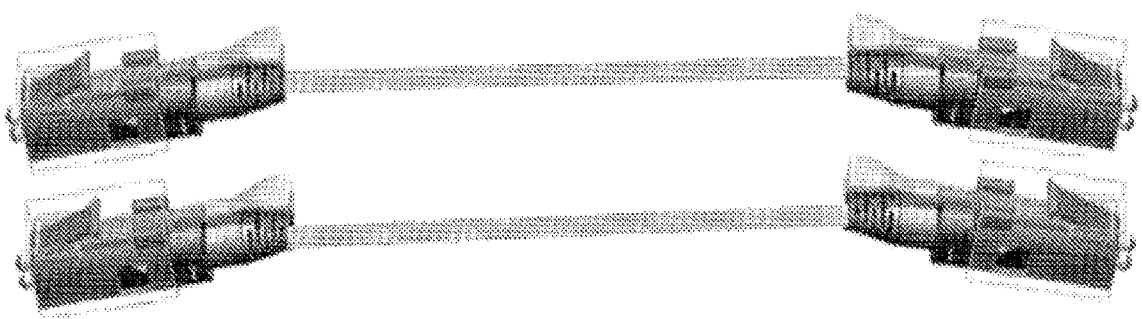


FIG. 62B

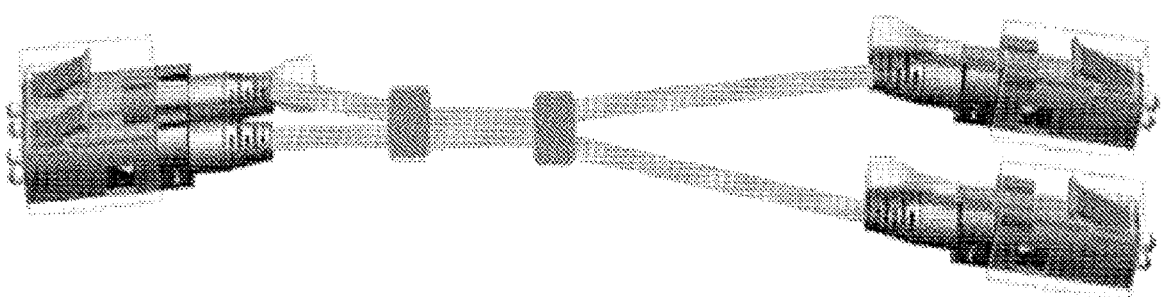


FIG. 62C

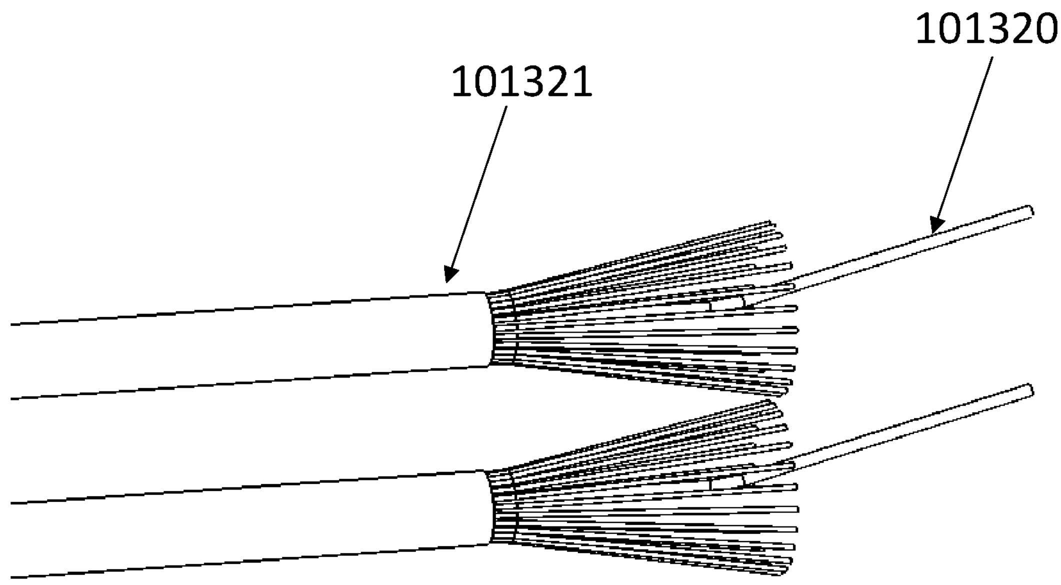


FIG.63A

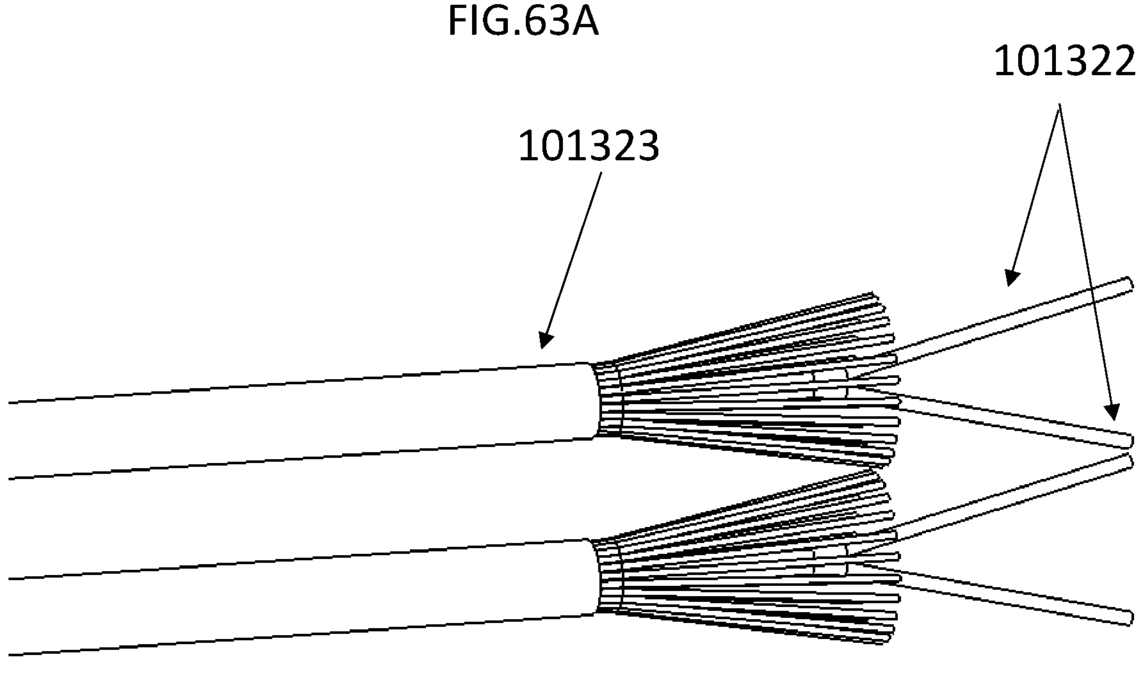
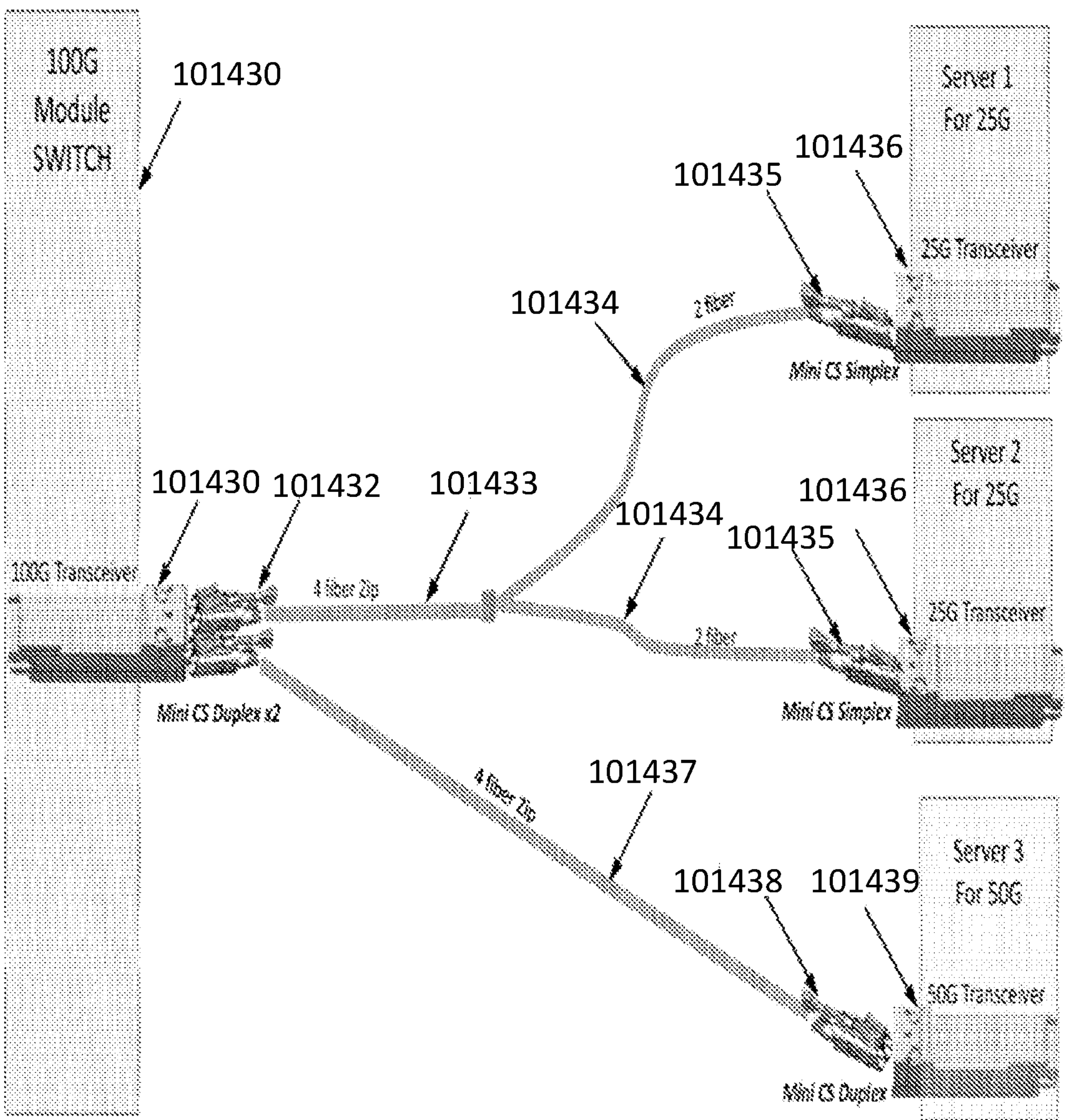


FIG.63B



100G Module SWITCH
101430
Server 1 For 25G
101436
101435
25G Transceiver
101434
2 fiber
Mini CS Simplex
Server 2 For 25G
101430
101432
101433
101434
101436
101435
100G Transceiver
4 fiber Zip
25G Transceiver
2 fiber
Mini CS Duplex x2
Mini CS Simplex
101437
4 fiber Zip
Server 3 For 50G
101438
101439
50G Transceiver
Mini CS Duplex

FIG.64

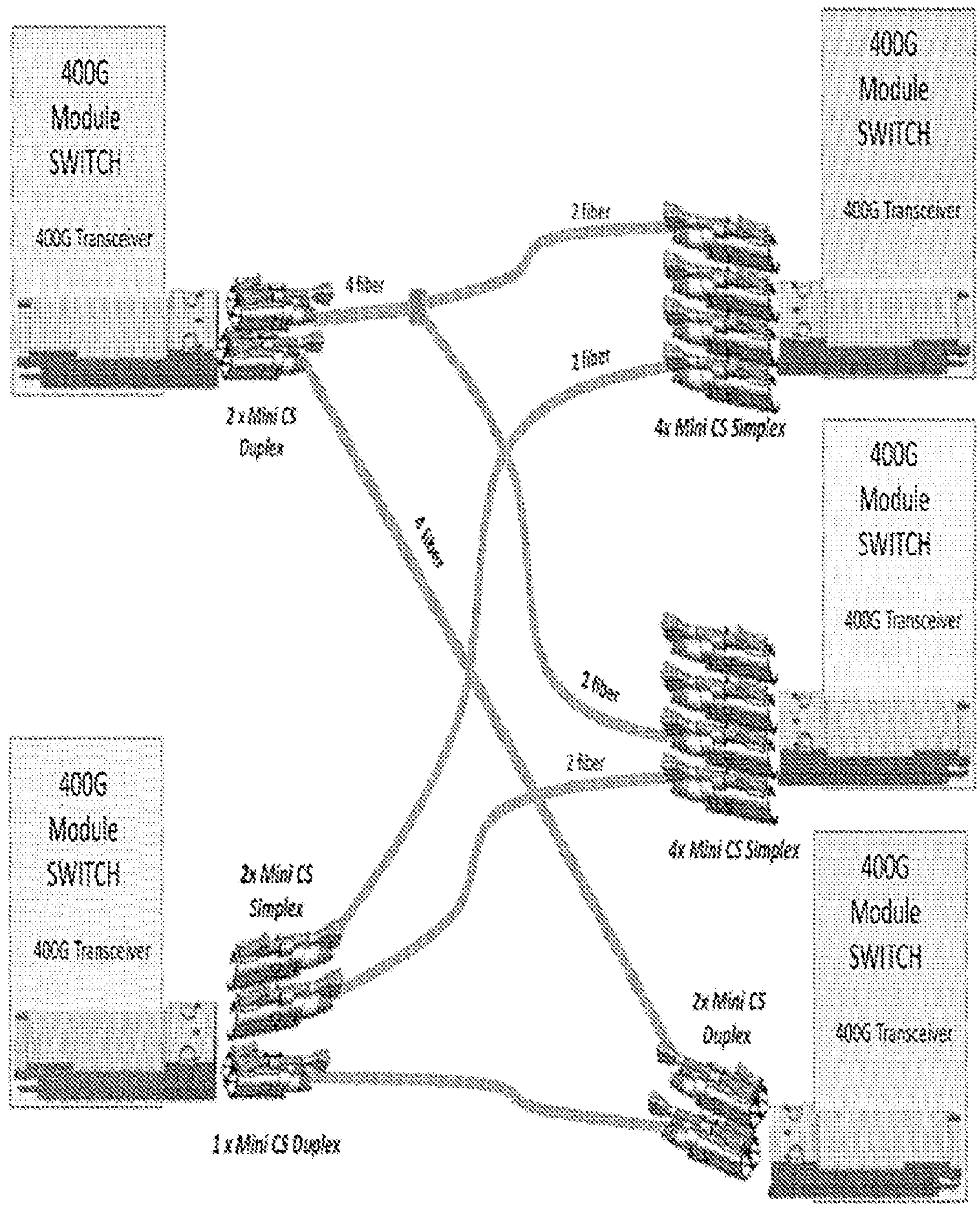

400G
Module
SWITCH
400G Transceiver
2 x Mini CS
Duplex
4 fiber
2 fiber
2 fiber
4x Mini CS Simplex
400G
Module
SWITCH
400G Transceiver
4 fibers
400G
Module
SWITCH
400G Transceiver
2 fiber
2 fiber
4x Mini CS Simplex
400G
Module
SWITCH
400G Transceiver
2x Mini CS
Simplex
400G
Module
SWITCH
400G Transceiver
2x Mini CS
Duplex
1 x Mini CS Duplex

FIG.65

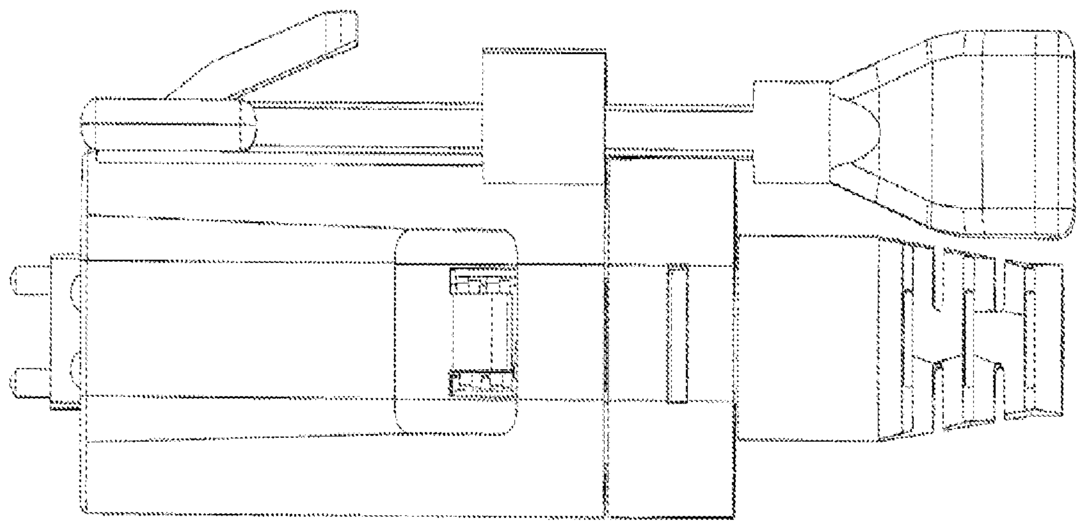


FIG.66A

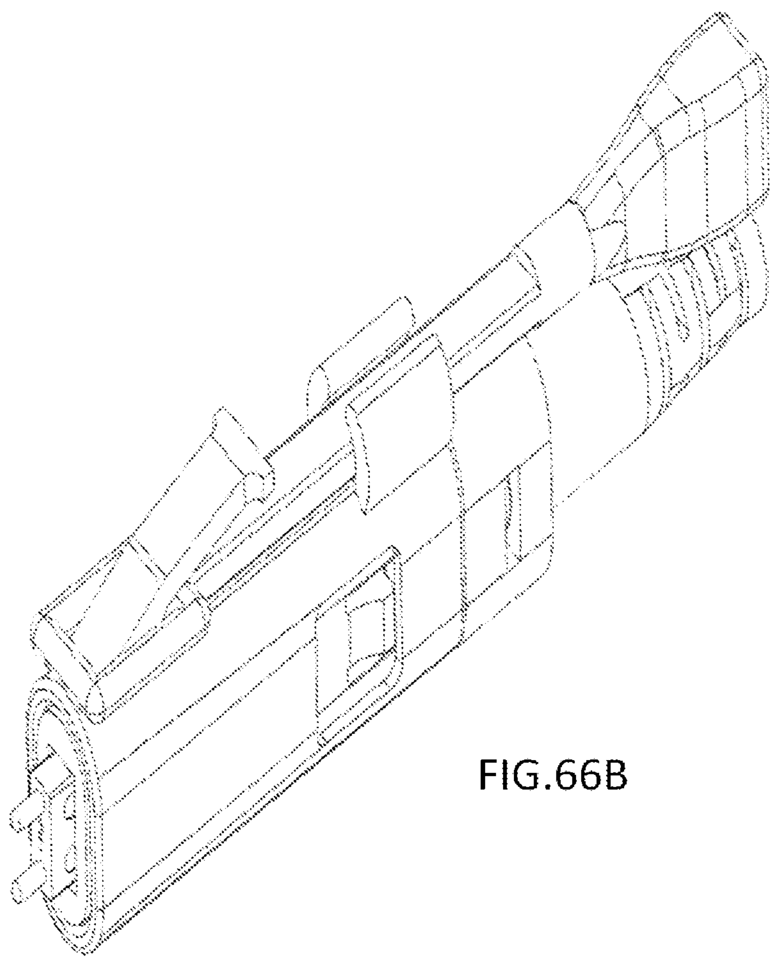


FIG.66B

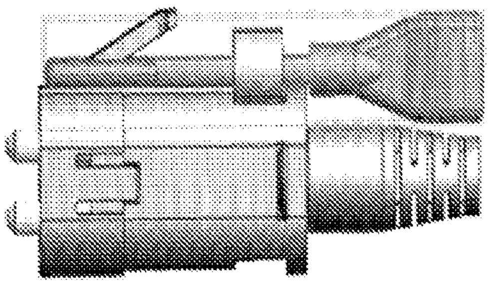


FIG.67A

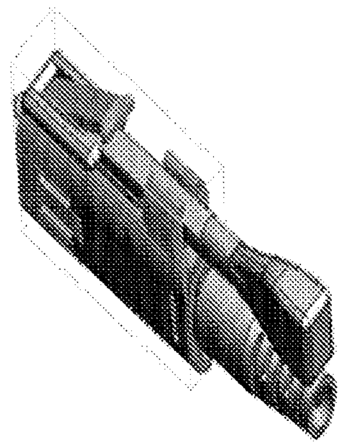


FIG.67B

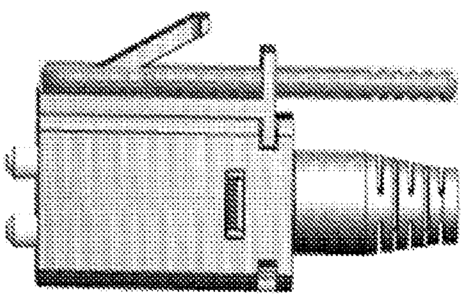


FIG.67C

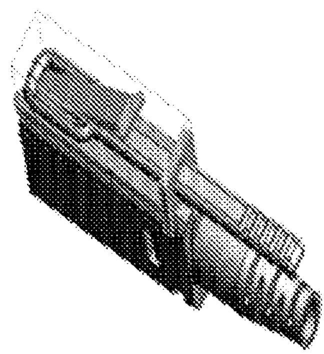


FIG.67D

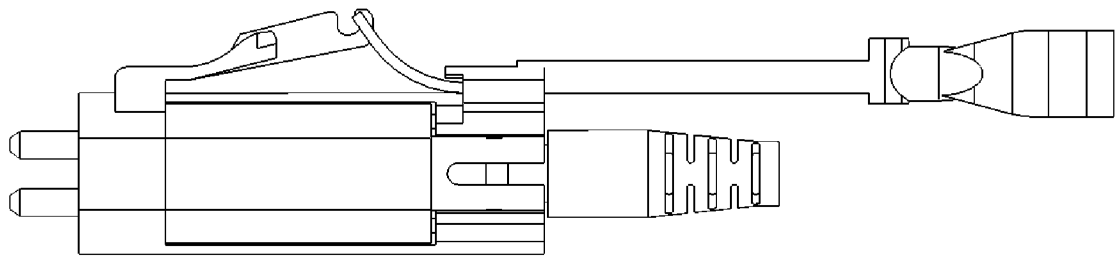


FIG.68A

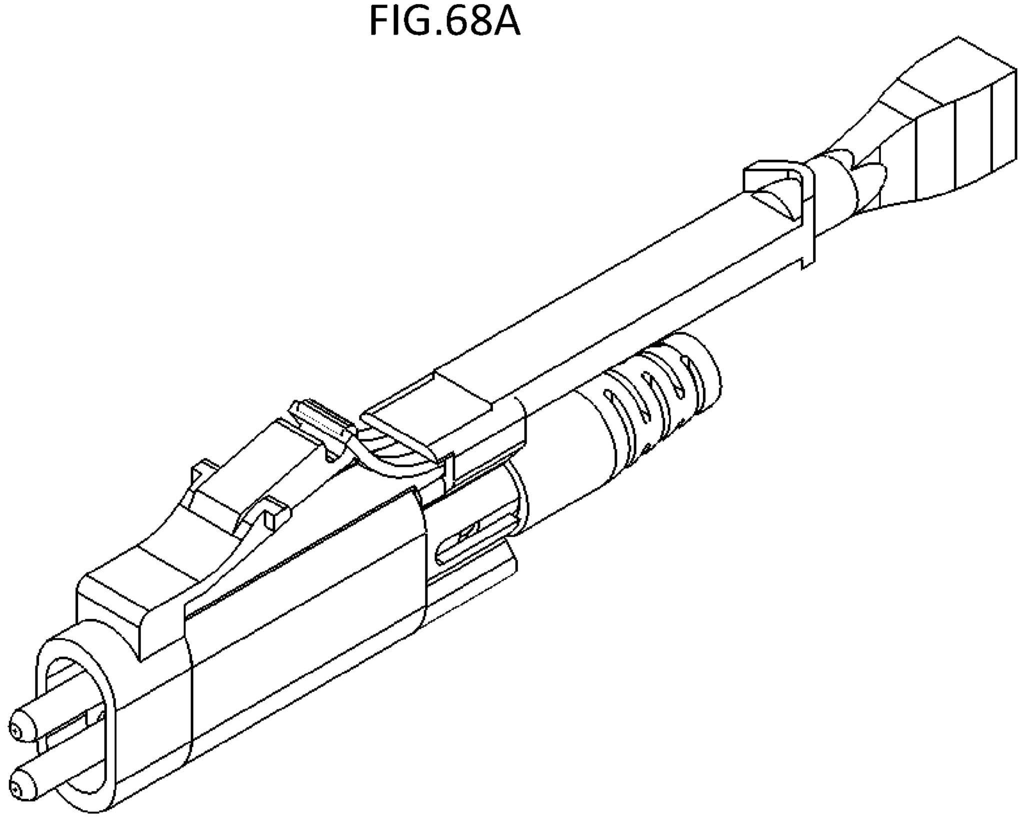


FIG.68B

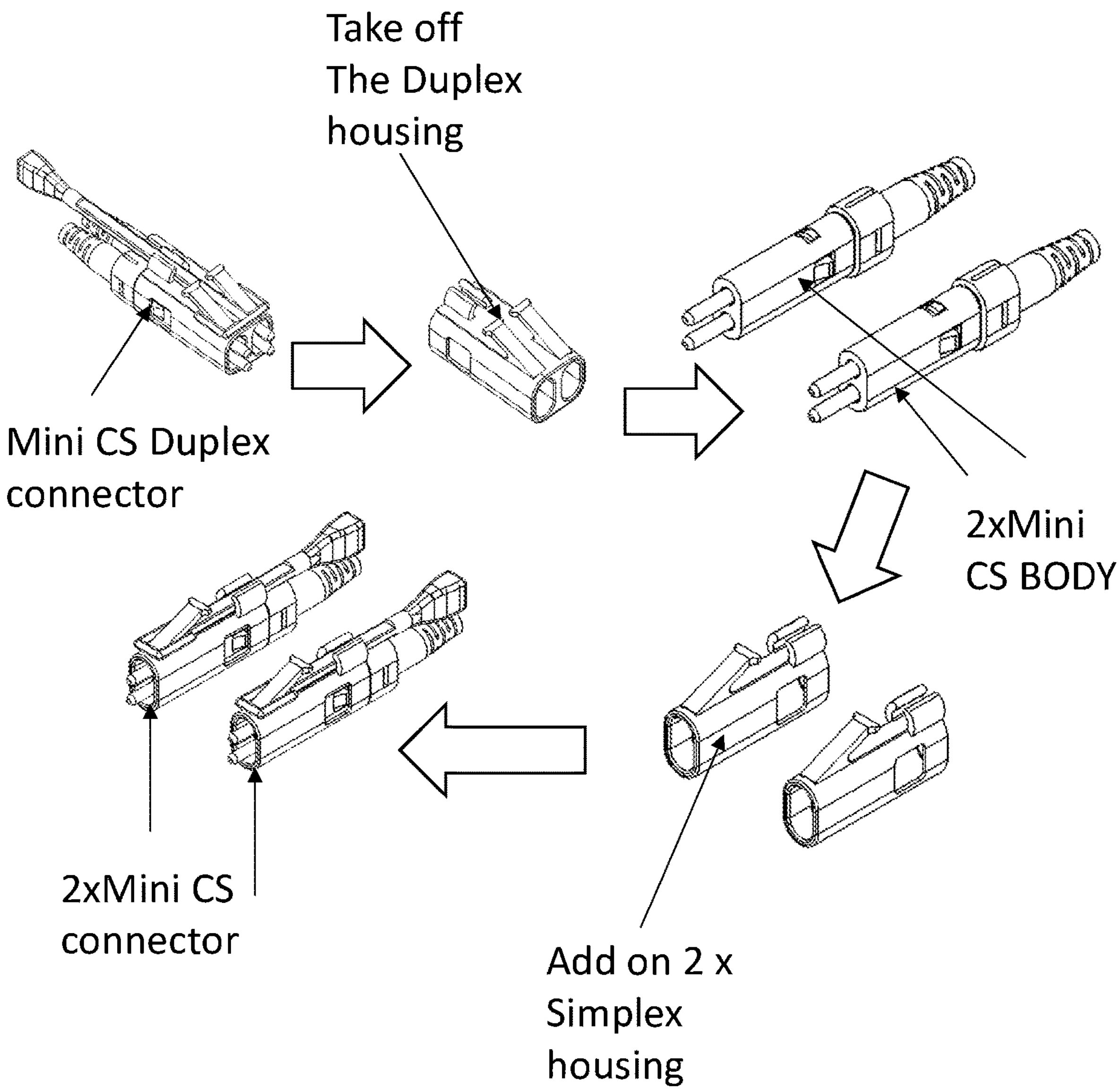

Take off
The Duplex
housing
Mini CS Duplex
connector
2xMini
CS BODY
2xMini CS
connector
Add on 2 x
Simplex
housing

FIG.69

ULTRA-SMALL FORM FACTOR OPTICAL CONNECTORS USED AS PART OF A RECONFIGURABLE OUTER HOUSING

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority as a continuation of U.S. patent application Ser. No. 17/591,298 filed on Feb. 2, 1922 entitled "Ultra-Small Form Factor Optical Connectors Used as Part of a Reconfigurable Outer Housing", which is a continuation of U.S. patent application Ser. No. 17/370,057 filed on Jul. 8, 1921 entitled "Ultra-Small Form Factor Optical Connectors Used as Part of a Reconfigurable Outer Housing", now U.S. Pat. No. 11,307,369 granted 04/19/22, which is a continuation of U.S. patent application Ser. No. 17/327,197 filed on May 21, 1921 entitled "Ultra-Small Form Factor Optical Connectors Used as Part of a Reconfigurable Outer Housing", now U.S. Pat. No. 11,340,413 granted 05/24/22, which is a continuation of Ser. No. 17/090,855 filed Nov. 5, 1920 entitled "Ultra-Small Form Factor Optical Connectors Used as a Part of a Reconfigurable Outer Housing", now U.S. Pat. No. 11,487,067 granted 11/01/22, which is a continuation of U.S. patent application Ser. No. 16/414,546 filed May 16, 2019 entitled "Ultra-Small Form Factor Optical Connectors Used as a Part of a Reconfigurable Outer Housing", now U.S. Pat. No. 10,859, 778 which is a continuation of U.S. patent application Ser. No. 16/388,053 filed Apr. 18, 2019 entitled "Ultra-Small Form Factor Optical Connectors", which is a continuation of U.S. patent application Ser. No. 16/035,691, filed Jul. 15, 2018 entitled "Ultra-Small Form Factor Optical Connectors" now U.S. Pat. No. 10,281,668 granted 05/17/19, which claims priority to the following: U.S. Provisional Patent Application Serial No. 62/588,276 filed Nov. 17, 2017, 62/549,655 filed Aug. 24, 2017, and, 62/532,710 filed Jul. 14, 2017, all the disclosures of which are incorporated by reference herein.

FIELD OF THE INVENTION

The present disclosure relates generally to ultra-small form factor optical connectors and related connections within adapters and optical transceivers.

BACKGROUND

The prevalence of the Internet has led to unprecedented growth in communication networks. Consumer demand for service and increased competition has caused network providers to continuously find ways to improve quality of service while reducing cost.

Certain solutions have included deployment of high-density interconnect panels. High-density interconnect panels may be designed to consolidate the increasing volume of interconnections necessary to support the fast-growing networks into a compacted form factor, thereby increasing quality of service and decreasing costs such as floor space and support overhead. However, room for improvement in the area of data centers, specifically as it relates to fiber optic connections, still exists. For example, manufacturers of connectors and adapters are always looking to reduce the size of the devices, while increasing ease of deployment, robustness, and modifiability after deployment. In particular, more optical connectors may need to be accommodated in the same footprint previously used for a smaller number of connectors in order to provide backward compatibility with existing data center equipment. For example, one current footprint is known as the small form-factor pluggable transceiver footprint (SFP). This footprint currently accommodates two LC type ferrule optical connections. However, it may be desirable to accommodate four optical connections (two duplex connections of transmit/receive) within the same footprint. Another current footprint is the quad small form-factor pluggable (QSFP) transceiver footprint. This footprint currently accommodates four LC-type ferrule optical connections. However, it may be desirable to accommodate eight optical connections of LC-type ferrules (four duplex connections of transmit/receive) within the same footprint.

In communication networks, such as data centers and switching networks, numerous interconnections between mating connectors may be compacted into high-density panels. Panel and connector producers may optimize for such high densities by shrinking the connector size and/or the spacing between adjacent connectors on the panel. While both approaches may be effective to increase the panel connector density, shrinking the connector size and/or spacing may also increase the support cost and diminish the quality of service.

In a high-density panel configuration, adjacent connectors and cable assemblies may obstruct access to the individual release mechanisms. Such physical obstructions may impede the ability of an operator to minimize the stresses applied to the cables and the connectors. For example, these stresses may be applied when the user reaches into a dense group of connectors and pushes aside surrounding optical fibers and connectors to access an individual connector release mechanism with his/her thumb and forefinger. Overstressing the cables and connectors may produce latent defects, compromise the integrity and/or reliability of the terminations, and potentially cause serious disruptions to network performance.

While an operator may attempt to use a tool, such as a screwdriver, to reach into a dense group of connectors and activate a release mechanism, adjacent cables and connectors may obstruct the operator's line of sight, making it difficult to guide the tool to the release mechanism without pushing aside the adjacent cables. Moreover, even when the operator has a clear line of sight, guiding the tool to the release mechanism may be a time-consuming process. Thus, using a tool may not be effective at reducing support time and increasing the quality of service.

SUMMARY OF THE INVENTION

An optical connector holding two or more LC-type optical ferrules is provided. The optical connector includes an outer body, an inner front body accommodating the two or more LC type optical ferrules, ferrule springs for urging the optical ferrules towards a mating receptacle, and a back body for supporting the ferrule springs. The outer body and the inner front body are configured such that four LC-type optical ferrules are accommodated in a small form-factor pluggable (SFP) transceiver footprint or eight LC-type optical ferrules are accommodated in a quad small form-factor pluggable (QSFP) transceiver footprint. A mating receptacle (transceiver or adapter) includes a receptacle hook and a housing with an opening that accommodates the receptacle hook in a flexed position as the optical connector makes connection with the mating receptacle by introducing the receptacle hook into an optical receptacle hook recess.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A is a perspective view of a prior art standard 6.25 mm pitch LC connector SFP;

FIG. **1**B is a perspective view of a prior art standard 6.25 mm pitch LC adapter;

FIG. **1**C is a top view of the prior art adapter of FIG. **1**B;

FIG. **1**D is a front view of the prior art adapter of FIG. **1**B, showing the 6.25 mm pitch;

FIG. **2**A is a perspective view of a prior art LC duplex connector;

FIG. **2**B is a perspective view of a prior art LC duplex connector with a remote release pull tab;

FIG. **2**C is a top view of a prior art LC connector used in the embodiments shown in FIGS. **2**A and **2**B;

FIG. **2**D is a side view of the prior art LC connector of FIG. **2**C;

FIG. **3** is an exploded view of one embodiment of a connector;

FIG. **4** is a perspective view of one embodiment of a connector;

FIG. **5** is a perspective view of one embodiment of a connector with the outer housing removed from the front body.

FIG. **6** is a perspective view of one embodiment of a duplex connector;

FIG. **7** is a perspective view of another embodiment of a duplex connector;

FIG. **8** is a perspective view of one embodiment of a quad connector;

FIG. **9** is another perspective view of one embodiment of a quad connector;

FIG. **10** shows various embodiments of adapter types;

FIG. **11**A is a side view of a connector connected to an adapter;

FIG. **11**B is a side view of a connector being removed from an adapter;

FIG. **12**A is a side view of the outer housing of a connector being removed;

FIG. **12**B is a perspective view of a transparent outer housing of a connector showing the front body;

FIG. **13** is a perspective view of one embodiment of a quad connector inserted into a corresponding adapter;

FIGS. **14**A-C are illustrative examples of cable management using various embodiments of connectors;

FIG. **15**A-B are illustrative examples of cable management using multiple fiber strands per jacket;

FIG. **16** is an illustrative example of using a cable management system using multiple fiber strands per jacket.

FIG. **17** is another illustrative example of using a cable management system using multiple fiber strands per jacket.

FIGS. **18**A-B are various views of one embodiment of a MT connector.

FIGS. **19**A-D are illustrative examples of possible alternative connector designs.

FIG. **20** shows moving two connectors from a duplex connector to two simplex connectors.

FIG. **21**A is an exploded view of a micro optical connector according to an embodiment.

FIG. **21**B is a perspective view of the assembled micro optical connector of FIG. **21**A.

FIG. **22** is a front view of the micro optical connector of FIG. **21**B showing overall connector dimensions and ferrule pitch.

FIG. **23**A is a cross-sectional view of the micro optical connector of FIG. **21**B latched into the adapter of FIG. **24**.

FIG. **23**B is a cross-sectional view of the micro optical connectors of FIG. **21**B unlatched from the adapter of FIG. **24**.

FIG. **24** is an exploded view of an adapter for the micro optical connectors of FIG. **21**B.

FIG. **25**A is a cross-sectional view of the adapter of FIG. **24**, assembled.

FIG. **25**B is a cross-sectional side view of the adapter housing of FIG. **24**.

FIG. **26** is a front view of the assembled adapter of FIG. **24**.

FIG. **27**A is an isometric view of the front body of the micro optical connector of FIG. **21**A.

FIG. **27**B is a right side view of the front body of FIG. **27**A.

FIG. **28**A is an isometric view of the back body of the micro optical connector of FIG. **21**A.

FIG. **28**B is a side view of the back body of FIG. **28**A.

FIG. **29**A is an isometric view of the outer housing of the micro optical connector of FIG. **21**A.

FIG. **29**B is a front view of the outer housing of FIG. **29**A.

FIG. **29**C is a cross-sectional view of the outer housing of FIG. **29**A showing the top of an orientation protrusion.

FIG. **29**D is an inner view of the outer housing of FIG. **29**A;

FIG. **29**E is an inner view of the outer housing of FIG. **29**A.

FIG. **30** is a side view of an adapter hook of the adapter of FIG. **24**.

FIG. **31** is an isometric view of the adapter of FIG. **24** assembled with the micro optical connectors of FIG. **21**B.

FIG. **32**A is cross-sectional view of a prior art connector showing a latch gap.

FIG. **32**B is a cross-sectional view of the micro optical connector of FIG. **21**B latched (left) and unlatched (right) within the adapter of FIG. **24**, assembled.

FIG. **33**A depicts the micro optical connector of FIG. **21**B in a QSFP footprint, depicting dimensions in millimeters.

FIG. **33**B depicts the micro optical connectors of FIG. **21**B in an SFP footprint, depicting dimensions in millimeters.

FIG. **34**A-**34**C depicts adapter hooks interacting with the micro optical connectors of FIG. **21**B before (FIG. **34**A), during (FIG. **34**B), and after (FIG. **34**C) latching.

FIG. **35**A-FIG. **35**C depicts the micro optical connector of FIG. **21**B side flap operation before (FIG. **35**A), during (FIG. **35**B), and after (FIG. **35**C) latching.

FIG. **36**A depicts plural micro optical connectors in a transceiver.

FIG. **36**B is a front view of the transceiver of FIG. **36**A.

FIG. **37** is an exploded view of a micro optical connector according to a further embodiment.

FIG. **38** is an isometric view of a front body of the micro optical connector of FIG. **37**.

FIG. **39** is an isometric view of a back body of the micro optical connector of FIG. **37**.

FIGS. **40**A, **40**B, and **40**C depict a technique for reversing polarity of the optical connector of FIG. **37**.

FIG. **41** is an exploded view of a micro optical connector according to a further embodiment.

FIG. **42**A is an isometric view of the front body of the micro optical connector of FIG. **41**.

FIG. **42**B is a side view of the front body of FIG. **42**A.

FIG. **43** is an isometric view of the back body of the micro optical connector of FIG. **41**.

FIGS. **44**A, **44**B, and **44**C are isometric views of the outer housings that may be used with any of the micro optical connectors of FIGS. **21**A, **37**, and **41**.

FIG. **45** is an exploded view of an adapter according to a further embodiment.

FIG. **46** is a cross-section of the adapter of FIG. **45**, assembled.

FIG. **47** is an exploded view of a connector according to another embodiment.

FIG. **48** is an isometric view of the back body and the back post of the connector of FIG. **47**.

FIG. **49** is a cross-section of the back post of FIG. **47** assembled with optical fibers.

FIG. **50** is a front view of the connector of FIG. **47**.

FIG. **51** is an isometric view of the boot of the connector of FIG. **47**.

FIG. **52** is a front view of the adapter of FIG. **45**.

FIG. **53** is a exploded view of one embodiment of a connector;

FIG. **54** is a perspective view of one embodiment of a connector;

FIG. **55** is a perspective view of one embodiment of a connector with the outer housing removed from the front body

FIG. **56** is a perspective view of one embodiment of a duplex connector;

FIG. **57** is a perspective view of another embodiment of a duplex connector;

FIG. **58** is a perspective of one embodiment of a quad connector;

FIG. **59** is a perspective of another embodiment of a quad connector;

FIG. **60** is a perspective of another embodiment of a quad connector;

FIG. **61** is a perspective of one embodiment of a quad connector inserted into a corresponding adapter;

FIGS. **62**A-C are illustrative examples of cable management using various embodiments of connectors;

FIG. **63**A-B are illustrative examples of cable management using multiple fiber strands per jacket;

FIG. **64** is an illustrative example of using a cable management system using multiple fiber strands per jacket.

FIG. **65** is another illustrative example of using a cable management system using multiple fiber strands per jacket;

FIG. **66**A-B are various views of one embodiment of a MT connector.

FIGS. **67**A-D are illustrative examples of possible alternative connector designs.

FIGS. **68**A-B are illustrative examples of additional possible alternative connector designs.

FIG. **69** is an illustrative examples of a method of switching modes of operation of one or more connectors.

DETAILED DESCRIPTION

This disclosure is not limited to the particular systems, devices and methods described, as these may vary. The terminology used in the description is for the purpose of describing the particular versions or embodiments only, and is not intended to limit the scope.

As used in this document, the singular forms "a," "an," and "the" include plural references unless the context clearly dictates otherwise. Unless defined otherwise, all technical and scientific terms used herein have the same meanings as commonly understood by one of ordinary skill in the art. Nothing in this disclosure is to be construed as an admission that the embodiments described in this disclosure are not entitled to antedate such disclosure by virtue of prior invention. As used in this document, the term "comprising" means "including, but not limited to."

The following terms shall have, for the purposes of this application, the respective meanings set forth below.

A connector, as used herein, refers to a device and/or components thereof that connects a first module or cable to

a second module or cable. The connector may be configured for fiber optic transmission or electrical signal transmission. The connector may be any suitable type now known or later developed, such as, for example, a ferrule connector (FC), a fiber distributed data interface (FDDI) connector, an LC connector, a mechanical transfer (MT) connector, a square connector (SC) connector, a CS connector, or a straight tip (ST) connector. The connector may generally be defined by a connector housing body. In some embodiments, the housing body may incorporate any or all of the components described herein.

A "fiber optic cable" or an "optical cable" refers to a cable containing one or more optical fibers for conducting optical signals in beams of light. The optical fibers can be constructed from any suitable transparent material, including glass, fiberglass, and plastic. The cable can include a jacket or sheathing material surrounding the optical fibers. In addition, the cable can be connected to a connector on one end or on both ends of the cable.

Various embodiments described herein generally provide a remote release mechanism such that a user can remove cable assembly connectors that are closely spaced together on a high density panel without damaging surrounding connectors, accidentally disconnecting surrounding connectors, disrupting transmissions through surrounding connectors, and/or the like. Various embodiments also provide narrow-pitch LC duplex connectors and narrow-width multi-fiber connectors, for use, for example, with future narrow-pitch LC SFPs and future narrow width SFPs. The remote release mechanisms allow use of the narrow-pitch LC duplex connectors and narrow-width multi-fiber connectors in dense arrays of narrow-pitch LC SFPs and narrow-width multi-fiber SFPs.

FIG. **1**A shows a perspective view of a prior art standard 6.25 mm pitch LC connector SFP **100**. The SFP **100** is configured to receive a duplex connector and provides two receptacles **102**, each for receiving a respective LC connector. The pitch **104** is defined as the axis-to-axis distance between the central longitudinal axes of each of the two receptacles **102**. FIG. **1**B shows a perspective view of a prior art standard 6.25 mm pitch LC adapter **106**. The adapter **106** is also configured to receive a duplex connector, and provides two receptacles **108**, each for receiving a respective LC connector. FIG. **1**C is a top view of the adapter **106** of FIG. **1**B. The pitch of the adapter **106** is defined similarly to that of the SFP **100**, as the axis-to-axis distance between the central longitudinal axes of each of the two receptacles **108**, as illustrated in FIG. **1**D, which shows a front view of the adapter **106**.

FIG. **2**A shows a prior art LC duplex connector **200** that may be used with the conventional SFP **100** and the conventional adapter **106**. The LC duplex connector **200** includes two conventional LC connectors **202**. FIG. **2**B shows another prior art LC duplex connector **204** having a remote release pull tab **206**, and including two conventional LC connectors **208**. As shown, the remote release pull tab includes two prongs **210**, each configured to couple to the extending member **212** of a respective LC connector **208**. FIGS. **2**C and **2**D show top and side views, respectively, of the conventional LC connector **208**, having a width of 5.6 mm, and further showing the extending member **212**.

As discussed herein, current connectors may be improved by various means, such as, for example, reducing the footprint, increasing the structural strength, enabling polarity changes, etc. Various embodiments disclosed herein offer improvements over the current state of the art, as will be further discussed below.

In some embodiments, as shown in FIG. **3**, a connector **300** may comprise various components. Referring to FIG. **3**, an illustrative embodiment of a connector **300** is shown in an exploded view to display detail. In some embodiments, and as discussed further herein, a connector **300** may have an outer housing **301**, a front body **302**, one or more ferrules **303**, one or more ferrule flanges **304**, one or more springs **305**, a back body **306**, a back post **307**, a crimp ring **308**, and a boot **309**. In some embodiments, the back body **306** may comprise one or more protrusions **306.1** which may interlock with a window/cutout **302.1** in the front body **302**. This may allow for the back body **306** and the front body **302** to be securely fastened together around the ferrule(s) **303**, ferrule flange(s) **304**, and the spring(s) **305**. The elements of FIG. **3** are configured such that two optical connectors having four LC-type optical ferrules may be accommodated in a small form-factor pluggable (SFP) transceiver footprint or at least two optical connectors having a total of eight LC-type optical ferrules may be accommodated in a quad small form-factor pluggable (QSFP) transceiver footprint.

Referring now to FIG. **4**, an embodiment is shown wherein the connector **400** is assembled. In some embodiments, the assembled connector may have an outer housing **401**, a front body **402** positioned within the outer housing, one or more ferrules **403**, one or more ferrule flanges (not shown), one or more springs (not shown), a back body **406**, a back post (not shown), a crimp ring (not shown), a boot **409**, and a push-pull tab **410**. In some embodiments, the connector may have one or more latching mechanisms made up of a window **412** on the outer housing **401** near the push-pull tab **410** and a protrusion **413** on the front body. The latching mechanism made up of the window **412** and protrusion **413** securely attaches the outer housing **401** to the front body **402**. In a further embodiment, the outer housing **401** may have a recess **411** to receive a locking tab or locking mechanism from an adapter (depicted in FIG. **13**, below). The recess **411** of the outer housing **401** is used to interlock with an adapter (depicted in FIG. **13**, below) or transceiver receptacle to secure the connector into the adapter. As would be understood by one skilled in the art, the push-pull tab **410** enables removal of the connector from a receptacle without requiring additional tools. Alternatively, the push-pull tab may be eliminated and the connector removed manually. In one or more further embodiments, the outer housing **401** may also have a key **414**. The key **414** may keep the connector in a given orientation when inserted into a receptacle such as an adapter or transceiver.

FIG. **5** depicts a procedure for changing the polarity of the optical connectors of the present disclosure. As shown in FIG. **5**, in some embodiments, the latching mechanism of the connector **500** may be made up of two main parts: a window (not visible) and one or more protrusions **513**. As illustrated in FIG. **5**, the outer housing **501** can slide on to or be removed from the front body **502** by disengaging the latching mechanisms formed by the protrusion **513** exiting through the window, whereby it contacts a rear wall of the window (refer to FIG. **4** for an illustrated example of the outer housing being attached to the front body via the latching mechanism). In some embodiments, the push-pull tab **510** may be permanently attached to the outer housing **501**, as shown.

The front body **502** may be removed from the outer housing **501**, rotated 180° as indicated by arrow **520**, and re-inserted into the outer housing. This allows for a change in the polarity of the front body **502**, as shown by the arrow diagram in FIG. **5**, and therefore the ferrules can switch quickly and easily without unnecessarily risking the delicate fiber cables and ferrules.

In some embodiments, it may be beneficial to connect two or more connectors together to increase structural integrity, reduce the overall footprint, and cut manufacturing costs. Accordingly, as shown in FIG. **6**, a connector **600** may in some embodiments, utilize an outer housing **601** that is capable of holding two front bodies **602**. Various other embodiments are disclosed herein, and it should be noted that the embodiments disclosed herein are all non-limiting examples shown for explanatory purposes only.

Accordingly, although the embodiment shown in FIG. **6** utilizes a duplex outer housing **601**, additional or alternative embodiments may exist with more capacity, for example, six or eight optical connectors within a single outer housing. As shown in FIG. **6**, in some embodiments, the outer housing **601** may accept two front bodies **602**, each with two separate ferrules **603**. As shown, the front body(s) **602** may securely fasten to the outer housing **601** via the latching mechanism **612** and **613**. In additional embodiments, the push-pull tab **610** may be modified, as shown, such that a single tab can be used to free the two or more connectors from an adapter. As illustrated in FIG. **6**, the uni-body push-pull tab **610** and the outer housing **601** may have two windows **612** with which to receive multiple protrusions **613** of the front body(s) **602**. As discussed herein the recesses **611** of the outer housing **601** are used to secure the connectors to an adapter (depicted in FIG. **13** below). In one or more further embodiments, the connectors may have individual back bodies **606** and boots **609** (i.e., one back body/boot per front body) as shown.

Alternatively, in some embodiments, such as that shown in FIG. **7**, the connector **700** may have a single boot **709** and a duplex (i.e., uni-body) back body **706** instead of individual back bodies (e.g., such as shown in FIG. **6**). In some embodiments, the duplex back body **706** may have different dimensions than that of the individual back bodies of FIG. **6**, such as, for example, they may be longer to accommodate the need for routing the fiber after it exits the boot **709**. As with other embodiments discussed herein, the connector shown in FIG. **7** may also include an outer housing (e.g., duplex outer housing) **701**, one or more ferrules **703**, at least one latching mechanism formed by the protrusion (not shown) exiting through one or more windows **712**, and a push-pull tab **710**.

As stated, it may be beneficial to connect two or more connectors together to increase structural integrity, reduce the overall footprint, and cut manufacturing costs. Accordingly, similar to FIG. **6**, FIG. **8** shows a connector **800** that may, in some embodiments, utilize an outer housing **801** that is capable of holding multiple (e.g., four) front bodies **802**.

As shown in FIG. **8**, some embodiments may have an outer housing **801** able to accept up to four front bodies **802**, each with one or more ferrules **803**. As shown, each front body **802** may securely fasten to the outer housing **801** via the latching mechanism **812** and **813**. In additional embodiments, the push-pull tab **810** may be modified such that a single tab can be used to remove the up to four connectors from an adapter. As illustrated in FIG. **8**, the push-pull tab **810** may include four recesses **811**, which as discussed herein are used to secure the connector to a receptacle such as an adapter (shown in FIG. **13**, below) or the front receptacle portion of a transceiver. In one or more further embodiments, the connectors may have individual back bodies **806** and boots **809** (i.e., one back body/boot per front body) as shown.

Similar to FIG. **8**, FIG. **9** shows an embodiment where the outer housing **901** is able to accept up to four front bodies **902**, each with one or more ferrules **903**. As shown, each front body **902** may securely fasten to the outer housing **901** via the latching mechanism **912** and **913**. In additional embodiments, the push-pull tab **910** may be modified such that a single tab can be used to remove the up to four CS connectors from an adapter. As illustrated in FIG. **9**, the push-pull tab **910** may include four recesses **911**, which as discussed herein are used to secure the connector to an adapter (shown in FIG. **13**, below) or the optical receptacle portion of a transceiver. The FIG. **9** embodiment may utilize a single back body **906** and a single boot **909**. In one or more further embodiments, the connectors may have individual back bodies **906** and boots **909** (i.e., one back body/boot for all four front bodies) as shown.

In another aspect, the present disclosure provides method for reconfiguring optical cables in which the outer housings of the connectors may be removed and the remaining portion of the assembled connector is inserted into a housing having a larger or smaller capacity.

For example, the outer housings of plural two-ferrule capacity housings may be removed and the connector inner body and associated components inserted into a second outer housing that has either a four-ferrule or eight-ferrule capacity. Alternatively, an outer housing with a four-ferrule capacity may be removed and the inner bodies and associated components are inserted into two second outer housings, each of the two second housings having a two-ferrule capacity. Similarly, an outer housing with an eight-ferrule capacity may be removed and replaced by two four-ferrule capacity housing or a four-ferrule capacity and two two-ferrule capacity housings. In this manner, cables may be flexibly reconfigured to match the capacity of a mating optical-electrical component such as a transceiver. This aspect of the present disclosure is demonstrated in connection with FIG. **10**.

Referring now to FIG. **10**, various embodiments may exist such as a single housing **1001** which receives a single connector **1002**. Additional embodiments may also exist, such as a duplex housing **1003** which receives two connectors **1004** and/or a quad housing **1005** which may receive up to four connectors **1006**. It should be understood by one skilled in the art that various other embodiments may exist that are not explicitly shown. For example, a housing with the capacity for 5, 6, 7, 8, 9, 10 or more connectors may be utilized for various embodiments disclosed herein. As shown below, it is desirable to have flexible housing configurations so that connectors may be grouped and ungrouped between optical and optoelectronic components such as adapters and transceivers.

Alternatively, in some embodiments the connector may utilize one or more duplex back bodies with a single boot, similar to that shown in FIG. **7**. Thus, similar to FIG. **7**, an embodiment may allow for a further reduced footprint, less cabling, and easier maintenance of the connector. Accordingly, one or more embodiments may have an outer housing that may accept up to four front bodies, each with one or more ferrules. In some embodiments, each front body may securely fasten to the outer housing via a latching mechanism. In additional embodiments, the push-pull tab may be modified such that a single tab can be used to free the up to four front bodies from an adapter. The push-pull tab may include four openings with which to receive multiple locking tabs of the outer housing. As discussed herein the locking tabs of the outer housing are used to secure the connectors to an adapter (shown in FIG. **13**) or the optical receptacle portion of a transceiver.

In further embodiments, the connector may utilize a single uni-body back body with a single boot (i.e., as shown in FIG. **9**). Thus, an embodiment may allow for a further reduced foot print, less cabling, and easier maintenance of the connector. Accordingly, one or more embodiments may have an outer housing that may accept up to four front bodies, each with one or more ferrules. Each front body may securely fasten to the outer housing via the latching mechanism as discussed herein. In additional embodiments, the push-pull tab may be modified such that a single tab can be used to remove up to four connectors from an adapter. The push-pull tab may include four openings with which to receive multiple locking tabs of the outer housing. As discussed herein the locking tabs of the outer housing are used to secure the connectors to an adapter.

The optical connectors of the present disclosure are all configured to be received in a receptacle. As used herein, the term "receptacle" relates generically to a housing that receives an optical connector. A receptacle includes both optical adapters, that is, components that mate two or more optical connectors, and transceivers, which include an optical receptacle to hold connectors that are to communicate with an optoelectronic component (e.g., a component that converts optical signals to electrical signals). As shown in FIG. **11**A, in one embodiment **1100**A, the outer housing **1101** may comprise one or more recesses **1111**. As discussed and shown herein, the one or more recesses may allow for a receptacle **1114** to securely connect to the connector **1100**A. Accordingly, in some embodiments, the receptacle **1114** may have a receptacle hook **1115**, which is flexible and can secure the connector **1100**A into the receptacle via latching onto the wall of the recess **1111**, as shown. This latching takes place when the outer housing **1101** is pushed forward into the receptacle. The sloped portions of the outer housing **1101** allow the receptacle hook **1115** to slide up and over the front of the outer housing thereby securing the connector **1100**A into the receptacle.

Additionally, or alternatively, in some embodiments, such as that shown in FIG. **11**B, a connector **11001**B may be removed from a receptacle **1114** by pulling the connector away from the adapter as indicated by the directional arrow. In some embodiments, the force may be applied by a user via the push-pull tab **1110**. Alternatively, when a push-pull tab is not present, the connector may still be manually removed from a receptacle. As shown in FIG. **11**B, as the connector **1100**B is removed from the receptacle **1114**, the flexible receptacle hooks **1115** separate and slide up the slope of the end of the connector and allow for removal of the connector from the receptacle.

Referring now to FIGS. **12**A and **12**B, as discussed herein and previously shown in FIG. **5**, the front body **1202** can be removed from the outer housing **1201**. In some embodiments, a portion of the outer body **1201** can be flexibly extended away from the front body **1202** as shown by the arrows in FIG. **12**A. As discussed herein, in some embodiments, the front body **1202** may comprise a protrusion **1213** which interlocks with a window (not shown) on the outer housing **1201**. Accordingly, when force is applied to the outer housing **1201** in a manner that removes the one or more protrusions **1213** from the one or more windows (not shown, see FIG. **4**), the front body **1202** may be removed from the outer housing.

Referring now to FIG. **13**, an embodiment **1300** is shown in which the connector (not shown in its entirety) is inserted into a receptacle such as adapter **1314**. In this specific non-limiting example, the connector is similar to that shown in FIG. **8** (i.e., comprising four front bodies each with their own back body **1306** and boot **1309**). However, unlike FIG. **8**, the embodiment shown here utilizes four individual push-pull tabs **1310** instead of a duplex push-pull tab system which manipulates two latching tabs per push-pull tab to allow the connector to be removed from the adapter **1314**.

Various benefits and details have been discussed herein with regard to the connectors and their modular ability (e.g., to include multiple connectors into a single housing). In addition to the reduced footprint, structural improvements, and cost reduction, various embodiments herein may also be beneficial with regard to reducing the burden of cabling in a data center environment. Illustrative embodiments shown in FIGS. **14**A through **14**C depict cable configurations that may be used to reduce the complexity of optical cables in a compact environment. Note that any of the optical connectors described in this disclosure may be used in these embodiments, including the optical connectors of FIGS. **21**B, **37**, and **41**, to be discussed in detail below. FIG. **14**A shows two duplex cables similar to the cable shown in FIG. **6**. In some embodiments, one or more detachable clips **1401** may be attached to two or more zip cables to prevent the zip cables from detaching. This allows for two or more cables to be bundled and reduce the risk of entanglement with additional cables. FIG. **14**B is an illustrative example of how easily an embodiment can separate into two individual connectors by unbinding the cables and thus quickly and easily creating two independent fiber optic channels that can move and be connected independently. FIG. **14**C shows an embodiment in which a duplex connector like that of FIGS. **6** and **14**A is connected to two separate individual connectors. Through the variable housing configurations depicted above in FIG. **10**, the cable of FIG. **14**A can be reconfigured as the cables of either **14**B or FIG. **14**C.

In addition to binding existing fiber cables, some embodiments herein may utilize a new four fiber zip cable. Referring now to FIG. **15**A, a conventional zip cable (i.e., one with a single fiber strand **1520** per jacket **1521**) is shown in comparison with an embodiment in which two fibers **1522** per jacket **1523** are utilized. It should be understood that this is merely a non-limiting example. In some embodiments, multiple fibers may be included per jacket, such as, for example, four fibers per jacket in order to utilize the single boot **909** and uni-body rear body **906** of the connector shown in FIG. **9**.

A specific example using multi-strand cables is shown in FIG. **16** for illustrative purposes only. It should be understood that numerous alternatives and modifications are possible, such as, for example, that shown in FIGS. **18**A-**18**B and FIGS. **19**A-**19**D. As shown, a switch (e.g., **100**G switch) **1630** is shown with a transceiver (e.g., **100**G transceiver) **1631**. The transceiver **1631** has a receptacle to receive duplex connectors **1632**. From each of the two duplex connectors **1632**, a four fiber cable **1633** extends to connect to various other connectors and transceivers. In some embodiments, as discussed herein, a clip (e.g., detachable clip) **1640** may connect two or more cables (e.g., **1633**) to ensure the zip cables do not come apart. As shown, one four fiber cable **1633** is split into two two-fiber cables **1634**, which are then each attached to a single simplex connector **1635** and placed into a transceiver (e.g., **25**G transceiver) **1636**. As further shown, one of the four fiber cables **1637** is connected to a single duplex connector **1638**, which is then inserted into another transceiver (e.g., **50**G transceiver) **1639**.

An additional or alternative embodiment is shown in FIG. **17**. As shown, one or more switches (e.g., **400**G switches) **1730** and **1732** are shown each with a transceiver (e.g., **400**G transceiver) **1731** and **1733**. The first transceiver **1731** has a receptacle that is receiving two simplex (single) connectors **1734** and one duplex (dual) connector **1735**. From each of the two simplex connectors **1734**, a two fiber cable **1736** extends to connect to various other connectors and transceivers. Similar to FIGS. **14** and **16**, some embodiments may have a clip (e.g., detachable clip) **1740** that may connect two or more cables (e.g., **1736**, **1738**, etc.) to ensure the zip cables do not come apart. From the duplex connector **1735** a four-fiber cable **1737** is split into two two-fiber cables **1738**, which are then each attached to a single simplex connector each and placed into a transceiver (e.g., **400**G transceiver).

Accordingly, embodiments described herein allow for improvements over the current state of the art. By way of specific example, connectors generally have three types of fixed cables. Moreover, some cables may be bifurcated. As such, the cable cannot be split once installed and the polarity of the cables cannot be changed. Alternatively, the embodiments discussed herein may allow a user to change from a four-way to a 2-Duplex, to a 4-simplex connector, etc. (e.g., FIG. **20**). Moreover, as discussed herein, the individual connectors can be split into individual connectors anytime, even after deployment. Additionally, the polarity can be changed within the connectors easily in a manner that does not risk damage to the one or more ferrules and fibers, as discussed above. It should also be noted that the depicted connectors are used herein merely for illustrative purposes, and that various other connectors may be used in any embodiment (e.g., an MT connector, such as that shown in FIGS. **18**A-**18**B, and the optical connectors of FIGS. **21**, **37**, and **41**).

FIGS. **18**A-**18**B depict an optical connector including an MT ferrule **1810** in a housing that is substantially similar to the housing **301** of FIG. **3**. As with the embodiment of FIG. **3**, the various features of the connector are configured such that two optical connectors having two MT-type optical ferrules may be accommodated in a small form-factor pluggable (SFP) transceiver footprint or at least four optical connectors having a total of four MT-type optical ferrules may be accommodated in a quad small form-factor pluggable (QSFP) transceiver footprint.

FIGS. **19**A-**19**D show alternative embodiments of the optical connectors of FIG. **3** in which the push-pull tabs are not integrated with the optical connector housing. As seen in FIGS. **19**A-**19**B, a push-pull tab **1930** is a separable element from a connector housing. The push-pull tab **1930** actuates a latch **1910** for inserting and extracting the connector from an adapter or transceiver. An alternative latching mechanism is depicted in FIGS. **19**C-**19**D. Latch **1950** includes a notch that is actuated by push-pull tab **1960**.

FIG. **20** depicts the disassembly of a four-connector housing (two duplex connectors in a single housing) into two duplex connectors. This may be performed in changing, for example, a connector as shown in FIG. **14**A to a connector as shown in FIG. **14**C. In FIG. **20**, an optical connector **2000** is depicted including a housing **2010** that houses two duplex connectors (four optical fibers). The housing **2010** is removed, leaving the two duplex connectors **2020**. Two housings **2030** are then provided and two individual duplex connectors **2040** are then created from the initial single housing connector **2000**. This reconfigurable housing simplifies cable management, for example, when optical cables are interconnected between lower-speed transceivers and higher-speed transceivers as seen in FIG. **16**.

FIG. **21**A depicts an embodiment of an optical connector **2100**, shown in exploded view while **21**B depicts the optical connector **2100** in an assembled view. Optical connector **2100** may include an outer housing **2110**, a front body **2115**, one or more ferrules **2122**, one or more ferrule flanges **2124**, one or more springs **2125**, a back body **2130**, a back post **2135**, a crimp ring **2140**, and a boot **2145**. The outer housing **2110** may include a longitudinal bore for accommodating the front body **2115** and a ferrule assembly **2120**, a connector alignment key **2105** used during interconnection, a connector flap **2103** and an optional pull tab **2107** to facilitate removal of the connector **2100** when connected in a dense array of optical connectors. Optionally, the ferrules may be LC-type ferrules having an outer diameter of 1.25 mm.

In prior art optical connectors, an inner enclosed housing was used in place of open front body **2115**. Front body **2115** includes top and bottom portions but no sidewalls, termed "open sidewalls" in this embodiment. By using front body **2115**, space occupied by the prior art inner housing sidewalls becomes available to increase the density of optical connectors within a given footprint, an advantage over prior art connectors. It was determined that the outer housing **2110**, combined with the front body **2115**, provided sufficient mechanical strength and ferrule protection, advantageously providing the space for additional optical connectors. Removal of sidewalls increases available space by 1-2 millimeters.

Note that, in this embodiment, the outer housing is configured to hold two optical ferrules **2122**. Typically, two optical ferrules may be used in a "transmit" and "receive" pairing of optical fibers, called a duplex connector. However, the outer housing may be configured to hold more or fewer optical ferrules including a single optical ferrule, multiples of single optical ferrules, or multiple pairs of optical ferrules, depending upon the application. Further, the front body **2115** may be removed from the outer housing **2110** and the front body placed in a larger outer housing with other front bodies to form a larger optical connector in a manner to be discussed in more detail below. In particular, two front bodies may be used with a four-ferrule outer housing or four front bodies may be used with an eight-ferrule outer housing.

Turning to FIGS. **29**A and **29**B, isometric and front views of the outer housing **2110** are shown. As seen in the front view of FIG. **29**B and the cross-sectional view of FIG. **29**C, connector orientation protrusions **2910** are provided within the interior of the outer housing **2110**. Connector protrusion **2910** is further seen in the inner view of the housing, FIG. **29**E. When the front body is inserted within the longitudinal bore **2101** of outer housing **2110**, the outer housing connector flap **2103** locks the outer housing **2110** to the front body **2115** in the following manner. As the front body **2115** is inserted into the outer housing **2110**, the outer housing locking surface **2114**, best seen in FIG. **27**C, engages the connector orientation protrusion **2910**, seen in an inside view of the outer housing in FIG. **29**D, labelled as "Flap A", flexing the connector flap **2103** outwardly from the outer housing body **2110**, depicted in the inset of FIG. **29**C. The flap protrusion mating location is indicated as "mating place B" in FIG. **29**D. Once the locking surface **2114** passes beyond the orientation protrusion, the connector flap returns to its original position (FIG. **29**A), and the protrusion **2910** engages locking surface **2114** and any withdrawal of the front body assembly from the outer housing **2110** is prevented as the proximal end face of the connector flap **2103** is stopped by protrusion **2910**.

FIGS. **35**A-**35**C depict the sequence of operations to remove an assembled front body from the outer housing in order to reverse polarity or to aggregate plural connectors in a multi-connector housing. To separate the front body from the outer housing, the connector flap **2103** is flexed outward using a finger or a tool, as depicted in FIG. **35**B. Flexing the connector flap **2103** outwardly causes the protrusion **2910** to disengage from the front body's outer housing locking surface **2114**, permitting the front body/ferrule assembly **2115** to be removed from the outer housing. This may be performed when it is desired to reverse the polarity of the connector (to be discussed below) or when desiring to aggregate plural connectors into a larger connector housing as discussed above. The separated components are depicted in FIG. **35**C, that is, front body **2115** with the ferrule assembled therein and outer housing **2110**.

In some embodiments, the back body **2130** may comprise one or more protrusions or hooks **2134**, best seen in FIGS. **28**A and **28**B, which may interlock with a back body hook window/cutout **2119** in the front body **2115**. This may allow for the back body **2130** and the front body **2115** to be securely fastened together around the ferrule(s) **2122**, ferrule flange(s) **2124**, and the spring(s) **2125**. The back body **2130** includes a cable bore **2820**, spring guides **2132**, and side protrusions **2810**.

During assembly, the ferrule flanges **2124** fit into ferrule flange alignment slots **2117** (see FIGS. **27**A and **27**B) adjacent the ferrule openings **2116** of the front body **2115**, compressing the springs **2125** (preload) which are positioned along front body spring holders **2118**. The ends of the springs **2125** are secured on spring guides **2132** (FIGS. **28**A, **28**B) of back body **2130** by spring tension. As seen in the assembled cross-sectional views of FIGS. **23**A and **23**B, the springs **2125** are positioned to urge the ferrules **2122** into contact with mating connectors or transceiver optics, ensuring minimum insertion loss. As further seen in FIGS. **27**A and **27**B, the front body includes a receptacle hook recess **2710** with a receptacle hook retainer surface **2720** the receiver a receptacle hook when mating with an adapter or with a transceiver receptacle, as shown in further detail below.

Further reductions in connector size may be obtained by reducing the size of springs **2125**, see FIG. **21**. By using a maximum spring outer diameter of 2.5 mm, the pitch of the ferrules, that is to say, the spacing between adjacent ferrules, may be reduced to 2.6 mm when coupled with the removal of inner housing walls and walls separating adjacent ferrules. This advantage is best seen in FIG. **22** which depicts the front of connector **2100** showing overall connector dimensions and ferrule pitch. The connector size 4.2×8.96×30.85 mm (excluding optional pull tab **2107** and connector alignment key **2105**) with a ferrule pitch of 2.6 mm.

As best seen in FIG. **21**B, the outer housing **2110** and the front body **2115** together provide a receptacle hook ramp **2940** (on the outer housing) used to guide a receptacle hook into a receptacle hook recess **2170** (in the front body **2115**), also shown in FIGS. **27**A and **27**B (receptacle hook recess **2710** and receptacle hook retainer surface **2720**). The receptacle hook, to be discussed in more detail below, may be from an adapter or a transceiver to secure the optical connector **2100** thereto.

The optical connectors **2100** may be used in a variety of connection environments. In some applications, the optical connectors **2100** will mate with other optical connectors. Typically, this mating will occur with a receptacle such as an adapter or optical transceiver receptacle. An exemplary adapter **2400** depicted in FIG. **24** in an exploded view and depicted in FIG. **31** having four mating pairs of optical connectors **2100** latched therein. In other applications, as when an optical signal is to be converted to an electrical signal, the micro optical connectors **2100** will mate with an optical receptacle in a transceiver **3600** as shown in FIG. **36**. Typically, transceiver **3600** may be found in a data center, switching center, or any other location where optical signals are to be converted to electrical signals. Transceivers are often a part of another electrical device such as a switch or a server, as is known in the art. Although much of the connection operation of this embodiment will be described with respect to an adapter, **2400**, it is understood that substantially similar mechanical retention mechanisms are positioned within the receptacle of transceiver **3600** so that any description of connector retention in adapter **2400** applies in a substantially similar way to retention of an optical connector within transceiver **3600**. An example of a transceiver optical receptacle is depicted in FIG. **36**B (holding optical connectors **2100**); as seen in FIG. **36**B, the connection environment is substantially similar to one-half of an adapter **2400**.

Turning to FIG. **24**, further size reductions in the overall optical assembly of connectors plus adapter or connectors plus transceiver may be obtained through various connection mechanisms to be described with respect to the adapter **2400** but also apply to optical connection features within the front end of transceiver **3600**. The adapter **2400** includes an adapter housing **2402** having an adapter alignment assembly **2430** positioned therein. The adapter alignment assembly **2430** includes alignment sleeves **2410** positioned within alignment sleeve openings **2440** of alignment sleeve holders **2442**. The adapter alignment assembly further includes receptacle hooks **2302** that will grip optical connectors **2100** through front body connector hook recess **2710** of FIG. **21**B. As seen in FIG. **30**, receptacle hooks **2302** include an inner surface **3110**. The adapter housing **2402** further includes connector alignment slots **2403** that mate with connector alignment key **2105** of FIG. **21**A. The connectors **2100** are received through connector opening **2405** of the adapter housing **2402** which also includes flex tab **2401**, cutout **2456**, mount plate **2452** and panel hook **2490**. To assemble the adapter alignment assembly **2430** in the adapter housing **2402**, adapter housing hooks **2432** are provided. Adapter housing hooks **2432** are received in housing adapter hook openings.

It should be understood that above description of connection mechanisms with respect to adapter **2400** may be applied in a substantially similar way with respect to the receptacle of transceiver **3600**. Particularly, the receptacle of transceiver **3600** may include a receptacle housing having a receptacle alignment assembly positioned therein. The receptacle alignment assembly includes alignment sleeves positioned within alignment sleeve openings of alignment sleeve holders. The receptacle alignment assembly further includes receptacle hooks that will grip optical connectors **2100** through front body connector hook recess **2710** of FIG. **21**B. As seen in FIG. **30**, receptacle hooks **2302** include an inner surface **3110**. The receptacle housing further includes connector alignment slots that mate with connector alignment key of FIG. **21**A. The connectors **2100** are received through connector opening of the receptacle housing which also includes flex tab, cutout, mount plate and panel hook. To assemble the receptacle alignment assembly in the receptacle housing, receptacle housing hooks are provided. Receptacle housing hooks are received in housing receptacle hook openings.

To further reduce the size of optical connectors and associated mating components, the adapter housing **2402** includes receptacle hook openings **2420**, seen in FIGS. **25**A and **25**B. Receptacle hook openings **2420** accommodate the clearance required by receptacle hooks **2302** when they flex upwards prior to latching with connectors **2100**. The interaction of the receptacle hooks **2302**, having slanted inner surfaces **3110**, with the receptacle hook openings **2420** is best seen in FIGS. **32**B and **34**A-C. Prior to latching (FIG. **34**A), the receptacle hook **2302** is in an unflexed condition within the receptacle (adapter or transceiver). As the connector **2100** is inserted into the adapter housing **2402** or the transceiver, the receptacle ramp **2490** pushes against the receptacle hook inner surfaces **3110**, flexing receptacle hook **2302** into the receptacle hook opening **2420**. Without providing the opening, additional clearance would need to be provided to accommodate the flexing of the receptacle hook **2302**. This additional required clearance is depicted in the prior art connector/adapter of FIG. **32**A. As seen in FIG. **32**A, a connector latch gap **3210** must be provided in the prior art to accommodate the prior art connector hooks, increasing the overall footprint of the prior art connector/adapter assembly. By providing receptacle hook openings **2420** in the present disclosure, approximately 2.25 mm of valuable footprint real estate is obtained which may be used to increase connector density.

Another improvement in adapter size is obtained by removing prior art adapter walls between adjacent connectors. This is best seen in the front view of an assembled adapter **2400** shown in FIG. **26**. As seen, pairs of ferrule alignment sleeves **2410** are separated only by connector gap **2610** with a 4.35 mm pitch between adjacent connectors. The adapter size is 19.0×10.71×32.5 mm (excluding the adapter flange **2460**). Also seen in FIG. **26** is the connector alignment slot **2403**, alignment sleeve holder **2442**, and a front view of receptacle hooks **2302**.

FIG. **31** depicts an assembled adapter **2400** with four pairs of mating connectors **2100** latched therein. Note that in the latched position, receptacle hooks **2302** do not extend into receptacle hook openings **2420**. This is further visible in the cross-sectional view of an assembled adapter **2400** of FIG. **25**A. Connector alignment keys **2105** are positioned within connector alignment slots **2403**. As seen in the cross-sectional view of FIG. **23**A, the push-pull tab **2017** may extend beyond the connector boot **2145** providing clearance to easily grip the tab and remove a connector. Also seen in FIG. **31** is adapter flex tab **2401** and panel hook **2490** for interaction with racks or other equipment.

Through the various features described above, the density of optical connectors **2100** that may be provided in the standard transceiver footprint connector spaces may be doubled. For example, in a small form factor pluggable (SFP) footprint of 14×12.25 mm, two connectors **2100** having four LC-type ferrules **2122** of 1.25 mm outer diameter may be accommodated as seen in FIG. **33**B. Similarly, in a quad small form factor pluggable (QSFP) footprint of 13.5×19 mm, four connectors **2100** having a total of eight LC-type ferrules **2122** may be accommodated as seen in FIG. **33**A. Further, by providing the connectors in transmit and receive pairs, greater flexibility in optical routing is obtained, as demonstrated by previous FIGS. **16** and **17**.

Turning to FIG. **37**, another embodiment of an optical connector is depicted. In this embodiment, the last two digits of each element correspond to the similar elements in the optical connector of FIG. **21**A et seq. In FIG. **37**, connector **3700** may include an outer housing **3710**, a front body **3715**, one or more ferrules **3722**, one or more ferrule flanges **3724**, one or more springs **3725**, a back body **3730**, a back post **3735**, a crimp ring **3740** (depicted with an optional heat shrink tube extending therefrom), and a boot **3745**. The outer housing **3710** may include a longitudinal bore **3701** for accommodating the front body **3715** and ferrules **3722**, a connector alignment key **3705** used during interconnection, a connector flap **3703** and an optional pull tab **3707** to facilitate removal of the connector **3700** when connected in a dense array of optical connectors. Optionally, the ferrules may be LC-type ferrules having an outer diameter of 1.25 mm.

In FIG. **38** an isometric view of the front body **3715** is depicted. In this embodiment, the back body hook cutout **3819** has been moved forward, advantageously strengthening the assembled connector in side load environments. An alignment tab **3895** is provided for mating with a receiving recess on the back body. The receptacle hook recess **3910** operates in a substantially similar manner to the recess of FIG. **21**A, described above. A ferrule flange alignment slot **3817** is also provided.

In FIG. **39**, the back body **3730** is depicted, showing alignment tab recess **3997** for receiving alignment tab **3895**. The front body hook **3934**, for interconnecting in back body hook cutout **3819**, extends outwardly from the main portion of the back body through extended hook arm **3996**. Through the extended hook arm **3996** and the alignment tab **3895**, breakage during side loads is reduced as the load is redistributed more evenly across the entire connector, reducing stress on the backpost.

As seen in FIGS. **40**A-**40**C, the assembled front body **3715** may be removed from the outer housing **3710**, rotated 180° as indicated by the arrow (FIG. **40**B), and re-inserted into the outer housing (FIG. **40**C). This allows for a change in the polarity of the front body **3715**, and therefore the ferrules can switch quickly and easily without unnecessarily risking the delicate fiber cables and ferrules. As described previously with respect to FIGS. **35**A-**35**C, connector flap **3703** is flexed outward to release the front body from the outer housing.

Turning to FIG. **41**, another embodiment of an optical connector is depicted. In this embodiment, the last two digits of each element correspond to the similar elements in the micro optical connectors of FIG. **21**A and FIG. **37**. In FIG. **41**, connector **4100** may include an outer housing **4110**, a front body **4115**, one or more ferrules **4122**, one or more springs **4125**, a back body **4130**, a crimp ring **4140**, and a boot **4145**. The outer housing **4110** may include a connector flap **4103** and an optional pull tab **4107** to facilitate removal of the connector **4100** when connected in a dense array of optical connectors. Optionally, the ferrules may be LC-type ferrules having an outer diameter of 1.25 mm.

As seen in FIG. **42**A, the front body **4015** in this embodiment includes a middle wall **4260** interposed between the ferrules and springs when the front body is assembled. This middle wall reduces the possibility of the springs becoming entangled with each other, binding the connector and breaking the optical fibers. The front body **4015** also includes an alignment cut out guide **4625**, seen in the side view of FIG. **42**B. The alignment cut out guides the back body **4030** into the front body **4015** during assembly of the connecter, and also further reduces the side load that leads to connector breakage or disconnection of the front body and the back body **4030**.

Back body **4030**, depicted in an enlarged view in FIG. **43**, includes an alignment guide **4377** that fits into the alignment cut out guide **4265** of FIG. **42**B. The wall structure **4378** also stops the front body to prevent over-compressing the springs and provides strength under a side load.

Various modifications to the outer housing, depicted in FIGS. **44**A-**44**C, may be used with any of the optical connectors depicted in FIGS. **21**, **37**, and **41** or earlier embodiments. In FIG. **44**A, the push-pull tab **3707** may include a release recess **4473**. Release recess **4473** permits insertion of a tool or fingernail to remove the connector from an adapter or transceiver, without disturbing adjacent connectors. Similarly, FIG. **44**B depicts a release hole **4499** in push-pull tab **3707** to permit insertion of an extraction tool to remove the connector from an adapter or transceiver. FIG. **44**C shows a modified connector flap **3703** with an increased cutout size of 1 mm to make it easier to insert a tool or a finger to flex the flap **3703** and remove the front body assembly when making a polarity change or aggregating the front body with other front bodies in a larger outer housing.

Another embodiment of an adapter/transceiver receptacle is depicted in FIG. **45**. Unlabeled elements are substantially similar to elements depicted in FIG. **24**. In this FIG., adapter housing hooks **4532** can be seen along with receptacle hooks **4502**. Turning to the cross-sectional view of the assembled adapter in FIG. **46**, the engagement of these elements may be seen.

Another embodiment of an optical connector **4700** is depicted in FIG. **47**. The optical connector of FIG. **47** includes outer housing **4710**, front body **4715**, ferrules **4722**, springs **4725**, back body **4730**, backpost **4735**, crimp ring **4740**, and boot **4745**. Here, the emphasis is on the back body, **4730**. A more detailed view of the back body **4730** is presented in FIG. **48**. In this embodiment, the backpost flange has a substantially rectangular shape in order to narrow the overall connector profile by approximately 0.5 mm. Back post overmolding **4859** accommodates the back post flange **4857** and reduces the potential for back post breakage. The back wall **4853** is extended in length to 3 mm from 1.5 mm to improve the sideload strength of the overall connector. The crimp ring positioning **4855** is inversed from earlier embodiments to improve holding of aramid fiber from an optical fiber cable, improving cable retention of the back post.

Many advantages are achieved by the backpost of FIG. **48**. In addition to increased connector strength, a longer fiber path **4901** is provided as shown in FIG. **49**. This longer fiber path, approximately 1.5 mm longer than in previous embodiments, allows for a gentler curve as the fibers are split from the fiber optic cable, improving insertion and return loss of the fibers. In FIG. **49**, the back wall **4853** can be seen as a portion of the back body **4730**.

In view of the various modifications of this embodiment, FIG. **50** depicts a connector **4700** front view showing overall reduced connector width of 3.85 mm. Such a size reduction permits **4** optical connectors (a total of 8 ferrules) to be accommodated in a transceiver or connector footprint of 16 mm (including tolerances). Thus, the connectors of the present invention may be used to connect 8 LC-ferrule-housed fibers in a QSFP footprint.

To further decrease the space required by the optical connectors, a side thickness reduction may be carried out on the boot of connector **4700**. Side thickness reduction **5103**, depicted in FIG. **51**, narrows the thickness of the boot on either side, reducing the space required by the boot to the 3.85 mm profile of connector **4700**. Thus four connectors will fit in the QSFP transceiver footprint. This footprint is shown in the adapter front view of FIG. **52**—as noted above, the front view of an adapter and that of a transceiver are substantially similar from the optical perspective. In FIG. **52**, the adapter inner wall is reduced from 17.4 mm to 16 mm. All of the modifications set forth in the FIG. **47** et seq. embodiment make it possible for the four connectors to fit in the profile of FIG. **52**.

In some embodiments, as shown in FIG. **53**, a connector **10300** may comprise various components. Referring to FIG. **53**, an illustrative embodiment of a connector **10300** is shown in an exploded view to display detail. In some embodiments, and as discussed further herein, a connector **10300** may have an outer housing **10301**, a front body **10302**, one or more ferrules **10303**, one or more ferrule flanges **10304**, one or more springs **10305**, a back body **10306**, a back post **10307**, a crimp ring **10308**, a boot **10309**, and a push-pull tab **10310**. In some embodiments, the back body **10306** may comprise one or more protrusions **10306.1** which may interlock with a window/cutout **10302.1** in the front body **10302**. This may allow for the back body **10306** and the front body **10302** to be securely fastened together around the ferrule(s) **10303**, ferrule flange(s) **10304**, and the spring(s) **10305**.

Referring now to FIG. **54**, an embodiment is shown wherein the connector **10400** is assembled. In some embodiments, the assembled connector may have an outer housing **10401**, a front body (not shown, see FIGS. **53** and **55**), one or more ferrules **10403**, one or more ferrule flanges (not shown), one or more springs (not shown), a back body **10406**, a back post (not shown), a crimp ring (not shown), a boot **10409**, a push-pull tab **10410**, and one or more latching mechanisms made up of a window **10412** on the outer housing and a protrusion **10413** on the front body. The latching mechanism **10412** and **10413** securely attaches the outer housing **10401** to the front body. In a further embodiment, the push-pull tab **10410** may have an opening to receive a locking tab **10411**. The locking tab **10411** of the outer housing **10401** is used to interlock with an adapter (not shown) to secure the connector into the adapter. As would be understood by one skilled in the art, the push-pull tab **10410** enables easy manipulation of the locking tab **10411** to allow for removal of the connector from the adapter without requiring additional tools.

As shown in FIG. **55**, in some embodiments, the latching mechanism of the connector **10500** may be made up of two parts: a window **10512** and a protrusion **10513**. As illustrated in FIG. **55**, the outer housing **10501** can slide on to or be removed from the front body **10502** by disengaging the latching mechanisms formed by the protrusion **10513** exiting through the window **10512**, whereby it contacts a side wall of the window (refer to FIG. **54** for an illustrated example of the outer housing being attached to the front body via the latching mechanism). In some embodiments, the push-pull tab **10510** may also be detached from the outer housing **10501**, as shown.

In a further embodiment, the front body **10502** may be removed from the outer housing **10501**, rotated 180°, and re-inserted into the outer housing. This allows for a change in the polarity of the front body **10502**, as shown by the arrow diagram in FIG. **55**, and therefore the ferrules can switch quickly and easily without unnecessarily risking the delicate fiber cables and ferrules.

In some embodiments, it may be beneficial to connect two or more connectors together to increase structural integrity, reduce the overall footprint, and cut manufacturing costs. Accordingly, as shown in FIG. **56**, a connector **10600** may in some embodiments, utilize an outer housing **10601** that is capable of holding two front bodies (not shown). Various other embodiments are disclosed herein, and it should be noted that the embodiments disclosed herein are all non-limiting examples shown for explanatory purposes only.

Accordingly, although the embodiment shown in FIG. **56** utilizes a duplex outer housing **10601**, additional or alternative embodiments may exist with more capacity. As shown in FIG. **56**, in some embodiments, the outer housing **10601** may accept two front bodies (not shown), each with two separate ferrules **10603**. As shown, the front body (not shown) may securely fasten to the outer housing **10601** via the latching mechanism **10612** and **10613**. In additional embodiments, the push-pull tab **10610** may be modified, as shown, such that a single tab can be used to free the two or more connectors from an adapter. As illustrated in FIG. **56**, the push-pull tab **10610** may include two openings with which to receive multiple locking tabs **10611** of the outer housing **10601**. As discussed herein the locking tabs **10611** of the outer housing **10601** are used to secure the connectors to an adapter (not shown). In one or more further embodiments, the connectors may have individual back bodies **10606** and boots **10609** (i.e., one back body/boot per front body) as shown.

Alternatively, in some embodiments, such as that shown in FIG. **57**, the connector **10700** may have a single boot **10709** and a duplex (i.e., uni-body) back body **10706** instead of individual back bodies (e.g., such as shown in FIG. **56**). In some embodiments, the duplex back body **10706** may have different dimensions than that of the individual back bodies of FIG. **56**, such as, for example, they may be longer to accommodate the need for routing the fiber after it exits the boot **10709**. As with other embodiments discussed herein, the connector shown in FIG. **57** may also include an outer housing (e.g., duplex outer housing) **10701**, one or more ferrules **10703**, at least one latching mechanism formed by the protrusion **10713** exiting through the window **10712**, and push-pull tab **10710**.

As stated, it may be beneficial to connect two or more connectors together to increase structural integrity, reduce the overall footprint, and cut manufacturing costs. Accordingly, similarly to FIG. **56**, FIG. **58** shows a connector **10800** that may, in some embodiments, utilize an outer housing **10801** that is capable of holding multiple (e.g., four) front bodies (not shown).

As shown in FIG. **58**, some embodiments may have an outer housing **10801** able to accept up to four front bodies, each with one or more ferrules **10803**. As shown, each front body (not shown) may securely fasten to the outer housing **10801** via the latching mechanism **10812** and **10813**. In additional embodiments, the push-pull tab **10810** may be modified, as shown, such that a single tab can be used to free the up to four connectors from an adapter. As illustrated in FIG. **58**, the push-pull tab **10810** may include four openings with which to receive multiple locking tabs **10811** of the outer housing **10801**. As discussed herein the locking tabs **10811** of the outer housing **10801** are used to secure the connectors to an adapter (not shown). In one or more further embodiments, the connectors may have individual back bodies **10806** and boots **10809** (i.e., one back body/boot per front body) as shown.

Alternatively, in some embodiments, such as that shown in FIG. **59**, the connector **10900** may utilize one or more duplex back bodies **10906** with a single boot **10909**, similar to that shown in FIG. **57**. Thus, similar to FIG. **57**, the embodiment shown in FIG. **59** may allow for a further reduced foot print, less cabling, and easier maintenance of the connector. Accordingly, one or more embodiments may have an outer housing **10901** may accept up to four front bodies, each with one or more ferrules **10903**. As shown, each front body (not shown) may securely fasten to the outer housing **10901** via the latching mechanism **10912** and **10913**. In additional embodiments, the push-pull tab **10910** may be modified, as shown, such that a single tab can be used to free the up to four front bodies from an adapter. As illustrated in FIG. **59**, the push-pull tab **10910** may include four openings with which to receive multiple locking tabs **10911** of the outer housing **10901**. As discussed herein the locking tabs **911** of the outer housing **10901** are used to secure the connectors to an adapter (not shown).

In further embodiments, such as that shown in FIG. **60**, the connector **101000** may utilize a single uni-body back body **101006** with a single boot **101009**. Thus, the embodiment shown in FIG. **59** may allow for a further reduced foot print, even less cabling, and easier maintenance of the connector. Accordingly, one or more embodiments may have an outer housing **101001** that may accept up to four front bodies, each with one or more ferrules **101003**. As shown, each front body (not shown) may securely fasten to the outer housing **101001** via the latching mechanism **101012** and **101013**. In additional embodiments, the push-pull tab **101010** may be modified, as shown, such that a single tab can be used to free up to four connectors from an adapter. As illustrated in FIG. **60**, the push-pull tab **101010** may include four openings with which to receive multiple locking tabs **101011** of the outer housing **101001**. As discussed herein the locking tabs **101011** of the outer housing **101001** are used to secure the connectors to an adapter (not shown).

Referring now to FIG. **61**, an embodiment **101100** is shown in which the connector (not shown in its entirety) is inserted into an adapter **101114**. In this specific non-limiting example, the connector is similar to that shown in FIG. **58** (i.e., comprising four front bodies each with their own back body **101106** and boot **101109**). However, unlike FIG. **58**, the embodiment shown here utilizes four individual push-pull tabs **101110** instead of a single push-pull tab which manipulates four latching tabs to allow the connector to be removed from the adapter **101114**.

Various benefits and details have been discussed herein with regard to the connectors and their modular ability (e.g., to include multiple connectors into a single unit). In addition to the reduced footprint, structural improvements, and cost reduction, various embodiments herein may also be beneficial with regard to reducing the burden of cabling in a data center environment. Illustrative embodiments shown in FIGS. **62**A through **62**C depict cable configurations that can be used to reduce the complexity of optical cables in a compact environment. FIG. **62**A shows two duplex cables similar to the cable shown in FIG. **56**. This allows for two or more cables to be bundled and reduce the risk of entanglement with additional cables. FIG. **62**B is an illustrative example, of how easily an embodiment can separate into two individual connectors by unbinding the cables and thus quickly and easily creating two independent fiber optic channels that can move independently. FIG. **62**C shows an embodiment in which a duplex connector like that of FIGS. **56** and **62**A is connected to two separate individual connectors.

In addition to binding existing fiber cables, some embodiments herein may utilize a new four fiber zip cable. Referring now to FIG. **63**A, a conventional zip cable (i.e., one with a single fiber strand **101320** per jacket **101321**) is shown in comparison with an embodiment where two fibers **101322** per jacket **101323** may be utilized. It should be understood that this is merely a non-limiting example. In some embodiments, multiple fibers may be included per jacket, such as, for example, four fibers per jacket in order to utilize the single boot **101009** and uni-body read body **101006** of the connector shown in FIG. **60**.

A specific example using multi-strand cables is shown in FIG. **64** for illustrative purposes only. It should be understood that numerous alternatives and modifications are possible, such as, for example, that shown in FIG. **66**A-**66**B, FIGS. **67**A-**67**D, and **68**A-**68**B. As shown, a switch (e.g., **100**G switch) **101430** is shown with a transceiver (e.g., **100**G transceiver) **101431**. The transceiver **101431** has an adapter to receive two mini duplex connectors **101432**. From each of the two duplex connectors **1432**, a four fiber cable **101433** extends to connect to various other connectors and transceivers. As shown, one four fiber cable **101433** is split into two two-fiber cables **101434**, which are then attached to a single simplex connector **101435** and placed into a transceiver (e.g., **25**G transceiver) **101436**. As further shown, one of the four fiber cables **101437** is connected to a single mini duplex connector **101438**, which is then inserted into another transceiver (e.g., **50**G transceiver) **101439**.

Accordingly, embodiments described herein allow for improvements over the current state of the art. By way of specific example, ROX connectors generally have three types of fixed cables: ROX **1**, ROX **2**, and ROX **4**. Moreover, ROX cables are bifurcated. As such, the cable cannot be split once installed and the polarity of the cables cannot be changed. Alternatively, the embodiments discussed herein may allow a user to change from a four way to a 2-Duplex, to a 4-simplex connector, etc. (e.g., FIG. **69**). Moreover, as discussed herein, the individual connectors can be split into individual connectors anytime, even after deployment. Additionally, as discussed herein, the polarity can be changed within the connectors in an easy manner that does not risk damage to the one or more ferrules. It should also be noted, as discussed herein that connectors are used herein merely for simplicity purposes, and that various other connectors may be used in any embodiment (e.g., an MT connector, such as that shown in FIG. **66**A-**66**B).

In the above detailed description, reference is made to the accompanying drawings, which form a part hereof. In the drawings, similar symbols typically identify similar components, unless context dictates otherwise. The illustrative embodiments described in the detailed description, drawings, and claims are not meant to be limiting. Other embodiments may be used, and other changes may be made, without departing from the spirit or scope of the subject matter presented herein. It will be readily understood that the aspects of the present disclosure, as generally described herein, and illustrated in the Figures, can be arranged, substituted, combined, separated, and designed in a wide variety of different configurations, all of which are explicitly contemplated herein.

The present disclosure is not to be limited in terms of the particular embodiments described in this application, which are intended as illustrations of various aspects. Many modifications and variations can be made without departing from its spirit and scope, as will be apparent to those skilled in the art. Functionally equivalent methods and apparatuses within the scope of the disclosure, in addition to those enumerated herein, will be apparent to those skilled in the art from the foregoing descriptions. Such modifications and variations are intended to fall within the scope of the appended claims. The present disclosure is to be limited only by the terms of the appended claims, along with the full scope of equivalents to which such claims are entitled. It is to be understood that this disclosure is not limited to particular methods, reagents, compounds, compositions or biological systems, which can, of course, vary. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to be limiting.

With respect to the use of substantially any plural and/or singular terms herein, those having skill in the art can translate from the plural to the singular and/or from the singular to the plural as is appropriate to the context and/or application. The various singular/plural permutations may be expressly set forth herein for sake of clarity.

It will be understood by those within the art that, in general, terms used herein, and especially in the appended claims (for example, bodies of the appended claims) are generally intended as "open" terms (for example, the term "including" should be interpreted as "including but not limited to," the term "having" should be interpreted as "having at least," the term "includes" should be interpreted as "includes but is not limited to," et cetera). While various compositions, methods, and devices are described in terms of "comprising" various components or steps (interpreted as meaning "including, but not limited to"), the compositions, methods, and devices can also "consist essentially of" or "consist of" the various components and steps, and such terminology should be interpreted as defining essentially closed-member groups. It will be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present. For example, as an aid to understanding, the following appended claims may contain usage of the introductory phrases "at least one" and "one or more" to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles "a" or "an" limits any particular claim containing such introduced claim recitation to embodiments containing only one such recitation, even when the same claim includes the introductory phrases "one or more" or "at least one" and indefinite articles such as "a" or "an" (for example, "a" and/or "an" should be interpreted to mean "at least one" or "one or more"); the same holds true for the use of definite articles used to introduce claim recitations. In addition, even if a specific number of an introduced claim recitation is explicitly recited, those skilled in the art will recognize that such recitation should be interpreted to mean at least the recited number (for example, the bare recitation of "two recitations," without other modifiers, means at least two recitations, or two or more recitations). Furthermore, in those instances where a convention analogous to "at least one of A, B, and C, et cetera" is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (for example, "a system having at least one of A, B, and C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, et cetera). In those instances where a convention analogous to "at least one of A, B, or C, et cetera" is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (for example, "a system having at least one of A, B, or C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, et cetera). It will be further understood by those within the art that virtually any disjunctive word and/or phrase presenting two or more alternative terms, whether in the description, claims, or drawings, should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms. For example, the phrase "A or B" will be understood to include the possibilities of "A" or "B" or "A and B."

In addition, where features or aspects of the disclosure are described in terms of Markush groups, those skilled in the art will recognize that the disclosure is also thereby described in terms of any individual member or subgroup of members of the Markush group.

As will be understood by one skilled in the art, for any and all purposes, such as in terms of providing a written description, all ranges disclosed herein also encompass any and all possible subranges and combinations of subranges thereof. Any listed range can be easily recognized as sufficiently describing and enabling the same range being broken down into at least equal halves, thirds, quarters, fifths, tenths, et cetera As a non-limiting example, each range discussed herein can be readily broken down into a lower third, middle third and upper third, et cetera As will also be understood by one skilled in the art all language such as "up to," "at least," and the like include the number recited and refer to ranges which can be subsequently broken down into subranges as discussed above. Finally, as will be understood by one skilled in the art, a range includes each individual member. Thus, for example, a group having 1-3 cells refers to groups having 1, 2, or 3 cells. Similarly, a group having 1-5 cells refers to groups having 1, 2, 3, 4, or 5 cells, and so forth.

Various of the above-disclosed and other features and functions, or alternatives thereof, may be combined into many other different systems or applications. Various presently unforeseen or unanticipated alternatives, modifications, variations or improvements therein may be subsequently made by those skilled in the art, each of which is also intended to be encompassed by the disclosed embodiments.

The invention claimed is:

1. An optical fiber connector for being plugged into a receptacle, the optical fiber connector comprising:

a connector housing having opposite upper and lower sides spaced apart along a connector height and opposite left and right sides spaced apart along a connector width, the connector width being less than the connector height, the upper side of the connector housing defining a groove;

at least one optical fiber ferrule received in the connector housing, the at least one optical fiber ferrule configured to terminate at least two optical fibers and to hold the at least two optical fibers so that tips of the at least two optical fibers are spaced apart along the connector height; and

a push-pull latch release mechanism disposed on the upper wall of the connector housing, the push-pull latch release mechanism comprising a latch component and a remote release component, the latch component configured to latch with the receptacle when the optical fiber connector is plugged into the receptacle, the remote release component including a front section and a rear section, the front section configured to be received in the receptacle when the optical fiber connector is plugged into the receptacle, the rear section configured to extend out of the receptacle when the optical fiber connector is plugged into the receptacle, the front section being slidably constrained in the groove such that the front section can slide along the groove to actuate the latch component for unlatching from the receptacle when the remote release component is pulled rearward.

2. The optical fiber connector as set forth in claim **1**, wherein the latch component comprises a depressible locking tab.

3. The optical fiber connector as set forth in claim **2**, wherein the front section of the remote release component is configured to engage the depressible locking tab inside the receptacle to depress the depressible locking tab.

4. The optical fiber connector as set forth in claim **3**, wherein the front section of the remote release component defines an opening, the depressible locking tab extending upward and rearward through the opening.

5. The optical fiber connector as set forth in claim **4**, wherein the opening is rectangular.

6. The optical fiber connector as set forth in claim **4**, wherein the front section includes an edge defining a front end of the opening, the edge configured to slide rearward along the depressible locking tab inside the receptacle to depress the depressible locking tab.

7. The optical fiber connector as set forth in claim **3**, wherein the rear section includes a push-pull tab.

8. The optical fiber connector as set forth in claim **1**, wherein the push-pull latch release mechanism does not protrude widthwise beyond the left and right sides of the connector housing.

9. The optical fiber connector as set forth in claim **1**, wherein the at least one optical fiber ferrule is a single multifiber ferrule configured to terminate a plurality of optical fibers.

10. The optical fiber connector as set forth in claim **9**, wherein the multifiber ferrule is an MT ferrule having opposite upper and lower sides spaced apart along a ferrule height and opposite left and right sides spaced apart along a ferrule width, the ferrule width being less than the ferrule height.

11. The optical fiber connector as set forth in claim **1**, further comprising a single cable boot extending rearward from the connector housing for receiving the at least two optical fibers into the optical fiber connector.

12. The optical fiber connector as set forth in claim **1**, further comprising at least one ferrule spring configured to urge the at least one ferrule forward in the connector housing.

13. The optical fiber connector as set forth in claim **1**, wherein the lower side of the connector housing is free of a groove capable of slidably constraining the front section.

14. The optical fiber connector as set forth in claim **1**, wherein the connector housing is formed from a first part, a second part, and a third part; the first part, the second part, and the third part being fastened together to form the connector housing.

15. The optical fiber connector as set forth in claim **14**, wherein the optical fiber connector has an exterior and wherein at least a portion of each of the first part, the second part, and the third part is exposed on the exterior of the connector.

16. The optical fiber connector as set forth in claim **15**, wherein the connector housing has a front end portion and the first part is an outer connector housing part at the front end portion.

17. The optical fiber connector as set forth in claim **16**, wherein the outer connector housing part comprises opposing outer side walls and each of the opposing outer side walls defines a latch opening, wherein the second part comprises opposing inner side wall sections, each of the opposing inner side wall sections comprising an outwardly projecting latch hook configured for latching with the latch opening of one of the opposing outer side walls.

18. The optical fiber connector as set forth in claim **17**, wherein the connector housing further comprises a rear end portion opposite the front end portion and wherein the third part is fastened to the second part at the rear end portion at a location rearwardly spaced from the outwardly projecting latch hooks.

19. The optical fiber connector as set forth in claim **18**, wherein each of the first part, the second part, and the third part is formed from a single piece of material and wherein the first part, the second part, and the third part fasten to one another via fastening features integrally formed in the first part, the second part, and the third part.

20. An optical fiber connector for being plugged into a receptacle, the optical fiber connector comprising:

a connector housing having opposite upper and lower sides spaced apart along a connector height and opposite left and right sides spaced apart along a connector width, the connector width being less than the connector height, the upper side of the connector housing defining a groove;

a single multifiber ferrule received in the connector housing, the multifiber ferrule having opposite upper and lower sides spaced apart along a ferrule height and opposite left and right sides spaced apart along a ferrule width, the ferrule width being less than the ferrule height, the multifiber ferrule disposed in the connector housing such that the ferrule width is parallel to the connector width and the ferrule height is parallel to the connector height, the multifiber fiber ferrule configured to terminate a plurality of optical fibers and to hold the optical fibers so that tips of the optical fibers are spaced apart along the connector height;

a ferrule spring configured to urge the at least one ferrule forward in the connector housing;

a single cable boot extending rearward from the connector housing for receiving the optical fibers into the optical fiber connector; and

a push-pull latch release mechanism disposed on the upper wall of the connector housing, the push-pull latch release mechanism comprising a latch component and a remote release component, the latch component configured to latch with the receptacle when the optical fiber connector is plugged into the receptacle, the remote release component including a front section and a rear section, the front section configured to be received in the receptacle when the optical fiber connector is plugged into the receptacle, the rear section configured to extend out of the receptacle when the optical fiber connector is plugged into the receptacle, the front section being slidably constrained in the groove such that the front section can slide along the groove in relation to the connector housing to actuate the latch component for unlatching from the receptacle when the remote release component is pulled rearward;

wherein the lower side of the connector housing is free of a groove capable of slidably constraining the front section;

wherein the latch component comprises a depressible locking tab and wherein the front section of the remote release component defines a rectangular opening and includes an edge defining a front end of the opening, the depressible locking tab extending upward and rearward through the rectangular opening, the edge configured to slide rearward along the depressible locking tab inside the receptacle to depress the depressible locking tab;

wherein the push-pull latch release mechanism does not protrude widthwise beyond the left and right sides of the connector housing.

21. The optical fiber connector as set forth in claim **20**, wherein the connector housing is formed from a first part, a second part, and a third part, the first part, the second part, and the third part being fastened together to form the connector housing,

wherein the optical fiber connector has an exterior and wherein at least a portion of each of the first part, the second part, and the third part is exposed on the exterior of the connector;

wherein the connector housing has a front end portion and the first part is an outer connector housing part at the front end portion, the outer connector housing part comprising opposing outer side walls and each of the opposing outer side walls defines a latch opening, wherein the second part comprises opposing inner side wall sections, each of the opposing inner side wall sections comprising an outwardly projecting latch hook configured for latching with the latch opening of one of the opposing outer side walls;

wherein the connector housing further comprises a rear end portion opposite the front end portion and wherein the third part is fastened to the second part at the rear end portion at a location rearwardly spaced from the outwardly projecting latch hooks; and

wherein each of the first part, the second part, and the third part is formed from a single piece of material and wherein the first part, the second part, and the third part fasten to one another via fastening features integrally formed in the first part, the second part, and the third part.

22. The optical fiber connector as set forth in claim **4**, wherein the depressible locking tab has a rear facing latch surface and wherein the entire front section of the remote release is below the rear facing latch surface along the connector height.

23. The optical fiber connector as set forth in claim **22**, wherein the front section of the remote release component includes a substantially planar portion lying flat on top of the upper side of the connector housing, the substantially planar portion defining a front edge of the opening.

24. The optical fiber connector as set forth in claim **22**, wherein a portion of the remote release component is slidably received in the groove behind the rear facing latch surface.

25. The optical fiber connector as set forth in claim **6**, wherein the front section of the remote release component includes a substantially planar portion lying flat on top of the upper side of the connector housing, the substantially planar portion defining the front edge of the opening.

26. The optical fiber connector as set forth in claim **1**, wherein the groove opens upward.

27. The optical fiber connector of claim **20**, wherein the depressible locking tab has a rear facing latch surface and wherein the entire front section of the remote release is below the rear facing latch surface along the connector height.

28. The optical fiber connector as set forth in claim **27**, wherein the front section of the remote release component includes a substantially planar portion lying flat on top of the upper side of the connector housing, the substantially planar portion defining a front edge of the opening.

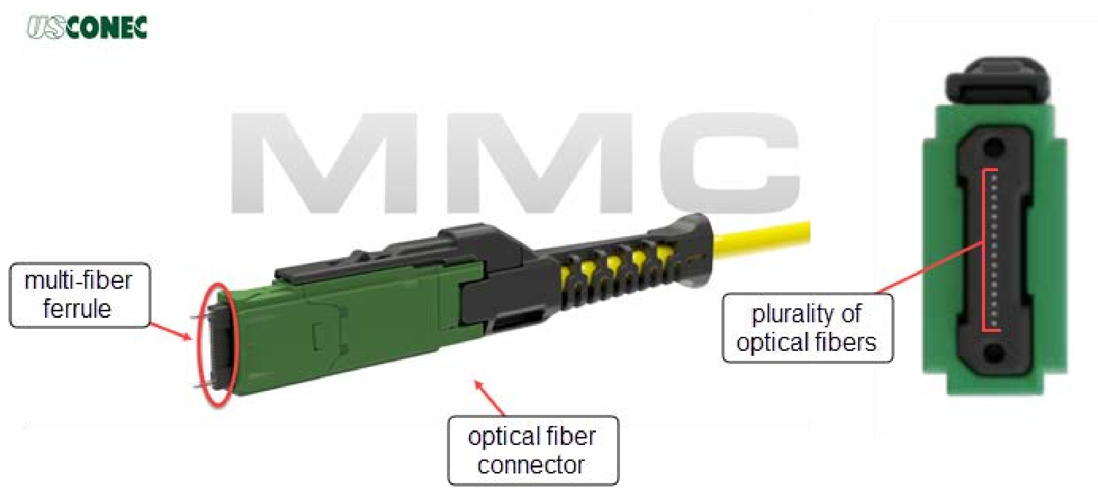
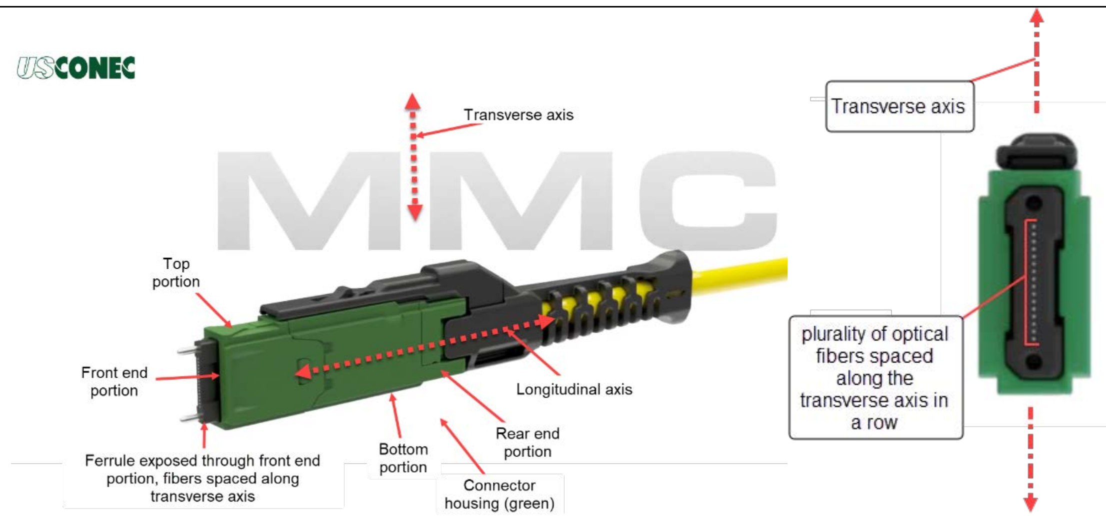
29. The optical fiber connector as set forth in claim **28**, wherein a portion of the remote release component is slidably received in the groove behind the rear facing latch surface.

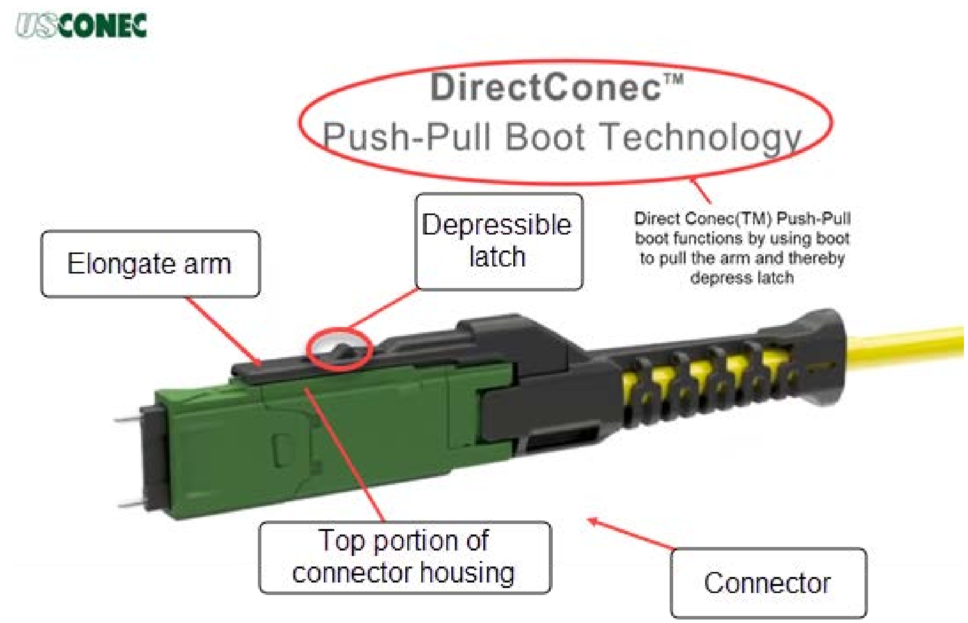
30. The optical fiber connector as set forth in claim **20**, wherein the front section of the remote release component includes a substantially planar portion lying flat on top of the upper side of the connector housing, the substantially planar portion defining the front edge of the opening.

31. The optical fiber connector as set forth in claim **20**, wherein the groove opens upward.

* * * * *

EXHIBIT N

U.S. Patent No. 11,307,369	MMC
23. An optical fiber connector comprising:	
multi-fiber ferrule configured to terminate a plurality of optical fibers;	
a connector housing having a front end portion and a rear end portion spaced apart along a longitudinal axis, the connector housing comprising a top portion and a bottom portion spaced apart along a transverse axis perpendicular to the longitudinal axis, the connector housing being configured to hold the multi-fiber ferrule such that the multi-fiber ferrule is exposed through the front end portion for making an optical connection and the plurality of optical fibers are spaced apart from one another in a row extending parallel to the transverse axis,	

U.S. Patent No. 11,307,369	MMC
a depressible latch above the top portion of the connector housing; and	
an elongate arm connected to the connector housing above the top portion and configured to be pulled to actuate the depressible latch;	

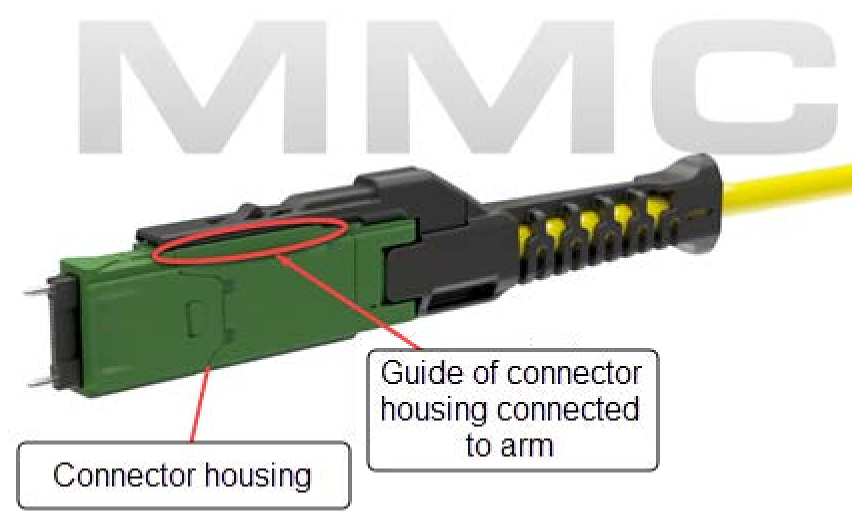
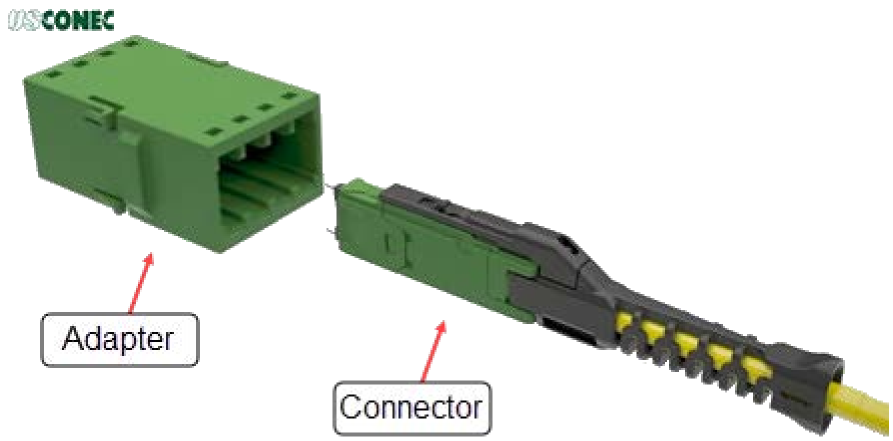
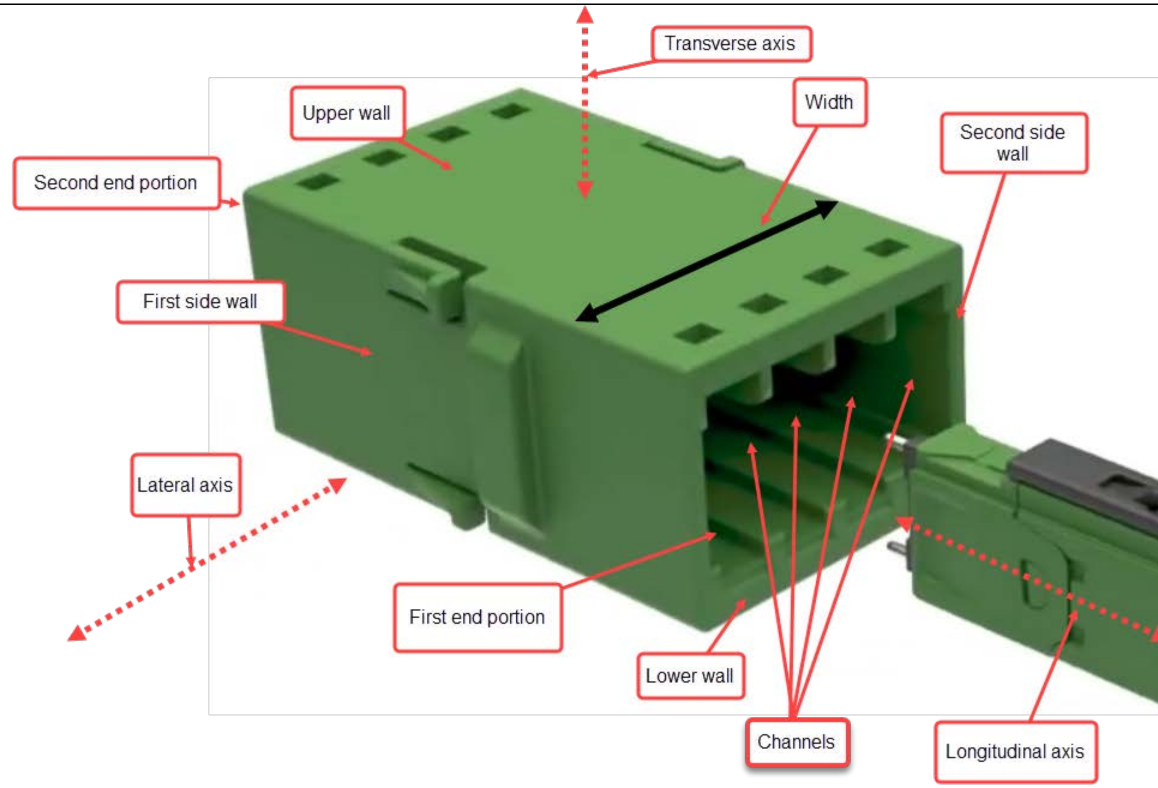
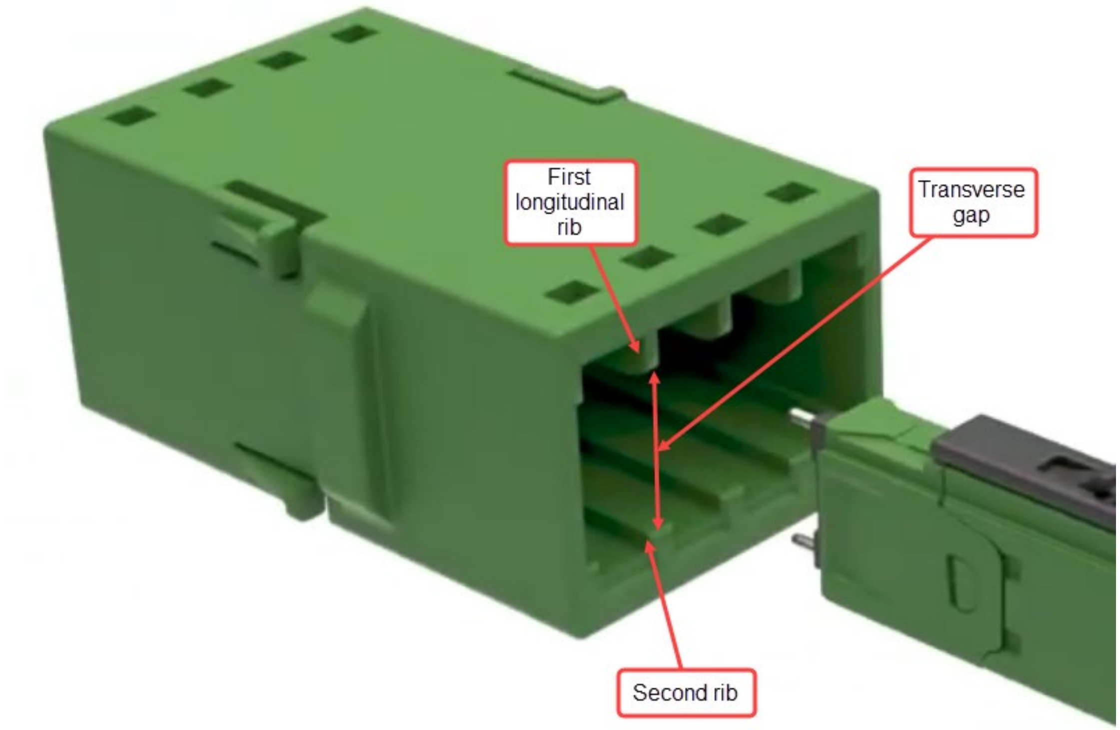
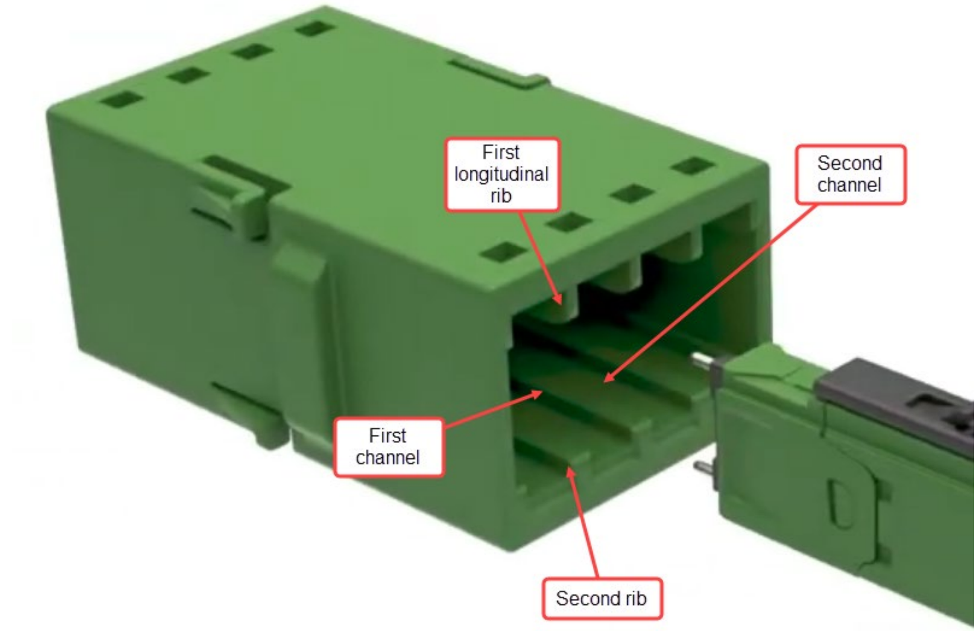
U.S. Patent No. 11,307,369	MMC
wherein the connector housing comprises a guide connecting the elongate arm to the optical fiber connector.	USCONEC 

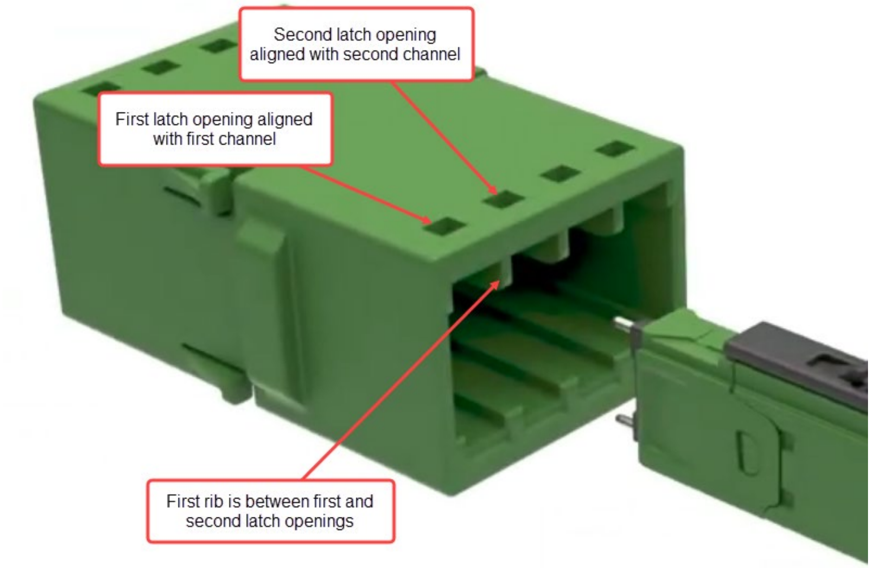
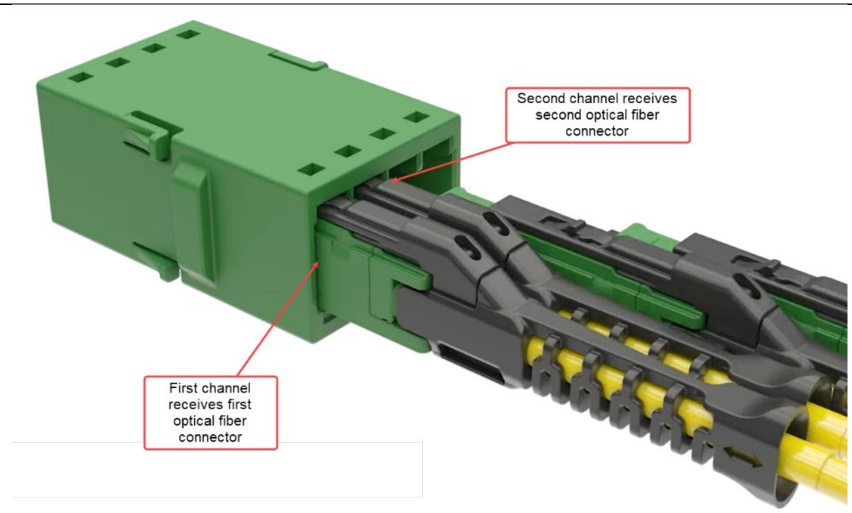
EXHIBIT O

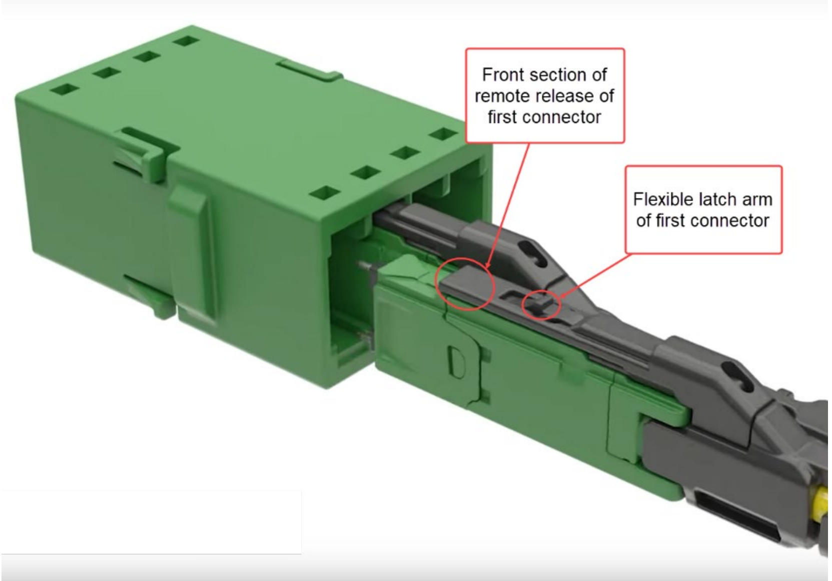
U.S. Pat. No. 11,333,836	MMC Adapters
1. An adapter for mating with optical fiber connectors, the adapter comprising:	

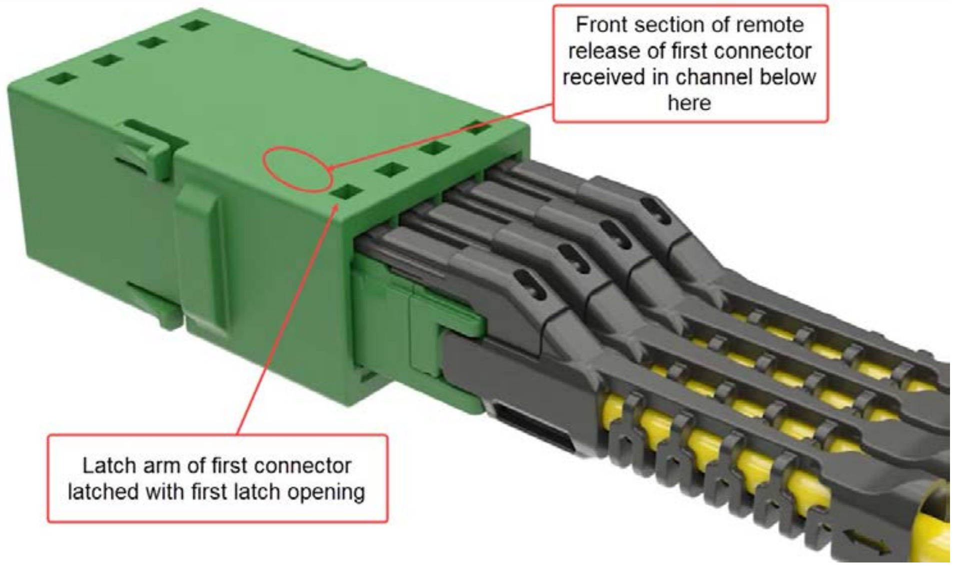
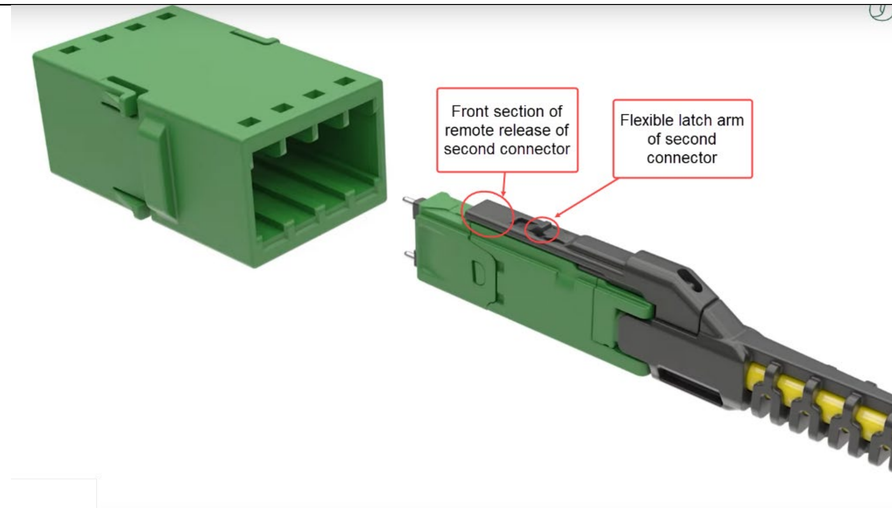
U.S. Pat. No. 11,333,836	MMC Adapters
an outer housing having a first end portion and a second end portion spaced apart along a longitudinal axis, the outer housing comprising a first side wall and a second side wall spaced apart along a lateral axis perpendicular to the longitudinal axis, the outer housing having a width extending along the lateral axis from the first side wall to the second side wall, the outer housing comprising a upper wall and a lower wall spaced apart along a transverse axis oriented perpendicular to the lateral axis and perpendicular to the longitudinal axis, each of the upper wall and the lower wall having an inner surface, the outer housing defining a plurality of channels spaced apart along the width, each of the channels being configured to receive an optical fiber connector, the plurality of channels including first and second channels; and	

U.S. Pat. No. 11,333,836	MMC Adapters
a first longitudinal rib formed on the inner surface of the upper wall at a location spaced apart along the width of the outer housing between the first side wall and the second side wall and a second rib formed on the inner surface of the lower wall at a location spaced apart along the width of the outer housing between the first side wall and the second side wall, the first and second ribs being aligned along the width of the outer housing, the first rib being spaced apart from the second rib along the transverse axis by a transverse gap,	

U.S. Pat. No. 11,333,836	MMC Adapters
wherein the first longitudinal rib and the second longitudinal rib are located between the first and second channels.	

U.S. Pat. No. 11,333,836	MMC Adapters
2. The adapter as set forth in claim 1, wherein the upper wall comprises a first latch opening aligned with the first channel and a second latch opening aligned with the second channel, the first rib being spaced apart between the first latch opening and the second latch opening along the width.	
3. The adapter as set forth in claim 2, wherein the adapter is configured to receive a first one of the optical fiber connectors in the first channel and a second one of the optical fiber connectors in the second channel such that:	

U.S. Pat. No. 11,333,836	MMC Adapters
a flexible latch arm of the first optical fiber connector is latched with the first latch opening and a front section of a remote release of the first optical fiber connector is received in the first channel at a location spaced apart from the first latch opening along the longitudinal axis toward the second end portion of the outer housing; and	

U.S. Pat. No. 11,333,836	MMC Adapters
	
a flexible latch arm of the second optical fiber connector is latched with the second latch opening and a front section of a remote release of the second optical fiber connector is received in the first channel at a location spaced apart from the second latch opening along the longitudinal axis toward the second end portion of the outer housing.	

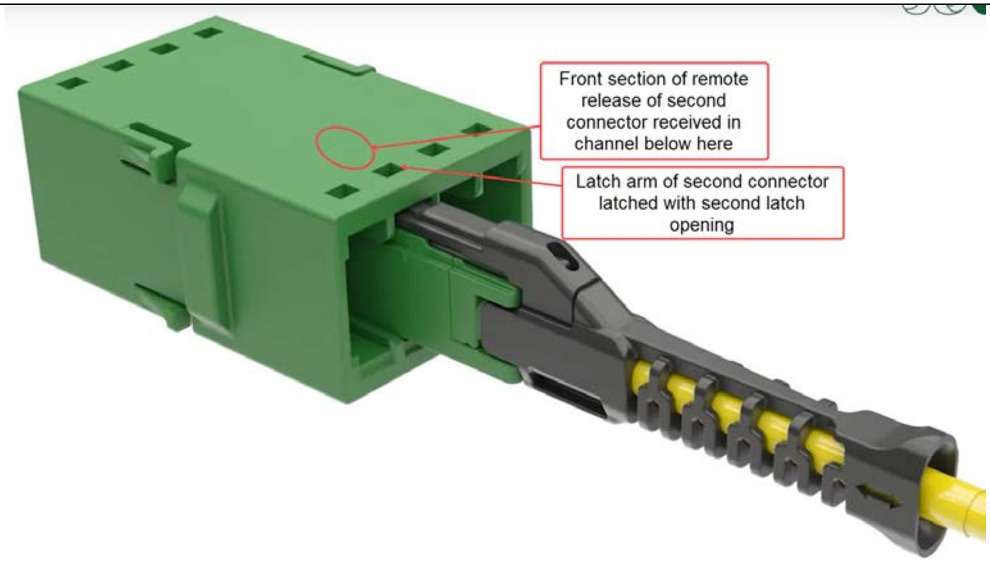
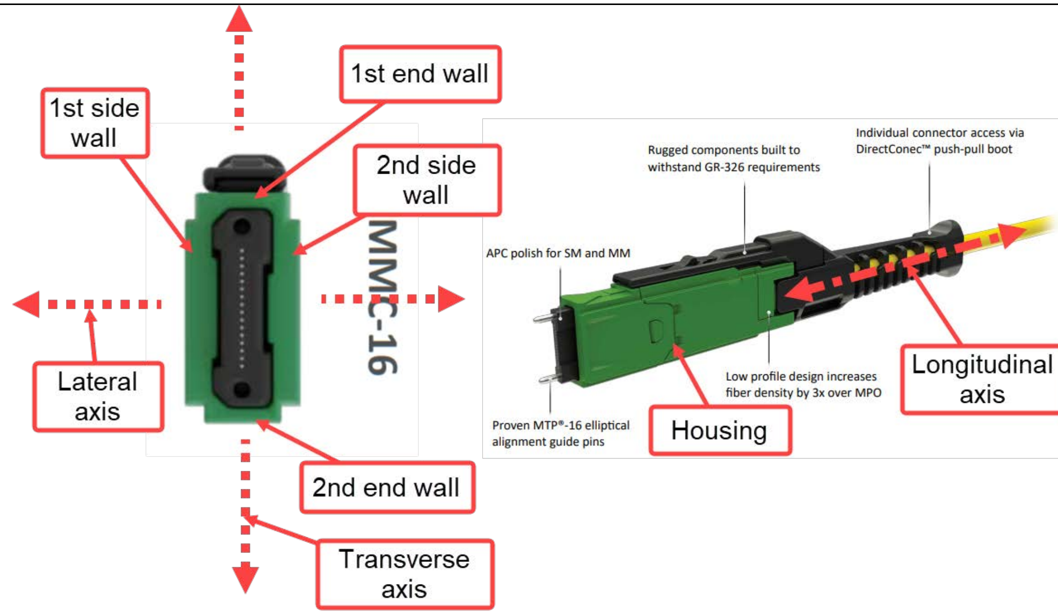
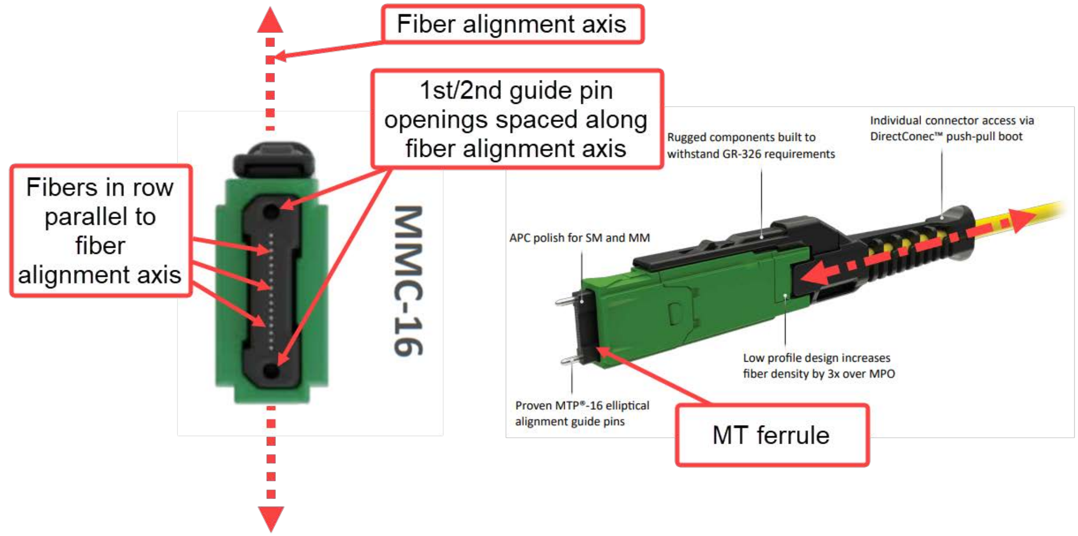
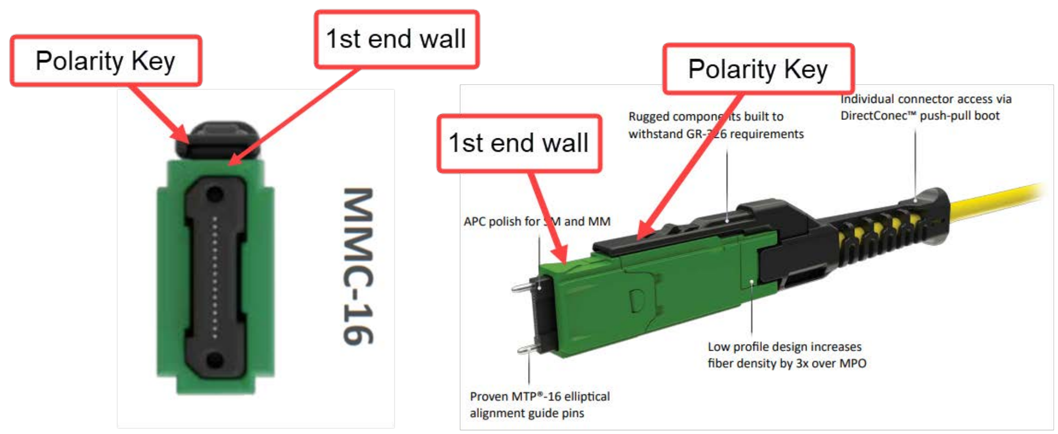
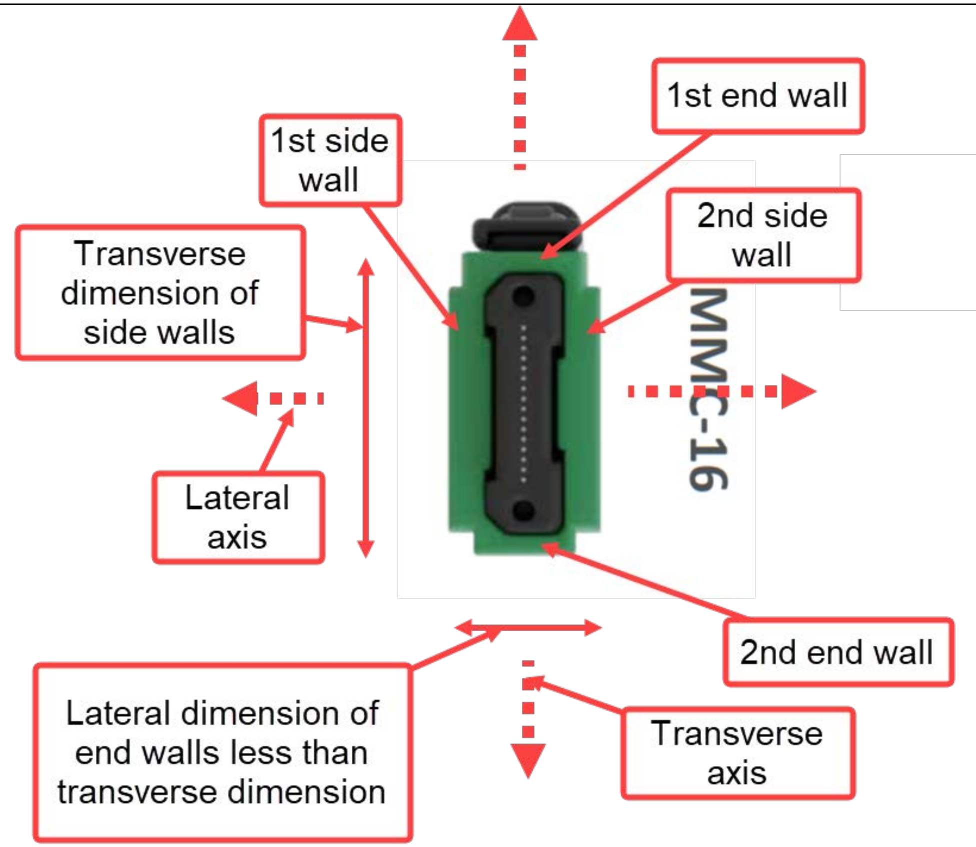
U.S. Pat. No. 11,333,836	MMC Adapters
	

EXHIBIT P

<table>
<tr><th>U.S. Patent No. 11,340,413</th><th>MMC Connector</th></tr>
<tr><td>1. An optical fiber connector comprising:</td><td></td></tr>
<tr><td>a housing having a longitudinal axis and a front end portion and a rear end portion spaced apart along the longitudinal axis, the housing comprising opposite first and second end walls spaced apart along a transverse axis oriented perpendicular to the longitudinal axis, the housing comprising opposite first and second side walls spaced apart along a lateral axis oriented perpendicular to the longitudinal axis and the transverse axis;</td><td>
</td></tr>
</table>

U.S. Patent No. 11,340,413	MMC Connector
an MT ferrule received in the housing and exposed through the front end portion of the housing for making an optical connection, the MT ferrule configured to receive plurality of fibers such that the fibers are spaced apart in a row that extends parallel to a fiber alignment axis, the MT ferrule further comprising first and second guide pin openings spaced apart along the fiber alignment axis; and	
a polarity key disposed on the first end wall;	

<table>
<tr><th>U.S. Patent No. 11,340,413</th><th>MMC Connector</th></tr>
<tr><td>wherein each of the first and second end walls has a lateral dimension along the lateral axis and each of the first and second side walls has a transverse dimension along the transverse axis, the lateral dimension being less than the transverse dimension;</td><td>
</td></tr>
</table>

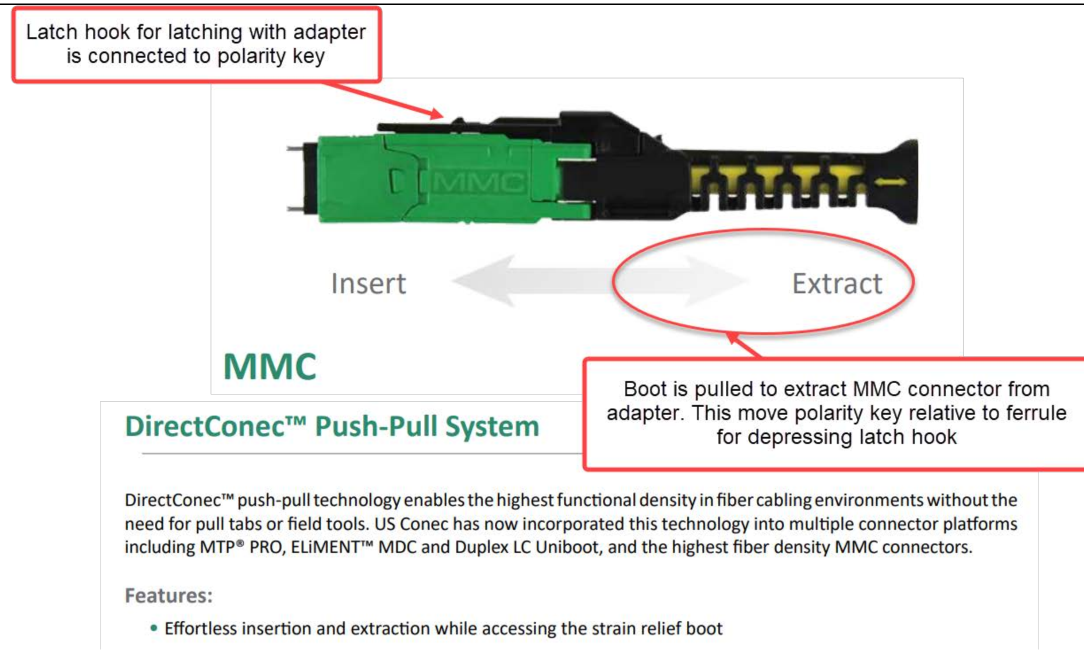
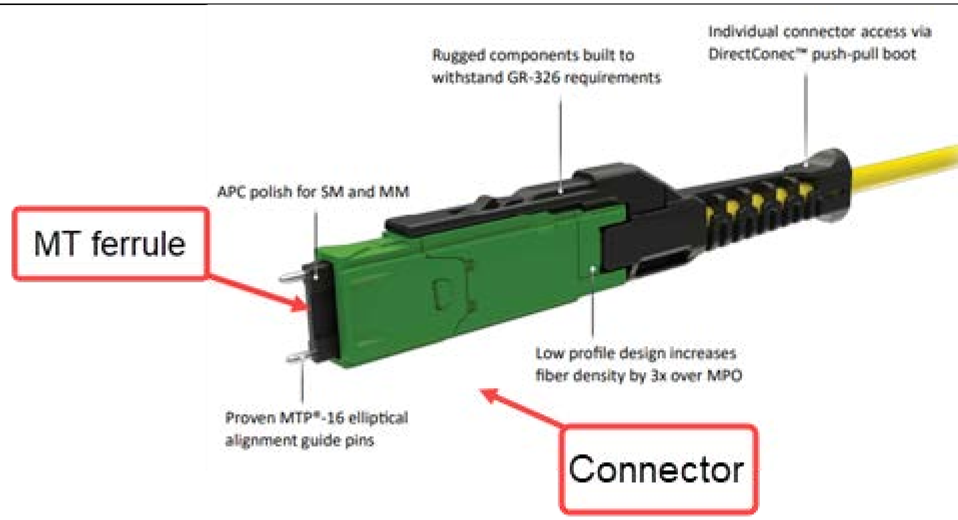
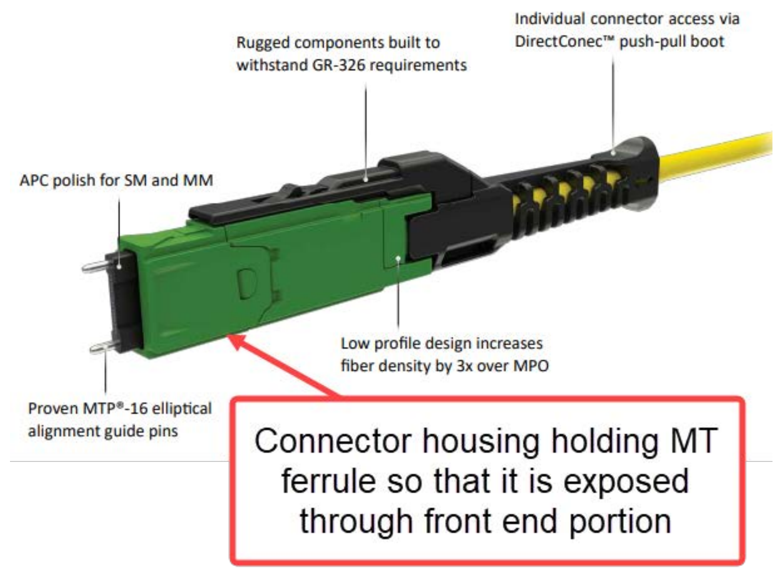
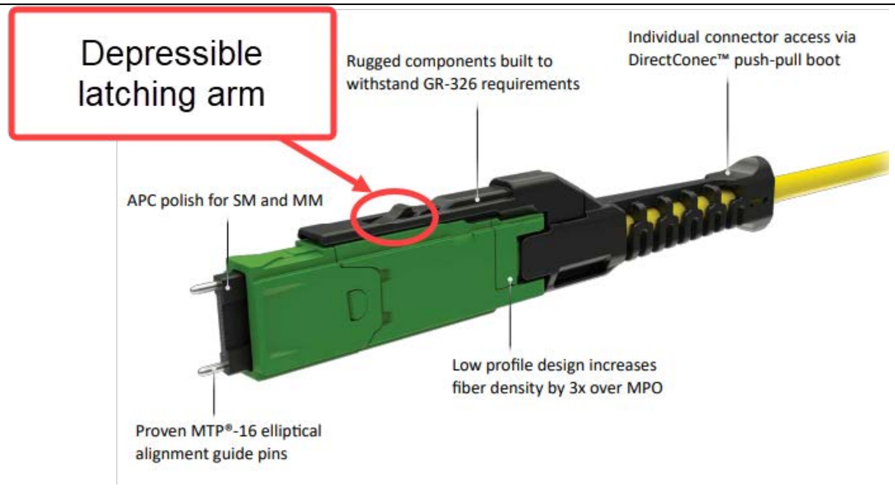
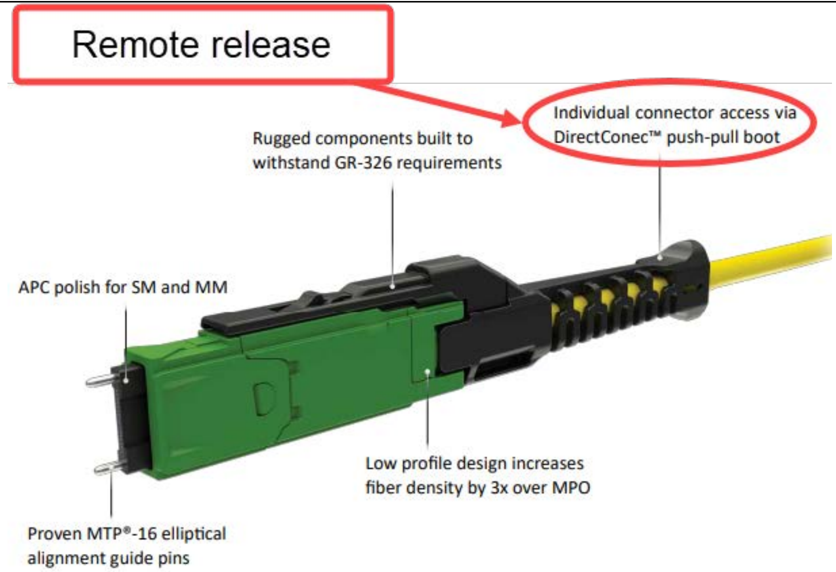
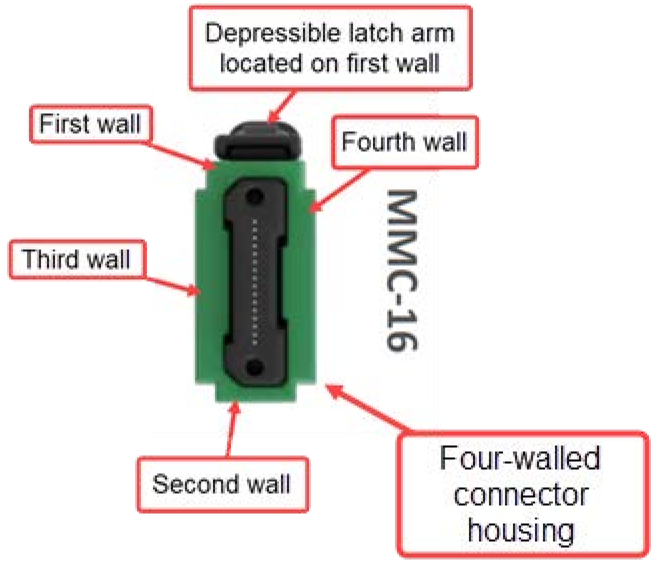
U.S. Patent No. 11,340,413	MMC Connector
wherein the optical fiber connector is configured to latch with a mating adapter and wherein the optical fiber connector is configured to be actuated to unlatch from the mating adapter by displacing a first portion of the optical fiber connector rearward relative to a second portion of the optical fiber connector, wherein said displacing the first portion of the optical fiber connector rearward relative to the second portion of the optical fiber connector displaces the polarity key rearward relative to the MT ferrule.	

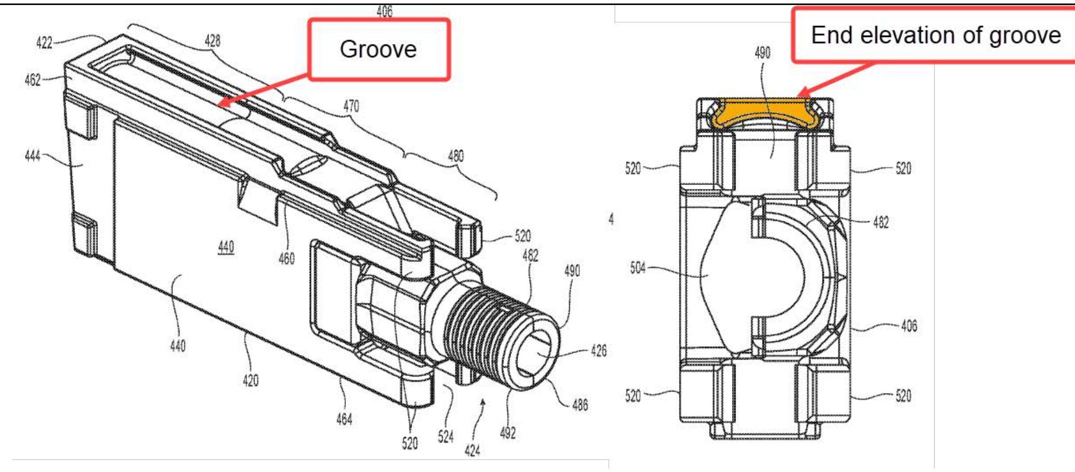
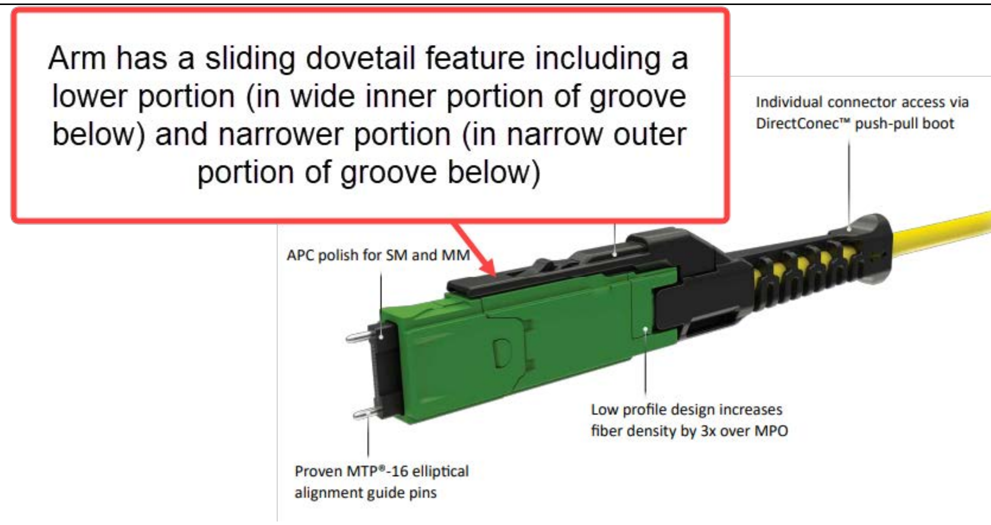
EXHIBIT Q

U.S. Patent No. 11,415,760	MMC Connector
1. An optical fiber connector configured for mating with a receptacle, the optical fiber connector comprising:	
an MT ferrule configured to hold a plurality of optical fibers;	

U.S. Patent No. 11,415,760	MMC Connector
a connector housing having a front end portion and a rear end portion spaced apart along a longitudinal axis, the connector housing configured to hold the MT ferrule such that the MT ferrule is exposed through the front end portion for making an optical connection;	
a depressible latching arm connected to the connector housing for latching with the receptacle when the optical fiber connector is mated with the receptacle to releasably retain the optical fiber connector in the receptacle; and	

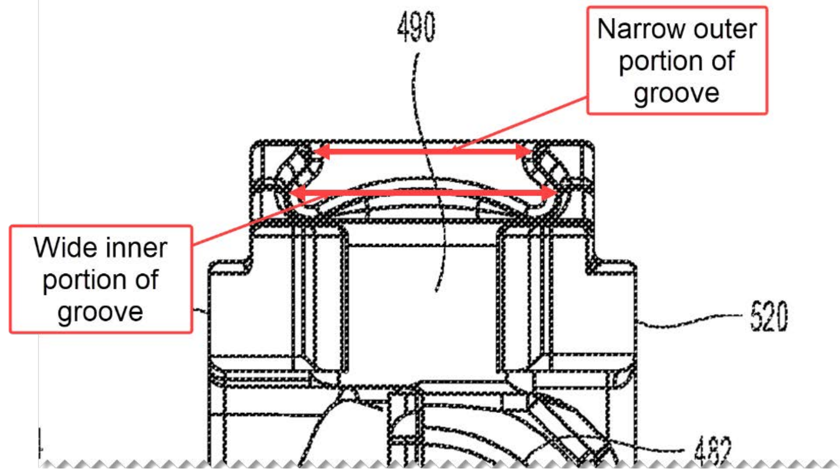
U.S. Patent No. 11,415,760	MMC Connector
a remote release connected to the connector housing for movement relative to the connector housing along the longitudinal axis, the remote release being configured to be pulled rearward along the longitudinal axis to depress the depressible latching arm for releasing the optical fiber connector from the receptacle;	

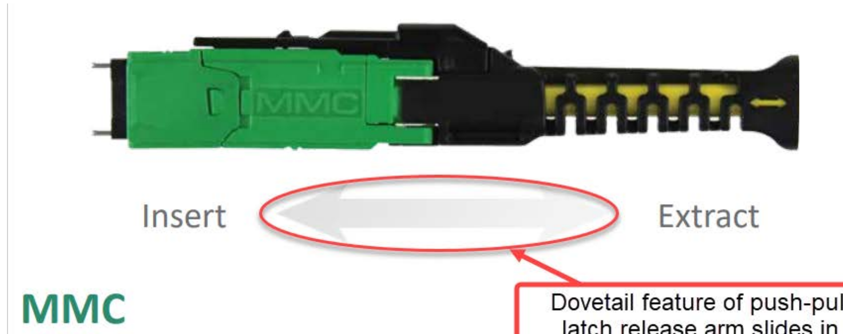
U.S. Patent No. 11,415,760	MMC Connector
wherein the connector housing has a generally rectangular perimeter including opposite first and second walls and opposite third and fourth walls, the depressible latching arm being located on an exterior of the first wall;	

U.S. Patent No. 11,415,760	MMC Connector
wherein the first wall of the connector housing defines a groove, the remote release being slidably received in the groove;	 [1]
wherein the remote release comprises a lower portion and a narrower portion above the lower portion, the lower portion being wider than the narrower portion;	

[1] Senko refers to black and white line drawings taken from US Conec's own WO 2021/217054 patent application, which drawings are an appropriate proxy for showing how US Conec's MMC product reads on relevant features of the claim.

<table>
<tr><th>U.S. Patent No. 11,415,760</th><th>MMC Connector</th></tr>
<tr><td>wherein the groove includes an inner portion and an outer portion, the inner portion being wider than the outer portion, the inner portion of the groove being configured to slidably receive the lower portion of the latch release and the outer portion of the groove being configured to slidably receive the narrower portion of the latch release such that the first wall releasably retains the latch release in the groove.</td><td>





DirectConec™ Push-Pull System

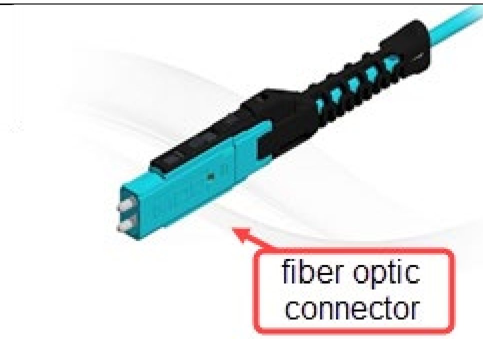
DirectConec™ push-pull technology enables the highest functional density in fiber cabling environments without the need for pull tabs or field tools. US Conec has now incorporated this technology into multiple connector platforms including MTP® PRO, ELiMENT™ MDC and Duplex LC Uniboot, and the highest fiber density MMC connectors.

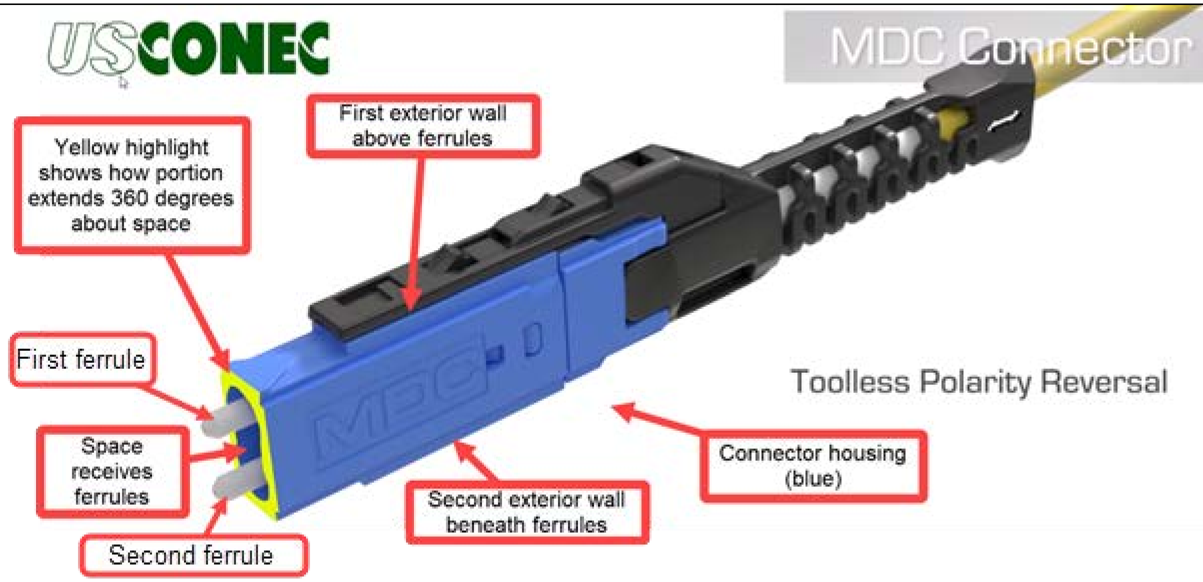
Features:

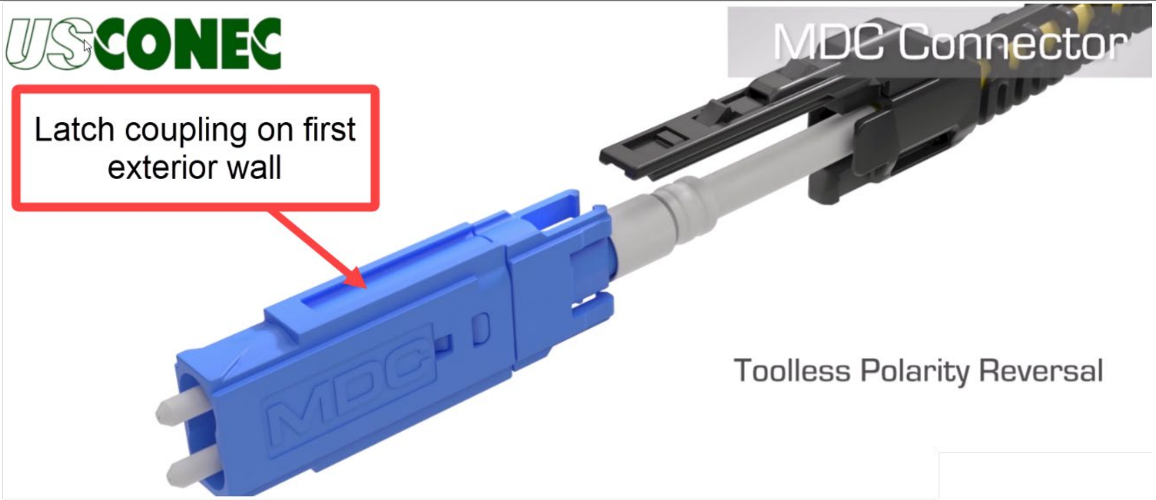
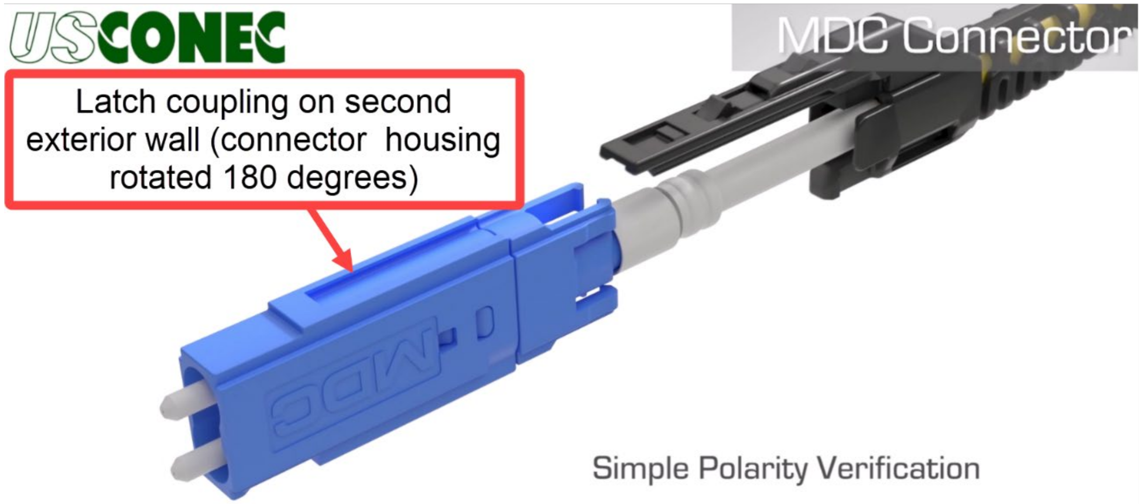
- Effortless insertion and extraction while accessing the strain relief boot

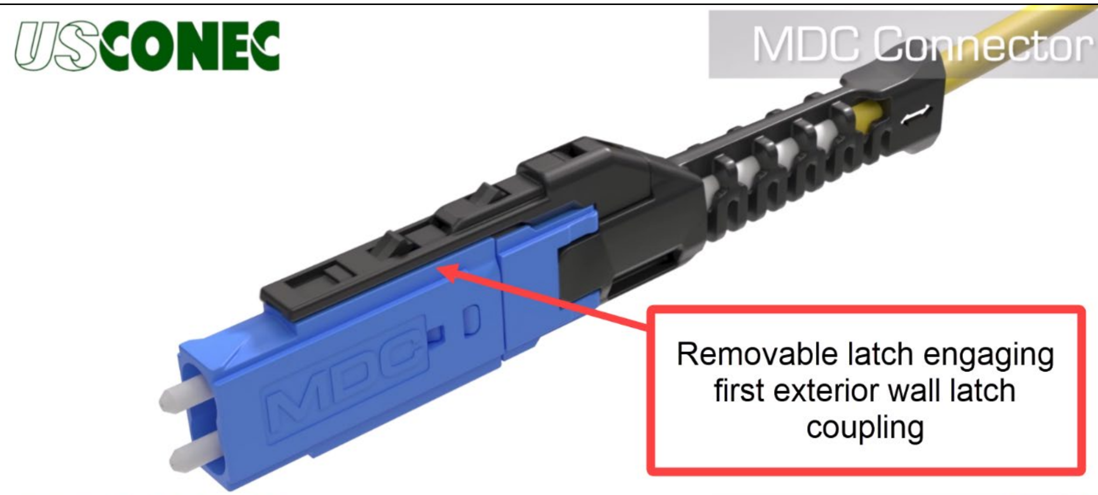
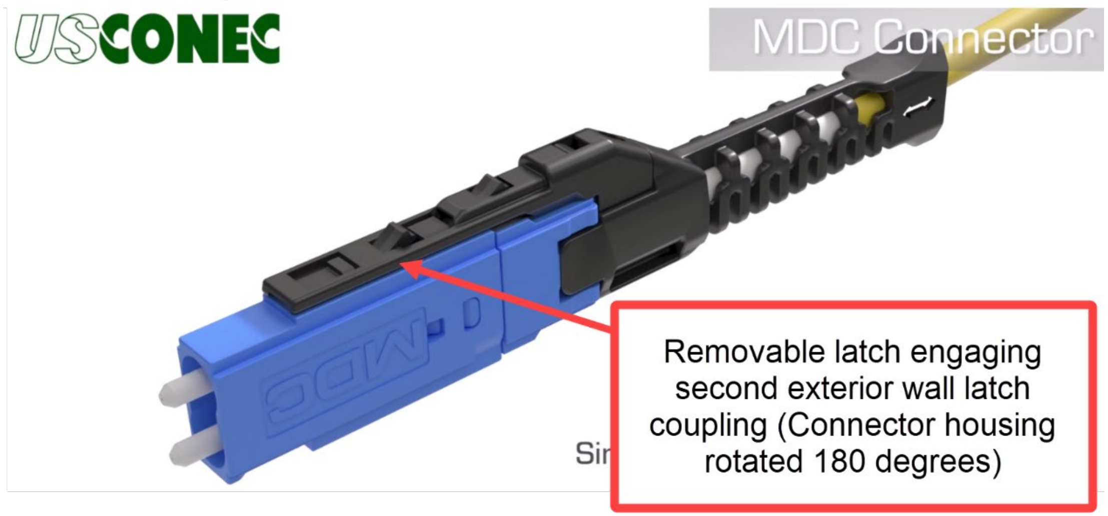
</td></tr>
</table>

EXHIBIT R

U.S. Pat. No. 10,191,230 C1	MDC
1. A reversible polarity fiber optic connector comprising:	Insertion and extraction of the MDC connector occurs with a simple push or pull on a flexible and robust strain relief boot providing functional density in very tight spaces. For faster error free installations, an optional aggregation component will allow for insertion and removal of multiple MDC connectors at once. Polarity of MDC connectors is effortlessly changed in the field or factory to support multiple cabling methodologies without the need for tools and without exposing or twisting delicate fibers. The MDC connector is designed for optimal stability exceeding the requirements of Telcordia GR-326 for carrier or data center applications. 
at least first and second optical ferrules;	

U.S. Pat. No. 10,191,230 C1	MDC
a connector housing having a longitudinal axis and comprising an exterior portion at least partially surrounding the first and second optical ferrules such that the exterior portion extends 360° circumferentially with respect to the longitudinal axis about a space in which each of the first and second optical ferrules are received, the exterior portion comprising a first exterior wall positioned above the first and second optical ferrules and a second exterior wall positioned beneath the first and second optical ferrules;	

U.S. Pat. No. 10,191,230 C1	MDC
a latch coupling positioned on each of the first and second exterior walls of the connector housing;	 

U.S. Pat. No. 10,191,230 C1	MDC
a removable latch for engaging either of the first and second exterior wall latch couplings on the connector housing;	 

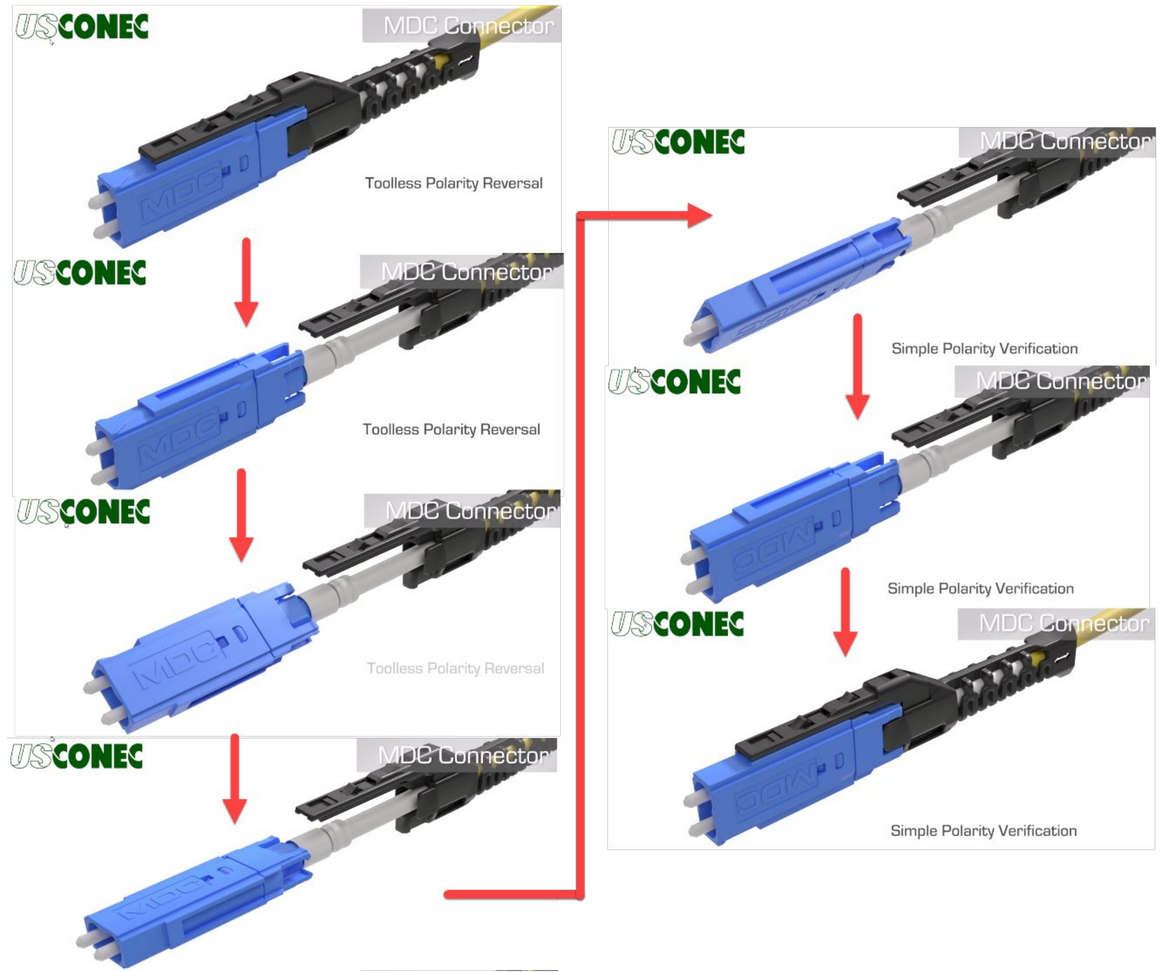
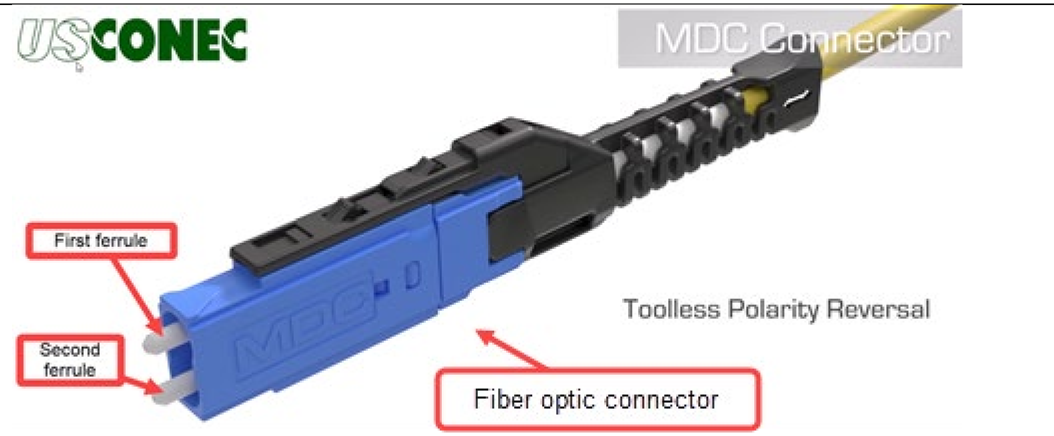
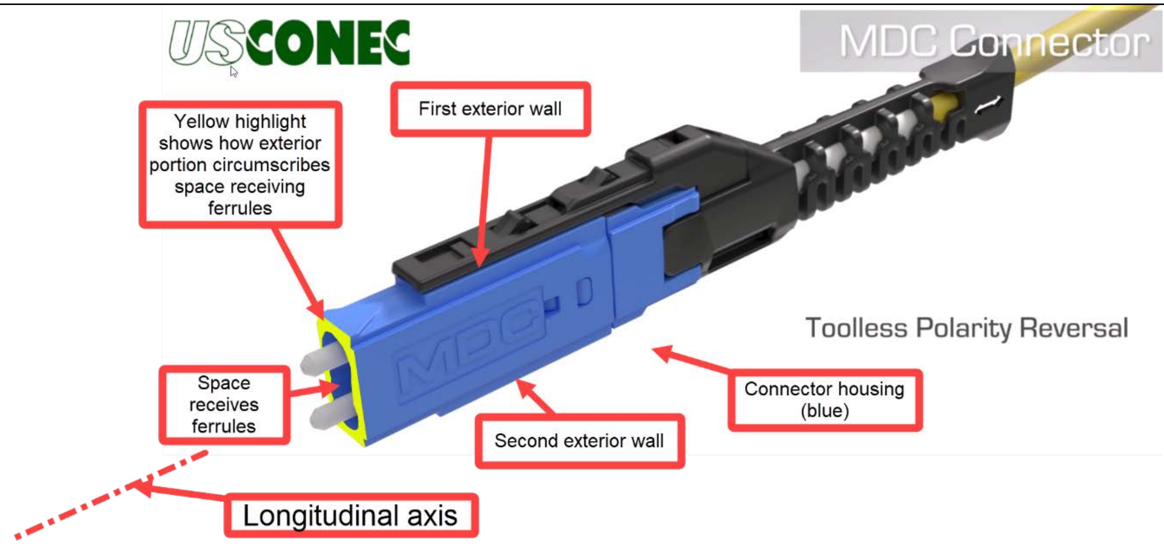
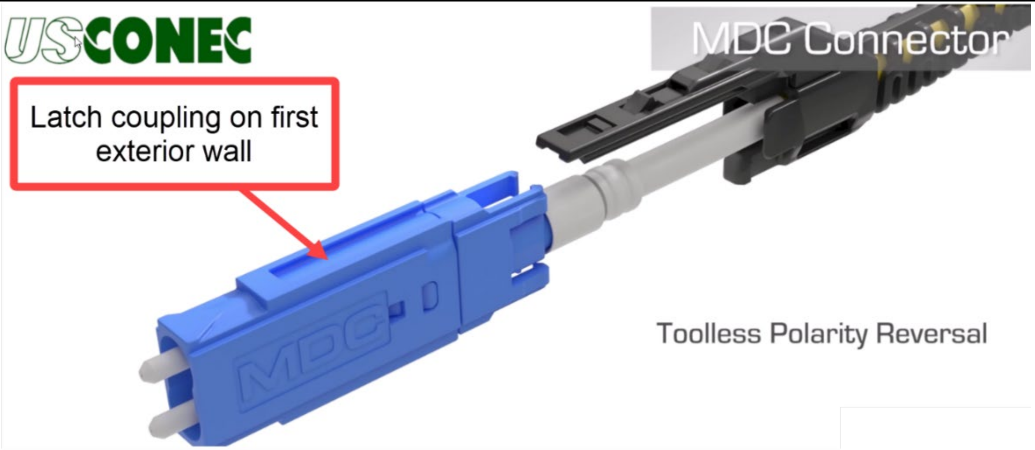
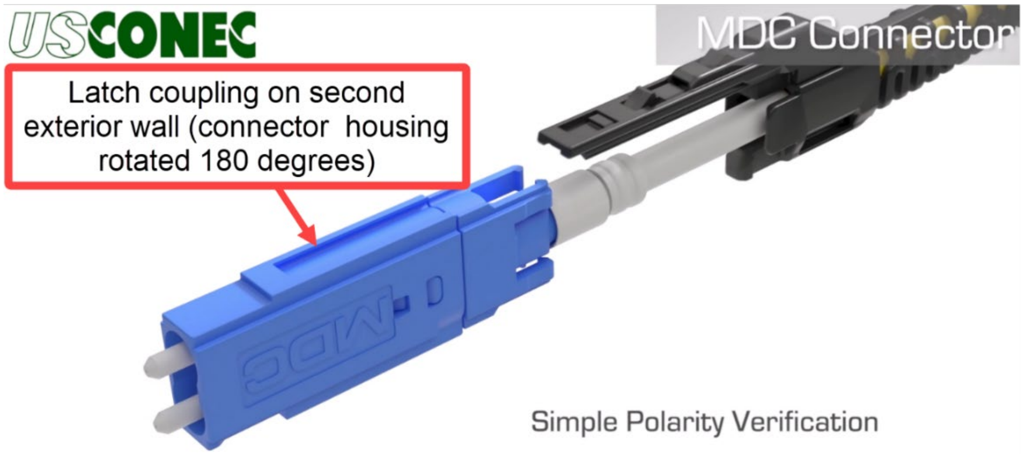
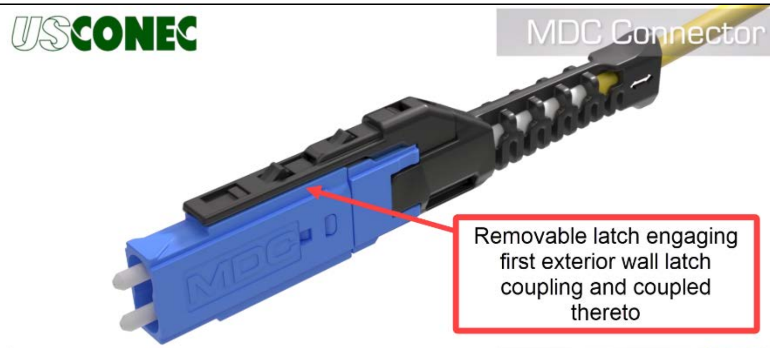
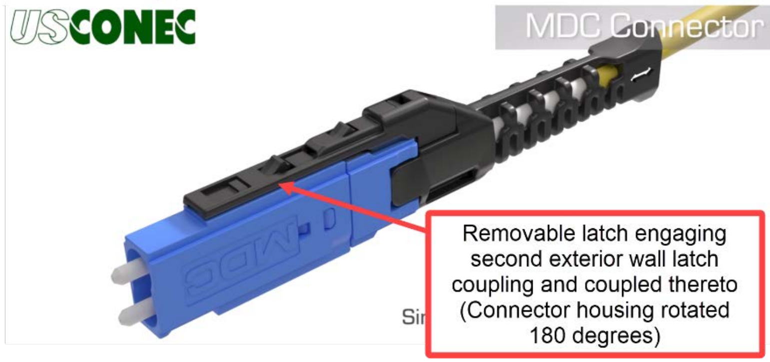
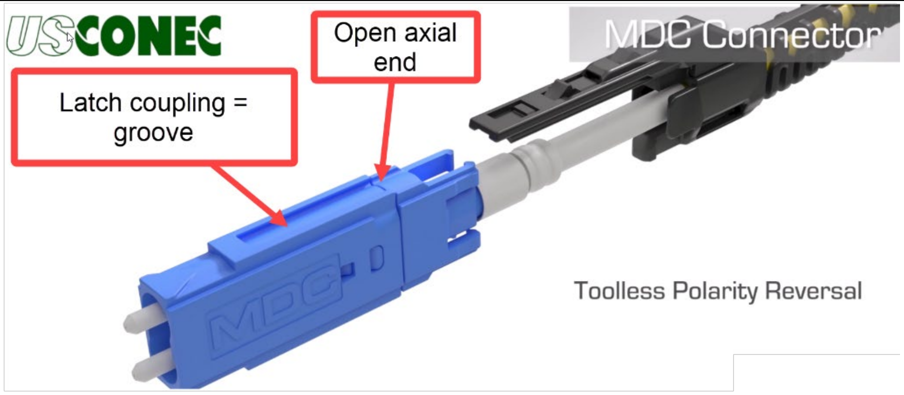
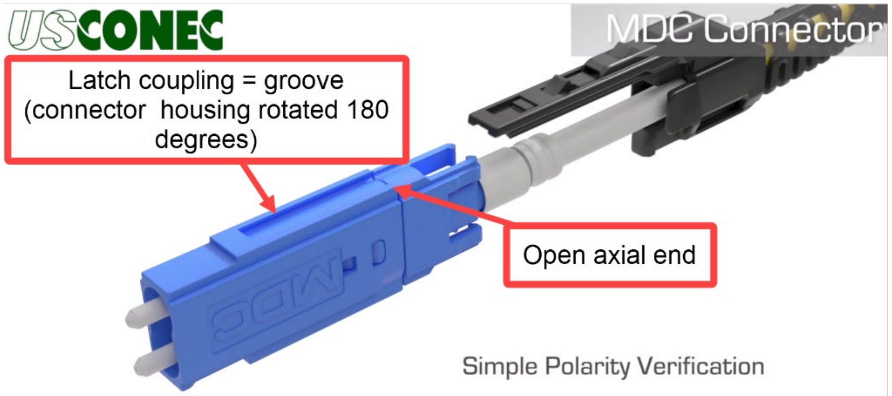
U.S. Pat. No. 10,191,230 C1	MDC
wherein positioning the removable latch on the first exterior wall of the connector housing yields a fiber optic connector with a first polarity and positioning the removable latch on the second exterior wall of the connector housing yields a fiber optic connector with a second polarity, the second polarity being opposite to the first polarity.	

EXHIBIT S

U.S. Pat. No. 11,181,701 B2	MDC
1. A fiber optic connector comprising:	
at least first and second optical ferrules;	
a connector housing having a longitudinal axis and comprising an exterior portion at least partially surrounding the first and second optical ferrules such that the exterior portion circumscribes a space in which each of the first and second optical ferrules are received, the exterior portion comprising a first exterior wall and a second exterior wall on an opposite side of the space from the first exterior wall;	

U.S. Pat. No. 11,181,701 B2	MDC
a latch coupling positioned on each of the first and second exterior walls of the connector housing;	 

U.S. Pat. No. 11,181,701 B2	MDC
a removable latch for engaging either of the first and second exterior wall latch couplings on the connector housing, whereby the removable latch couples to the respective latch coupling;	

U.S. Pat. No. 11,181,701 B2	MDC
wherein each latch coupling comprises a groove extending along the axis and having an open axial end; and	

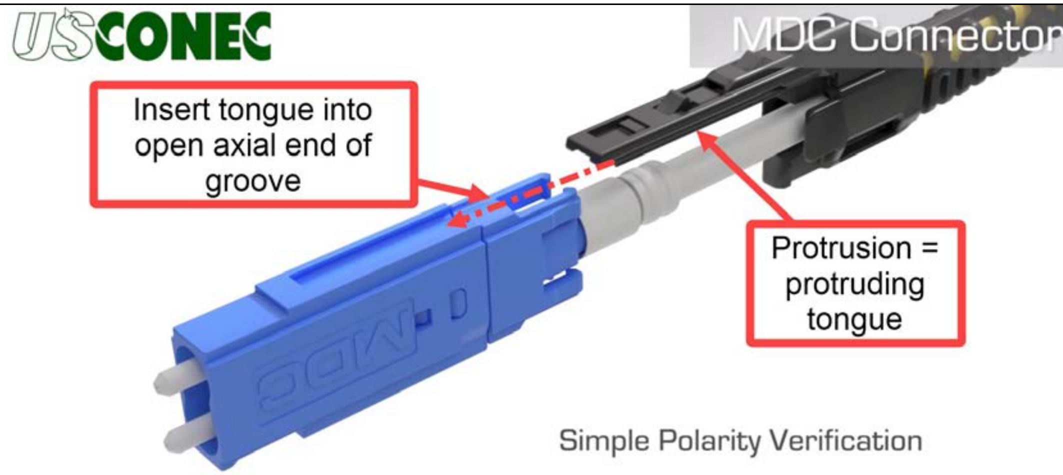
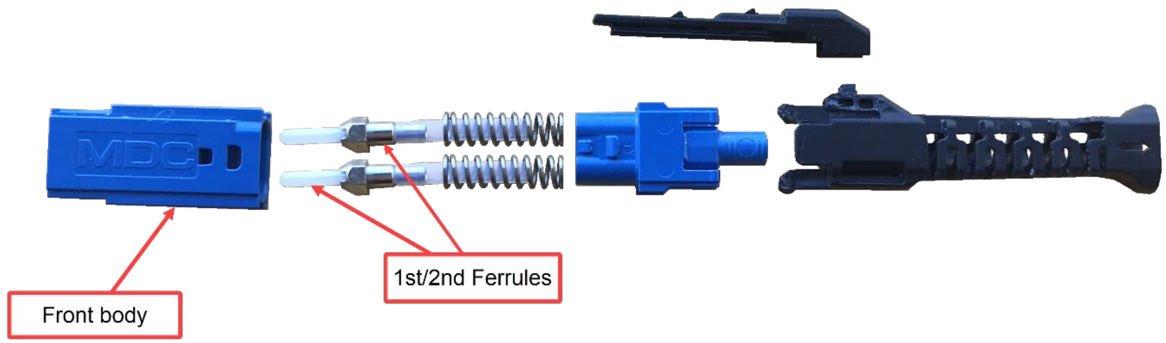
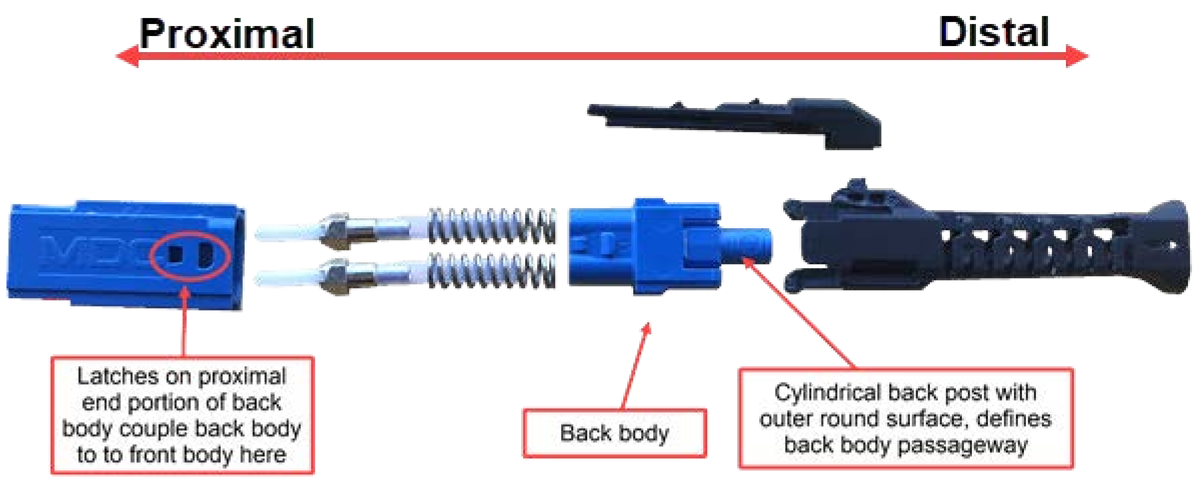
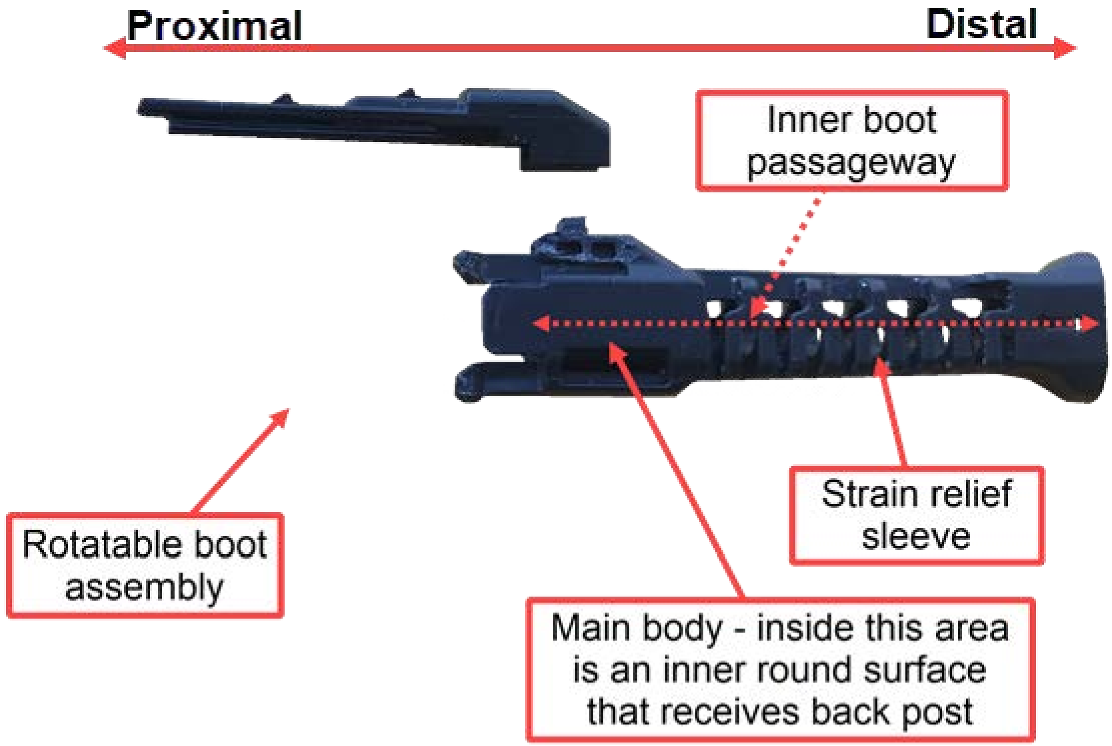
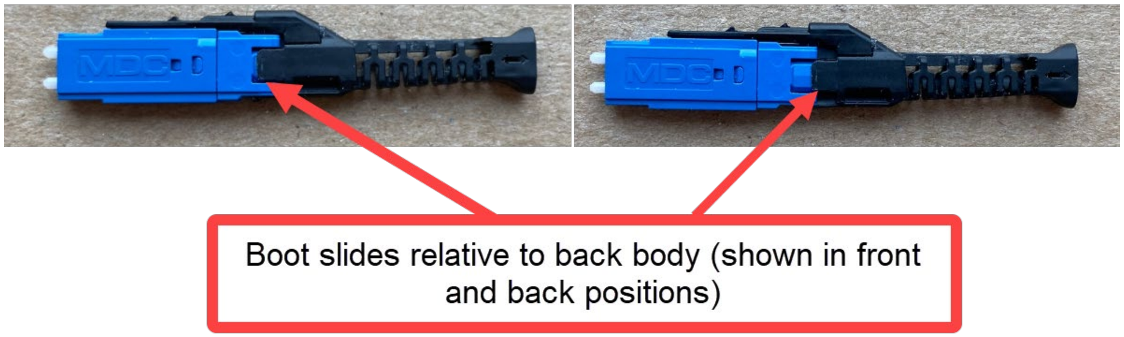
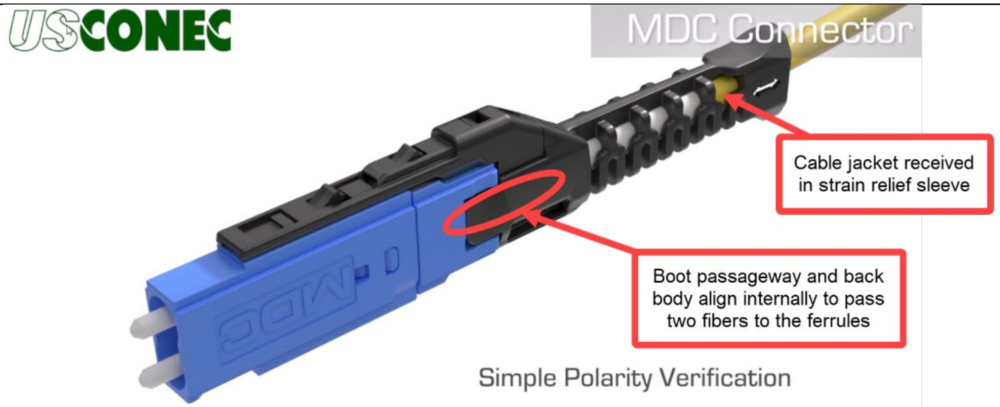
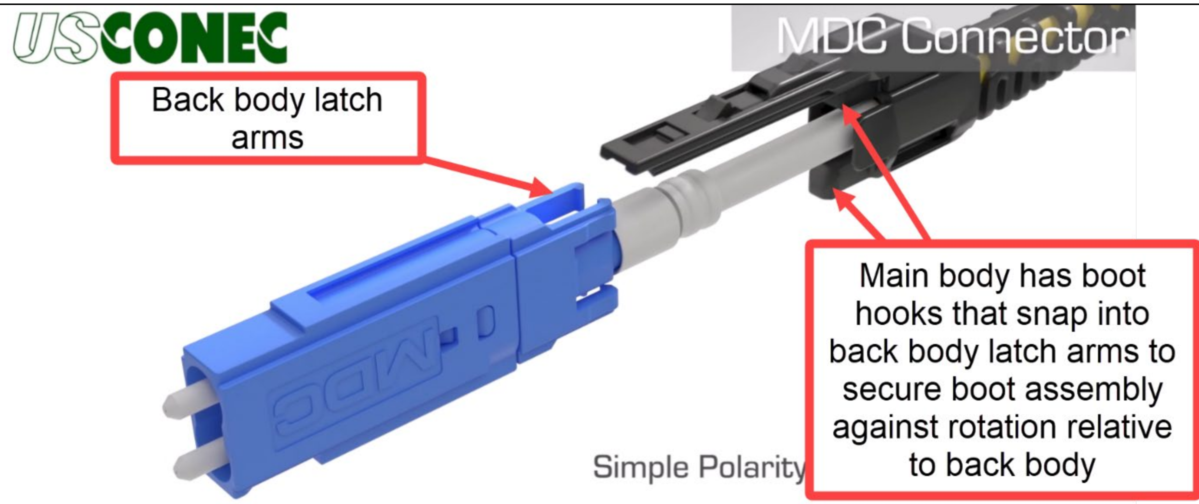
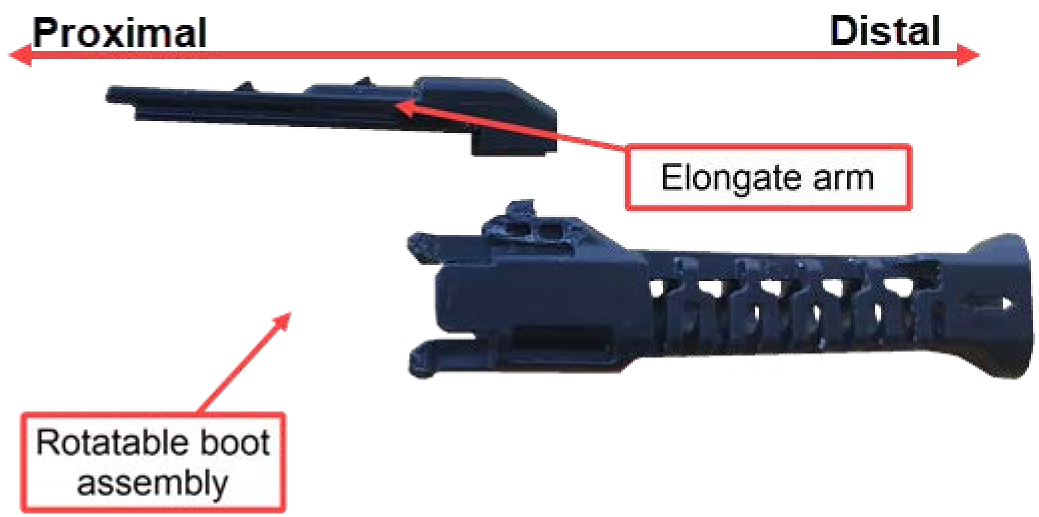
U.S. Pat. No. 11,181,701 B2	MDC
wherein the removable latch comprises a protrusion for being inserted into the open axial end of the groove by movement relative to the housing along the axis.	

EXHIBIT T

<table>
<tr><th>U.S. Pat. No. 11,061,190</th><th>MDC Connector</th></tr>
<tr><td>1. An optical fiber connector comprising:</td><td></td></tr>
<tr><td>a front body configured to hold first and second ferrules;</td><td>
</td></tr>
<tr><td>a back body having a proximal end portion and a distal end portion spaced apart along a longitudinal axis, the proximal end portion of the back body configured to couple to the front body, the distal end portion of the back body comprising a cylindrical back post having an outer round surface extending along the longitudinal axis, the back body defining a back body passageway extending from the distal end portion through the proximal end portion; and</td><td>
</td></tr>
</table>

U.S. Pat. No. 11,061,190	MDC Connector
a rotatable boot assembly having a proximal end portion and a distal end portion spaced apart along the longitudinal axis, the rotatable boot assembly comprising a main body and a strain relief sleeve extending longitudinally from the main body to the distal end portion of the rotatable boot assembly, the rotatable boot assembly comprising a boot passageway extending from the distal end portion through the main body, the main body comprising an inner round surface extending along the longitudinal axis, the inner round surface defining a proximal end portion of the boot passageway, the rotatable boot assembly configured to be disposed on the back body such that (i) the outer round surface of the back post is matingly received in the inner round surface of the main body and	

U.S. Pat. No. 11,061,190	MDC Connector
(ii) the cable boot member is slidable along the longitudinal axis relative to the back body for releasing the optical fiber connector from an adapter,	
the optical fiber connector being configured to terminate a fiber optic cable such that a jacket of the cable is received in the strain relief sleeve in the boot passageway, the boot passageway and the back body passageway configured to align for passing first and second fibers from the fiber optic cable to the front body to complete a signal path to the first and second ferrules within the front body;	

U.S. Pat. No. 11,061,190	MDC Connector
the main body further comprising at least one boot hook configured for releasably securing the multi-purpose rotatable boot assembly against rotation relative to the back body,	
and the rotatable boot assembly further comprising an elongate arm extending longitudinally from the main body in a proximal direction along the longitudinal axis,	

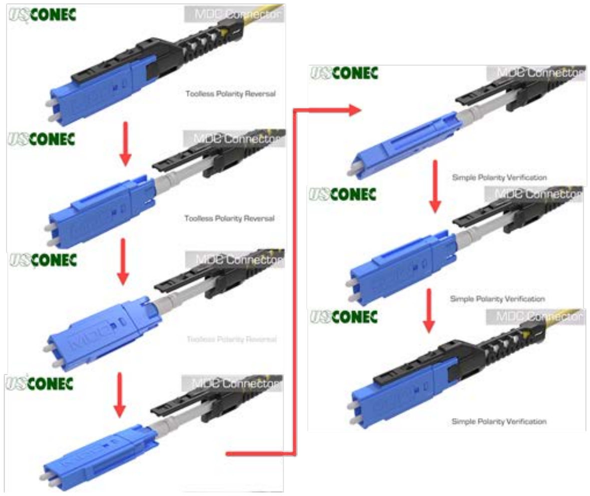
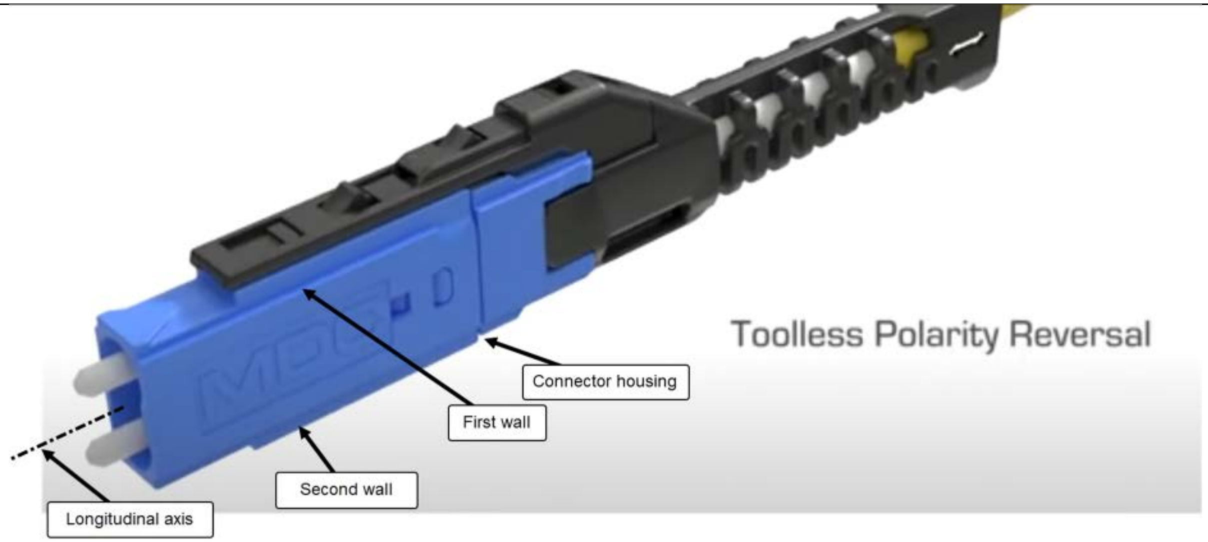
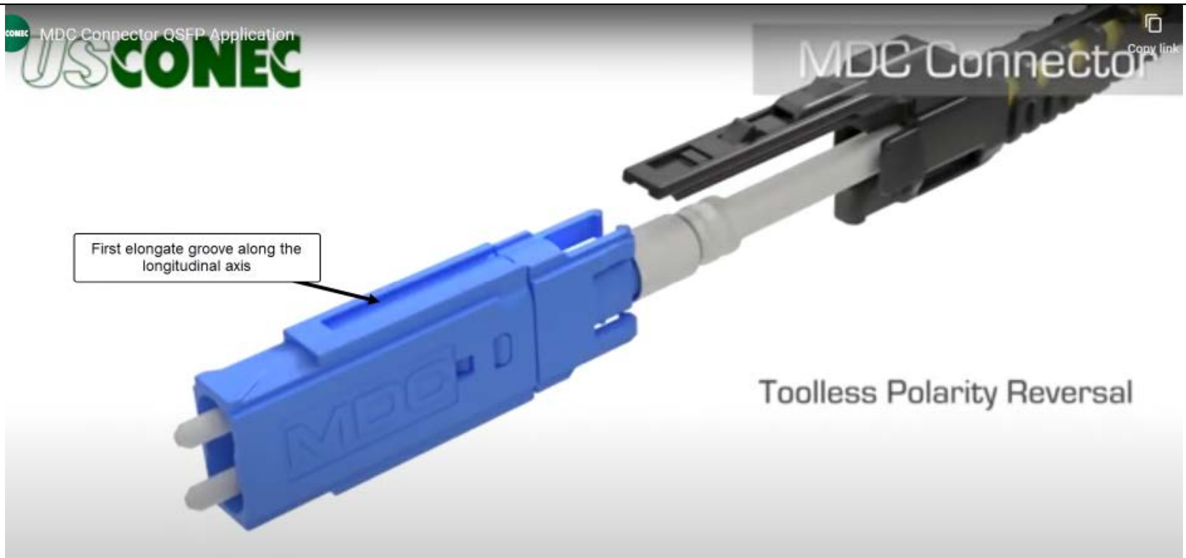
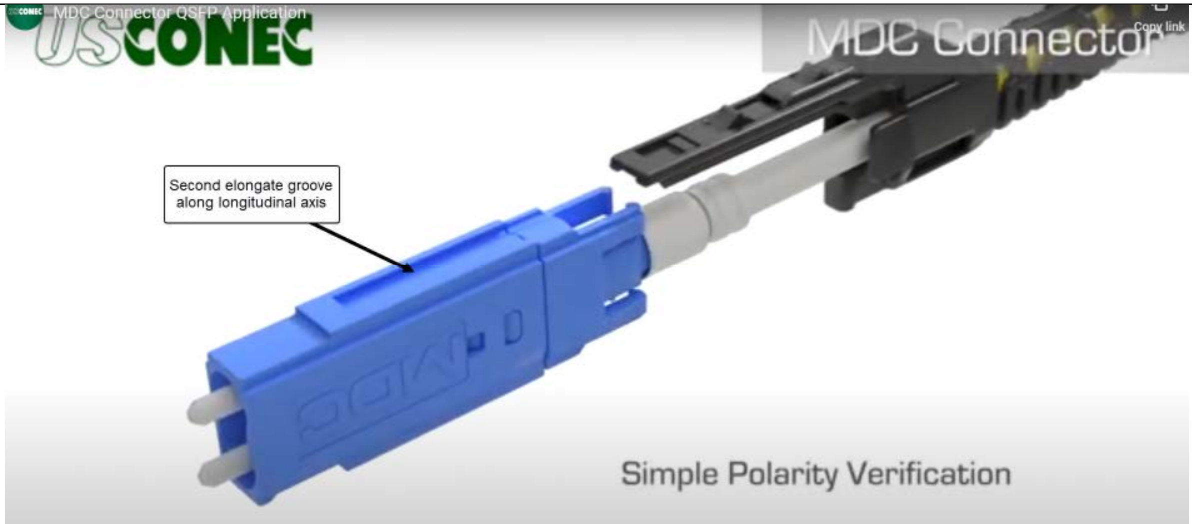
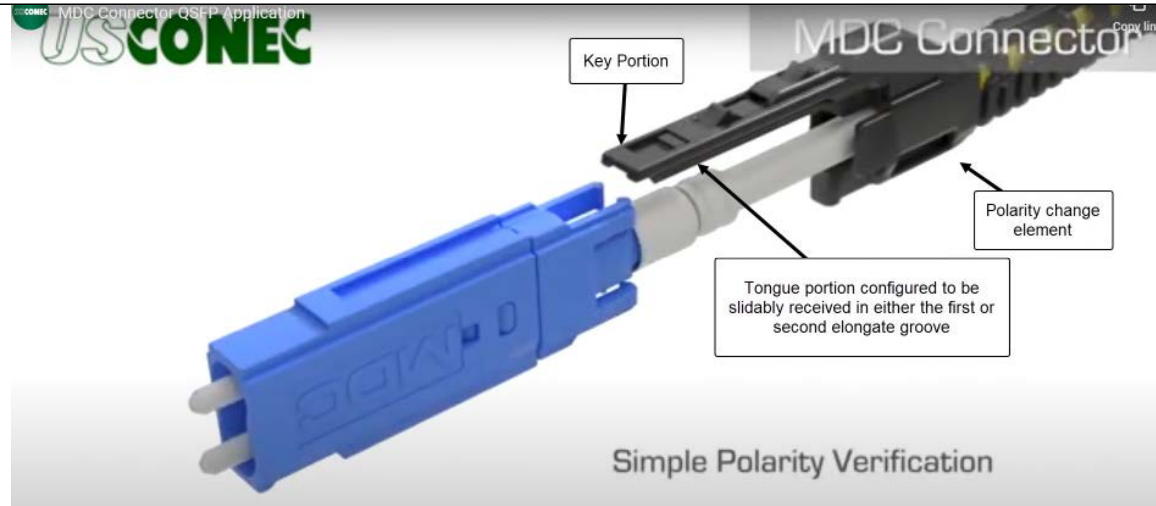
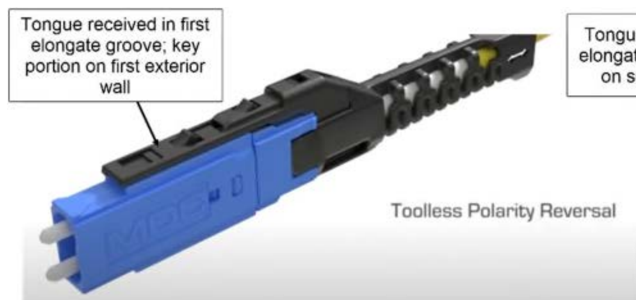
U.S. Pat. No. 11,061,190	MDC Connector
the elongate arm being configured for selectively setting the optical fiber connector to each of a first polarity and a second polarity.	Boot assembly is rotatable so that arm attaches to either top or bottom of housing, whereby elongate arm selectively configures connector for either first or second polarity 

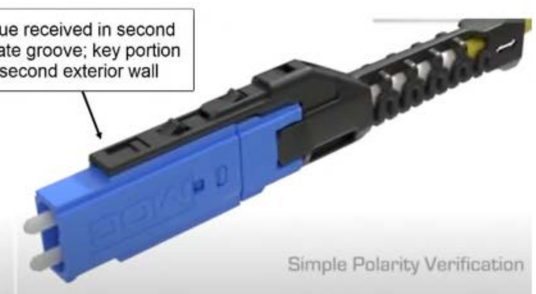
EXHIBIT U

U.S. Pat. No. 11,391,895 C1	MDC
1. A fiber optic connector comprising:	
a connector housing having a longitudinal axis and comprising an exterior portion extending circumferentially about a space with respect to the longitudinal axis, the exterior portion including first and second exterior walls on opposite sides of the longitudinal axis, the connector housing being configured to receive a plurality of optical fibers in the space between the first and second exterior walls,	

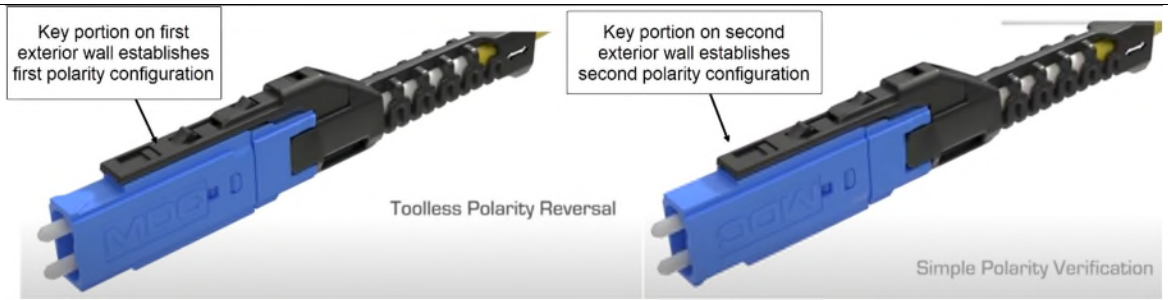
U.S. Pat. No. 11,391,895 C1	MDC
the first exterior wall comprising a first elongate groove along the longitudinal axis and	
the second exterior wall comprising a second elongate groove along the longitudinal axis; and	

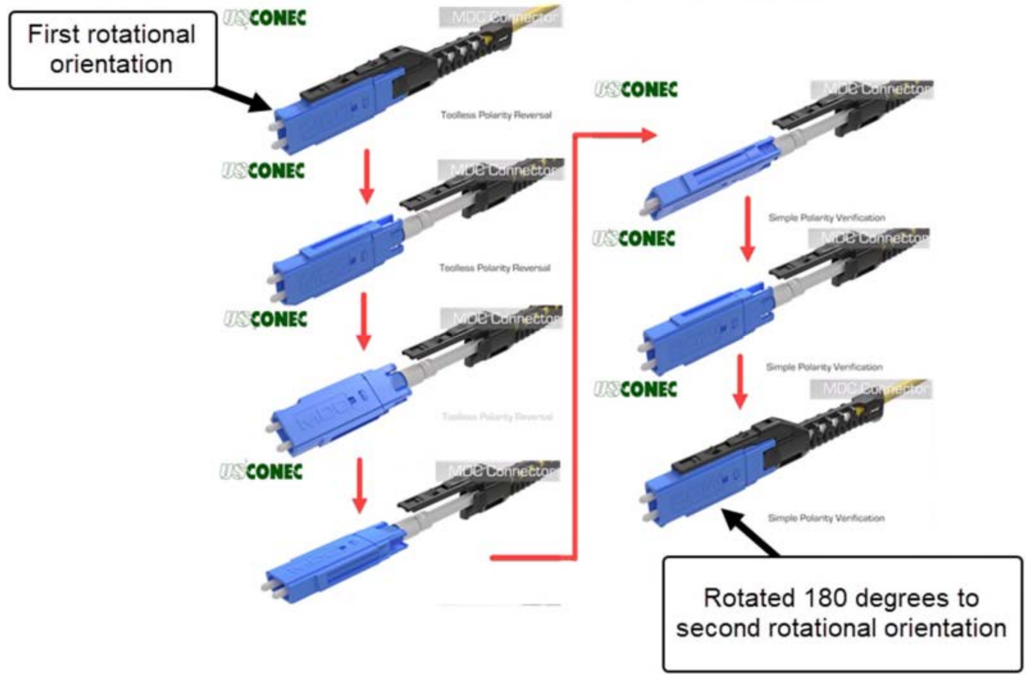
<table>
<tr><th>U.S. Pat. No. 11,391,895 C1</th><th>MDC</th></tr>
<tr><td>a polarity change element comprising a key portion and a tongue, the tongue being configured to be slidably received in a selected one of each of the first elongate groove and the second elongate groove to selectively and releasably position the polarity change element on a corresponding one of the first exterior wall and the second exterior wall such that the key portion is externally positioned on the respective one of the first exterior wall and the second exterior wall,</td><td>


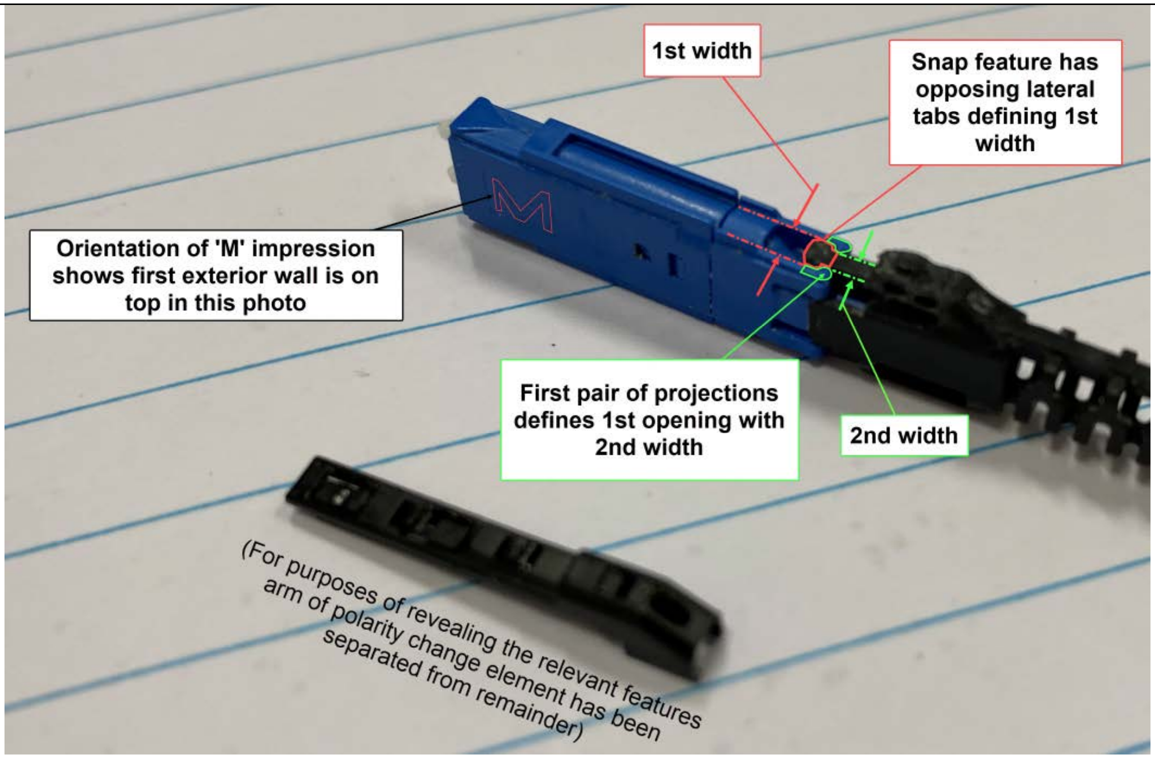


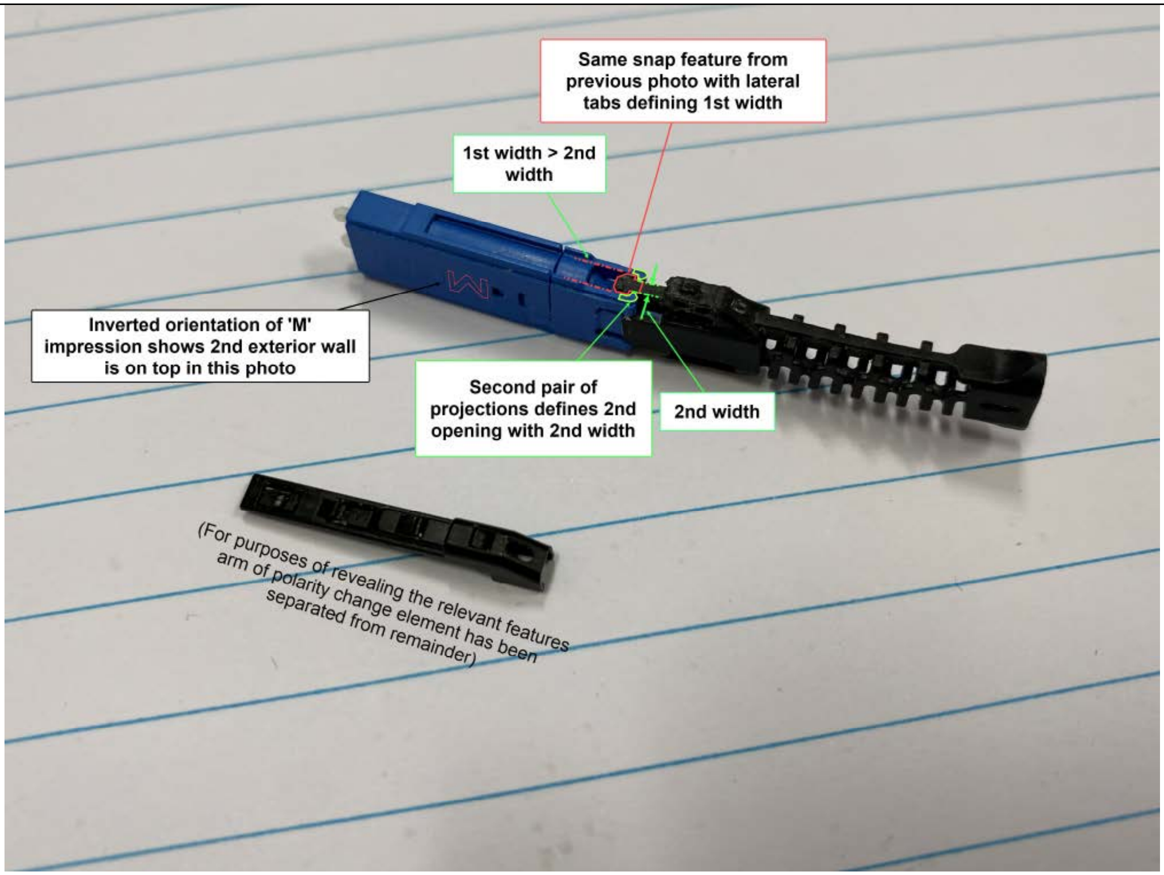


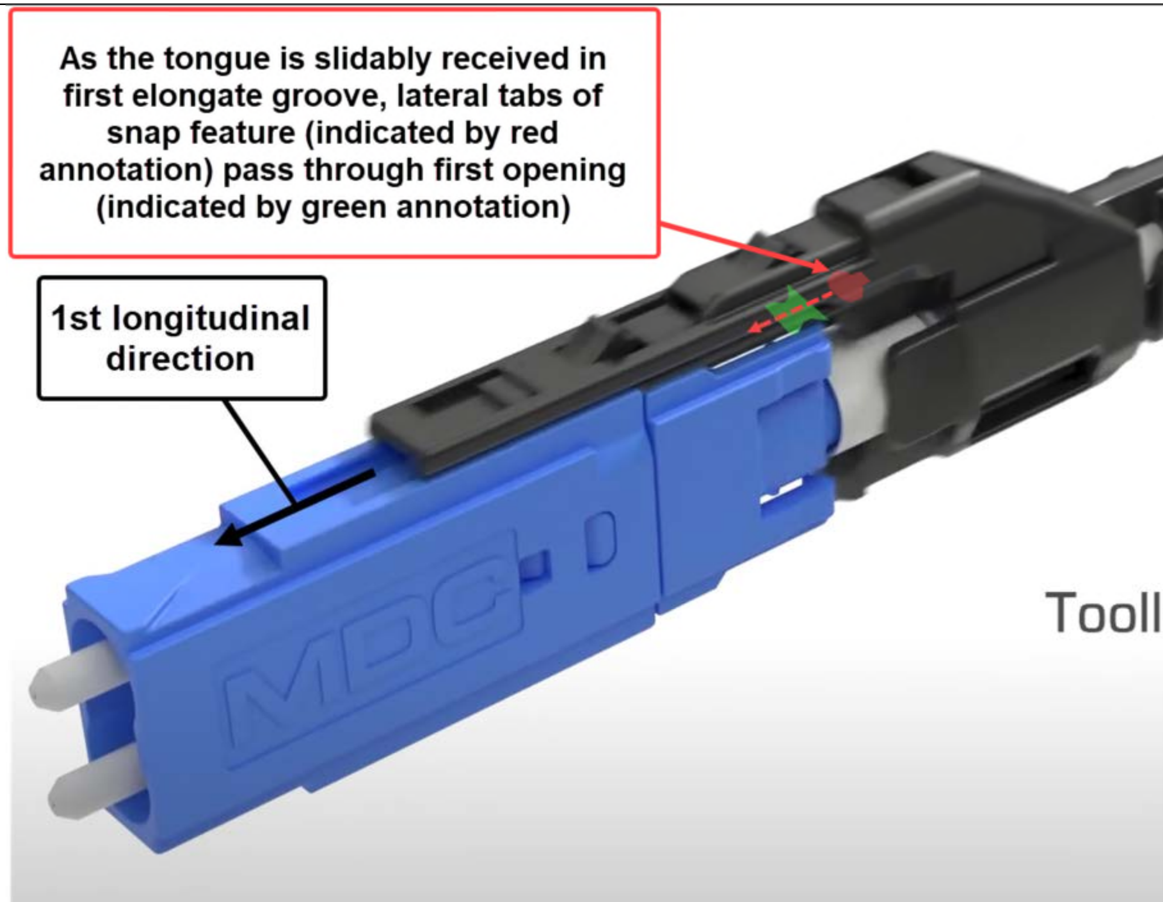
</td></tr>
</table>

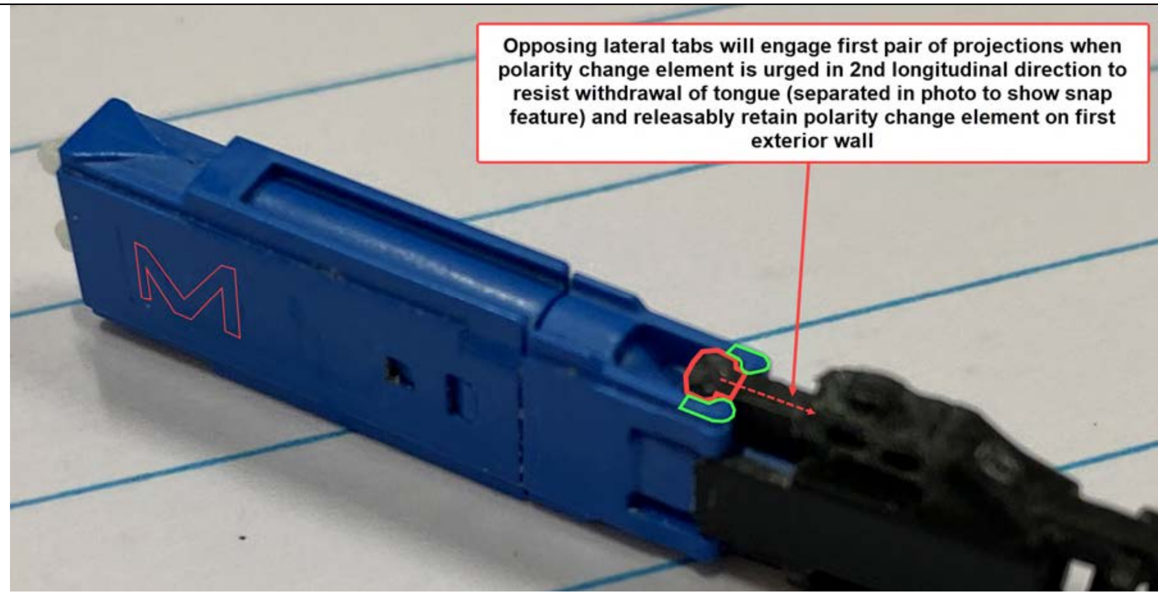
U.S. Pat. No. 11,391,895 C1	MDC
wherein positioning the polarity change element on the first exterior wall such that the key portion is externally positioned on the first exterior wall configures the fiber optic connector in a first polarity configuration and positioning the polarity change element on the second exterior wall such that the key portion is externally positioned on the second exterior wall configures the fiber optic connector in a second polarity configuration; and	

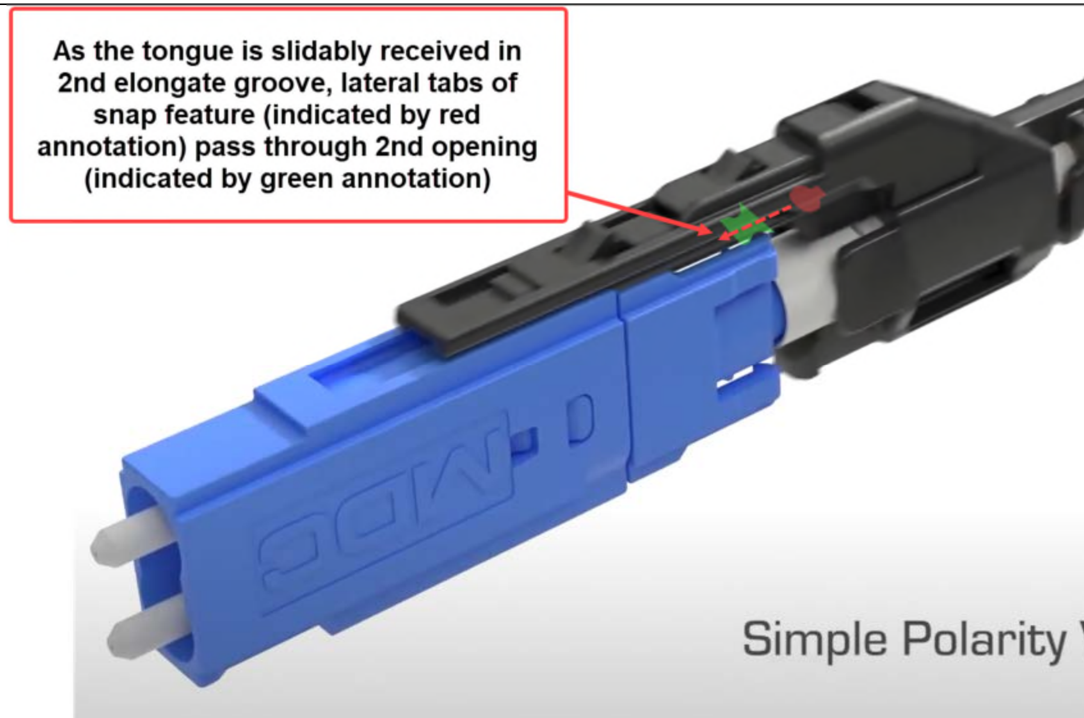
U.S. Pat. No. 11,391,895 C1	MDC
wherein the fiber optic connector is configured to be plugged into a mating receptacle with the connector housing in a first rotational orientation about the longitudinal axis when the fiber optic connector is in the first polarity configuration and the fiber optic connector is configured to be plugged into the mating receptacle with the connector housing in a second rotational orientation about the longitudinal axis when the fiber optic connector is in the second polarity configuration, the second rotational orientation being offset from the first rotational orientation about the axis by 180°;	 *In both rotational orientations indicated above, MDC connector can be inserted into a mating receptacle.*

U.S. Pat. No. 11,391,895 C1	MDC
wherein the polarity change element comprises opposing lateral tabs defining a first width and the connector housing includes a first pair of projections adjacent the first elongate groove and a second pair of projections adjacent the second elongate groove, the first pair of projections separated by a first opening having a second width and the second pair of projections separated by a second opening having the second width, the first width being greater than the second width;	

U.S. Pat. No. 11,391,895 C1	MDC
	

U.S. Pat. No. 11,391,895 C1	MDC
wherein the fiber optic connector is configured so that: as the tongue is slidably received in the first elongate groove to position the polarity change element on the first exterior wall to configure the fiber optic connector is in the first polarity configuration, the opposing lateral tabs pass through the first opening in a first longitudinal direction, and	

U.S. Pat. No. 11,391,895 C1	MDC
when the fiber optic connector is in the first polarity configuration, the opposing lateral tabs are configured to engage the first pair of projections when the polarity change element is urged in a second longitudinal direction opposite the first longitudinal direction in relation to the connector housing to resist withdrawal of the tongue from the first elongate groove, whereby the opposing lateral tabs and the second pair of projections releasably retain the polarity change element on the first exterior wall; and	

U.S. Pat. No. 11,391,895 C1	MDC
wherein the fiber optic connector is further configured so that: as the tongue is slidably received in the second elongate groove to position the polarity change element on the second exterior wall to configure the fiber optic connector is in second first polarity configuration, the opposing lateral tabs pass through the second opening in the first longitudinal direction, and	

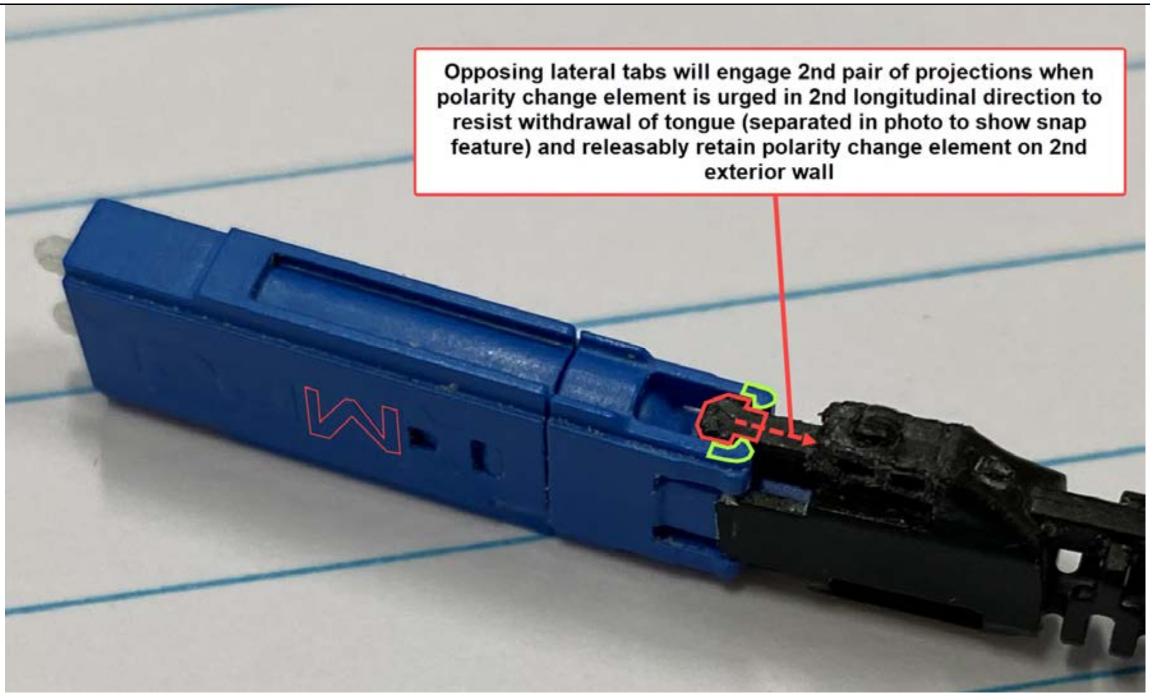
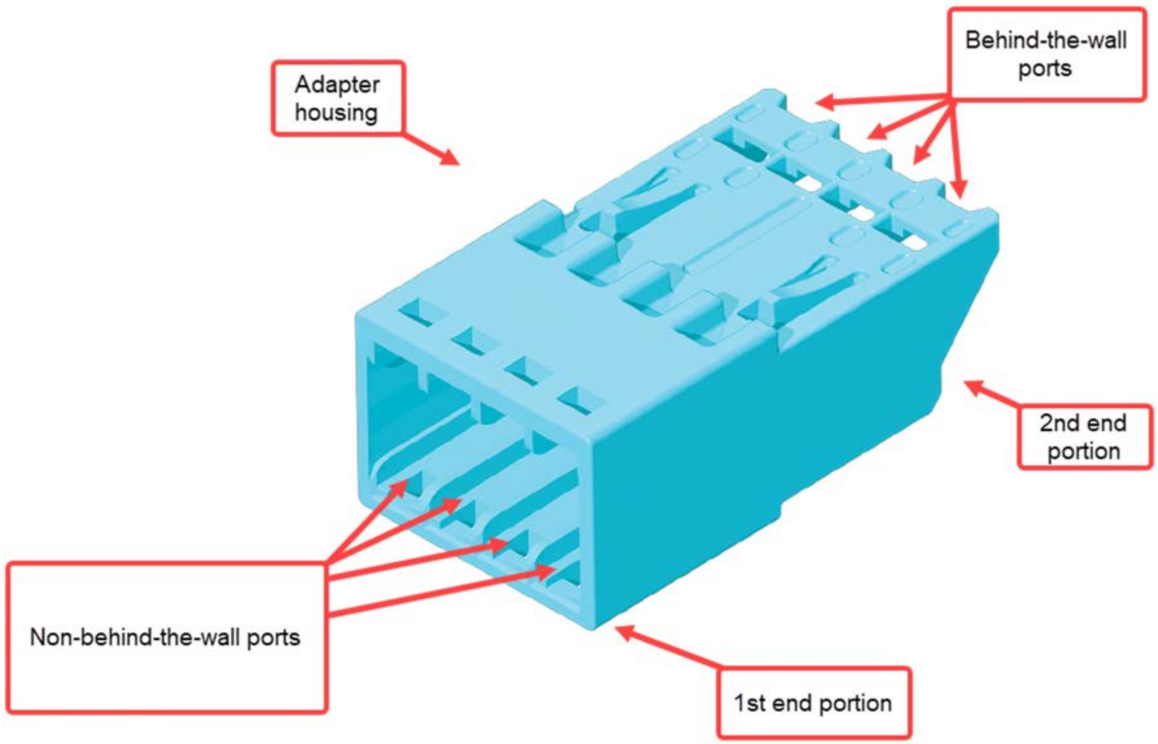
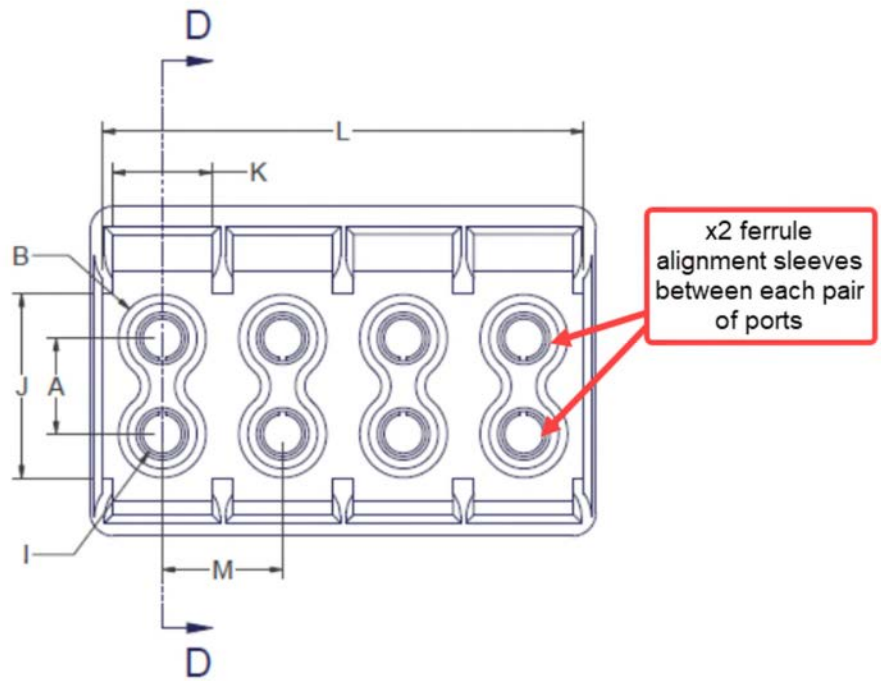
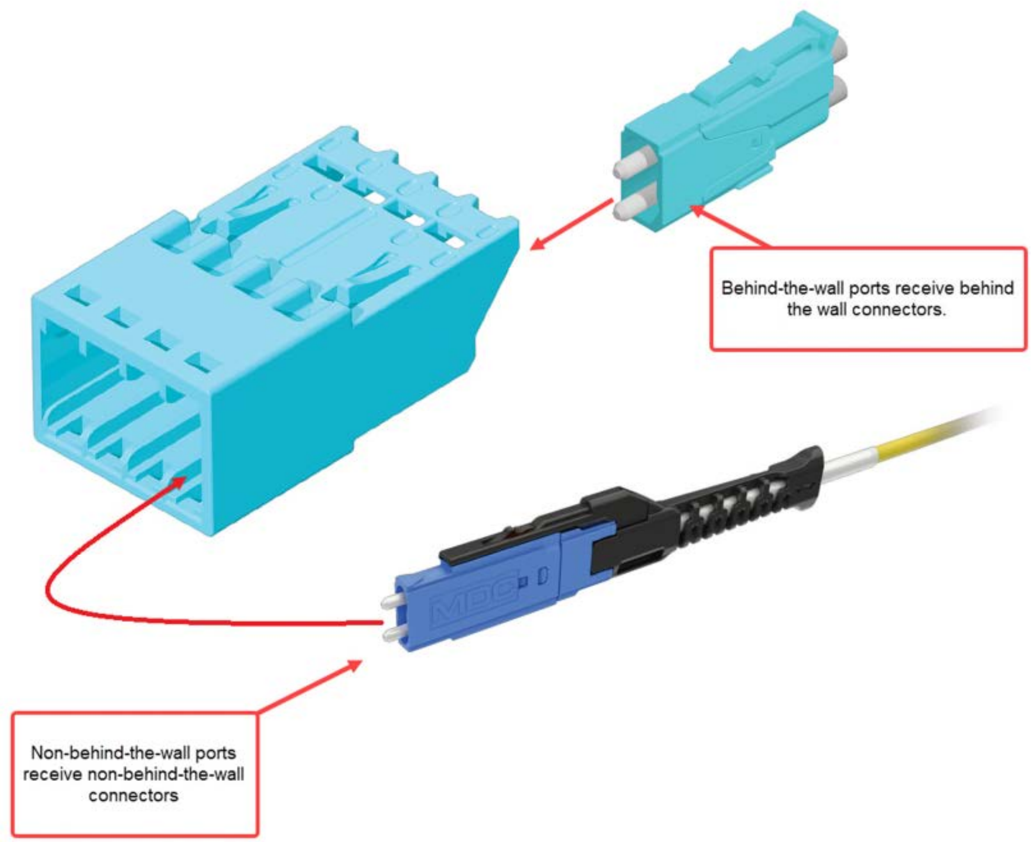
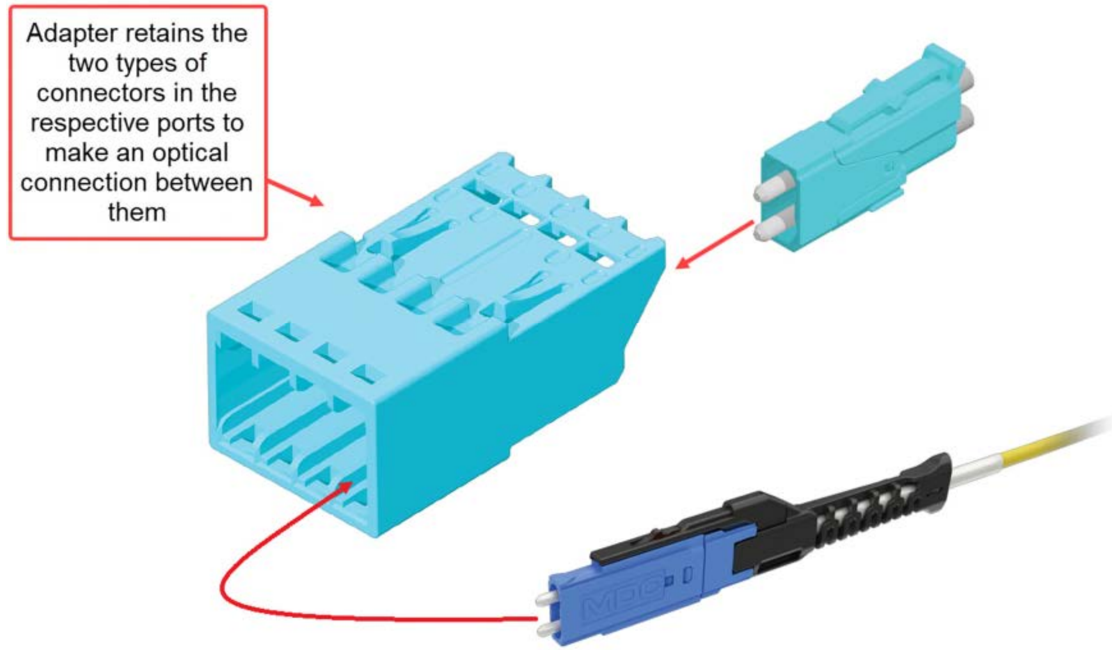
U.S. Pat. No. 11,391,895 C1	MDC
when the fiber optic connector is in the second polarity configuration, the opposing lateral tabs are configured to engage the second pair of projections when the polarity change element is urged in the second longitudinal direction in relation to the connector housing to resist withdrawal of the tongue from the first elongate groove, whereby the opposing lateral tabs and the second pair of projections releasably retain the polarity change element on the second exterior wall.	

EXHIBIT V

U.S. Pat. No. 11,435,535	MDC/MDC Jr. Adapter
1. An adapter for optical connectors, the adapter comprising:	
an adapter housing having a first end portion and an opposite second end portion spaced apart along a longitudinal axis, the adapter housing defining a plurality of behind-the-wall ports and a plurality of non-behind-the-wall ports aligned with corresponding behind-the-wall ports, each behind-the-wall port opening through the first end portion of the adapter housing and each non-behind-the-wall port opening through the opposite second end portion of the adapter housing; and	

U.S. Pat. No. 11,435,535	MDC/MDC Jr. Adapter
a plurality of ferrule alignment sleeves between each behind-the-wall port and the corresponding non-behind-the-wall port;	

U.S. Pat. No. 11,435,535	MDC/MDC Jr. Adapter
wherein the adapter housing is configured to receive a behind-the-wall optical connector in each behind-the-wall port and a non-behind-the-wall connector in each non-behind-the-wall port, each behind-the-wall connector and each non-behind-the-wall connector comprising a plurality of optical fiber ferrules, the plurality of ferrule alignment sleeves between each behind-the-wall port and the corresponding non-behind-the-wall port configured to receive the plurality of optical ferrules of the behind-the-wall optical connector received in the behind-the-wall port and the plurality of optical ferrules of the non-behind-the-wall connector in received in the non-behind-the-wall port;	

U.S. Pat. No. 11,435,535	MDC/MDC Jr. Adapter
wherein the adapter is configured to retain the behind-the-wall connector in the behind-the-wall port and the non-behind-the-wall connector in the non-behind-the-wall port such that an optical connection is made between the plurality of ferrules of the behind-the-wall connector and the plurality of ferrules of the non-behind-the-wall connector in the adapter housing;	

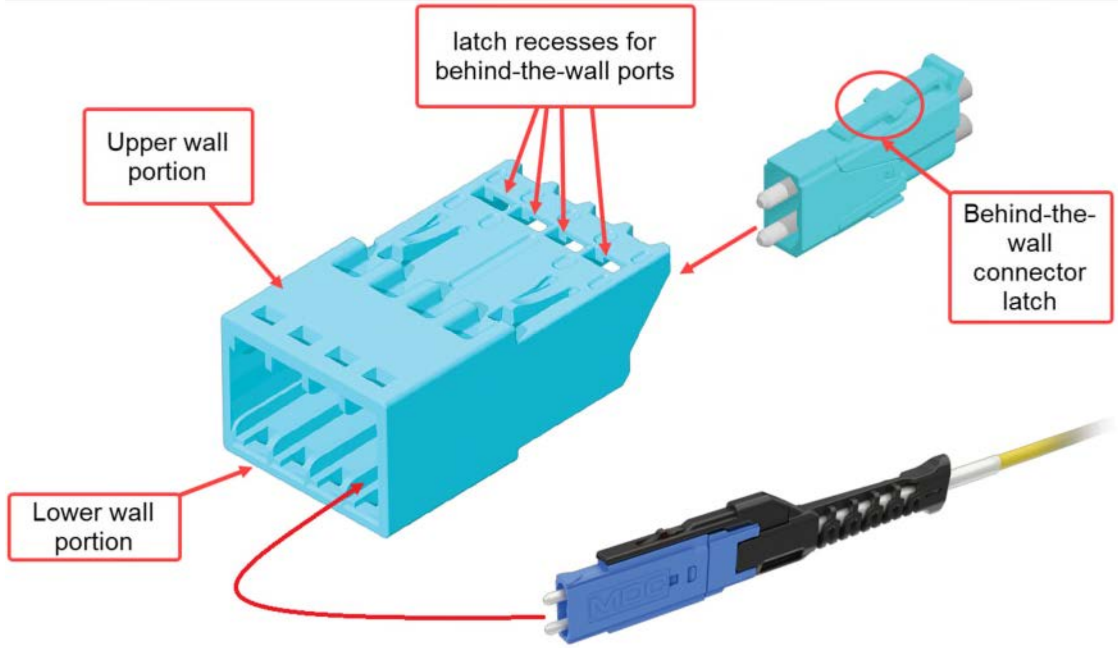
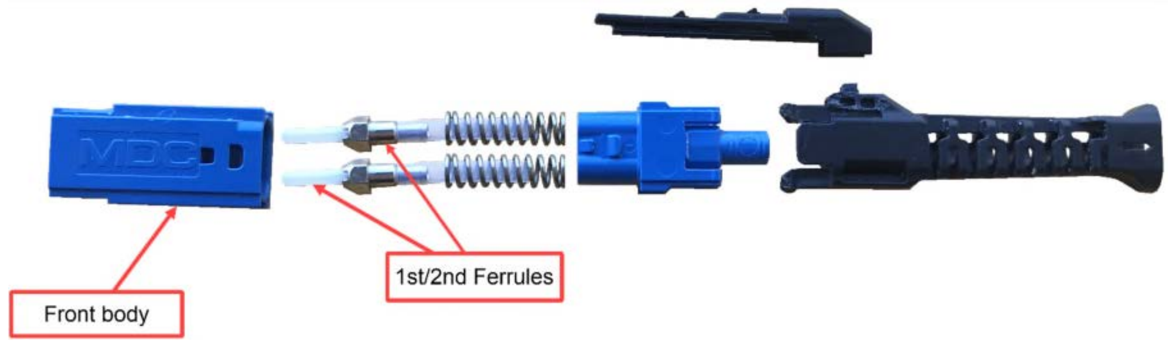
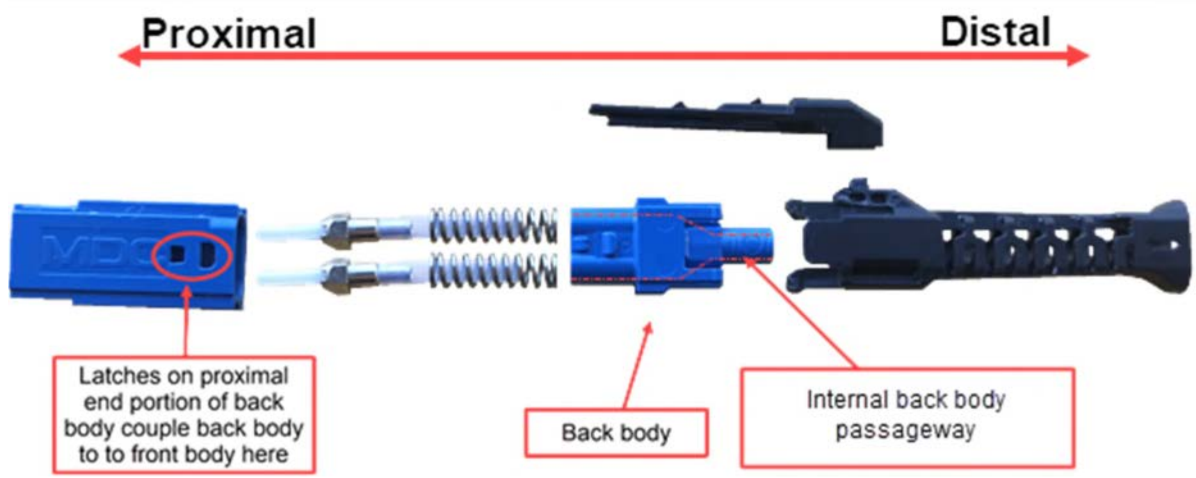
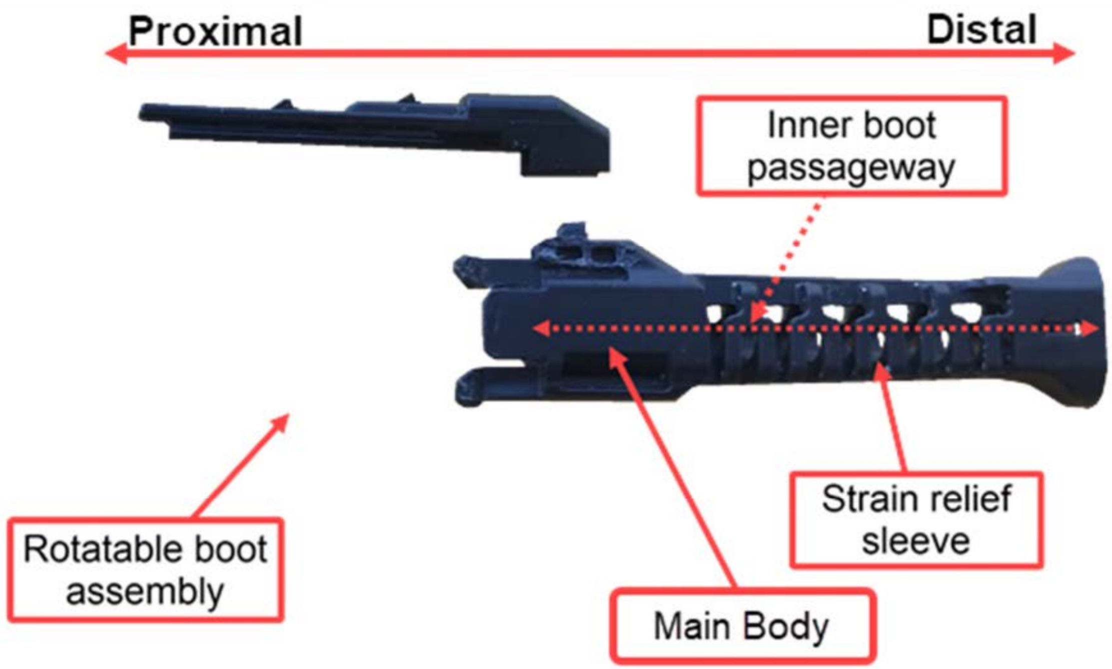
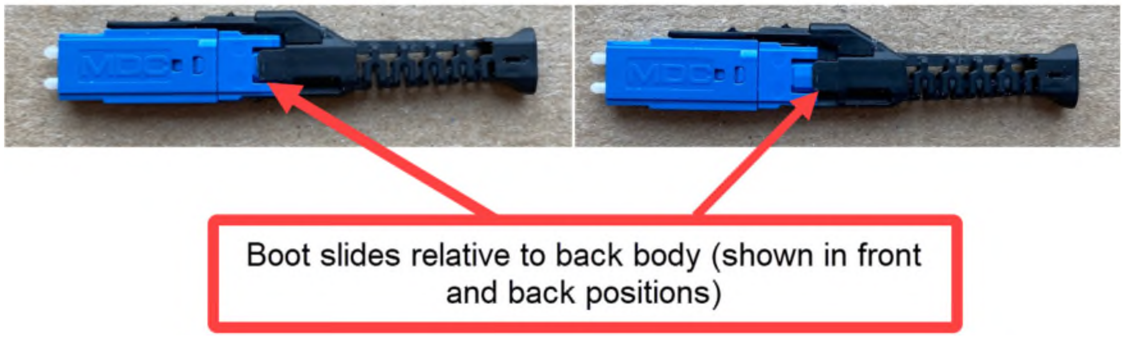
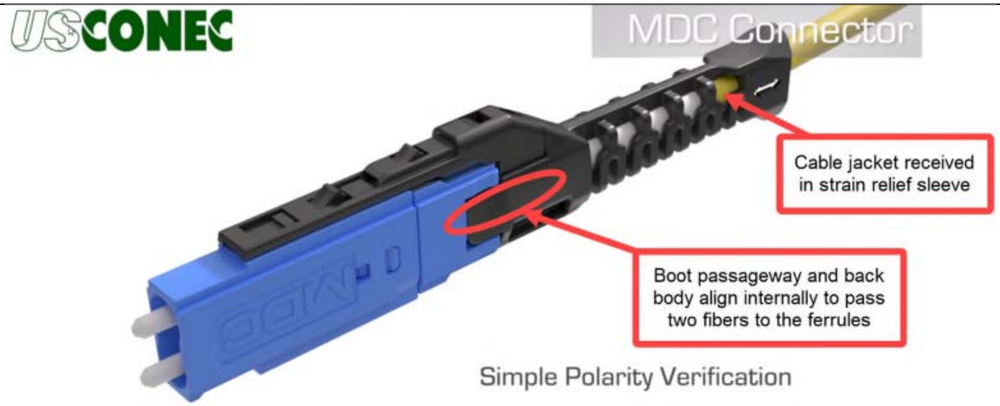
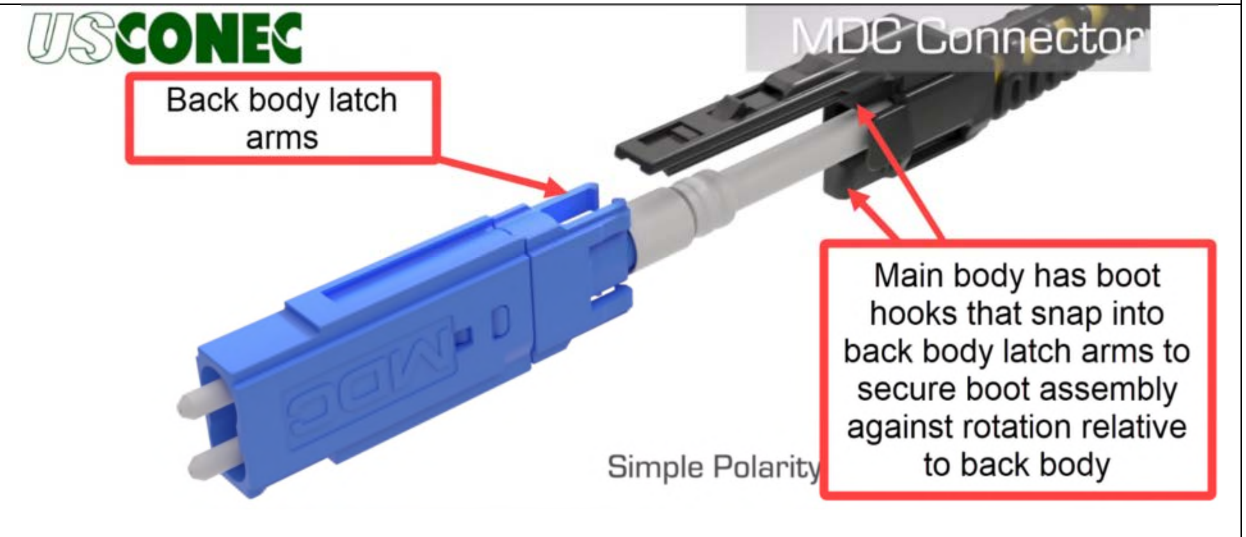
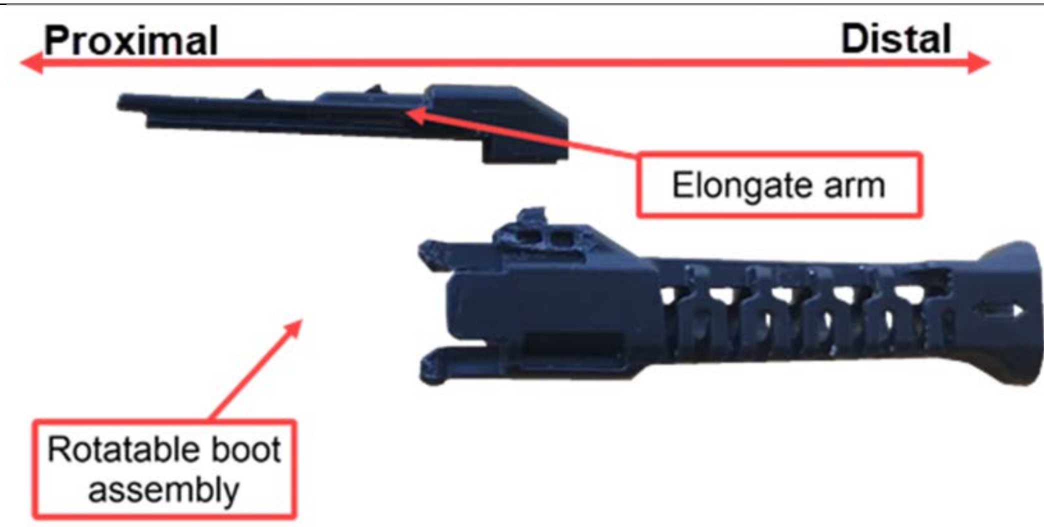
U.S. Pat. No. 11,435,535	MDC/MDC Jr. Adapter
wherein the adapter housing has an upper wall portion and an opposite lower wall portion, the upper wall portion defining a latch recess for each behind-the-wall port configured to latch with a depressible latch arm on a connector housing of the behind-the-wall connector received in the behind-the-wall port to retain the behind-the-wall connector in the behind-the-wall port.	

EXHIBIT W

U.S. Pat. No. 11,585,989	MDC Connector
1. An optical fiber connector comprising:	
a front body configured to hold first and second ferrules;	
a back body having a proximal end portion and a distal end portion spaced apart along a longitudinal axis, the proximal end portion of the back body configured to couple to the front body, the back body defining a back body passageway extending from the distal end portion through the proximal end portion; and	

U.S. Pat. No. 11,585,989	MDC Connector
a rotatable boot assembly having a proximal end portion and a distal end portion spaced apart along the longitudinal axis, the rotatable boot assembly comprising a main body and a strain relief sleeve extending longitudinally from the main body to the distal end portion of the rotatable boot assembly, the rotatable boot assembly comprising a boot passageway extending from the distal end portion through the main body,	

U.S. Pat. No. 11,585,989	MDC Connector
the rotatable boot assembly configured to be disposed on the back body such that the cable boot member is slidable along the longitudinal axis relative to the back body for releasing the optical fiber connector from an adapter,	
the optical fiber connector being configured to terminate a fiber optic cable such that a jacket of the cable is received in the strain relief sleeve in the boot passageway, the boot passageway and the back body passageway configured to align for passing first and second fibers from the fiber optic cable to the front body to complete a signal path to the first and second ferrules within the front body;	

U.S. Pat. No. 11,585,989	MDC Connector
the main body being configured to releasably secure the multi-purpose rotatable boot assembly against rotation relative to the back body,	
and the rotatable boot assembly further comprising an elongate arm extending longitudinally from the main body in a proximal direction along the longitudinal axis,	

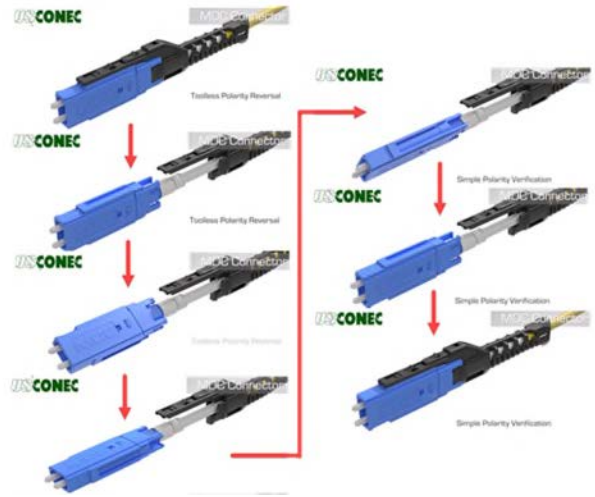
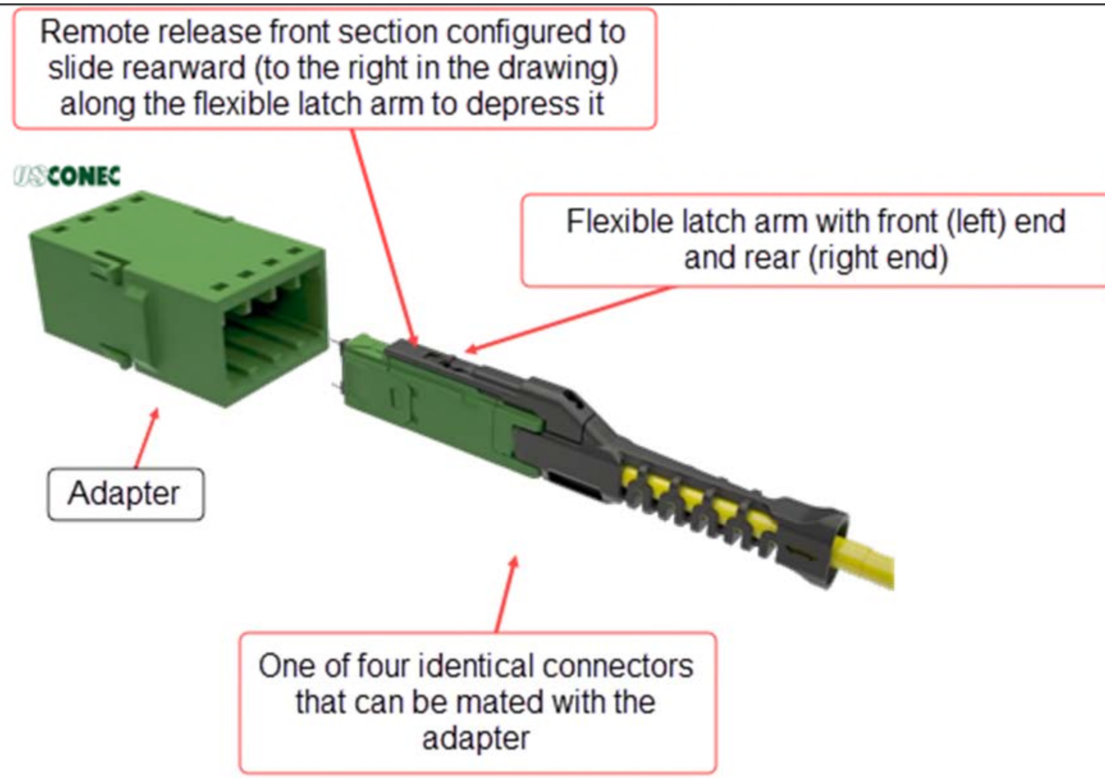
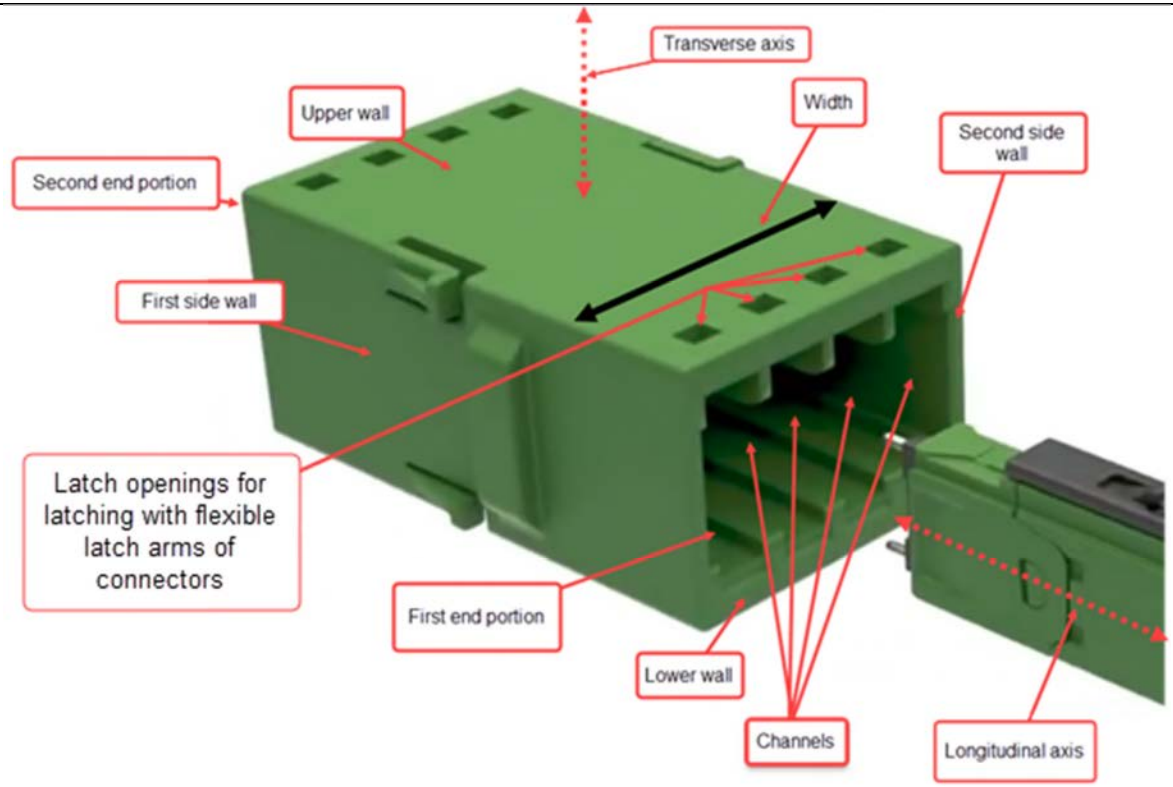
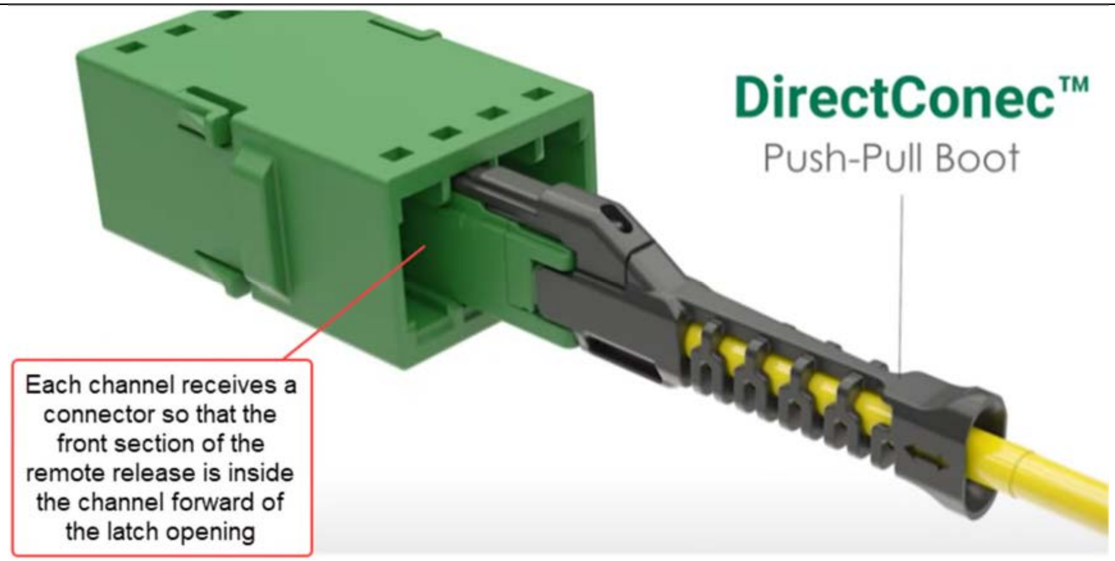
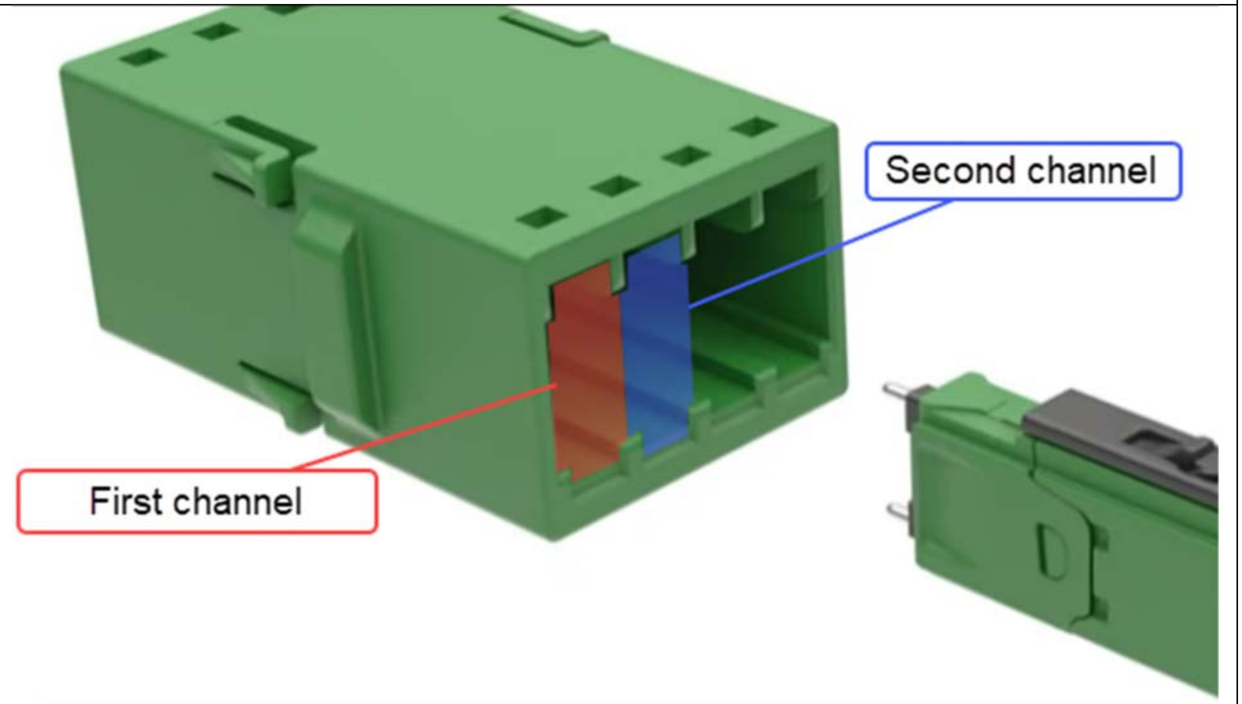
U.S. Pat. No. 11,585,989	MDC Connector
the elongate arm being configured for selectively setting the optical fiber connector to each of a first polarity and a second polarity.	Boot assembly is rotatable so that arm attaches to either top or bottom of housing, whereby elongate arm selectively configures connector for either first or second polarity 

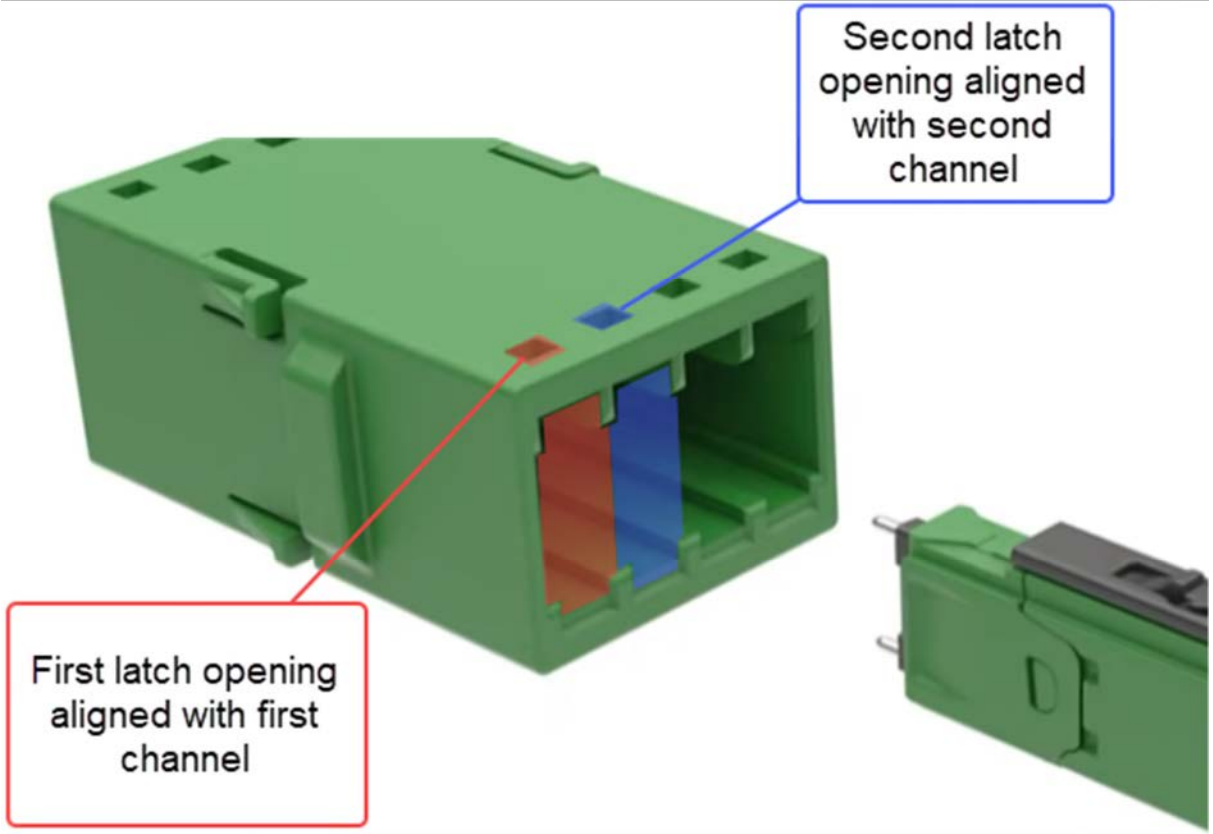
EXHIBIT X

U.S. Pat. No. 11,774,685	MMC Adapters
1. An adapter for mating with a plurality of optical fiber connectors, each of the plurality of optical fiber connectors comprising a connector housing holding multiple optical fibers, a flexible latch arm having a front end and a rear end spaced apart rearward of the front end, and a remote release comprising a front section configured to slide rearward along the flexible latch arm to depress the flexible latch arm, the adapter comprising:	

U.S. Pat. No. 11,774,685	MMC Adapters
an outer housing having a first end portion and a second end portion spaced apart along a longitudinal axis and a first side wall and a second side wall spaced apart along a width, the outer housing defining a plurality of channels side-by-side along the width of the outer housing, each of the plurality of channels opening through the first end portion such that the plurality of optical fiber connectors can be inserted forward along the longitudinal axis into the plurality of channels through the first end portion to mate the adapter with the plurality of optical fiber connectors for making an optical connection to the optical fibers via the adapter, the outer housing comprising an upper wall and a lower wall spaced apart along a transverse axis perpendicular to the longitudinal axis, the upper wall defining a plurality of latch openings configured to latch with the flexible latch arms of the plurality of optical fiber connectors,	

U.S. Pat. No. 11,774,685	MMC Adapters
the plurality of channels being configured to receive the plurality of optical fiber connectors such that the front sections of the remote releases are inside the plurality of channels forward of the plurality of latch openings when the plurality of latch openings latch with the flexible latch arms;	

U.S. Pat. No. 11,774,685	MMC Adapters
wherein the plurality of channels includes a first channel and a second channel;	

U.S. Pat. No. 11,774,685	MMC Adapters
wherein the plurality of latch openings includes a first latch opening aligned with the first channel and a second latch opening aligned with the second channel;	

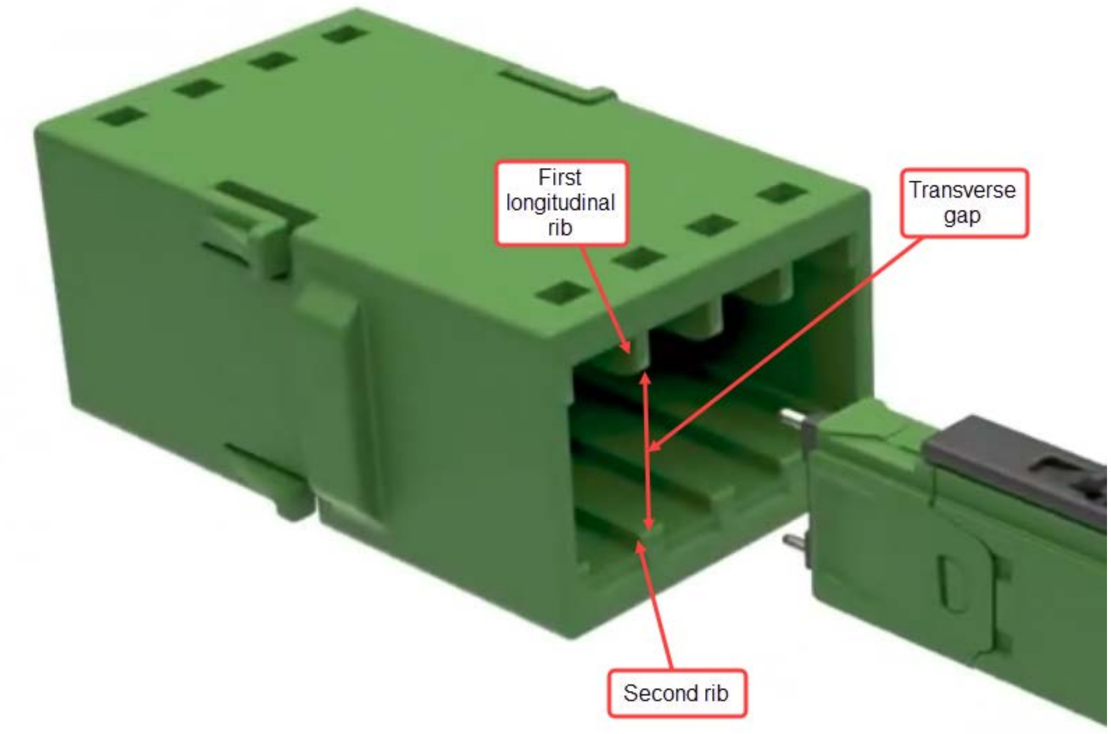
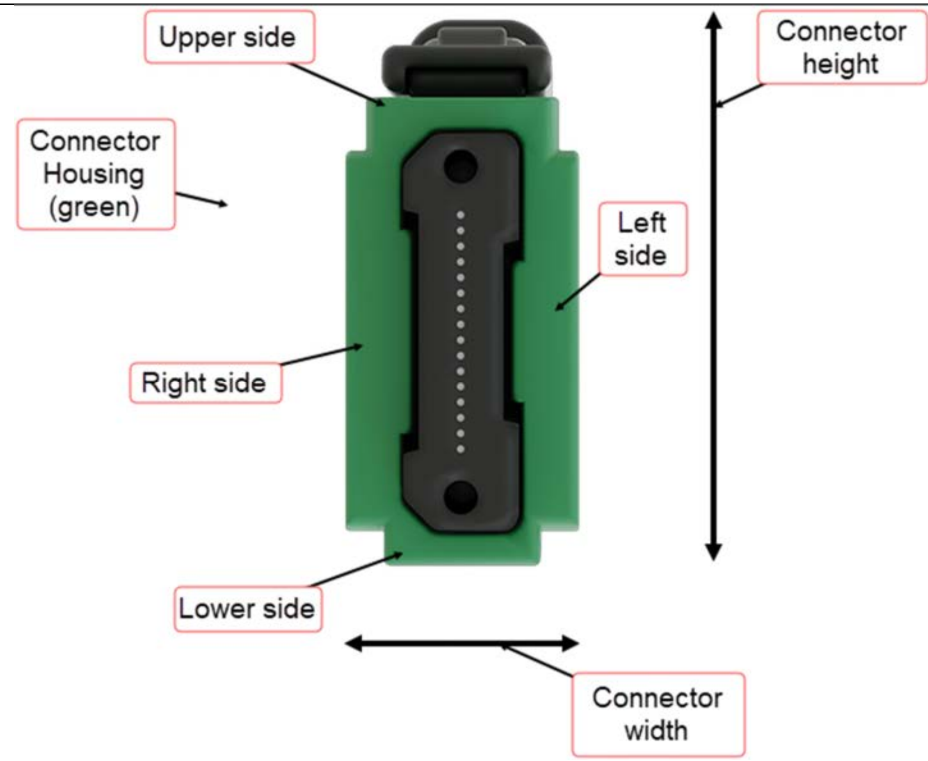
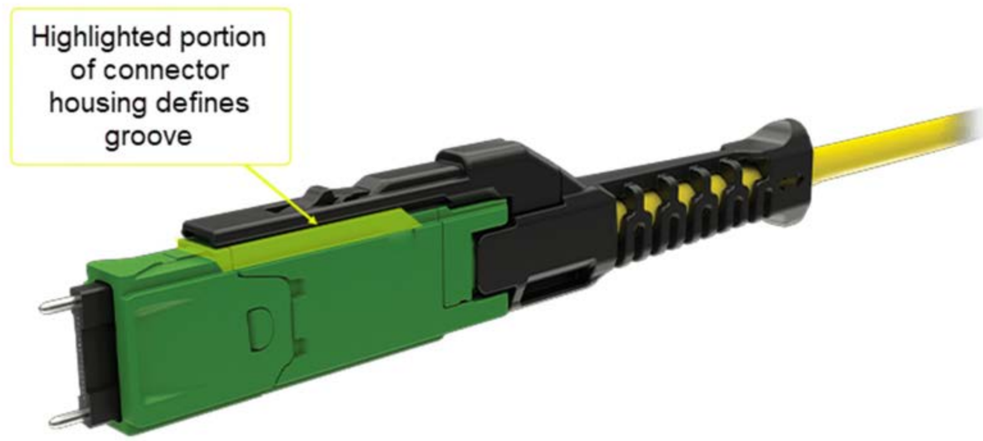
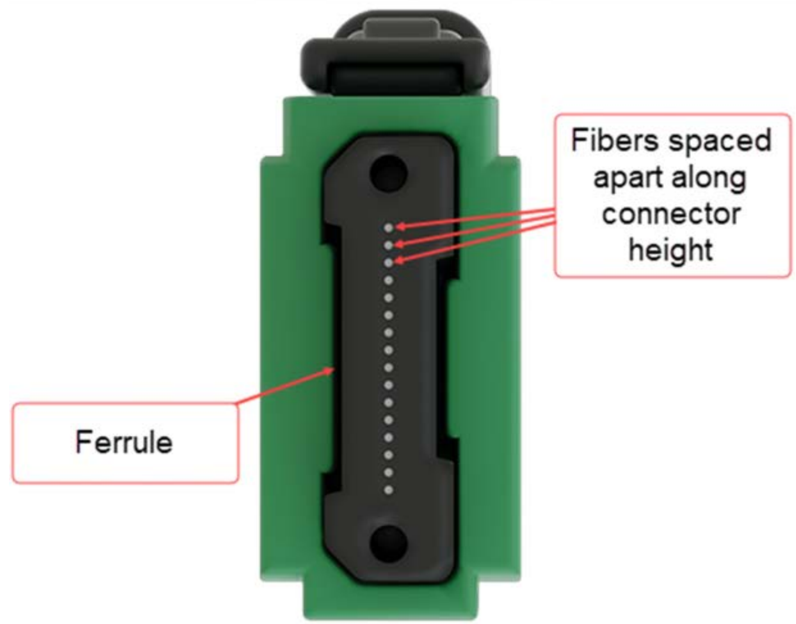
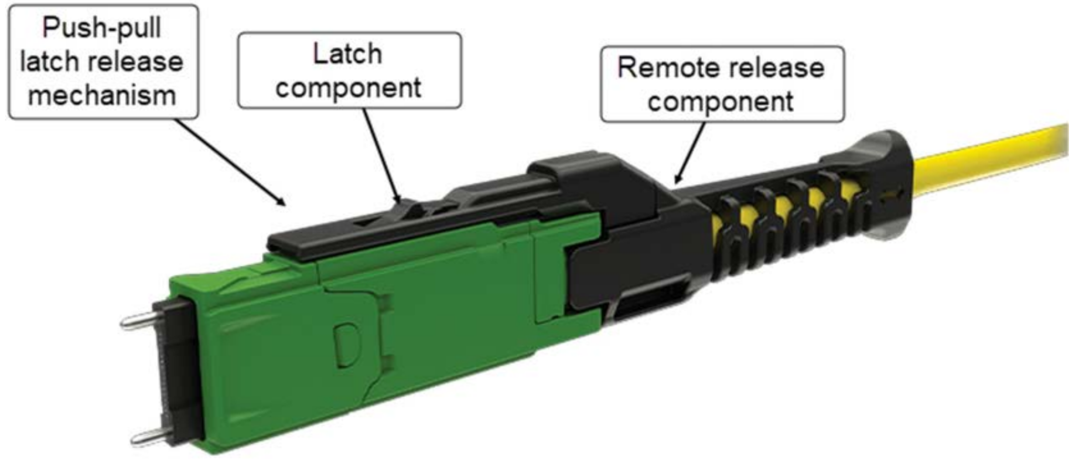
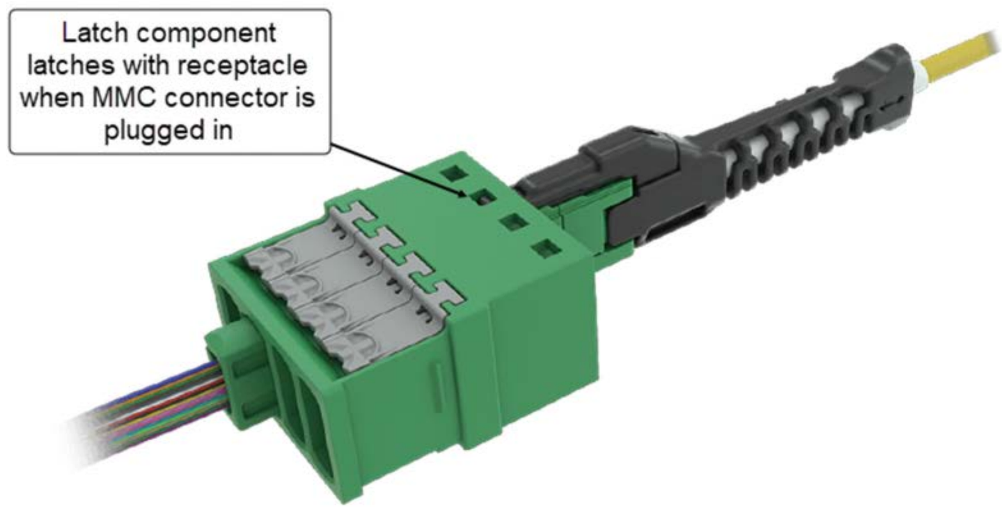
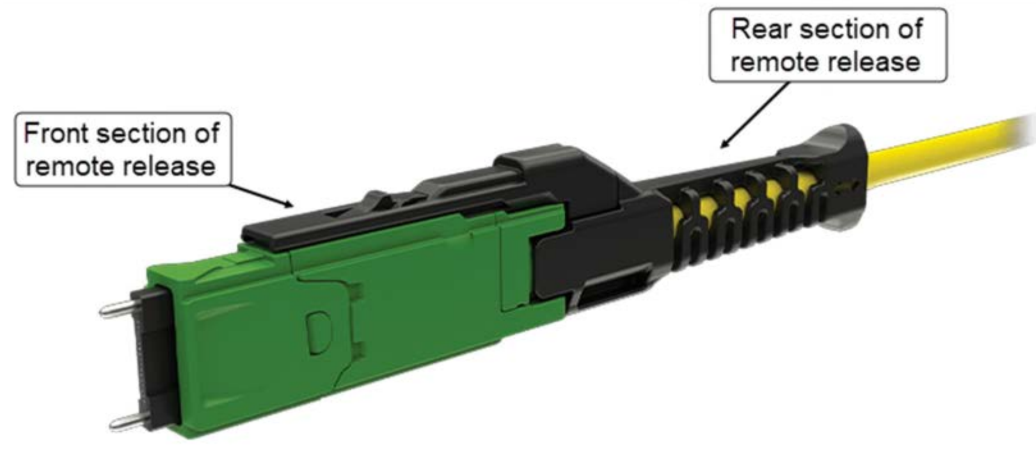
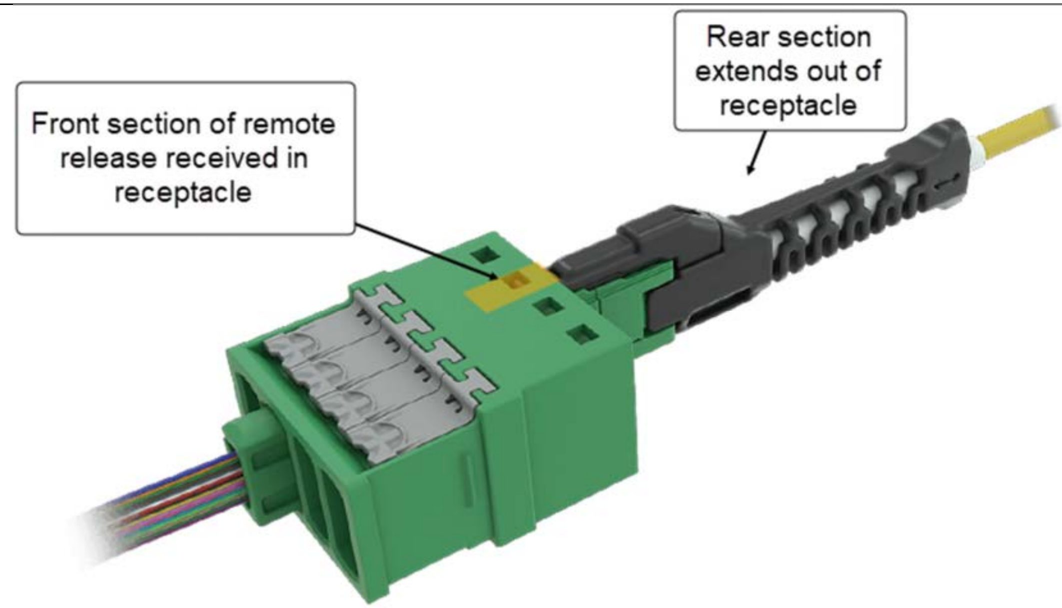
U.S. Pat. No. 11,774,685	MMC Adapters
wherein the upper wall comprises a first longitudinal rib projecting inwardly along the transverse axis toward the lower wall and the lower wall comprises a second longitudinal rib projecting inwardly along the transverse axis toward the upper wall, the first longitudinal rib and the second longitudinal rib being aligned along the width of the outer housing and located between the first and second channels, the first longitudinal rib being spaced apart from the second longitudinal rib along the transverse axis by a transverse gap, the first channel being open to the second channel through the transverse gap.	

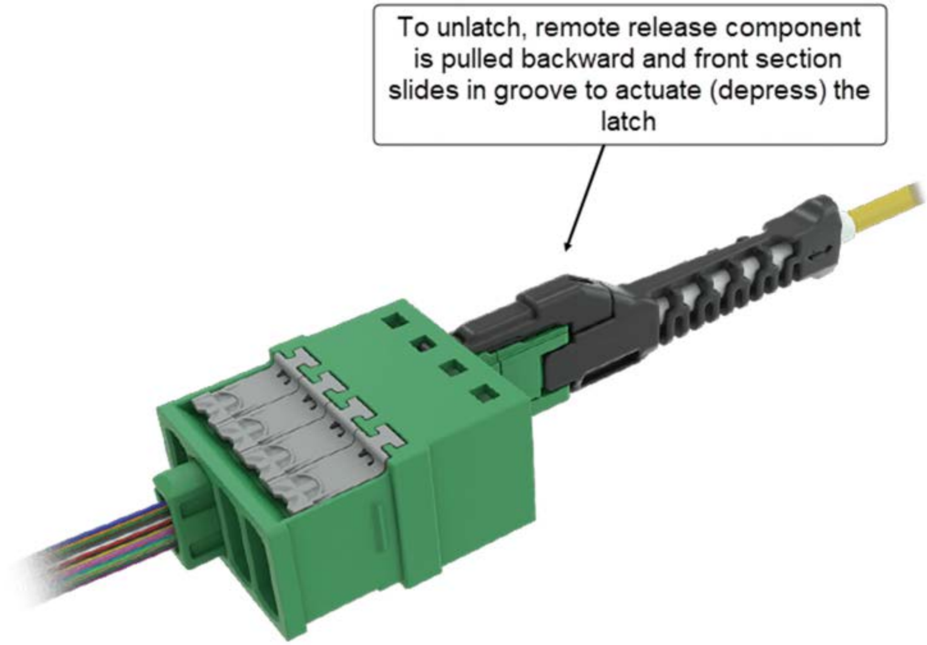
EXHIBIT Y

U.S. Patent No. 11,809,006	MMC
1. An optical fiber connector for being plugged into a receptacle, the optical fiber connector comprising:	
a connector housing having opposite upper and lower sides spaced apart along a connector height and opposite left and right sides spaced apart along a connector width, the connector width being less than the connector height,	

U.S. Patent No. 11,809,006	MMC
the upper side of the connector housing defining a groove;	
at least one optical fiber ferrule received in the connector housing, the at least one optical fiber ferrule configured to terminate at least two optical fibers and to hold the at least two optical fibers so that tips of the at least two optical fibers are spaced apart along the connector height; and	

U.S. Patent No. 11,809,006	MMC
a push-pull latch release mechanism disposed on the upper wall of the connector housing, the push-pull latch release mechanism comprising a latch component and a remote release component,	
the latch component configured to latch with the receptacle when the optical fiber connector is plugged into the receptacle,	

U.S. Patent No. 11,809,006	MMC
the remote release component including a front section and a rear section,	
the front section configured to be received in the receptacle when the optical fiber connector is plugged into the receptacle, the rear section configured to extend out of the receptacle when the optical fiber connector is plugged into the receptacle,	

U.S. Patent No. 11,809,006	MMC
the front section being slidably constrained in the groove such that the front section can slide along the groove to actuate the latch component for unlatching from the receptacle when the remote release component is pulled rearward.	

CERTIFICATE OF SERVICE

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