IN THE UNITED STATES DISTRICT COURT FOR THE DISTRICT OF DELAWARE

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

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	40% HIGHER DENSITY compared to LC Connector 1,5 mm	
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

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	Individual connector access via DirectConec** push-pull boot Rugged components built to withstand GR-326 requirements UPC or APC polish Low profile design increases fiber density by 3x Simple polarity verification Highest duplex connector density with 432F per 1RU	
MMC	Rugged components built to Directal connector access via Directal	

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 Patent². 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.

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.

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

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.
- 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.
- 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.

<u>COUNT EIGHT</u> (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.
- 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.

<u>COUNT TEN</u> (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.
- 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.

<u>COUNT ELEVEN</u> (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.
- 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

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Attorneys for Plaintiff
Senko Advanced Components, Inc.

Index of Exhibits to Complaint

EXHIBIT NO.	<u>DESCRIPTION</u>
A	US PATENT NO. 11,307,369
В	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
Н	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
О	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



(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.

(Continued)

(58) Field of Classification Search

None

See application file for complete search history.

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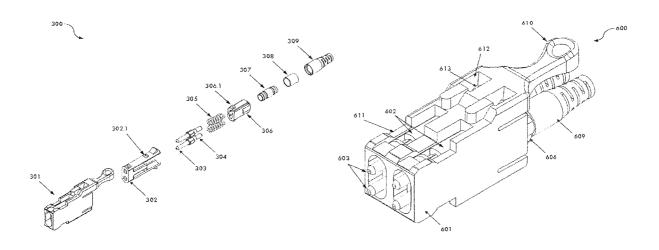
(Continued)

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



US 11,307,369 B2

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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)

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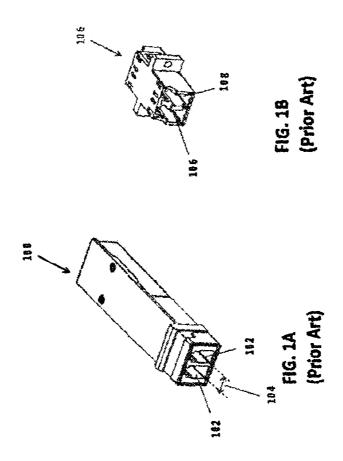
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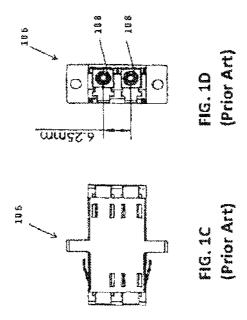
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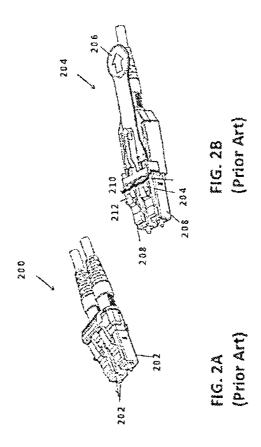
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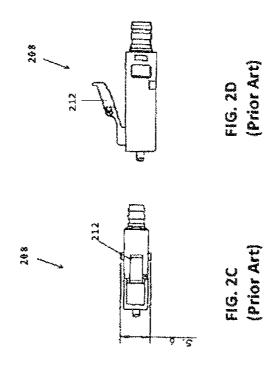
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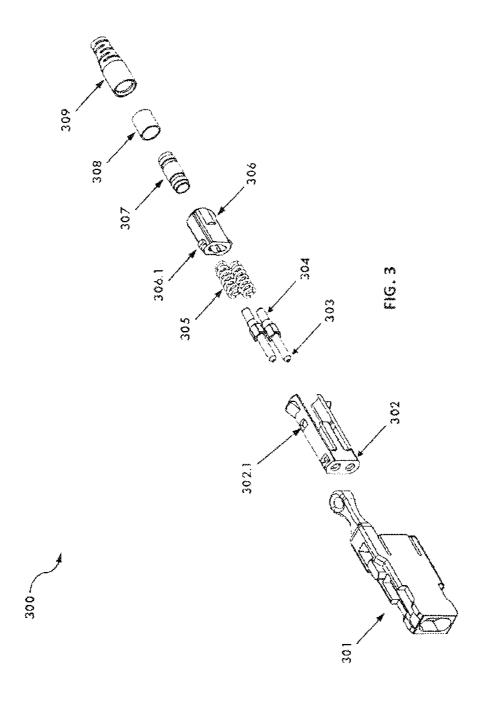
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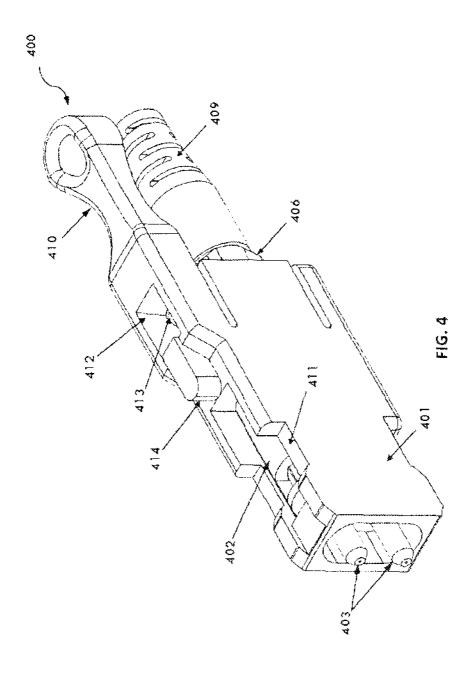
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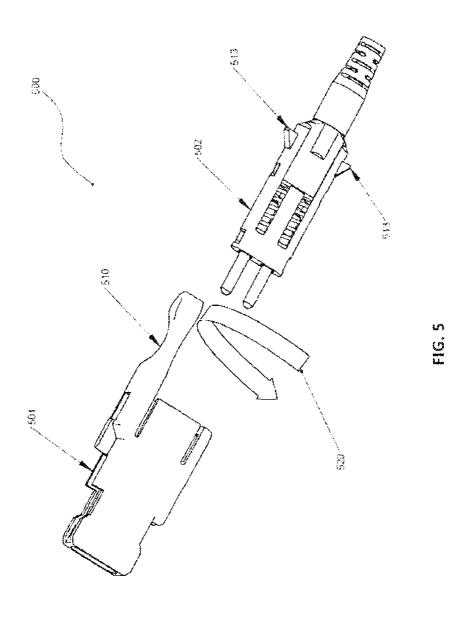
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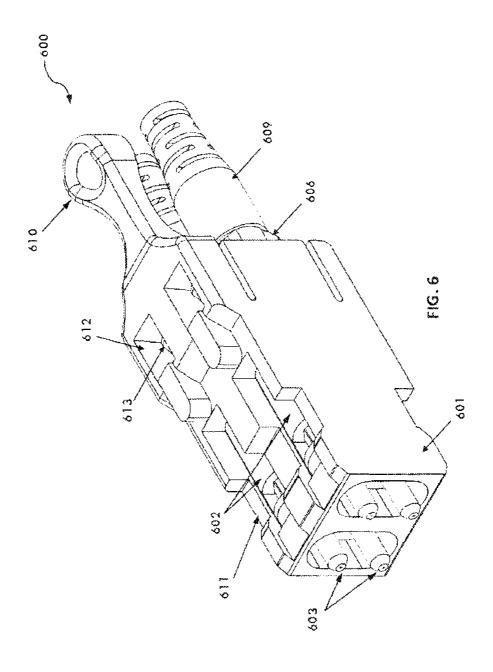
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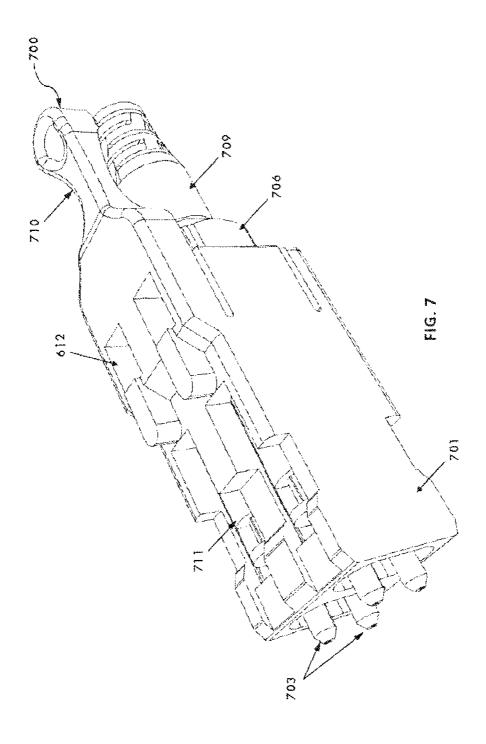
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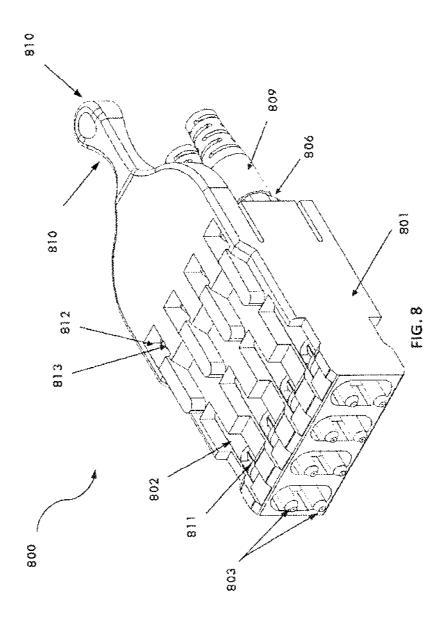
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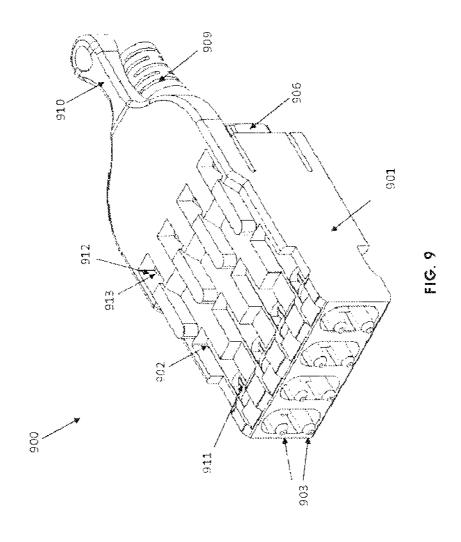
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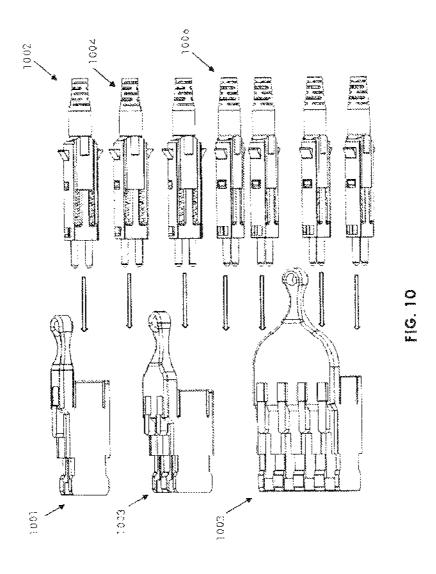
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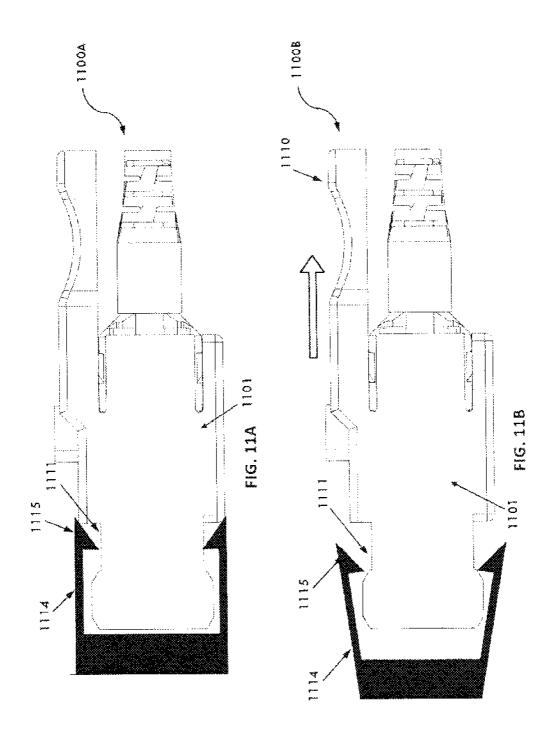
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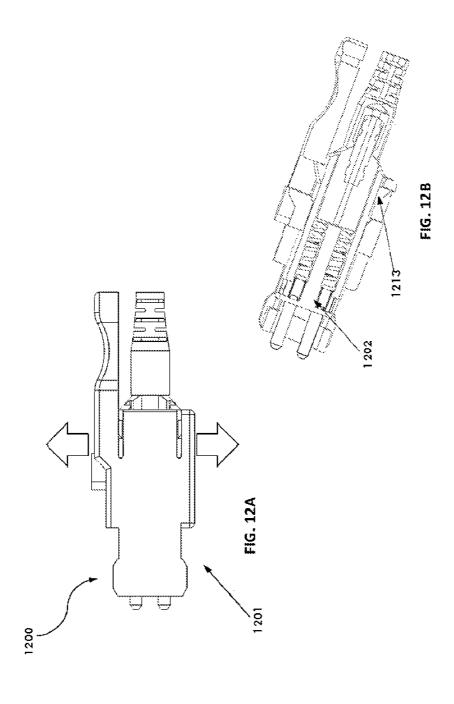
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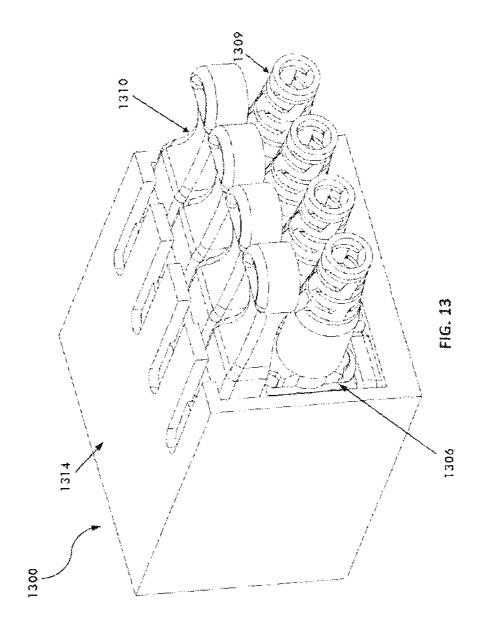
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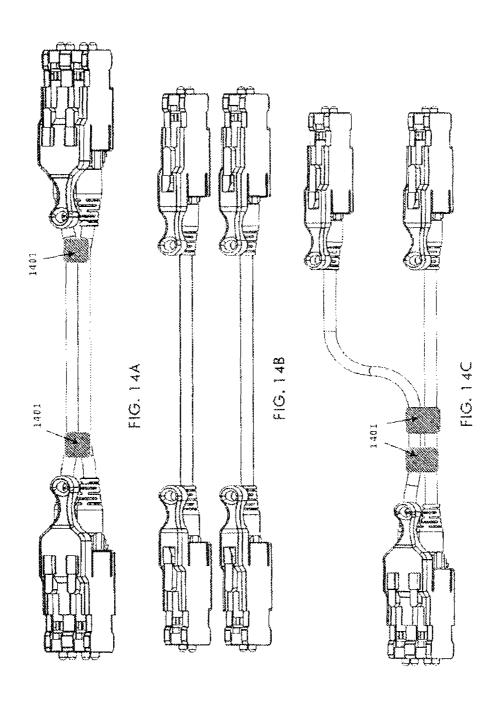
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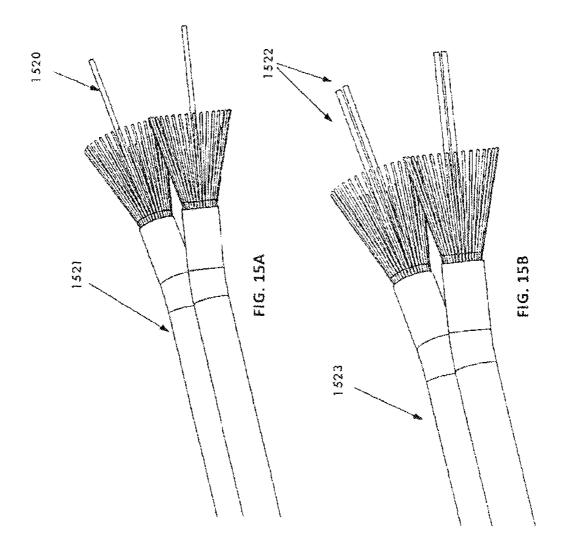
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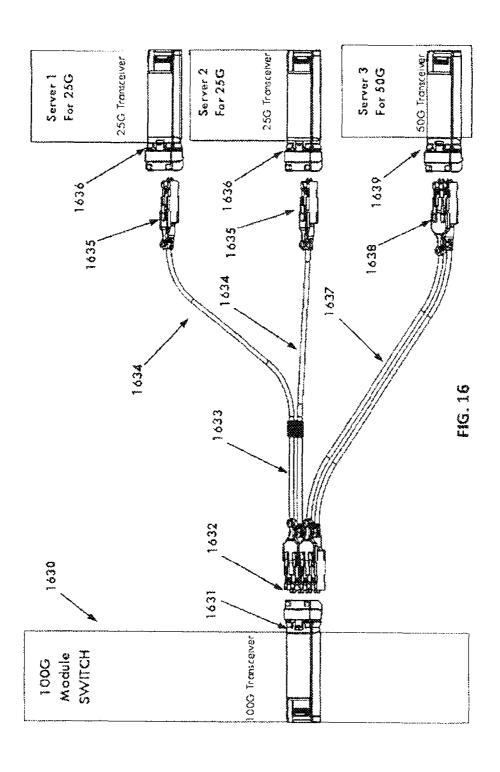
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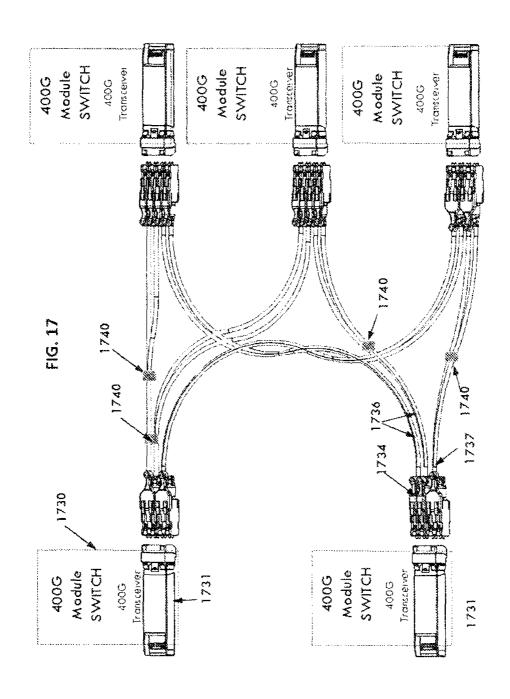
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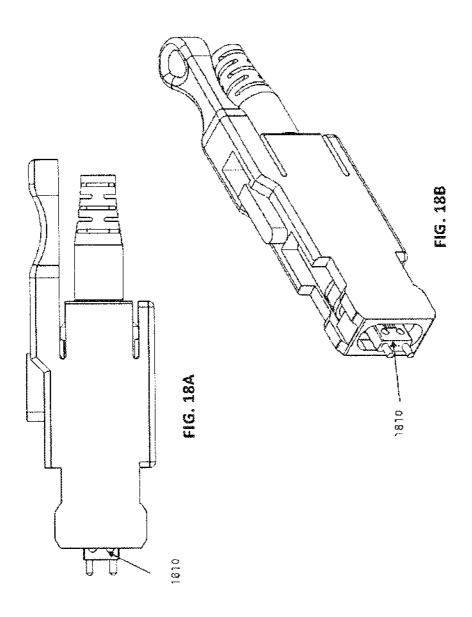
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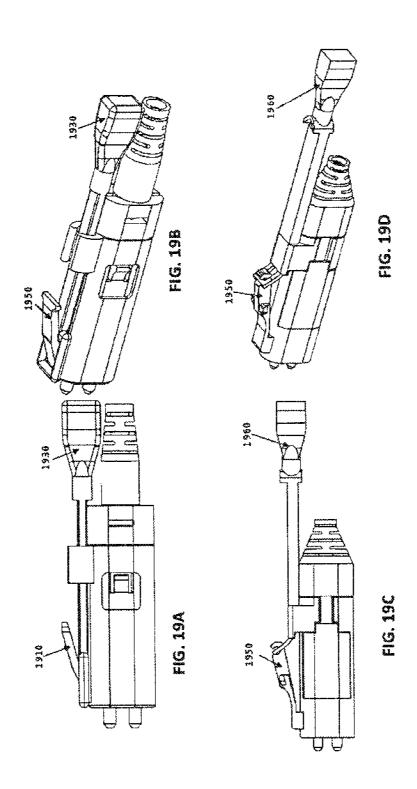
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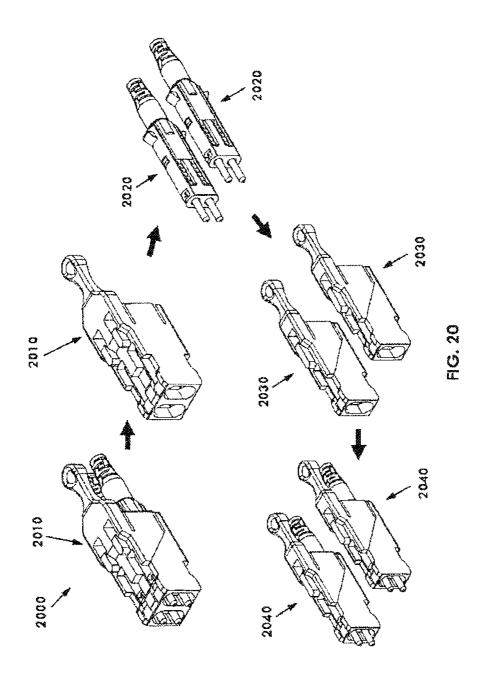
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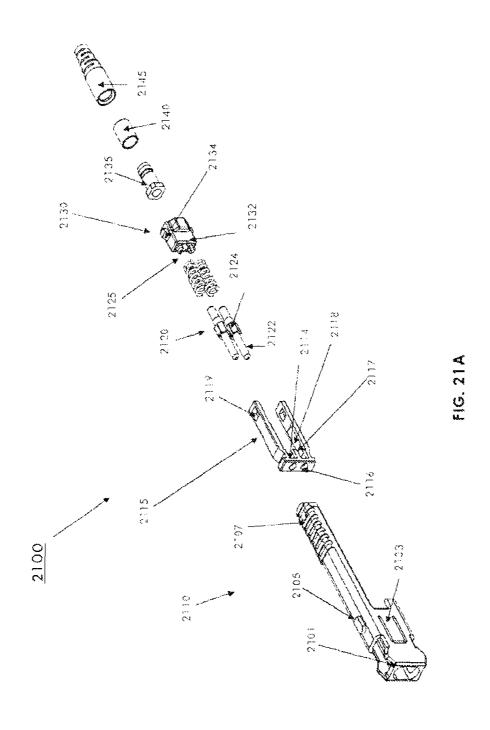
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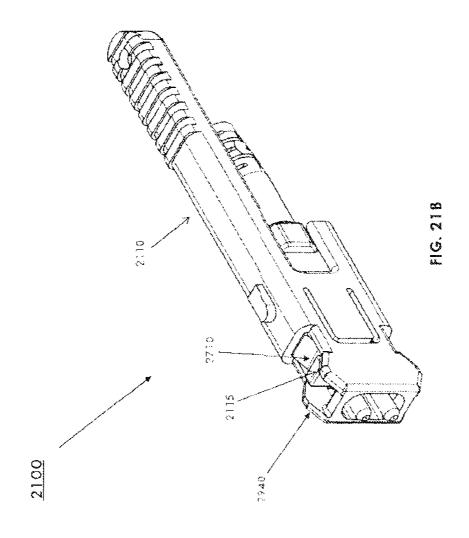
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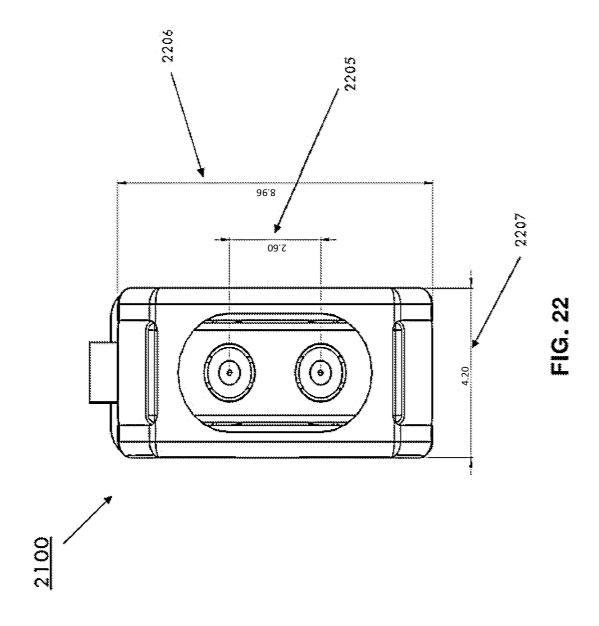
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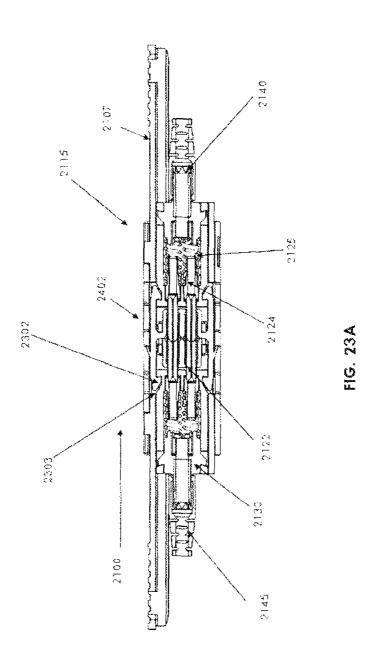
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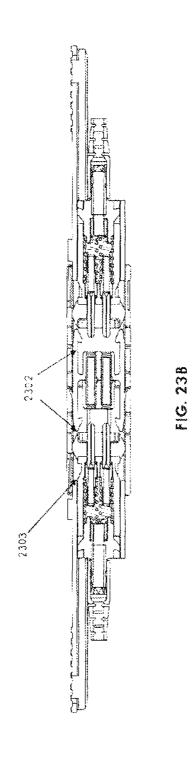
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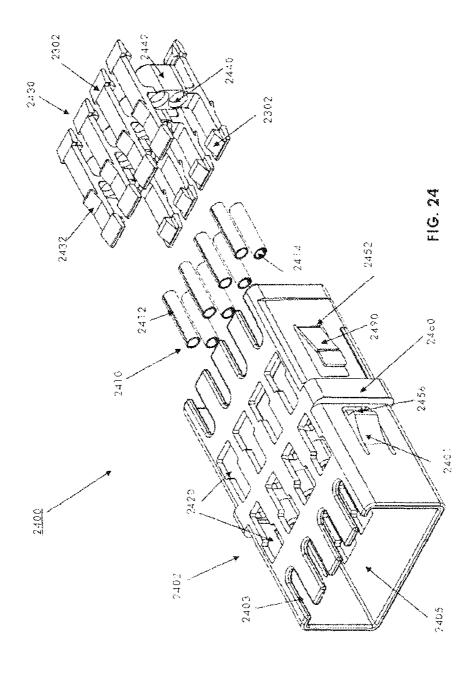
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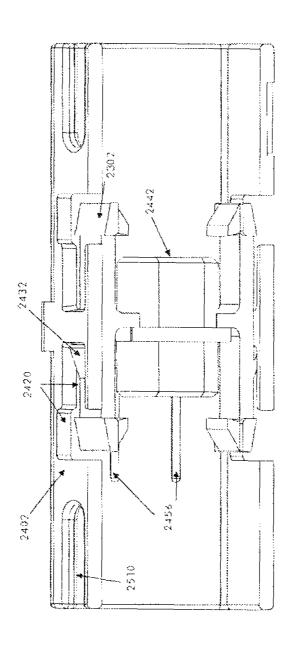
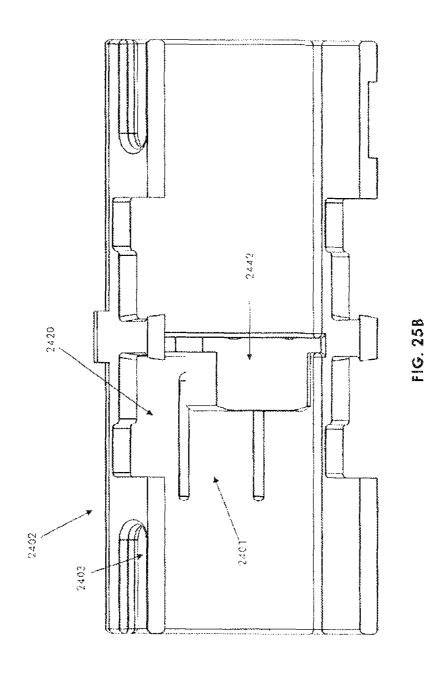


FIG. 25A

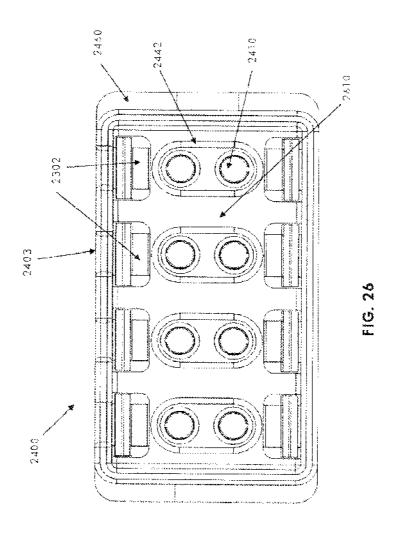
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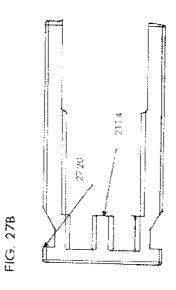
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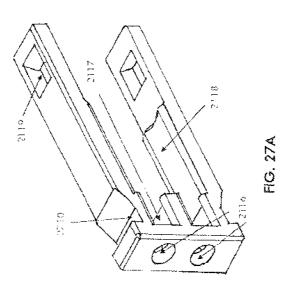
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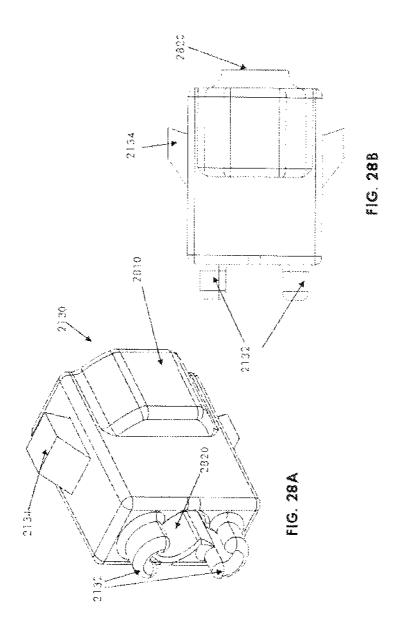
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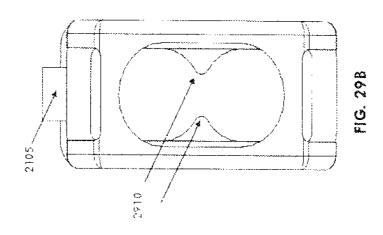
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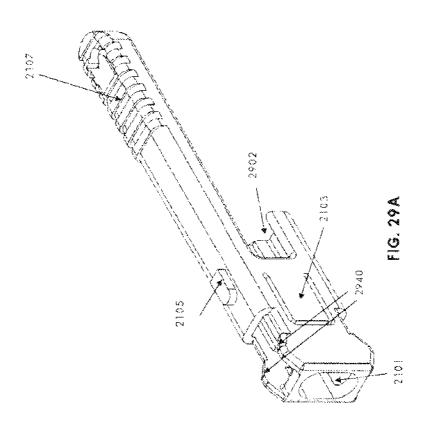
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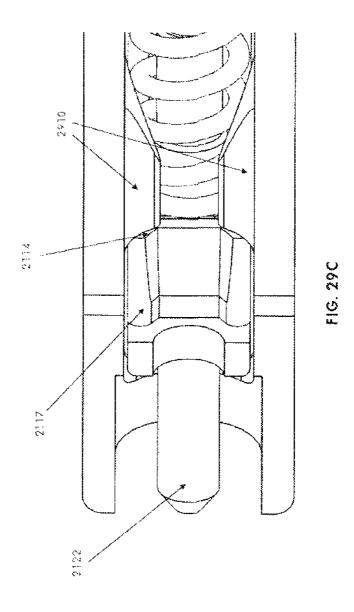
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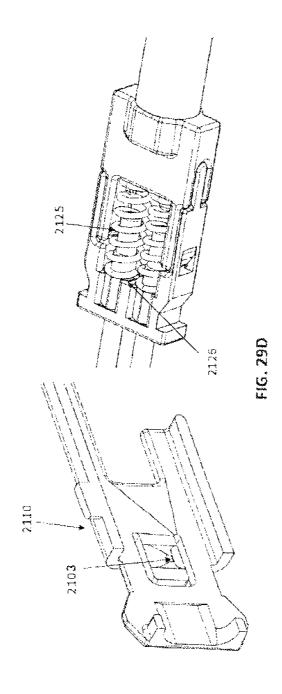
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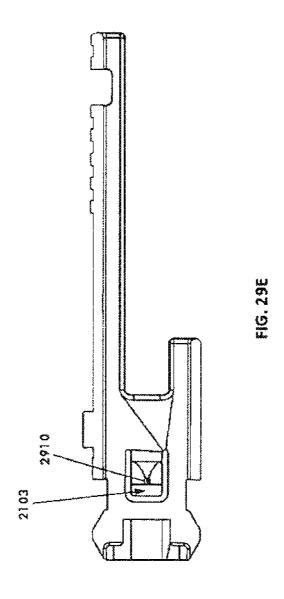
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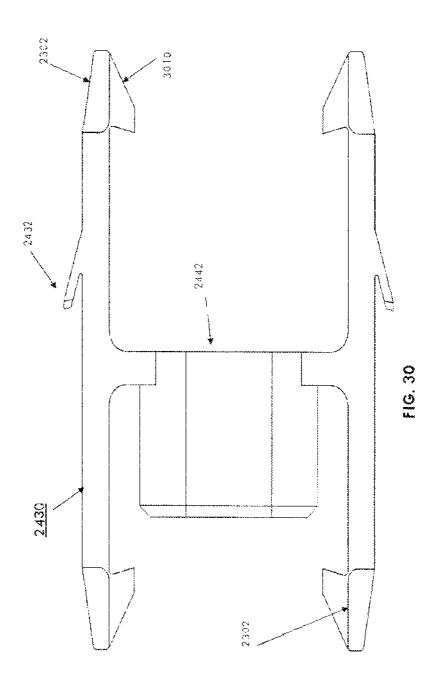
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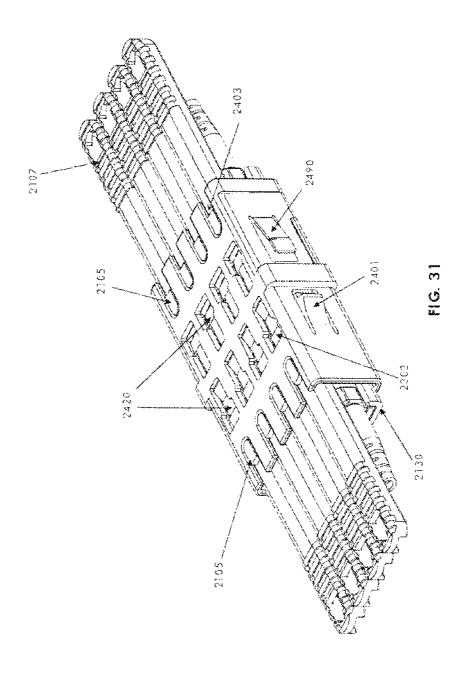
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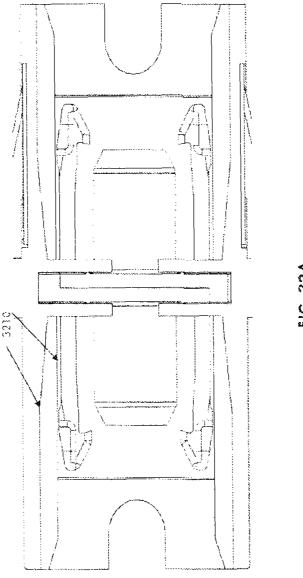
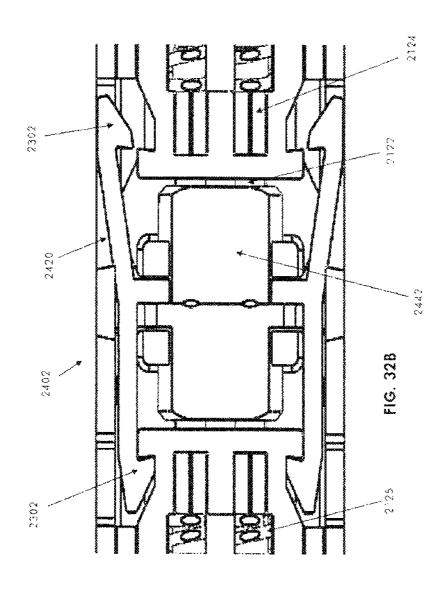


FIG. 32A

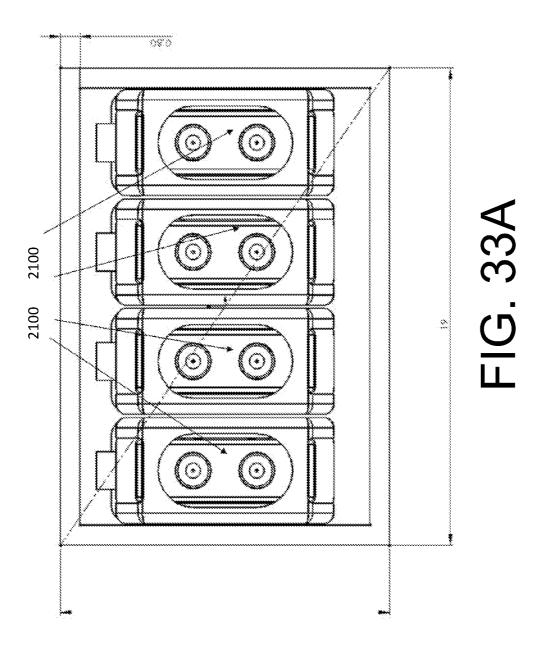
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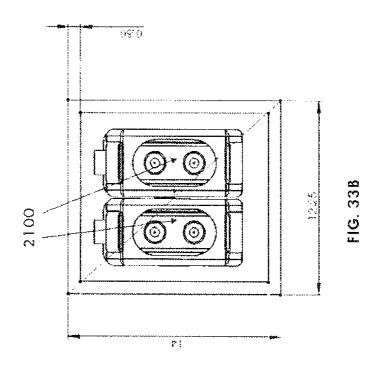
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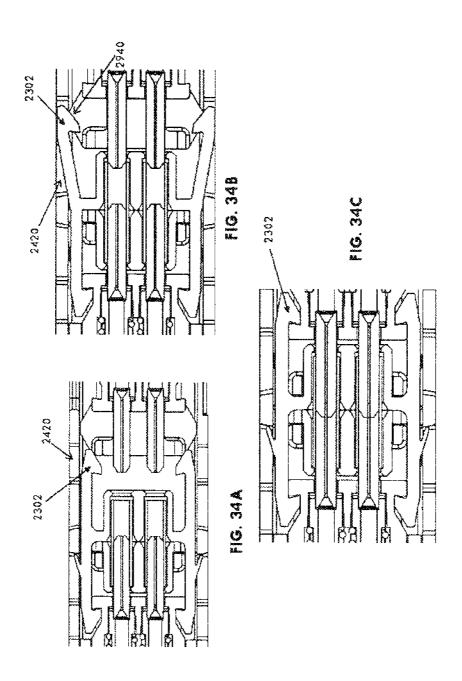
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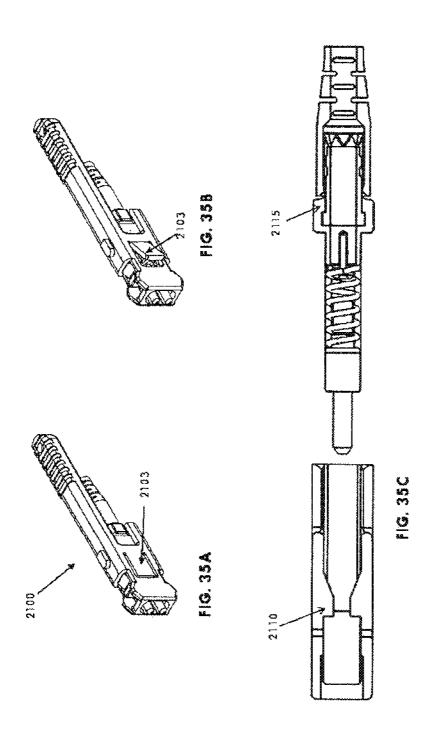
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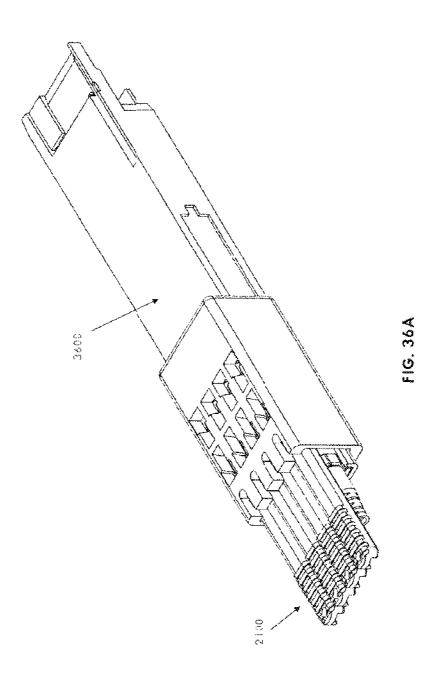
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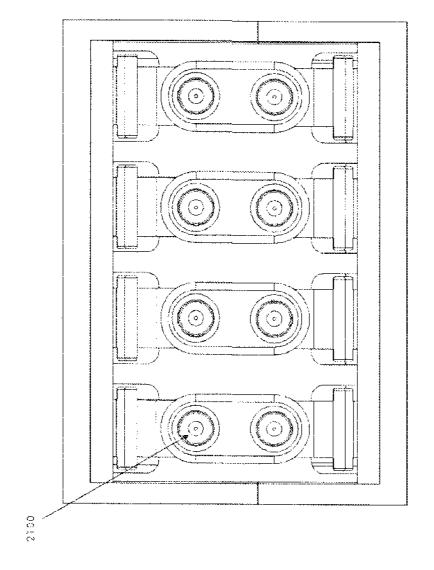
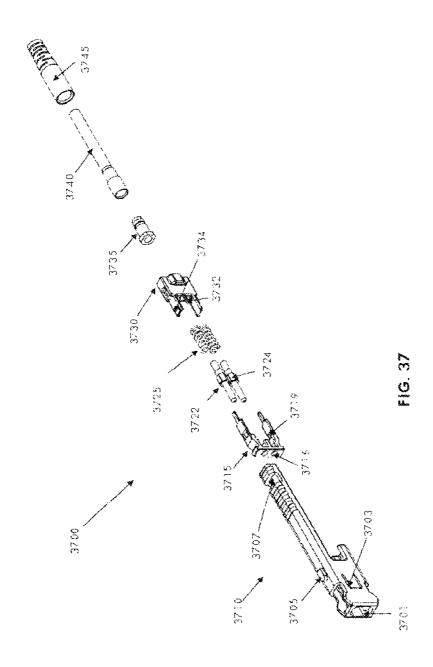


FIG. 368

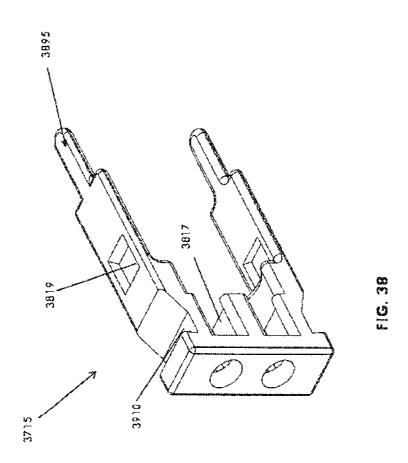
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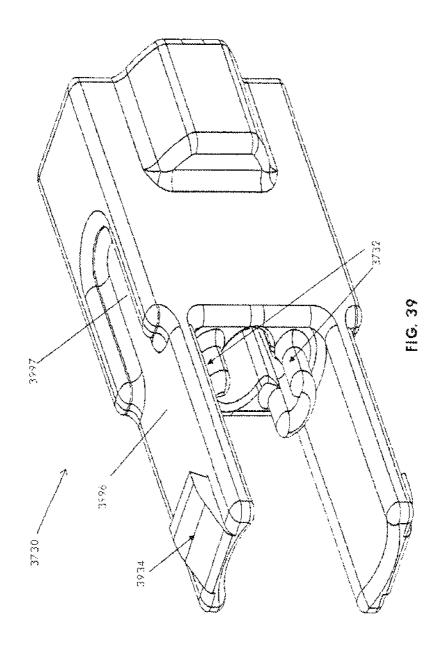
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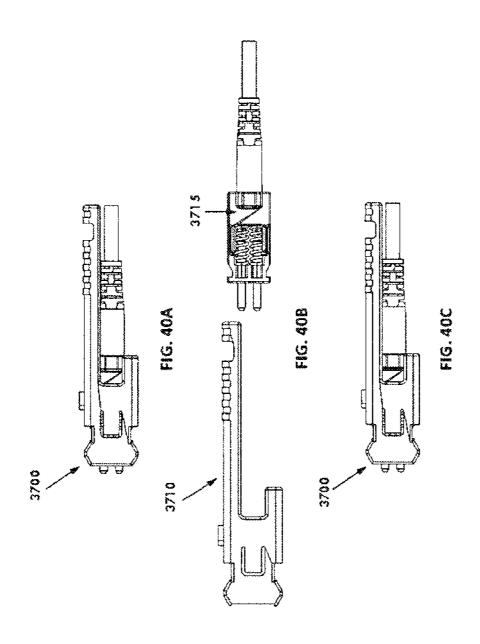
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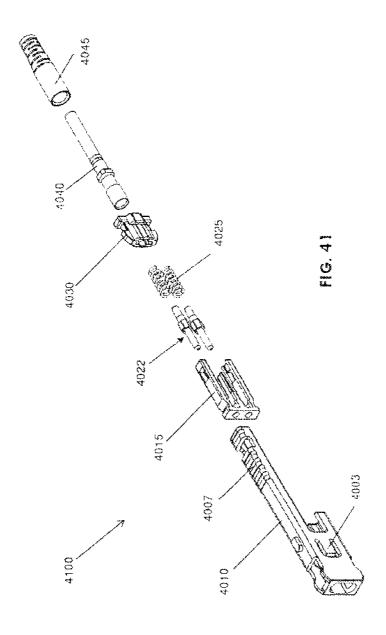
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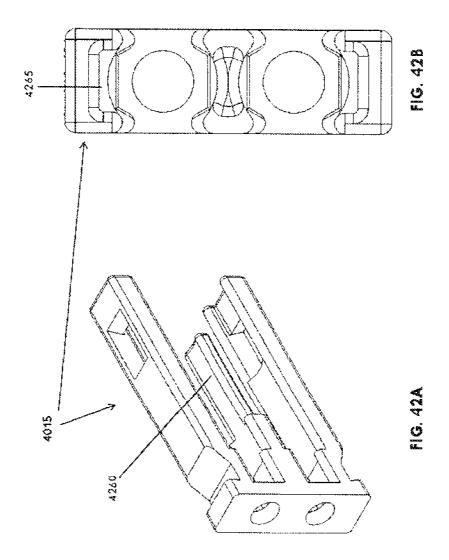
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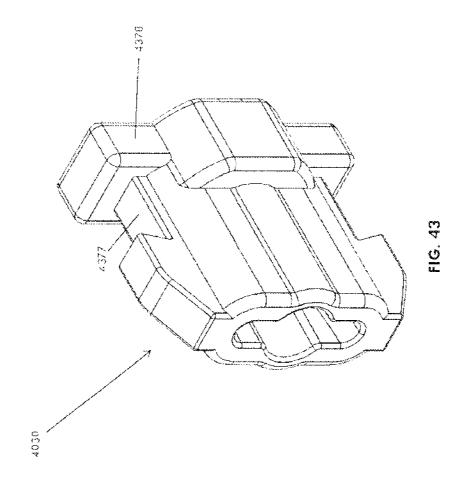
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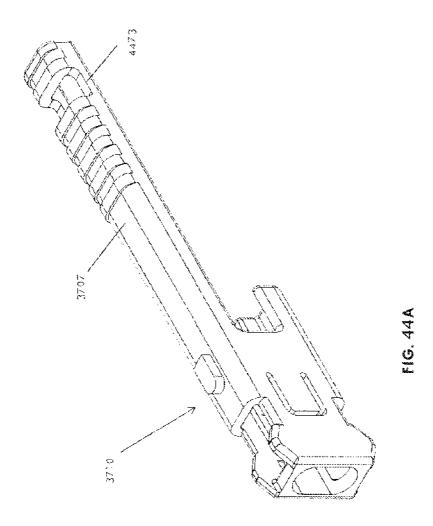
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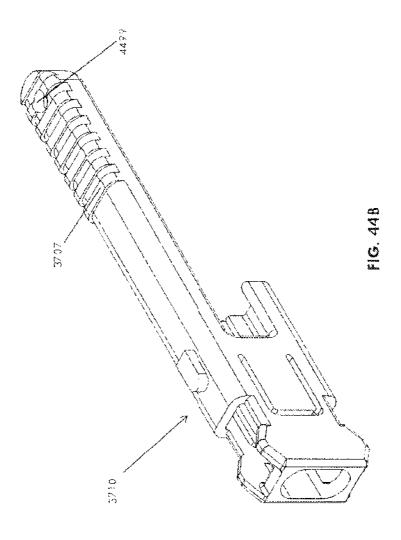
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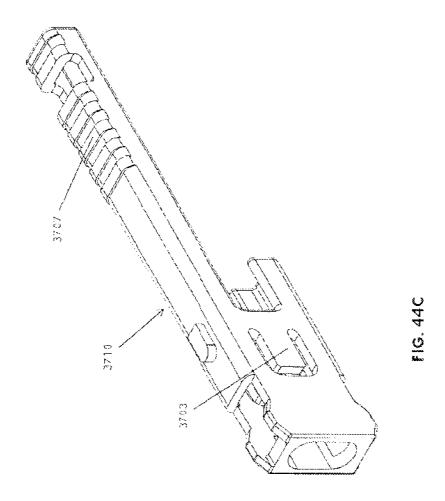
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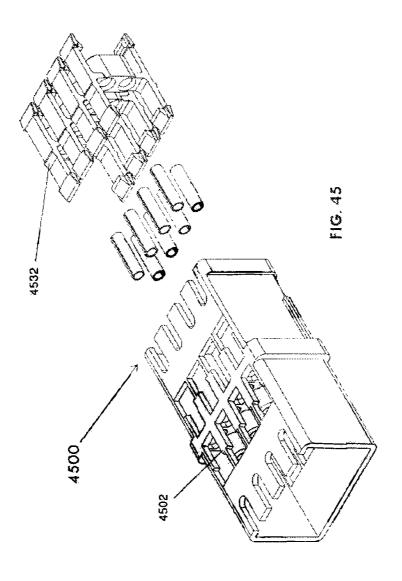
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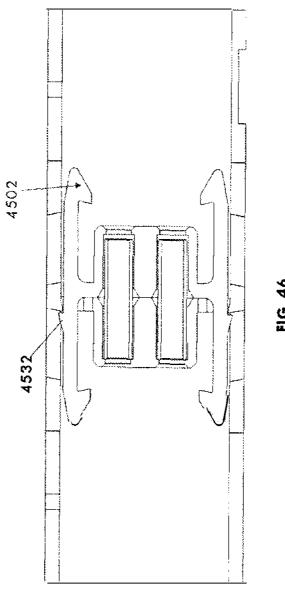
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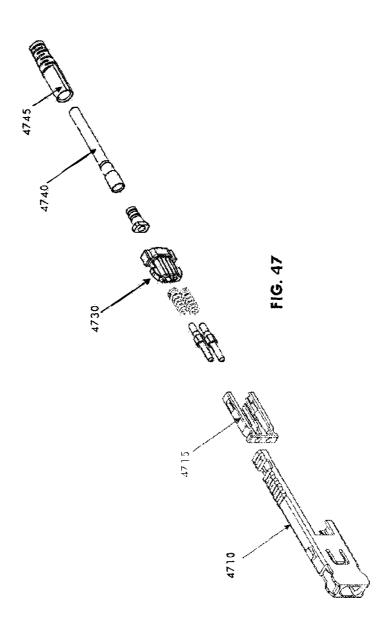
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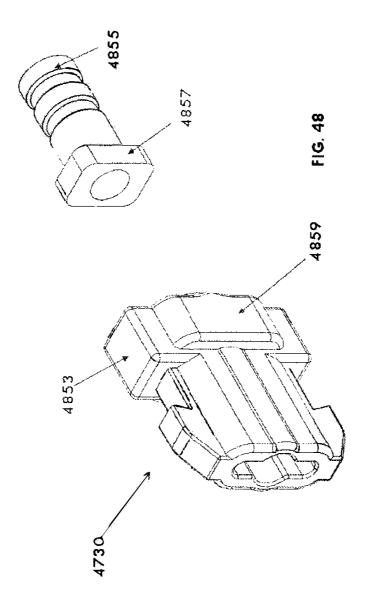
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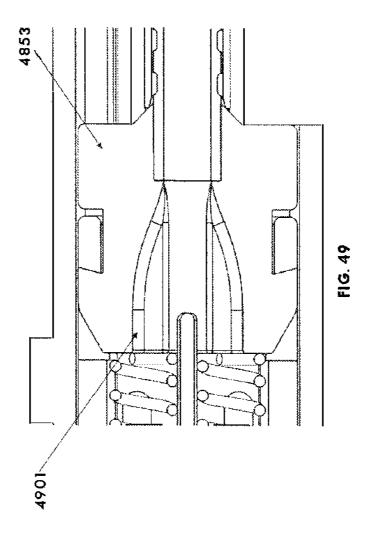
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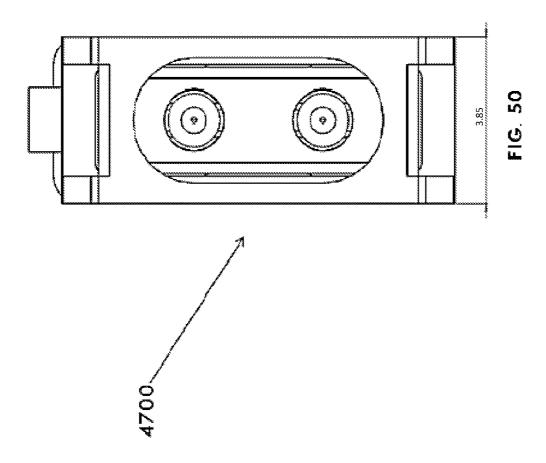
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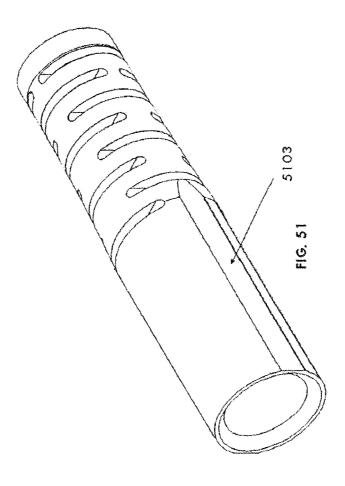


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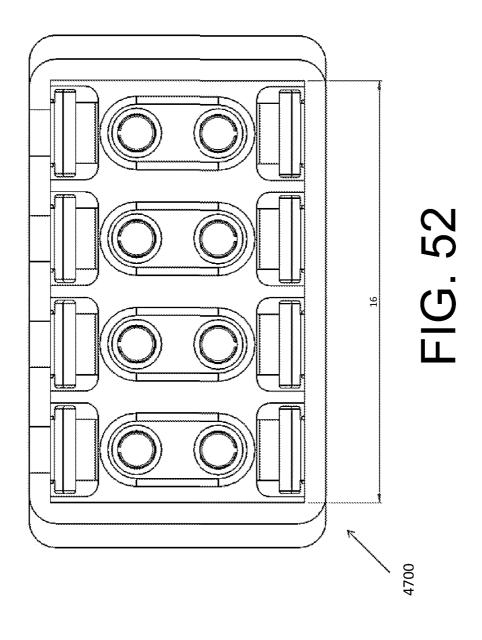


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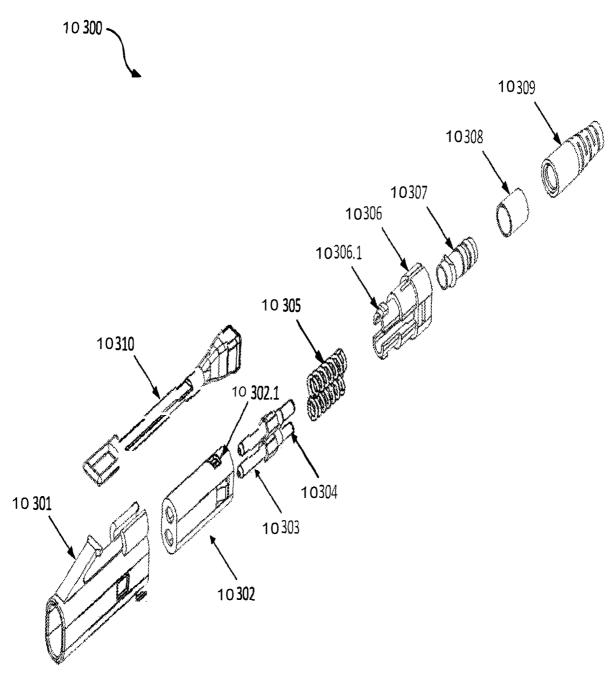


FIG. 53

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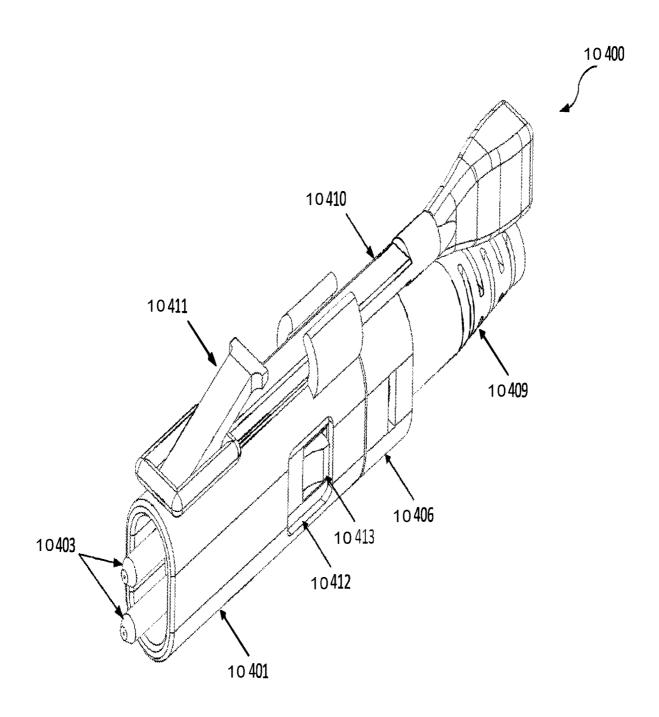
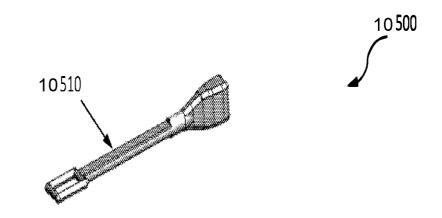
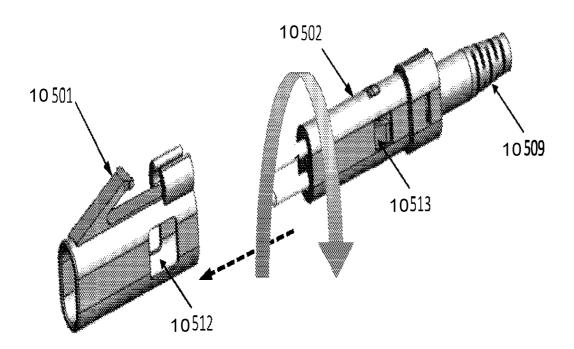


FIG. 54

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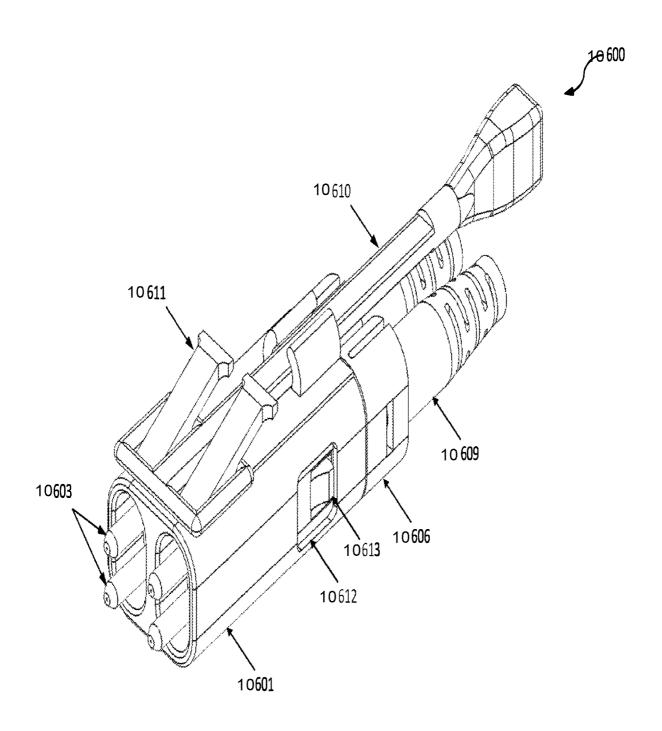


FIG. 56

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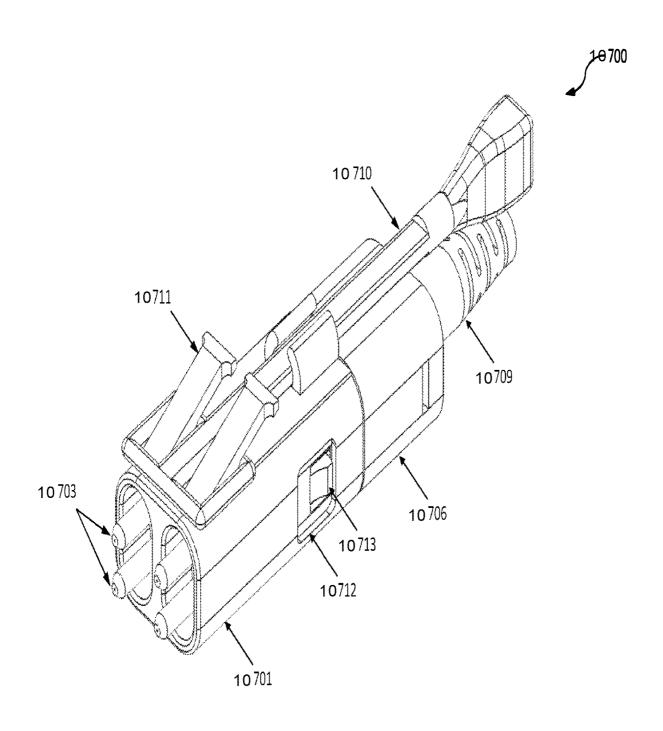


FIG. 57

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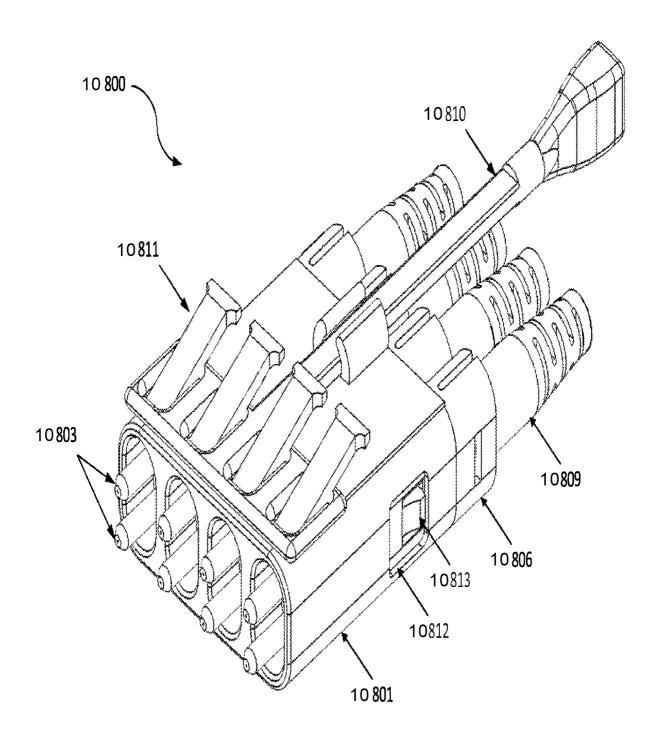


FIG. 58

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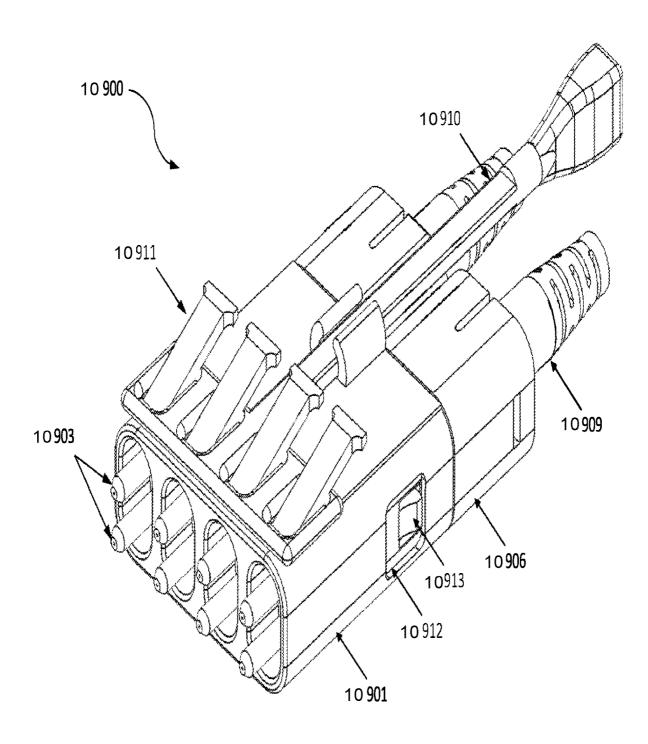


FIG. 59

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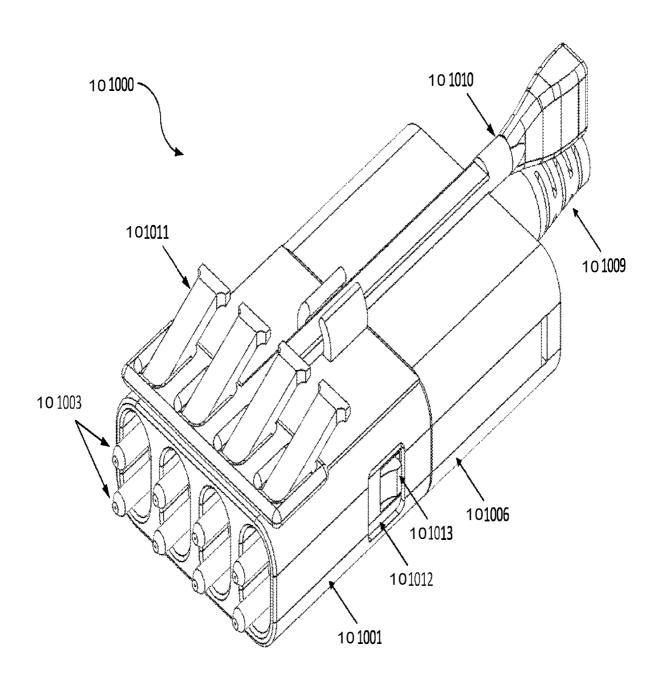


FIG. 60

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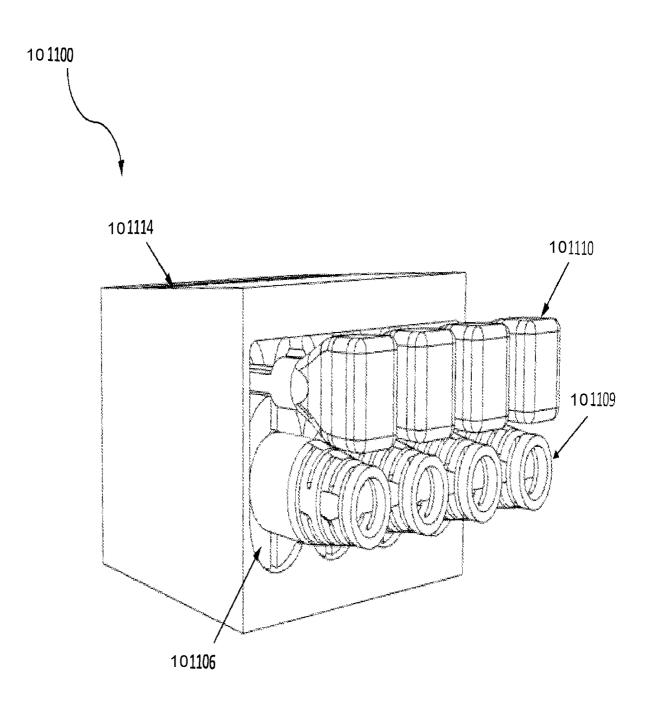


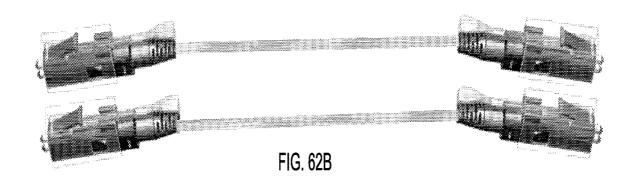
FIG. 61

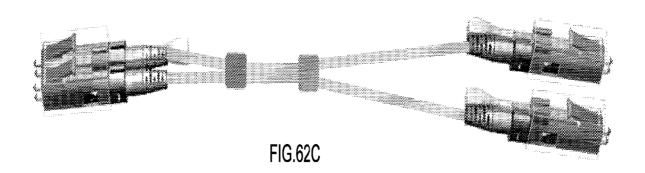
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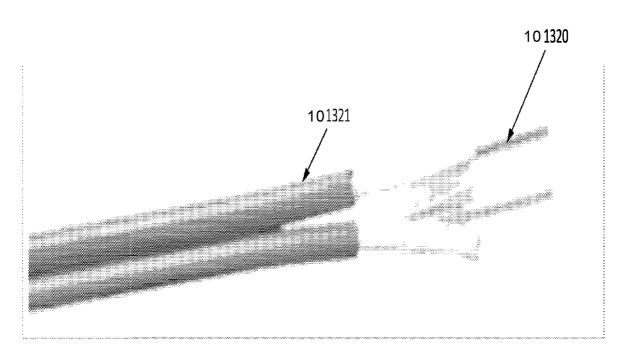
FIG. 62A





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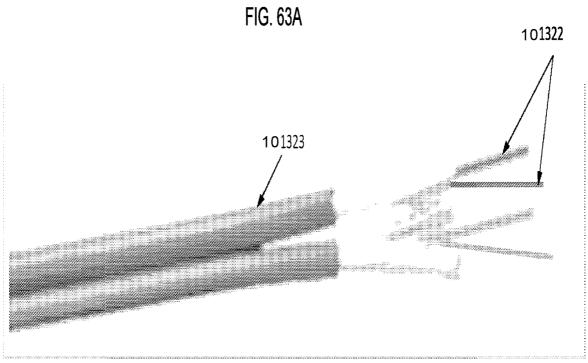


FIG. 63B

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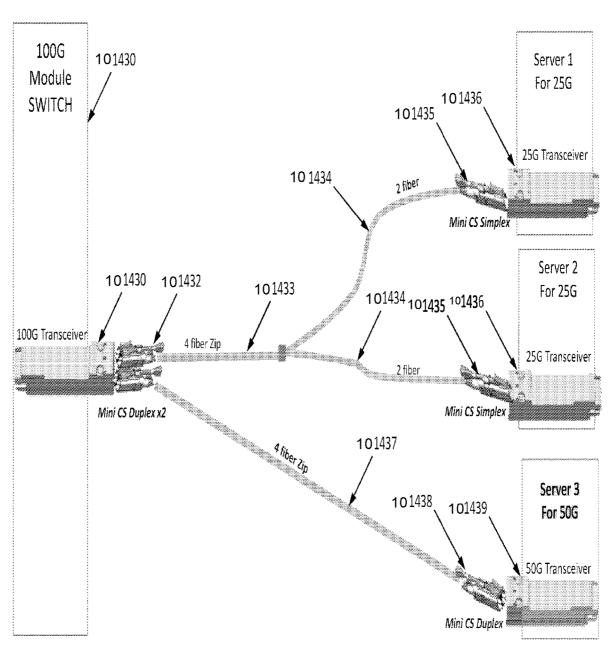


FIG. 64

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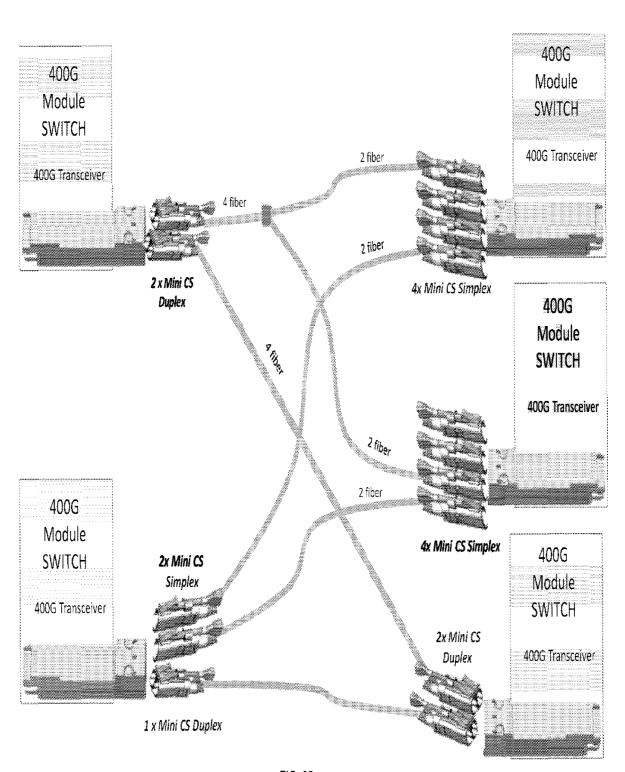
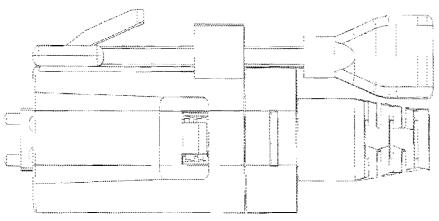
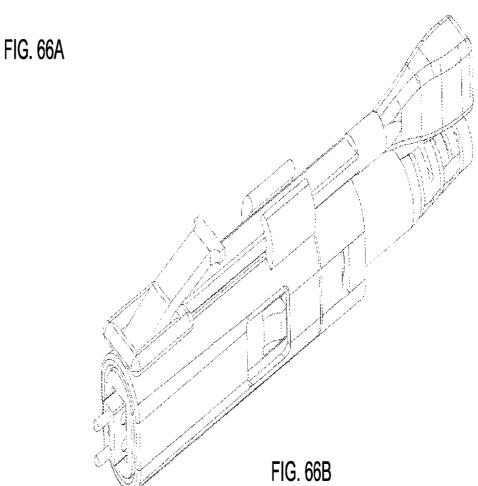


FIG. 65

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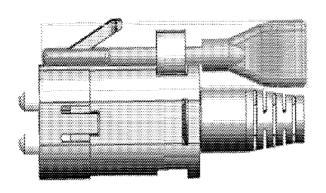


FIG. 67A

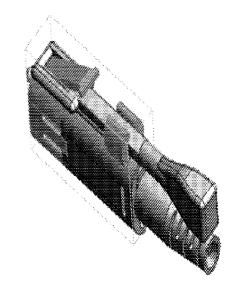


FIG. 67B

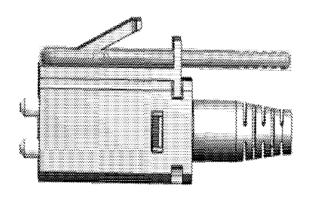


FIG. 67C

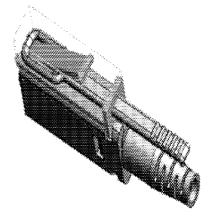


FIG. 67D

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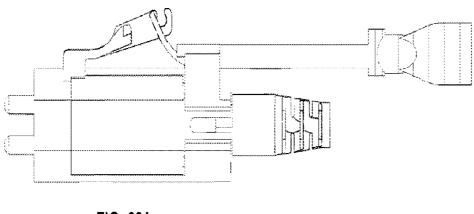
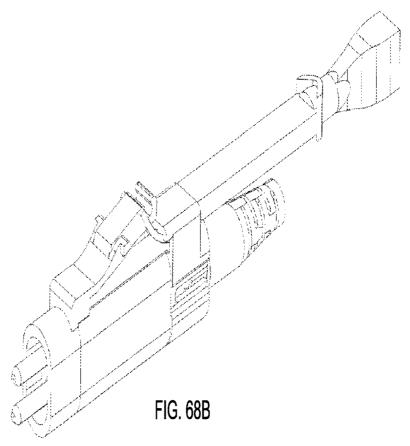


FIG. 68A



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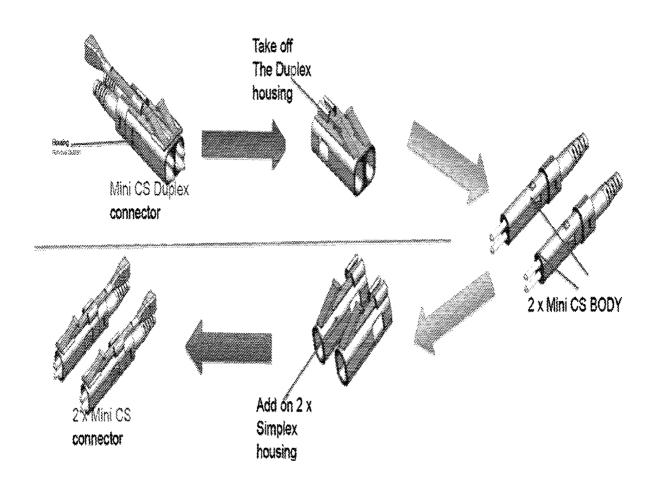


FIG. 69

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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 OPTI- 10 CAL CONNECTORS USED AS PART OF A RECONFIG-URABLE 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 CONNEC-TORS USED AS PART OF A RECONFIGURABLE OUTER HOUSING" which is a continuation of U.S. patent 20 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, 25 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 ³⁵ within adapters and optical transceivers.

BACKGROUND

The prevalence of the Internet has led to unprecedented 40 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- 45 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 50 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, 55 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 60 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 65 same footprint. Another current footprint is the quad small form-factor pluggable (QSFP) transceiver footprint. This

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

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

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- FIG. 2A 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. 2C is a top view of a prior art LC connector used in ⁵ the embodiments shown in FIGS. 2A and 2B;
- FIG. 2D is a side view of the prior art LC connector of FIG. 2C:
- 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. 11A is a side view of a connector connected to an adapter;
- FIG. 11B is a side view of a connector being removed from an adapter;
- FIG. 12A is a side view of the outer housing of a 30 connector being removed;
- FIG. 12B 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. 15A-B are illustrative examples of cable management using multiple fiber strands per jacket;
- FIG. 16 is an illustrative example of using a cable 40 transceiver. management system using multiple fiber strands per jacket. FIG. 36E
- 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. 19A-D are illustrative examples of possible alternative connector designs.
- FIG. 20 shows moving two connectors from a duplex connector to two simplex connectors.
- FIG. 21A is an exploded view of a micro optical connector according to an embodiment.
- FIG. 21B is a perspective view of the assembled micro optical connector of FIG. 21A.
- FIG. 22 is a front view of the micro optical connector of FIG. 21B showing overall connector dimensions and ferrule 55 pitch.
- FIG. 23A is a cross-sectional view of the micro optical connector of FIG. 21B latched into the adapter of FIG. 24.
- FIG. 23B is a cross-sectional view of the micro optical connectors of FIG. 21B unlatched from the adapter of FIG. 60
- FIG. 24 is an exploded view of an adapter for the micro optical connectors of FIG. 21B.
- FIG. 25A is a cross-sectional view of the adapter of FIG. 24, assembled.
- FIG. 25B is a cross-sectional side view of the adapter housing of FIG. 24.

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- FIG. **26** is a front view of the assembled adapter of FIG. **24**.
- FIG. 27A is an isometric view of the front body of the micro optical connector of FIG. 21A.
- FIG. **27**B is a right side view of the front body of FIG. **27**A.
- FIG. 28A is an isometric view of the back body of the micro optical connector of FIG. 21A.
 - FIG. 28B is a side view of the back body of FIG. 28A.
- FIG. **29**A is an isometric view of the outer housing of the micro optical connector of FIG. **21**A.
 - FIG. 29B is a front view of the outer housing of FIG. 29A.
- FIG. **29**C is a cross-sectional view of the outer housing of FIG. **29**A showing the top of an orientation protrusion.
- FIG. 29D is an inner view of the outer housing of FIG. 29A.
- 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 20 of FIG. 24.
 - FIG. 31 is an isometric view of the adapter of FIG. 24 assembled with the micro optical connectors of FIG. 21B.
 - FIG. 32A is cross-sectional view of a prior art connector showing a latch gap.
 - FIG. 32B is a cross-sectional view of the micro optical connector of FIG. 21B latched (left) and unlatched (right) within the adapter of FIG. 24, assembled.
 - FIG. 33A depicts the micro optical connector of FIG. 21B in a QSFP footprint, depicting dimensions in millimeters.
 - FIG. 33B depicts the micro optical connectors of FIG. 21B in an SFP footprint, depicting dimensions in millimeters
 - FIG. 34A-34C depicts adapter hooks interacting with the micro optical connectors of FIG. 21B before (FIG. 34A), during (FIG. 34B), and after (FIG. 34C) latching.
 - FIG. 35A-FIG. 35C depicts the micro optical connector of FIG. 21B side flap operation before (FIG. 35A), during (FIG. 35B), and after (FIG. 35C) latching.
 - FIG. **36**A depicts plural micro optical connectors in a transceiver
 - FIG. 36B is a front view of the transceiver of FIG. 36A.
 - 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. 40A, 40B, and 40C 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. 42A is an isometric view of the front body of the micro optical connector of FIG. 41.
 - FIG. 42B is a side view of the front body of FIG. 42A.
 - FIG. 43 is an isometric view of the back body of the micro optical connector of FIG. 41.
 - FIGS. 44A, 44B, and 44C are isometric views of the outer housings that may be used with any of the micro optical connectors of FIGS. 21A, 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 20 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 ³⁰ 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, 45 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," 50 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 55 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 60 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. 65 The connector may be any suitable type now known or later developed, such as, for example, a ferrule connector (FC), a

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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 15 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, 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 parrow-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. 1A 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. 1B 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. 1C is a top view of the adapter 106 of FIG. 1B. 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. 1D, which shows a front view of the adapter 106.

FIG. 2A 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. 2B 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. 2C and 2D 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 5 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 15 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, 20 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 25 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 30 401 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 35 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 40 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 45 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 55 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 60 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 65 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

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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 5 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 capac- 20 ity 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 25 capacity housing or a four-ferrule capacity and two twoferrule 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 40 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. Accord- 50 ingly, 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 55 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 60 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 65 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 mechanical transfer of the control of the contr

nism 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.

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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. 11A, in one embodiment 1100A, 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 1100A. Accordingly, in some embodiments, the receptacle 1114 may have a receptacle hook 1115, which is flexible and can secure the connector 1100A 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

Additionally or alternatively, in some embodiments, such as that shown in FIG. 11B, a connector 1100B 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. 11B, as the connector 1100B 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.

connector 1100A into the receptacle.

Referring now to FIGS. 12A and 12B, 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. 12A. 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.

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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 5 beneficial with regard to reducing the burden of cabling in a data center environment. Illustrative embodiments shown in FIGS. 14A through 14C depict cable configurations that may be used to reduce the complexity of optical cables in a compact environment. Note that any of the optical connec- 10 tors described in this disclosure may be used in these embodiments, including the optical connectors of FIGS. 21B, 37, and 41, to be discussed in detail below. FIG. 14A shows two duplex cables similar to the cable shown in FIG. 6. In some embodiments, one or more detachable clips 1401 15 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. 14B is an illustrative example of how easily an embodiment can separate into two individual 20 connectors by unbinding the cables and thus quickly and easily creating two independent fiber optic channels that can move and be connected independently. FIG. 14C shows an embodiment in which a duplex connector like that of FIGS. 6 and 14A is connected to two separate individual connec- 25 tors. Through the variable housing configurations depicted above in FIG. 10, the cable of FIG. 14A can be reconfigured as the cables of either 14B or FIG. 14C.

In addition to binding existing fiber cables, some embodiments herein may utilize a new four fiber zip cable. Referring now to FIG. 15A, 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, 35 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 40 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. 18A-18B and FIGS. 19A-19D. As shown, a switch (e.g., 100G switch) **1630** is shown with a transceiver (e.g., 100G transceiver) 45 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 50 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) 55 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)

An additional or alternative embodiment is shown in FIG. 60 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 65 the two simplex connectors 1734, a two fiber cable 1736 extends to connect to various other connectors and trans-

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ceivers. 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. 18A-18B, and the optical connectors of FIGS. 21, 37, and **41**).

FIGS. 18A-18B 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. 19A-19D 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. 19A-19B, 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. 19C-19D. 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. 14A to a connector as shown in FIG. 14C. 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. 21A depicts an embodiment of an optical connector 2100, shown in exploded view while 21B 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

protrusions 2810.

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.

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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 15 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 20 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 30 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- 35 ferrule outer housing.

Turning to FIGS. 29A and 29B, isometric and front views of the outer housing 2110 are shown. As seen in the front view of FIG. 29B and the cross-sectional view of FIG. 29C, connector orientation protrusions 2910 are provided within 40 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 45 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. 27C, engages the connector orientation protrusion 2910, seen in an inside view of the outer housing in FIG. 29D, labelled as "Flap A", 50 flexing the connector flap 2103 outwardly from the outer housing body 2110, depicted in the inset of FIG. 29C. The flap protrusion mating location is indicated as "mating place B" in FIG. 29D. Once the locking surface 2114 passes beyond the orientation protrusion, the connector flap returns 55 to its original position (FIG. 29A), 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. 35A-35C 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 65 using a finger or a tool, as depicted in FIG. 35B. 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 permitted of the p

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. 35C, that is, front body 2115 with the ferrule assembled therein and outer housing 2110.

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In some embodiments, the back body 2130 may comprise one or more protrusions or hooks 2134, best seen in FIGS. 28A and 28B, 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

During assembly, the ferrule flanges 2124 fit into ferrule flange alignment slots 2117 (see FIGS. 27A and 27B) 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. 28A, 28B) of back body 2130 by spring tension. As seen in the assembled cross-sectional views of FIGS. 23A and 23B, 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. 27A and 27B, 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. 21B, 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. 27A and 27B (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 5 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 10 transceiver optical receptacle is depicted in FIG. 36B (holding optical connectors 2100); as seen in FIG. 36B, the connection environment is substantially similar to one-half

of an adapter 2400.

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Turning to FIG. 24, further size reductions in the overall 15 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 20 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 25 receptacle hooks 2302 that will grip optical connectors 2100 through front body connector hook recess 2710 of FIG. 21B. 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 30 alignment key 2105 of FIG. 21A. 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 35 2402, adapter housing hooks 2432 are provided. Adapter housing hooks 2432 are received in housing adapter hook

It should be understood that above description of connection mechanisms with respect to adapter 2400 may be 40 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 45 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. 21B. As seen in FIG. 30, receptacle hooks 2302 include an 50 inner surface 3110. The receptacle housing further includes connector alignment slots that mate with connector alignment key of FIG. 21A. The connectors 2100 are received through connector opening of the receptacle housing which 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 60 associated mating components, the adapter housing 2402 includes receptacle hook openings 2420, seen in FIGS. 25A and 25B. Receptacle hook openings 2420 accommodate the clearance required by receptacle hooks 2302 when they flex upwards prior to latching with connectors 2100. The inter- 65 action of the receptacle hooks 2302, having slanted inner surfaces 3110, with the receptacle hook openings 2420 is

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best seen in FIGS. 32B and 34A-C. Prior to latching (FIG. 34A), 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. 32A. As seen in FIG. 32A, 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. 25A. Connector alignment keys 2105 are positioned within connector alignment slots 2403. As seen in the crosssectional view of FIG. 23A, 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. 33B. 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. 33A. 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 also includes flex tab, cutout, mount plate and panel hook. 55 connector is depicted. In this embodiment, the last two digits of each element correspond to the similar elements in the optical connector of FIG. 21A 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 17

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 53819 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 10 FIG. 21A, 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 15 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 20 stress on the backpost.

As seen in FIGS. 40A-40C, the assembled front body 3715 may be removed from the outer housing 3710, rotated 180° as indicated by the arrow (FIG. 40B), and re-inserted into the outer housing (FIG. 40C). This allows for a change 25 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. 35A-35C, connector flap 3703 is flexed outward to release the front body from the 30 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. 21A and FIG. 37. In FIG. 35 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 40 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. 42A, the front body 4015 in this embodiment includes a middle wall 4260 interposed between the 45 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. 50 42B. 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. 42B. 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. 44A-44C, may be used with any of the optical connectors depicted in FIGS. 21, 37, and 41 or earlier embodiments. In FIG. 44A, the push-pull tab 3707 may include a release recess 4473. Release recess 4473 permits 65 insertion of a tool or fingernail to remove the connector from an adapter or transceiver, without disturbing adjacent con-

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nectors. Similarly, FIG. 44B 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. 44C 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

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

body) as shown.

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 5 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 10 spring(s) 10305.

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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 15 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 20 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 25 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 30 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 35 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 40 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 45 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 55 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 60 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 65 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

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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 50 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 5 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 10 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 15 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).

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Referring now to FIG. **61**, an embodiment **101100** is shown in which the connector (not shown in its entirety) is 20 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 pushpull 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., 30 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 35 FIGS. 62A through 62C depict cable configurations that can be used to reduce the complexity of optical cables in a compact environment. FIG. 62A 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 entangle- 40 ment with additional cables. FIG. 62B 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. 62C shows an 45 embodiment in which a duplex connector like that of FIGS. 56 and 62A is connected to two separate individual connec-

In addition to binding existing fiber cables, some embodiments herein may utilize a new four fiber zip cable. Referring now to FIG. 63A, 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 55 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 60 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. **66A-66B**, FIGS. **67A-67D**, and **68A-68B**. As shown, a switch (e.g., 100G switch) **101430** is shown with a transceiver (e.g., 65 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

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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. 66A-66B).

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.

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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 5 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 understand- 20 ing, 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" 25 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 35 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 40 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 45 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 50 longitudinal axis. 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 55 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 60 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 65 described in terms of any individual member or subgroup of members of the Markush group.

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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 embodi-

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
- 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
- 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.

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- 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, 5 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
- 12. The optical fiber connector as set forth in claim 11, further comprising a single cable boot extending rearward 15 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, 20 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, 25 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, 30 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 35 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 45 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 50 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 55 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

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- 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 longitu-
- the optical fiber connector further comprising a push/pull tab extending from the rear end portion of the elongate
- 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:

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- 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

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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

- 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**, $_{20}$ 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, 25 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 $_{40}$ 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**, 45 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 50 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**, 65 further comprising a single cable boot extending rearward from the connector housing.

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- 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;

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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



(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

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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

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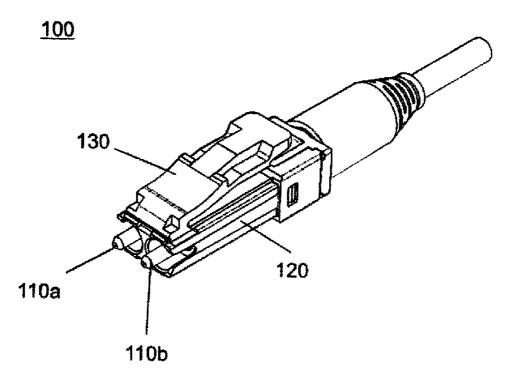
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Primary Examiner — Jerry M Blevins

(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.

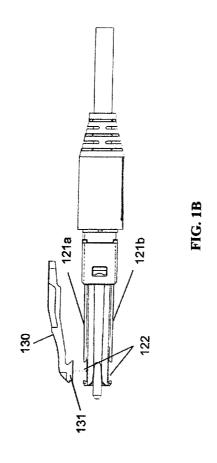
13 Claims, 28 Drawing Sheets

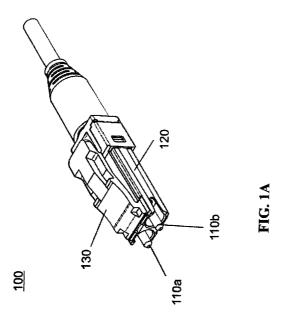


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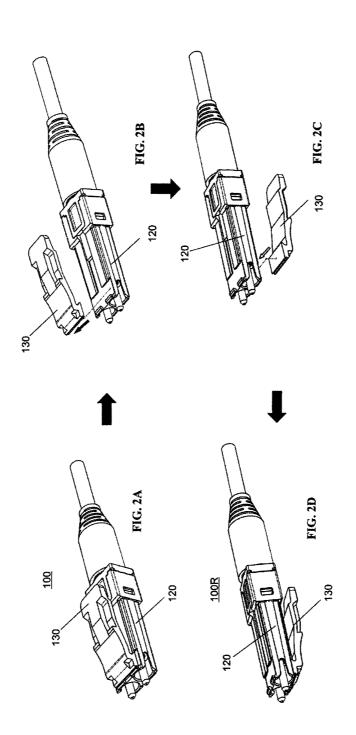




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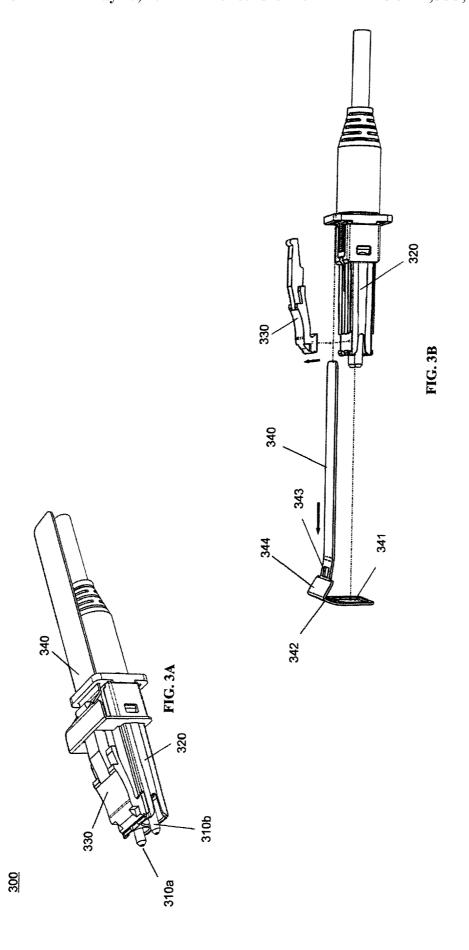


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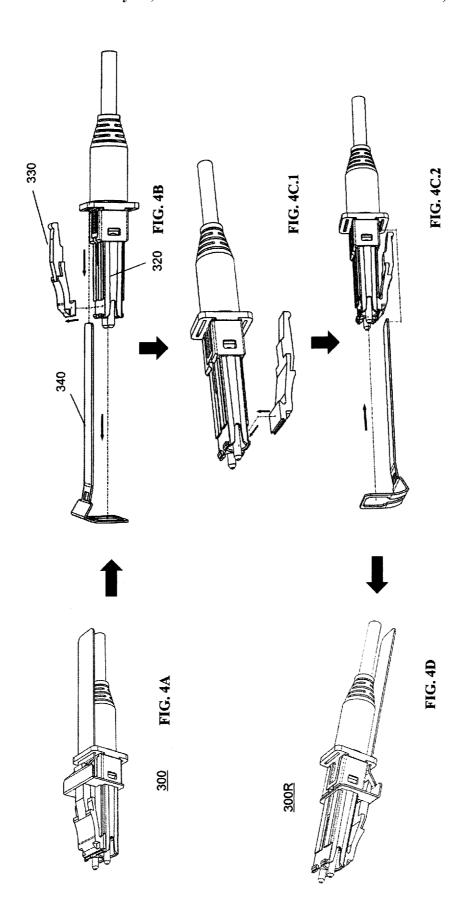
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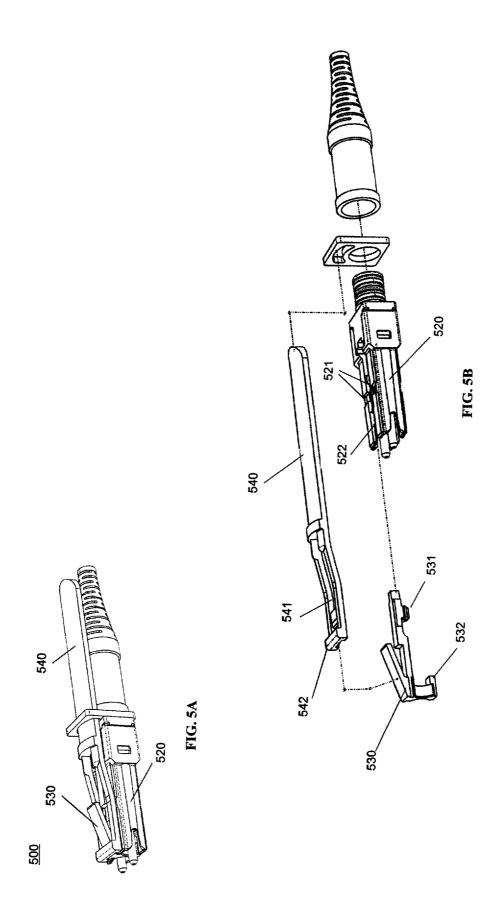
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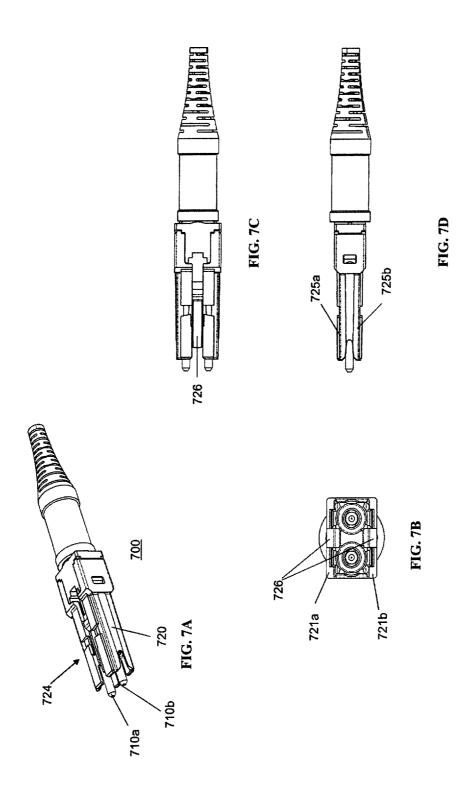
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U.S. Patent US 11,333,836 B2 May 17, 2022 Sheet 6 of 28 520 540 530 FIG. 6D 200 500R

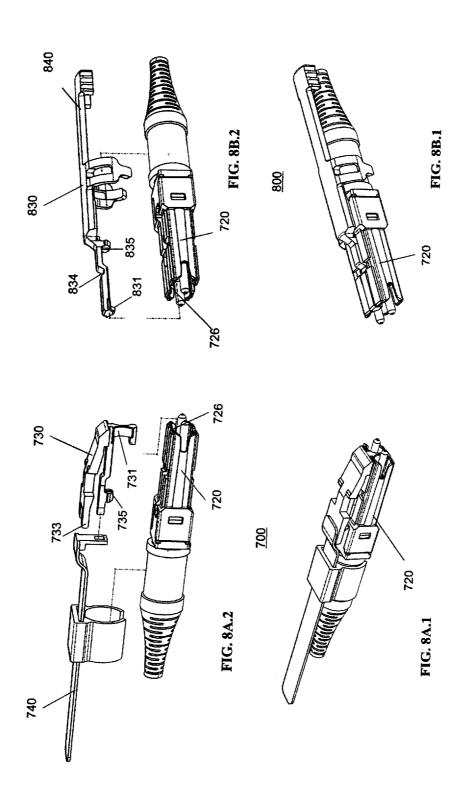
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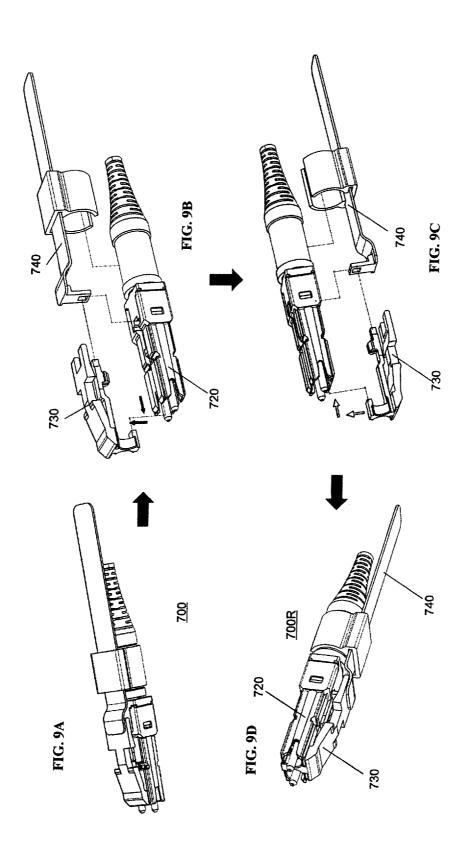
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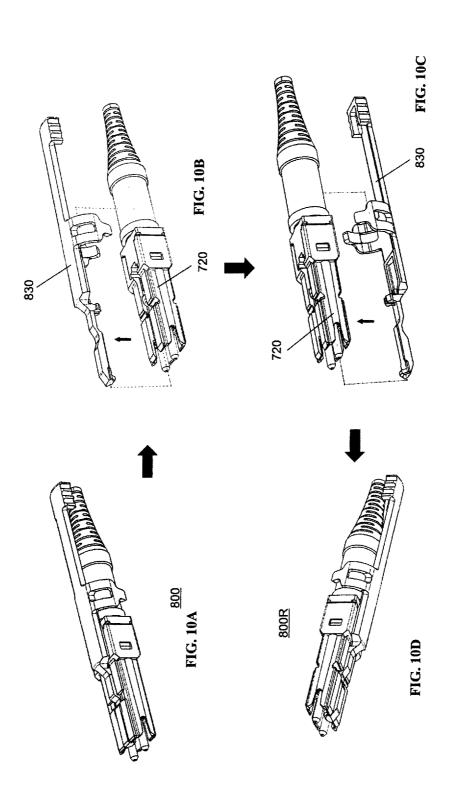
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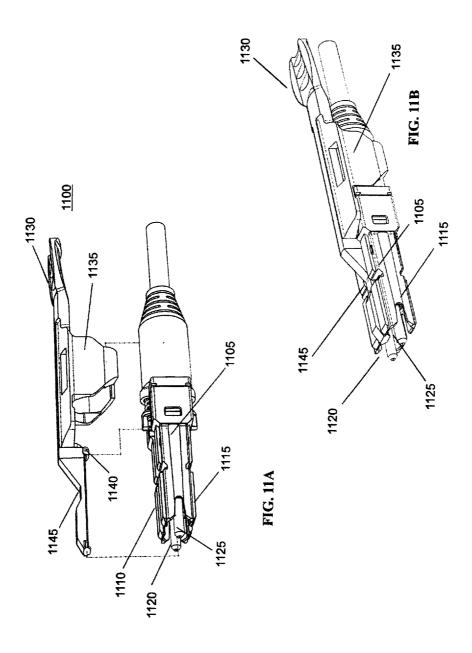
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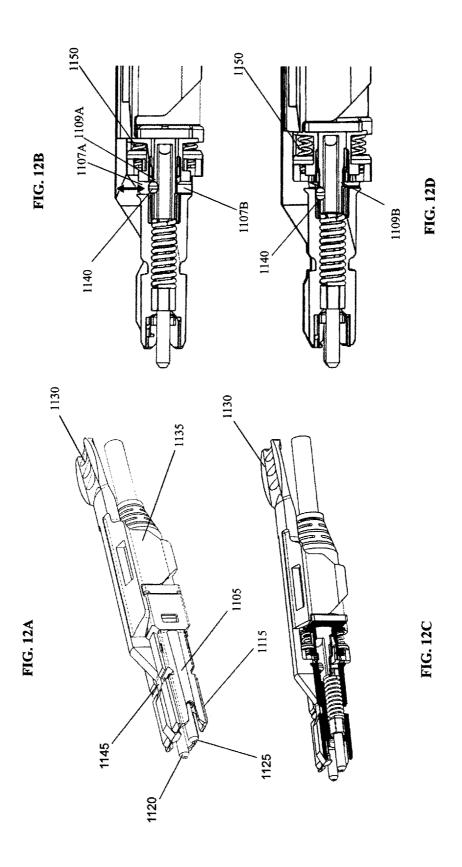
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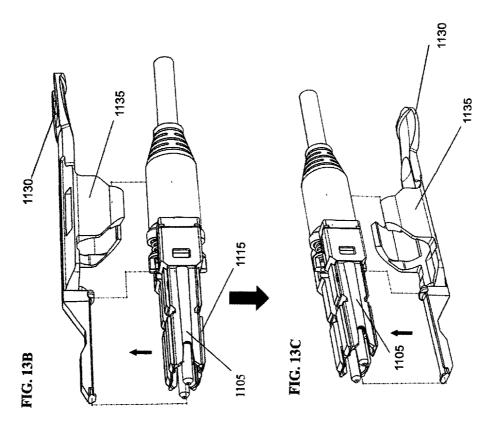


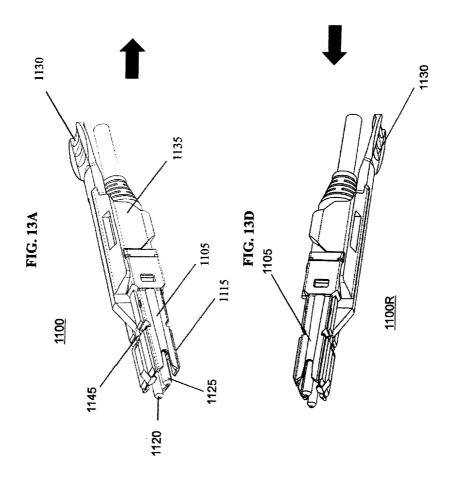
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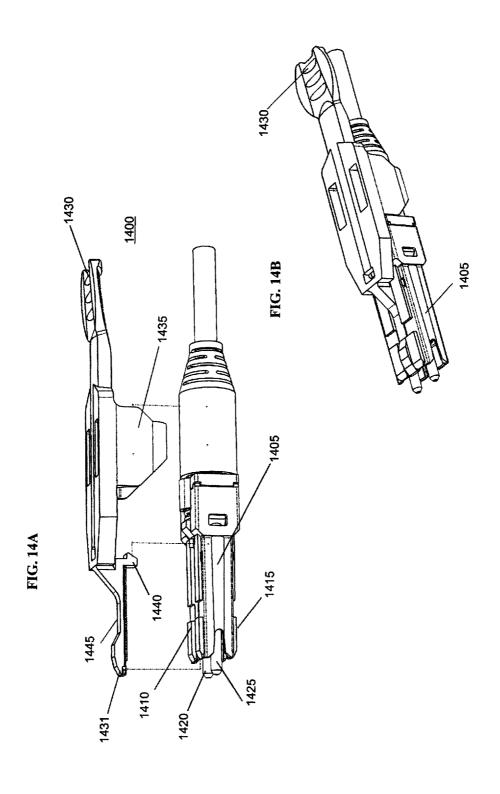
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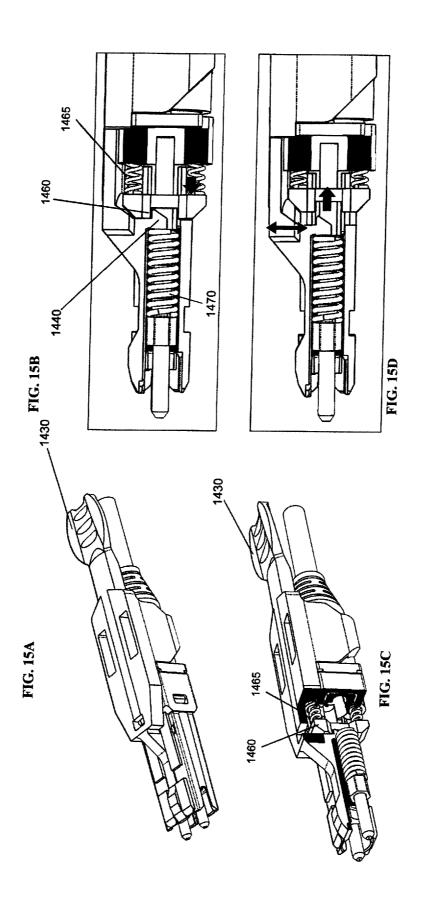
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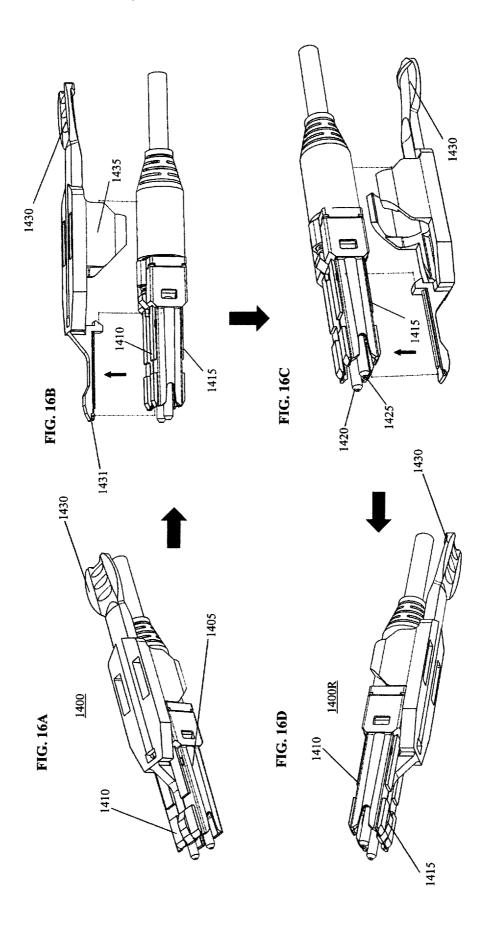


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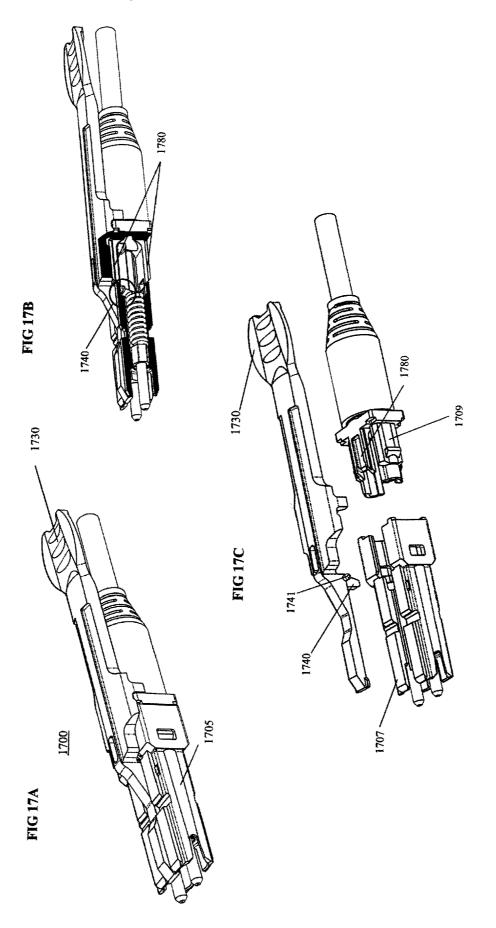
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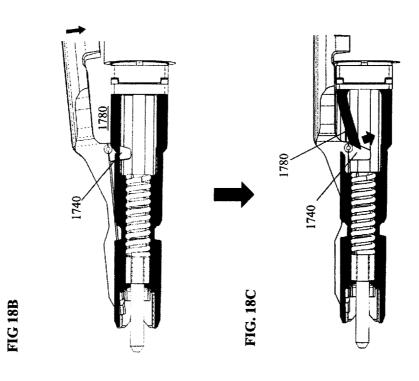


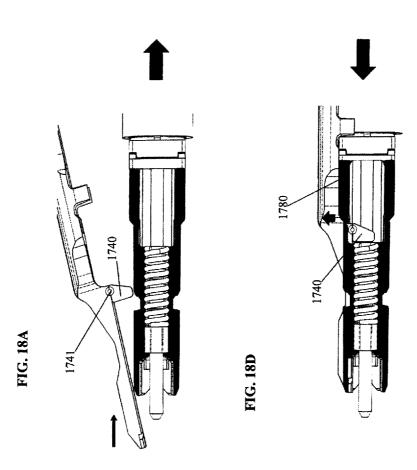
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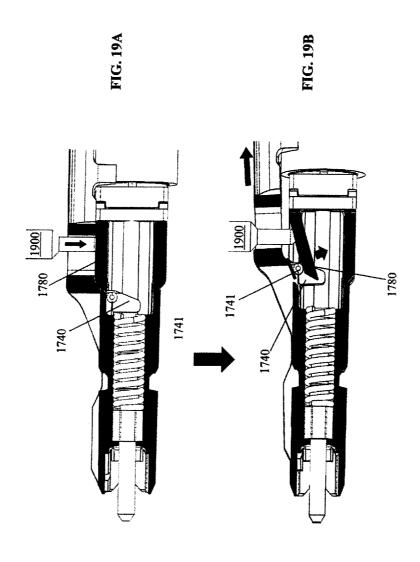
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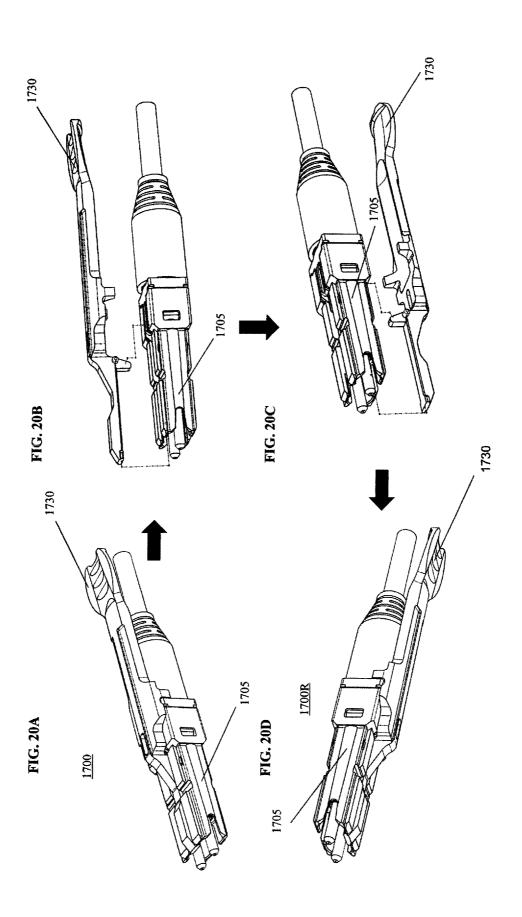


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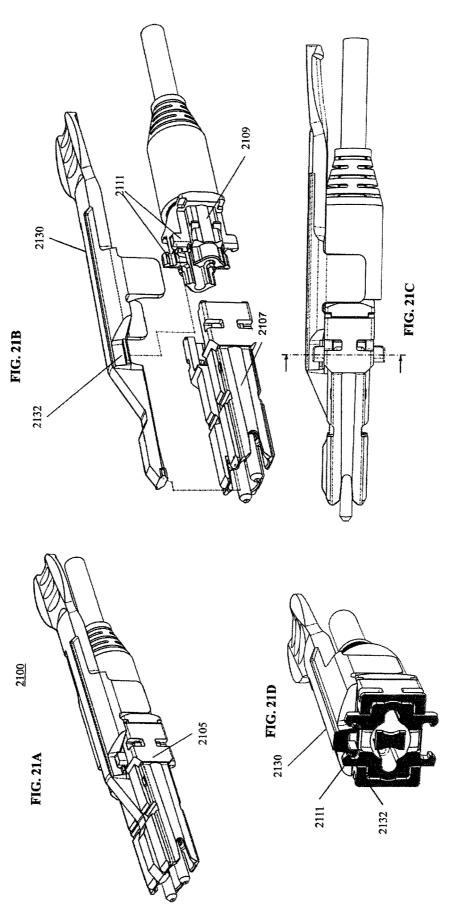
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U.S. Patent May 17, 2022 US 11,333,836 B2 **Sheet 22 of 28** 2130 FIG. 22B FIG. 22D FIG. 22C 2130 2130 2100R **FIG. 22A** FIG. 22E 2100 2111

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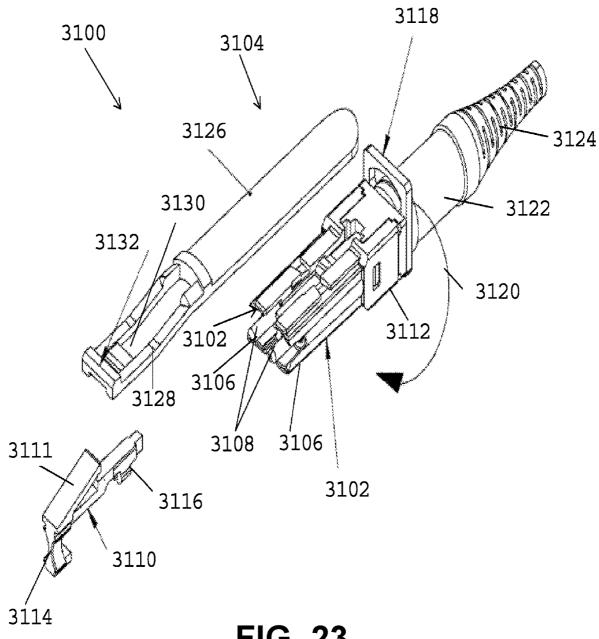


FIG. 23

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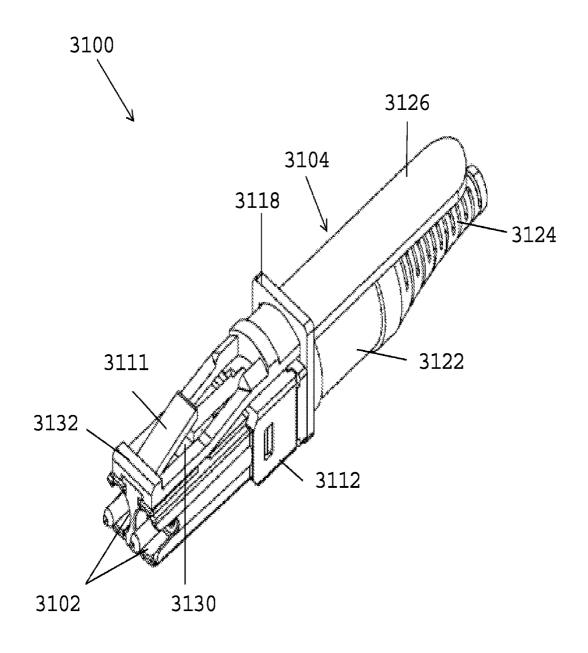


FIG. 24

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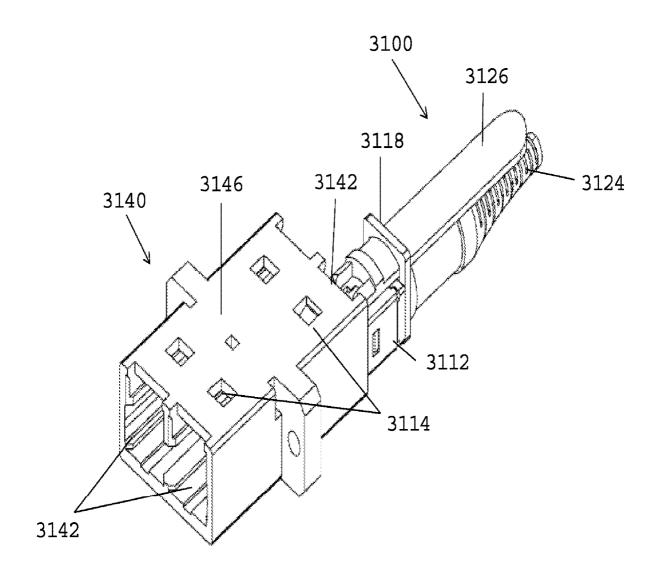


FIG. 25

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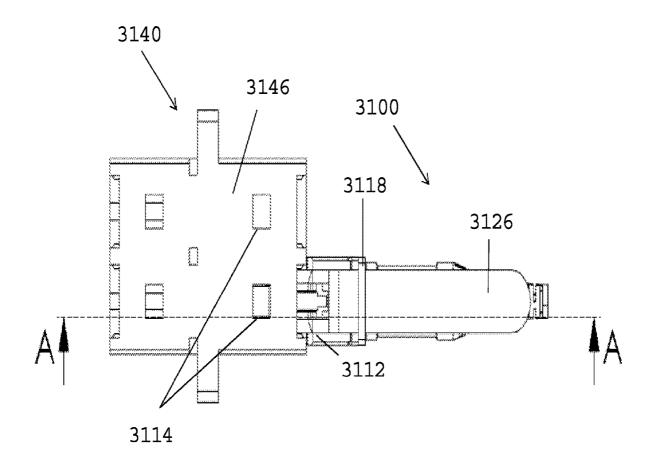


FIG. 26

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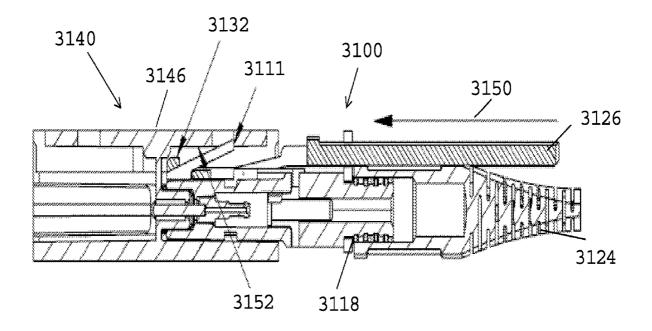


FIG. 27

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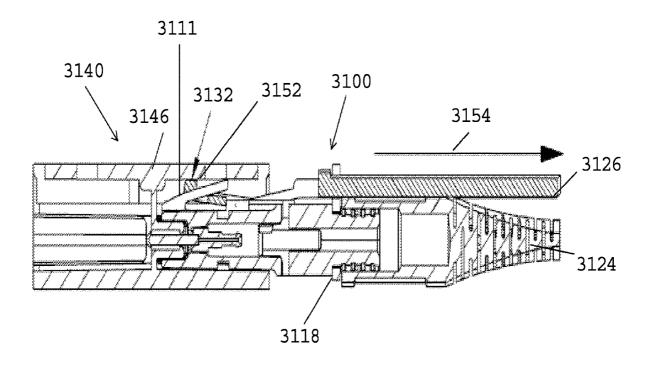


FIG. 28

1 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. 15 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. 20

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 30 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 highdensity interconnect panels. High-density interconnect pan- 35 els 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 40 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 opti- 45 cal 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). 50 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) 55 footprint. This footprint currently accommodates four LCtype 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 65 the spacing between adjacent connectors on the panel. While both approaches may be effective to increase the panel

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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 revers-60 ible 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 5 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 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 25 reversible polarity fiber optic connector of FIG. 3A; 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 30 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 35 FIG. 4A; 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 40 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 con- 45 figured 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 50 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 55 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 60 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 embodi- 65 ments, the at least one connector may include the latch arm as an integral structure.

BRIEF DESCRIPTION OF THE DRAWINGS

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

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

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

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

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

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

FIG. 3A is a perspective view of an embodiment of a push-pull tab retainer is positioned on the second exterior 20 reversible polarity fiber optic connector with a pull tab according to aspects of the present disclosure;

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

> FIG. 4A is a perspective view of the polarity of the

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

FIG. 4C.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. 4A;

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

FIG. **9**B is an exploded view of a step in the process of changing the polarity of the reversible polarity fiber optic ⁵ connector of FIG. **8**A.1:

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

FIG. 9D is a perspective view of the reversible polarity fiber optic connector of FIG. 8A.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. 10B is an exploded view of a step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. 8B.1;

FIG. 10C is an exploded view of a next step in the process of changing the polarity of the reversible polarity fiber optic 20 connector of FIG. 8B.1;

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

FIGS. 11A and 11B respectively depict exploded and perspective views of a reversible polarity optical connector 25 according to a further embodiment of the disclosure;

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

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

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

FIGS. 17A-17C respectively depict perspective, partial cross-section, and exploded views of a reversible polarity optical connector according to a further embodiment of the 40 disclosure:

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

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

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

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

FIGS. 22A-22E 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 55 narrow pitch duplex LC connector including two LC conaccording to aspects of the present disclosure; In some embodiments, such as that shown, the two

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

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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 5 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 10 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 15 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 20

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 25 without twisting the fibers or performing any complex disassembly of the duplex connector.

FIGS. 1A and 1B depict a fiber optic connector with reversible polarity according to one aspect of the present disclosure. As shown in FIG. 1A, a reversible polarity fiber optic connector may include first and second optical ferrules and 110*a* and 110*b* and a connector housing 120 at least partially surrounding the first and second optical ferrules. A removable latch have 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. 3A is a perspective view of another embodiment of a reversible polarity fiber optic connector 300. As shown, the

FIG. 1B is a side view of the reversible polarity fiber optic connector of FIG. 1A with the removable latch 130 being separated from the connector housing. As shown, the connector housing 120 may have a first exterior wall 121a positioned above the first and second optical ferrules and a 40 second exterior wall 121b 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 45 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 50 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 55 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 60 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,

FIGS. 2A-2D depict the process for changing the polarity of the fiber optic connector of FIG. 1A from a first polarity,

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FIG. 2A to a second, opposite polarity, FIG. 2D. The removable latch 130 may be removed from the latch coupling on the first exterior wall of the connector housing, FIG. 2B, positioned adjacent the second exterior wall on beneath the ferrules, FIG. 2C, and then coupled with the latch coupling on the second exterior wall of the connector housing to yield a connector 100R, FIG. 2D, 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. 3A 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. 3B is an exploded view of the reversible polarity fiber optic connector of FIG. 3A. 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. 4A-4D depict the process for changing the polarity of the fiber optic connector 300 from a first polarity, FIG. 4A to a second polarity 300R, FIG. 4D. 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. 2B. The removable latch is then detached from the latch coupling on the first exterior wall of the connector housing, FIG. 4C.1. Next, the removable latch is engaged with the latch coupling on the second exterior wall of the connector housing, beneath the ferrules, FIG. 4C.2. Finally, the pull tab 340 is positioned surrounding the connector housing and engaging the removable latch tip, resulting in the assembled optical connector 300R having polarity opposite to that of connector 300, FIG. 4D.

FIGS. 5A and 5B are a perspective view and exploded view, respectively, of another embodiment of a reversible

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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** 5 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 10 removable latch 530 when the pull tab is pulled in a direction away from the ferrule side of the optical connector.

FIGS. 6A-6D depict the process for changing the polarity of the fiber optic connector 500 from a first polarity, FIG. 6A to a second polarity, FIG. 6D. The pull tab 540 is disengaged 15 from the connector housing and the removable latch 530 on the first exterior wall of the connector housing, FIG. 6B, and the removable latch is decoupled from the latch coupling on the first exterior wall of the connector housing. Then the the second exterior wall of the connector housing, beneath the optical ferrules in FIG. 6C, 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 500R, FIG. 6D.

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 30 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. 7A is a perspective view of a common connector 35 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 710b and the common connector housing 720 at least partially surrounding the first and second optical ferrules.

FIGS. 7B, 7C and 7D 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 45 exterior wall 725a positioned above the first and second optical ferrules and a second exterior wall 725b 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 50 include a receiving track 726 in the coupling surface.

FIG. 8A.1 shows the common connector housing 720 used to create a latch-type connector 700 and FIG. 8B.1 shows the common connector housing 720 used to create a recess-type connector 800. Both of connectors 700 and 800 55 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. 8A.2 and 8B.2 respectively. The removable arms 730 and 830 may each respectively include a projection 735 or 835 for engaging in the receiving 60 track 726 of the coupling surface 724, FIGS. 8A.2 and 8B.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 65 surface of the housing yields a fiber optic connector with the opposite polarity.

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Still referring to FIGS. 8A.2 and 8B.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. 8A.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. 8A.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. 8B.2.

FIGS. 9A-9D depict the process for changing the polarity removable latch may be coupled with the latch coupling on 20 of the latch-type fiber optic connector from a first polarity 700, FIG. 9A to a second polarity 700R, FIG. 9D. 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. 9B. 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. 9C, creating the opposite polarity connector 700R.

> FIGS. 10A-10C depicts the process for changing the polarity of the recess-type fiber optic connector 800 from a first polarity, FIG. 10A to a second polarity, FIG. 10D. 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. 10B. Then the removable arm may be coupled with the coupling surface 724 of the second exterior wall of the common connector housing 720, FIG. 10C to create opposite polarity optical connector 800R, FIG. 10D.

FIGS. 11A and 11B depict a further embodiment 1100 of may comprise first and second optical ferrules 710a and 40 the reversible polarity optical connectors of the present disclosure. In FIG. 11A, 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, 1109A, beneath the housing exterior wall 1110 or a second aperture, 1109B, 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. 12B and 12D, push-pull tab protrusion 1140 may be inserted into first aperture 1109A of housing 1105 through a first exterior housing aperture 1107A. Alternatively, in the reverse-polarity configuration, the push-pull tab protrusion 1140 may be inserted into second housing aperture 1109B through second exterior housing aperture 1107B. When the push-pull tab 1130 is

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moved forward, the protrusion slides within the aperture 1109A or 1109B, as shown in FIG. 12B. 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, 5 depicted in FIG. 12B. When the position spring 1150 is in its relaxed (uncompressed) position, FIGS. 12C and 12D, the protrusion 1140 is slid forward within the aperture 1109A or 1109B.

To change polarity of the optical connector 1100, FIGS. 13A-13D, the push-pull tab 1130 is removed by withdrawing the protrusion 1140 from the housing 1105 through exterior housing aperture 1107A along with detaching clips 1135 and decoupling projection 1131, thus releasing the push-pull tab from the first exterior housing wall 1110 (FIG. 15 13B). The push-pull tab is moved toward second exterior housing wall 1115 and the protrusion 1140 is inserted into aperture 1109B through exterior housing aperture 1107B in FIG. 13C. Projection 1131 is fitted between ferrules 1120 and 1125 and clips 1135 are affixed to the connector. The 20 resultant connector 1100R of 13D is of opposite polarity to the connector 1100 of FIG. 13A.

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 25 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. 14A 30 and 14B 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 35 1425. In FIG. 14B, 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. 15B 40 and 15D. To release the protrusion 1440, push-pull tab position spring 1465 is compressed in FIG. 15C such that housing projection 1460 is retracted sufficiently to allow removal of protrusion 1440 through the housing 1405, FIG. 15D.

To change polarity of the optical connector 1400 from the first polarity of FIG. 16A, 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 50 from the first exterior housing wall 1110 (FIG. 16B). 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. 16C. 55 The resultant connector 1400R of FIG. 16D is of opposite polarity to the connector of FIG. 16A.

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 60 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. 17A, the connector 1700 includes a connector housing 1705 which may optionally include a back body housing portion 1709 for connecting with a housing 65 front portion 1707 (FIG. 17C). The back body housing portion 1709 includes a deformable region 1780, seen in the

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partial cross-section of FIG. 17B and the perspective view of FIG. 17C. 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. 18B) 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. 18C, the deformable region 1780 returns to its original position (FIG. 18D), securing the push-pull tab 1730 to the connector housing.

Removal of the push-pull tab 1730 is depicted in FIGS. 19A and 19B. 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. 20A, the push-pull tab 1730 is removed in FIG. 20B by using the removal tool technique depicted in FIGS. 19A and 19B. 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. 20C. The resultant connector 1700R of FIG. 20D is of opposite polarity to the connector of FIG. 20A

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. 21A-21D, a connector 2100 having a housing 2105 is provided with a housing front portion 2107 and a back portion 2109. FIG. 21A depicts an assembled connector 2100 with housing 2105. FIG. 21B depicts an exploded view of connector 2100 of FIG. 21A. 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. 21C 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. 21D. As shown in FIG. 21D, receiving surface 2132 may be a recess with a protrusion along the edge that engages the hook-shaped edge of the clips.

FIG. 22A through FIG. 22E depicts the operation of polarity change for connector 2100 of FIG. 21A-FIG. 21D. FIG. 22A 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. 22A to the second, opposite polarity of FIG. 22E, the retainer 2111 is removed from receiving surface 2132. Referring to FIG. 21B, lifting push-pull tab 2130 in direction of up-arrow, separates retainer 2111 from receiving surface. As shown in FIG. 22C, push-pull tab clips separate from the connector as the retainer is removed. Continuing with FIG. 22C, push-pull tab 2130 is moved to the opposite housing exterior wall in FIG. 22C. FIG. 22D depicts receiving surface 2132 engages with the retainer 2111. In FIG. 21E the assembled connector

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2100R having the opposite polarity to the connector of FIG. 22A 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. 22E.

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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 10 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 15 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 20 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 25 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 30 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 35 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 40 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 45 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 50 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 55 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 60 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 65 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.

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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 5 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.

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In some embodiments, the remote release tab 3104 may 10 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 15 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 20 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 25 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 30 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 35 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, 40 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 45 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 55 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 65 3111. The protrusion 3132 does not yet contact an inner portion 3152 of the top surface 3146.

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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

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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 5 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 10 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 15 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 20 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 25 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, 30 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, 35 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 40 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 45 "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 50 connectors in the first channel and a second one of the 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. 55 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 60 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 65 skilled in the art, a range includes each individual member. Thus, for example, a group having 1-3 cells refers to groups

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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 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

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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 20 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

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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.

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EXHIBIT C

(12) United States Patent

Takano et al.

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

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(52) U.S. Cl.

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(58) Field of Classification Search

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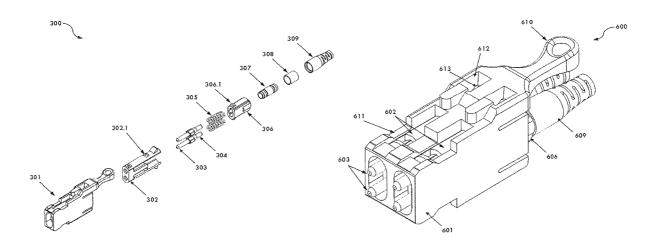
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Primary Examiner — Tina M Wong

(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



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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)

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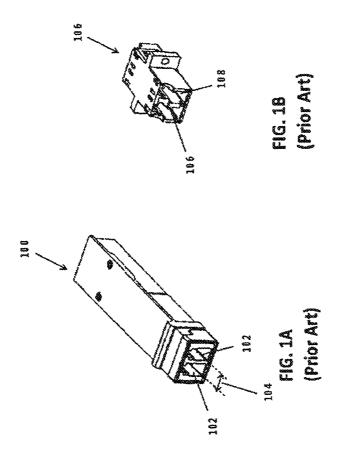
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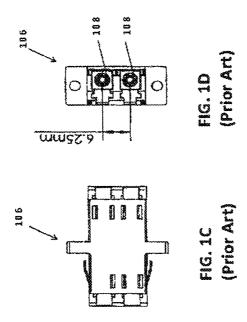
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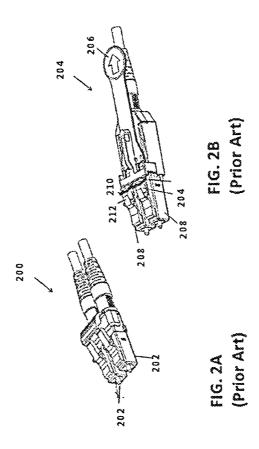
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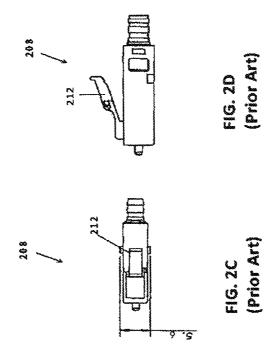
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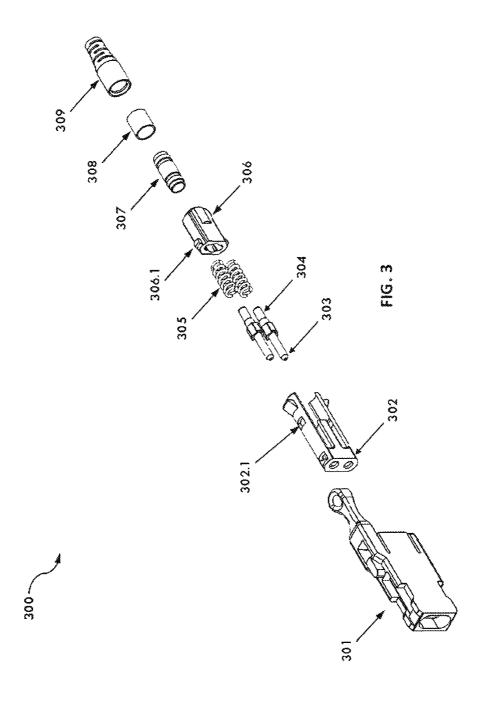
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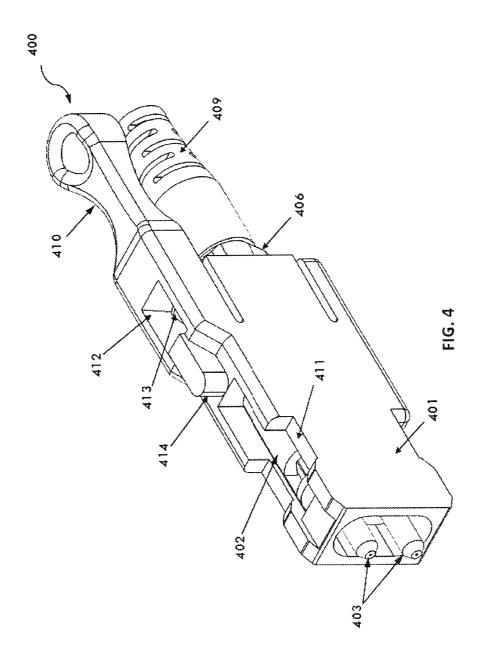
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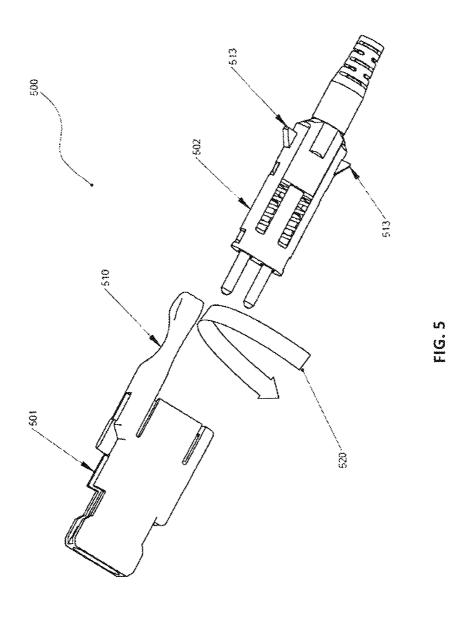
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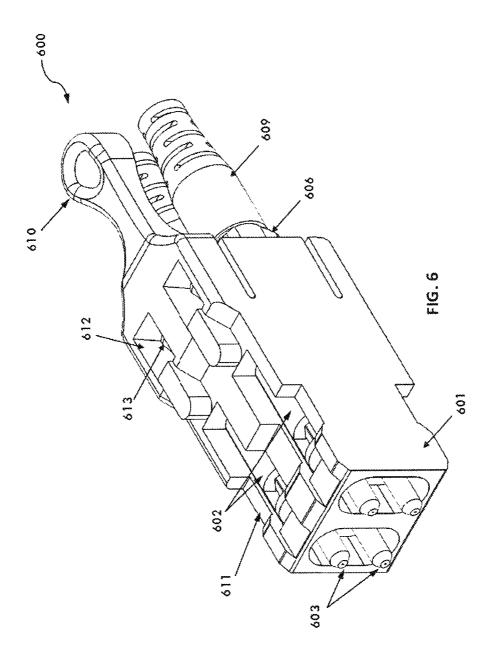
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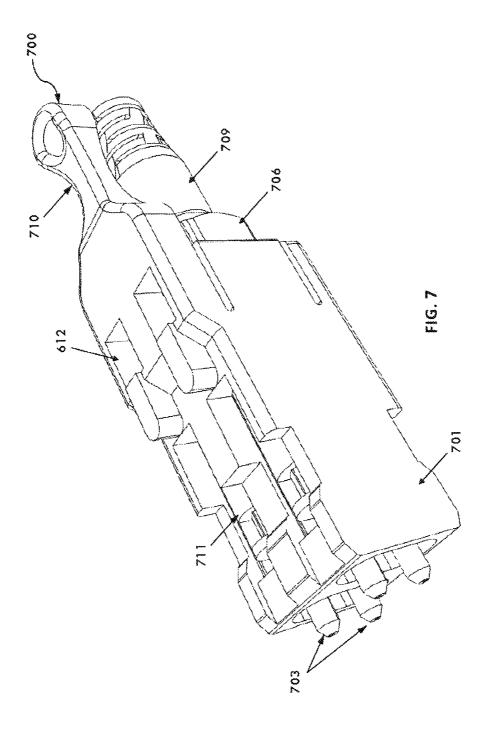
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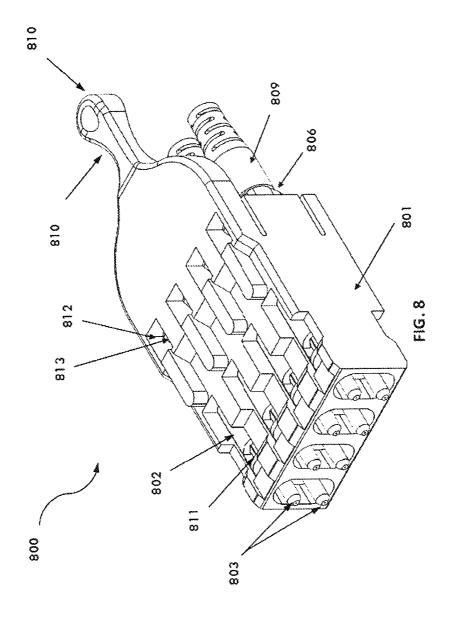
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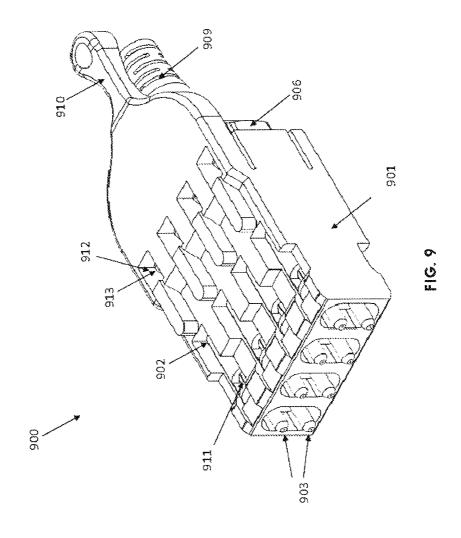
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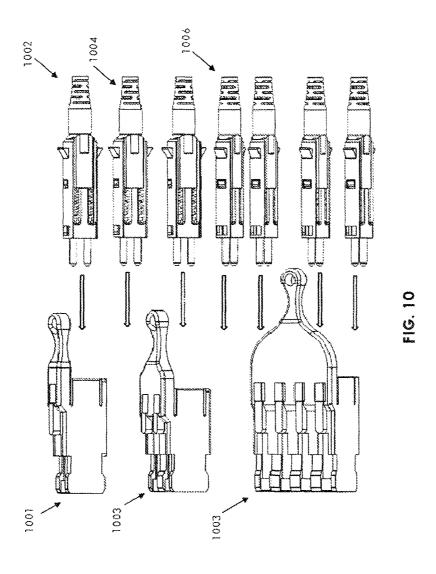
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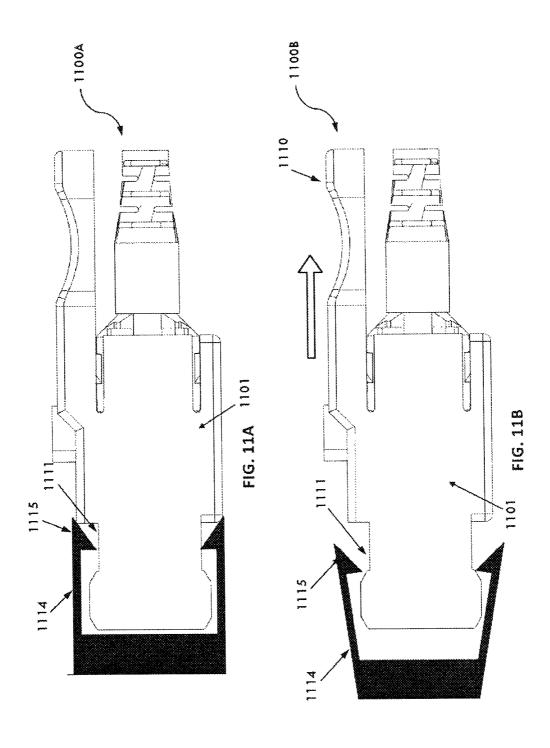
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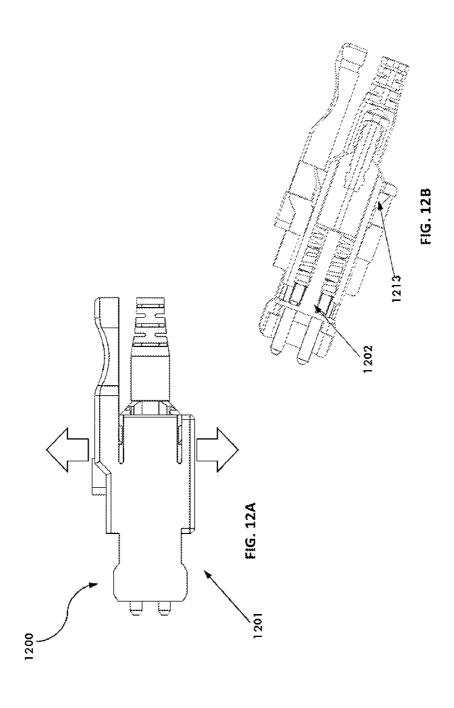
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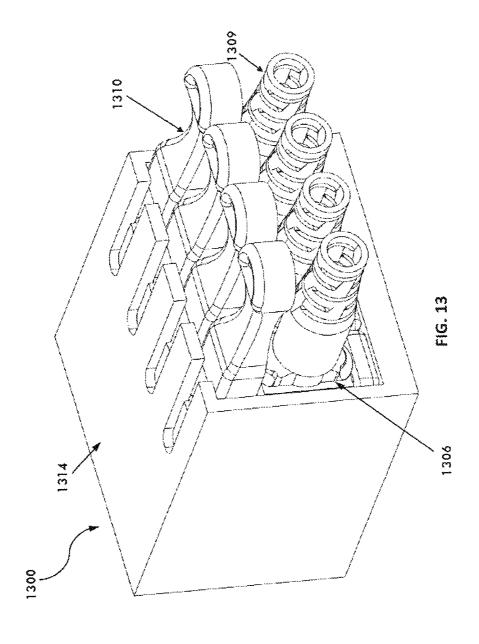
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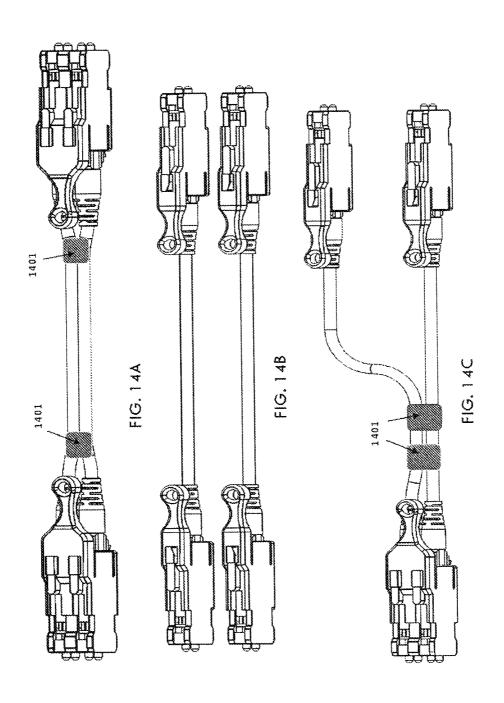
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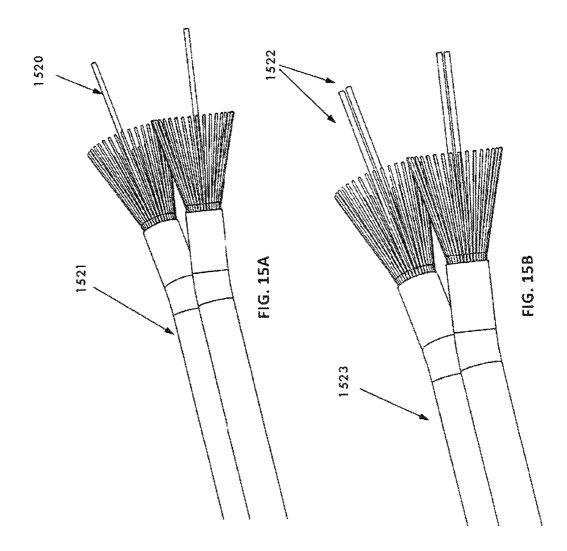
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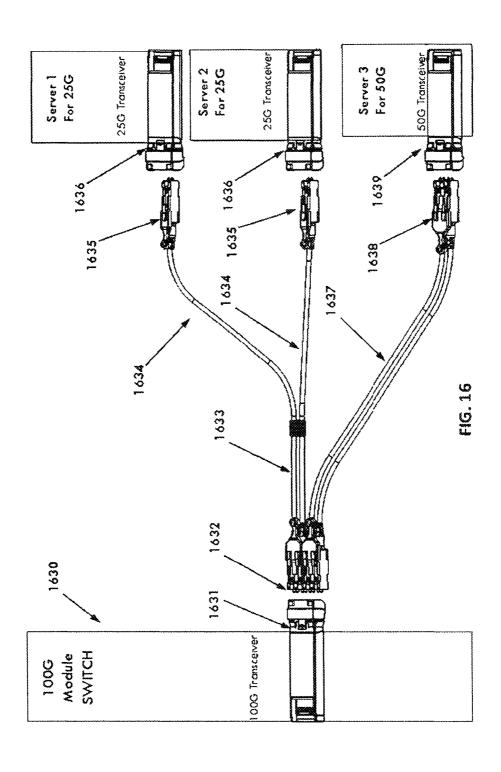
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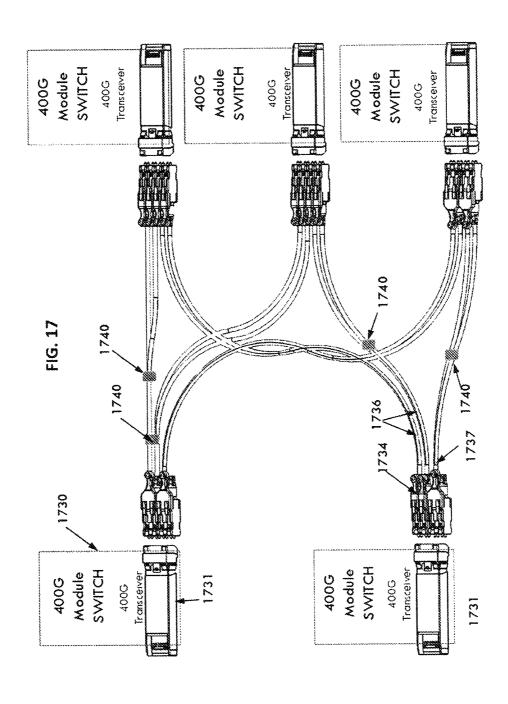
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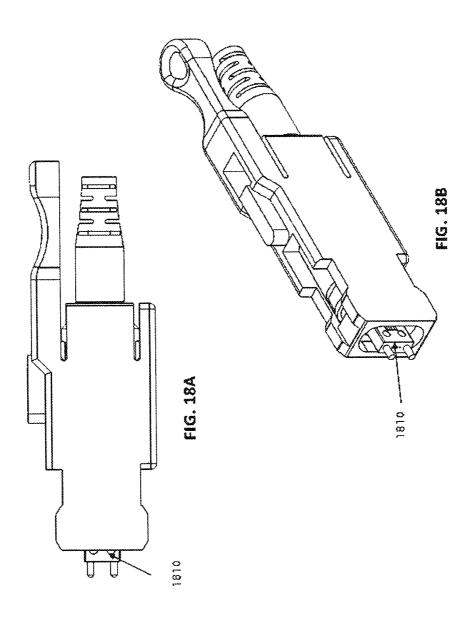
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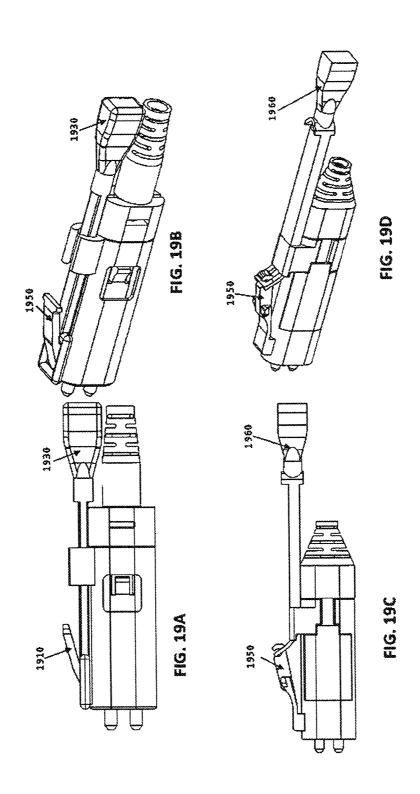
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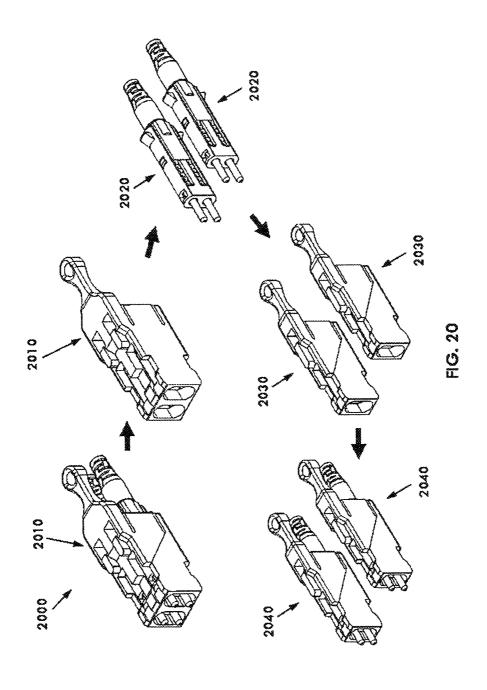
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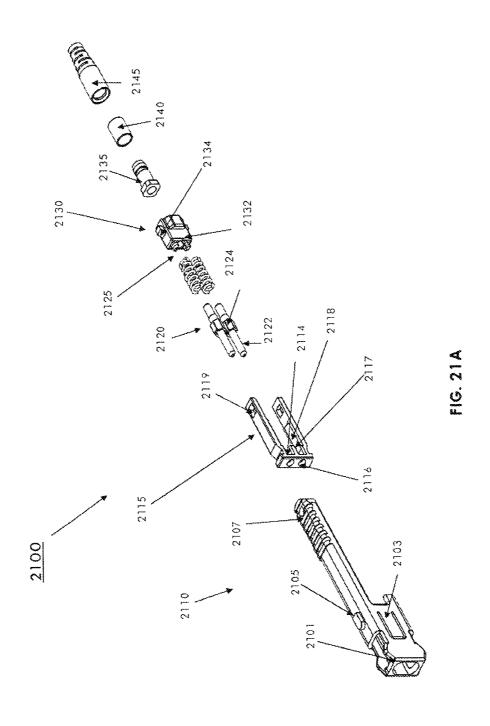
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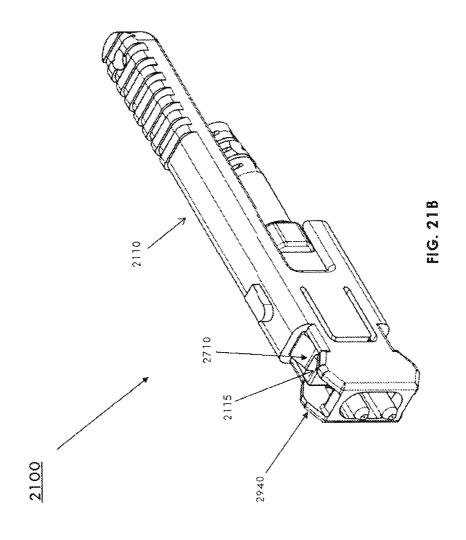
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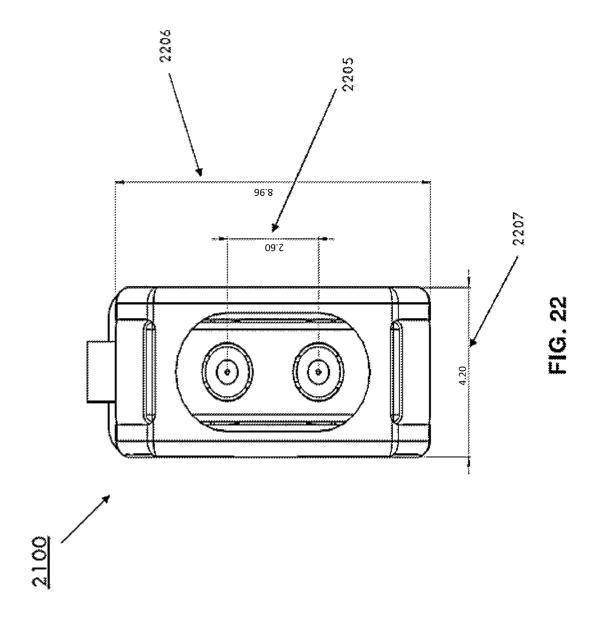
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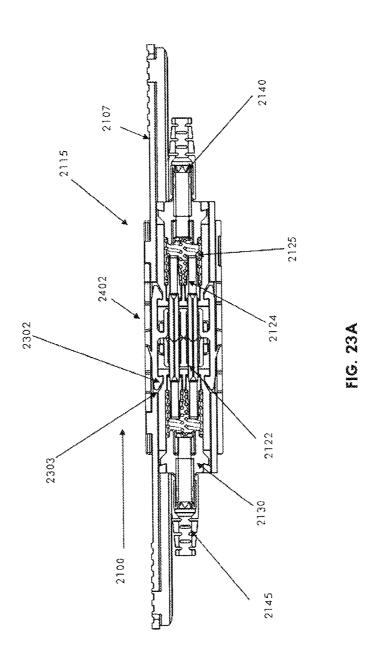
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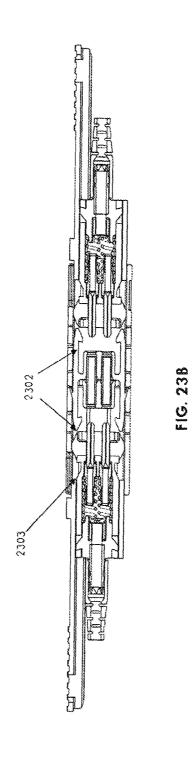
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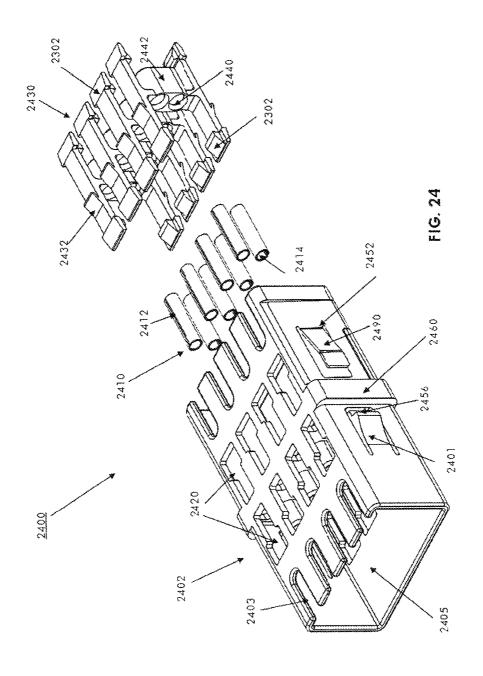
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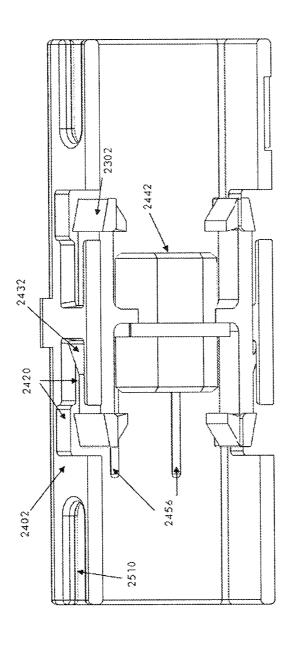
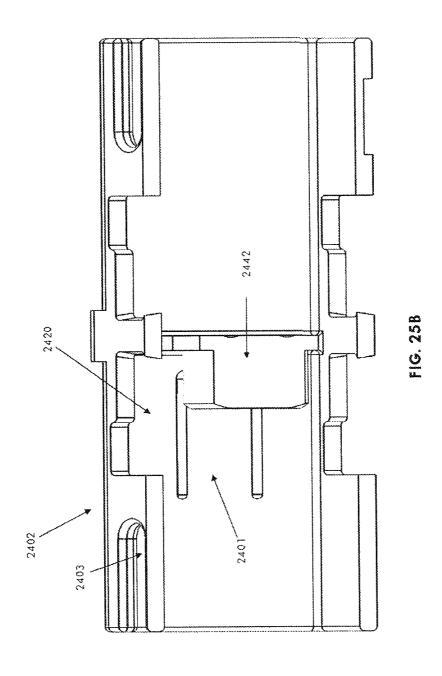


FIG. 25A

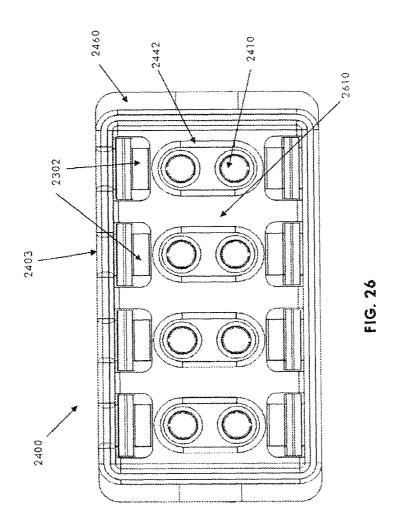
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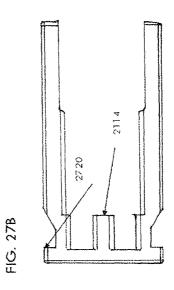
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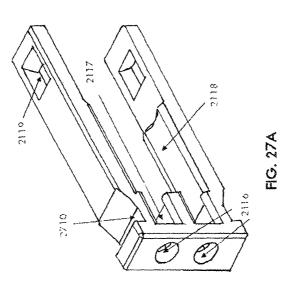
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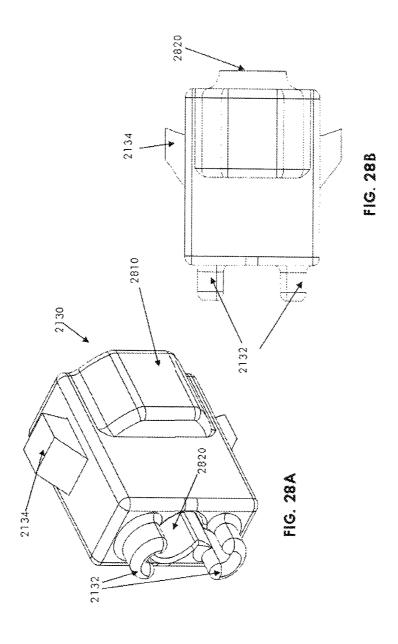
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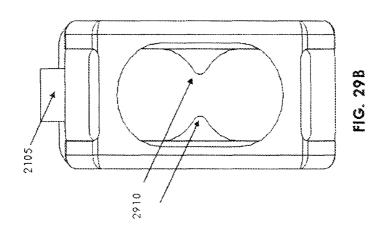
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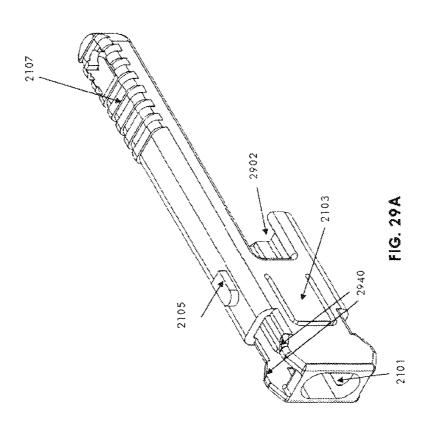
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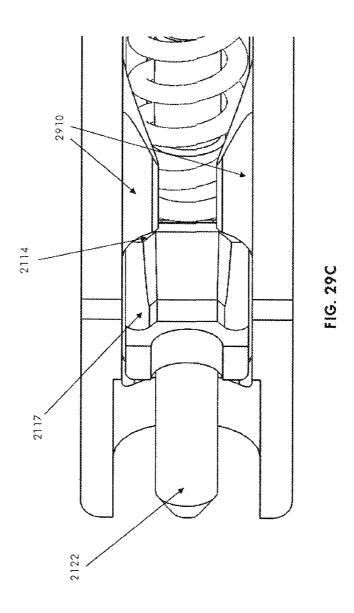
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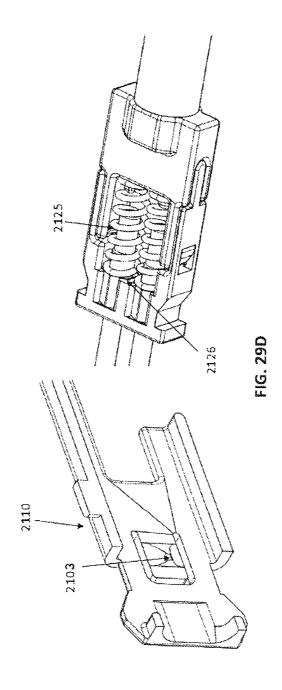
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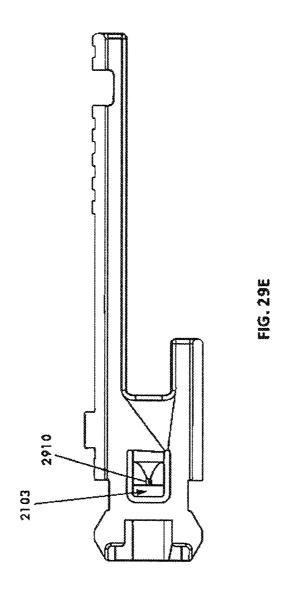
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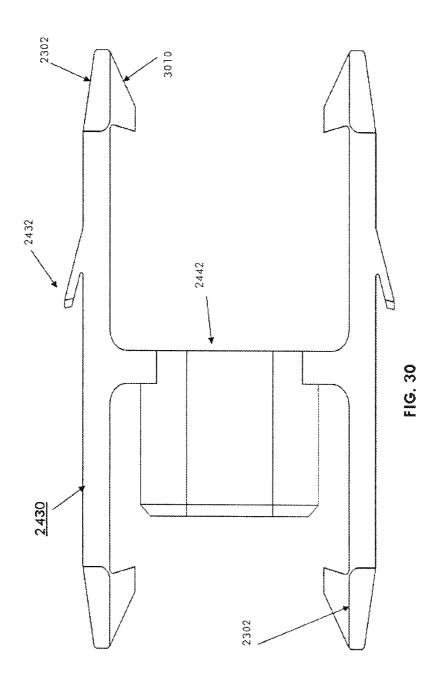
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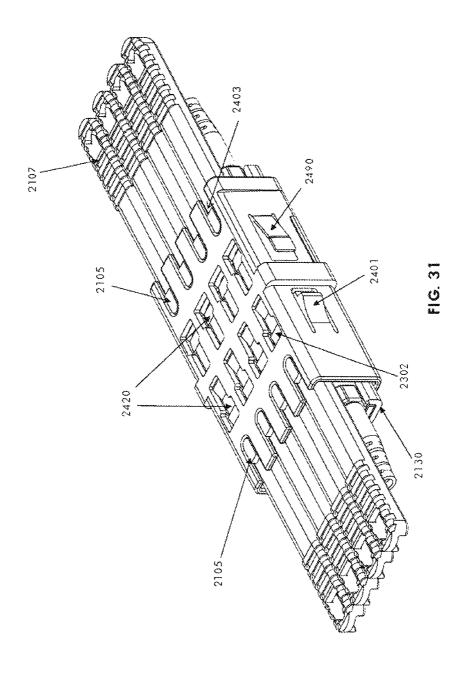
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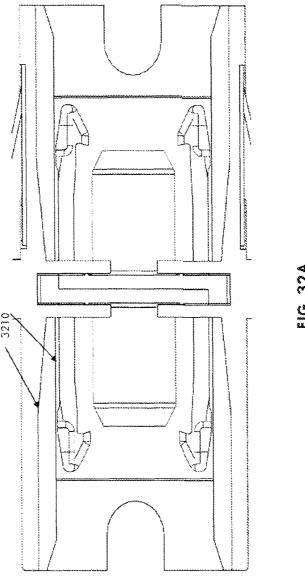
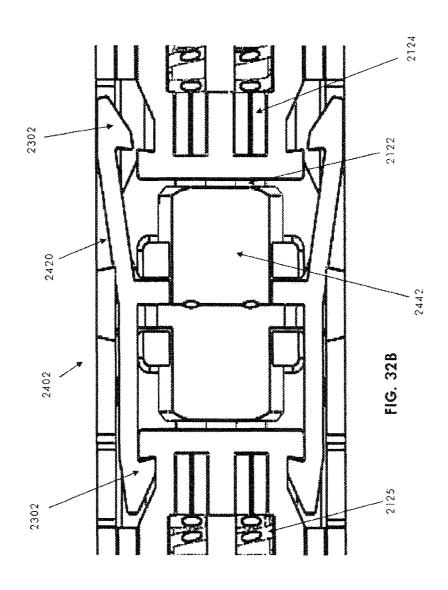


FIG. 32A

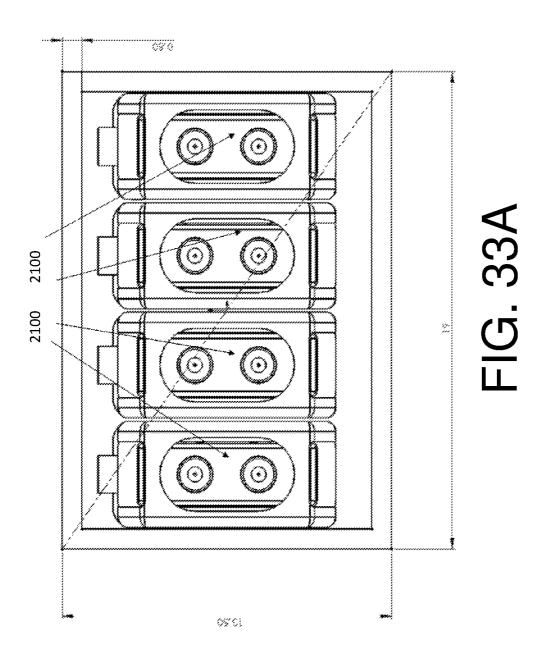
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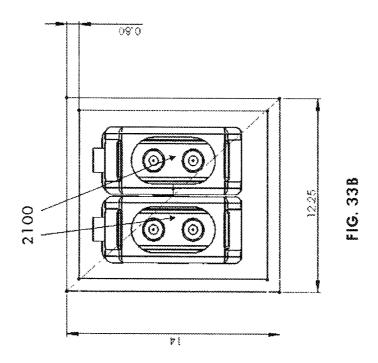
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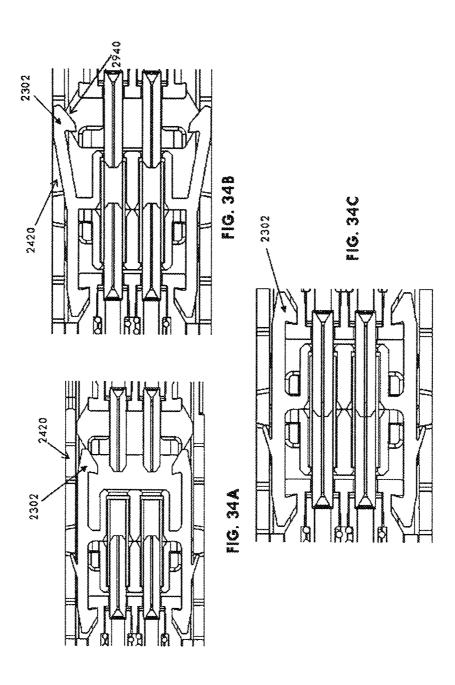
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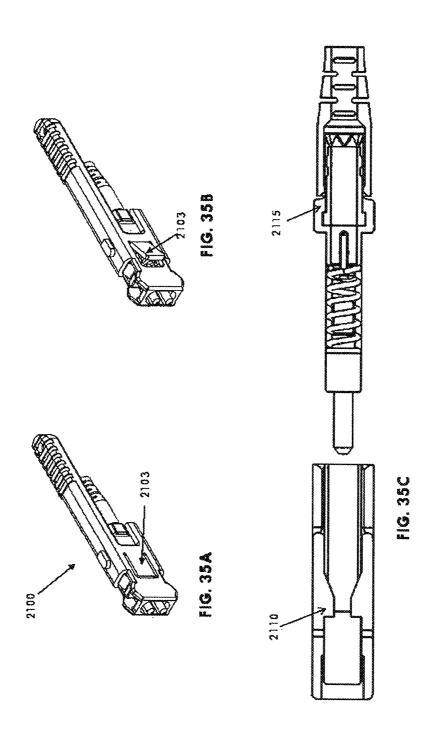
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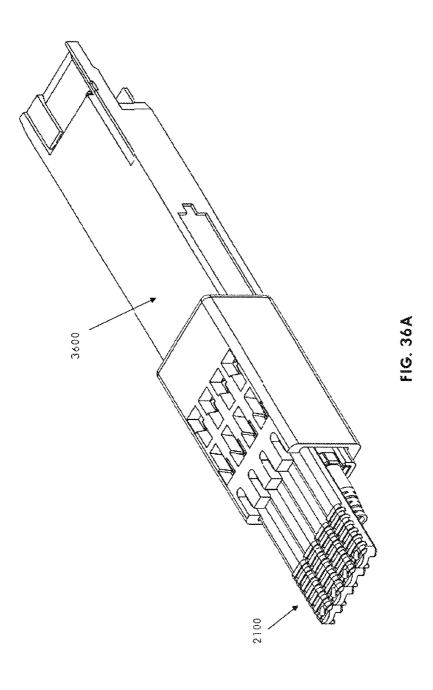
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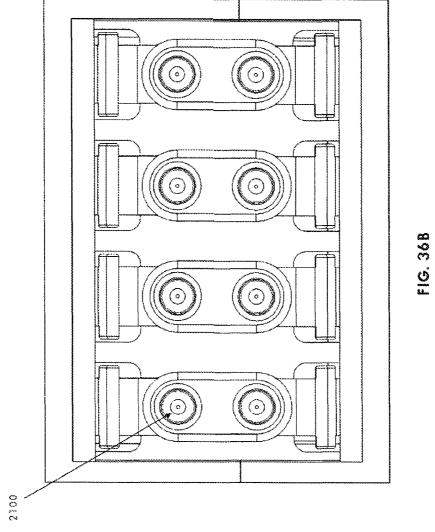
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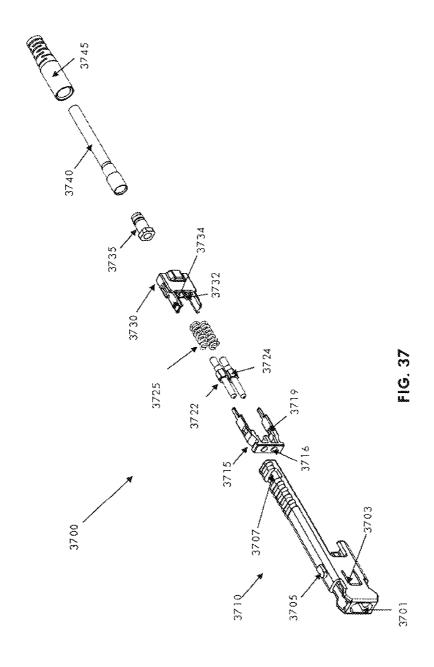
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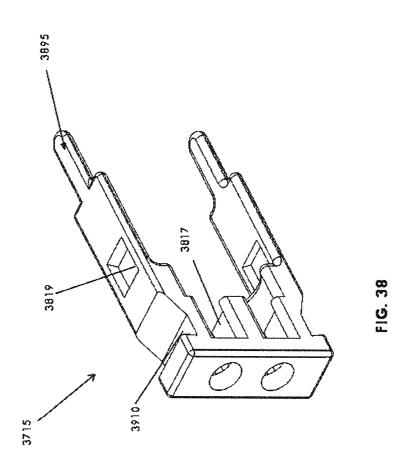
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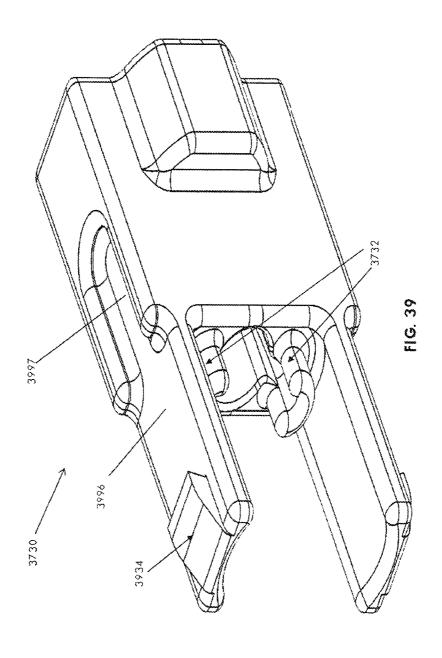
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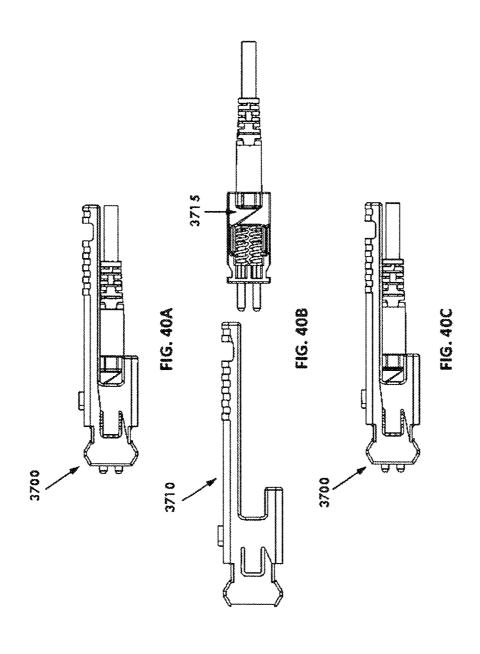
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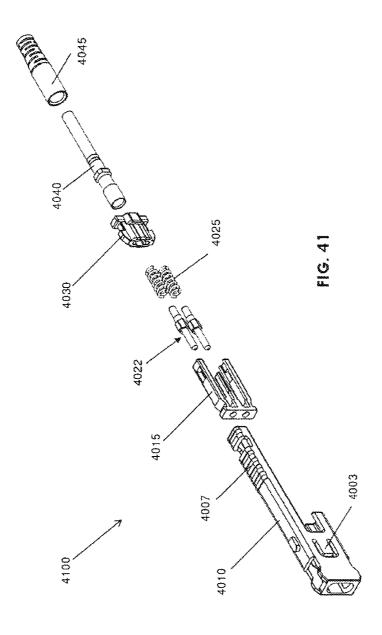
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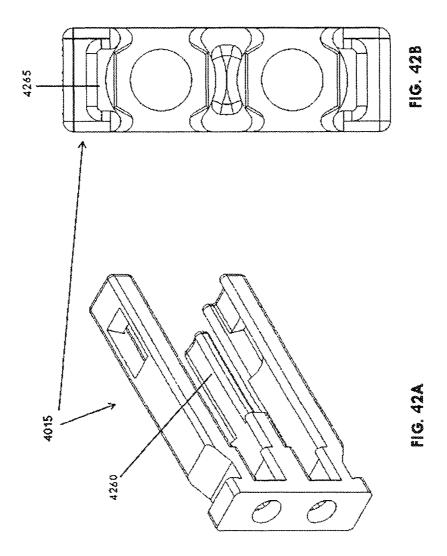
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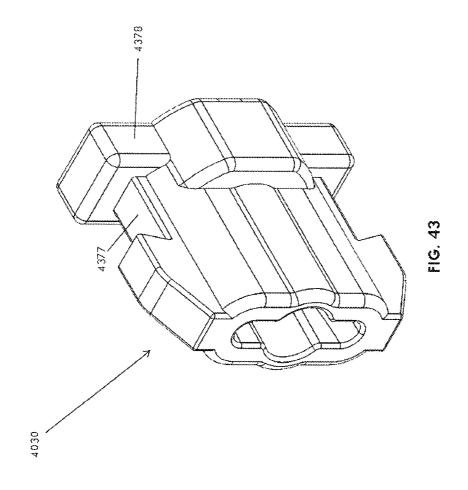
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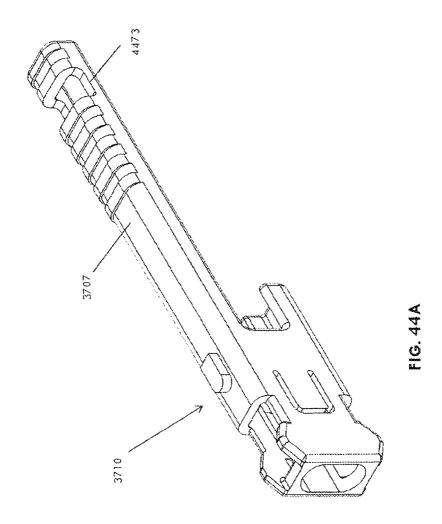
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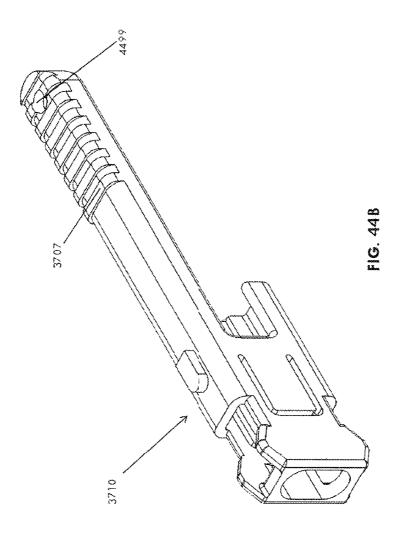
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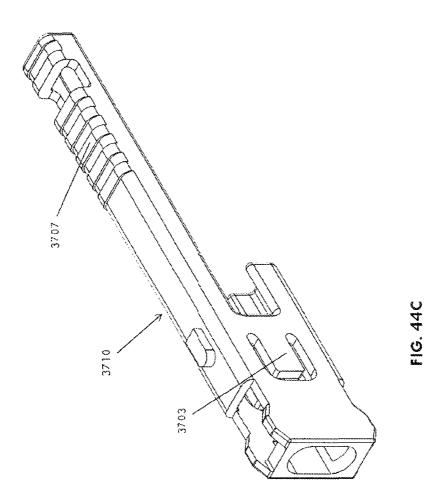
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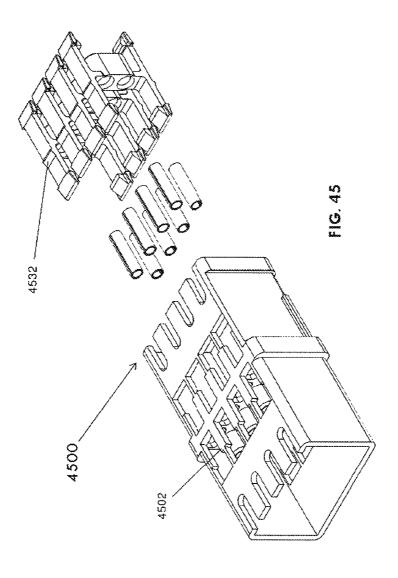
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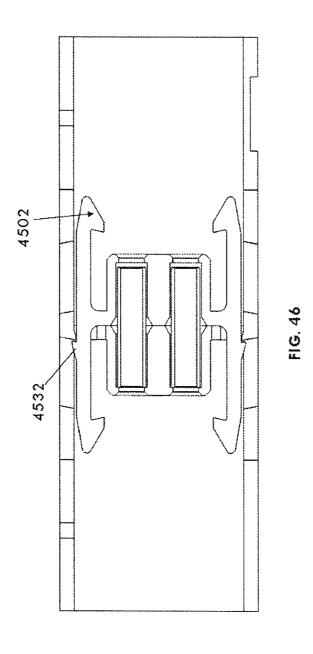
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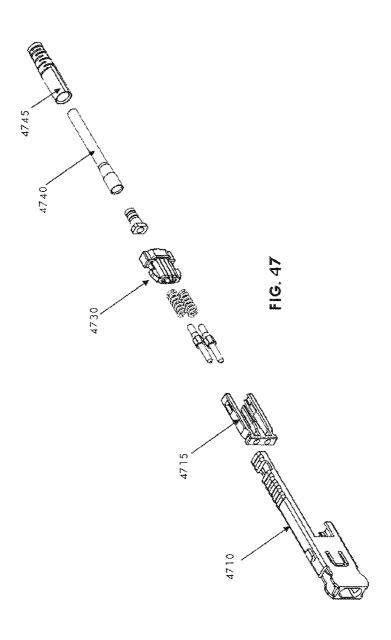
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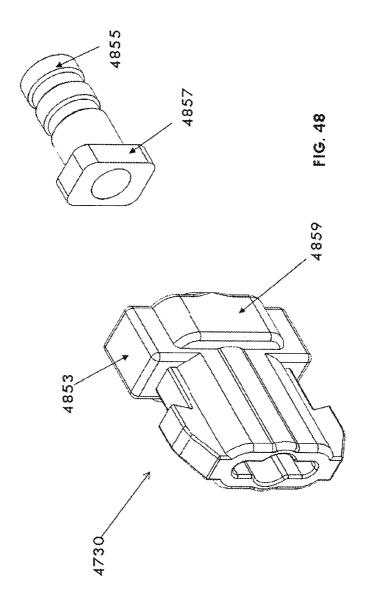
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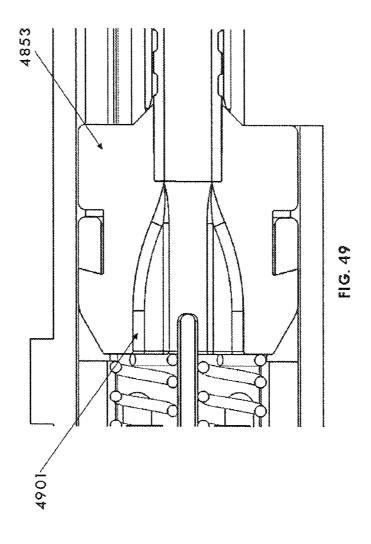
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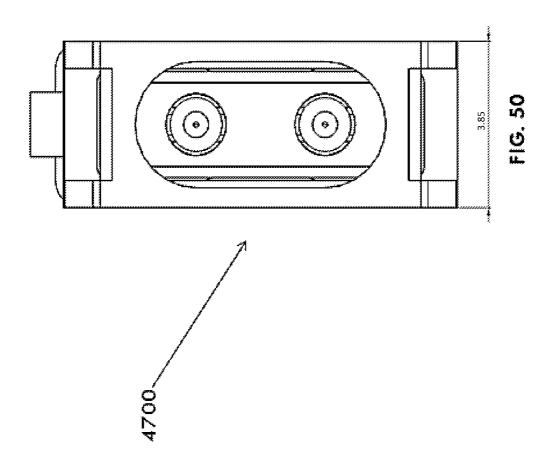
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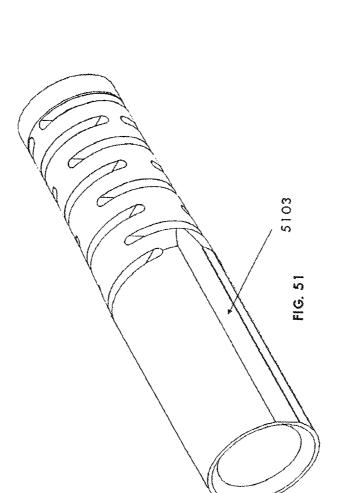


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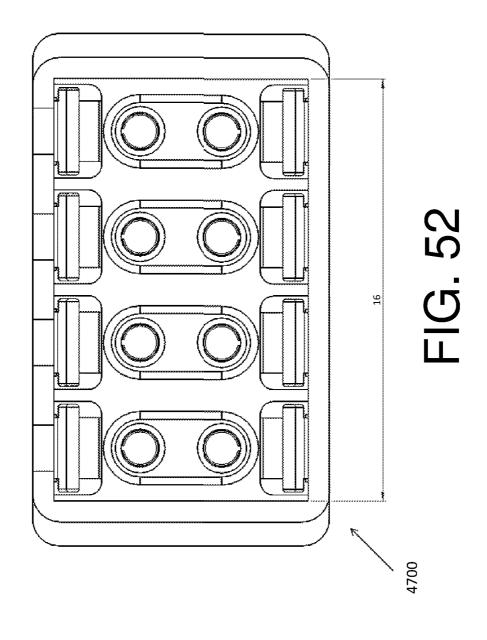


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ULTRA-SMALL FORM FACTOR OPTICAL CONNECTORS USED AS PART OF A RECONFIGURABLE OUTER HOUSING

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 RECONFIGUR-ABLE 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 15 CONNECTORS USED AS PART OF A RECONFIGUR-ABLE 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. 20 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 25 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 highdensity interconnect panels. High-density interconnect panels may be designed to consolidate the increasing volume of 45 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 50 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 55 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 65 footprint currently accommodates four LC-type ferrule optical connections. However, it may be desirable to accommo2

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

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

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

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- FIG. 2B is a perspective view of a prior art LC duplex connector with a remote release pull tab;
- FIG. 2C is a top view of a prior art LC connector used in the embodiments shown in FIGS. 2A and 2B;
- FIG. 2D is a side view of the prior art LC connector of ⁵ FIG. 2C:
- 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.
- $\overline{\text{FIG}}$. 6 is a perspective view of one embodiment of a $_{15}$ 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. 11A is a side view of a connector connected to an adapter;
- FIG. 11B is a side view of a connector being removed from an adapter;
- FIG. 12A is a side view of the outer housing of a connector being removed;
- FIG. 12B is a perspective view of a transparent outer 30 ters. 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 40 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. 21A is an exploded view of a micro optical connector according to an embodiment.
- FIG. 21B is a perspective view of the assembled micro 50 optical connector of FIG. 21A.
- FIG. 22 is a front view of the micro optical connector of FIG. 21B showing overall connector dimensions and ferrule pitch.
- FIG. 23A is a cross-sectional view of the micro optical 55 connector of FIG. 21B 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 60 optical connectors of FIG. **21**B.
- FIG. 25A is a cross-sectional view of the adapter of FIG. 24, assembled.
- FIG. 25B 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**

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- FIG. 27A is an isometric view of the front body of the micro optical connector of FIG. 21A.
- FIG. 27B is a right side view of the front body of FIG. 27A.
- FIG. **28**A is an isometric view of the back body of the micro optical connector of FIG. **21**A.
 - FIG. 28B is a side view of the back body of FIG. 28A.
- FIG. **29**A is an isometric view of the outer housing of the micro optical connector of FIG. **21**A.
 - FIG. 29B is a front view of the outer housing of FIG. 29A.
- 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. 29E is an inner view of the outer housing of FIG. 29A
- 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. 21B.
 - FIG. 32A is cross-sectional view of a prior art connector showing a latch gap.
 - FIG. 32B is a cross-sectional view of the micro optical connector of FIG. 21B latched (left) and unlatched (right) within the adapter of FIG. 24, assembled.
 - FIG. 33A depicts the micro optical connector of FIG. 21B in a QSFP footprint, depicting dimensions in millimeters.
 - FIG. 33B depicts the micro optical connectors of FIG. 21B in an SFP footprint, depicting dimensions in millimeters.
 - FIG. 34A-34C depicts adapter hooks interacting with the micro optical connectors of FIG. 21B before (FIG. 34A), during (FIG. 34B), and after (FIG. 34C) latching.
- FIG. 35A-FIG. 35C depicts the micro optical connector ofFIG. 21B side flap operation before (FIG. 35A), during (FIG. 35B), and after (FIG. 35C) latching.
 - FIG. 36A depicts plural micro optical connectors in a transceiver.
 - FIG. 36B is a front view of the transceiver of FIG. 36A.
 - 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. 40A, 40B, and 40C 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. 42A is an isometric view of the front body of the micro optical connector of FIG. 41.
 - FIG. 42B is a side view of the front body of FIG. 42A.
 - FIG. 43 is an isometric view of the back body of the micro optical connector of FIG. 41.
 - FIGS. 44A, 44B, and 44C are isometric views of the outer housings that may be used with any of the micro optical connectors of FIGS. 21A, 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.

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5 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 10 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 15 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 25 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 30 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 55 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. 1A shows a perspective view of a prior art standard 60.25 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 65 receptacles 102. FIG. 1B shows a perspective view of a prior art standard 6.25 mm pitch LC adapter 106. The adapter 106

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is also configured to receive a duplex connector, and provides two receptacles 108, each for receiving a respective LC connector. FIG. 1C is a top view of the adapter 106 of FIG. 1B. 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. 1D, which shows a front view of the adapter 106.

FIG. 2A 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. 2B 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. 2C and 2D 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 10 (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 15 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 25 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. 30 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 35 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 40 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 45 610 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 50 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 55 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 60 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 65 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.

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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 twoferrule 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, 10 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 15 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 20 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 30 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 35 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 45 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. 11A, in one embodiment 1100A, the outer housing 50 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 1100A. Accordingly, in some embodiments, the receptacle 1114 may have a receptacle hook 1115, which is flexible and 55 can secure the connector 1100A 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 60 over the front of the outer housing thereby securing the connector 1100A into the receptacle.

Additionally or alternatively, in some embodiments, such as that shown in FIG. 11B, a connector 1100B may be removed from a receptacle 1114 by pulling the connector 65 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. 11B, as the connector 1100B is removed from the receptacle 1114, the flexible

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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. 12A and 12B, 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. 12A. 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. 14A through 14C depict cable configurations that 40 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. 21B, 37, and 41, to be discussed in detail below. FIG. 14A 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. 14B 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. 14C shows an embodiment in which a duplex connector like that of FIGS. 6 and 14A is connected to two separate individual connectors. Through the variable housing configurations depicted above in FIG. 10, the cable of FIG. 14A can be reconfigured as the cables of either 14B or FIG. 14C.

In addition to binding existing fiber cables, some embodiments herein may utilize a new four fiber zip cable. Referring now to FIG. 15A, 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. 18A-18B and FIGS. 19A-19D. 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 15 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) 20 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. 25
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 30 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 35 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 45 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, 50 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, 55 and that various other connectors may be used in any embodiment (e.g., an MT connector, such as that shown in FIGS. 18A-18B, and the optical connectors of FIGS. 21, 37,

FIGS. **18**A-**18**B depict an optical connector including an 60 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

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may be accommodated in a quad small form-factor pluggable (QSFP) transceiver footprint.

FIGS. 19A-19D 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. 19A-19B, 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. 19C-19D. 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. 14A to a connector as shown in FIG. 14C. 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. 21A depicts an embodiment of an optical connector 2100, shown in exploded view while 21B 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

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 eightferrule outer housing.

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Turning to FIGS. 29A and 29B, isometric and front views of the outer housing 2110 are shown. As seen in the front view of FIG. 29B and the cross-sectional view of FIG. 29C. 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 $_{15}$ locking surface 2114, best seen in FIG. 27C, engages the connector orientation protrusion 2910, seen in an inside view of the outer housing in FIG. 29D, labelled as "Flap A", flexing the connector flap 2103 outwardly from the outer housing body 2110, depicted in the inset of FIG. 29C. The 20 flap protrusion mating location is indicated as "mating place B" in FIG. 29D. Once the locking surface 2114 passes beyond the orientation protrusion, the connector flap returns to its original position (FIG. 29A), and the protrusion 2910 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. 35A-35C 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. 35B. 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 40 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. 35C, 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. 28A and 28B, 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 50 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 55 flange alignment slots 2117 (see FIGS. 27A and 27B) 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. 28A, 60 28B) of back body 2130 by spring tension. As seen in the assembled cross-sectional views of FIGS. 23A and 23B, 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. 27A 65 and 27B, the front body includes a receptacle hook recess 2710 with a receptacle hook retainer surface 2720 the

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receiver a receptacle hook when mating with an adapter or with a transceiver receptacle, as shown in further detail

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. 21B, 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. 27A and 27B (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 engages locking surface 2114 and any withdrawal of the 25 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. 36B (holding optical connectors 2100); as seen in FIG. 36B, 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. 21B. 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. 21A. 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 5 housing hooks 2432 are received in housing adapter hook openings.

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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 10 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 15 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. 21B. As seen in FIG. 30, receptacle hooks 2302 include an inner surface 3110. The receptacle housing further includes 20 connector alignment slots that mate with connector alignment key of FIG. 21A. 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 recep- 25 tacle 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 30 includes receptacle hook openings 2420, seen in FIGS. 25A and 25B. 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 35 surfaces 3110, with the receptacle hook openings 2420 is best seen in FIGS. 32B and 34A-C. Prior to latching (FIG. 34A), 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 40 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 45 2302. This additional required clearance is depicted in the prior art connector/adapter of FIG. 32A. As seen in FIG. 32A, 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/ 50 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 55 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. 60 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 65 of mating connectors 2100 latched therein. Note that in the latched position, receptacle hooks 2302 do not extend into

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receptacle hook openings 2420. This is further visible in the cross-sectional view of an assembled adapter 2400 of FIG. 25A. Connector alignment keys 2105 are positioned within connector alignment slots 2403. As seen in the cross-sectional view of FIG. 23A, 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. 33B. 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. 33A. 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. 21A 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

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. 21A, 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. 40A-40C, the assembled front body 3715 may be removed from the outer housing 3710, rotated 180° as indicated by the arrow (FIG. 40B), and re-inserted into the outer housing (FIG. 40C). 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. 35A-35C, 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. 21A 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.

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As seen in FIG. 42A, 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. 20 42B. 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. 42B. 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. 44A-44C, may be used with any of the optical connectors depicted in FIGS. 21, 37, and 41 or earlier embodiments. In FIG. 44A, 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. 44B 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. 44C 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 45 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 **50 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 55 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 60 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 65 from 1.5 mm to improve the sideload strength of the overall connector. The crimp ring positioning 4855 is inversed from

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earlier embodiments to improve holding of aramid fiber from an optical fiber cable, improving cable retention of the back nost

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

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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 5 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 10 "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, 15 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 20 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 25 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 recita- 30 tion, 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 35 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 recita- 40 tions," 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 45 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 50 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 55 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, 60 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 20

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.

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- 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 ⁵ 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 $_{15}$ 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, 30 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 40 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 45 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 trans- 50 ceiver 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 55 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 60 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 65 polarity key is configured to be spaced apart along the fiber alignment axis above the MT ferrule;

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- 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
 35 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.

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27. The optical fiber connector as set forth in claim 17, further comprising a ferrule spring yieldably biasing the MT 5 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 10 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 15 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 20 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 25 rear end of the ferrule spring.

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EXHIBIT D

(12) United States Patent

Takano et al.

(54) NARROW WIDTH ADAPTERS AND CONNECTORS WITH PULL TAB RELEASE

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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 dis-

claimer.

(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
H01R 13/633

(2006.01) (2006.01)

(52) U.S. Cl.

 (10) Patent No.: US 11,415,760 B2

(45) **Date of Patent:** *Aug. 16, 2022

(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.

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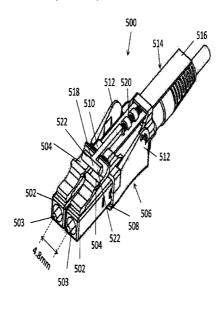
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Primary Examiner — Robert Tavlykaev

(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



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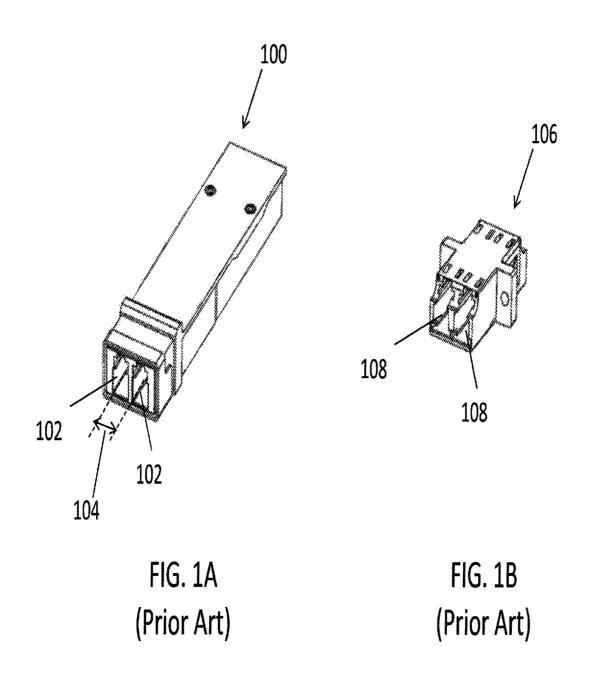
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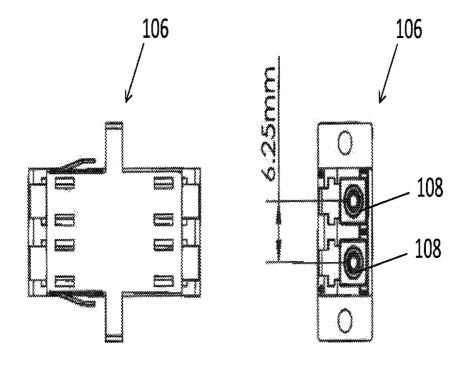
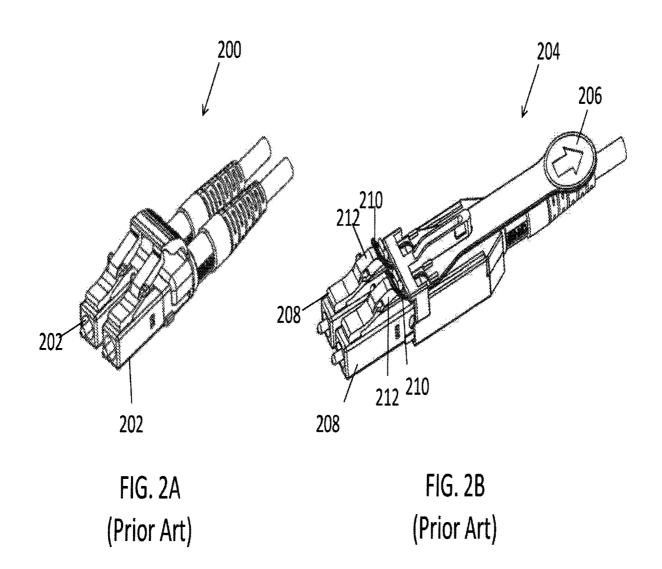


FIG. 1C (Prior Art)

FIG. 1D (Prior Art)

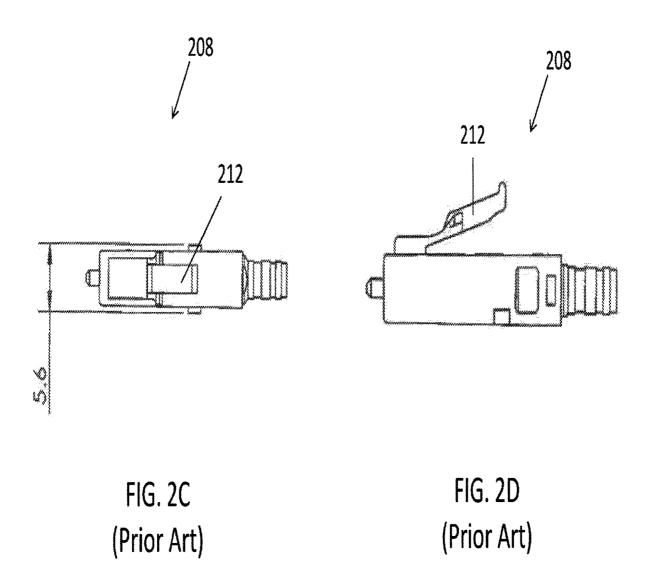
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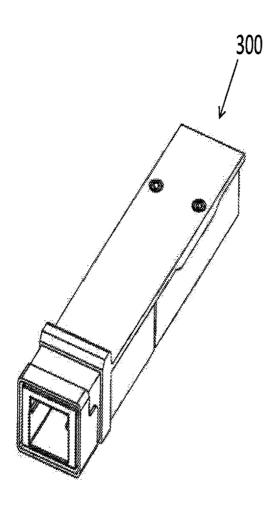


FIG. 3

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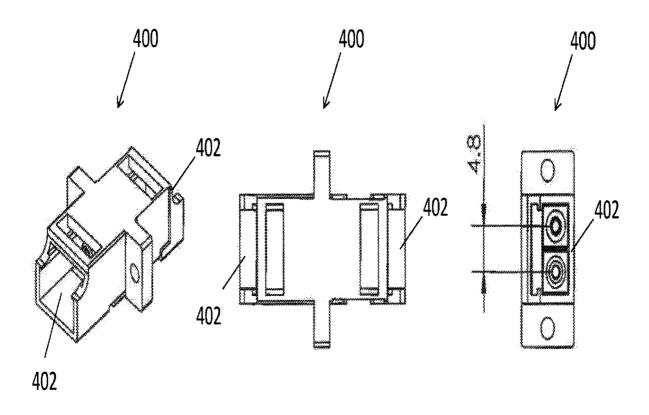


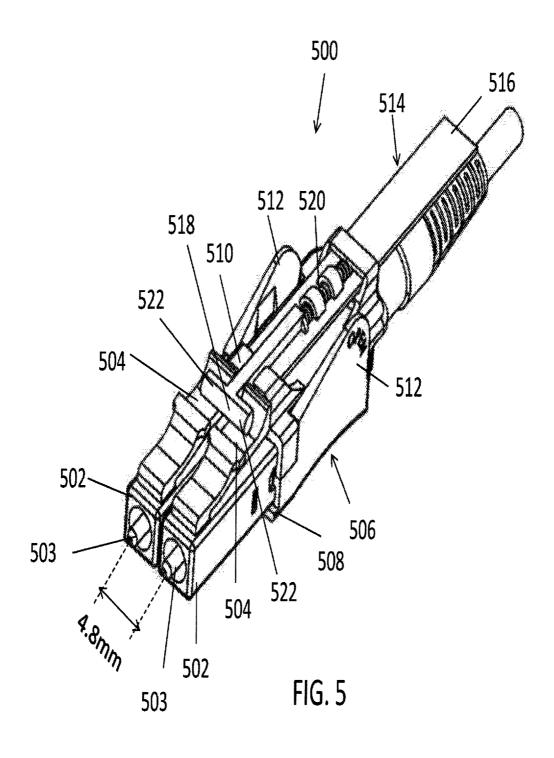
FIG. 4A

FIG. 4B

FIG. 4C

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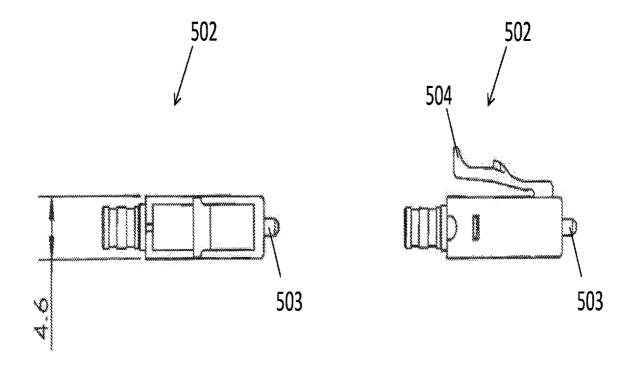
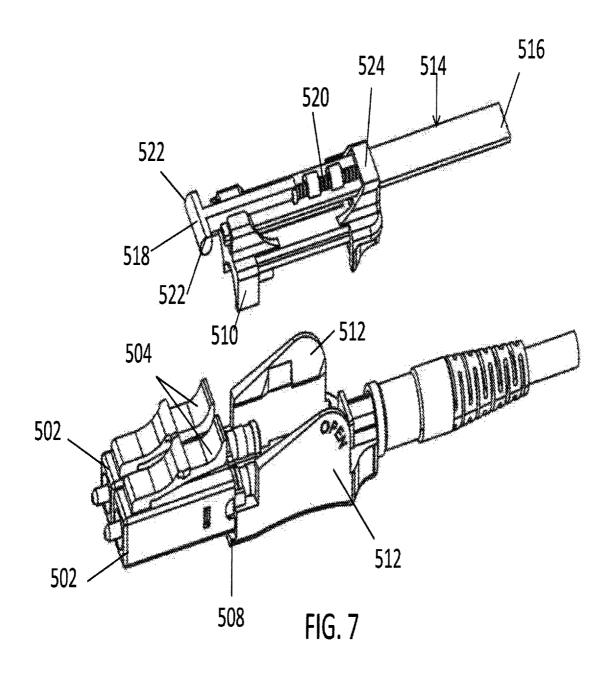


FIG. 6A

FIG. 6B

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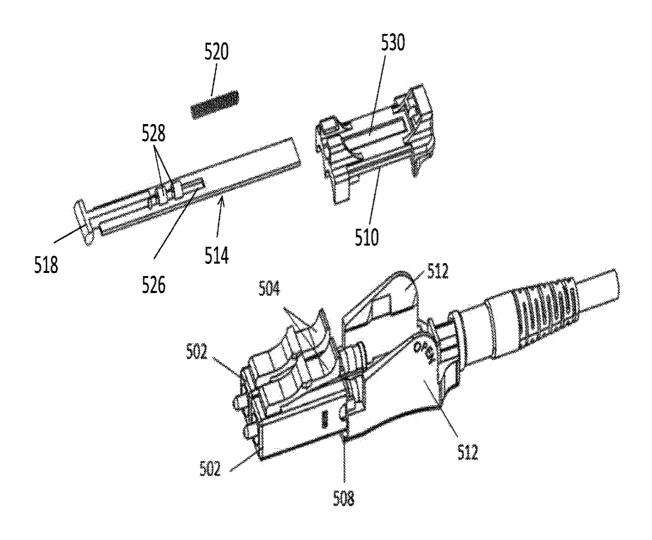


FIG. 8

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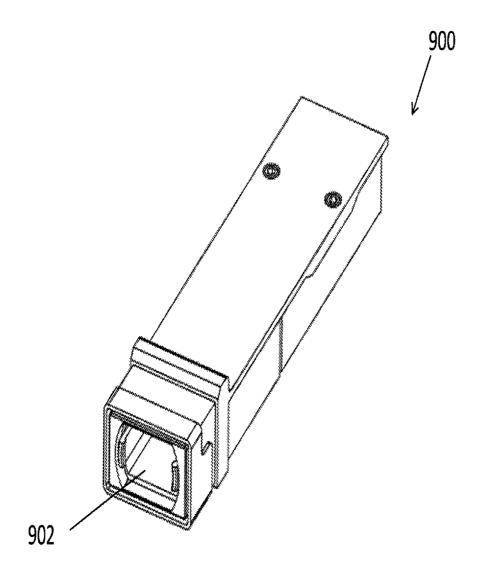


FIG. 9 (Prior Art)

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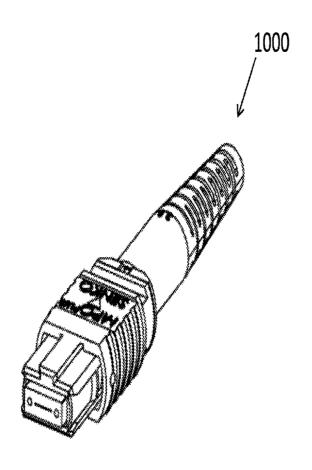


FIG. 10A (Prior Art)

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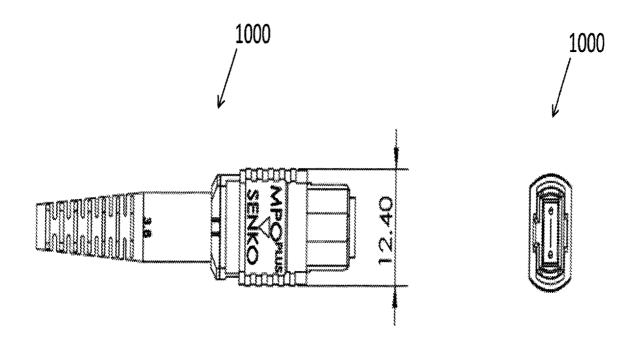


FIG. 10B (Prior Art) FIG. 10C (Prior Art)

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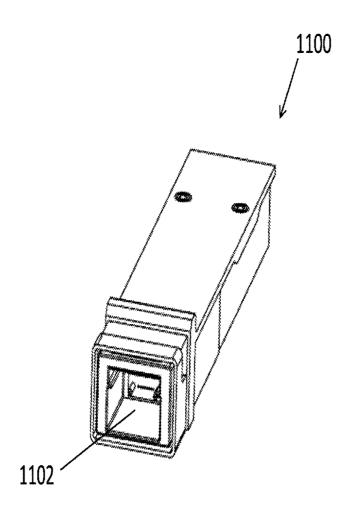


FIG. 11

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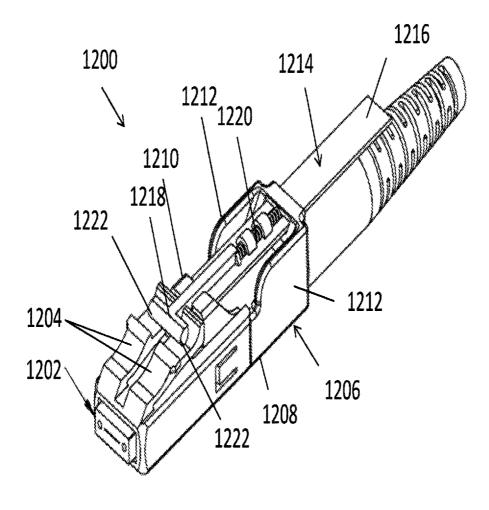


FIG. 12A

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FIG. 12C

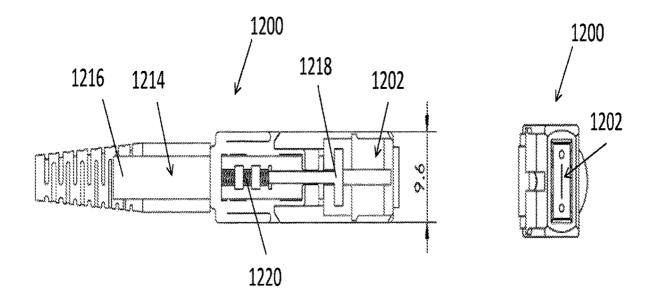
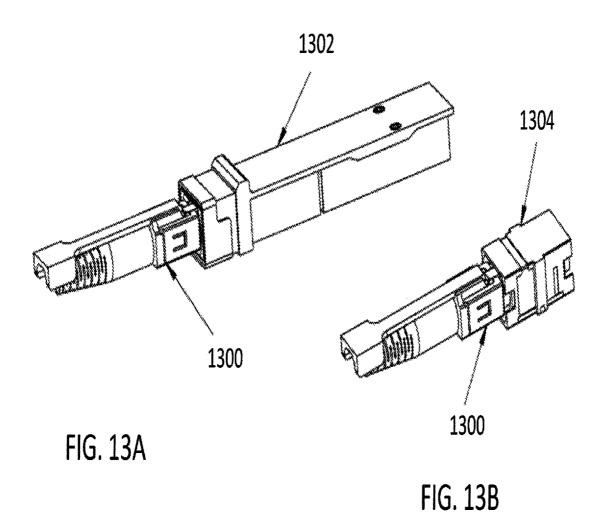


FIG. 12B

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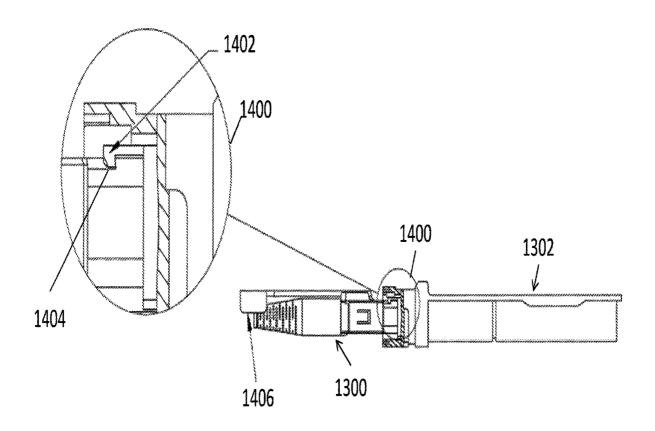


FIG. 14

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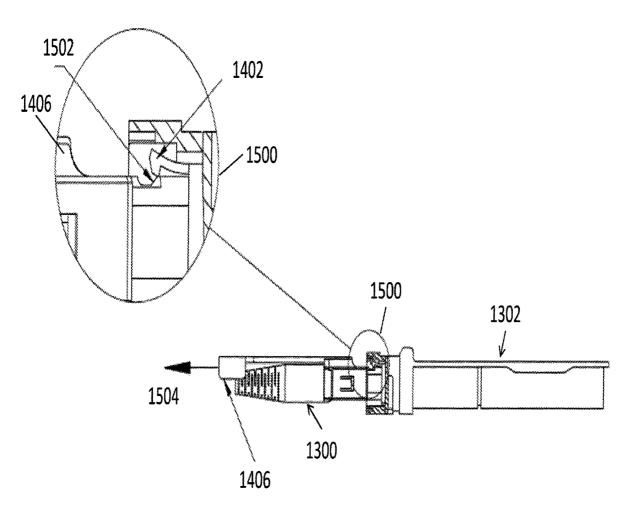


FIG. 15

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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. 15 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 25 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 30 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 45 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 50 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 55 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 65 screwdriver, to reach into the dense group of connectors and activate the release mechanism, the adjacent cables and

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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 3

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 5 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 10 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 20 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 25 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 ³⁰ 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 40 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 45 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. 1A is a perspective view of a prior art standard 6.25 mm pitch LC connector SFP;

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

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

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

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

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

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

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. 4B is a top view of the narrow pitch LC adapter of FIG. 4A;

FIG. 4C is a front view of the narrow pitch LC adapter of FIG. 4A, 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. 6B is a side view of the LC connector of FIG. 6A 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. 10B is a top view of the prior art MPO connector of FIG. 10A, having a width of 12.4 mm;

FIG. 10C is a front view of the prior art MPO connector of FIG. 10A;

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. 12A 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. 12B is a top view of the narrow width multi-fiber connector of FIG. 12A, having a width of 9.6 mm according to aspects of the present disclosure;

FIG. 12C is a front view of the narrow width multi-fiber connector of FIG. 12A according to aspects of the present disclosure:

FIG. **13**A is a perspective view of a narrow width multifiber 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-65 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. 13A 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 5 connector of FIG. 13A, 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 15 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 20 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 25 "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 30 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 35 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 40 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 45 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 50 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 multifiber 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. 1A shows a perspective view of a prior art standard 6.25 mm pitch LC connector SFP 100. The SFP 100 is 65 configured to receive a duplex connector, and provides two receptacles 102, each for receiving a respective LC connec-

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tor. The pitch 104 is defined as the axis-to-axis distance between the central longitudinal axes of each of the two receptacles 102. FIG. 1B 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. 1C is a top view of the adapter 106 of FIG. 1B. 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. 1D, which shows a front view of the adapter 106.

FIG. 2A 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. 2B 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. 2C and 2D 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. 4A to 4C 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. 4B shows a top view of the adapter 400. FIG. 4C 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. 2B, 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 20 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 25 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 30 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 35 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 40 514 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 45 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 50 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 55 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. 6A and 6B show top and side views, respectively, of the LC connector 502 of the narrow pitch connector 500.

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FIG. 6A further shows that the LC connector **502** has a width of 4.6 mm. FIG. 6B 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. 10A to 10C.

FIG. 10A shows a perspective view of a conventional MPO connector 1000. As shown in FIG. 10B, the conventional MPO connector 1000 has a width of 12.4 mm. FIG. 10C 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. 12A 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. 12B. 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. 10B. 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

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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 5 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 15 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 20 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 25 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 35 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 40 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 45 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. 13A 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. 13B shows the narrow pitch connector 1300 inserted into a 55 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. 13A coupled to the narrow width SFP 1302. Details of the coupling are shown within the circle 1400. 60 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 65 to a position that will allow the SFP latch 1402 to engage with the connector recess 1404. When the pull tab 1406 is in

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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. 13A 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. 13A.

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

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"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, 5 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 10 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 15 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 recita- 20 tion, 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 25 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 recita- 30 tions," 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 35 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 40 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 45 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, 50 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

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 65 describing and enabling the same range being broken down into at least equal halves, thirds, quarters, fifths, tenths, et

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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.

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- 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**, 5 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, $_{25}$ 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.

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- 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

(12) United States Patent

Wong et al.

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(45) **Date of Patent:**

Jan. 29, 2019

(54) OPTICAL CONNECTORS WITH REVERSIBLE POLARITY

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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.

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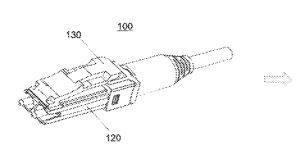
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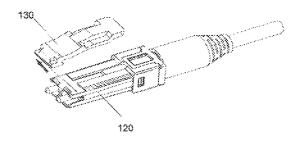
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(57) ABSTRACT

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





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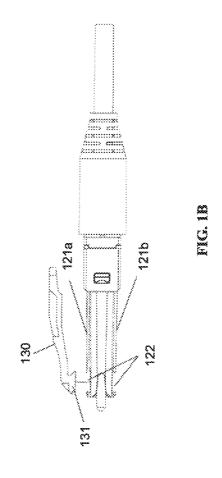
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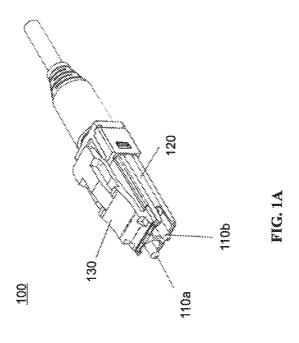
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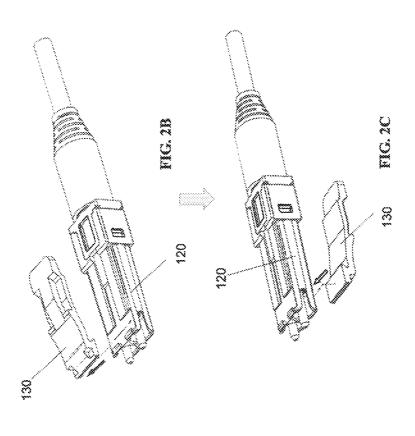
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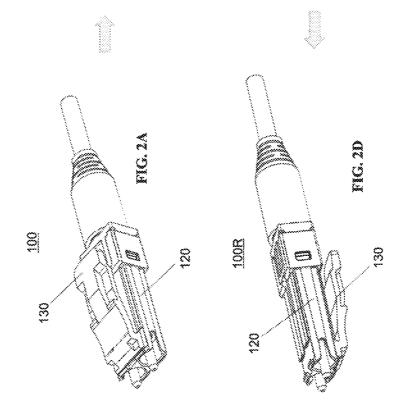




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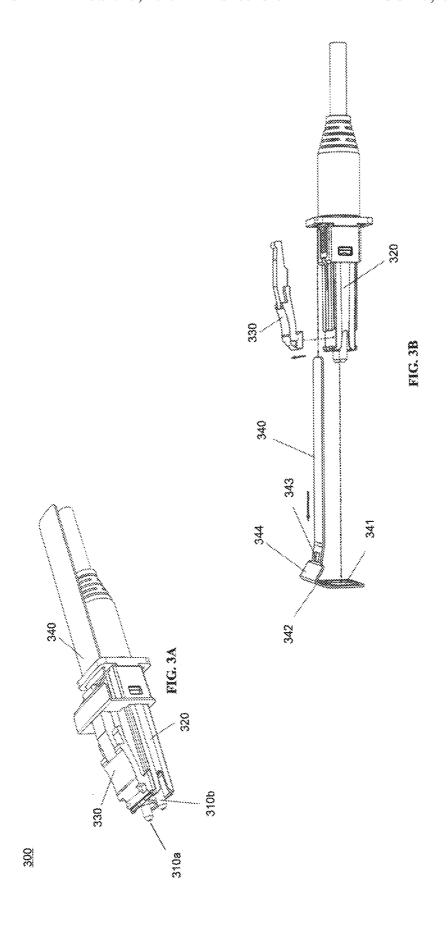
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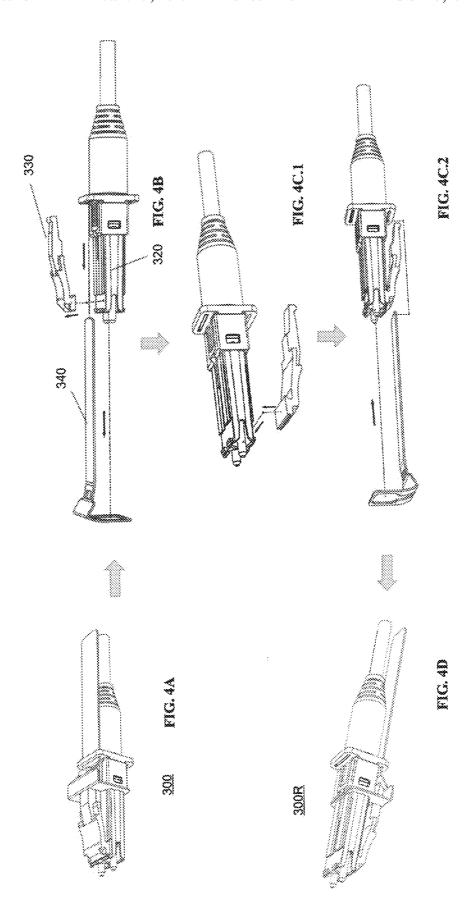


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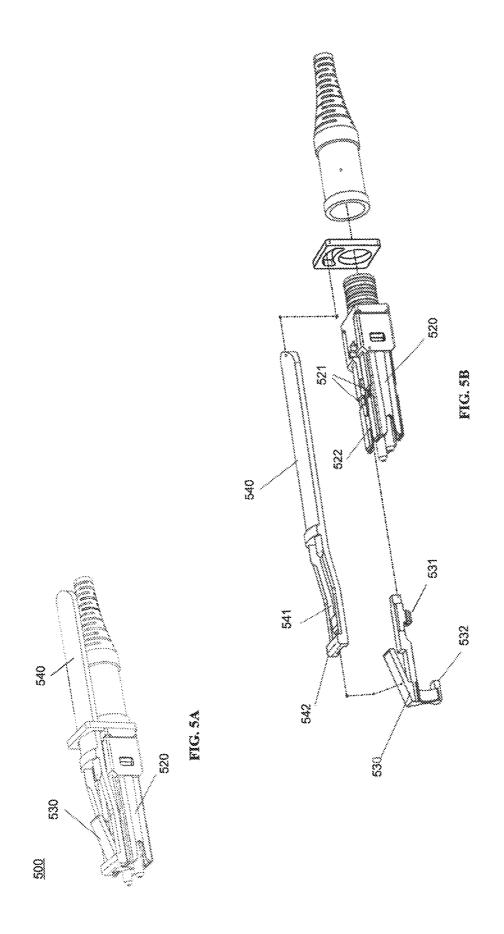
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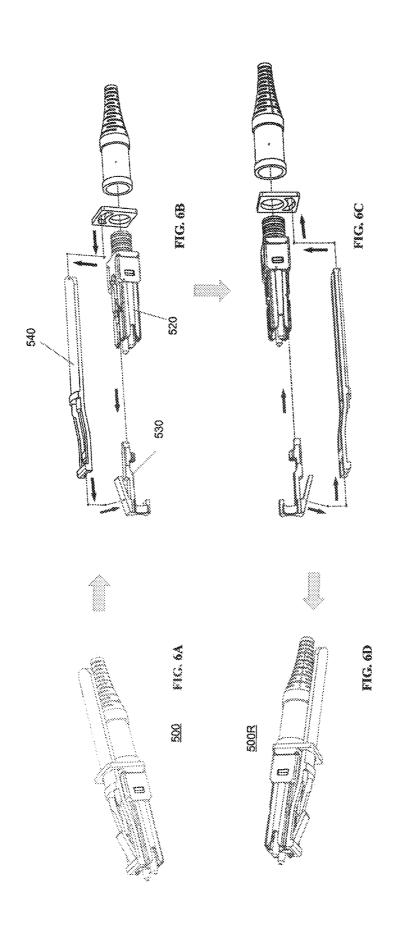
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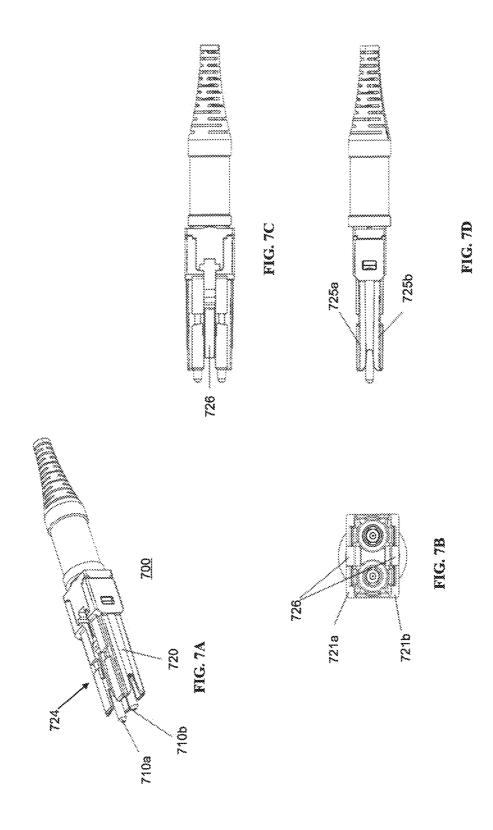
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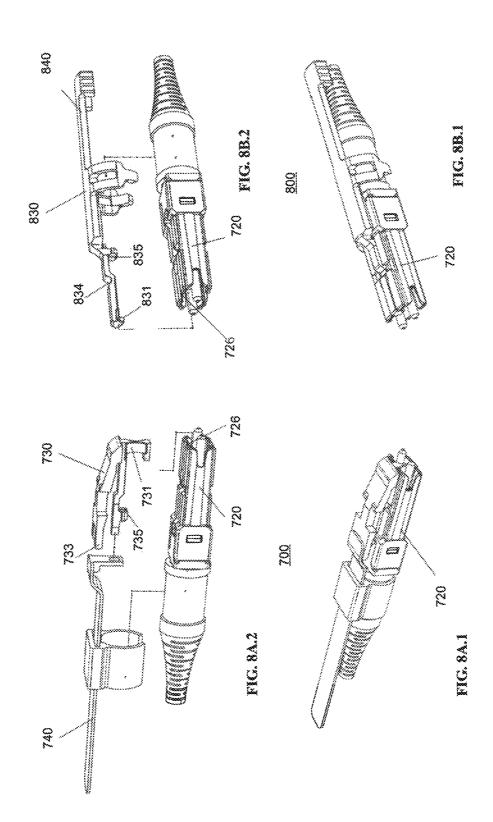
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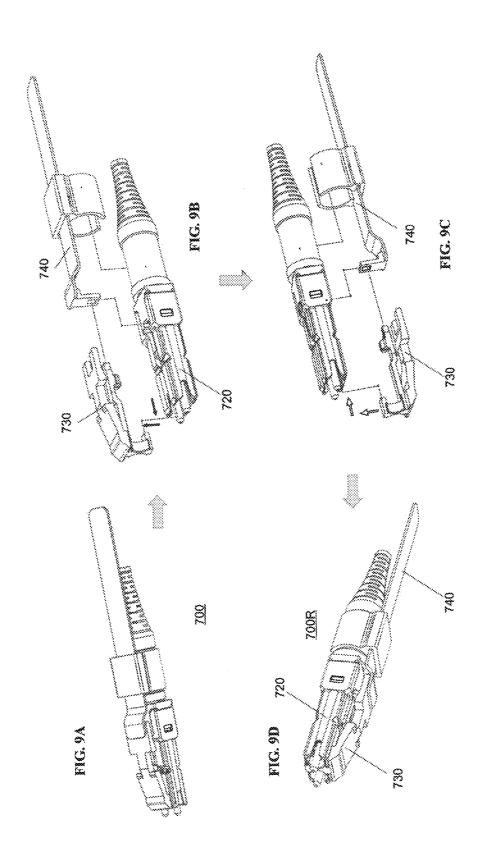
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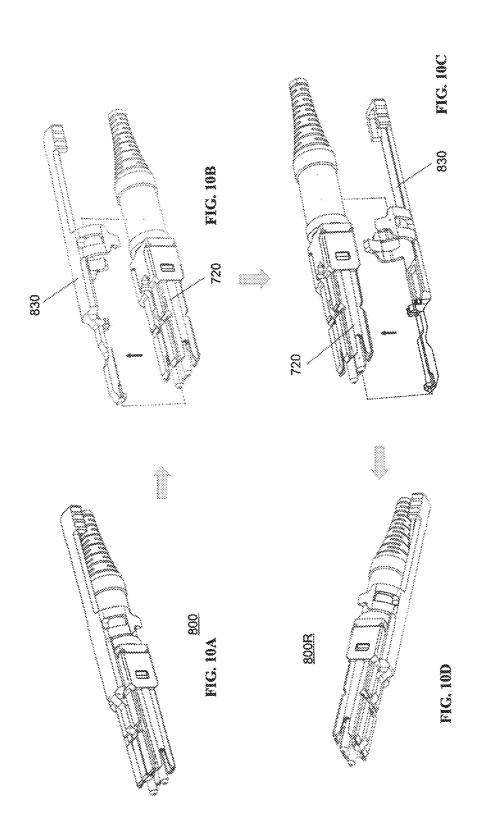
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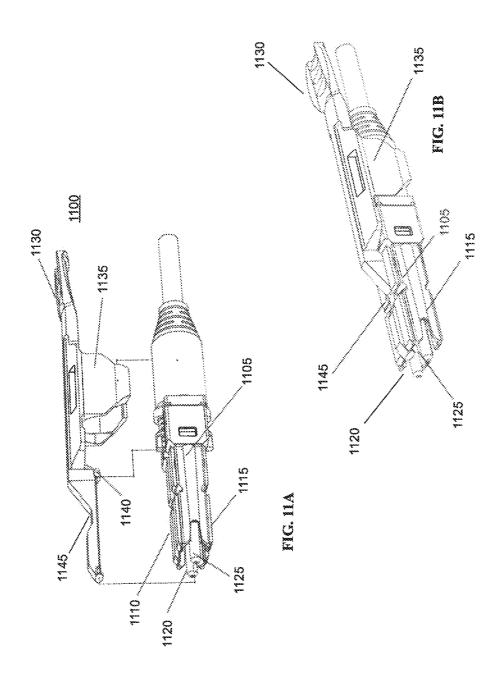
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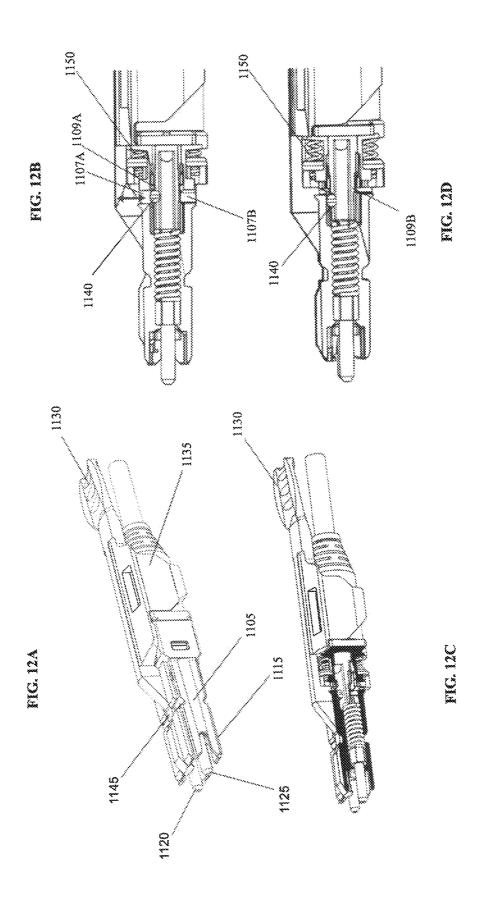
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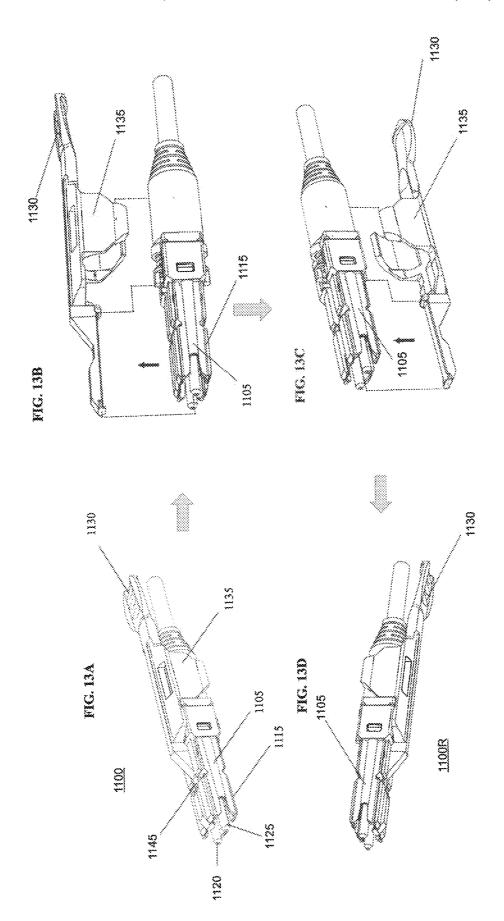


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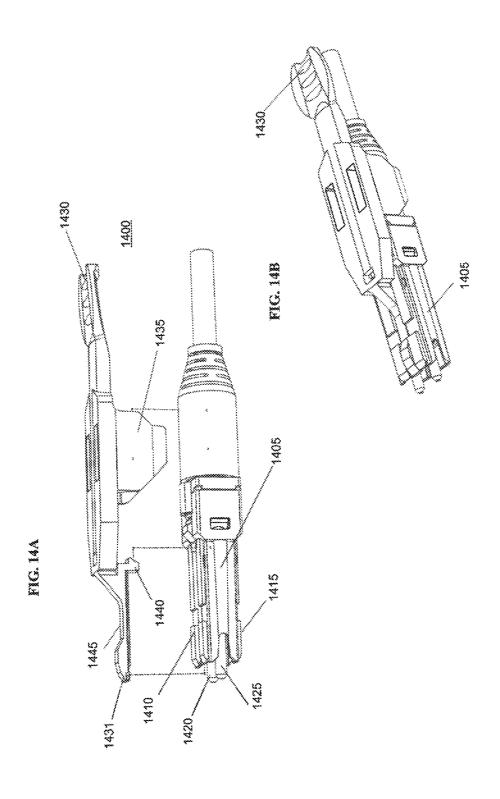


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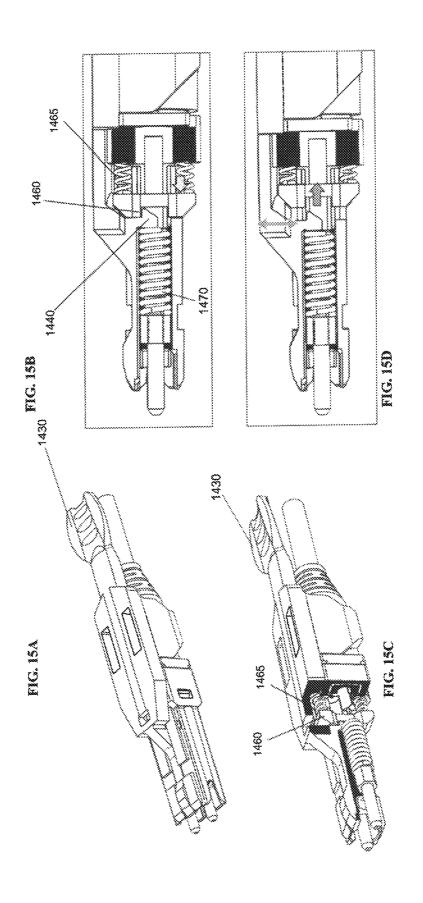
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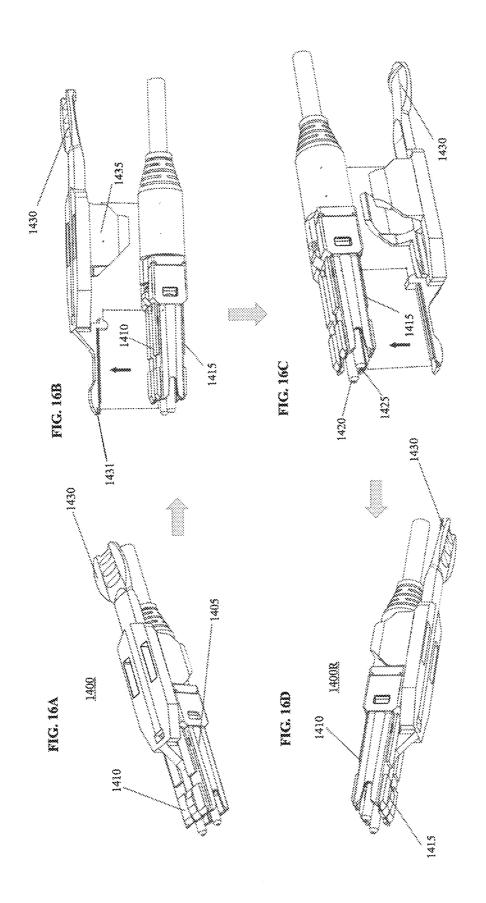
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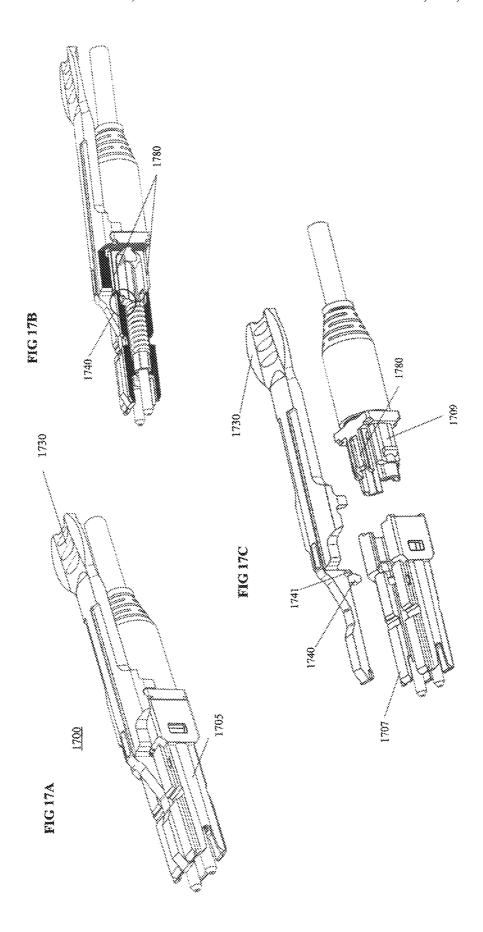


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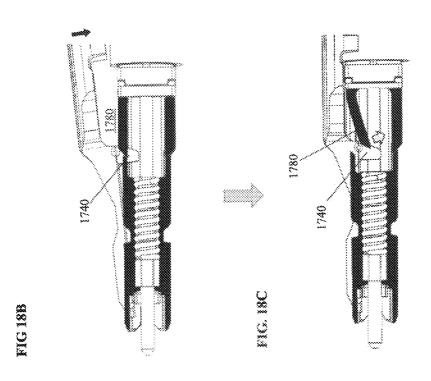
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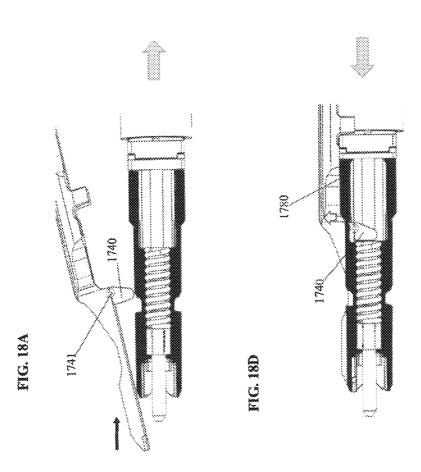
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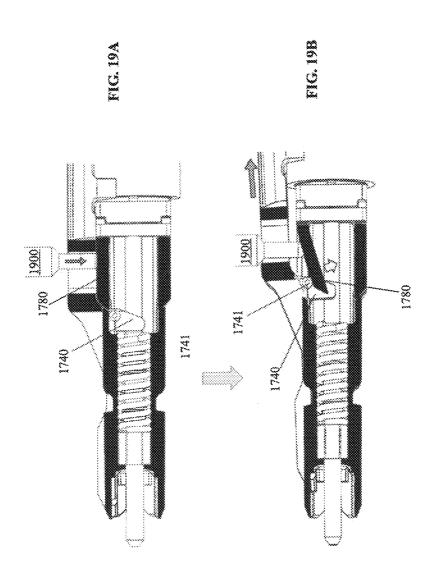
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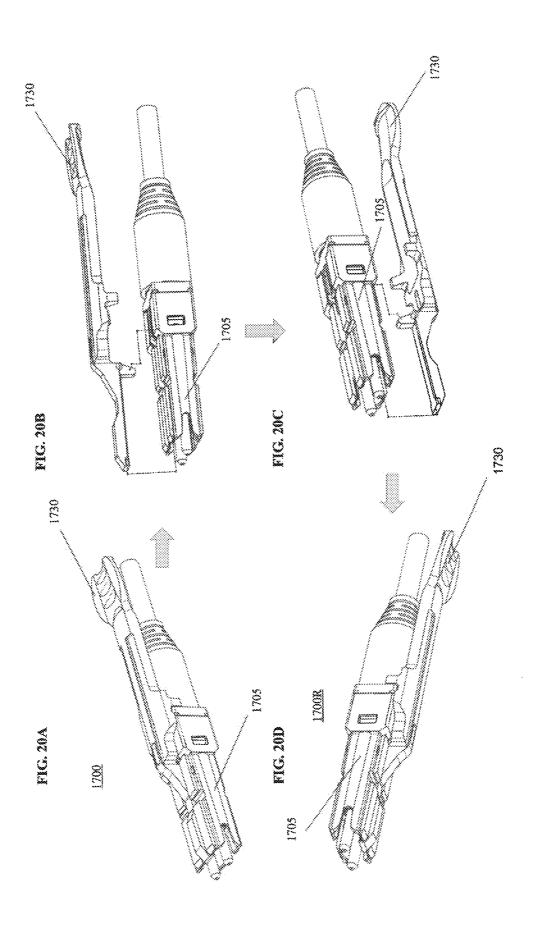


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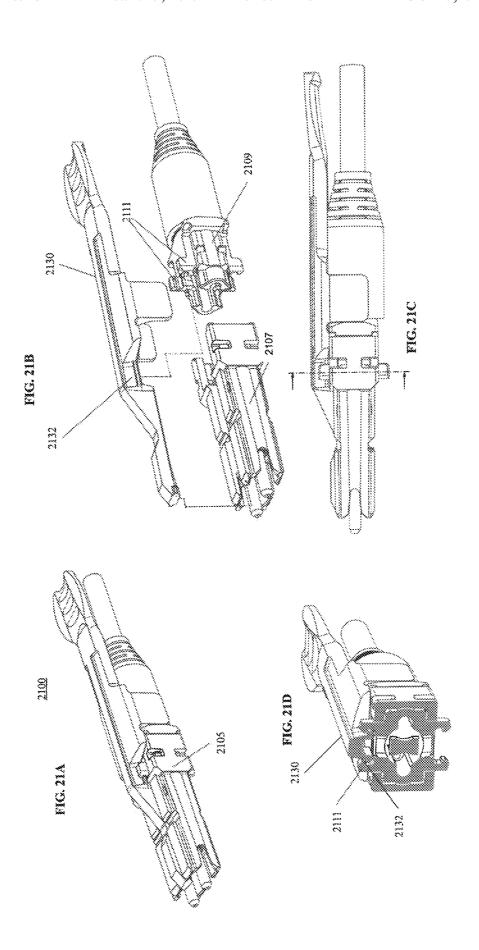


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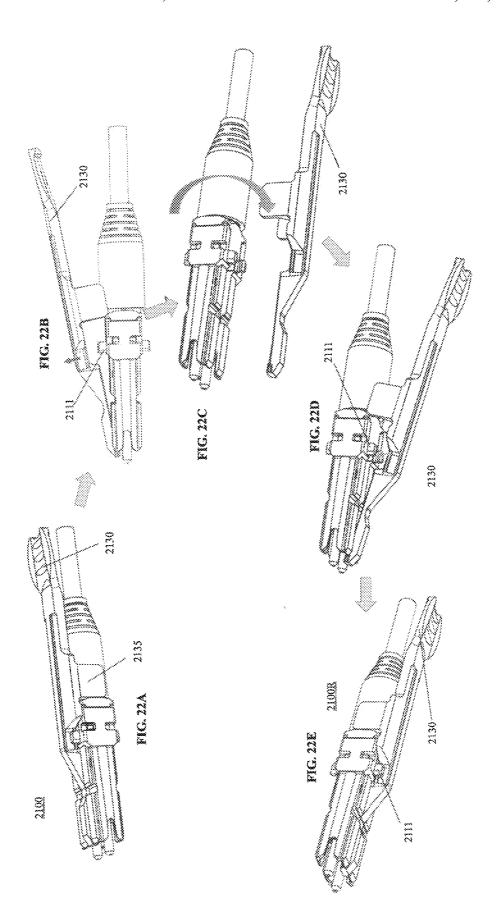


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OPTICAL CONNECTORS WITH REVERSIBLE POLARITY

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. 10 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 highdensity interconnect panels. High-density interconnect panels may be designed to consolidate the increasing volume of 30 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 35 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 40 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 45 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- 50 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 55 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 60 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 65 and cable assemblies may obstruct access to the individual release mechanisms. Such physical obstructions may

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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

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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 5 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 10 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 15 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. 1A is a perspective view of one embodiment of a reversible polarity fiber optic connector according to some aspects of the present disclosure;
- FIG. 1B is a side view of the reversible polarity fiber optic connector of FIG. 3A with the removable latch being removed from the connector housing;
- FIG. 2A is a perspective view of the reversible polarity fiber optic connector of FIG. 1A;
- FIG. 2B is an exploded view of a step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. 2A;
- FIG. **2**C is an exploded view of a next step in the process of changing the polarity of the reversible polarity fiber optic 35 connector of FIG. **2**A;
- FIG. 2D is a perspective view of the fiber optic connector of FIG. 1A with its polarity reversed;
- FIG. 3A is a perspective view of an embodiment of a reversible polarity fiber optic connector with a pull tab 40 according to aspects of the present disclosure;
- FIG. 3B is an exploded view of the reversible polarity fiber optic connector of FIG. 3A;
- FIG. 4A is a perspective view of the polarity of the reversible polarity fiber optic connector of FIG. 3A;
- FIG. 4B is an exploded view of a step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. 4A;
- FIG. 4C.1 is an exploded view of positioning the latch in the process of changing the polarity of the reversible polarity 50 fiber optic connector of FIG. 4A;
- FIG. 4C.2 is an exploded view of attaching the removed components of FIG. 4B in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. 4Δ .
- FIG. 4D is a perspective view of the reversible polarity fiber optic connector of FIG. 4A with its polarity reversed;
- FIG. 5A 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. 5B is an exploded view of the reversible polarity fiber optic connector of FIG. 5A;
- FIG. 6A is a perspective view of the polarity of the fiber optic connector of FIG. 5A;
- FIG. **6**B is an exploded view of a step in the process of 65 changing the polarity of the reversible polarity fiber optic connector of FIG. **5**A;

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- FIG. 6C is an exploded view of a next step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. 6A;
- FIG. **6**D is a perspective view of the reversible polarity fiber optic connector of FIG. **6**A with its polarity reversed;
- FIG. 7A 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. 7B is the front view of the common connector housing of FIG. 7A;
- FIG. 7C is the top view of the common connector housing of FIG. 7A;
- FIG. 7D is the side view of the common connector housing of FIG. 7A;
 - FIG. **8**A.**1** shows how the common connector housing of FIG. **7**A is used to create a latch-type connector;
 - FIG. 8A.2 is an exploded view of FIG. 8A.1;
- FIG. **8**B.**1** shows how the common connector housing of FIG. **7**A is used to create a recess-type connector;
 - FIG. 8B.2 is an exploded view of FIG. 8B.1;
- FIG. 9A is a perspective view of FIG. 8A.1 of the polarity of the latch-type fiber optic connector of FIG. 8A.1;
- FIG. 9B is an exploded view of a step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. 8A.1;
- FIG. 9C is an exploded view of a next step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. 8A.1;
- FIG. 9D is a perspective view of the reversible polarity fiber optic connector of FIG. 8A.1 with its polarity reversed;
- FIG. 10A is a perspective view of FIG. 8B.1 of the polarity of the recess-type fiber optic connector of FIG. 8B.
- FIG. 10B is an exploded view of a step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. 8B.1;
- FIG. 10C is an exploded view of a next step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. 8B.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. 11A and 11B respectively depict exploded and perspective views of a reversible polarity optical connector according to a further embodiment of the disclosure;
- FIGS. 12A-12D depict the operation of the reversible polarity optical connector of FIGS. 11A and 11B;
- FIGS. 13A-13D depict the process for changing the polarity of the optical connector of FIGS. 11A and 11B;
- 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. 15-15D depict the operation of the reversible polarity optical connector of FIGS. 14A and 14B;
- FIGS. 16A-16D depict the process for changing the polarity of the optical connector of FIGS. 14A and 14B;
- FIGS. 17A-17C 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. 19A-19B depict the removal of the push-pull tab from the connector body using a tool;

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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. 15 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 25 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 35 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 40 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 45 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 50 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 55 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 60 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 65 a duplex connector, needs to have the ferrules rotated or swapped, for example, for exchanging transmit and receive

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

FIG. 1B is a side view of the reversible polarity fiber optic connector of FIG. 1A with the removable latch 130 being separated from the connector housing. As shown, the connector housing 120 may have a first exterior wall 121a positioned above the first and second optical ferrules and a second exterior wall 121b 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,

FIGS. 2A-2D depict the process for changing the polarity of the fiber optic connector of FIG. 1A from a first polarity, FIG. 2A to a second, opposite polarity, FIG. 2D. The removable latch 130 may be removed from the latch coupling on the first exterior wall of the connector housing, FIG. 2B, positioned adjacent the second exterior wall on beneath the ferrules, FIG. 2C, and then coupled with the latch coupling on the second exterior wall of the connector

housing to yield a connector 100R, FIG. 2D, 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. 10 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 15 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 20 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 25 secure overall design when dealing with the shrinking footprint of fiber optic connectors.

FIG. 3A 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. 3B is an exploded view of the reversible polarity fiber optic connector of FIG. 3A. As shown, the pull tab 340 35 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 40 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. 4A-4D depict the process for changing the polarity of the fiber optic connector 300 from a first polarity, FIG. 4A to a second polarity 300R, FIG. 4D. 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. 2B. The removable latch is then detached from the latch coupling on the first exterior wall of the connector housing, FIG. 4C.1. Next, the removable latch is engaged with the latch coupling on the second exterior wall of the connector housing, beneath the ferrules, FIG. 55 4C.2. Finally, the pull tab 340 is positioned surrounding the connector housing and engaging the removable latch tip, resulting in the assembled optical connector 300R having polarity opposite to that of connector 300, FIG. 4D.

FIGS. 5A and 5B are a perspective view and exploded 60 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. 65 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.

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FIGS. 6A-6D depict the process for changing the polarity of the fiber optic connector **500** from a first polarity, FIG. **6A** to a second polarity, FIG. **6D**. 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. **6B**, 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. **6C**, 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 **500R**, FIG. **6D**.

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. 7A 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 710a and 710b and the common connector housing 720 at least partially surrounding the first and second optical ferrules.

FIGS. 7B, 7C and 7D 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 725a positioned above the first and second optical ferrules and a second exterior wall 725b 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. 8A.1 shows the common connector housing 720 used to create a latch-type connector 700 and FIG. 8B.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. 8A.2 and 8B.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. 8A.2 and 8B.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. 8A.2 and 8B.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. 8A.1

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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. 8B.1.

The fiber optic connector may further include a pull tab. When a removable arm with a latch 730 is positioned on the 5 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. 8A.2. When a removable arm includes a recess 830 is positioned on the coupling surface of the common connector housing 720 to 10 create a recess-type connector 800, the pull tab 840 is integrated with the removable arm, FIG. 8B.2.

FIGS. 9A-9D depict the process for changing the polarity of the latch-type fiber optic connector from a first polarity 700, FIG. 9A to a second polarity 700R, FIG. 9D. The 15 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. 9B. Then the sub-assembly of the removable arm 730 and the pull tab 740 may be coupled with the coupling surface of the second 20 exterior wall of the connector housing, FIG. 9C, creating the opposite polarity connector 700R.

FIGS. 10A-10C depicts the process for changing the polarity of the recess-type fiber optic connector 800 from a first polarity, FIG. 10A to a second polarity, FIG. 10D. The 25 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. 10B. Then the removable arm may be coupled with the coupling surface 724 of the second exterior wall of the common 30 connector housing 720, FIG. 10C to create opposite polarity optical connector 800R, FIG. 10D.

FIGS. 11A and 11B depict a further embodiment 1100 of the reversible polarity optical connectors of the present disclosure. In FIG. 11A, a push-pull tab 1130 may intercon- 35 nect 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 40 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 45 clip onto the optical connector, optionally in a boot region, and protrusion 1140 that fits within a first aperture, 1109A. beneath the housing exterior wall 1110 or a second aperture, 1109B, beneath housing exterior wall 1115 (to be discussed in more detail below), and projection 1131 for inserting into 50 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. 12B and 12D, push-pull tab 55 protrusion 1140 may be inserted into first aperture 1109A of housing 1105 through a first exterior housing aperture 1107A. Alternatively, in the reverse-polarity configuration, the push-pull tab protrusion 1140 may be inserted into second housing aperture 1109B through second exterior 60 housing aperture 1107B. When the push-pull tab 1130 is moved forward, the protrusion slides within the aperture 1109A or 1109B, as shown in FIG. 12B. To maintain the push-pull tab in a forward-biased position, tab position spring 1150 is provided. During insertion or removal of the 65 protrusion 1140, tab position spring 1150 is compressed, depicted in FIG. 12B. When the position spring 1150 is in its

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relaxed (uncompressed) position, FIGS. 12C and 12D, the protrusion 1140 is slid forward within the aperture 1109A or 1109B

To change polarity of the optical connector 1100, FIGS. 13A-13D, the push-pull tab 1130 is removed by withdrawing the protrusion 1140 from the housing 1105 through exterior housing aperture 1107A 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 1109B through exterior housing aperture 1107B in FIG. 13C. Projection 1131 is fitted between ferrules 1120 and 1125 and clips 1135 are affixed to the connector. The resultant connector 1100R of 13D is of opposite polarity to the connector 1100 of FIG. 13A.

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. 14A and 14B 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. 14B, 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. 15B and 15D. To release the protrusion 1440, push-pull tab position spring 1465 is compressed in FIG. 15C such that housing projection 1460 is retracted sufficiently to allow removal of protrusion 1440 through the housing 1405, FIG. 15D

To change polarity of the optical connector 1400 from the first polarity of FIG. 16A, 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. 16B). 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. 16C. The resultant connector 1400R of FIG. 16D is of opposite polarity to the connector of FIG. 16A.

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. 17A, 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. 17C). The back body housing portion 1709 includes a deformable region 1780, seen in the partial cross-section of FIG. 17B and the perspective view of FIG. 17C. 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. 18B) 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. 18C, the deformable region 1780 returns to its original position (FIG. 18D), securing the push-pull tab 1730 to the connector housing.

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Removal of the push-pull tab 1730 is depicted in FIGS. 19A and 19B. 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, 10 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 15 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. 21A-21D, a connector 2100 having a housing 2105 is provided with a housing front portion 2107 and a back portion 2109. FIG. 21A depicts an 25 assembled connector 2100 with housing 2105. FIG. 21B depicts an exploded view of connector 2100 of FIG. 21A. 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. Extend- 30 ing 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. 21C depicts connector 2100 showing a section view cut given by the arrows and broken line near the proximal end 35 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. 21D. As shown in FIG. 21D, receiving surface 2132 may be a recess with a protrusion along the edge that engages the hook-shaped edge of the 40 clips.

FIG. 22A through FIG. 22E depicts the operation of polarity change for connector 2100 of FIG. 21A-FIG. 21D. FIG. 22A depicts connector 2100 with pull-push tab clips 2135 (opposing side not shown) engaged around connector. 45 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 50 known in the art. To change the polarity of connector 2100 from the polarity depicted in FIG. 22A to the second, opposite polarity of FIG. 22E, the retainer 2111 is removed from receiving surface 2132. Referring to FIG. 21B, lifting push-pull tab 2130 in direction of up-arrow, separates 55 retainer 2111 from receiving surface. As shown in FIG. 22C, push-pull tab clips separate from the connector as the retainer is removed. Continuing with FIG. 22C, push-pull tab 2130 is moved to the opposite housing exterior wall in FIG. 22C. FIG. 22D depicts receiving surface 2132 engages 60 with the retainer 2111. In FIG. 21E the assembled connector **2100**R having the opposite polarity to the connector of FIG. 22A 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. 22E.

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 embodi-

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ments 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 20 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 explic-

itly 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 5 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 10 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 15 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 20 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 25 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."

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In addition, where features or aspects of the disclosure are described in terms of Markush groups, those skilled in the 30 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 descrip- 35 tion, 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 40 portion and a second deformable portion; 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 45 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 50 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 prestions, 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 embodi-

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 65 ferrules and a second exterior wall positioned beneath the first and second optical ferrules;

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- 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,
- 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
 - 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 $\mathbf{6}$, ently unforeseen or unanticipated alternatives, modifica- 55 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, 60 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;

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- 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 hous-
- 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 15 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
- 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
- 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 50 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 55 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 60
- 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.

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- 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
 - 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 35 19, further comprising a spring to urge the push-pull tab
- 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 40 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

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(12) EX PARTE REEXAMINATION CERTIFICATE (11755th)

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(54) OPTICAL CONNECTORS WITH REVERSIBLE POLARITY

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(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)

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None

See application file for complete search history.

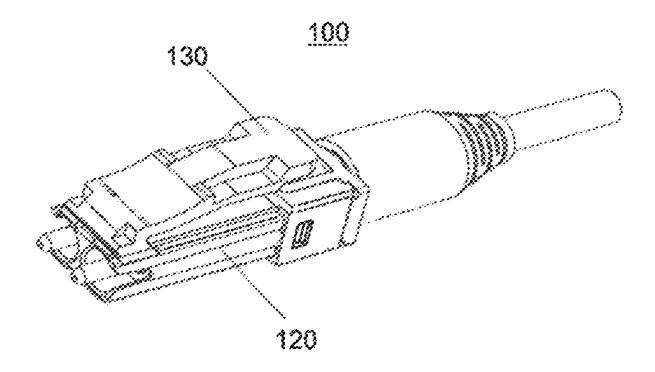
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To view the complete listing of prior art documents cited during the proceeding for Reexamination Control Number 90/014,456, please refer to the USPTO's public Patent Application Information Retrieval (PAIR) system under the Display References tab.

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.



US 10,191,230 C1

1 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 ¹⁵ 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 $_{20}$ 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 30 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 40 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 50 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

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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

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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 ²⁰ 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 25 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 30 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 35 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



(12) United States Patent Wong et al.

US 11,181,701 B2 (10) Patent No.:

(54) OPTICAL CONNECTORS WITH REVERSIBLE POLARITY AND METHOD OF

(45) Date of Patent: Nov. 23, 2021

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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.

Appl. No.: 17/200,134

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> US 2021/0199901 A1 Jul. 1, 2021

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- (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 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 See application file for complete search history.

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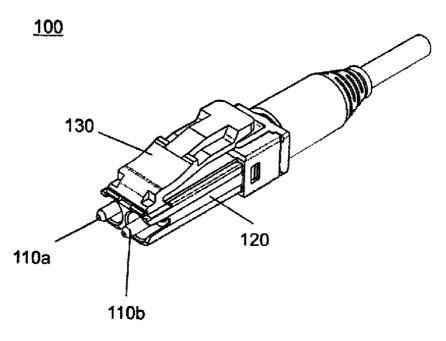
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Primary Examiner — Jerry M Blevins

ABSTRACT (57)

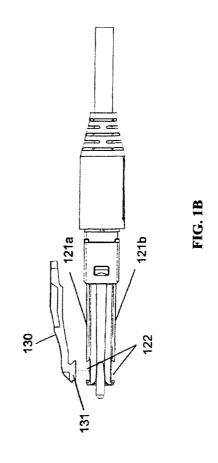
Reversible polarity fiber optic connectors are provided having housings at least partially surrounding first and second optical ferrules with walls above and beneath the ferrules. Positioning removable elements such as latches, removable arms, or push-pull tabs on the first wall above the ferrules yields 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.

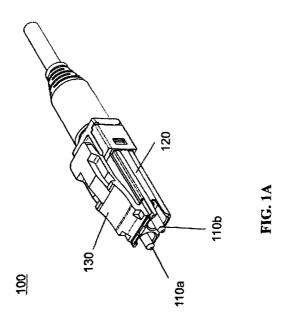
53 Claims, 22 Drawing Sheets



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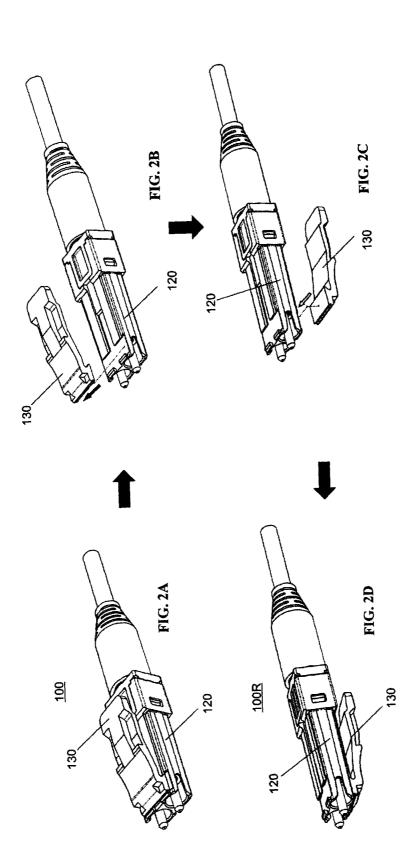
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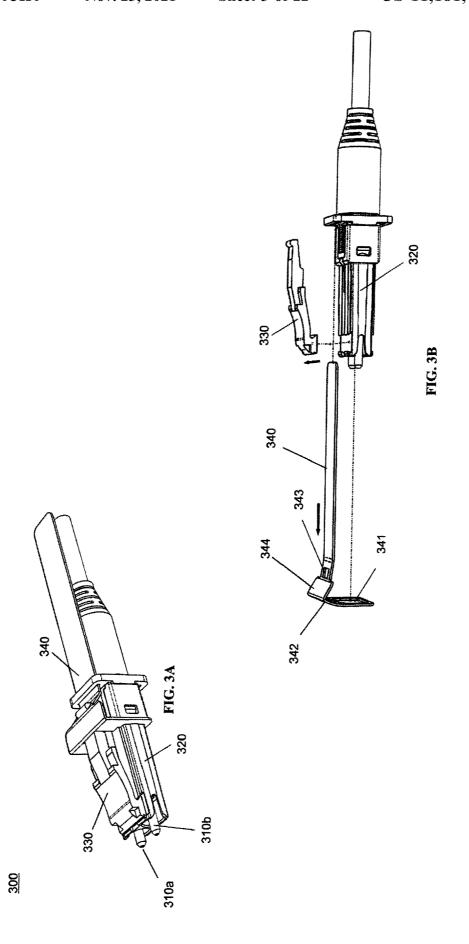


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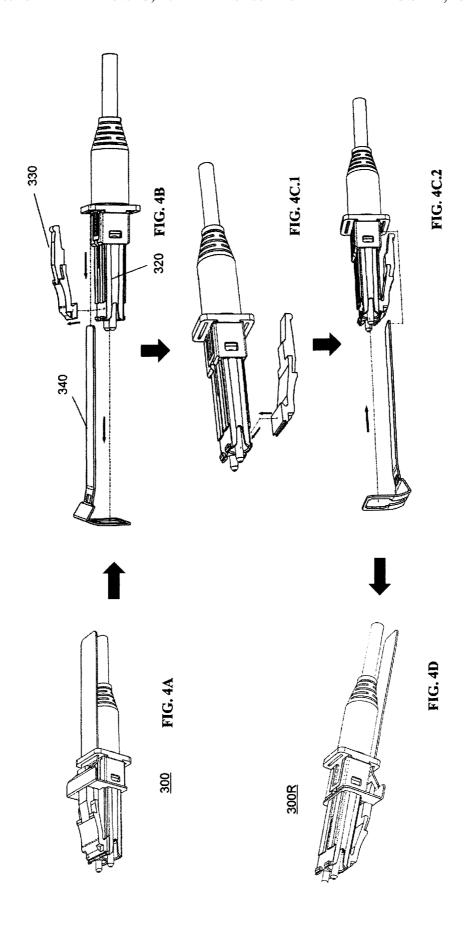
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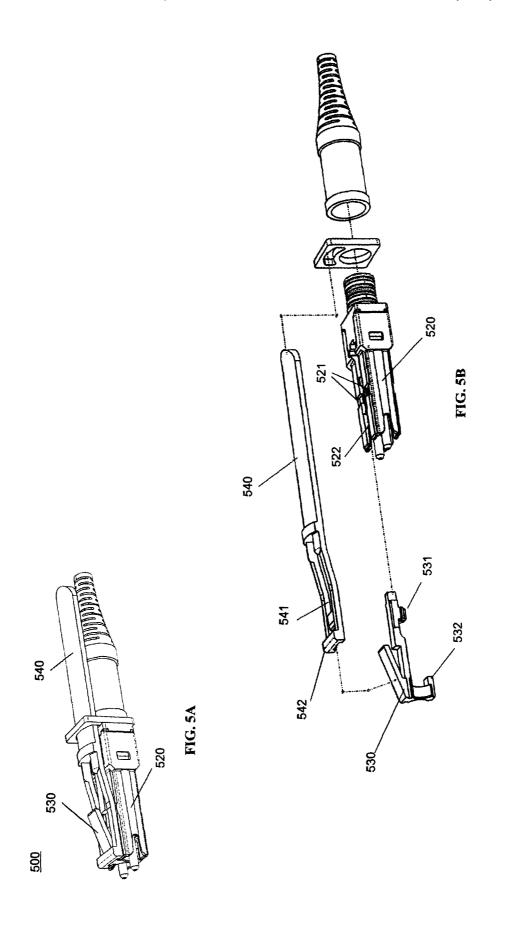
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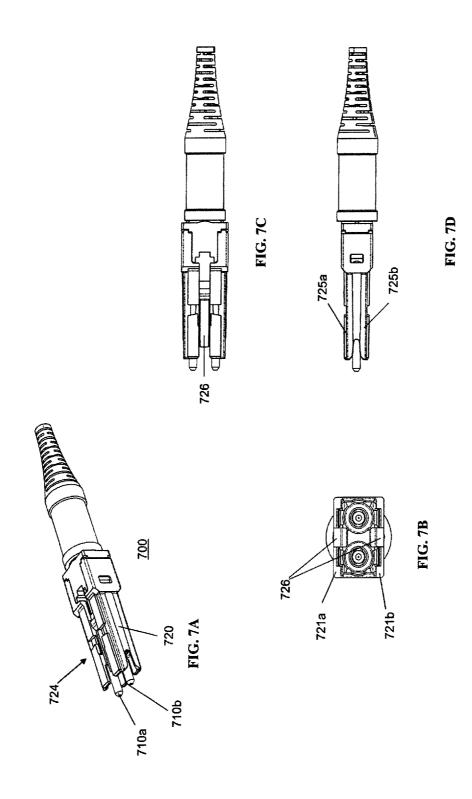
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U.S. Patent US 11,181,701 B2 Nov. 23, 2021 Sheet 6 of 22 520 540 530 FIG. 6D 200 500R

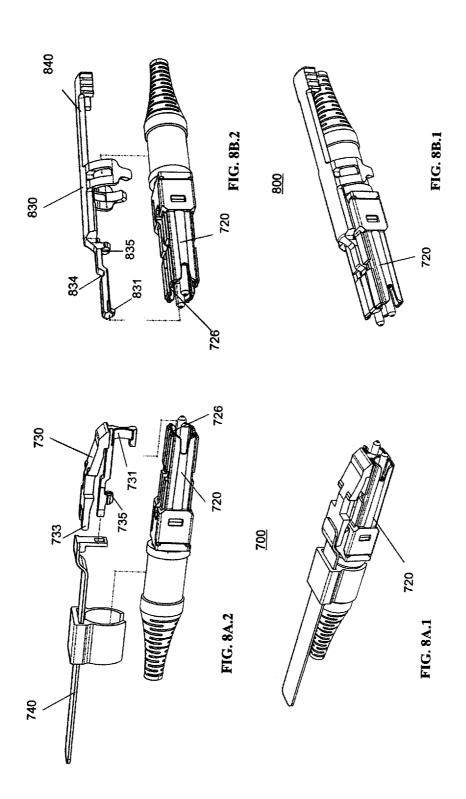
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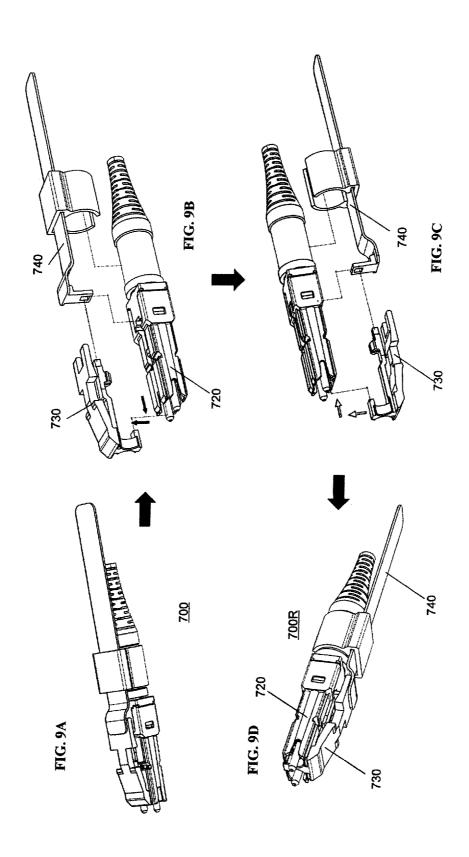
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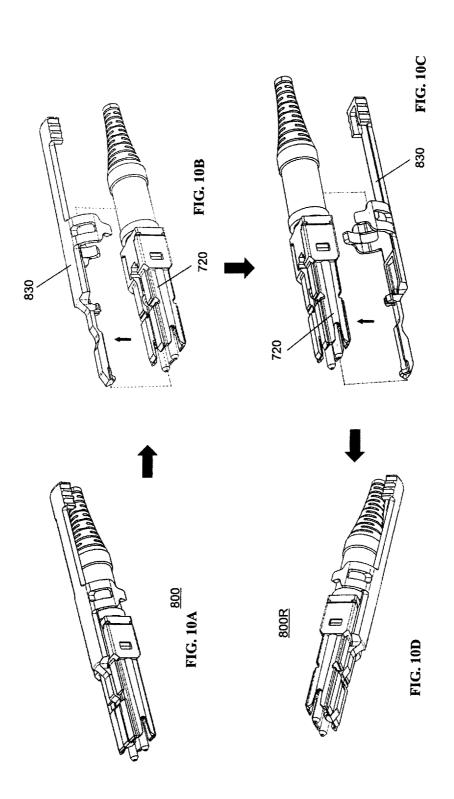
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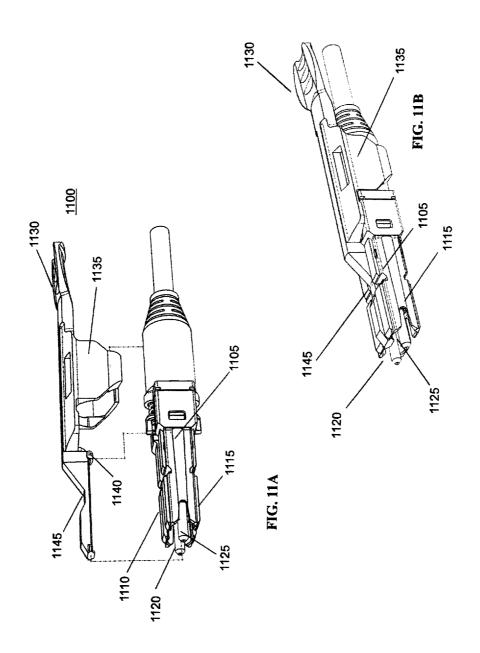
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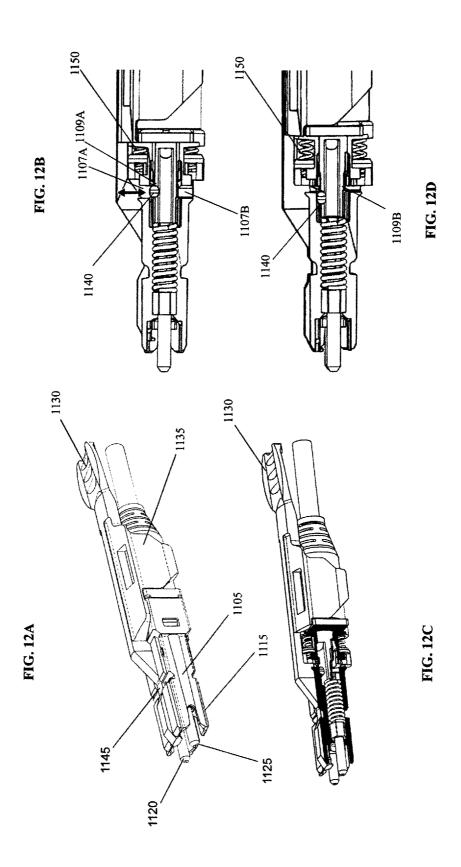
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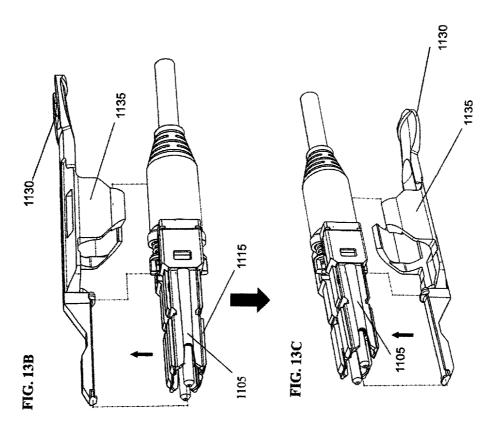


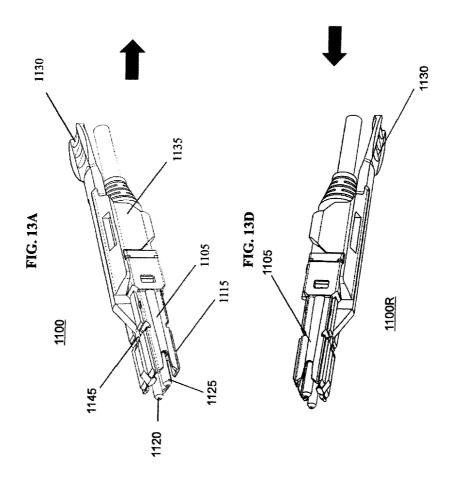
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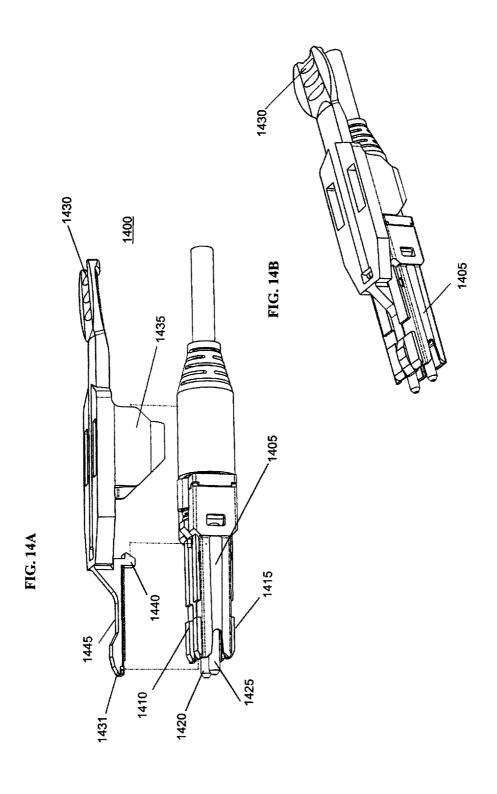
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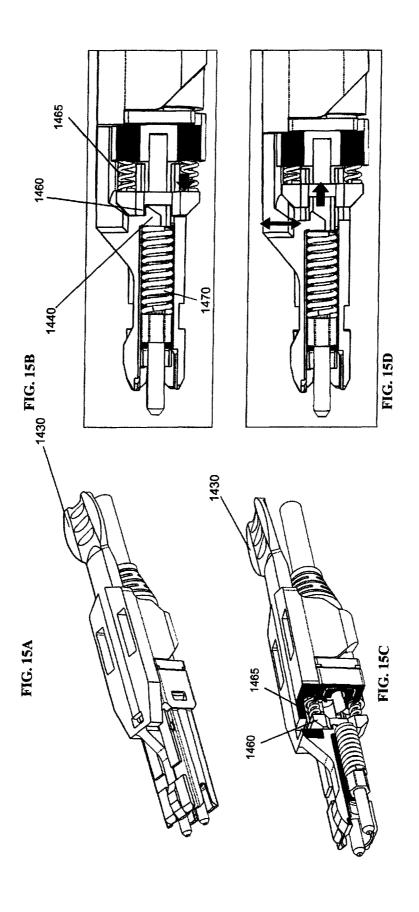
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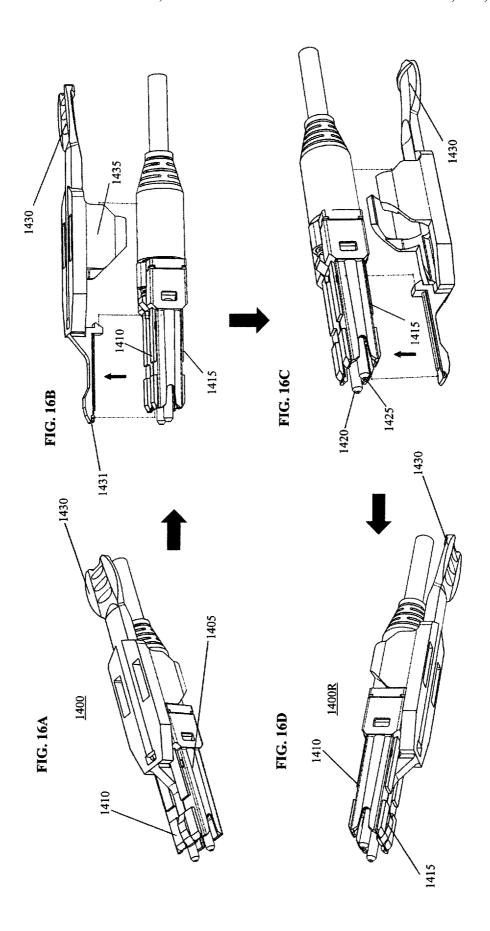


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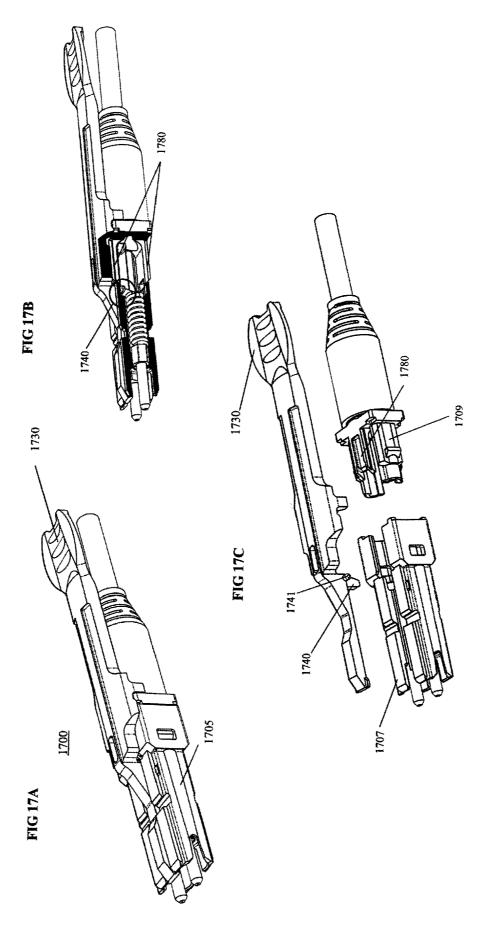
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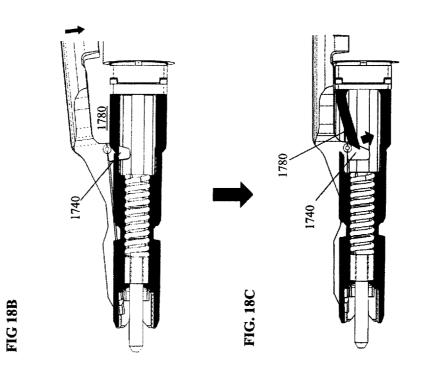


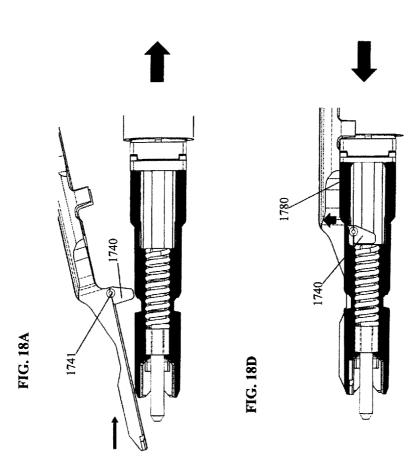
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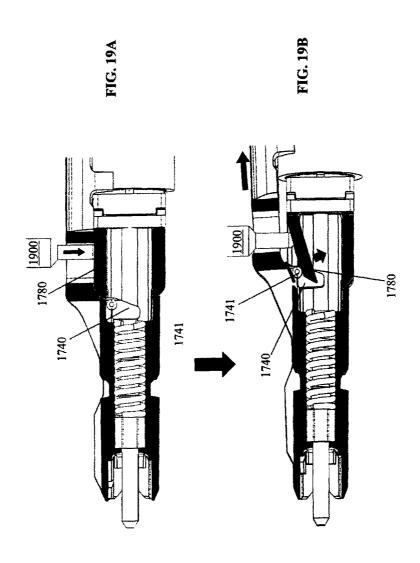
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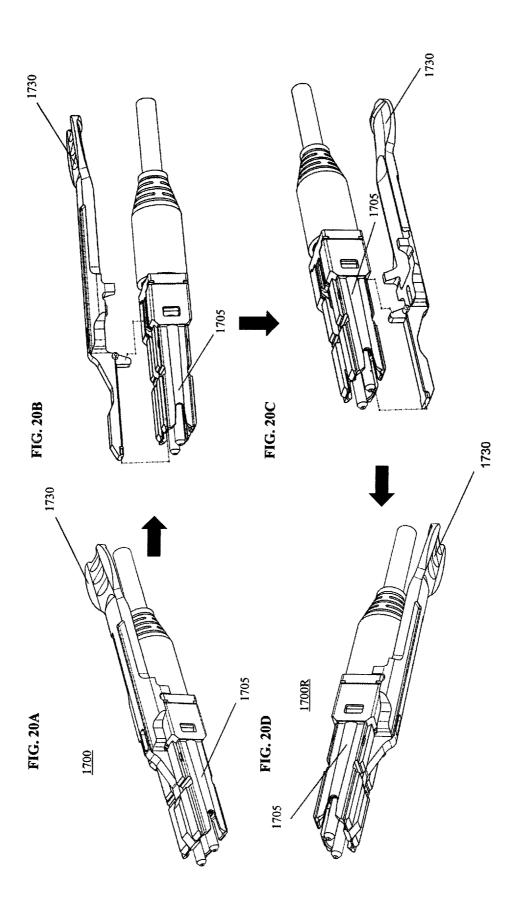


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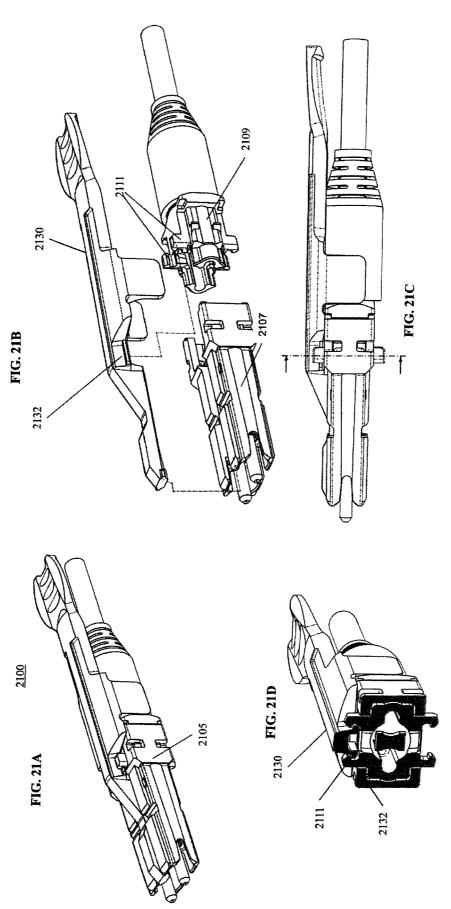
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U.S. Patent US 11,181,701 B2 Nov. 23, 2021 **Sheet 22 of 22** 2130 FIG. 22B FIG. 22D FIG. 22C 2130 2130 2100R FIG. 22A FIG. 22E 2100 2111

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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 10 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, 15 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 30 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 highdensity interconnect panels. High-density interconnect pan- 35 els 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 40 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 opti- 45 cal 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). 50 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) 55 footprint. This footprint currently accommodates four LCtype 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 65 the spacing between adjacent connectors on the panel. While both approaches may be effective to increase the panel

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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 5 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 20 of FIG. 7A: 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 25 with a second, opposite polarity.

BRIEF DESCRIPTION OF THE DRAWINGS

- FIG. 1A is a perspective view of one embodiment of a 30 of the latch-type fiber optic connector of FIG. 8A.1; reversible polarity fiber optic connector according to some aspects of the present disclosure;
- FIG. 1B is a side view of the reversible polarity fiber optic connector of FIG. 3A with the removable latch being removed from the connector housing;
- FIG. 2A is a perspective view of the reversible polarity fiber optic connector of FIG. 1A;
- FIG. 2B is an exploded view of a step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. 2A;
- FIG. 2C is an exploded view of a next step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. 2A;
- FIG. 2D is a perspective view of the fiber optic connector of FIG. 1A with its polarity reversed;
- FIG. 3A 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. 3B is an exploded view of the reversible polarity fiber optic connector of FIG. 3A;
- FIG. 4A is a perspective view of the polarity of the reversible polarity fiber optic connector of FIG. 3A;
- FIG. 4B is an exploded view of a step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. 4A;
- FIG. 4C.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. 4A;
- FIG. 4C.2 is an exploded view of attaching the removed components of FIG. 4B in the process of changing the 60 polarity of the reversible polarity fiber optic connector of FIG. **4**A:
- FIG. 4D is a perspective view of the reversible polarity fiber optic connector of FIG. 4A with its polarity reversed;
- FIG. 5A is a perspective view of another embodiment of 65 a reversible polarity fiber optic connector with a pull tab according to aspects of the present disclosure;

- FIG. 5B is an exploded view of the reversible polarity fiber optic connector of FIG. 5A;
- FIG. 6A is a perspective view of the polarity of the fiber optic connector of FIG. **5**A;
- FIG. 6B is an exploded view of a step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. 5A;
- FIG. 6C is an exploded view of a next step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. 6A;
- FIG. 6D is a perspective view of the reversible polarity fiber optic connector of FIG. 6A with its polarity reversed;
- FIG. 7A 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. 7B is the front view of the common connector housing of FIG. 7A;
- FIG. 7C is the top view of the common connector housing
- FIG. 7D is the side view of the common connector housing of FIG. 7A;
- FIG. 8A.1 shows how the common connector housing of FIG. 7A is used to create a latch-type connector;
 - FIG. 8A.2 is an exploded view of FIG. 8A.1;
- FIG. 8B.1 shows how the common connector housing of FIG. 7A is used to create a recess-type connector;
 - FIG. 8B.2 is an exploded view of FIG. 8B.1;
- FIG. 9A is a perspective view of FIG. 8A.1 of the polarity
- FIG. 9B is an exploded view of a step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. 8A.1;
- FIG. 9C is an exploded view of a next step in the process 35 of changing the polarity of the reversible polarity fiber optic connector of FIG. 8A.1;
 - FIG. 9D is a perspective view of the reversible polarity fiber optic connector of FIG. 8A.1 with its polarity reversed;
 - FIG. 10A is a perspective view of FIG. 8B.1 of the polarity of the recess-type fiber optic connector of FIG. **8**B.1:
 - FIG. 10B is an exploded view of a step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. 8B.1;
 - FIG. 10C is an exploded view of a next step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. 8B.1;
 - FIG. 10D is a perspective view of the reversible polarity fiber optic connector of FIG. 8B.1 with its polarity reversed;
 - FIGS. 11A and 11B respectively depict exploded and perspective views of a reversible polarity optical connector according to a further embodiment of the disclosure;
 - FIGS. 12A-12D depict the operation of the reversible polarity optical connector of FIGS. 11A and 11B;
 - FIGS. 13A-13D depict the process for changing the polarity of the optical connector of FIGS. 11A and 11B;
 - FIGS. 14A and 14B respectively depict exploded and perspective views of a reversible polarity optical connector according to a further embodiment of the disclosure;
 - FIGS. 15A-15D depict the operation of the reversible polarity optical connector of FIGS. 14A and 14B;
 - FIGS. 16A-16D depict the process for changing the polarity of the optical connector of FIGS. 14A and 14B;
 - FIGS. 17A-17C respectively depict perspective, partial cross-section, and exploded views of a reversible polarity optical connector according to a further embodiment of the disclosure;

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

FIGS. 19A-19B 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 ⁵ polarity of the optical connector of FIGS. **17**A-**17**C.

FIGS. 21A-21D 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. 25 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 35 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 40 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 45 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 50 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 55 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 60 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 65 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

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

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.

specialized tools and preparation time to perform safely and

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

FIG. 1B is a side view of the reversible polarity fiber optic connector of FIG. 1A with the removable latch 130 being separated from the connector housing. As shown, the connector housing 120 may have a first exterior wall 121a positioned above the first and second optical ferrules and a second exterior wall 121b 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,

FIGS. 2A-2D depict the process for changing the polarity of the fiber optic connector of FIG. 1A from a first polarity, 5 FIG. 2A to a second, opposite polarity, FIG. 2D. The removable latch 130 may be removed from the latch coupling on the first exterior wall of the connector housing, FIG. 2B, positioned adjacent the second exterior wall on beneath the ferrules, FIG. 2C, and then coupled with the latch 10 coupling on the second exterior wall of the connector housing to yield a connector 100R, FIG. 2D, 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 15 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 con- 20 nector 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 25 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 30 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 35 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. 3A is a perspective view of another embodiment of a reversible polarity fiber optic connector 300. As shown, the 40 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. 3B is an exploded view of the reversible polarity 45 fiber optic connector of FIG. 3A. 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 50 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 55 ferrules.

FIGS. 4A-4D depict the process for changing the polarity of the fiber optic connector 300 from a first polarity, FIG. 4A to a second polarity 300R, FIG. 4D. The pull tab 340 may be disengaged from the connector housing 320 and the 60 removable latch 330 on the first exterior wall of the connector housing, FIG. 2B. The removable latch is then detached from the latch coupling on the first exterior wall of the connector housing, FIG. 4C.1. Next, the removable latch is engaged with the latch coupling on the second exterior 65 wall of the connector housing, beneath the ferrules, FIG. 4C.2. Finally, the pull tab 340 is positioned surrounding the

connector housing and engaging the removable latch tip, resulting in the assembled optical connector 300R having polarity opposite to that of connector 300, FIG. 4D.

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FIGS. 5A and 5B 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. 6A-6D depict the process for changing the polarity of the fiber optic connector **500** from a first polarity, FIG. 6A to a second polarity, FIG. 6D. 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. 6B, 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. 6C, 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. 6D.

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. 7A 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 710a and 710b and the common connector housing 720 at least partially surrounding the first and second optical ferrules.

FIGS. 7B, 7C and 7D 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 725a positioned above the first and second optical ferrules and a second exterior wall 725b 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. 8A.1 shows the common connector housing 720 used to create a latch-type connector 700 and FIG. 8B.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. 8A.2 and 8B.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. 8A.2 and 8B.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.

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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. 8A.2. When 20 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. 8B.2.

FIGS. 9A-9D depict the process for changing the polarity of the latch-type fiber optic connector from a first polarity 700, FIG. 9A to a second polarity 700R, FIG. 9D. 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. 9B. Then the 30 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. 9C, creating the opposite polarity connector 700R.

FIGS. 10A-10C depicts the process for changing the 35 polarity of the recess-type fiber optic connector 800 from a first polarity, FIG. 10A to a second polarity, FIG. 10D. 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. 10B. 40 Then the removable arm may be coupled with the coupling surface 724 of the second exterior wall of the common connector housing 720, FIG. 10C to create opposite polarity optical connector 800R, FIG. 10D.

FIGS. 11A and 11B depict a further embodiment 1100 of 45 the reversible polarity optical connectors of the present disclosure. As shown in FIG. 11A or FIG. 12A, 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 50 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. 12A or FIG. 11A. Alternatively, push-pull tab 1130 may include a latch (not shown). Various features of the push-pull tab 1130 55 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, 1109A, 60 beneath the housing exterior wall 1110 or a second aperture, 1109B, 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.

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

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

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. 14A and 14B 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. 14B, 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. 15B and 15D. To release the protrusion 1440, push-pull tab position spring 1465 is compressed in FIG. 15C such that housing projection 1460 is retracted sufficiently to allow removal of protrusion 1440 through the housing 1405, FIG. 15D. FIG. 15A depicts connector with pull tab 1430 fully assembled.

To change polarity of the optical connector 1400 from the first polarity of FIG. 16A, 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. 16B). 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. 16C. The resultant connector 1400R of FIG. 16D is of opposite polarity to the connector of FIG. 16A.

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. 17A, the connector 1700 includes a connector housing 1705 which may optionally include a back 5 body housing portion 1709 for connecting with a housing front portion 1707 (FIG. 17C). The back body housing portion 1709 includes a deformable region 1780, seen in the partial cross-section of FIG. 17B and the perspective view of FIG. 17C. The push-pull tab 1730 includes a protrusion 1740 with a projection 1741 extending therefrom.

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Turning to FIG. 18A, to affix the push-pull tab to the connector housing, the protrusion 1740 penetrates the deformable region 1780 (FIG. 18B) causing the deformable region to yield and accept entry of the protrusion 1740 into 15 the housing. As the projection 1741 enters the housing as depicted in FIG. 18C, the deformable region 1780 returns to its original position (FIG. 18D), securing the push-pull tab 1730 to the connector housing.

Removal of the push-pull tab 1730 is depicted in FIGS. 20 19A and 19B. 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. 20A, the push-pull tab 1730 is removed in FIG. 20B by using the removal tool technique depicted in FIGS. 19A and 19B. The push-pull tab is moved toward the second exterior housing wall and the protrusion 1740 is 30 inserted into the housing 1705 through the deformable region 1780 in FIG. 20C. The resultant connector 1700R of FIG. 20D is of opposite polarity to the connector of FIG. 20A

In another aspect of the disclosure, a retaining member 35 may be provided in the connector housing to retain a push-pull tab. As seen in FIGS. 21A-21D, a connector 2100 having a housing 2105 is provided with a housing front portion 2107 and a back portion 2109. FIG. 21A depicts an assembled connector 2100 with housing 2105. FIG. 21B 40 depicts an exploded view of connector 2100 of FIG. 21A. 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 45 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. 21B. FIG. 21C depicts connector 2100 showing a section view cut given by the arrows and broken line near the proximal end of connector 2100. Optionally, 50 when the retainer 2111 includes clips, the clips may be hook-shaped as seen in the cross-sectional view of FIG. 21D. As shown in FIG. 21D, receiving surface 2132 may be a recess with a protrusion along the edge that engages the hook-shaped edge of the clips.

FIG. 22A through FIG. 22E depicts the operation of polarity change for connector 2100 of FIG. 21A-FIG. 21D. FIG. 22A 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 60 2130 forward or toward front of connector or backward or toward rear of connector, and as describe in FIG. 21B 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. 22A to the second, opposite polarity of FIG. 22E, the retainer 2111 is removed

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from receiving surface 2132. Referring to FIG. 22B, lifting push-pull tab 2130 in direction of up-arrow, separates retainer 2111 from receiving surface. As shown in FIG. 22C, push-pull tab clips separate from the connector as the retainer is removed. Continuing with FIG. 22C, push-pull tab 2130 is moved to the opposite housing exterior wall in FIG. 22C. FIG. 22D depicts receiving surface 2132 engages with the retainer 2111. In FIG. 21E the assembled connector 2100R having the opposite polarity to the connector of FIG. 22A 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. 22E.

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 understand-

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ing, 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 15 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 20 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 25 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 30 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 35 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 40 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 45 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 50 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 55 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 60 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. 65

Various of the above-disclosed and other features and functions, or alternatives thereof, may be combined into 14

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 5 the depressible latch arm is received in the opening.

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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 10 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 15 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, 20 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 25 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 30 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.
- 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 45 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: 50 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 55 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 60 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 65 ferrules, the single back body being configured to attach to the single front body such that the back body

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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
- 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 16. The fiber optic connector as set forth in claim 1, 35 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.

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- 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 15 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**, 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 30 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 35 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 40 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 45 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 50 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
 - 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 60 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

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- 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.
- remove the free rear end portion from the opening and unlatch the fiber optic connector from the receptacle; 55 forth in claim 46, wherein the removable latch is configured for being inserted into the open axial end of each groove by remote release including an elongate front section 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.

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19 connector as set forth in claim 51.

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 5 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



(12) United States Patent

Takano et al.

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(45) **Date of Patent:** *Jul. 13, 2021

(54) SMALL FORM FACTOR FIBER OPTIC CONNECTOR WITH MULTI-PURPOSE BOOT ASSEMBLY

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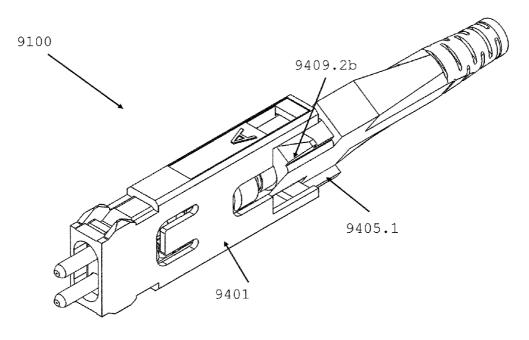
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Primary Examiner — Eric Wong

(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



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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.

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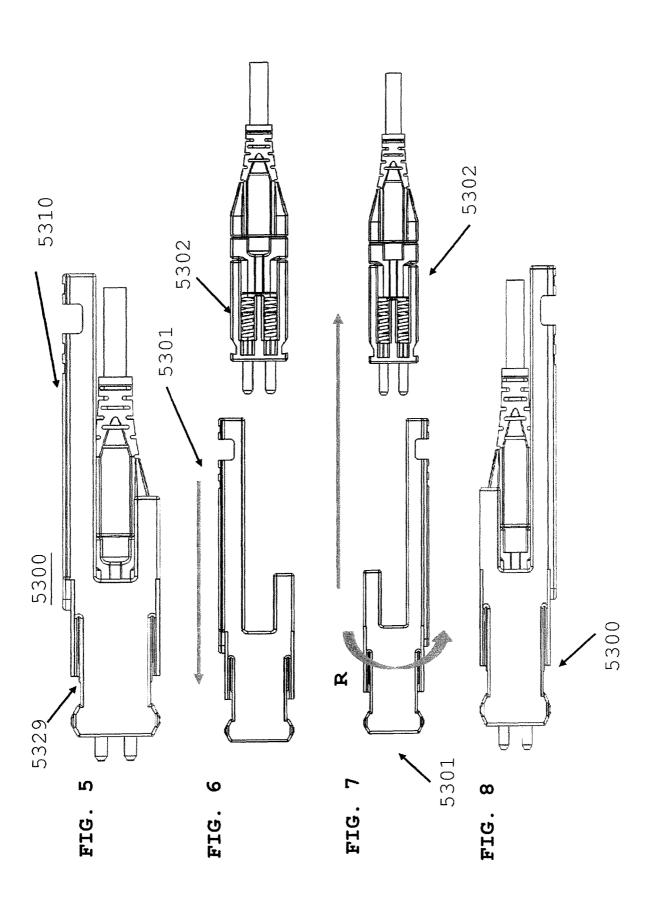
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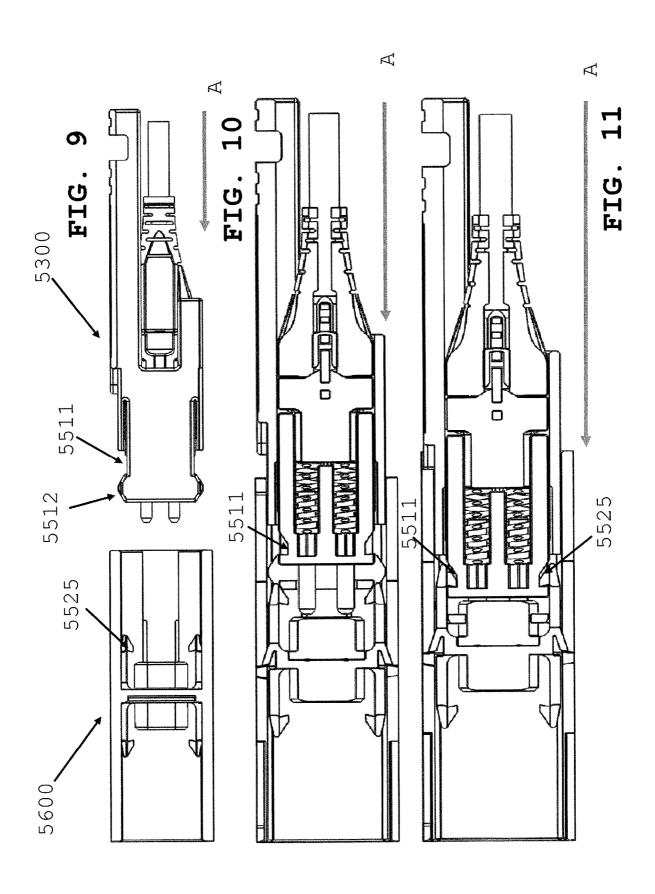
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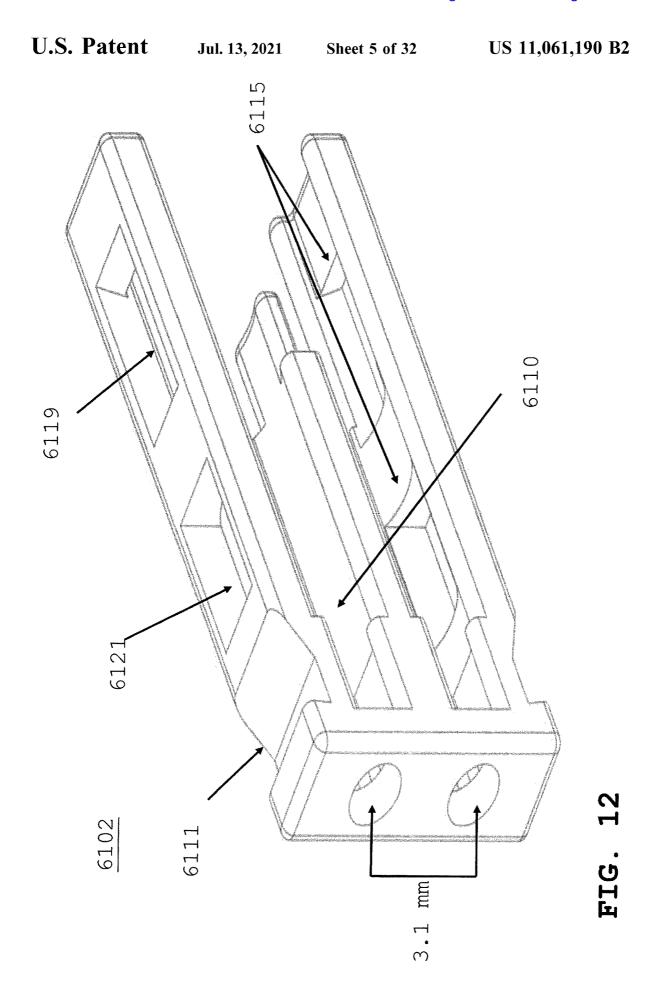
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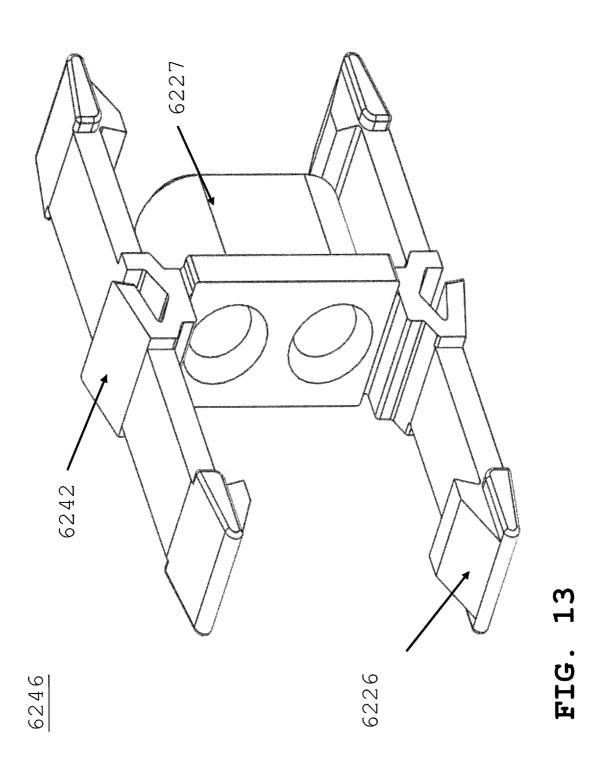
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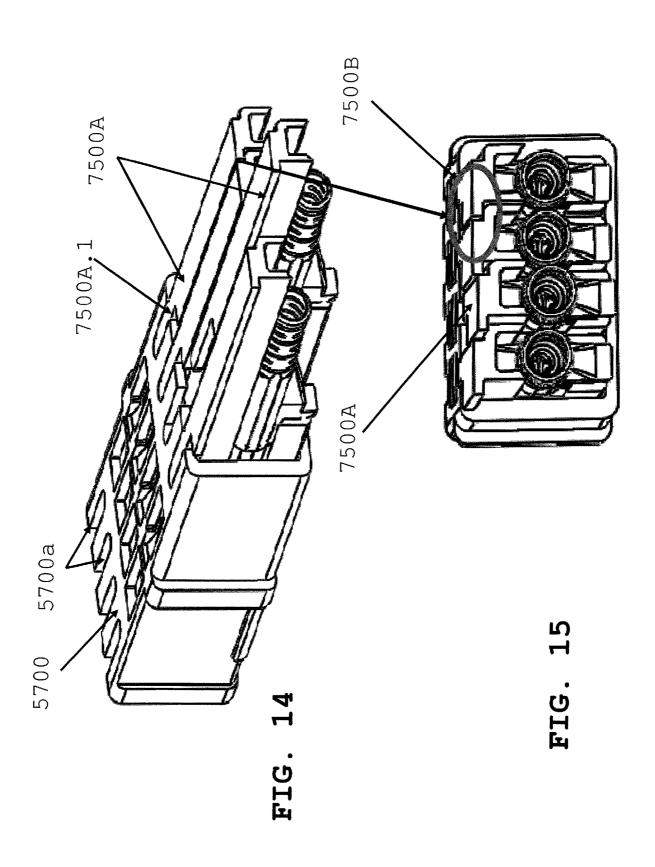
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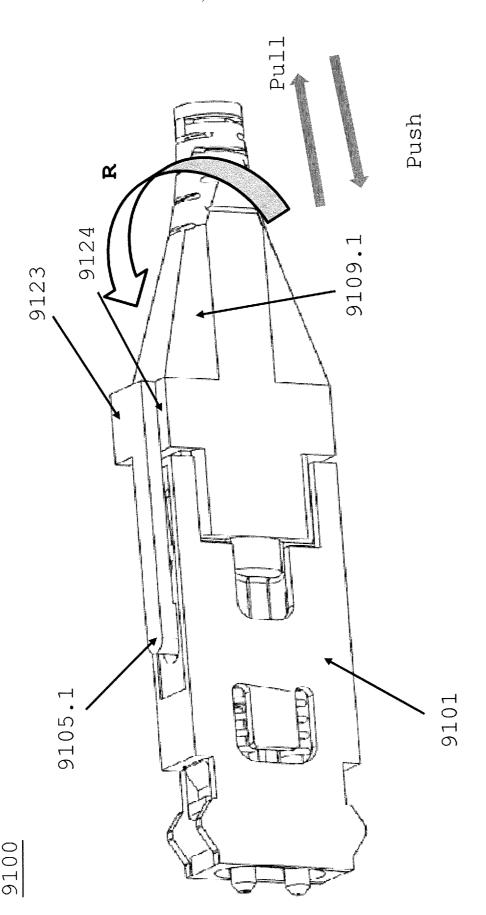


FIG. 16

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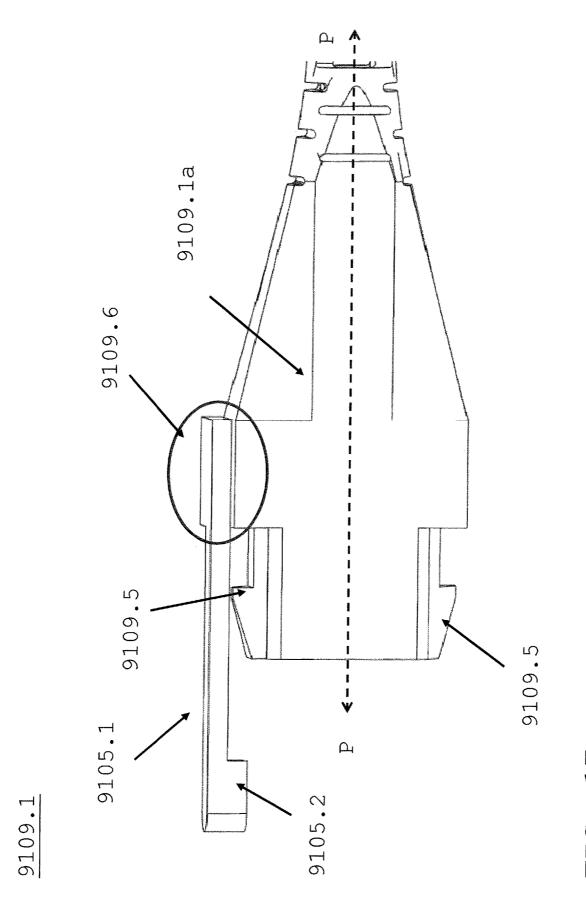
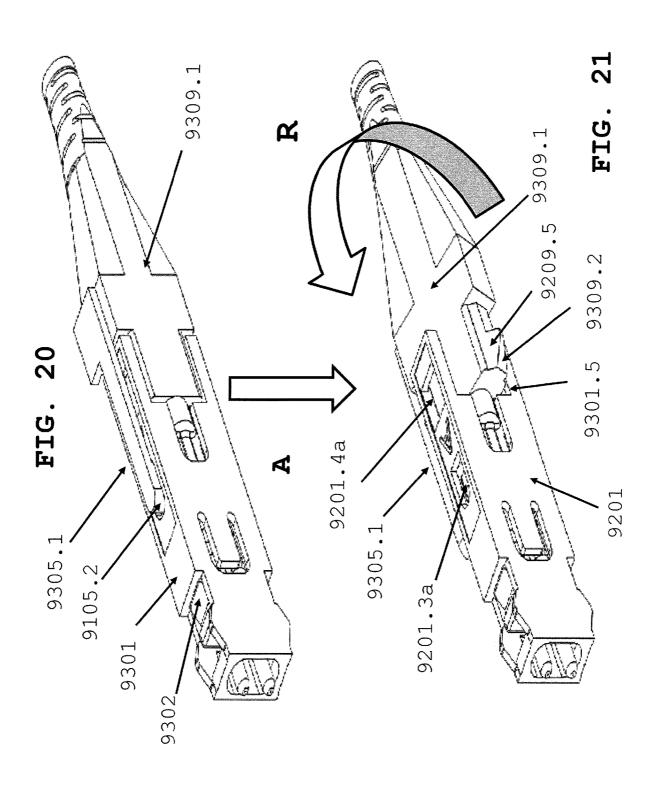


FIG. 17

U.S. Patent US 11,061,190 B2 Jul. 13, 2021 **Sheet 10 of 32** 9209.1 9024 Polarity_{9201.4b} 9023 9209.5 9201.4a 9206 9205.2 Second 9202 9201.3b 9201 9205.1 9201 FIG. 9203

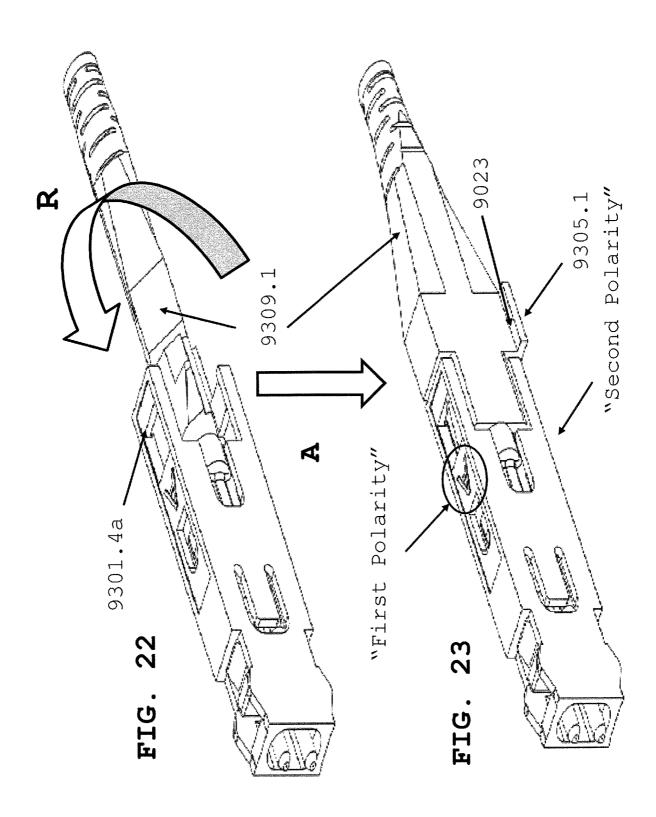
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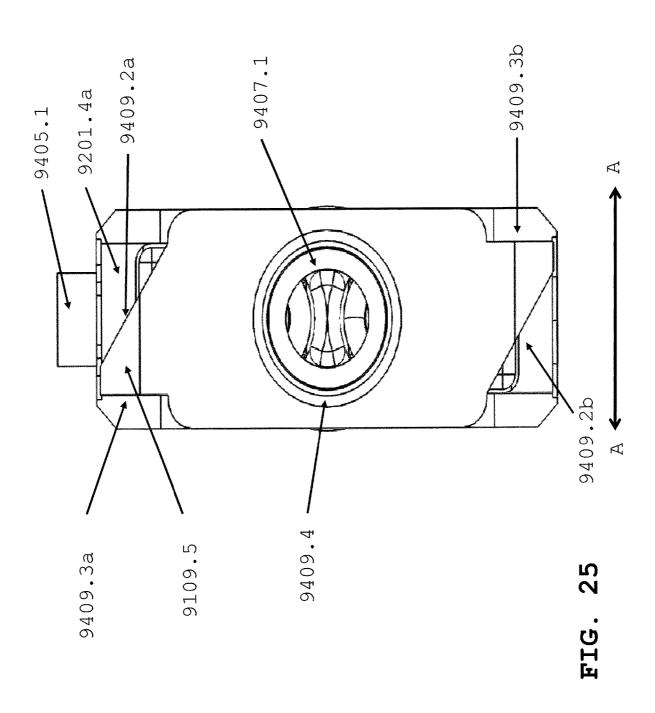
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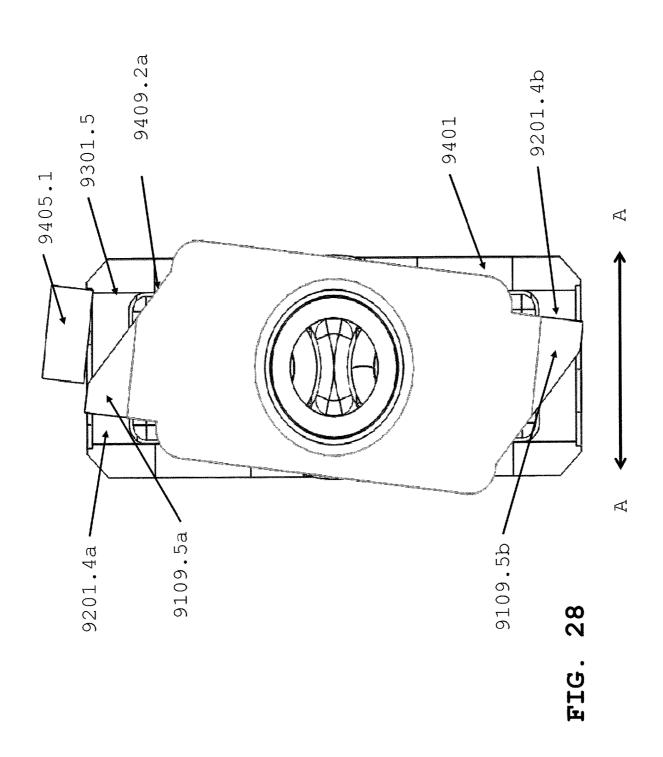
Sheet 14 of 32



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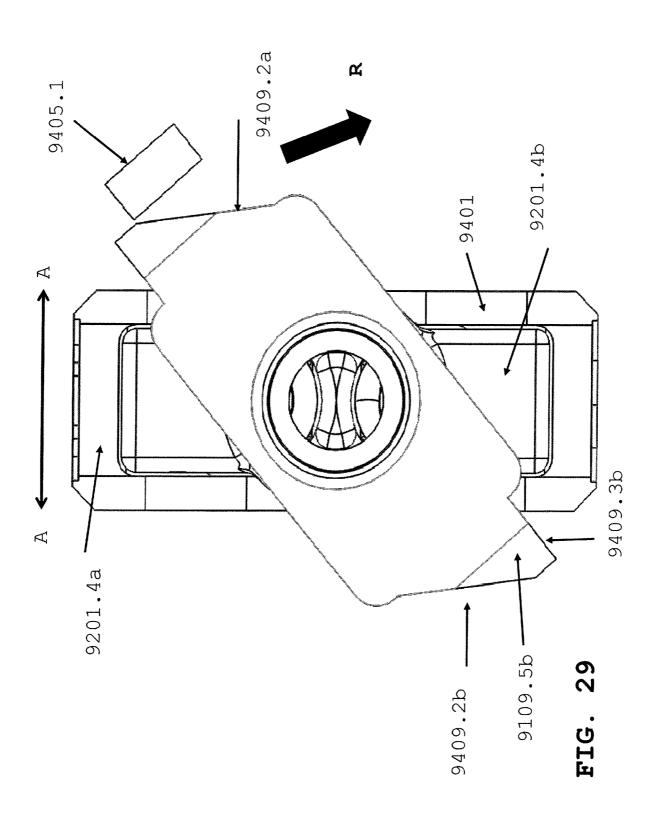
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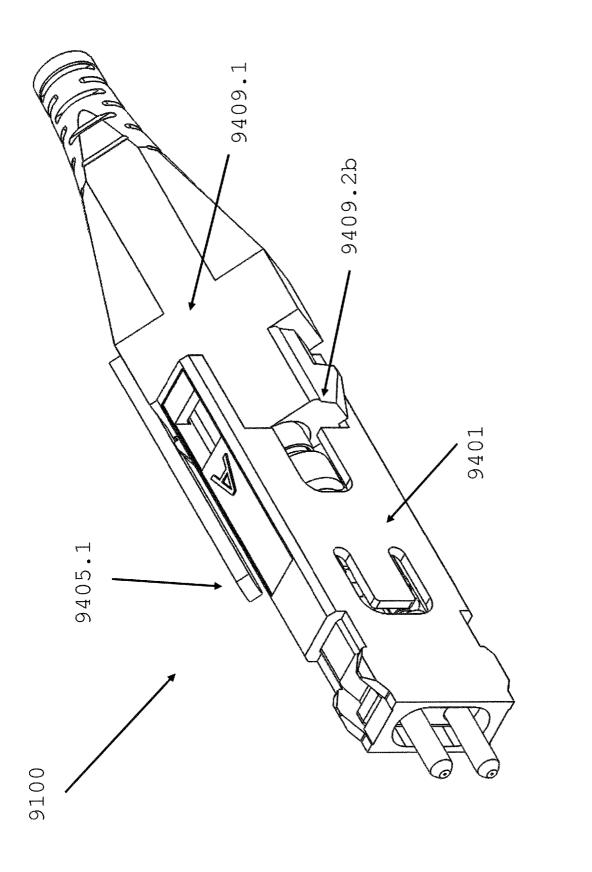


FIG. 30

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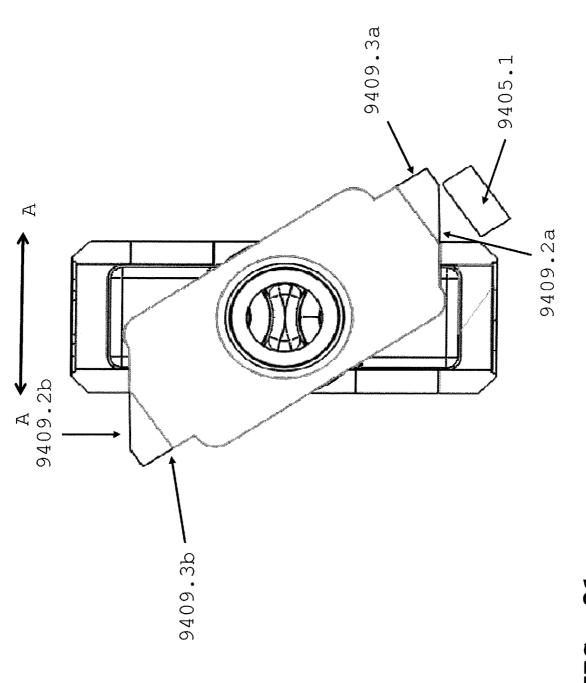


FIG. 31

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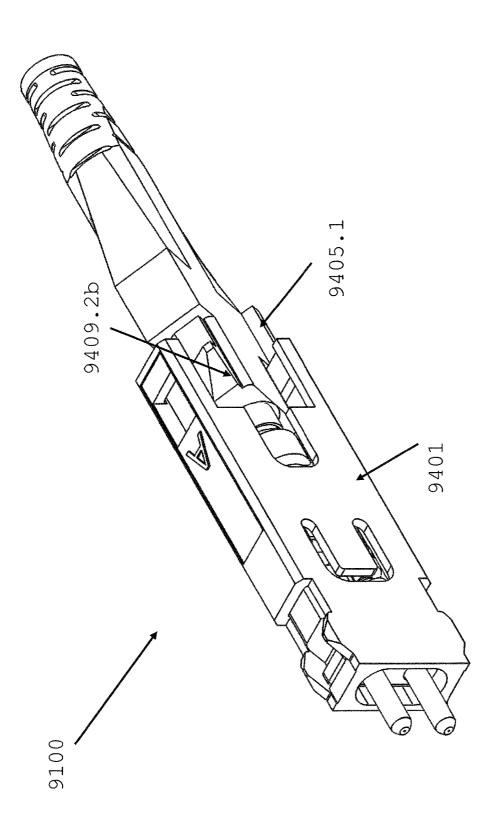
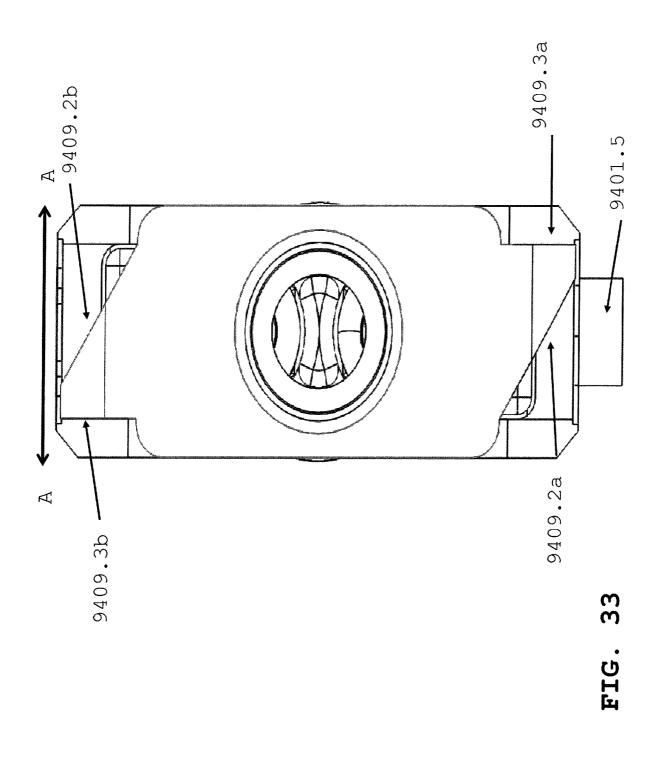
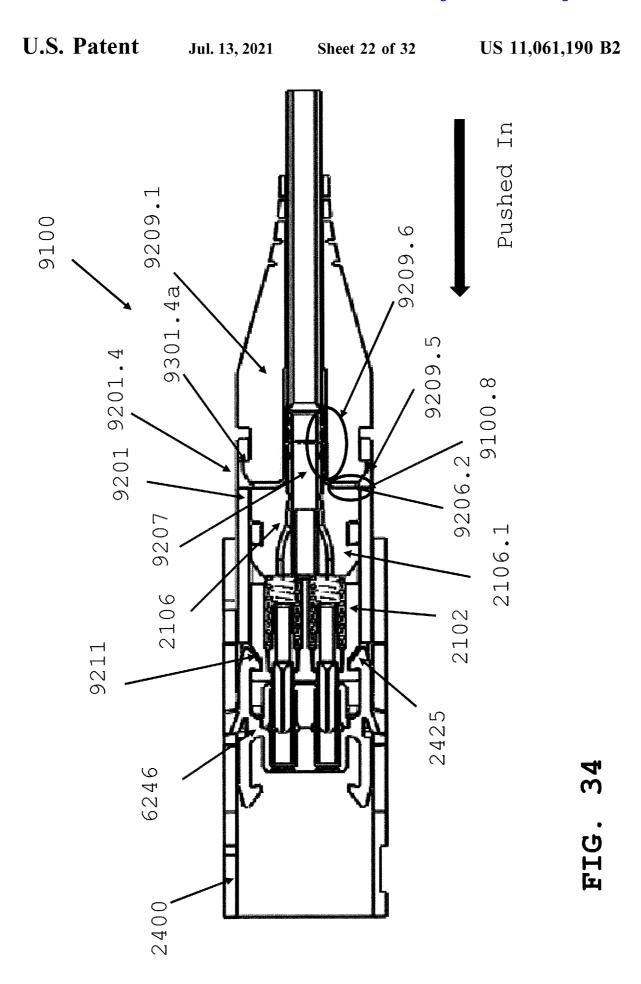


FIG. 32

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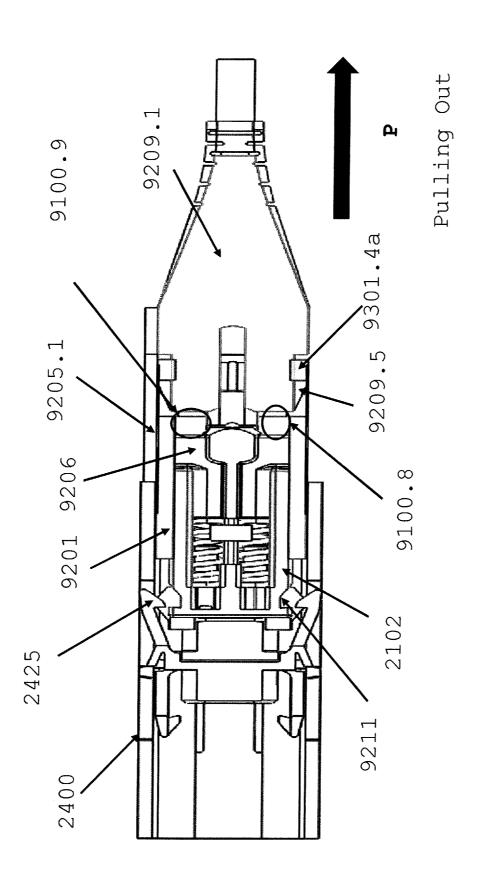


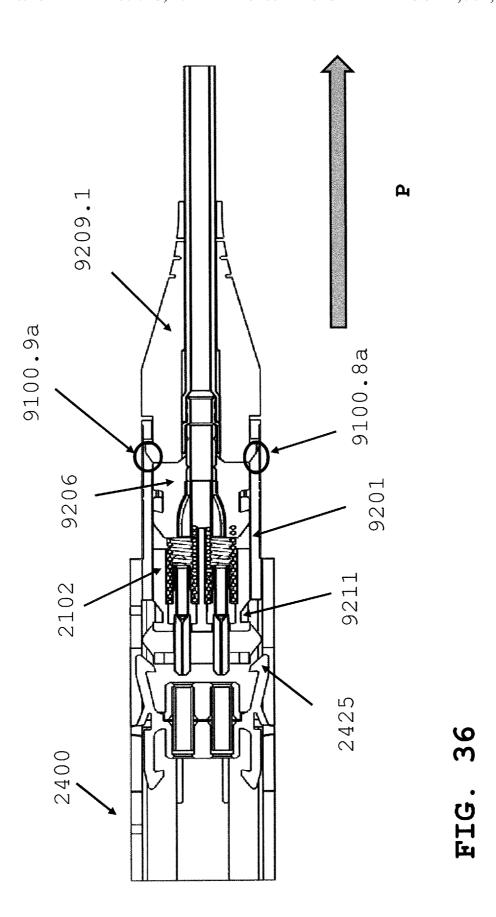
FIG. 35

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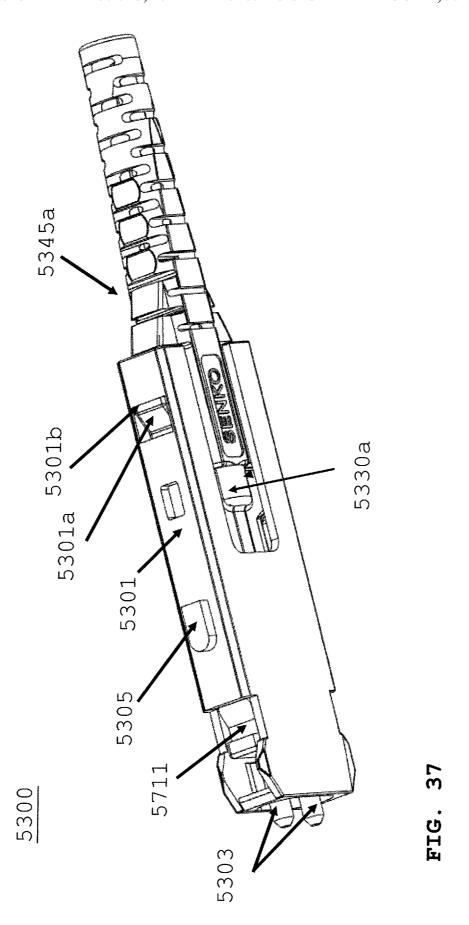
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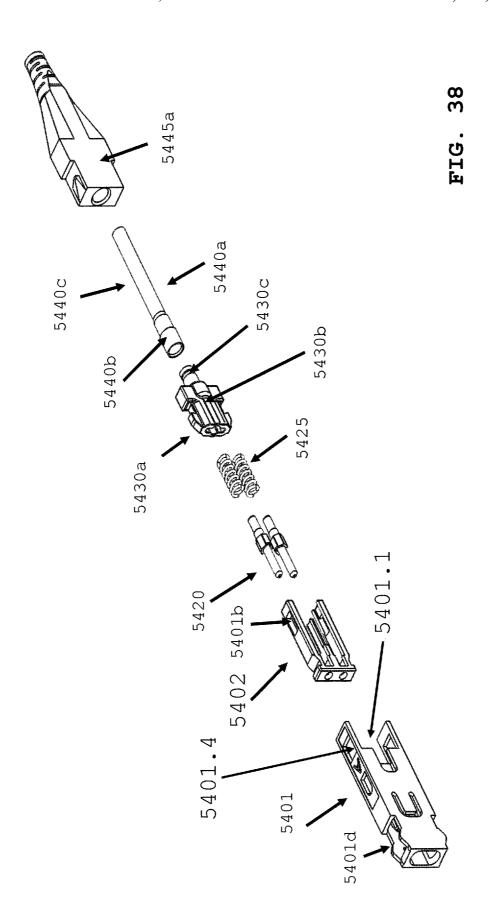
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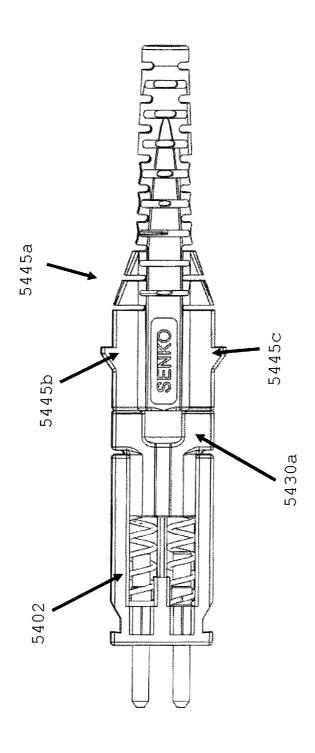


FIG.

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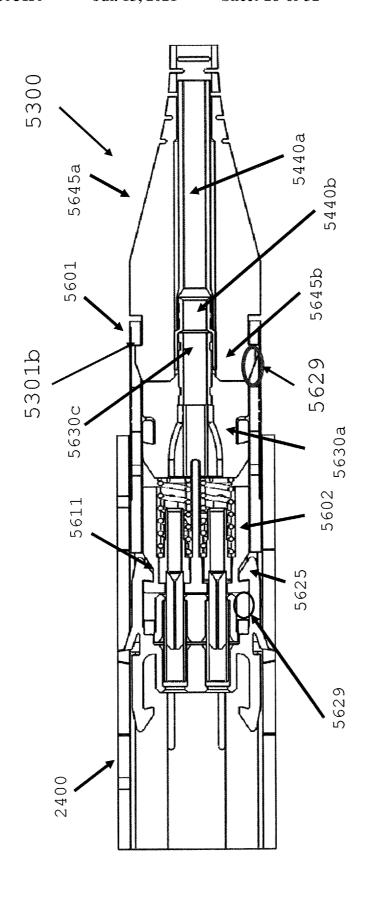


FIG. 4

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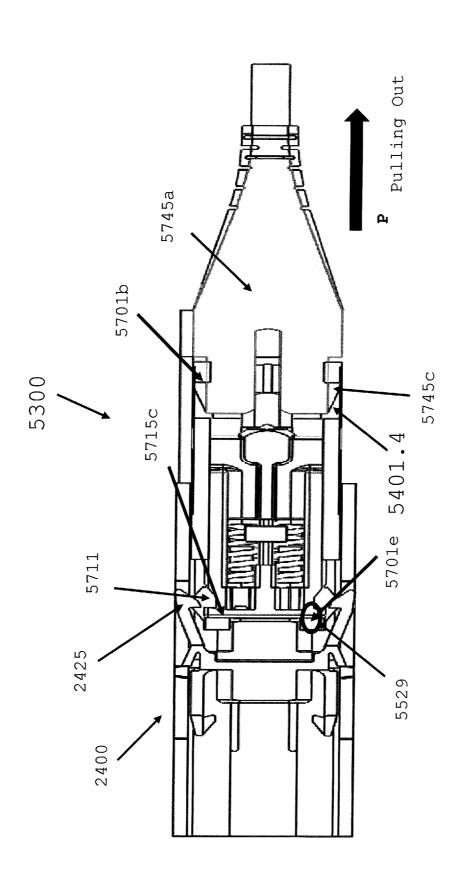


FIG. 4

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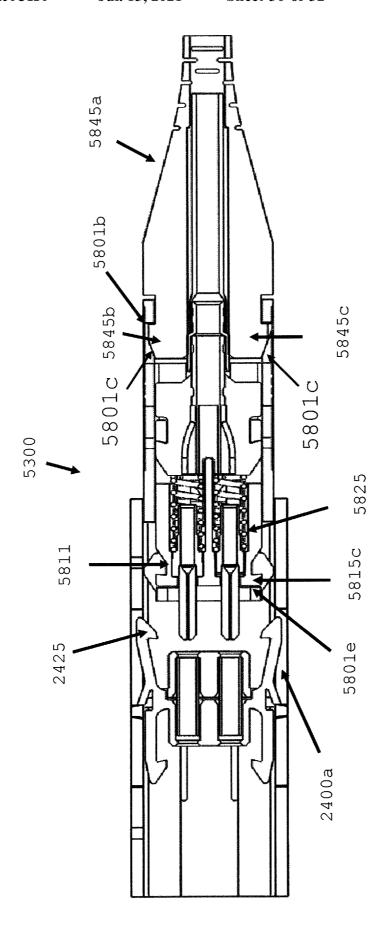
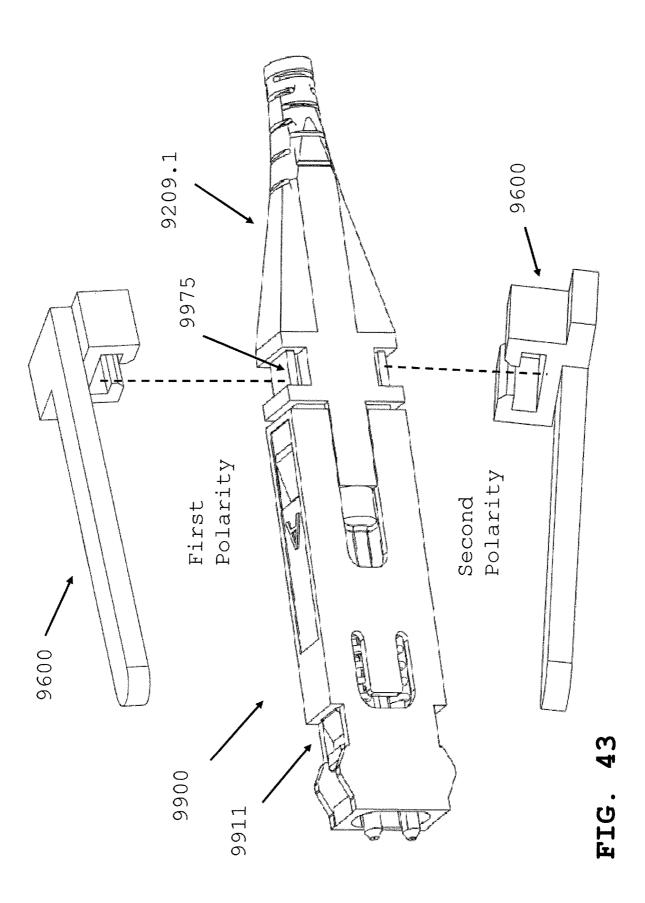
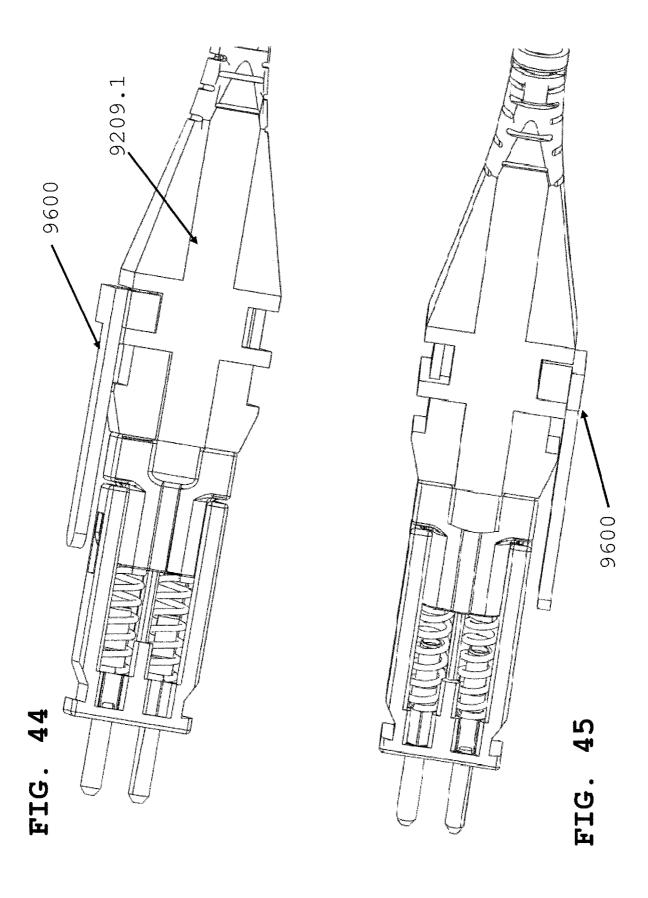


FIG. 42

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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 10 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 Applica- ²⁰ tion 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 30 transceivers.

BACKGROUND

The prevalence of the Internet has led to unprecedented 35 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- 40 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 45 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, robust- 50 ness, 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 55 connectors of FIG. 14. 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 60 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 65 duplex connections of transmit/receive) within the same footprint.

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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. ${\bf 1}$

FIGS. **5-8** depict polarity changing according to an another embodiment of the present invention of a microconnector.

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

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 5 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 15 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 ³⁰ 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". ³⁵

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. 40

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 65 for fiber optic transmission or electrical signal transmission. The connector may be any suitable type now known or later

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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 multifiber 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 60 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.

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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 5 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 20 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 25 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 30 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 35 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 40 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 45 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 50 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 55 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 7500A 60 inserted into an adapter 5700. Adapter 5700 has plural of slots 5700a configured to accept an alignment key 7500A.1 proximal on the alignment and offset key (7500A, 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 7500B with the group of micro connectors 7500A of FIG. 14. Alignment/

offset key 7500B adds stability and reduces misalignment during insertion when key 7500B acts as a support between connectors as shown. Key 75008 also helps determine

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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 9201.4a and 9201.4b 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 9201.3b in connector housing 9201 (refer to FIG. 18) to further secure multipurpose rotatable boot assembly 9109.1 to front body 9202 or outer housing 9201. Multi-purpose rotatable boot assembly 9109.1 comprises a body 9109.1a 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 9201.3b and second slot 9201.4b. 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 9201.4a 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 9201.3b 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 5 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 10 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** 15 and shown in FIG. 20) lifts out of first slot 9201.3b 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 direc- 20 tion 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 25 is shown as it exits the outer housing 9401 of connector 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 9201.3b.

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 35 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 40 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 45 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 50 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 55 "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 60 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 65 further comprises first chamfer 9409.2a and first stopping wall 9409.3a, and second chamfer 9409.2b and second

stopping wall 9409.3b, in a first polarity position. Boot hooks 9109.5 rotate between second slot 9201.4a and second slot 9201.4b during polarity change. Second slot

9201.4a corresponds to the connector being in a "A" polarity position. Likewise, second slot 9201.4b corresponds to the connector being in "B" polarity configuration. Securing protrusion 9405.1 resides in first slot 9201.3a for "A polarity, and then resides in first slot 920i.3b for "B" polarity after boot release 9309.1 rotation.

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Referring to FIG. 28, rotating of the boot assembly is started and chamfer 9409.2a engages connector housing wall 9301.5 and begins to lift first boot wing 9109.5a out of

second slot 9201.4a. Likewise, a second boot wing 9109.5b 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 9201.3a (refer to FIG. 20 and FIG. 21), and boot wing 9109.5a is lifted out of second slot 9201.4a at a top surface and upon 180 degree rotation, securing protrusion 9105.2 (refer to FIG. 20) is accepted into first slot 9201.4b 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 9100. Chamfer 9409.2b 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 9409.2b 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 9409.2b in second slot 9401.4a 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 9301.4a 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 5 distance "d" because boot wing 9209.5 engages outer housing face 9301.4a, 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 10 assembly 9209.1. This distance matches channel distance, FIG. 36, 9100.9a, 9100.8a 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 15 pulled rearward at least this distance.

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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 20 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 5345a at its distal end receiving a fiber cable with 25 a plural of fiber strands therein, and a proximal end configured to connect and secure to back body assembly 5330a secured with outer housing 5301. Outer housing 5301 has alignment key 5305, further has opening 5301a with stop face 5301b that boot wings (5445b, 5445c) (refer to FIG. 38) 30 engage when boot assembly 5345a 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 5445a accepts crimp ring assembly 5440a having protective tube 5440c covering fiber strands and crimp ring 5440b secured to back post 5430c of back body assembly 5430a including back body 5430b. A pair of 40 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 5430a, as described for connector 2100. Front body 5402 is inserted into distal opening 5401.1 of 45 outer housing 5401 with boot assembly wing 5430a secured within a distal opening 5415b 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 5445a is secured on back post 5430c of back body 5430a via crimp ring 5440a, as described in FIG. 38. Wings (5445b, 5445c) secure FIG. 39 assembly within outer housing 5301, 55 and during release of connector 5300 from a receptacle, wings (5445b, 5445c) 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 60 body 5402 is secured to connector housing 5401 with back body 5430a 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 65 connector recess 561.1 formed within front body 5601, at its proximal end. A gap of distance "d" 5629 limits travel of

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front body 5601 as boot release wing 5645b engages stop face 5301b of outer housing 5601. This "d" travel removes hook 5625 from connector recess 5611 thereby unlatching or releasing connector from adapter 2400. Crimp ring 5440b is shown secured to back post 5630c. Back body 5630a is secured within front body 5402 at distal openings 5401b (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 5401d (FIG. 38), as boot assembly 5745a is being pulled rearward or in a distal direction. Gap 5529 is closed as shown in FIG. 41. Inner face of connector housing 5715c is flush with front face of front body 5701e, 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 5745c 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 5845a. In this embodiment, wings (5845b, 5845c) are flush with outer housing wall 5801b. Wings (5845b, 5845c) move within gap or opening 5801c within connector housing outer wall, as boot 5845a is pulled rearward to release connector from adapter 2400 as shown. Spring 5825 biases forward front body face 5815c to be flush with front body face 5801e, when pull force is released from boot assembly. Hook or latch 2425 is displaced from recess 5811, and hook resides in adapter housing gap 2400a 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 releasebly 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

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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 10 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 20 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 25 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 30 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 35 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 40 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 45 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, 50 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**, 55 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 60 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 65 connector upon inserting the fiber optic connector into the adapter;

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- 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

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when the boot assembly is in the second polarity position, the elongate arm is radially spaced apart from the longitu-

dinal 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 15 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 20 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

14 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 seg-

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



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(54) OPTICAL FIBER CONNECTOR WITH CHANGEABLE POLARITY

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CPC .. G02B 6/3895; G02B 6/3831; G02B 6/3885; G02B 6/3825; G02B 6/3893

See application file for complete search history.

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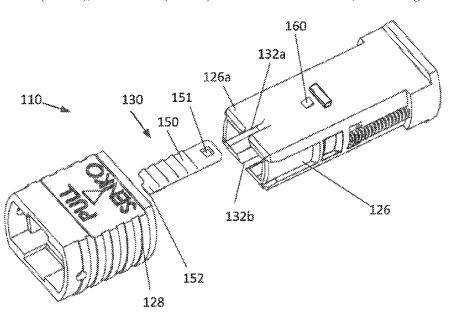
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(57) ABSTRACT

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



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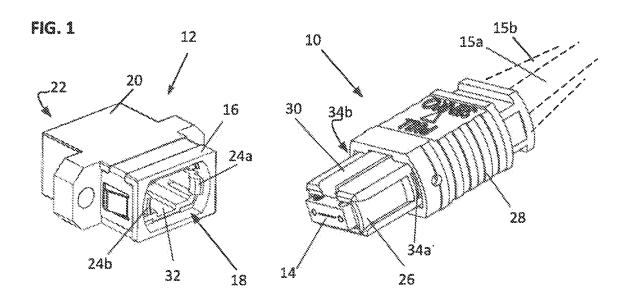
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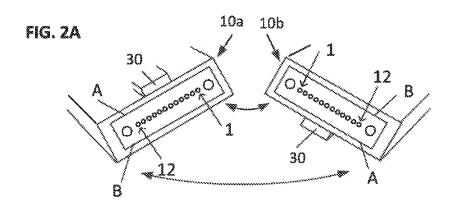
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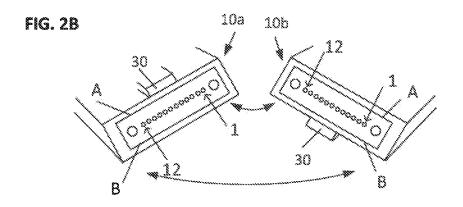
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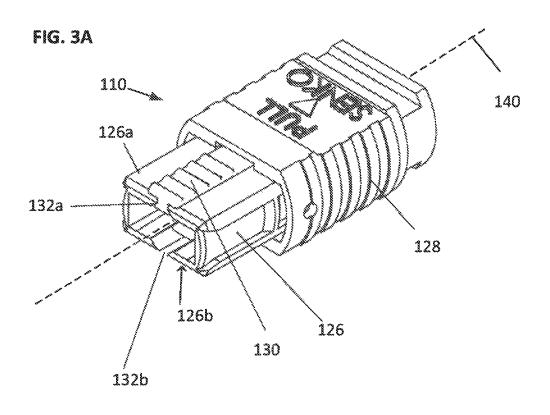


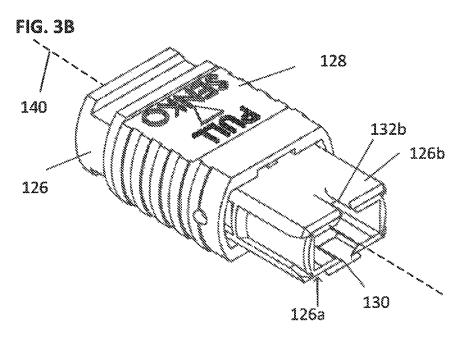




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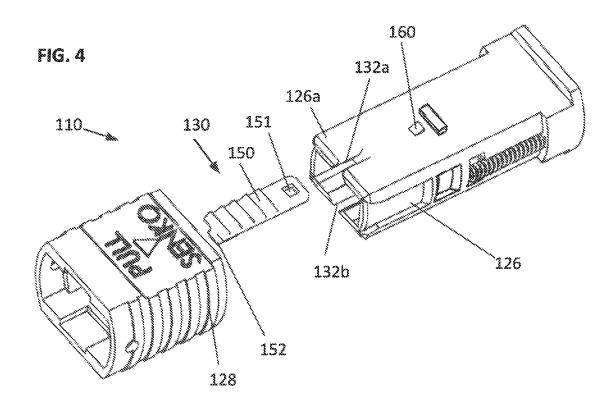
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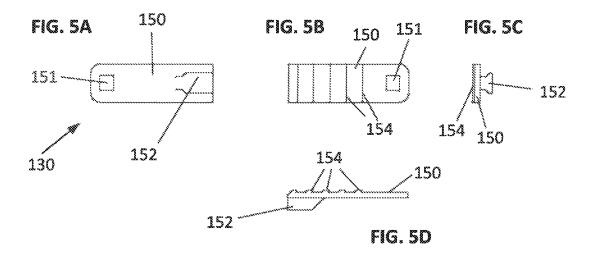




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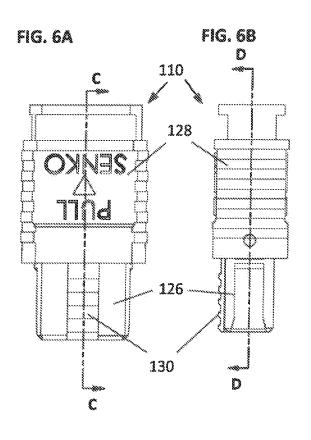
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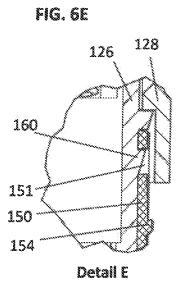


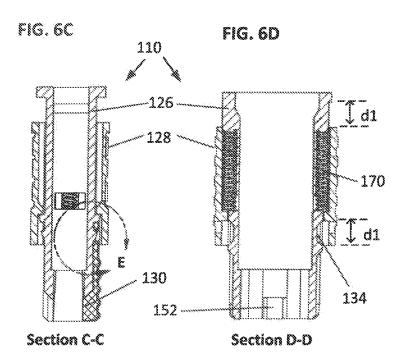


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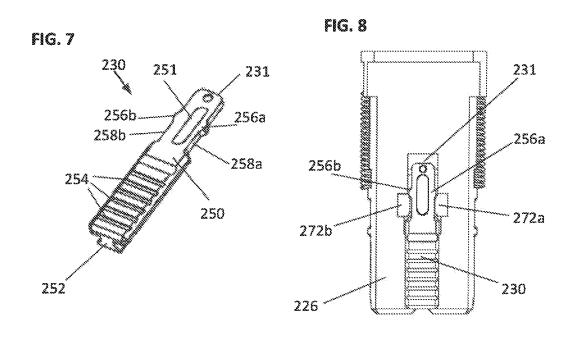


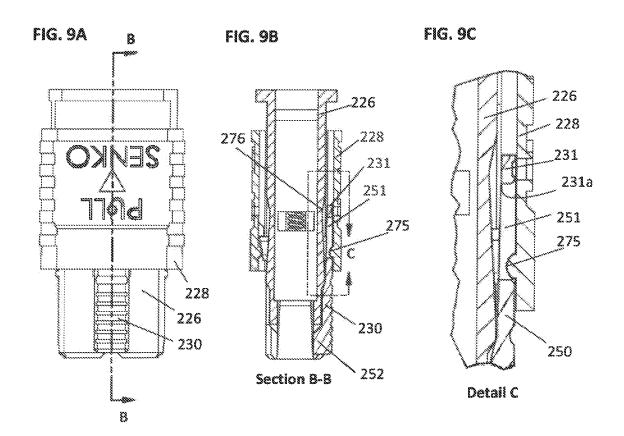




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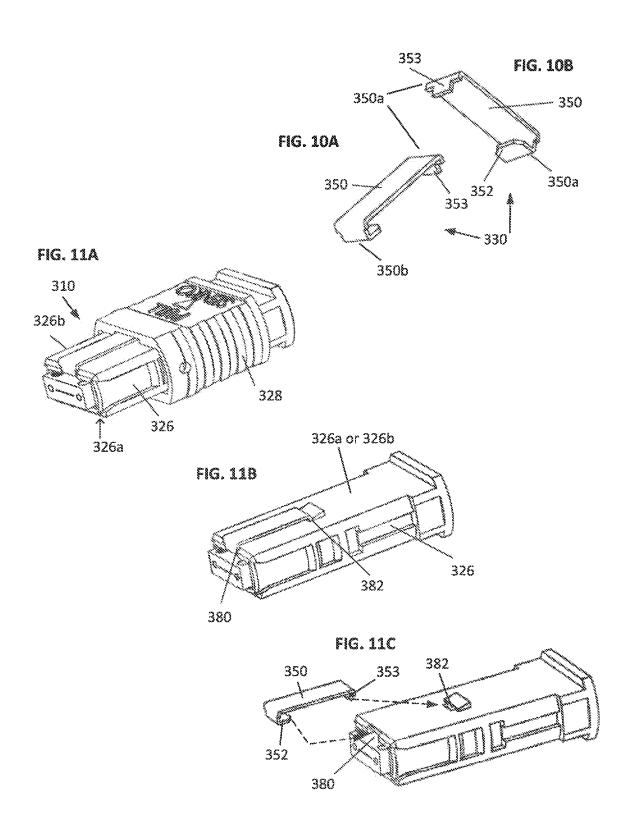
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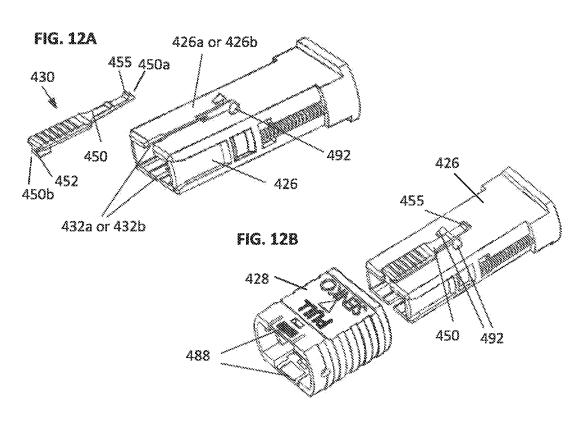
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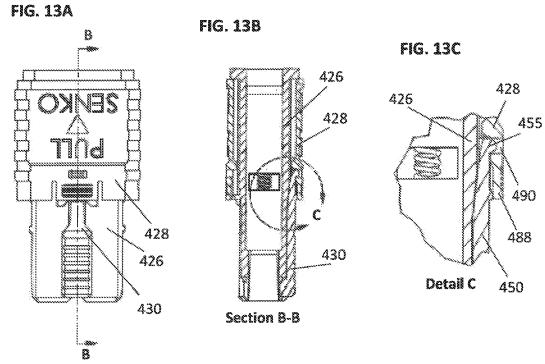
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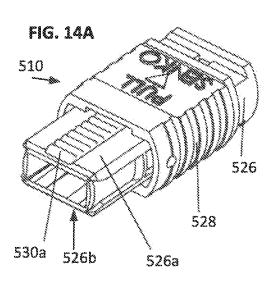
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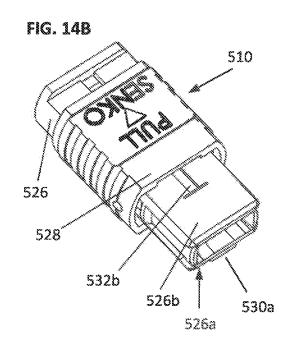


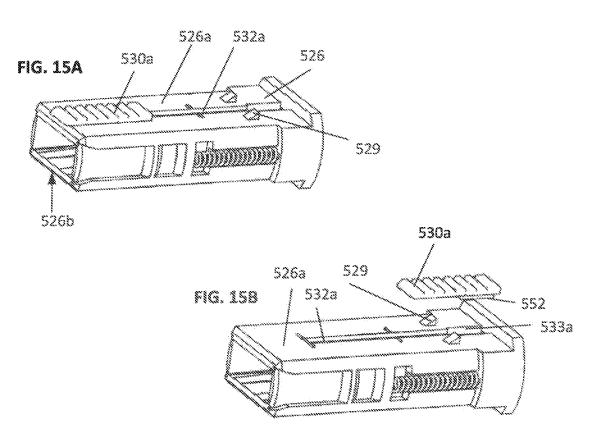


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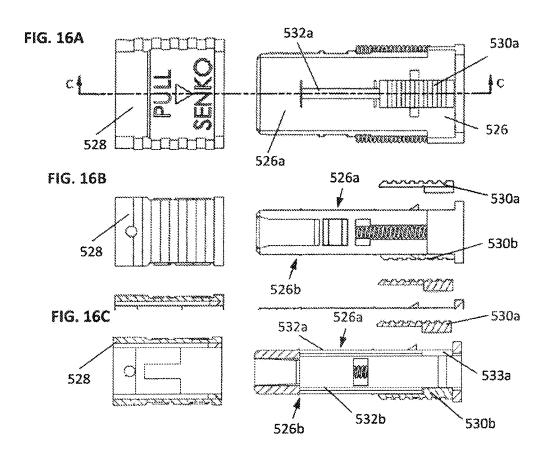


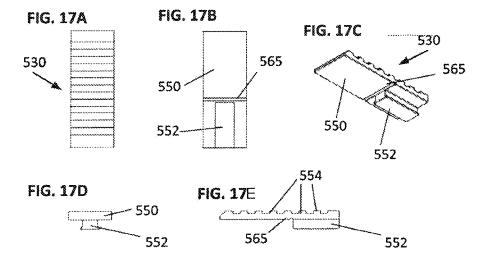




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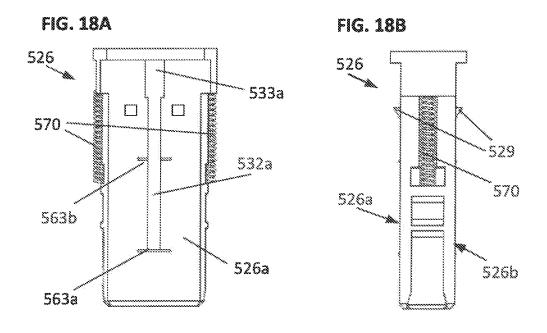
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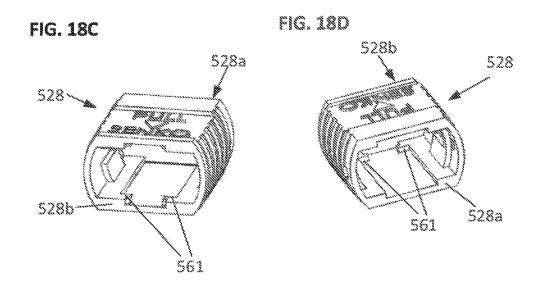




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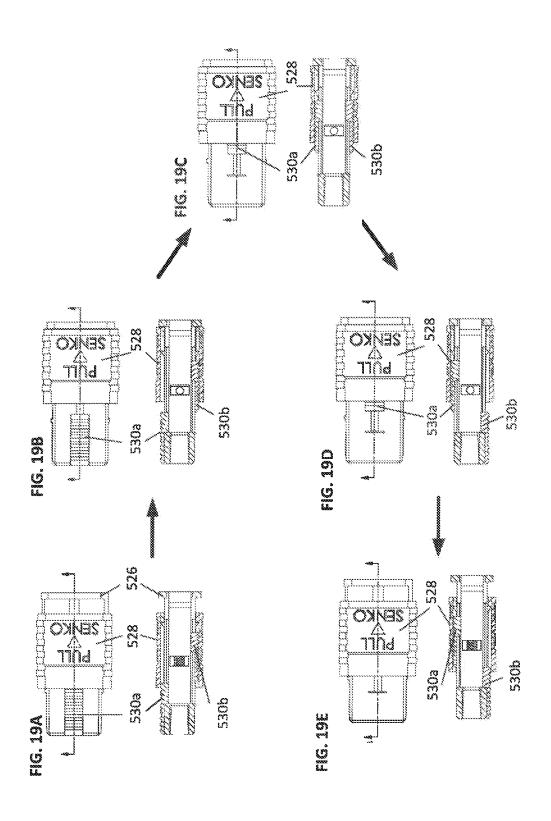
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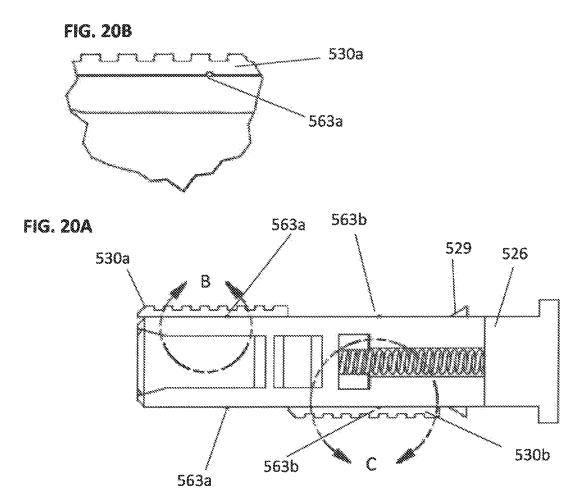
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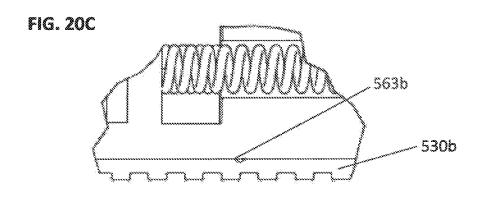
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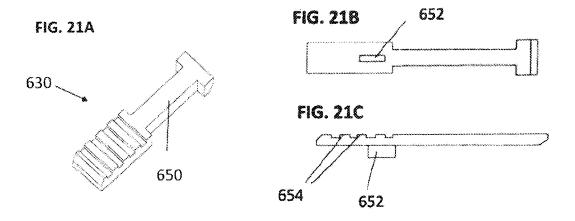
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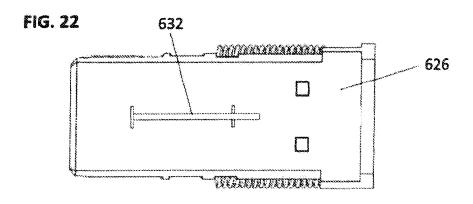




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FIG. 23A

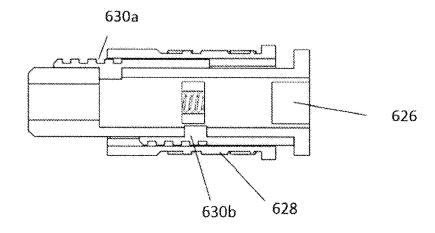


FIG. 23B

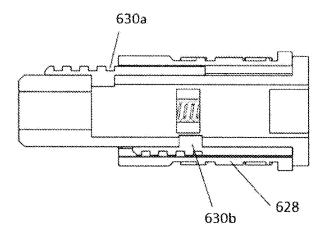
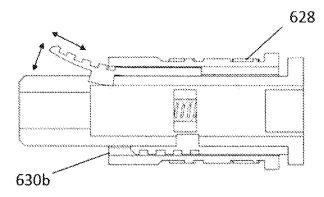
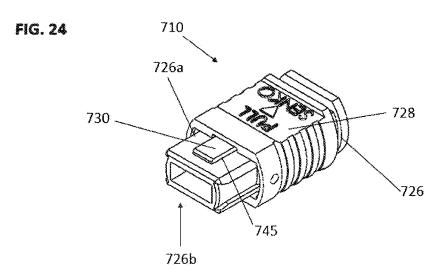


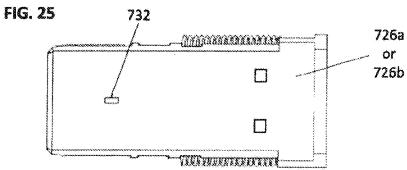
FIG. 23C

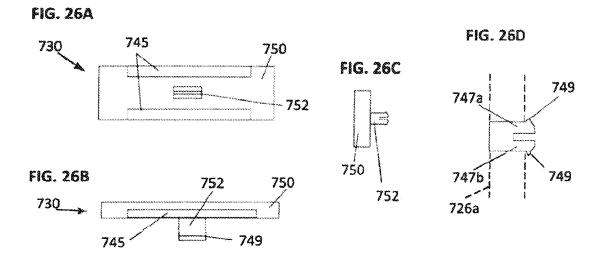


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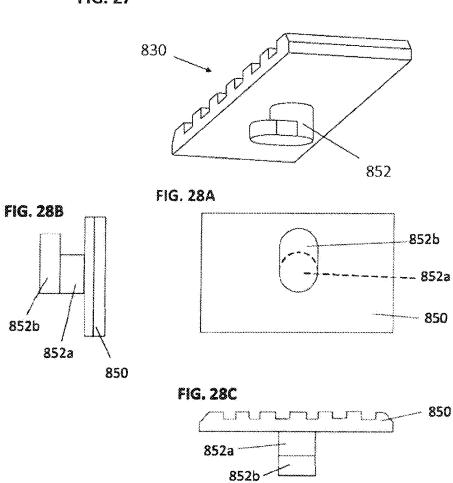


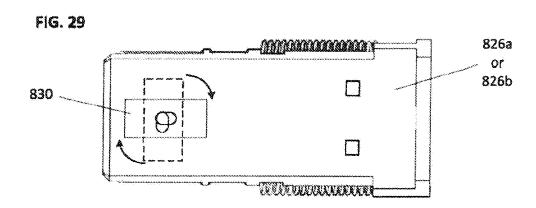


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FIG. 27





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FIG. 30A

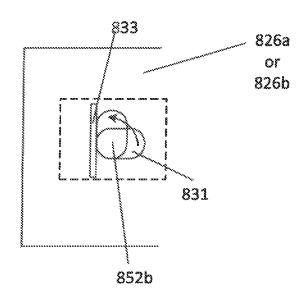
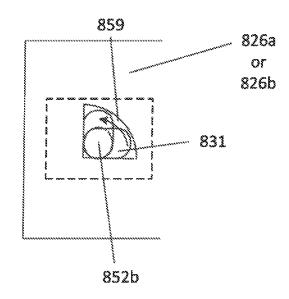


FIG. 30B



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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 10 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 15 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 25 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 30 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 35 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 40 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 45 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 60 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 65 make it difficult to change the polarity of the connection on site

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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 20 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

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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 $_{15}$ 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 con- 20 nector. 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 25 key according to an embodiment. second opposite polarity for the fiber optic connector.

BRIEF DESCRIPTION OF THE FIGURES

FIG. 1 depicts perspective views of an MPO connector 30 and adapter according to an embodiment.

FIGS. 2A and 2B depict mating/polarity configurations of MPO connectors according to an embodiment.

FIGS. 3A and 3B are representative top and bottom perspective views of a fiber optic connector housing with a 35 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. 3A and 3B.

FIGS. 5A-5D are bottom, top, end and side views of a key according to the embodiment of FIGS. 3A and 3B.

FIGS. 6A-6E are face, side, cross-sectional and detail views of the fiber optic connector housing according to the embodiment of FIGS. 3A and 3B.

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. 9A-9C are face, cross-sectional and detailed views 50 of a connector of the embodiment of FIG. 8.

FIGS. 10A and 10B are different perspective views of an alternative key according to embodiment.

FIGS. 11A-11C are various views of a connector with the key of FIGS. 10A and 10B according to an embodiment.

FIGS. 12A and 12B are different perspective views of an alternative key according to an embodiment.

FIGS. 13A-13C are various views of a connector with the key of FIGS. 12A and 12B according to an embodiment.

FIGS. 14A and 14B are perspective views of a connector 60 with movable keys according to an embodiment.

FIGS. 15A and 15B are views of components of the connector of FIGS. 14A, 14B with the outer housing removed according to an embodiment.

FIGS. 16A-16C show top, side and cross-sectional views 65 of the connector or FIG. 14A, 14B according to an embodiment.

FIGS. 17A-17E are various views of the moveable key of FIGS. 14A, 14B according to an embodiment.

FIGS. 18A-18D show views of the inner and outer housing components of the connector of FIGS. 14A, 14B according to an embodiment.

FIGS. 19A-19E show sequential views (top and crosssectional) of the process of switching the polarity of the connector of FIGS. 14A, 14B according to an embodiment.

FIGS. 20A-20C show side and detailed views of the connector of FIGS. 14A, 14B according to an embodiment.

FIGS. 21A-21C 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. 21A-21C according to an embodiment.

FIGS. 23A-23C show cross-sectional views of a connector assembly with the keys of FIGS. 21A-21C 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. 26A-26D 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

FIGS. 28A-28C 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. 30A and 30B 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 40 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 15a and cable boot 15b (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 5 of fiber optic device therein.

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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 24a, 24b 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 26a, 26b to mount the adapter via 15 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 20 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 25 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 30 housing 26 may slide into port 18 until tabs 24a, 24b engage into slots 34a, 34b of the inner housing. The outer housing 28 may be moved towards the second end to allow the tabs 24a, 24b to engage into slots 34a, 34b, and to retain the tabs in the slots, the outer housing may be slid back towards the 35 first end and over the tabs. The outer housing 28 may be biased towards the first end via springs (shown for example in FIG. 6D) or alternative types of biasing devices.

FIGS. 2A and 2B represent the two different modes of connection alignment to provide for the two different modes 40 of polarity. FIG. 2A may be indicated as representing what may be termed a 'normal' polarity wherein fiber No. 1 of the connector 10a may mate with fiber No. 1 of connector 10b, and similarly, fiber No. 12 of the connector 10a may mate with fiber No. 12 of the connector 10b. For this type of 45 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 10a, 10b, as shown in FIG. 2B, the key 50 position of the key 30 of connector 10b would need to be changed to the opposite surface for reversed alignment in an adapter 12, fiber No. 1 of the connector 10a may mate with fiber No. 12 of connector **10***b*, and similarly, fiber No. 12 of the connector 10a may mate with fiber No. 1 of the con- 55 nector 10b. Alternatively, the key 30 of the connector 10a 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 60 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 65 and any cable and cabling components are omitted. The connector may include an inner housing 126 and an outer

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housing 128. The inner housing may have a top side wall 126a and a bottom side wall 126b 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 126a and 126b may be similar, or essentially the same, and each side wall may include a corresponding slot 132a and 132b 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 132a and 132b. The key 130 may be configured in conjunction with the walls 126a and 126b to be removably attached with either the top wall 126a or the bottom wall 126b. In an embodiment, when key 130 is disposed with the top wall 126a, 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 126b, 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. 3A and 3B. In an embodiment, as shown in greater detail in FIGS. 5A-5D, 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 132a, 132b 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 132a, 132b 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 132a, 132b 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. 5C 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 132a or 132b, 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. 6A-6F. FIGS. 6A and 6B show representative face and side views of the connector 110 with the key 130 installed. FIG. 6C is a cross-sectional view along line C-C in FIG. 6A, and FIG. 6D is a cross-sectional view along line D-D in FIG. 6B. 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. 6D. Tabs 129, as shown in detail in FIG. 6E, may be configured to limit forward

movement of the outer housing 128 along the inner housing

The outer housing 128 may be moved rearwardly on the inner housing by a distance d1. Movement of the outer housing over the distance d1 provides access to the slots 134 for engagement into the slots of adaptor tabs (such as tabs 24a, 24b in FIG. 1) for engagement of the connector 110 within an adapter. Similarly, the outer housing 128 may be displaced by the distance d1 to release the adapter tabs for removal of the connector 110 from the adapter. FIG. 6E 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. 6E, the second end of the body 150 may fit between the inner housing 126 and 20 outer housing 128. As such, in an embodiment, the outer housing 128 may be displaced by the distance d1 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 25 released from the projection 160. To remove the key 130, the outer housing 128 may be slid rearwardly by the distance d1 to provide clearance for lifting of the key body 150 outwardly away from around the projection 160 as shown in FIG. 6F.

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 35 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 embodi- 40 ment, 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 45 configuration for releasably retaining the key 230 with the inner housing 226 may include lateral tabs 256a, 256b 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 258a, 258b. The top or bottom surface 226, 50 in addition to having slots for receiving the guide rail 252 (not shown, but essentially similar to slots 132a, 132b in FIG. 4), may include projections 272a, 272b configured to straddle the key body 250 wherein the width between the projections may be substantially the same as the width of the 55 key body between the lateral recesses 258a, 258b.

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 60 deflected inwardly to allow for the tabs to pass between the projections 272a, 272b. 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 256a, 256b to permit the tabs to 65 move past the projections 272a, 272b. Once past the projections 272a, 272b, the tabs 256a, 256b 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.

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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. 9A-9C) 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 272a, 272b.

FIGS. 9A-9C 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 231a 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. 9B and 9C, 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. 10A and 101B. 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 350a and a second end 350b. A connector 310 in conjunction with a key 330 is represented in FIGS. 11A-11C. At the front end 327, each of the sidewalls 326a and 326b may include a recess or notch 280 that is configured to receive the second end of the key 330 therein. The second end 350b 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 326a and 326b, and may prevent movement transversely away from the housing, or a lifting off from the housing via the second end.

The first end 350a of the key 330 may include a tab 353 that extends substantially orthogonally from the body 350.

As represented in FIGS. 11B and 11C, 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. 11A, outer housing 328 may prevent the first 5 end 350a of the key 330 from being lifted away from the

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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 10 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 15 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 350a 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 20 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 25 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 450b. The guide rail 452 may be configured to engage in a slot 432a, 432b of the inner housing 426 in a manner as described earlier with regard to 30 FIGS. 6A-6E. 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. 13C, the outer housing 428 may include a receptacle 490 into which the 35 projection may extend when the outer housing is in place around the inner housing 426.

Similar to earlier embodiments, the second end 450b of the key 430 may be retained in the slots 432a, 432b in the lateral and transverse directions by the configuration of the 40 guide rail 452. The second end 450b may essentially be movable in only the longitudinal direction upon insertion or removal of the key 430. When inserted, the first end 450a of the key 430 may be held in place from lateral movement by a pair of projections 492 extending from the inner housing 45 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 450a to release the projection 455 from engagement in the receptacle 50

In an alternative embodiment, as shown in FIGS. 14A, **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 connector 510 may be configured so that each sidewall 526a, **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. 60 Each sidewall **526***a*, **526***b* may include a longitudinal slot 532a, 532b 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 530a or 65 530b may be positioned forwardly in the slots 532a, 532b, while the other is positioned out of the way, or hidden under

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the outer housing. In an embodiment, the width of the slots 532a, 532b may widen in a direction from the external surfaces of the housing to the internal surface.

As shown in FIGS. 17A-17E, 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. 5A-5D. 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 532a, 532b may include an enlarged entry port 533a, 533b that has a width sufficient to allow for passage of the guide rail 552 therethrough. FIG. 16B shows the key 530a disposed over the slot 532a with the guide rail 552 over the entry port 533a, and the key 530bdisposed within the slot 532b. Once inserted through the entry ports, the keys 530a, 530b may be displaceable longitudinally along the slots 532a, 532b, 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. 18A-18D 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 528b 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. 19A-19E represent the operation of the displaceable keys 530a, 530b in relation to the displaceable outer housing 528 and inner housing 526. FIG. 19A represents a connector configured with a first polarity with key 530a in a forward 'active' position and key 530b 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. 19B. After displacing the outer housing 528, key 530 will be partially exposed. Key 530a may be slid rearwardly out of its 'active' position into its 'inactive' position and, as shown in FIG. 19C, both keys may be in their 'inactive' position. Key 530b may be slid forwardly out of its 'inactive' hidden position into its 'active' position as shown in FIG. 19D, and the outer housing 528 may be released to return to its forward position as represented in

While the above-described sequence represents one mode face of the top or bottom sidewalls of the connector, a 55 of switching the polarities, the sequence of movements may be altered. For example, key 530b may be moved forwardly prior to moving key 530a rearwardly. To hold the keys 530a, **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. 20A-20C, (see also FIG. 18A) the exterior surfaces of walls 526a, 526b may include a ridge 563a positioned corresponding to the forward position of a key, and a ridge 563b positioned corresponding to a rearward position of a key. The keys 530a, 530b, as represented in FIGS. 17A-17E may include a corresponding slot 565 (FIGS. 17B, 17C, 17E) for engaging with either of the ridges 563a or 563b depending on the

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location of the key. Each key 530a, 530b 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 5 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 10 and recesses, similar to projections 256a and recesses 258a may be provided on the sides of a key 530a, 530b and the housing surface could include a projection such as projections 272a, so that a similar engagement as previously described may be provided for positioning of the keys on the 15 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 20 key 630 may have a longer body 650 so that more than half of the length of the body, for example about 3/5 to about 2/3 of the key body, will be covered by the outer housing 628, as depicted in FIG. 23A, when the outer housing is in its rest, or forward position. With this type of configuration, the 25 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 30 bottom surfaces of the inner housing 626 may essentially be identical.

Since at least, for example, about 3/s of the length of the key 630 may be disposed between the inner housing and the outer housing, the outer housing will essentially prevent 35 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 630a in FIG. 23A in its forward, or 'active' position. In this position of the outer housing 628, the key 630b will essentially be hidden in its 40 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 45 FIG. 23B. In this embodiment, for example, only \(^{1}\)3 to \(^{2}\)5 of the 'active' key may then be covered by the outer housing. In this position of the outer housing 628 the 'inactive' key 630b may be exposed for engaging the key to pull the key forward, if desired. The 'active' key 630a may by pushed 50 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. 23C, when the outer housing 628 is in its rearward position, the keys 630a and/or 630b may be removed from the connector or inserted 55 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, 60 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 65 member **752** that is configured to fit into the slot **732** and retain the key **730** in engagement with the inner body **726**.

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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 747a and 747b 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 747a, 747b may return to their natural position. One or both of the leg portions 747a, 747b 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. 26D, with an inner housing wall depicted in outline, when the leg portions 747a, 747b 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 28A-28C, 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 852a that extends from the body portion 850 and an arm portion 852b that extends away from the shaft portion. In an embodiment, the arm portion 852b may extend from the shaft portion 852a to only one side of the shaft as shown. Alternatively, the arm portion 852b and shaft portion 852a 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 826a and 826b may include a corresponding passage 831 having a size and shape configured for passage of the arm portion 826b therethrough. The shaft portion 852a 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 826a and 826b at least in the vicinity of the passage 831. The arm portion 852b, may thereby engage with an inner surface of the top or bottom walls 826a and 826b after being inserted through the passage 831 and then rotated about the shaft 852a as represented in FIG. 29.

As shown in FIG. 29, the key 830 may be attached to either of the top or bottom walls 826a and 826b 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 826b 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 826b 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 826a and 826b

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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 5 be rotated back to its transverse position (dashed line), lifted from the top or bottom walls 826a, 826b, 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. 30A, which, upon rotation of 10 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. 18A and 20A. 20 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 25 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 852a 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 35 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, 40 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 45 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 embodi- 50 ments 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, 55 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 60 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 65 herein, will be apparent to those skilled in the art from the foregoing descriptions. Such modifications and variations

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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

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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, 10 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, 15 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 20 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 descrip- 25 tion, 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. 30 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 35 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 40 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 55 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 60 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 65 groove and the second elongate groove to selectively and releasably position the polarity change element on

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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 con-

nector 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

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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 ⁵ 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 a 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**, ²⁵ 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 45 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 50 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 55 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 60 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 65 positioning the polarity change element on the second exterior wall such that the key portion is externally

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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.

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- 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**, ¹⁰ 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**, ²⁰ 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, ²⁵ 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, ³⁰ 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

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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



(12) United States Patent

Chang et al.

(54) BEHIND THE WALL OPTICAL CONNECTOR WITH REDUCED COMPONENTS

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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)

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(58) Field of Classification Search

None

See application file for complete search history.

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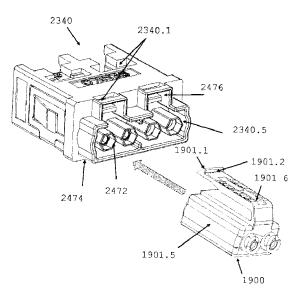
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(57) ABSTRACT

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



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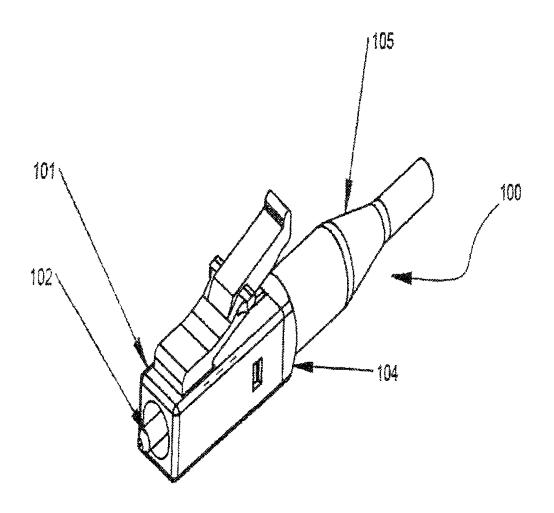


FIG. 1

Prior Art

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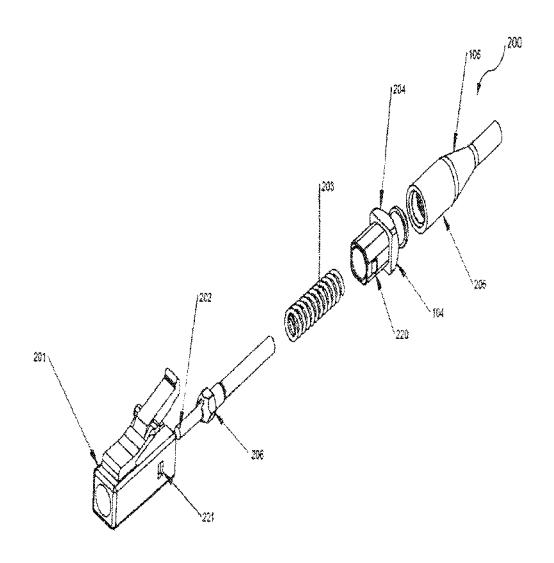
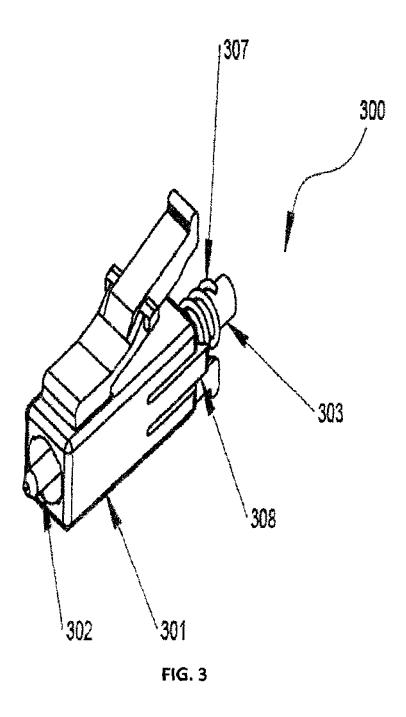


FIG. 2 Prior Art

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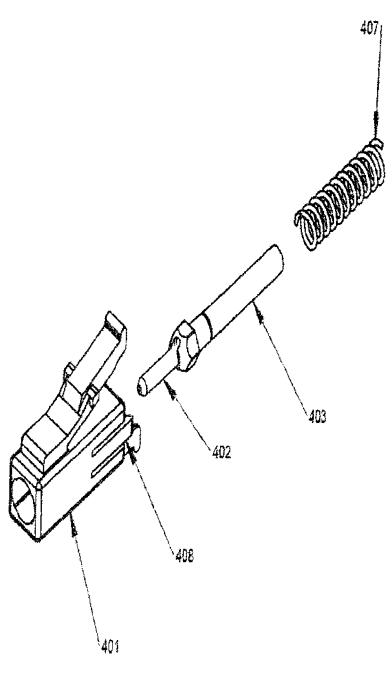


FIG. 4

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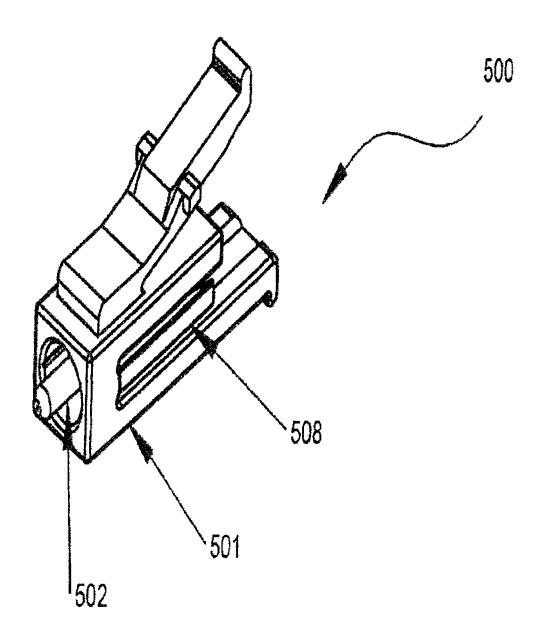


FIG. 5

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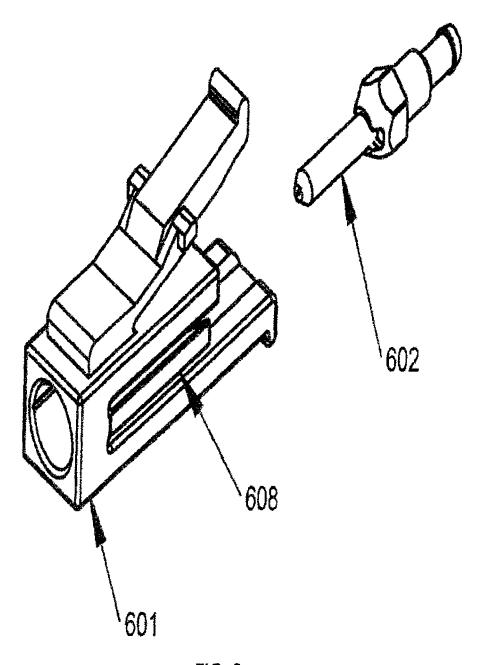


FIG. 6

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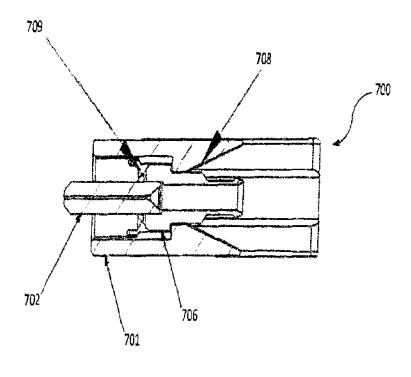


FIG. 7

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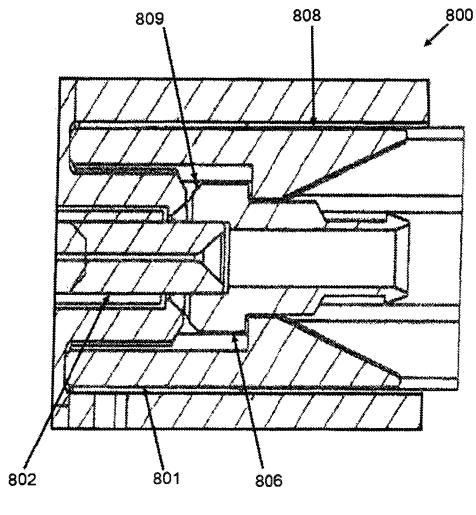
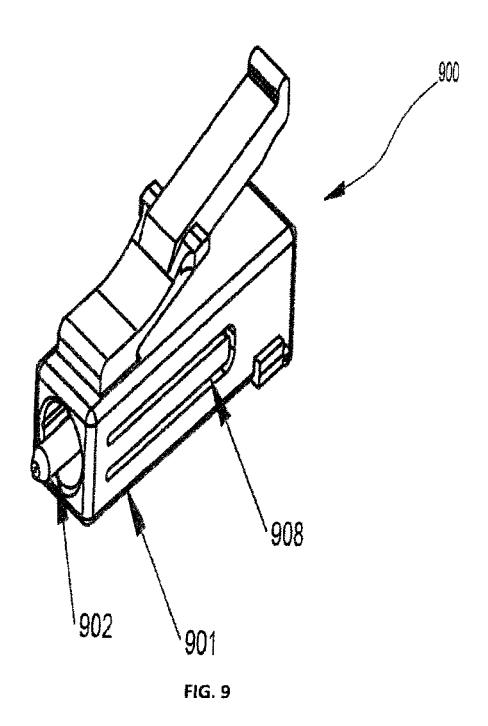


FIG. 8

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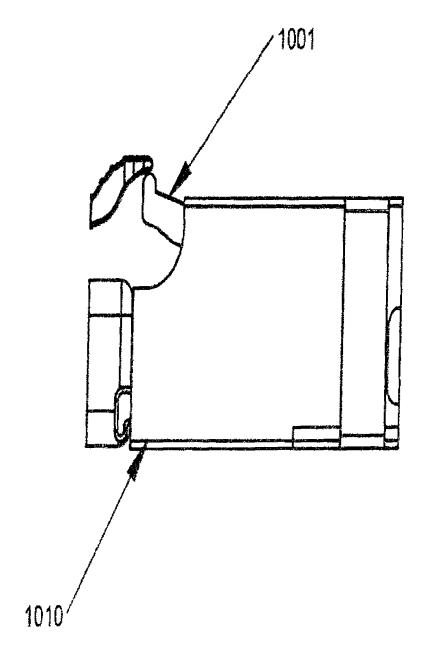


FIG. 10

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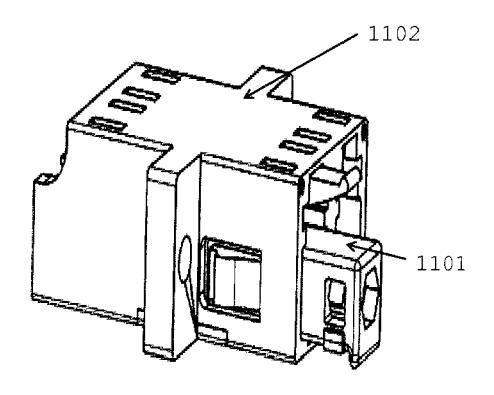


FIG. 11A

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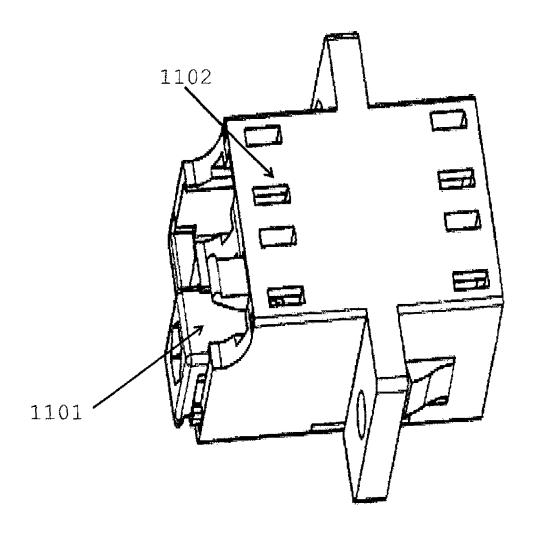


FIG. 11B

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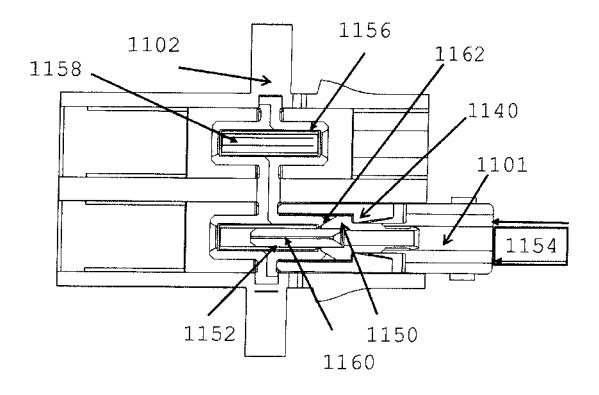


FIG. 11C

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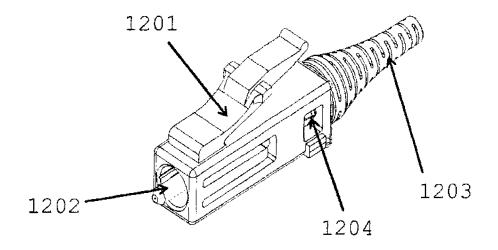
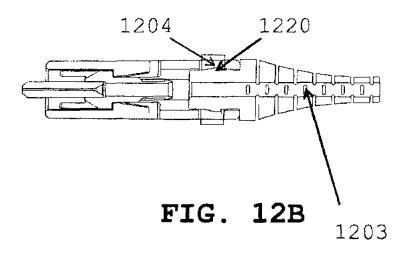


FIG. 12A



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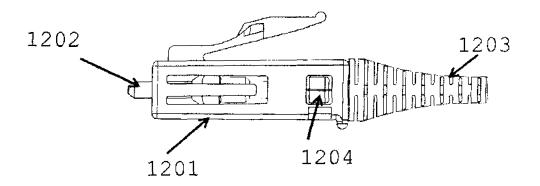


FIG. 12C

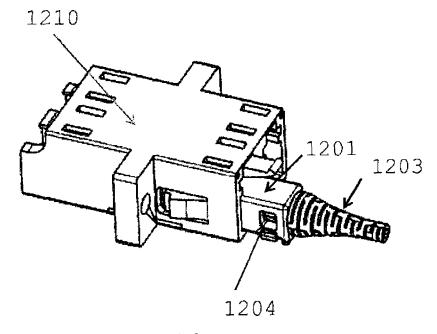


FIG. 12D

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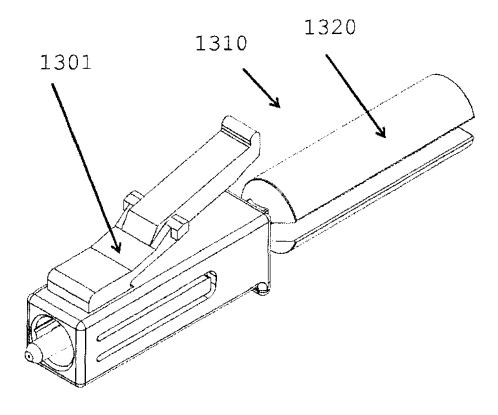


FIG. 13A

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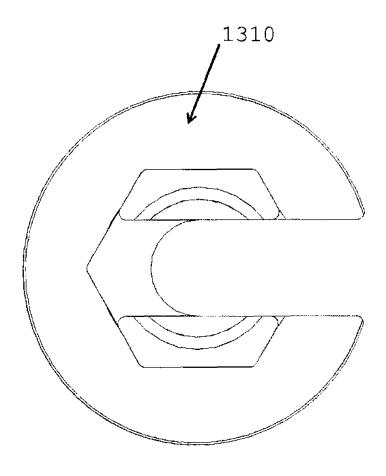


FIG. 13B

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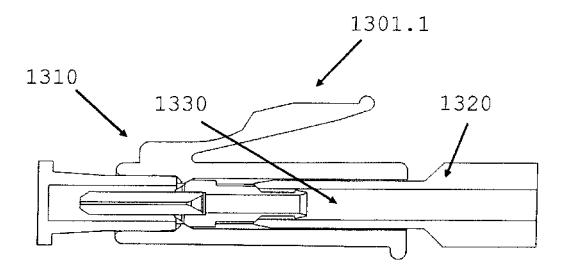
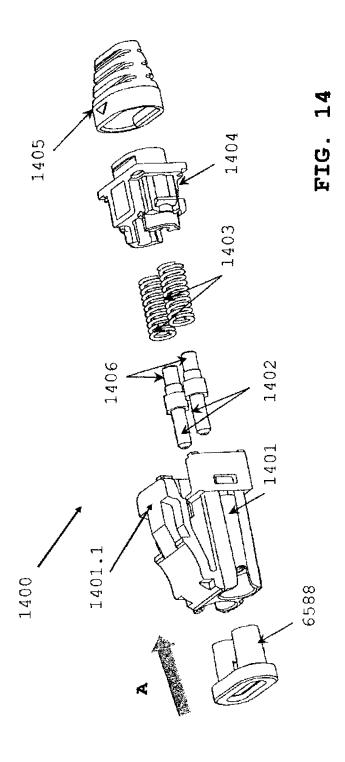


FIG. 13C

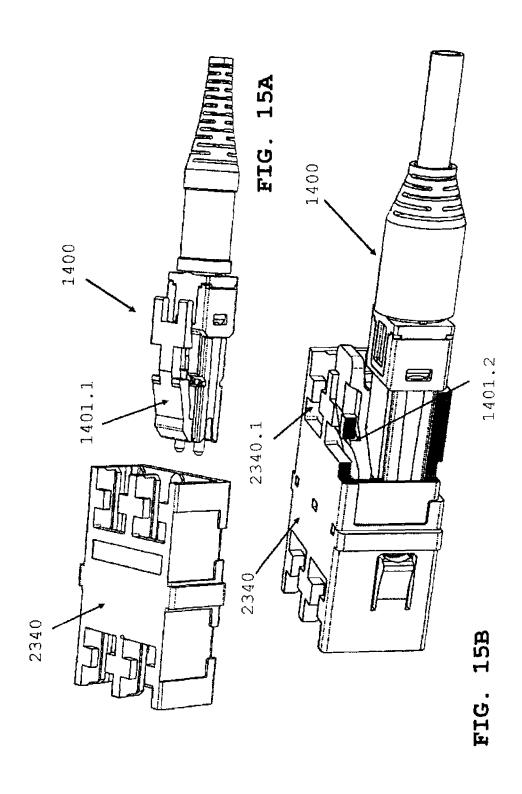
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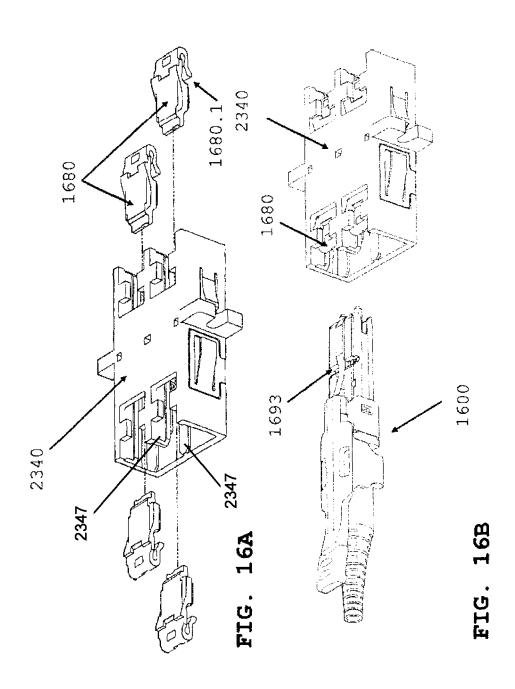
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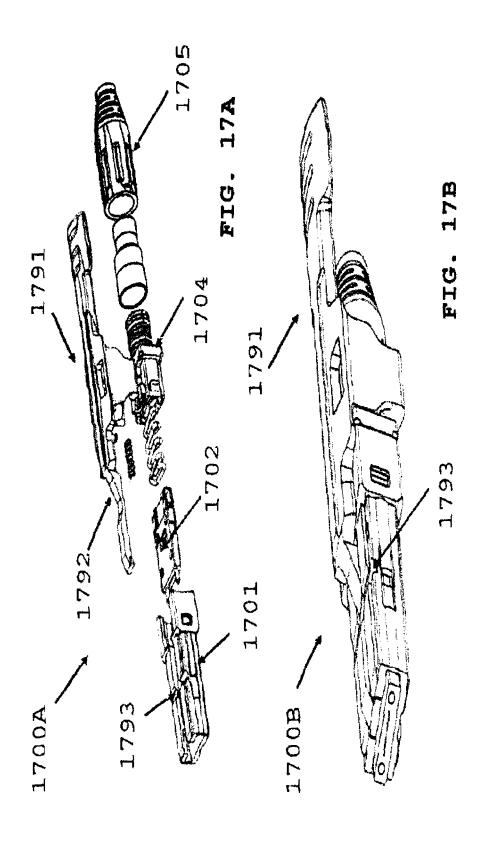
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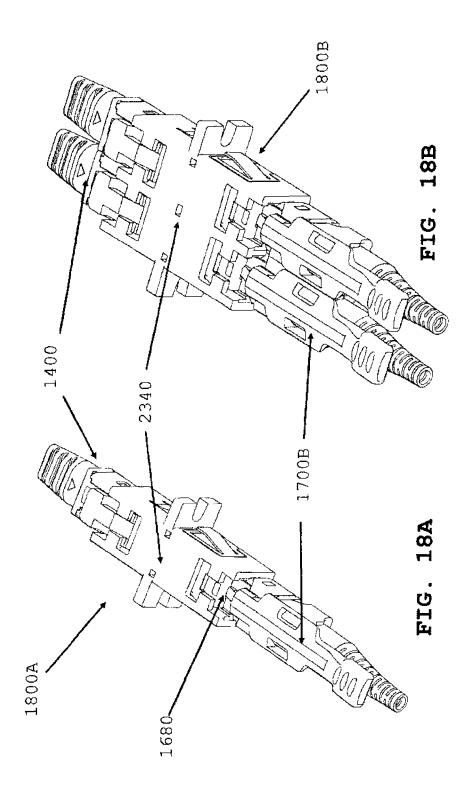
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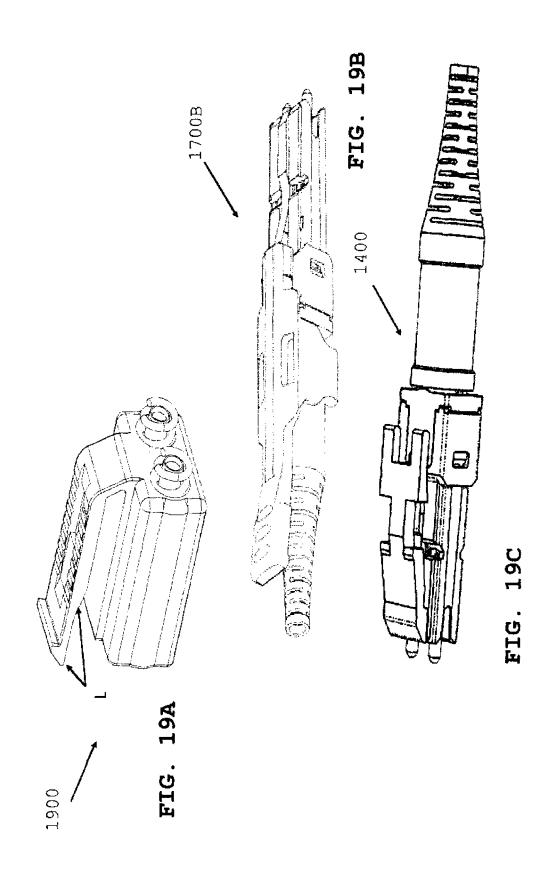
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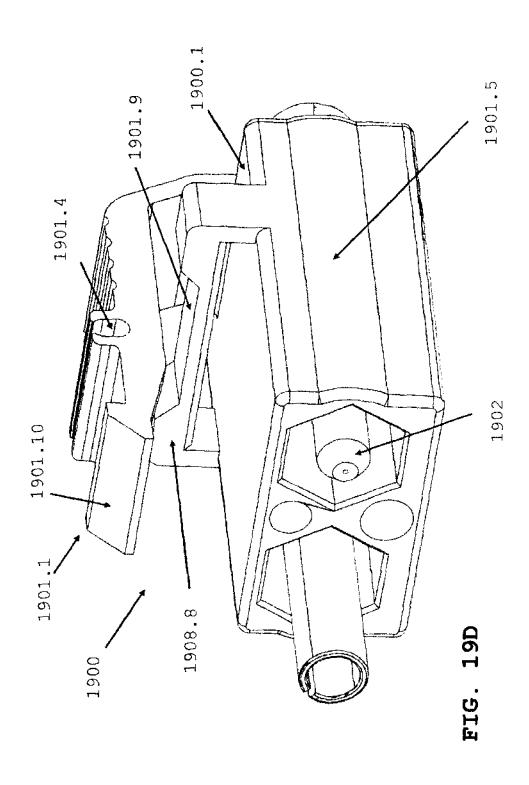
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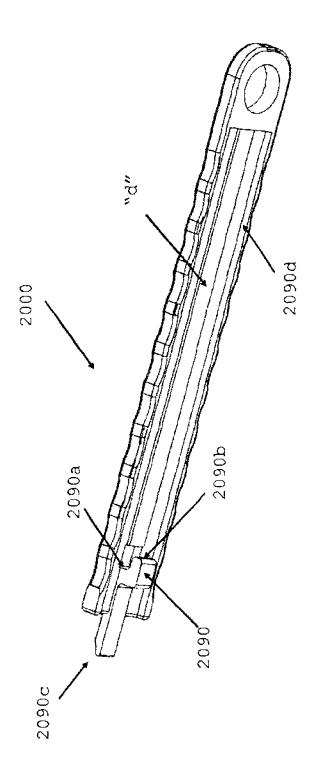
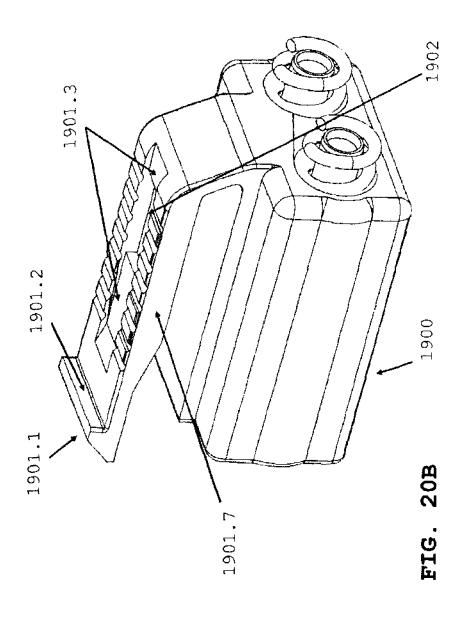


FIG. 201

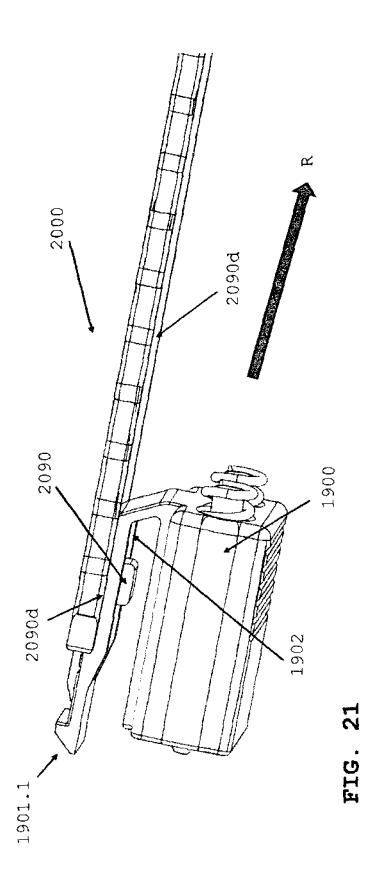
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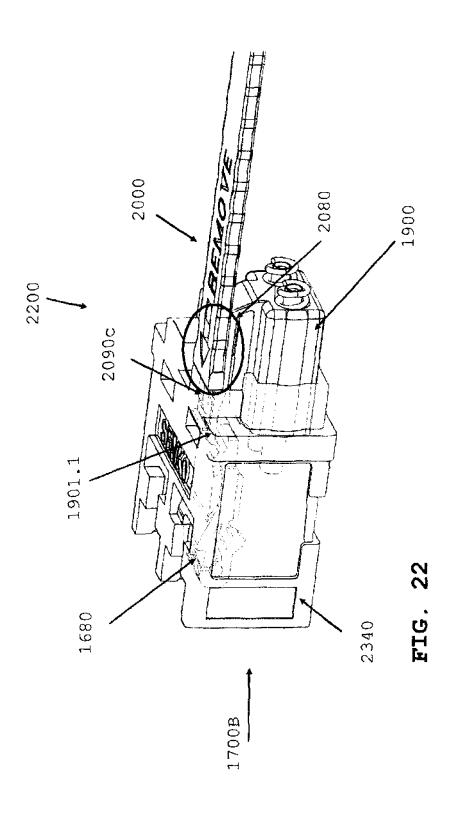
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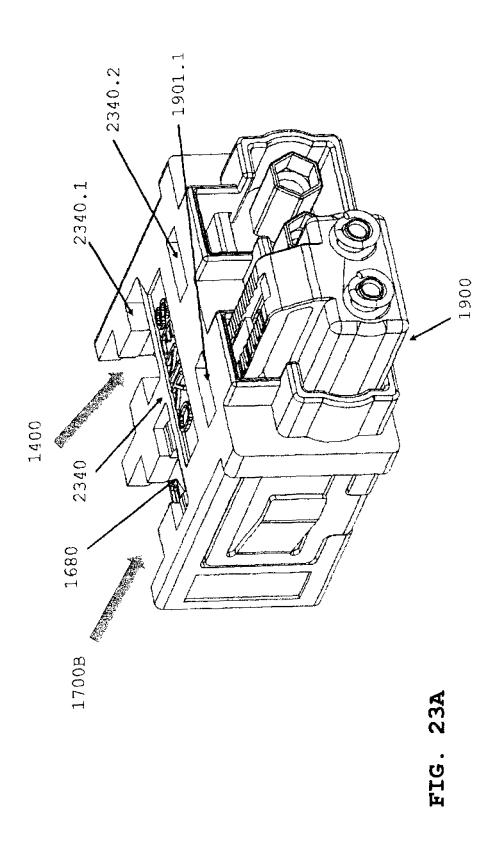
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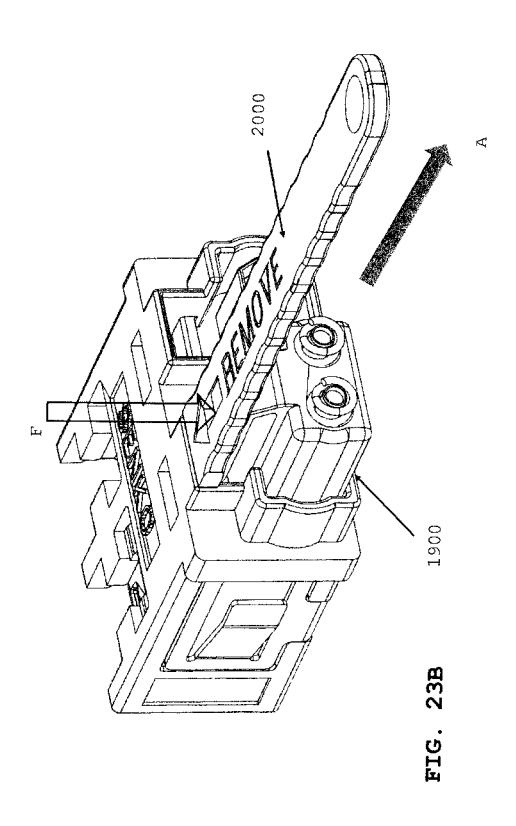
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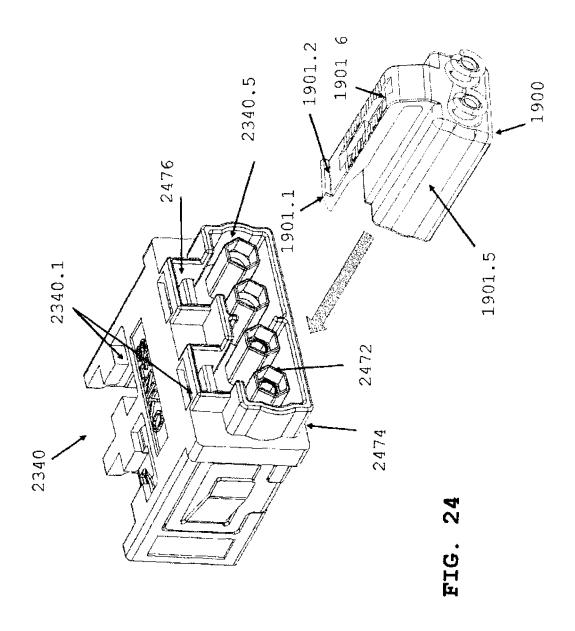
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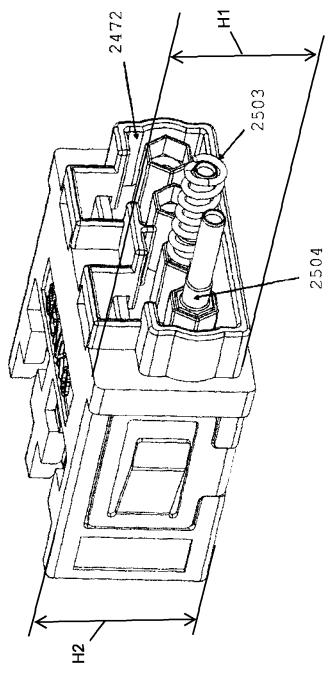


FIG. 2

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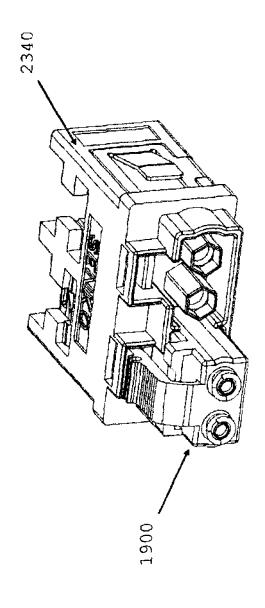
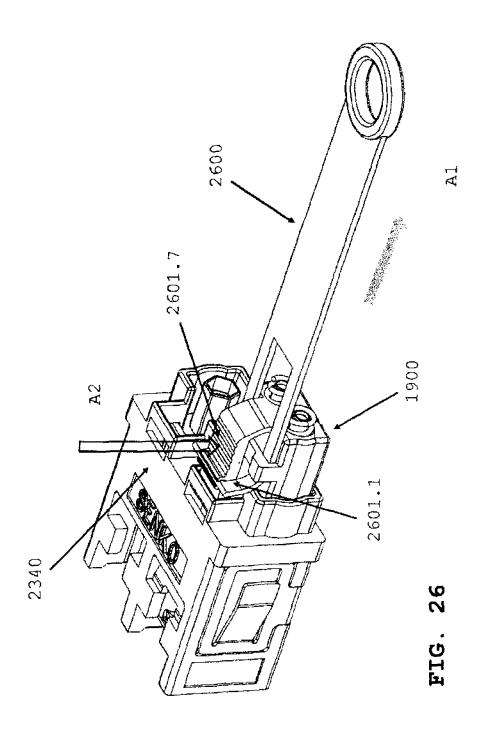


FIG. 251

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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 COMPO-NENTS," 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 COMPO-NENTS", 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 COMPO-NENTS", 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 COM-PONENTS", 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 20 adapter. 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

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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

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 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.

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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. 11A and 11B are illustrative embodiments of connectors within junior and senior sides of an adapter housing, respectively; FIG. 11C is a cross-sectional view of a connector within an adapter housing.

FIGS. 12A, 12B, 12C, and 12D show embodiments of a connector with an optional boot according to a further embodiment.

FIGS. 13A and 13C depict an optical connector with a connector insertion tool; FIG. 13B depicts a cross-section of $_{15}$ 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 20 an adapter.

FIG. 15B is a cross-section view of an adapter with the connector of FIG. 14 inserted and latched in an adapter.

FIG. 16A is an exploded view of the adapter in FIG. 15A with a plural of hooks prior to insertion into an adapter.

FIG. 16B is a perspective view of a connector according to an embodiment of the present invention prior to insertion into the adapter of FIG. 16A with a plural of hooks inserted into an adapter.

FIG. 17A is an exploded view of a connector according to an embodiment of the present invention.

FIG. 17B is a view of the assembled connector of FIG. 17A

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 40 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. 19B is a perspective view of a pull tab connector.

FIG. 19C is a perspective view of a bend latch connector.

FIG. 19D is a perspective view of a behind-the-wall connector at a proximal end.

FIG. 20A is a perspective view of a removal tool.

FIG. 20B 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. 20A attached to the behind-the-wall connector of FIG. 20B.

FIG. 22 is a transparent view of the connector assembly of FIG. 21 inserted into the adapter of FIG. 16A 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 60 connector of FIG. **20**B latched into an adapter.

FIG. 23B is a perspective view of connector and adapter assembly of FIG. 23A with the removal tool of FIG. 20A 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.

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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. 25B 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.

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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 5 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 10 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 15 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 20 (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. 25

FIG. 1 shows a perspective view of a standard behindthe-wall (BTW) connector 100. Generally, and as shown, a BTW connector may comprise a plug frame 101, a ferruleflange 102, an extender cap 104, and a boot 105. As shown in FIG. 2, a BTW connector is comprised of various parts 30 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 35 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 40 201. 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 60 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 65 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

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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

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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 5 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

Referring now to FIG. 10, in some embodiments, the plug frame 1001 may be placed in an adaptor 1010. In some 1: 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. 11A-C, additional views of an optical connector 1101 inserted into an adapter 1102 are depicted. In FIG. 11A, the connector 1101 is positioned in the junior side of the adapter 1102. In FIG. 11B, the connector 1101 is positioned in the senior side of the adapter 25 1102. Both connectors have a ferrule 1152 that upon insertion into either adapter side, engages an opening 1158 of a resilient member 1156 (FIG. 11C). The resilient member 1156 is configured to expand and secure the ferrule 1152, while aligning the ferrule 1152.

FIG. 11C 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 35 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 40 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 45 (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. 50 11C.

In the cross-sectional view of FIG. 11C, 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 55 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 60 1156

A central bore 1154 receives the annular collar 1150. The central bore 1154 is also shown in FIG. 11A, where the inner dimensions of the bore 1154 match the outer dimensions of the extended collar 206 or annular ferrule collar 1150. The 65 annular ferrule collar 1150 is generally round or annular and can contain surface features to aid in placement in the plug

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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. 12A-12D, 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. 12B, engagement projections 20 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. 12C and the adapter/ connector assembly view of 12D, 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. 13A-13C. In FIG. 13A, 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. 13B, with various cross-sectional shapes along its length to receive the ferrule and the ferrule collar. As seen in FIG. 13C, 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. 15B, 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. 15A, the connector 1400 with an alternative latch 1401.1 is shown prior to insertion into an adapter 2340. Referring to FIG. 15B, 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. 16A, the adapter 2340 may accept a hook engagement device 1680. Referring to FIG. 16A, a hook surface 1680.1 locks into a widthwise groove 1693 on a front body 1701 of the connector 1600 as shown in FIG. 16B, 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. 17A) interacting with

groove 1693 to unlock the connector (1600, 1700) from the hook surface 1680.1 located within the adapter 2340.

Referring to FIG. 17A, an exploded view of a pull tab connector 1700A further comprises a ferrule assembly 1702 called a multi-port optical ferrule or MPO ferrule. The 5 connector 1700A 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 1700A 10 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. 17B, the connector 1700A is assembled 1700B illustrating the widthwise 15 groove 1793 and pull tab 1791.

Referring to FIG. 18A, a connector 1700B and a connector 1400 are inserted into a simplex adapter 1800A at opposing ends. The connector 1700B, as described above engages and secures to a hook 1680 inserted into the adapter 20 2340. Referring to FIG. 18B, a pair of connectors 1700B and connectors 1400 are inserted into a duplex adapter 1800B at opposing ends. These connectors extend beyond the adapter because of the additional structure such as boot 1405 and pull tab 1791. A connector 1700B 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 1700B or 1600 or 1400 as shown in FIGS.

Referring to FIG. 19A, 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 35 the connector 1900 mates within an adapter (not shown), while minimizing overall connector length exposed outside of adapter (not shown), as shown in FIG. 19A as compared with FIGS. 19B and 19C. Like connector 900 of FIG. 9, the boot assembly is excluded in the behind-the-wall connector 40 1900. Comparing connector 1700B as shown in FIG. 18B, the connector 1900 is substantially shorter in length and more compact, even as compared with connector 1400 as shown in FIG. 19C. Referring to FIG. 19D, connector 1900 further comprises a housing 1900.1 with a mating surface 45 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 50 (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 55 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 60 pushes the latch downward upon contact with corresponding adapter structure for an essentially resistant free insertion.

Referring to FIG. 20A, removal tool 2000 is configured to engage the connector 1900 via a protrusion 2090 configured to be inserted an opening 1902 (refer to FIG. 20B). Pulling 65 tool 2000 rearward in a direction "R" (FIG. 21), depresses latch 1901.1 (refer to FIG. 20B), which releases connector

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1900 from adapter 2340 as shown in FIG. 23A. Referring to FIG. 20A, removal tool 2000 and its protrusion 2090 further comprise a cutout 2909a and a stop surface 2090b. The cutout 2090a 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. 23B) 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. 20B, the connector 1900 comprises an opening 1902 configured to receive the protrusion 2090, a channel 1901.3 configured to receive an alignment tab 2090c 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. 20A, a projection 2090d 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 2090d to engage a side face 1901.7 of the latch 1901. The width of the projection opening defines a distance "d" between the projections 2090d (refer to FIG. 21) and "d" is sized to engage a top surface of the latch 1901.1. Projection 2090b 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 2090d 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 2090d are shown in the call out 2280 as further securing and stabilizing the tool 2000 to latch 1901.1. The alignment tab 2090c 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 1700B and mate the fiber optic pathways contained in the ferrules of the connectors 1700B 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 1700B, and form the same signal path with the connector 1900.

Referring to FIG. 23A, 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 1700B, 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. 20B) thereby securing connector 1900 into the adapter 2340. Referring to FIG. 23A, removal tool 2000 is not inserted onto connector 1900. Referring to FIG. 23B, 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.

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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 5 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. 23A) and a latch face 1901.2 will engage and lock with a corresponding adapter latching surface 2340.1.

Referring to FIG. 25A, the adapter of FIG. 24 further comprises a ferrule flange 2506 inserted into the ferrule flange alignment sleeve holder 2472, and further comprises 15 a spring 2503 over ferrule flange (1906, 2504) and alignment sleeve 1906.1. The connector outer housing is not shown. FIG. 25A shows that the adapter 2340 has a height H1 at the first end of the adapter and a height H2 at the second end of the adapter, and the height H1 at the first end is less than the 20 height H2 at the second end. Referring to FIG. 25B, 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. 16A shows that the adapter 2340 includes upper and 25 lower longitudinal ribs 2347 between the non-behind-thewall 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 30 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 "A2", 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 40 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. 45 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, 50 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 55 described in terms of Markush groups, those skilled in the 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 60 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 65 "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

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In addition, where features or aspects of the disclosure are 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 13

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:

hind-the-wall port;

- 1. An adapter for optical connectors, the adapter compris- 20 ing:
 - 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 nonbehind-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-be-
- wherein the adapter housing is configured to receive a behind-the-wall optical connector in each behind-the- 35 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 45 received in the non-behind-the-wall port;
- wherein the adapter is configured to retain the behindthe-wall connector in the behind-the-wall port and the non-behind-the-wall connector in the non-behind-thewall port such that an optical connection is made 50 between the plurality of ferrules of the behind-the-wall connector and the plurality of ferrules of the nonbehind-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 55 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. 60
- 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 65 engage the plurality of optical fiber ferrules of the non-behind-the-wall connector at an optical reference plane.

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- 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.

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15. 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 5 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 10 along the longitudinal axis to unlatch the non-behind-the-wall connector from the non-behind-the-wall port of the
- 19. The connection system as set forth in claim 17, wherein the behind-the-wall connector has a length and the 15 non-behind-the-wall connector has a length greater than the length of the behind-the-wall connector.

* * * * *

EXHIBIT K

(12) United States Patent

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(54) SMALL FORM FACTOR FIBER OPTIC CONNECTOR WITH MULTI-PURPOSE **BOOT**

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Field of Classification Search

CPC G02B 6/387; G02B 6/3821; G02B 6/3825; G02B 6/3831

See application file for complete search history.

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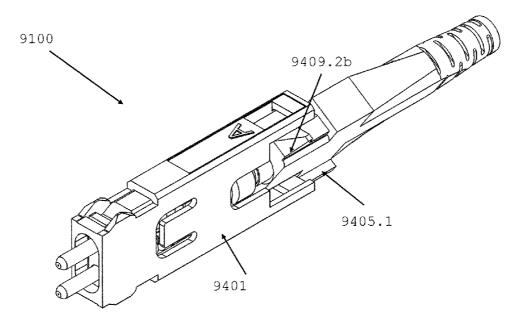
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Primary Examiner — Eric Wong

(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



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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.

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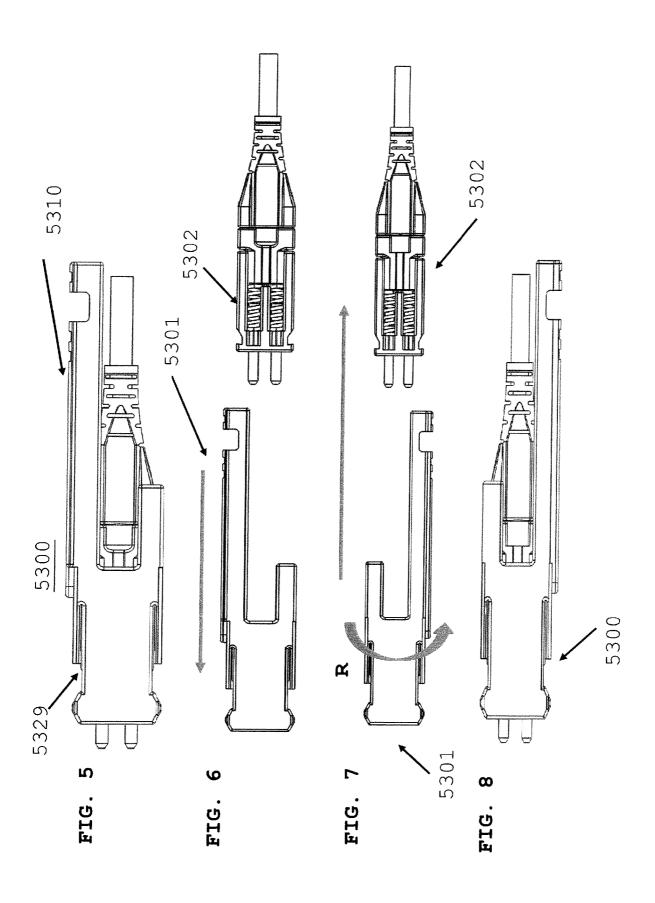
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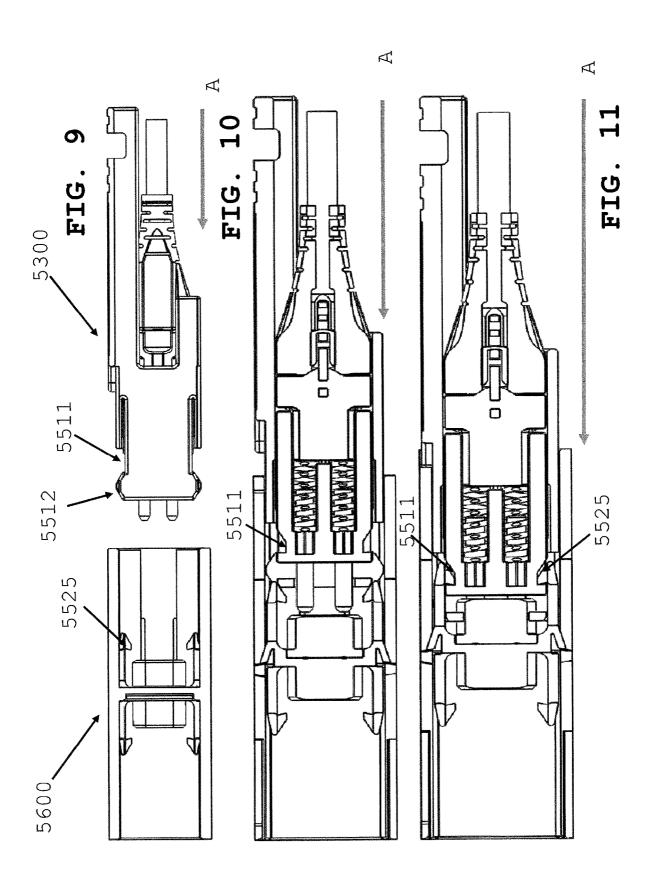
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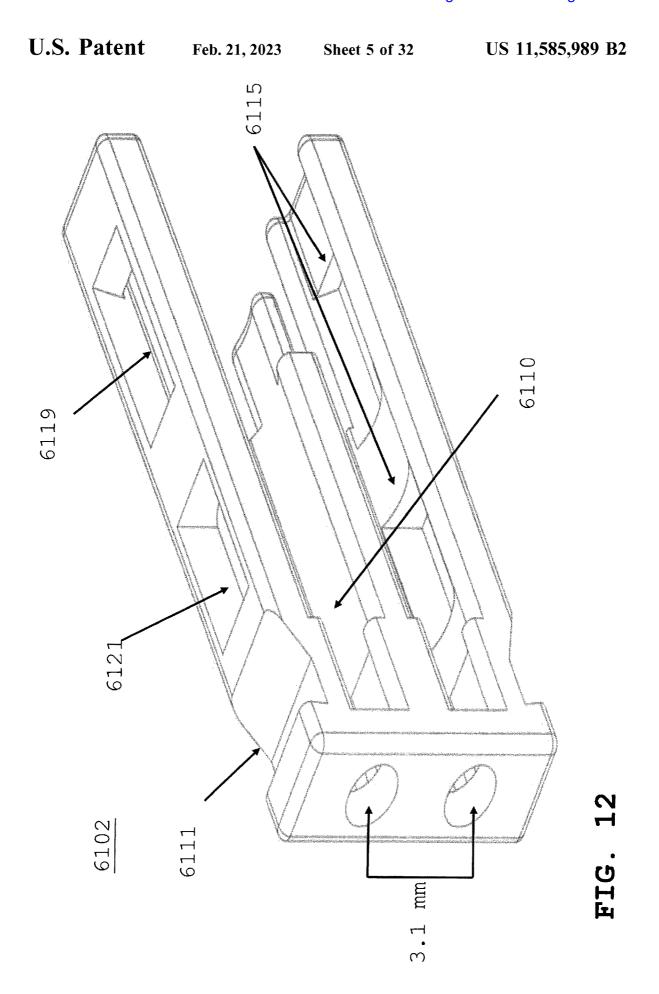
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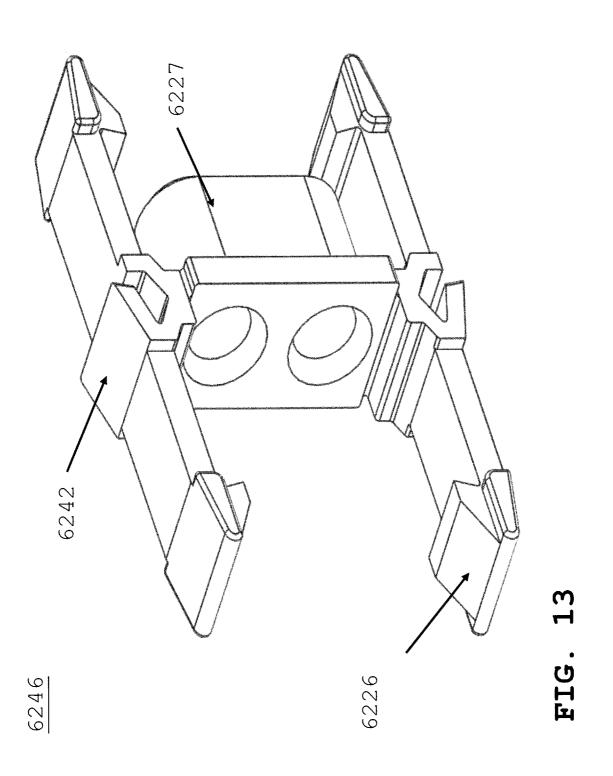
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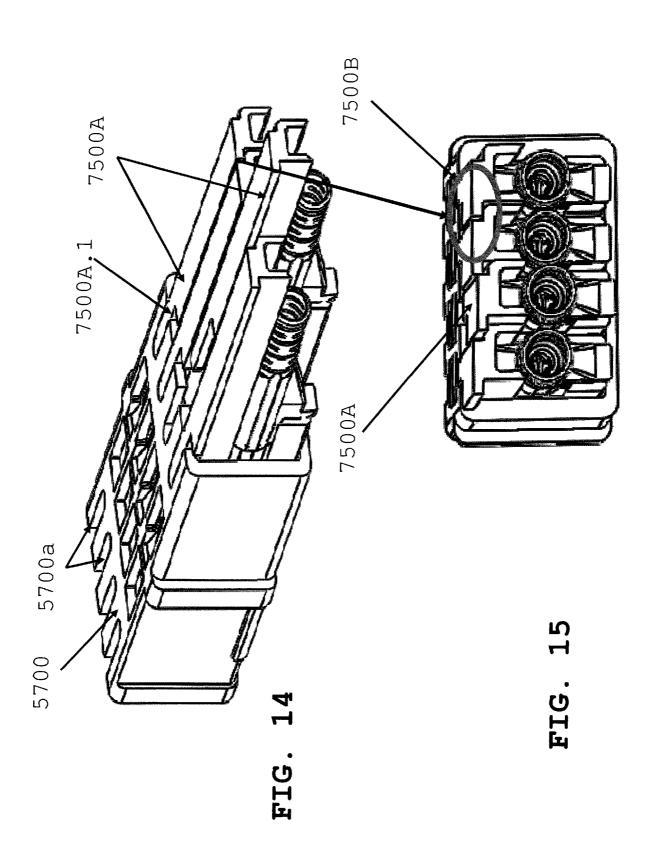
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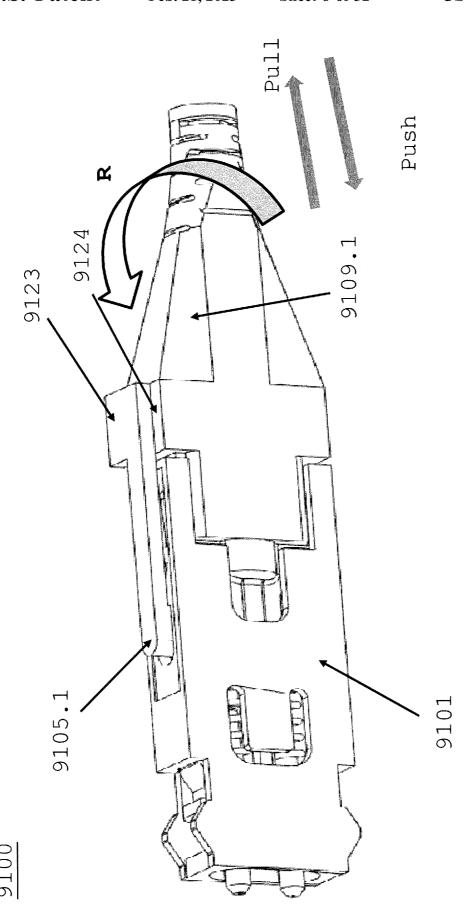


FIG. 16

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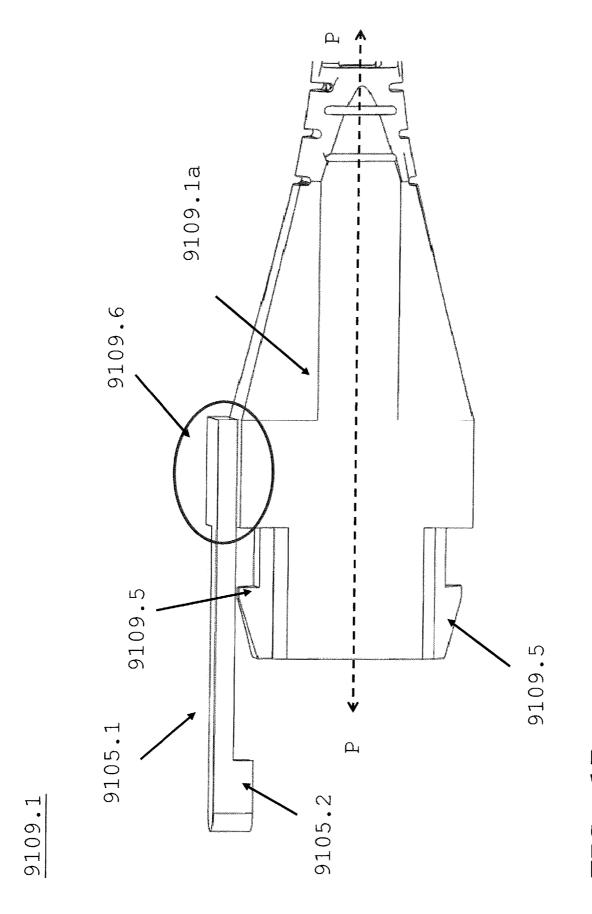
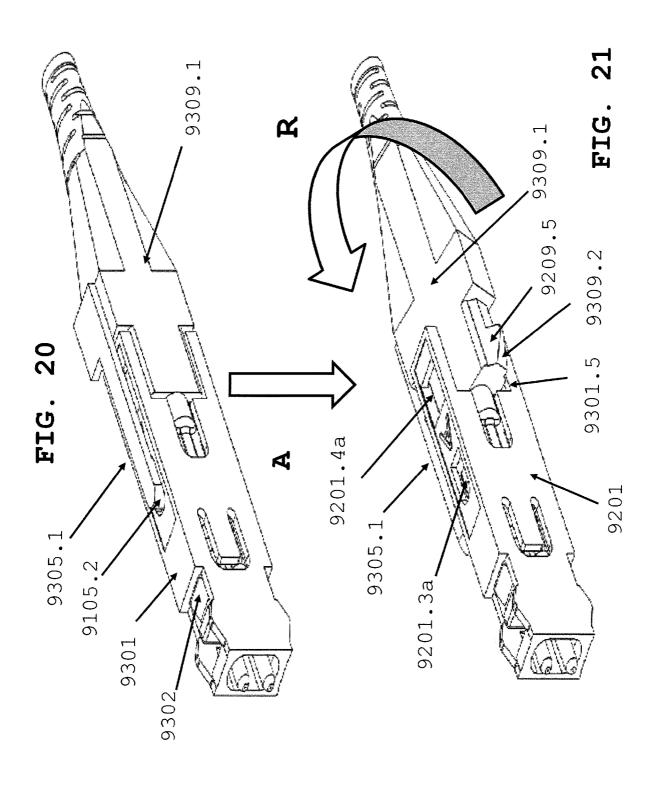


FIG. 17

U.S. Patent US 11,585,989 B2 Feb. 21, 2023 **Sheet 10 of 32** 9209 9024 Polarity_{9201.4b} 9023 9209.5 9201.4a 9206 ~ Second 9205. 9202 9201.3b 9201 9205.1 9201 9203

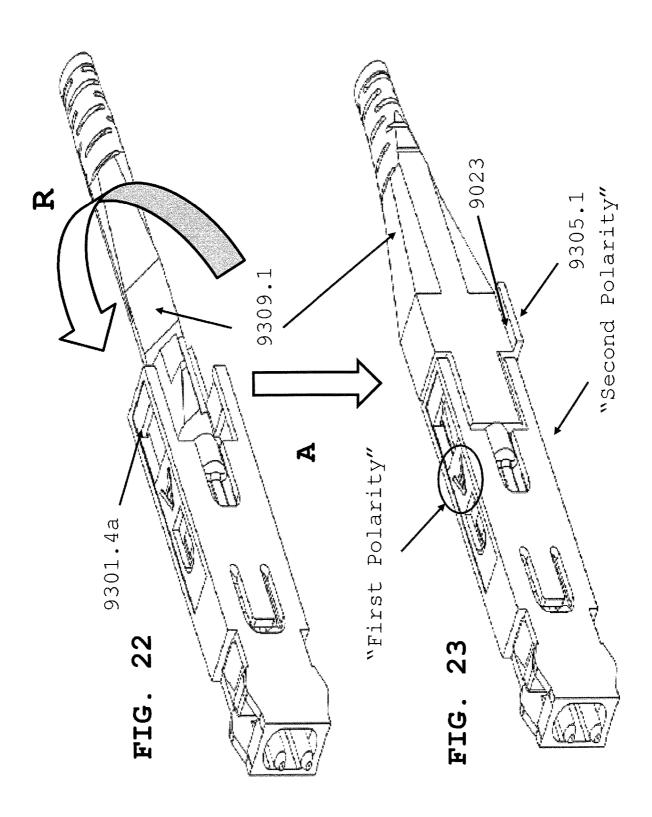
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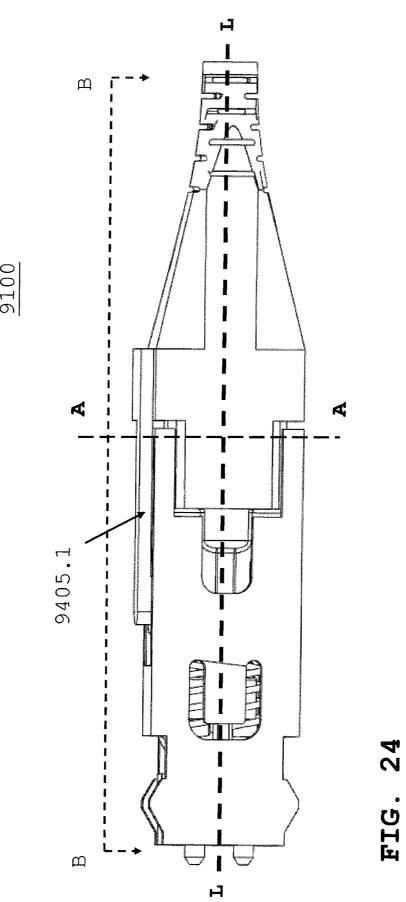


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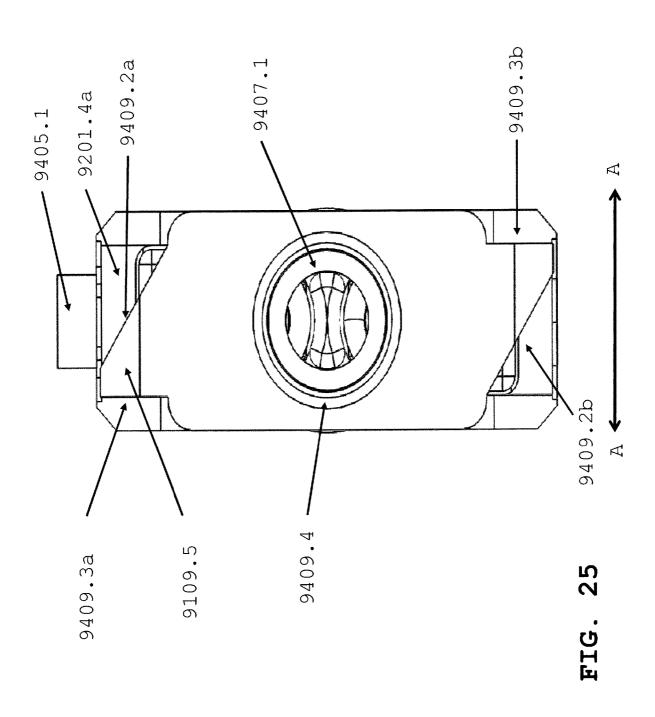


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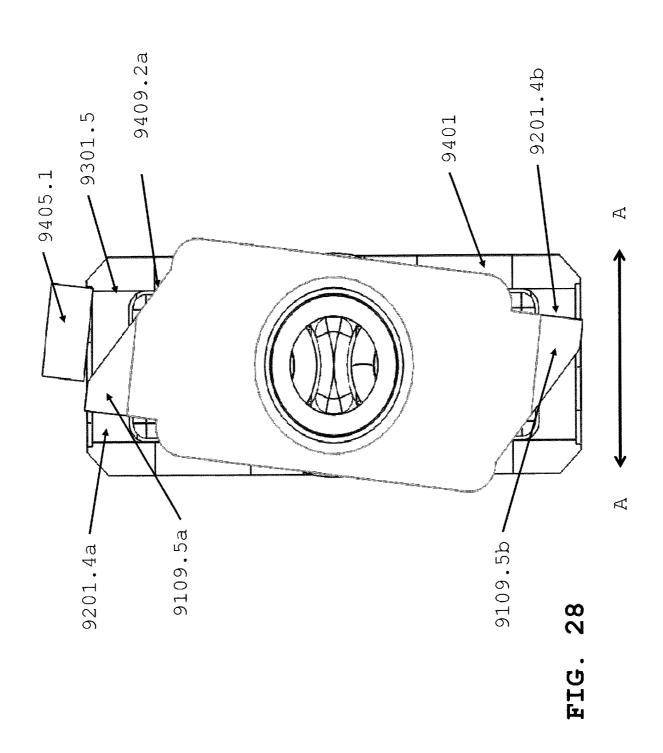
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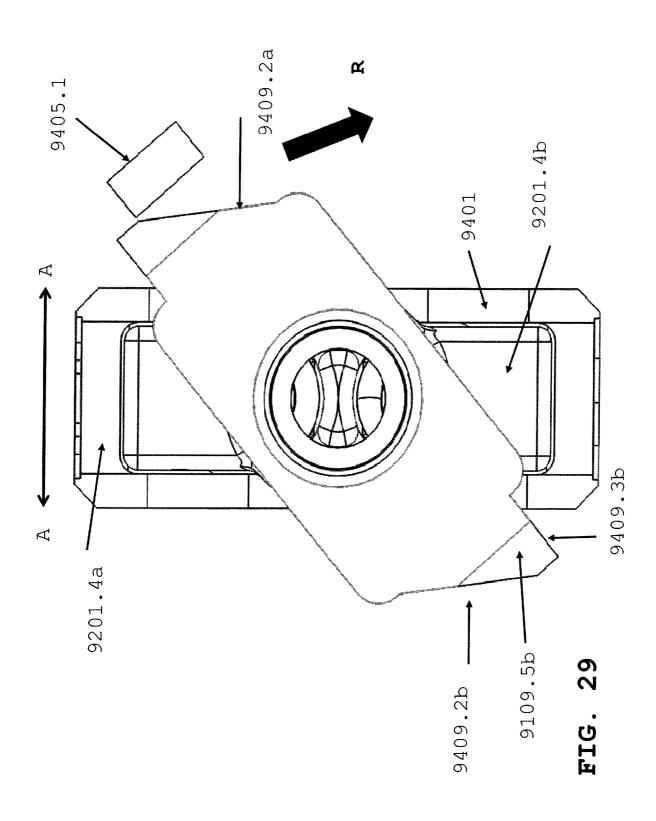
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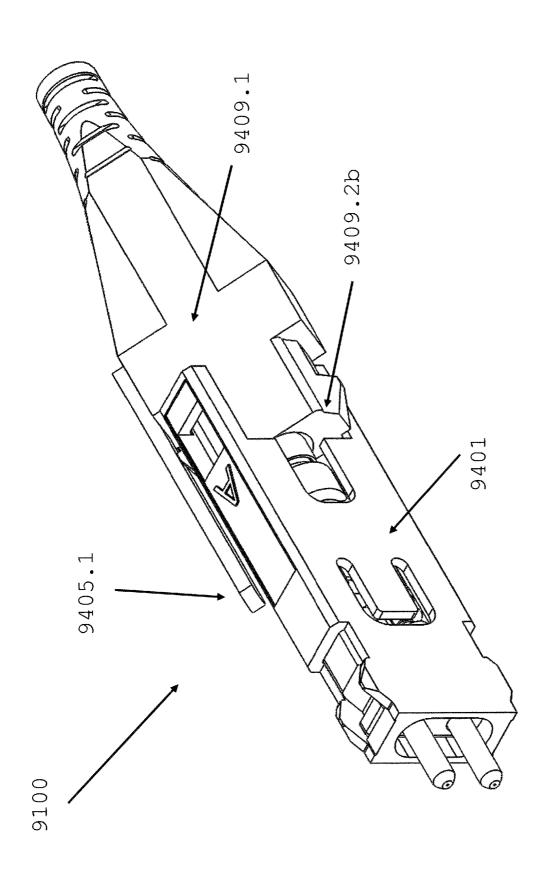


FIG. 30

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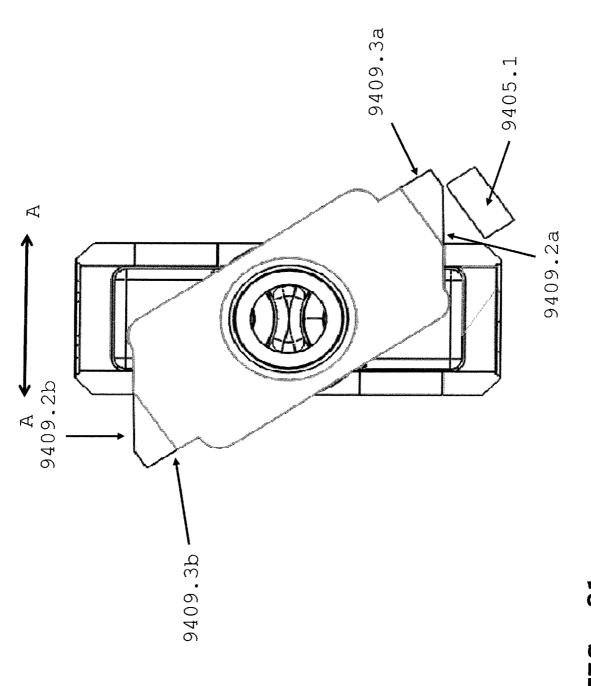


FIG. 31

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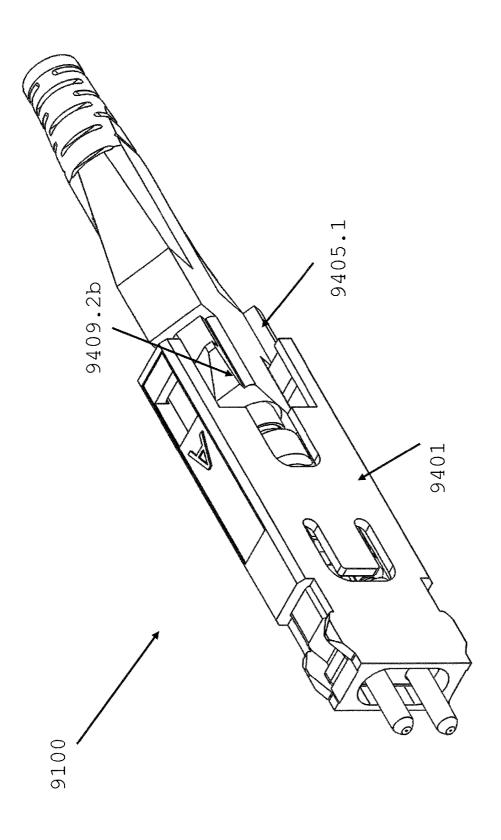
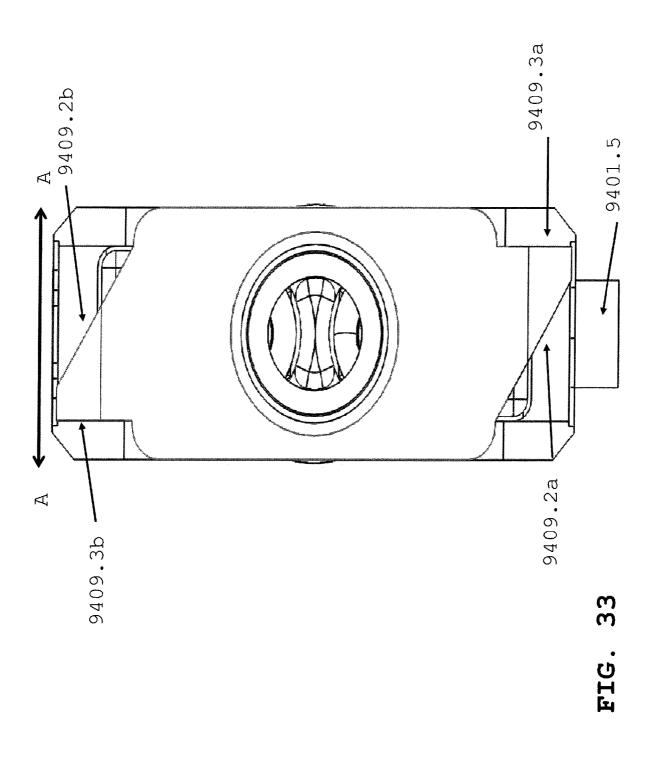
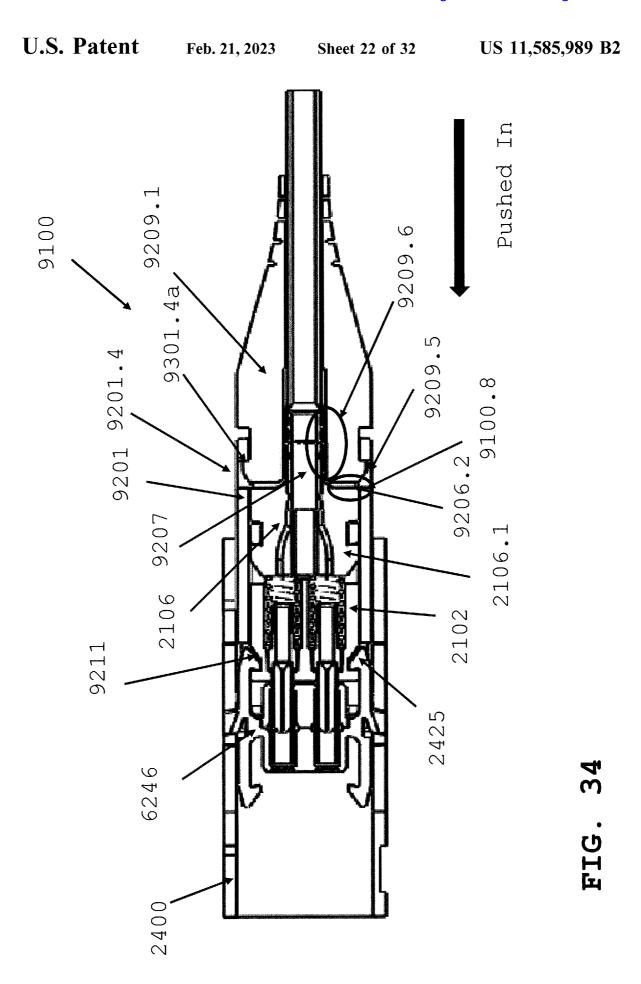


FIG. 32

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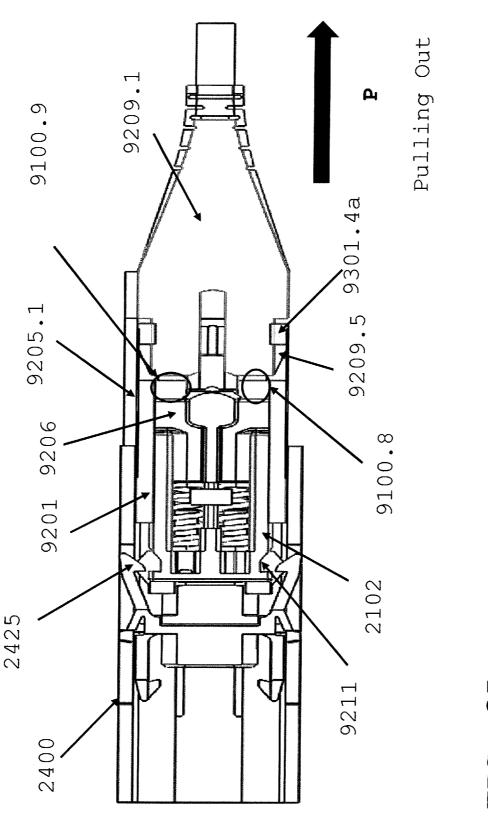
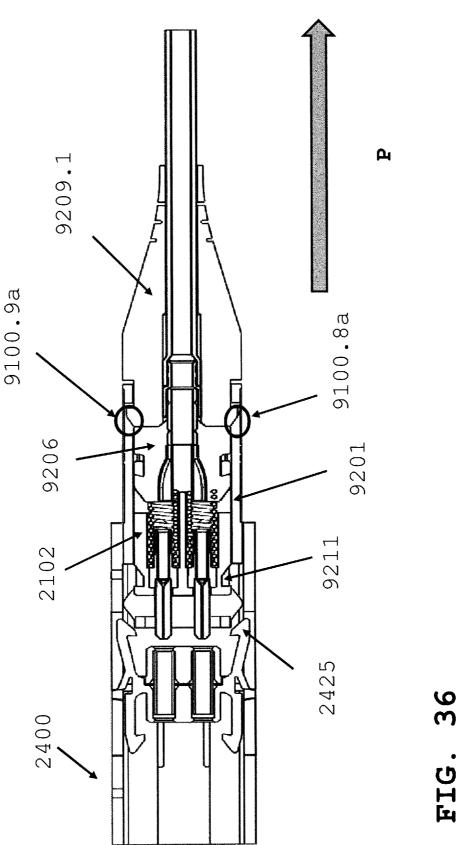


FIG. 35

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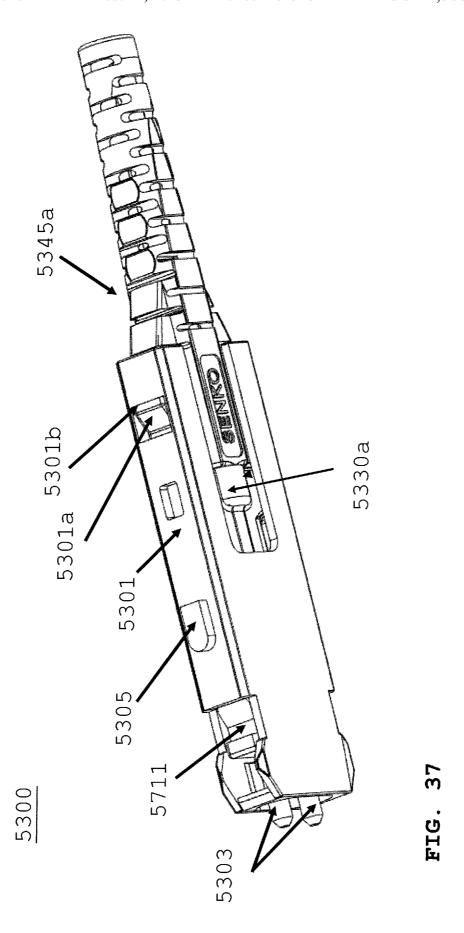


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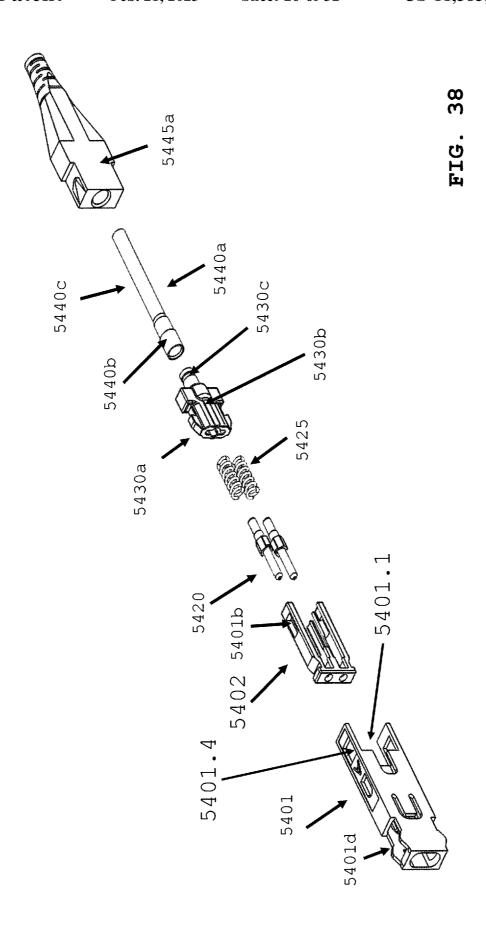


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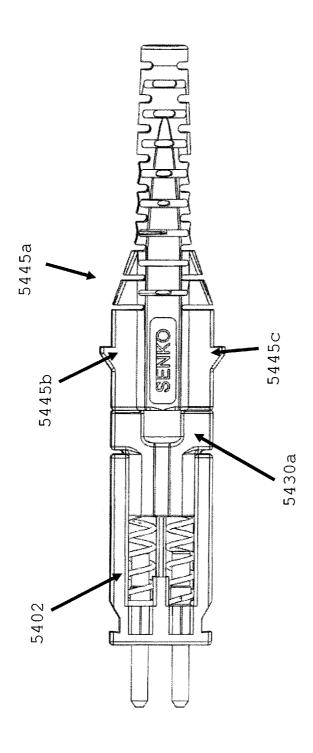


FIG. 3

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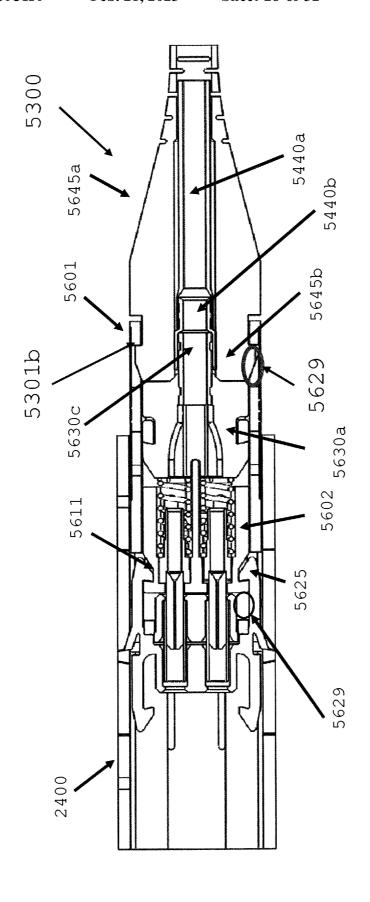


FIG. 4

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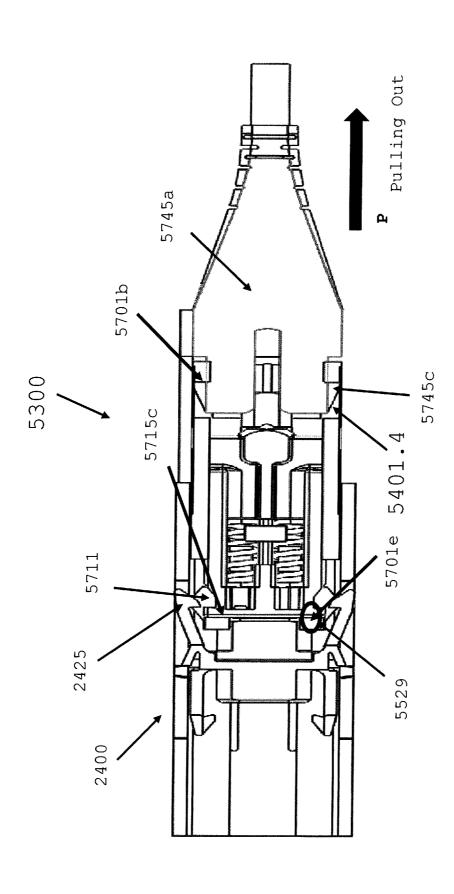


FIG. 4

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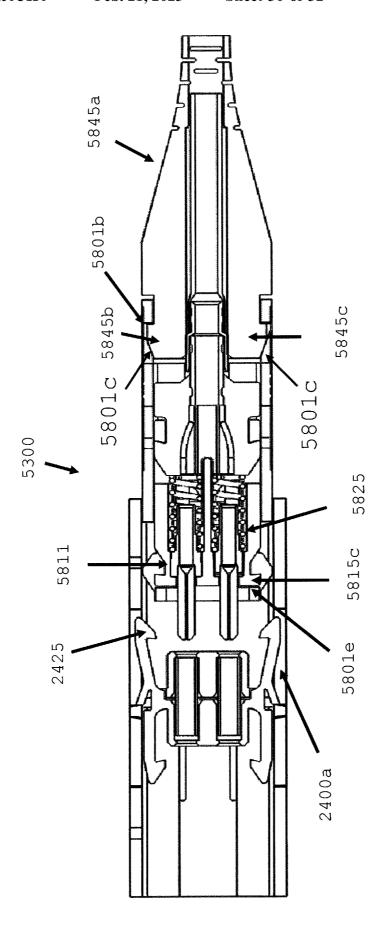
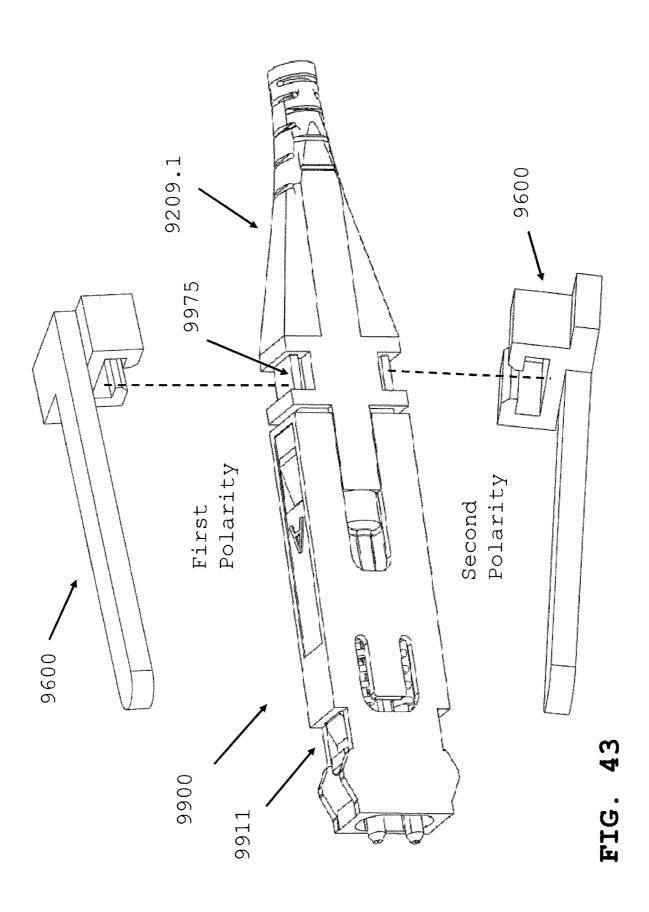


FIG. 4

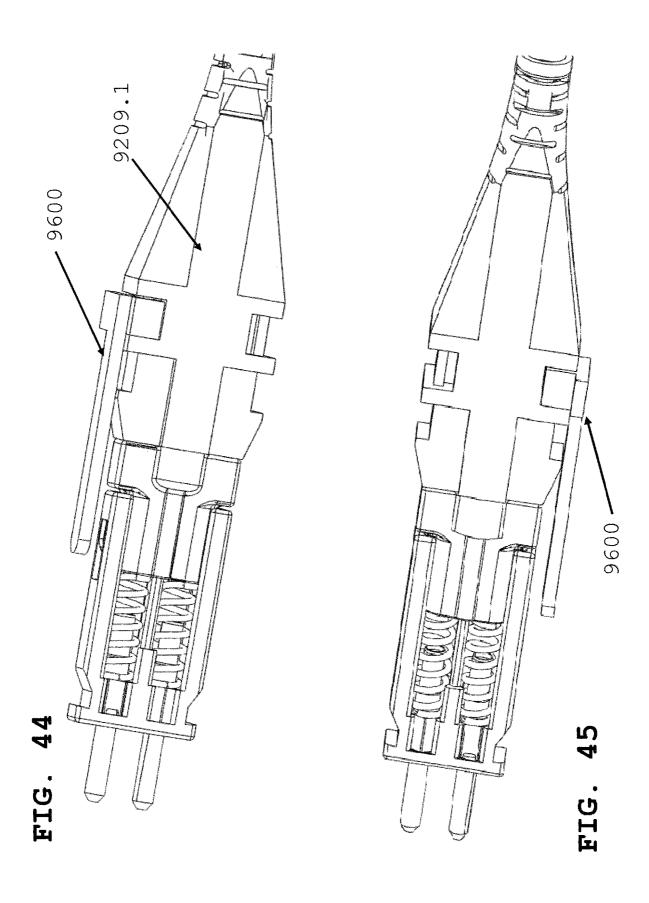
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SMALL FORM FACTOR FIBER OPTIC CONNECTOR WITH MULTI-PURPOSE BOOT

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 10 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; 15 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, 20 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, 25 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 highdensity interconnect panels. High-density interconnect panels may be designed to consolidate the increasing volume of 45 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 50 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 55 1 inserted into an adapter. 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 accommo- 60 dates 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 65 footprint currently accommodates four LC-type ferrule optical connections. However, it may be desirable to accommo2

date 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. ${\bf 1}$

FIGS. 5-8 depict polarity changing according to an another embodiment of the present invention of a microconnector.

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.

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0 is a perspective view of the micro

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 5 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 15 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 ²⁰ 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" ²⁵ 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" ³⁰ 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 65 components thereof that connects a first module or cable to a second module or cable. The connector maybe configured

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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 multifiber 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 35 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 40 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 45 **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 60 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 5 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 15 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".

"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 105.1, releasable at release point 9109.6, also refer to FIG. 30. Alignment and offset key 2105 may be fixed on conscription as shown in FIG. 1 or at 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. 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 35511, 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 40 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 45 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. 50 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 55 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 60 (not shown).

FIG. 14 illustrates a group of micro connectors 7500A inserted into an adapter 5700. Adapter 5700 has plural of slots 5700a configured to accept an alignment key 7500A.1 proximal on the alignment and offset key (7500A, 9105.1) 65

Alignment key, and alignment and offset key is defined as a protrusion adjacent to a side of the connector housing.

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FIG. 15 depicts alignment and offset key 7500B with the group of micro connectors 7500A of FIG. 14. Alignment/ offset key 7500B adds stability and reduces misalignment during insertion when key 7500B acts as a support between connectors as shown. Key 7500B 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 9201.4a and 9201.4b 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 9201.3b in connector housing 9201 (refer to FIG. 18) to further secure multipurpose rotatable boot assembly 9109.1 to front body 9202 or outer housing 9201. Multi-purpose rotatable boot assembly 9109.1 comprises a body 9109.1a 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 9201.3b and second slot 9201.4b. 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 9201.4a 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 9201.3b and second slot 9201.4b, 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. 5

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 10 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 15 connector housing 9301 and is freed from second slot 9201.4b, and securing protrusion 9105.2 (refer to FIG. 17 and shown in FIG. 20) lifts out of first slot 9201.3b thereby allowing the boot assembly to rotate as shown in the direction "R", FIG. 21. Chamfer 9309.2 may engage wall 20 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 25 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 ³⁰ 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 35 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 40 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 45 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 50 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 55 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 60 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

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further comprises first chamfer 9409.2a and first stopping wall 9409.3a, and second chamfer 9409.2b and second stopping wall 9409.3b, in a first polarity position. Boot hooks 9109.5 rotate between second slot 9201.4a and second slot 9201.4b during polarity change. Second slot 9201.4a corresponds to the connector being in a "A" polarity position. Likewise, second slot 9201.4b corresponds to the connector being in "B" polarity configuration. Securing protrusion 9405.1 resides in first slot 9201.3a for "A" polarity, and then resides in first slot 9201.3b for "B" polarity after boot release 9309.1 rotation.

Referring to FIG. 28, rotating of the boot assembly is started and chamfer 9409.2a engages connector housing wall 9301.5 and begins to lift first boot wing 9109.5a out of second slot 9201.4a. Likewise, a second boot wing 9109.5b is rotating out of second slot 9201.4b.

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 9201.3a (refer to FIG. 20 and FIG. 21), and boot wing 9109.5a is lifted out of second slot 9201.4a at a top surface and upon 180 degree rotation, securing protrusion 9105.2 (refer to FIG. 20) is accepted into first slot 9201.4b at a bottom surface of the outer housing 9401. Boot wing 9109.5b moves out of second slot 9201.4b.

Referring to FIG. 30, the rotation of boot assembly 9409.1 is shown as it exits the outer housing 9401 of connector 9100. Chamfer 9409.2b 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 9409.2b in an opposite orientation to itself in FIG. 25. Referring to FIG. 32, connector 9100 shows chamfer 9409.2b 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 9409.2b in second slot 9401.4a 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 9301.4a 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".

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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 5 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 9301.4a, and pulls outer housing 9201 rearward. Outer housing 9201 is pulled rearward connector 9100 is 10 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, 9100.9a, 9100.8a in which boot hooks slide upon pulling connector from adapter using rotatable boot assem- 15 bly. 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 20 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 5345a 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 5330a secured with outer housing 5301. Outer housing 5301 has 30 alignment key 5305, further has opening 5301a with stop face 5301b that boot wings (5445b, 5445c) (refer to FIG. 38) engage when boot assembly 5345a 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 35 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 5445a accepts crimp ring assembly 5440a having protective tube 5440c covering fiber strands 40 and crimp ring 5440b secured to back post 5430c of back body assembly 5430a including back body 5430b. 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 45 back body assembly 5430a, as described for connector 2100. Front body 5402 is inserted into distal opening 5401.1 of outer housing 5401 with boot assembly wing 5430a secured within a distal opening 5415b of front body and wing is secured through opening 5401.4 of outer housing securing 50 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 5445a is secured on back post 5430c of back body 5430a via 55 crimp ring 5440a, as described in FIG. 38. Wings (5445b, 5445c) secure FIG. 39 assembly within outer housing 5301, and during release of connector 5300 from a receptacle, wings (5445b, 5445c) pull back outer housing a specific distance "d", which releases adapter/receptacle hook or latch 605625 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 5430a 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

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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 5645b engages stop face 5301b of outer housing 5601. This "d" travel removes hook 5625 from connector recess 5611 thereby unlatching or releasing connector from adapter 2400. Crimp ring 5440b is shown secured to back post 5630c. Back body 5630a is secured within front body 5402 at distal openings 5401b (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 5401d (FIG. 38), as boot assembly 5745a is being pulled rearward or in a distal direction. Gap 5529 is closed as shown in FIG. 41. Inner face of connector housing 5715c is flush with front face of front body 5701e, 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 5745c 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 5845a. In this embodiment, wings (5845b, 5845c) are flush with outer housing wall 5801b. Wings (5845b, 5845c) move within gap or opening 5801c within connector housing outer wall, as boot 5845a is pulled rearward to release connector from adapter 2400 as shown. Spring 5825 biases forward front body face 5815c to be flush with front body face 5801e, when pull force is released from boot assembly. Hook or latch 2425 is displaced from recess 5811, and hook resides in adapter housing gap 2400a 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").

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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 15 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 20 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 25 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 30 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 rotat- 35 able 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 selec- 40 tively 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, 45 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 50 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 60 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**, 65 wherein the first and second boot hooks are releasable to allow the rotatable boot assembly to rotate on the fiber optic

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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

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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**, 5 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.

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- 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



(12) United States Patent Wong et al.

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(54) ADAPTER FOR OPTICAL CONNECTORS

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- (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.

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(2013.01); G02B 6/3879 (2013.01)

(58) Field of Classification Search

See application file for complete search history.

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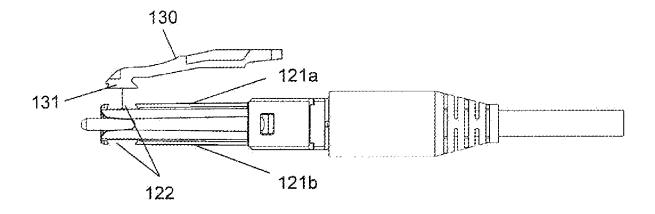
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(57) ABSTRACT

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



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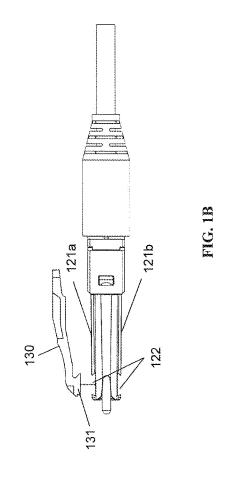
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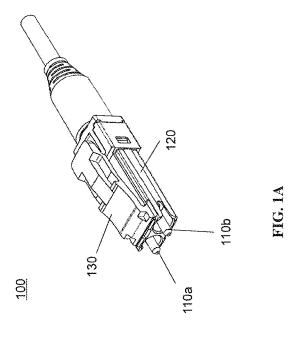
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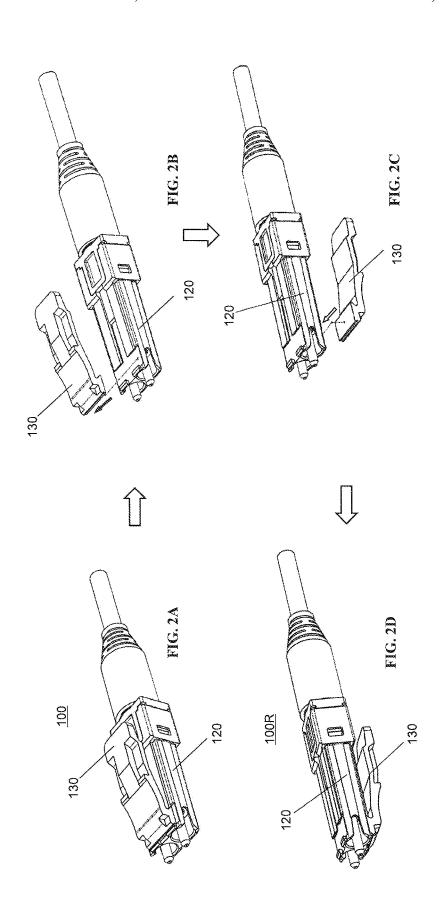




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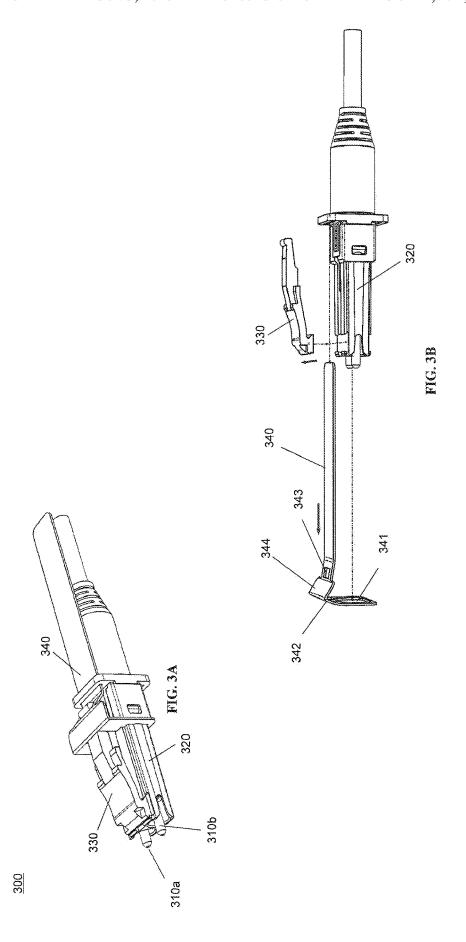


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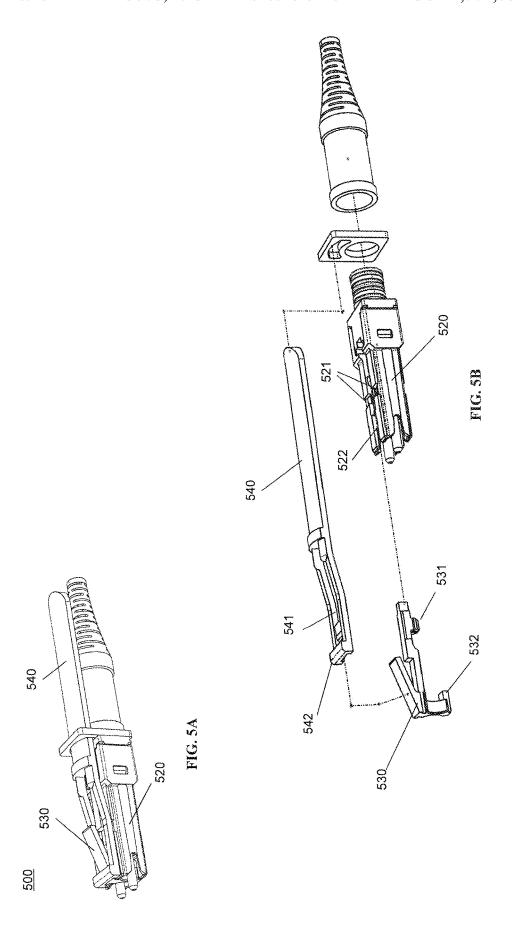


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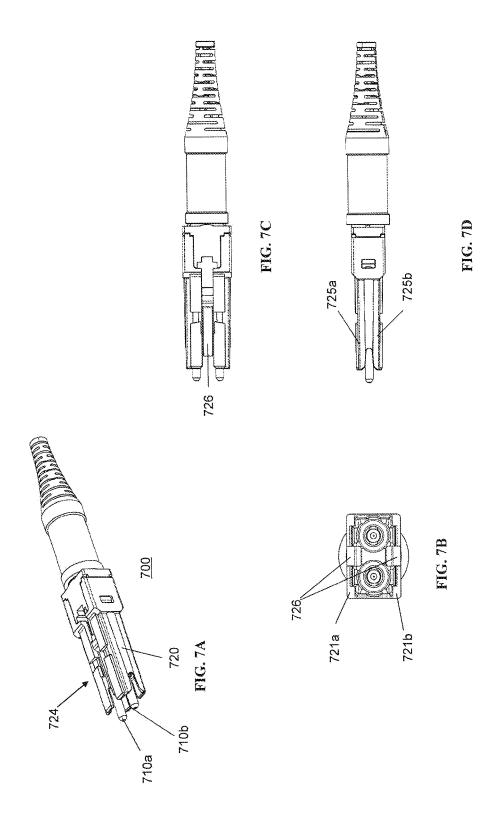
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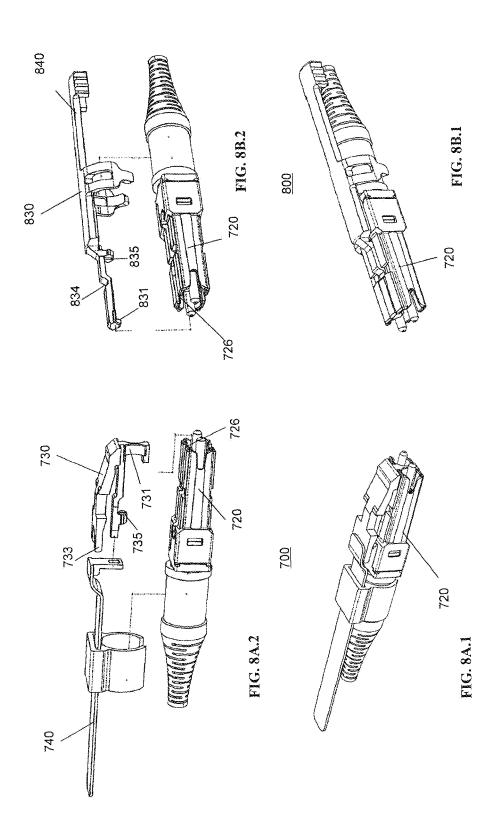
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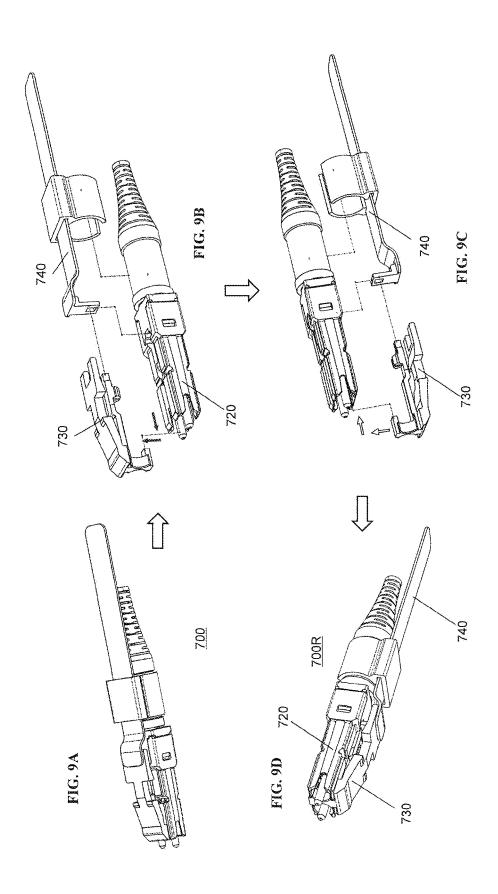
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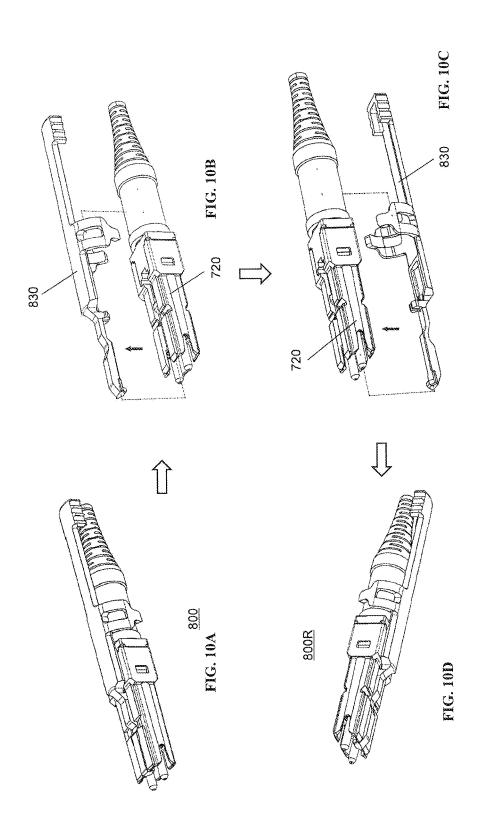
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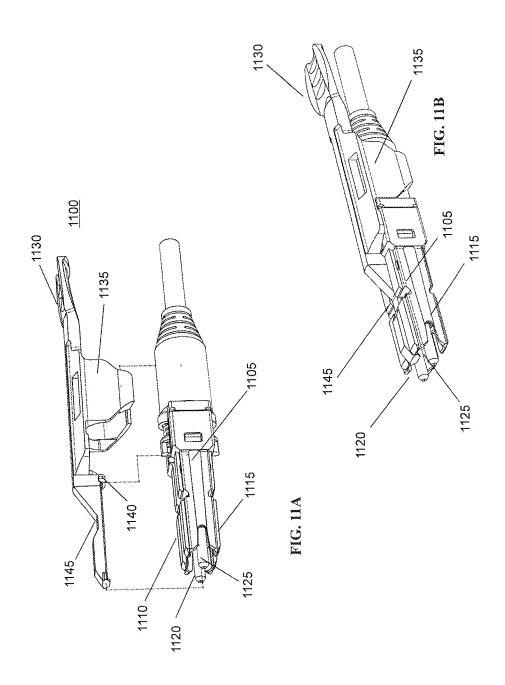
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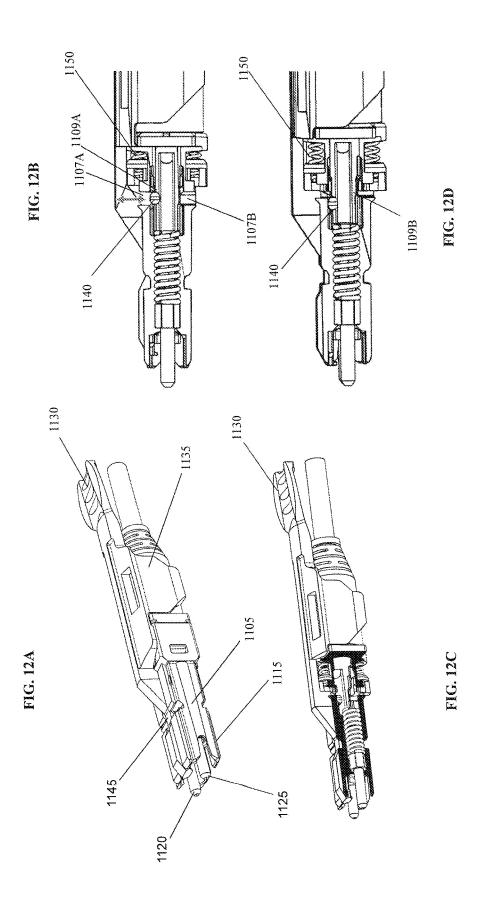
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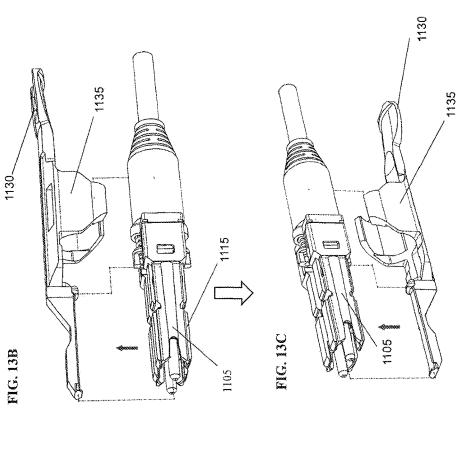


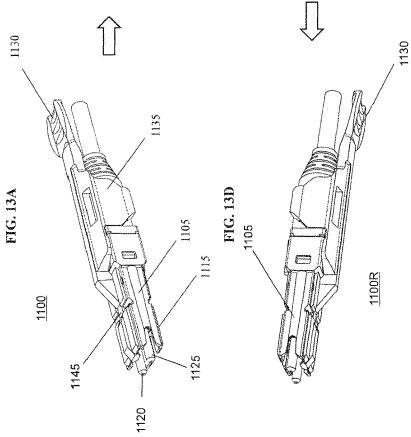
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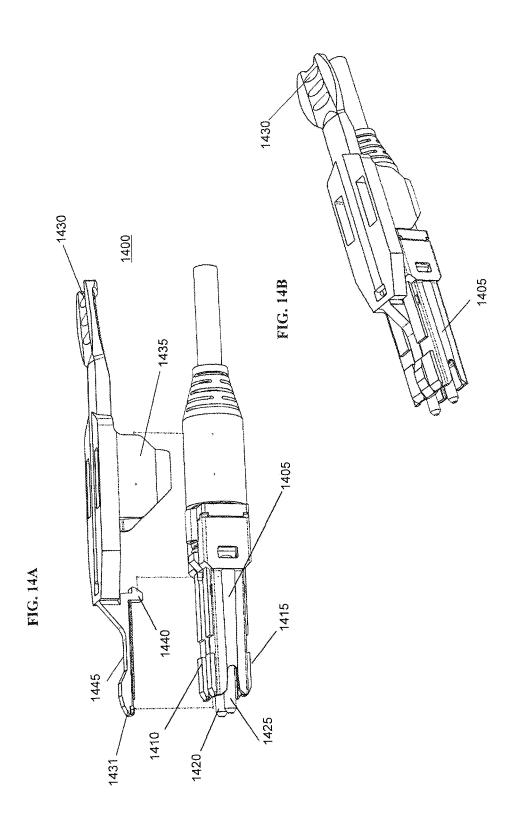
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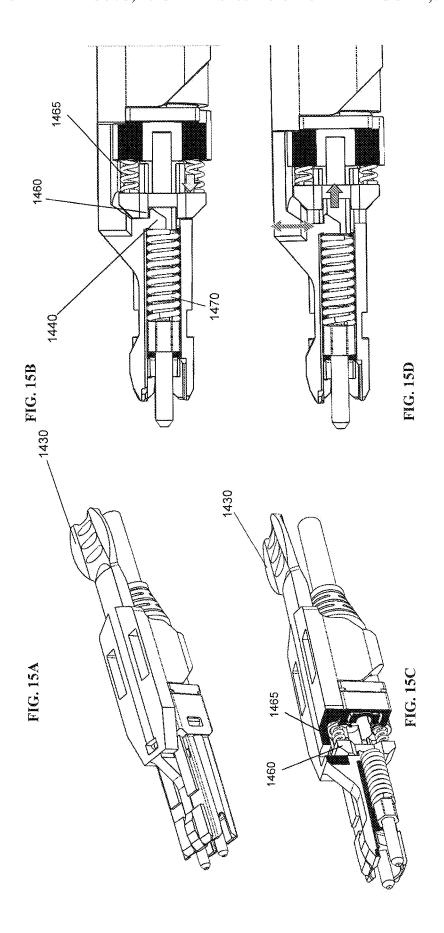
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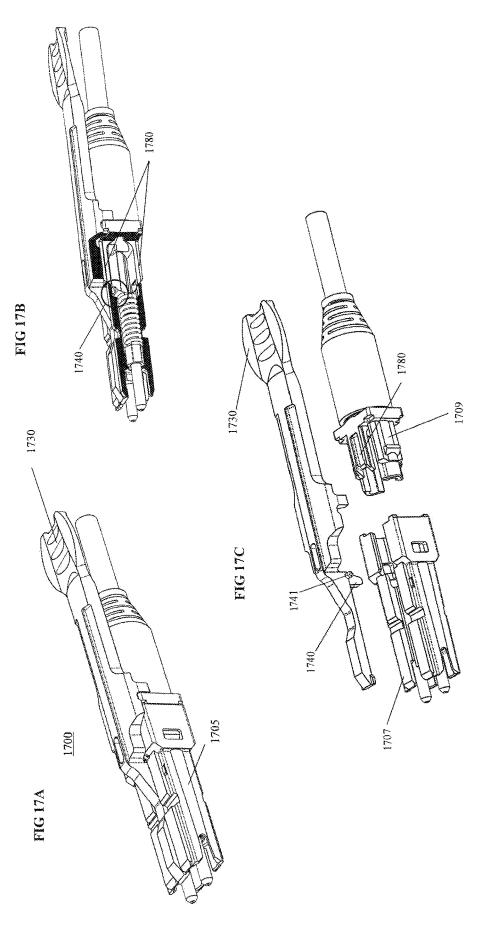
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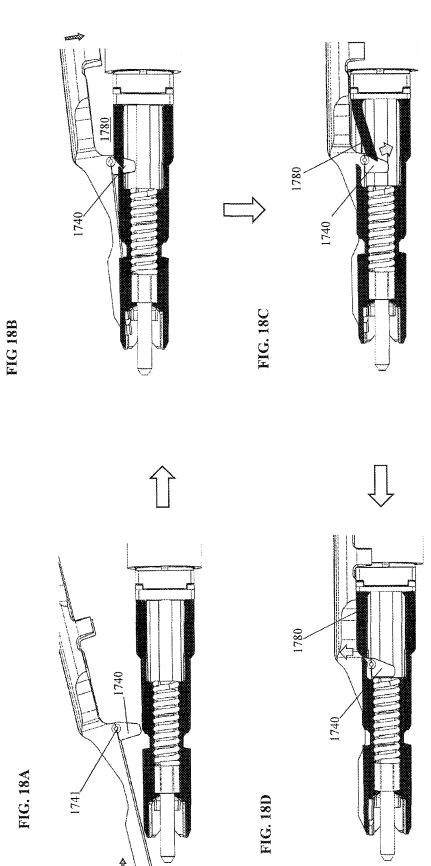


U.S. Patent Oct. 3, 2023 US 11,774,685 B2 **Sheet 16 of 28** 1430 1435 1430 FIG. 16C 1415 FIG. 16B 1400R 1400 FIG. 16D FIG. 16A 1410

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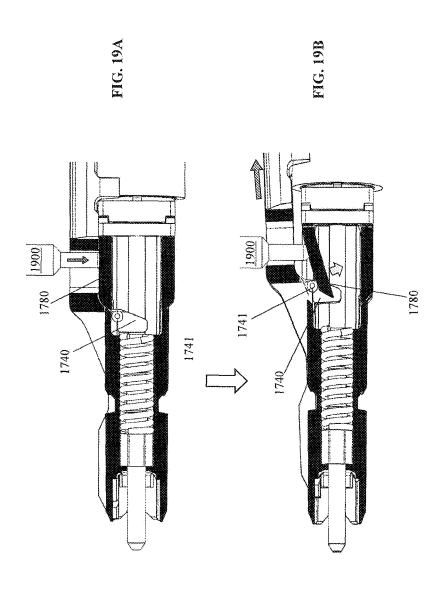


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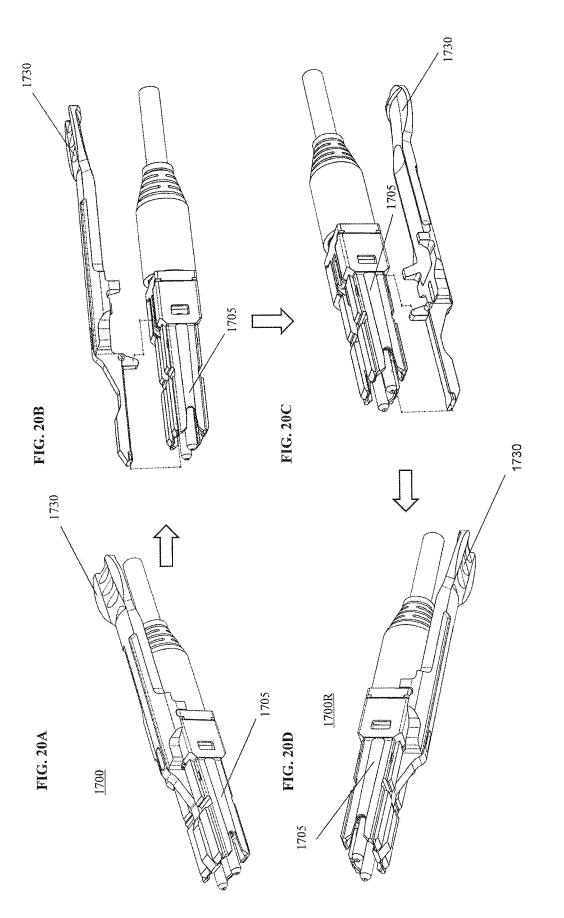


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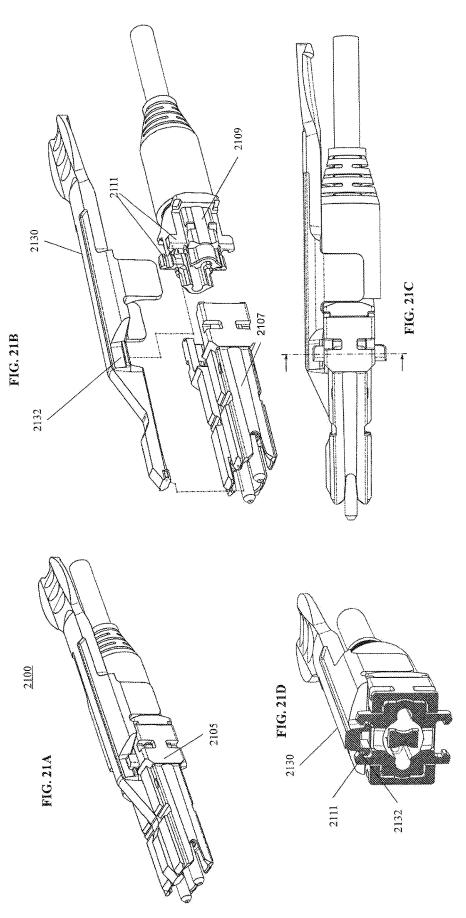
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U.S. Patent Oct. 3, 2023 US 11,774,685 B2 **Sheet 22 of 28** 2130 FIG. 22B FIG. 22D FIG. 22C 2130 2135 2100R FIG. 22A FIG. 22E 2100

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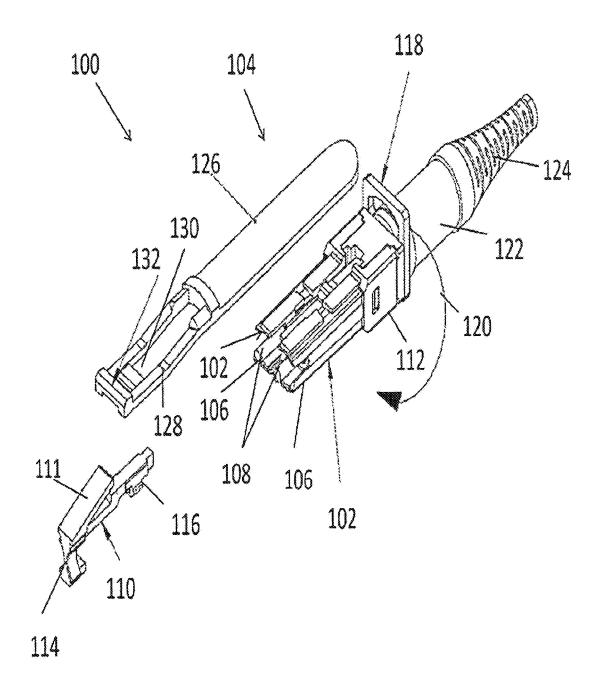


FIG. 23

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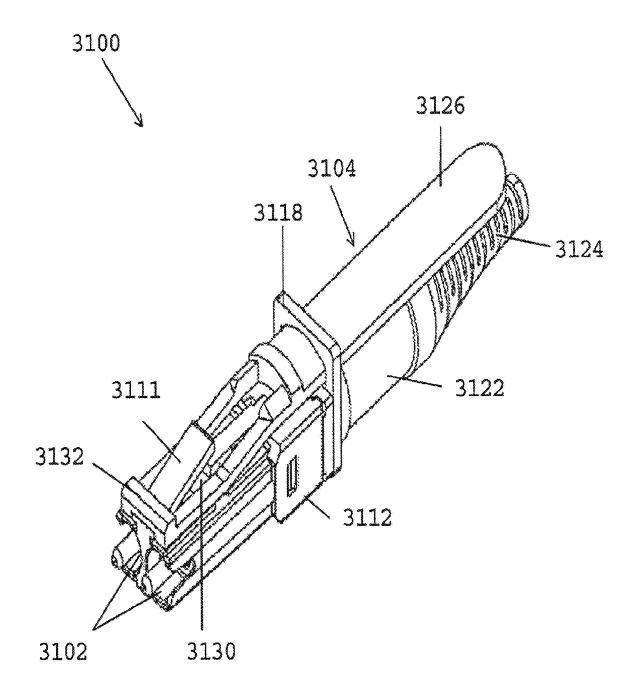


FIG. 24

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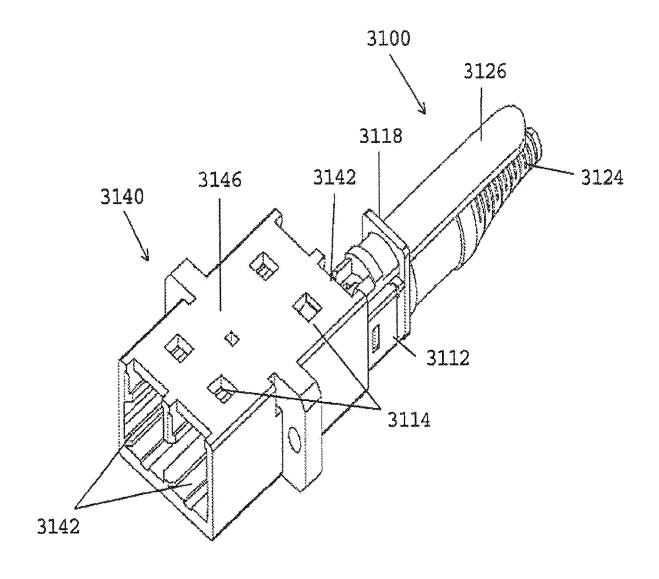


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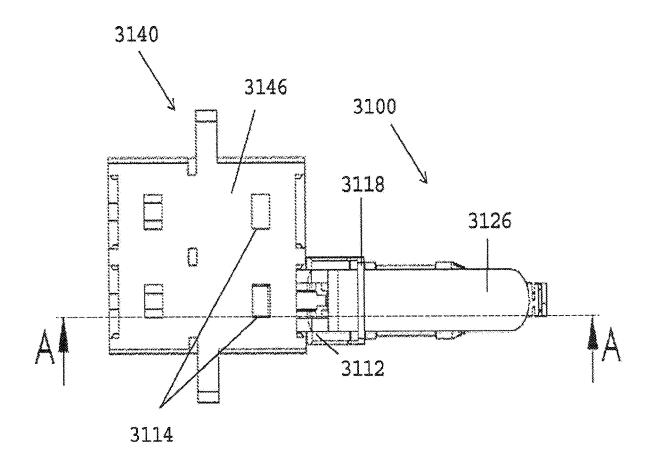


FIG. 26

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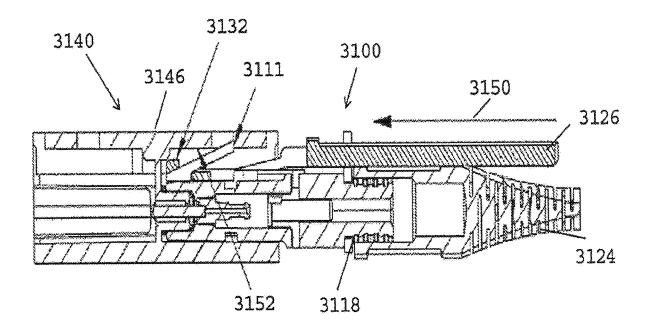


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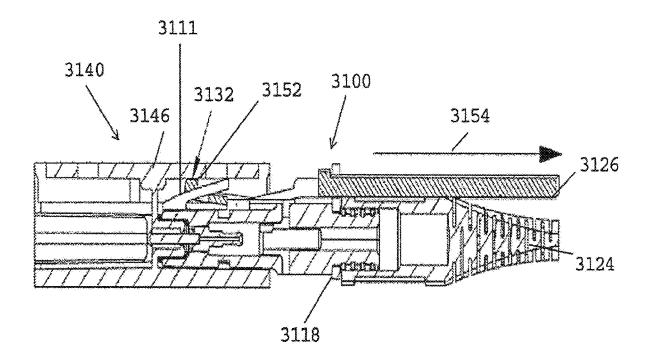


FIG. 28

1 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 10 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. ²⁰ 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 highdensity 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 40 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 45 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 50 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 55 transmit/receive) within the same footprint. Another current footprint is the quad small form-factor pluggable (QSFP) footprint. This footprint currently accommodates four LCtype ferrule optical connections. However, it may be desirable to accommodate eight optical connections of LC-type 60 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 65 panels. Panel and connector producers may optimize for such high densities by shrinking the connector size and/or

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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

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and positioning the removable push-pull tab with its protrusion within the second aperture yields a fiber optic connector $\ ^{10}$ 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 15 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 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 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 40 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 45 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 por- 50 tion 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 assem- 55 bly 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 assem- 60 bly 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 65 of FIG. 7A; 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 embodi-

ments, the at least one connector may include the latch arm as an integral structure.

BRIEF DESCRIPTION OF THE DRAWINGS

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

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

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

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

FIG. 2C is an exploded view of a next step in the process removable push-pull tab is provided. A first push-pull tab 20 of changing the polarity of the reversible polarity fiber optic connector of FIG. 2A;

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

FIG. 3A is a perspective view of an embodiment of a fiber optic connector with a first polarity and positioning the 25 reversible polarity fiber optic connector with a pull tab according to aspects of the present disclosure;

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

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

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

FIG. 4C.1 is an exploded view of positioning the latch in 35 the process of changing the polarity of the reversible polarity fiber optic connector of FIG. 4A;

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

FIG. 9D is a perspective view of the reversible polarity fiber optic connector of FIG. 8A.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. 10B is an exploded view of a step in the process of changing the polarity of the reversible polarity fiber optic connector of FIG. 8B.1;

FIG. 10C is an exploded view of a next step in the process of changing the polarity of the reversible polarity fiber optic 25 connector of FIG. 8B.1;

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

FIGS. 11A and 11B respectively depict exploded and perspective views of a reversible polarity optical connector 30 according to a further embodiment of the disclosure;

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

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

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

FIGS. 17A-17C respectively depict perspective, partial cross-section, and exploded views of a reversible polarity optical connector according to a further embodiment of the 45 disclosure;

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

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

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

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

FIGS. 22A-22E 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 60 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;

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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 strown 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 5 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. 20 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. 1A and 1B depict a fiber optic connector with reversible polarity according to one aspect of the present disclosure. As shown in FIG. 1A, a reversible polarity fiber optic connector may include first and second optical ferrules 110a and 110b and a connector housing 120 at least partially surrounding the first and second optical ferrules. A removable latch 130 is depicted in FIG. 1A in its assembled state and in FIG. 1B removed from the connector housing 120.

FIG. 1B is a side view of the reversible polarity fiber optic connector of FIG. 1A with the removable latch 130 being separated from the connector housing. As shown, the connector housing 120 may have a first exterior wall 121a positioned above the first and second optical ferrules and a 45 second exterior wall 121b 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 50 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 55 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 60 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 65 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,

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FIGS. 2A-2D depict the process for changing the polarity of the fiber optic connector of FIG. 1A from a first polarity, FIG. 2A to a second, opposite polarity, FIG. 2D. The removable latch 130 may be removed from the latch coupling on the first exterior wall of the connector housing, FIG. 2B, positioned adjacent the second exterior wall on beneath the ferrules, FIG. 2C, and then coupled with the latch coupling on the second exterior wall of the connector housing to yield a connector 100R, FIG. 2D, 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.

able latch 130 is depicted in FIG. 1A in its assembled state and in FIG. 1B removed from the connector housing 120.

FIG. 1B is a side view of the 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 separated from the connector housing. As shown, the connector housing 120 may have a first exterior wall 121a direction away from the fiber optic ferrules.

FIG. 3B is an exploded view of the reversible polarity fiber optic connector of FIG. 3A. 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. 4A-4D depict the process for changing the polarity of the fiber optic connector 300 from a first polarity, FIG. 4A to a second polarity 300R, FIG. 4D. 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. 2B. The removable latch is then detached from the latch coupling on the first exterior wall of the connector housing, FIG. 4C.1. Next, the removable latch is engaged with the latch coupling on the second exterior wall of the connector housing, beneath the ferrules, FIG. 4C.2. Finally, the pull tab 340 is positioned surrounding the

connector housing and engaging the removable latch tip, resulting in the assembled optical connector 300R having polarity opposite to that of connector 300, FIG. 4D.

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FIGS. 5A and 5B are a perspective view and exploded view, respectively, of another embodiment of a reversible 5 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 15 removable latch 530 when the pull tab is pulled in a direction away from the ferrule side of the optical connector.

FIGS. 6A-6D depict the process for changing the polarity of the fiber optic connector 500 from a first polarity, FIG. 6A to a second polarity, FIG. 6D. The pull tab 540 is disengaged 20 from the connector housing and the removable latch 530 on the first exterior wall of the connector housing, FIG. 6B, 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 25 the second exterior wall of the connector housing, beneath the optical ferrules in FIG. 6C, 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 500R, FIG. 6D.

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 35 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. 7A is a perspective view of a common connector 40 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 710b and the common connector housing 720 at least partially surrounding the first and second optical ferrules.

FIGS. 7B, 7C and 7D 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 50 exterior wall 725a positioned above the first and second optical ferrules and a second exterior wall 725b 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 55 include a receiving track 726 in the coupling surface.

FIG. 8A.1 shows the common connector housing 720 used to create a latch-type connector 700 and FIG. 8B.1 shows the common connector housing 720 used to create a recess-type connector 800. Both of connectors 700 and 800 60 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. 8A.2 and 8B.2 respectively. The removable arms 730 and 830 may each respectively include a projection 735 or 835 for engaging in the receiving 65 track 726 of the coupling surface 724, FIGS. 8A.2 and 8B.2 respectively. As with the previous embodiments, positioning

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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. 8A.2 and 8B.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. 8A.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. 8A.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. 8B.2.

FIGS. 9A-9D depict the process for changing the polarity of the latch-type fiber optic connector from a first polarity 700, FIG. 9A to a second polarity 700R, FIG. 9D. 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. 9B. 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. 9C, creating the opposite polarity connector 700R.

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

FIGS. 11A and 11B depict a further embodiment 1100 of may comprise first and second optical ferrules 710a and 45 the reversible polarity optical connectors of the present disclosure. In FIG. 11A, 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, 1109A, beneath the housing exterior wall 1110 or a second aperture, 1109B, 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. 12B and 12D, push-pull tab protrusion 1140 may be inserted into first aperture 1109A of

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housing 1105 through a first exterior housing aperture 1107A. Alternatively, in the reverse-polarity configuration, the push-pull tab protrusion 1140 may be inserted into second housing aperture 1109B through second exterior housing aperture 1107B. When the push-pull tab 1130 is 5 moved forward, the protrusion slides within the aperture 1109A or 1109B, as shown in FIG. 12B. 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, 10 depicted in FIG. 12B. When the position spring 1150 is in its relaxed (uncompressed) position, FIGS. 12C and 12D, the protrusion 1140 is slid forward within the aperture 1109A or 1109B.

To change polarity of the optical connector 1100, FIGS. 15 13A-13D, the push-pull tab 1130 is removed by withdrawing the protrusion 1140 from the housing 1105 through exterior housing aperture 1107A along with detaching clips 1135 and decoupling projection 1131, thus releasing the push-pull tab from the first exterior housing wall 1110 (FIG. 20 13B). The push-pull tab is moved toward second exterior housing wall 1115 and the protrusion 1140 is inserted into aperture 1109B through exterior housing aperture 1107B in FIG. 13C. Projection 1131 is fitted between ferrules 1120 and 1125 and clips 1135 are affixed to the connector. The 25 resultant connector 1100R of 13D is of opposite polarity to the connector 1100 of FIG. 13A.

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 30 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. 14A 35 and 14B 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 40 **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. 15B and 15D. To release the protrusion 1440, push-pull tab position spring 1465 is compressed in FIG. 15C such that housing projection 1460 is retracted sufficiently to allow removal of protrusion 1440 through the housing 1405, FIG. 15D.

To change polarity of the optical connector 1400 from the first polarity of FIG. 16A, 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 55 from the first exterior housing wall 1110 (FIG. 16B). 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. 16C. 60 The resultant connector 1400R of FIG. 16D is of opposite polarity to the connector of FIG. 16A.

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 65 housing region to allow entry of a push-pull tab protrusion during affixing of the push-pull tab to the connector housing.

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As seen in FIG. 17A, 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. 17C). The back body housing portion 1709 includes a deformable region 1780, seen in the partial cross-section of FIG. 17B and the perspective view of FIG. 17C. 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. 18B) 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. 18C, the deformable region 1780 returns to its original position (FIG. 18D), securing the push-pull tab 1730 to the connector housing.

Removal of the push-pull tab 1730 is depicted in FIGS. 19A and 19B. 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. 20A, the push-pull tab 1730 is removed in FIG. 20B by using the removal tool technique depicted in FIGS. 19A and 19B. 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. 20C. The resultant connector 1700R of FIG. 20D is of opposite polarity to the connector of FIG. 20A.

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. 21A-21D, a connector 2100 having a housing 2105 is provided with a housing front portion 2107 and a back portion 2109. FIG. 21A depicts an assembled connector 2100 with housing 2105. FIG. 21B depicts an exploded view of connector 2100 of FIG. 21A. 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. 21C 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. 21D. As shown in FIG. 21D, receiving surface 2132 may be a recess with a protrusion along the edge that engages the hook-shaped edge of the clips.

FIG. 22A through FIG. 22E depicts the operation of polarity change for connector 2100 of FIG. 21A-FIG. 21D. FIG. 22A 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. 22A to the second, opposite polarity of FIG. 22E, the retainer 2111 is removed from receiving surface 2132. Referring to FIG. 21B, lifting push-pull tab 2130 in direction of up-arrow, separates retainer 2111 from receiving surface. As shown in FIG. 22C,

push-pull tab clips separate from the connector as the retainer is removed. Continuing with FIG. 22C, push-pull tab 2130 is moved to the opposite housing exterior wall in FIG. 22C. FIG. 22D depicts receiving surface 2132 engages with the retainer 2111. In FIG. 21E the assembled connector 5 2100R having the opposite polarity to the connector of FIG. 22A 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. 22E.

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

FIGS. 23-28

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 15 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 20 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 35 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 40 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 45 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 55 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 60 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, 65 the wedge shape comes in contact with an inner portion of the top surface of the adapter. Upon additional retraction of

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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 5 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 15 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 20 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 25 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 30 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 35 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 40 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, 45 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 50 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 60 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

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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

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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 15 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 20 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 25 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 30 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, 35 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, 40 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 45 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 50 "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 55 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. 60 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 65 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,"

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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

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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 multifiber ferrule.
 - 7. The adapter as set forth in claim 1,
 - wherein the first longitudinal rib has a bottom edge 25 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 30 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 40 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 45 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 50 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 55 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 60 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

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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, 5 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 30 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, 50 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 55 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 60 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 65 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
- 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

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does not protrude widthwise past the first and second side

18. The connection system as set forth in claim 16, 5 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 10 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



(12) United States Patent

Takano et al.

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

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This patent is subject to a terminal dis-

claimer.

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(52) **U.S. Cl.**

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CPC G02B 6/42; G02B 6/4292; G02B 6/38; G02B 6/3825; G02B 6/3893

See application file for complete search history.

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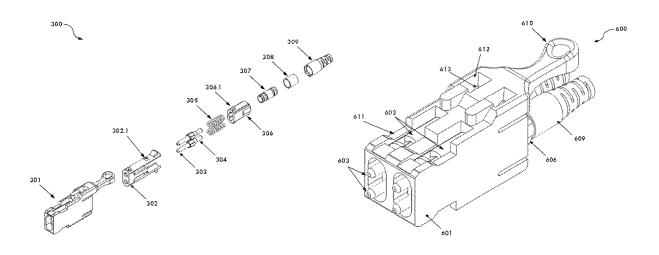
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(57) ABSTRACT

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



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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.

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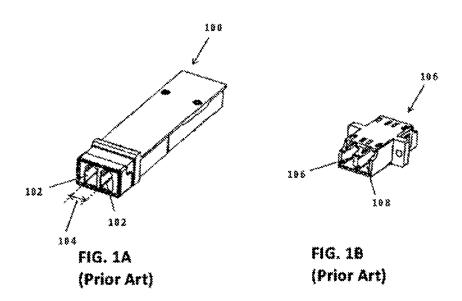
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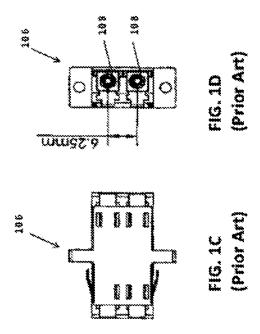
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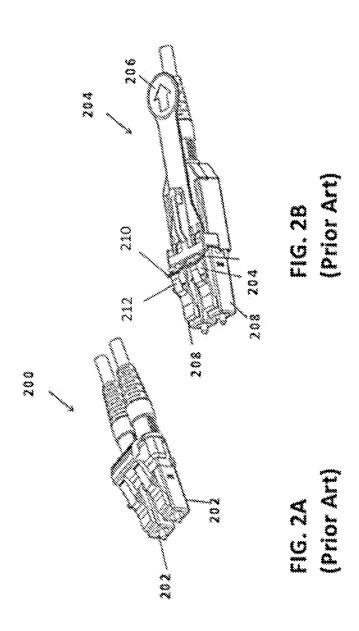
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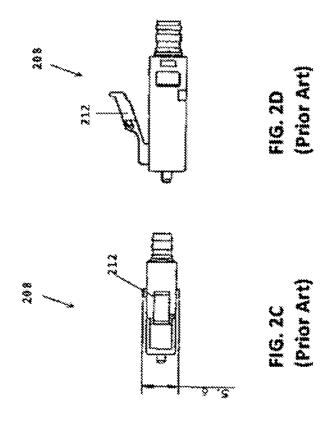
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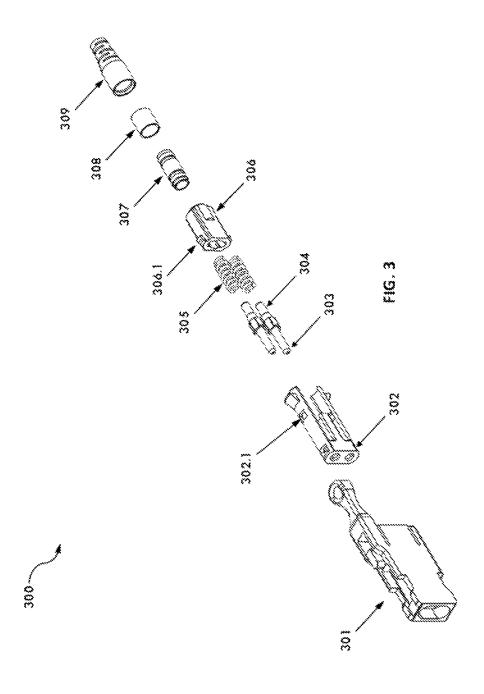
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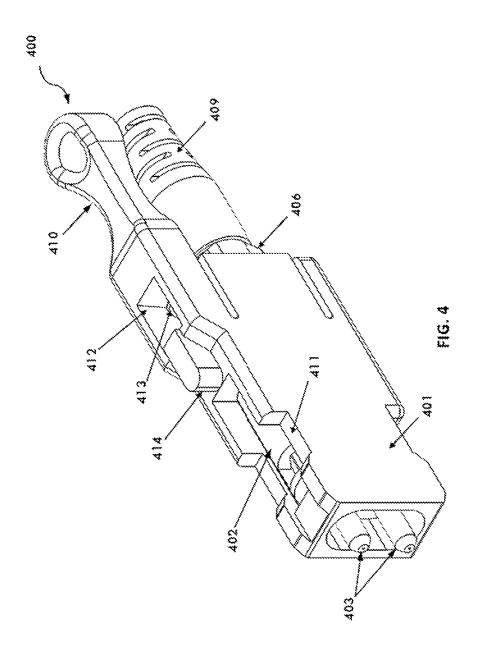
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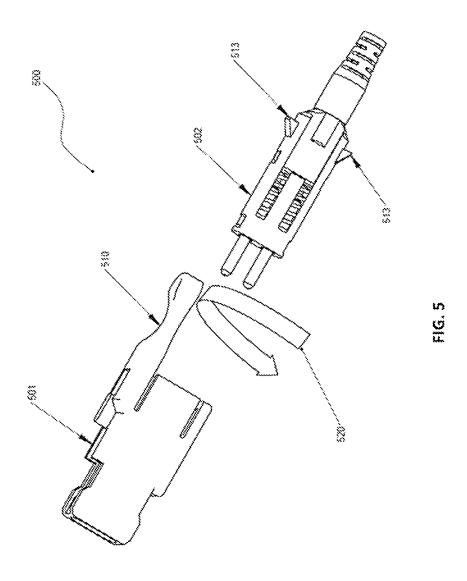
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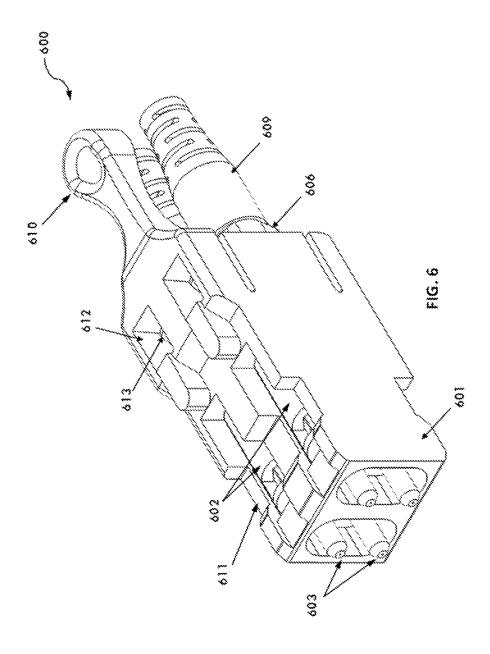
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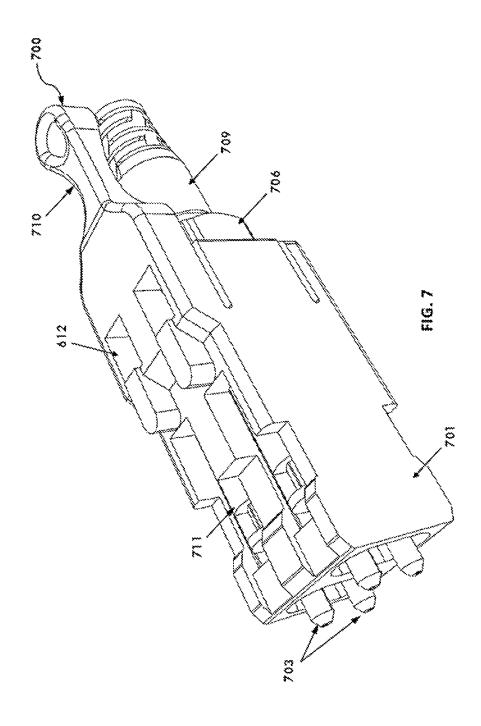
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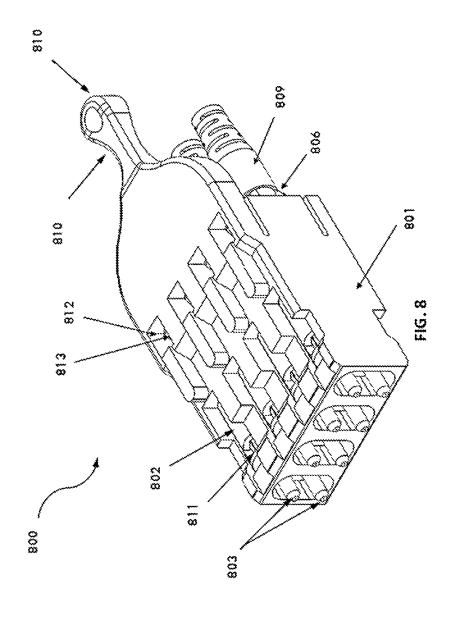
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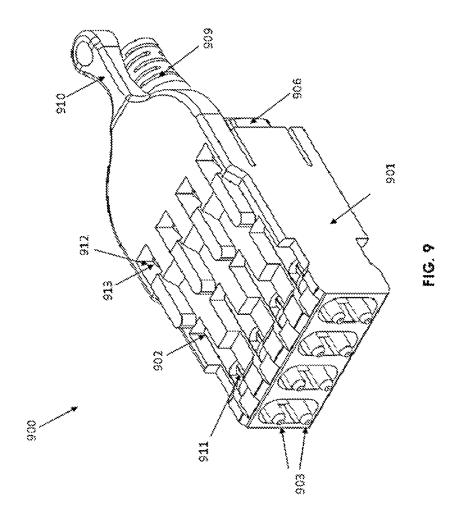
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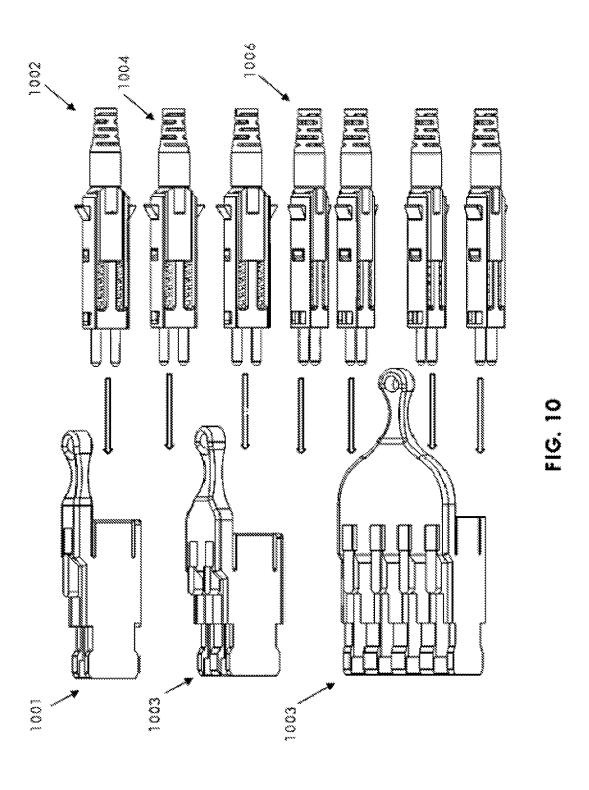
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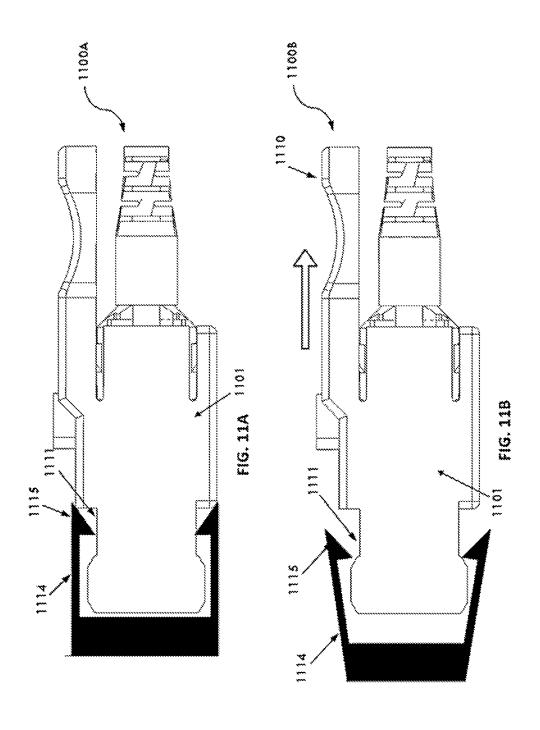
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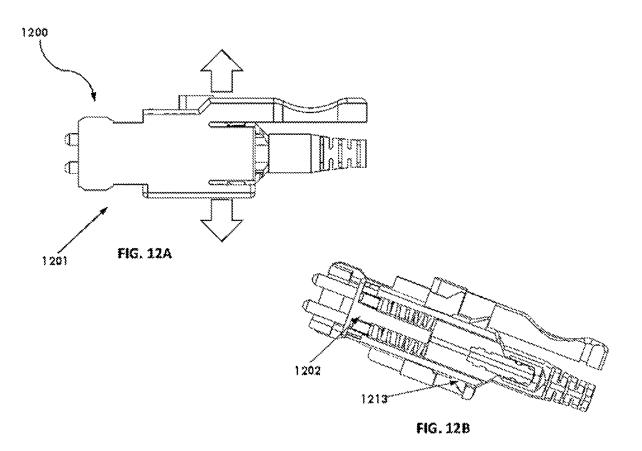
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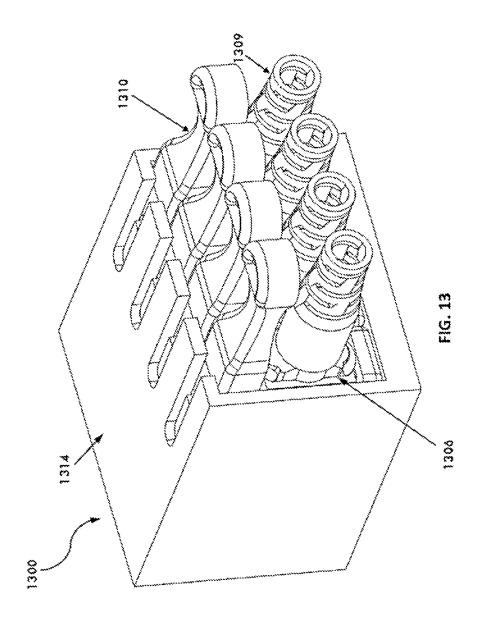
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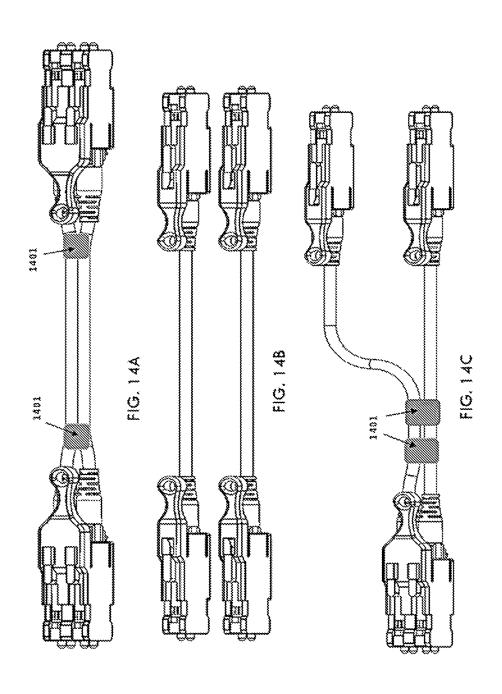
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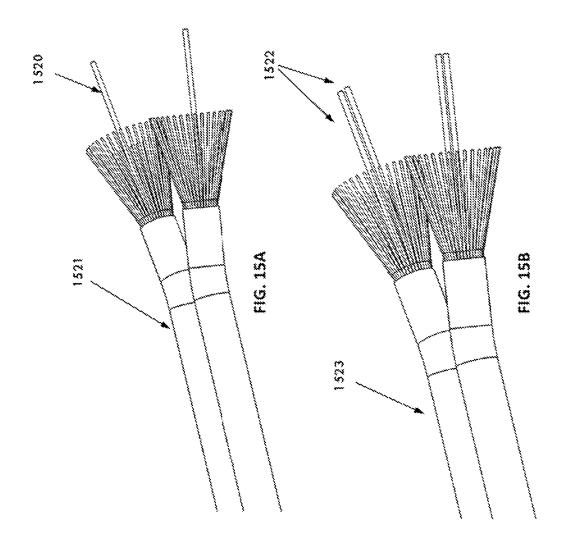
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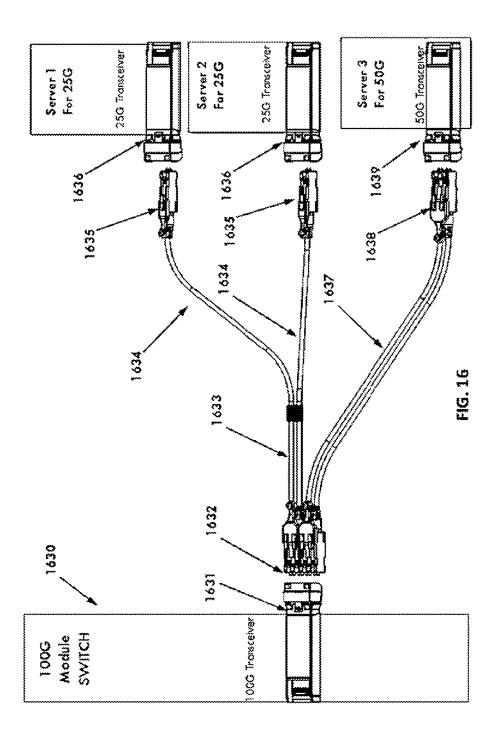
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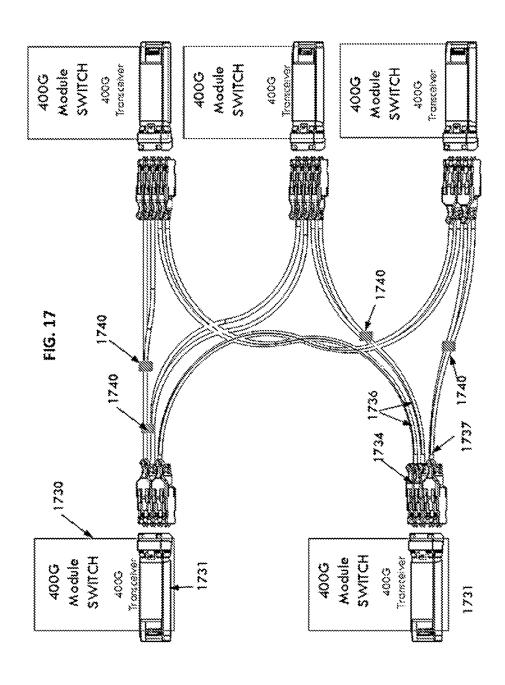
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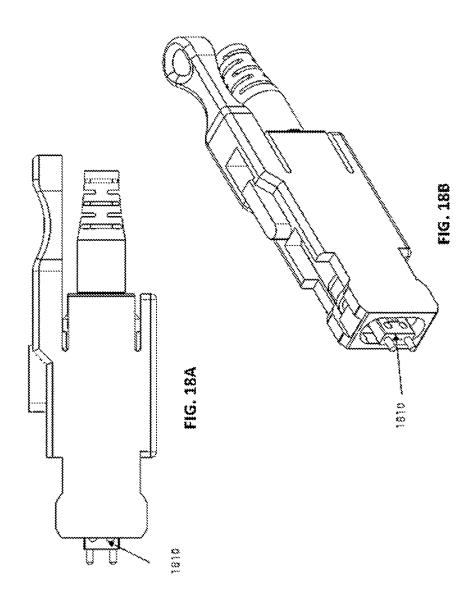
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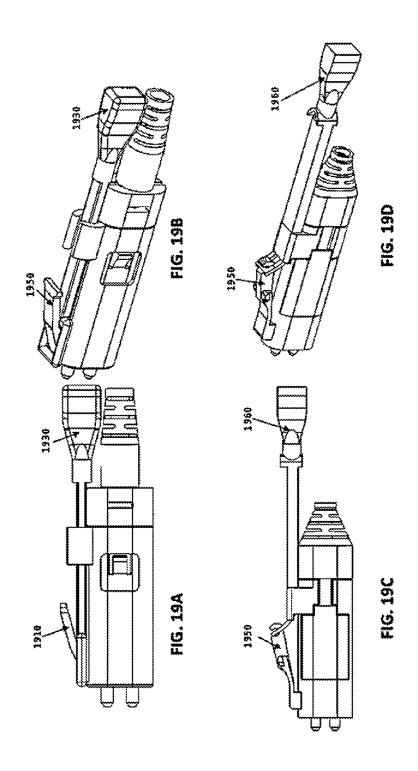
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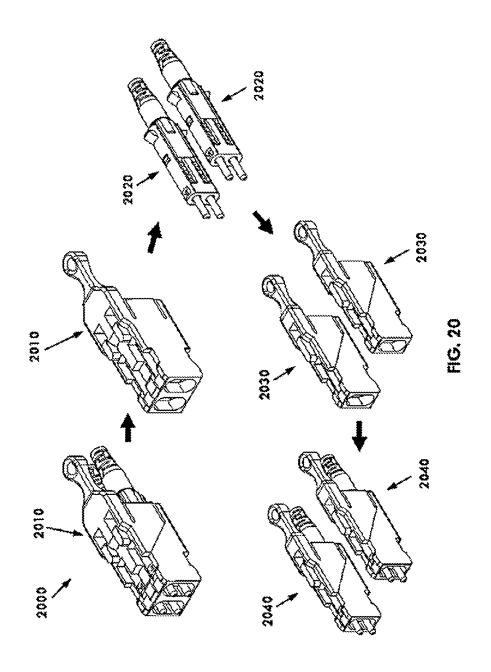
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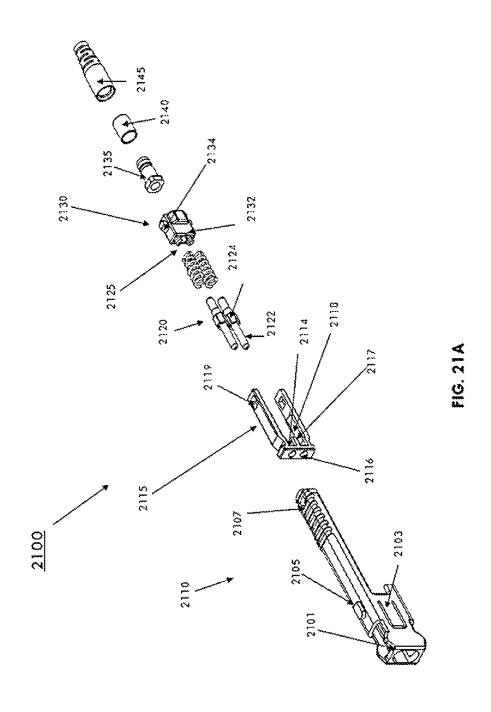
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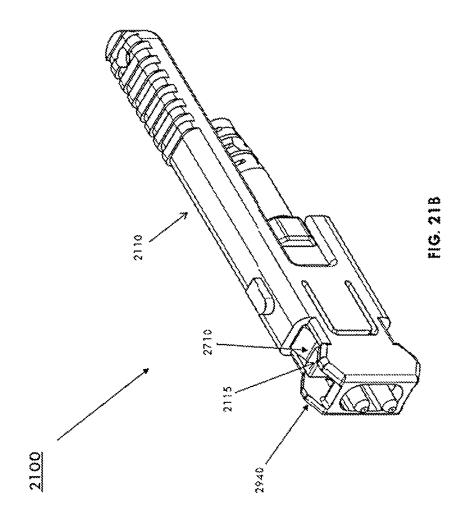
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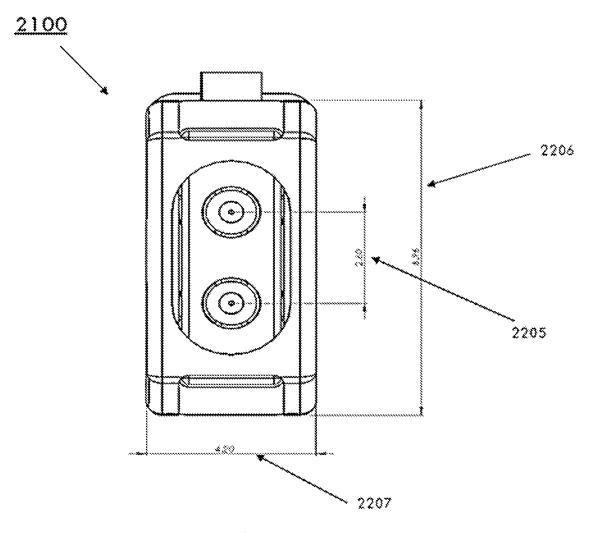
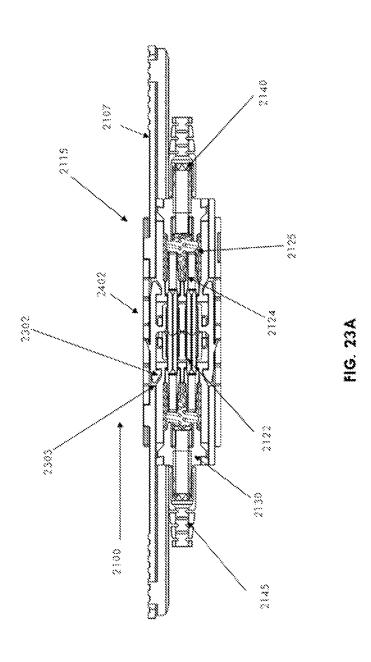


FIG. 22

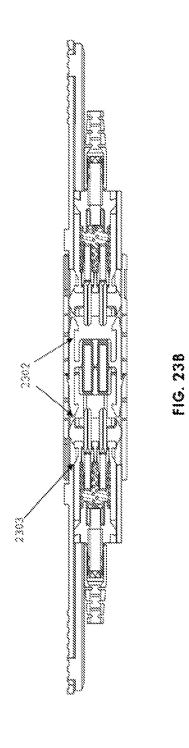
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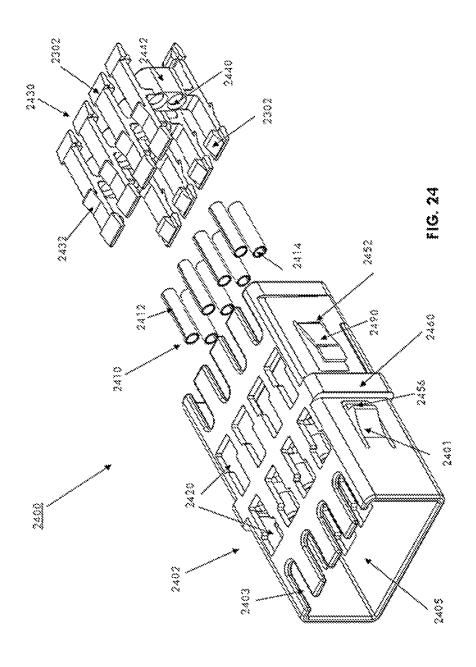
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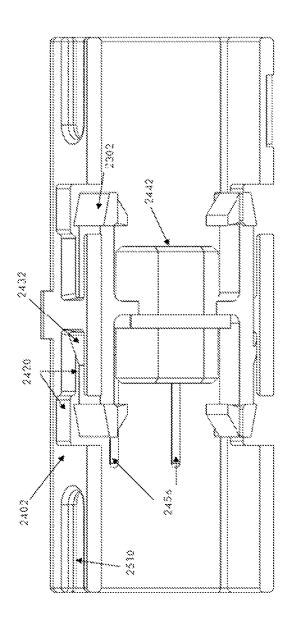
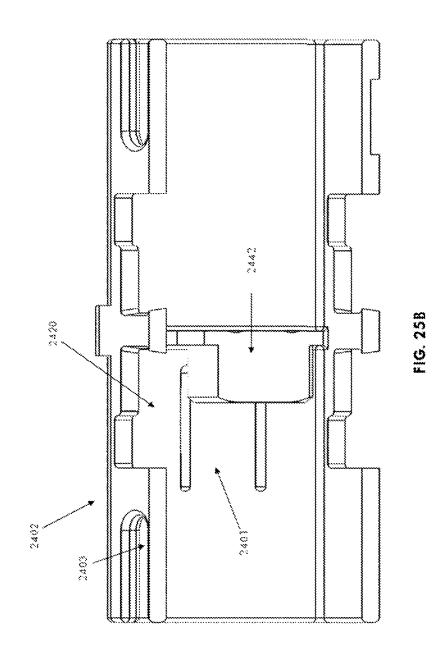


FIG. 25A

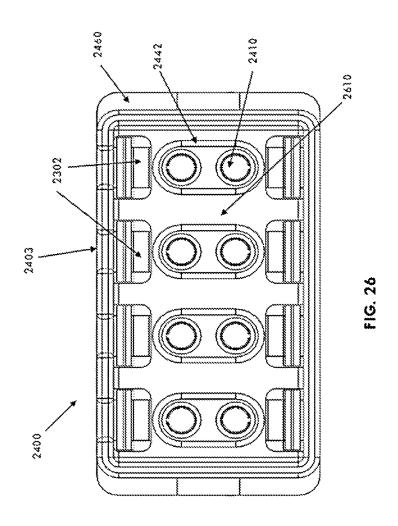
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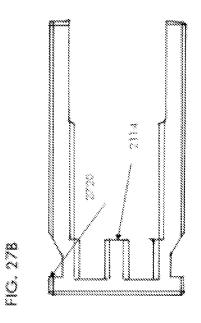
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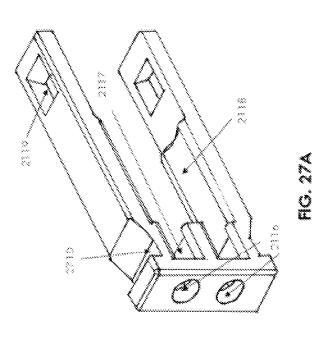
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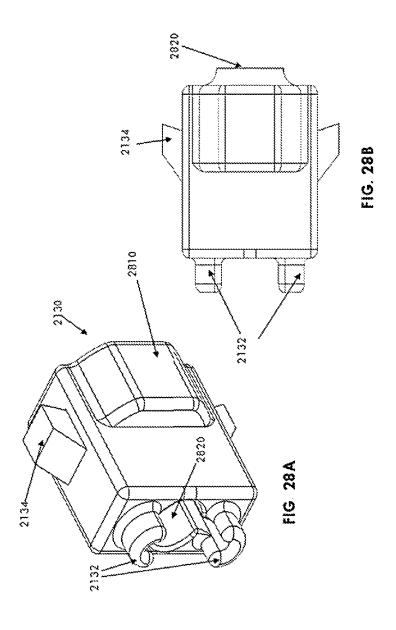
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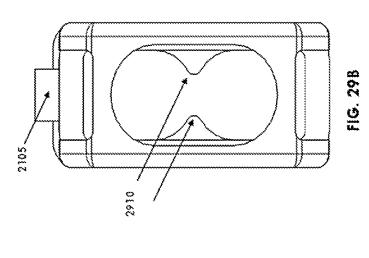
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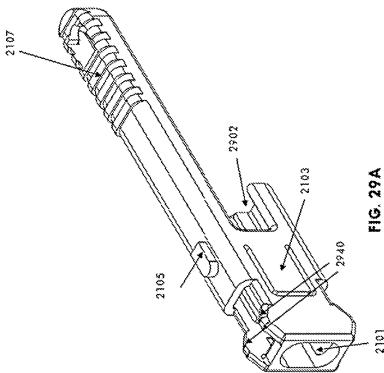
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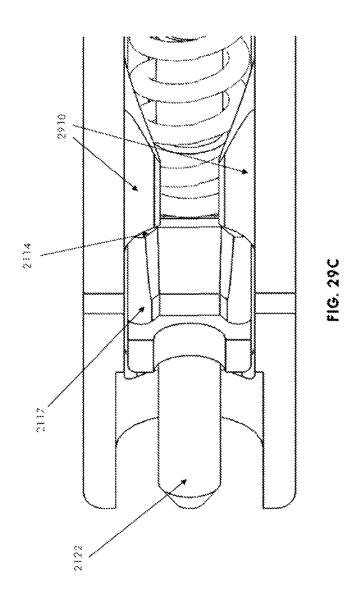
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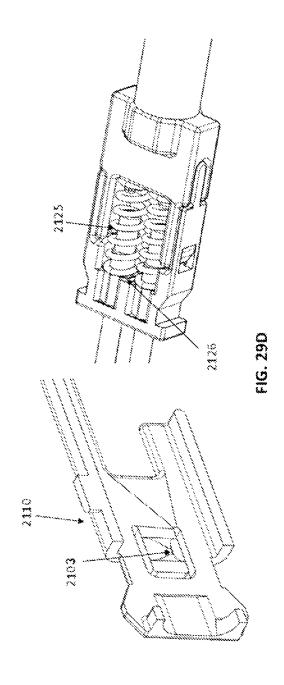
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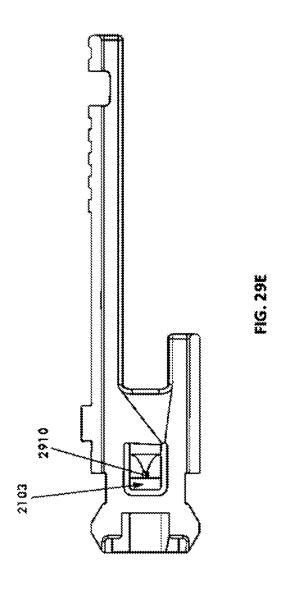
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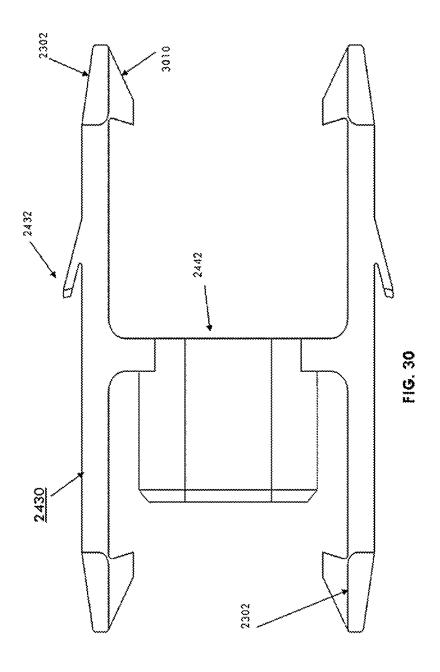
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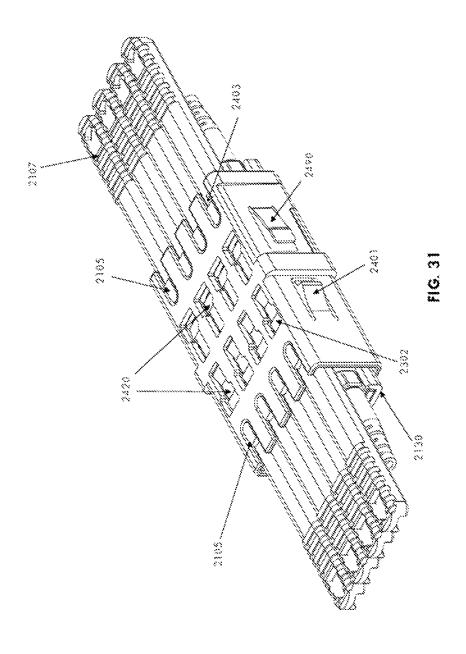
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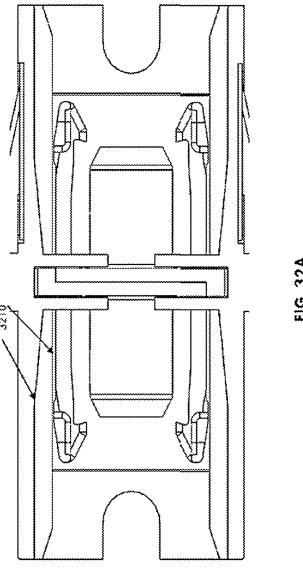
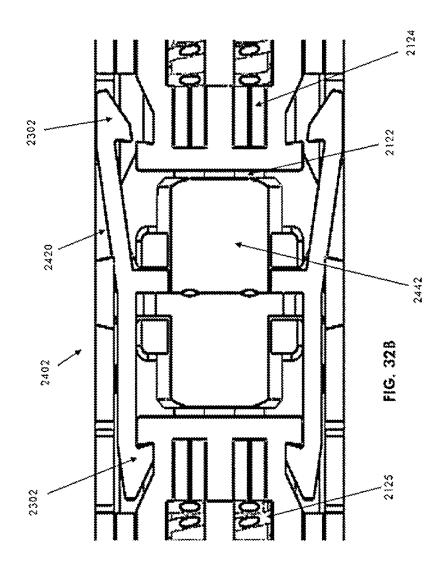


FIG. 32A

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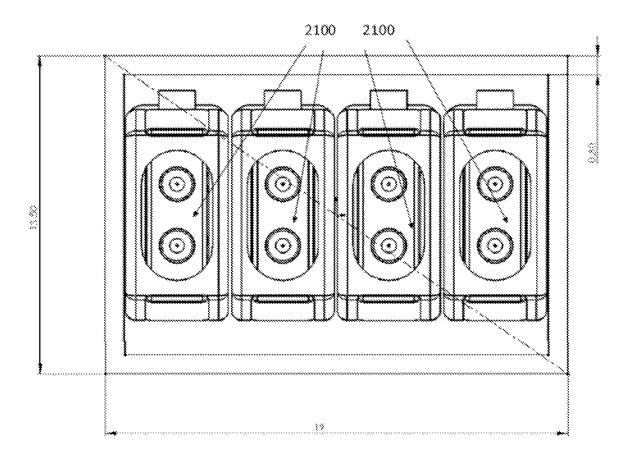
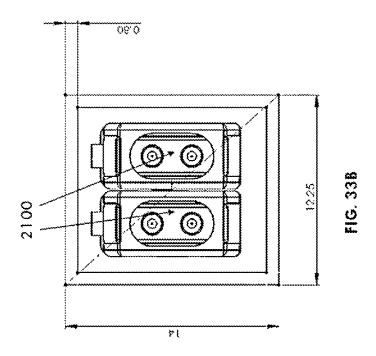


FIG. 33A

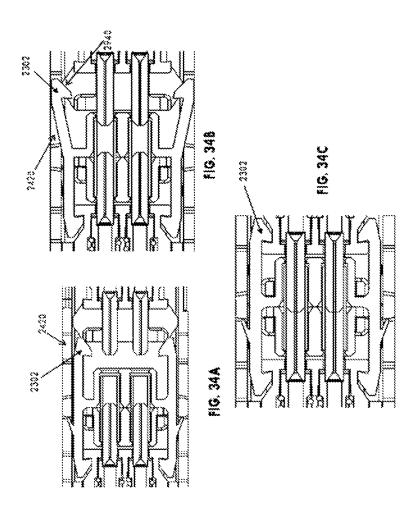
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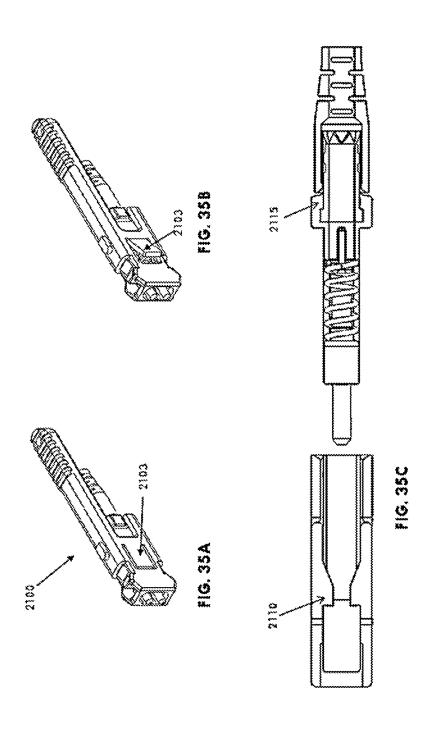
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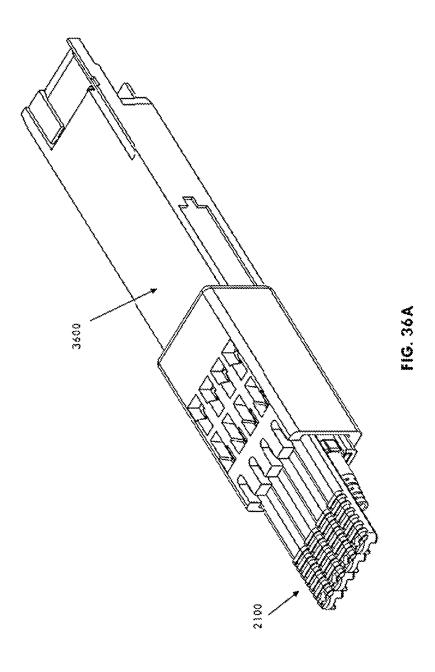
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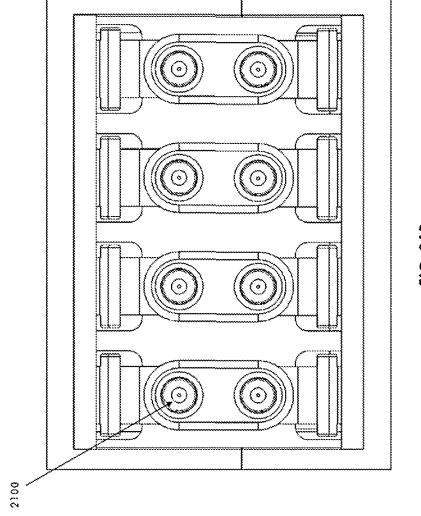
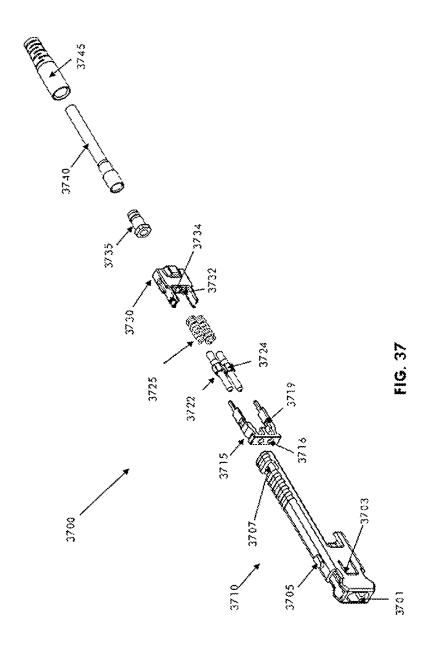


FIG. 36B

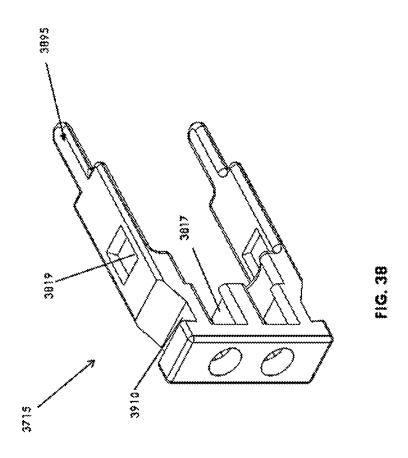
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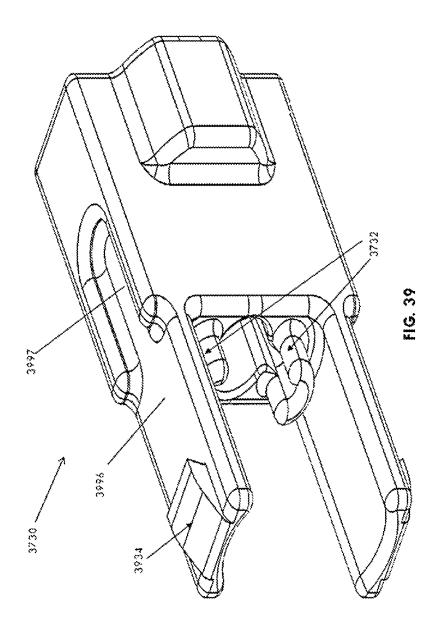
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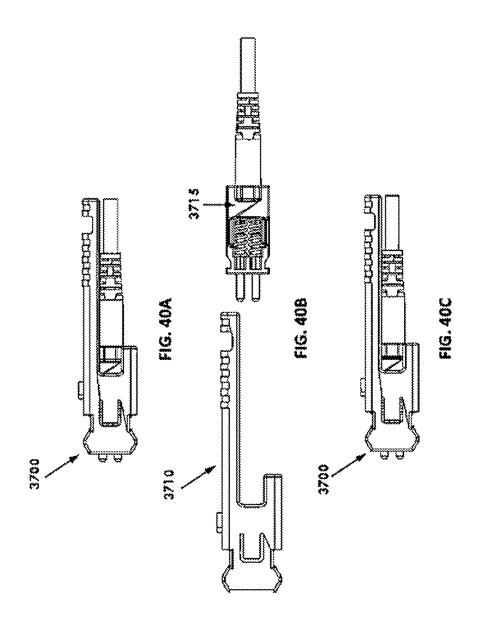
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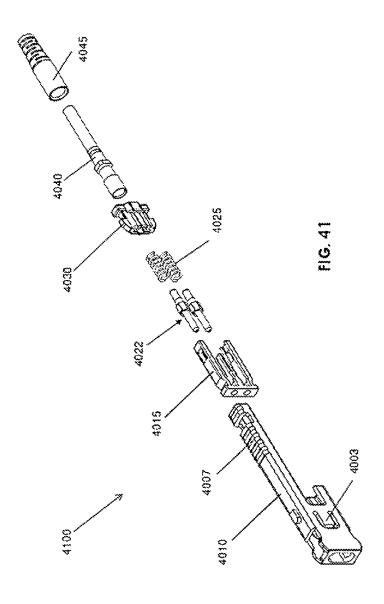
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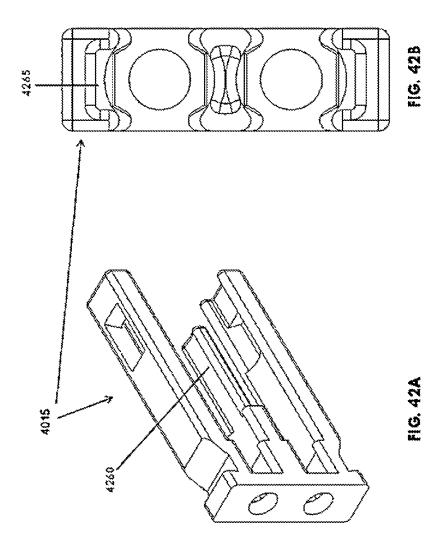
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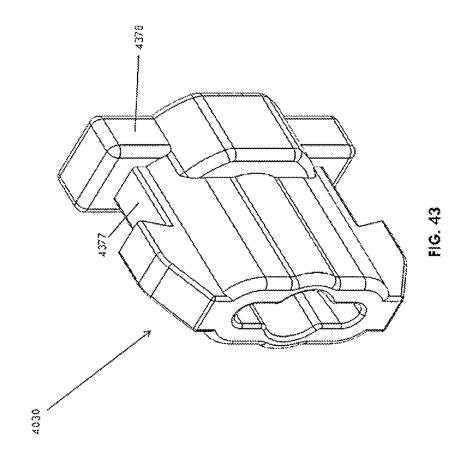
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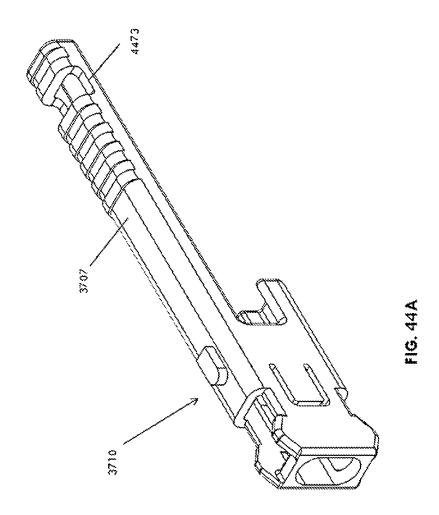
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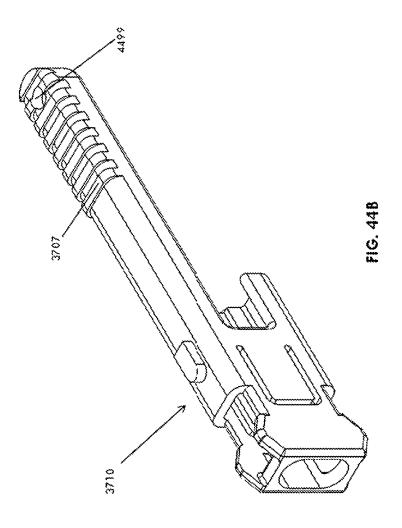
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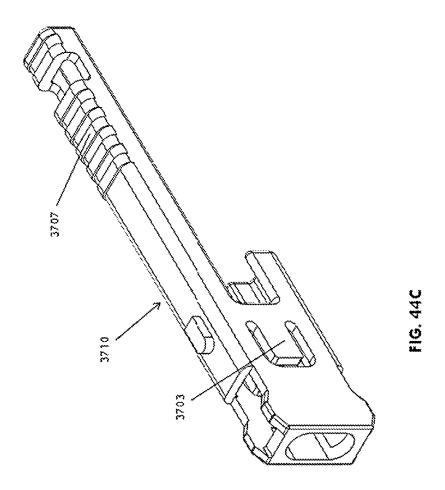
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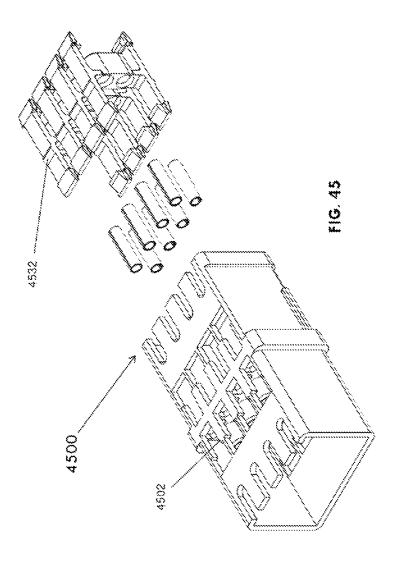
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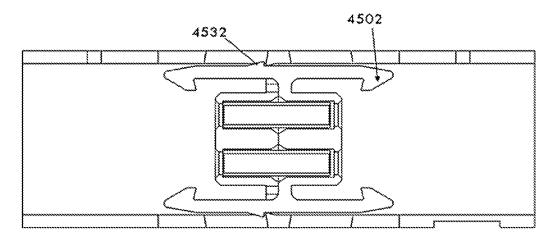
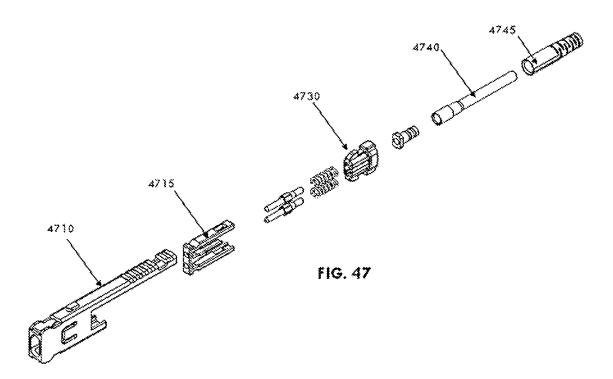


FIG. 46

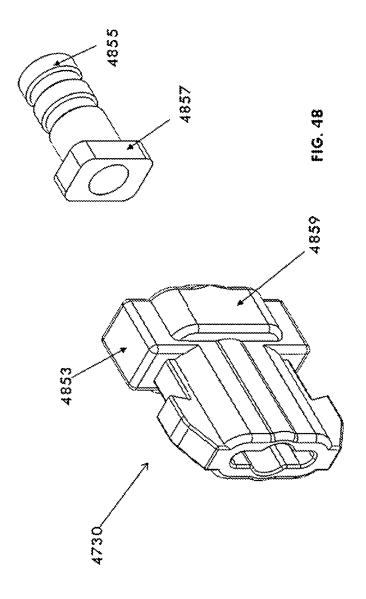
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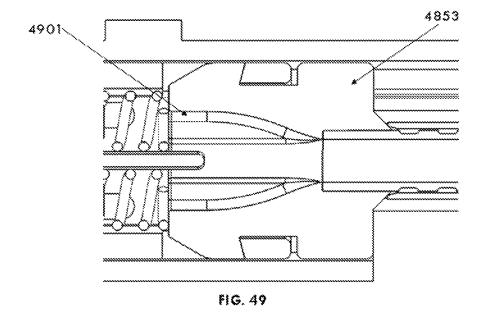
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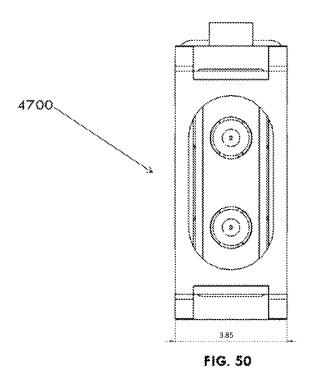
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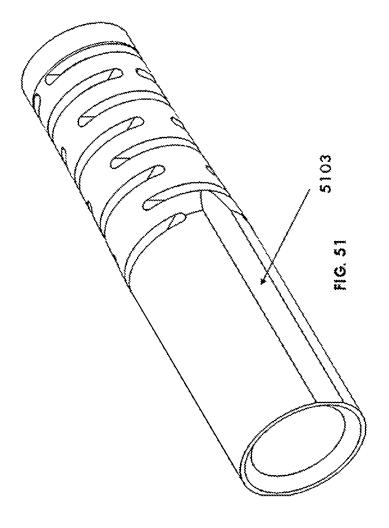


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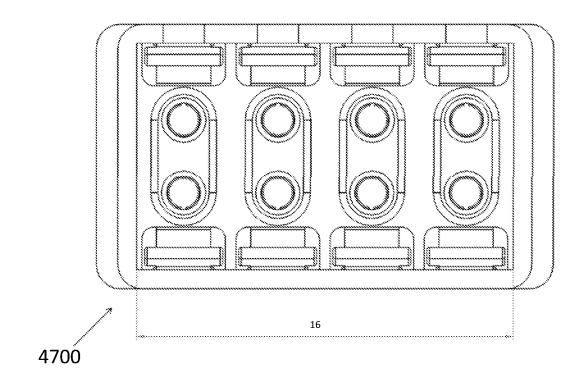


FIG. 52

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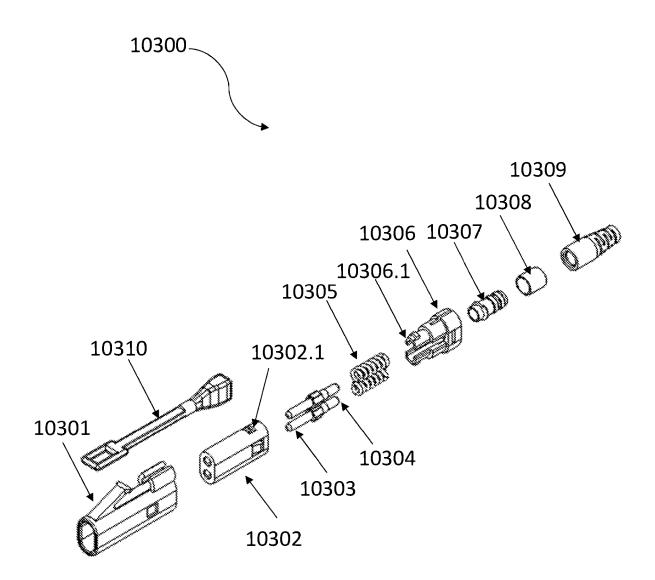


FIG.53

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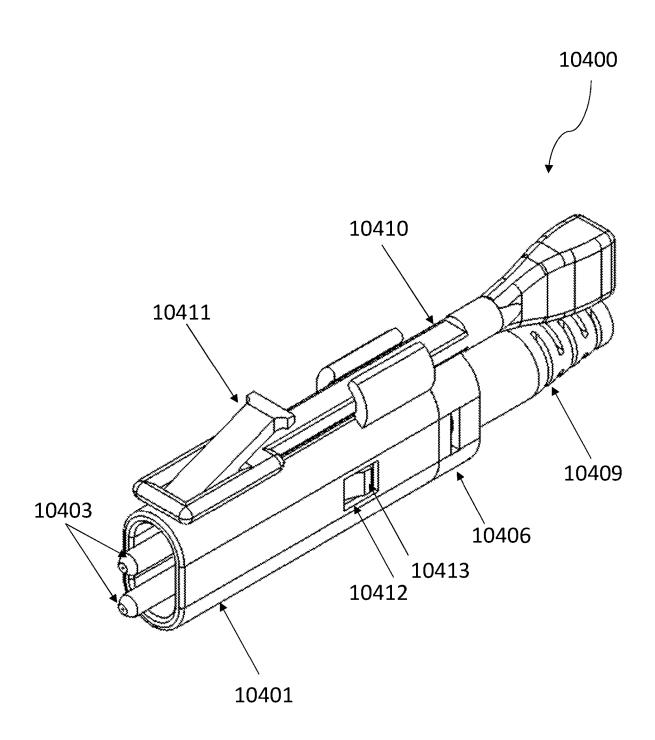


FIG.54

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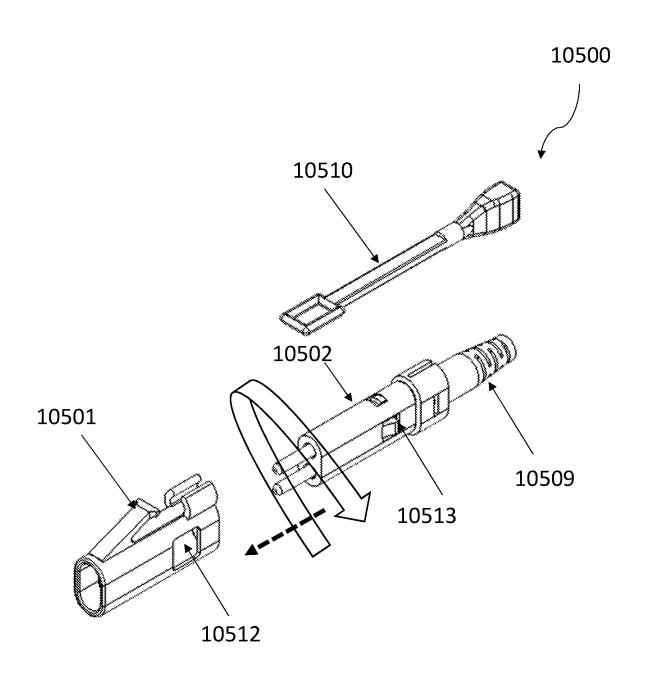


FIG.55

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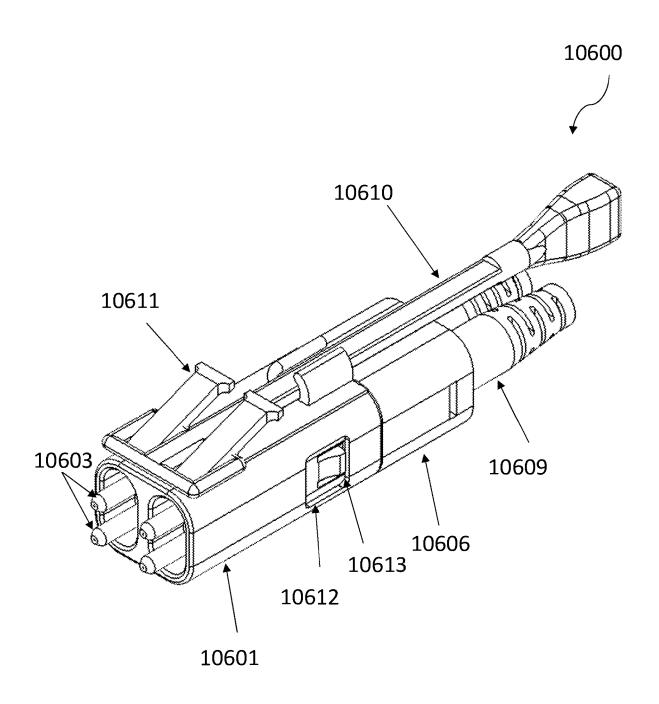


FIG.56

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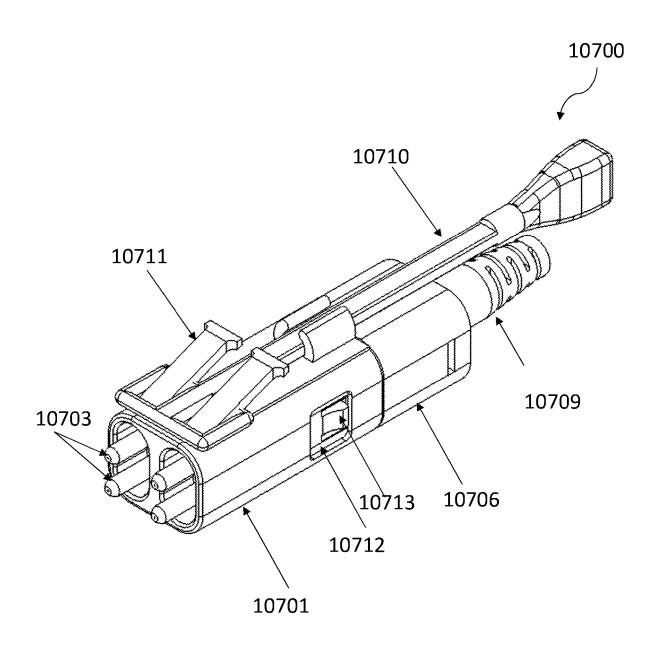


FIG.57

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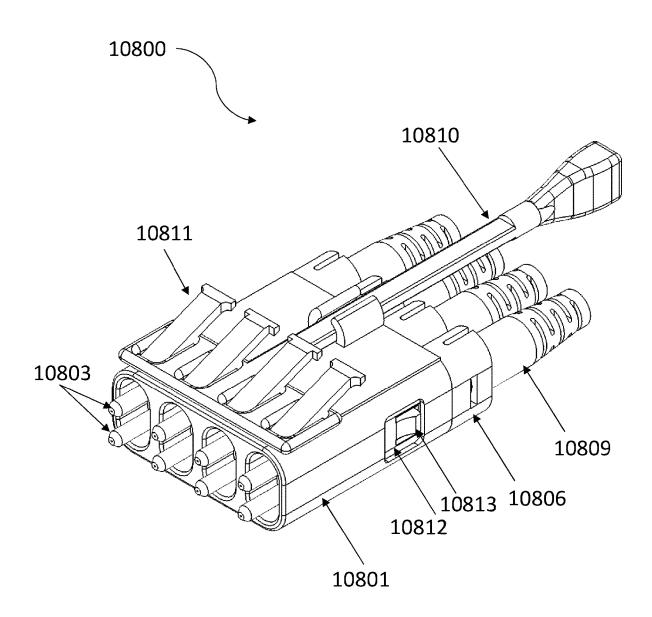


FIG.58

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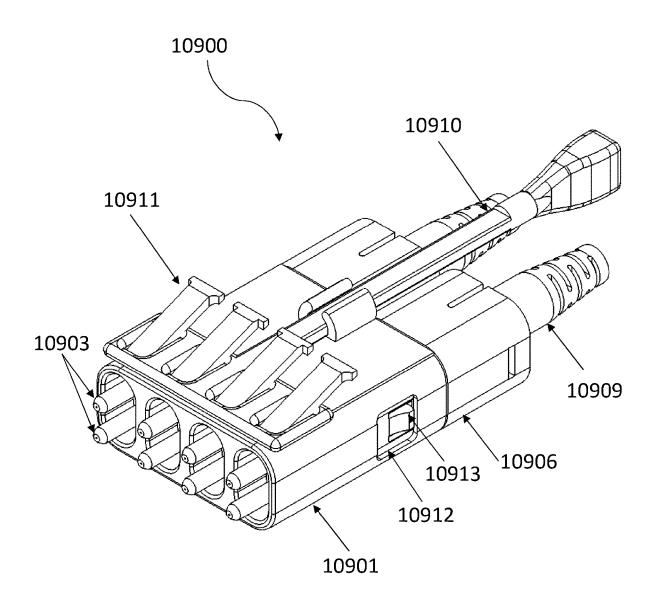


FIG.59

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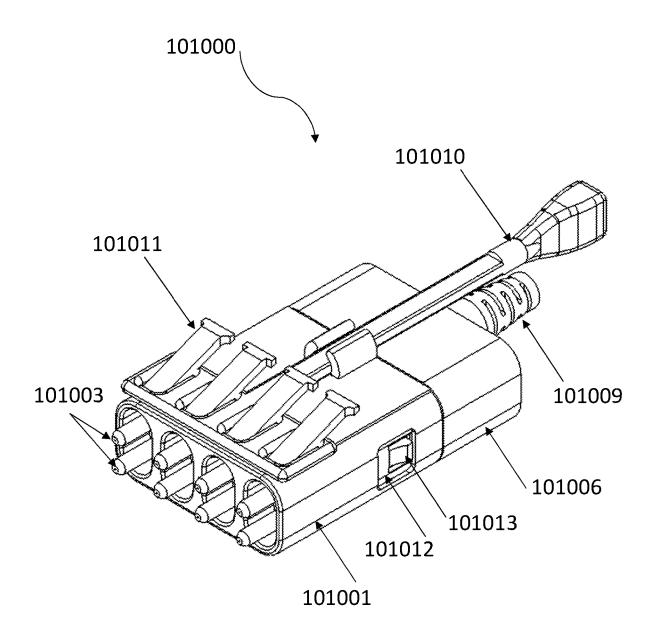
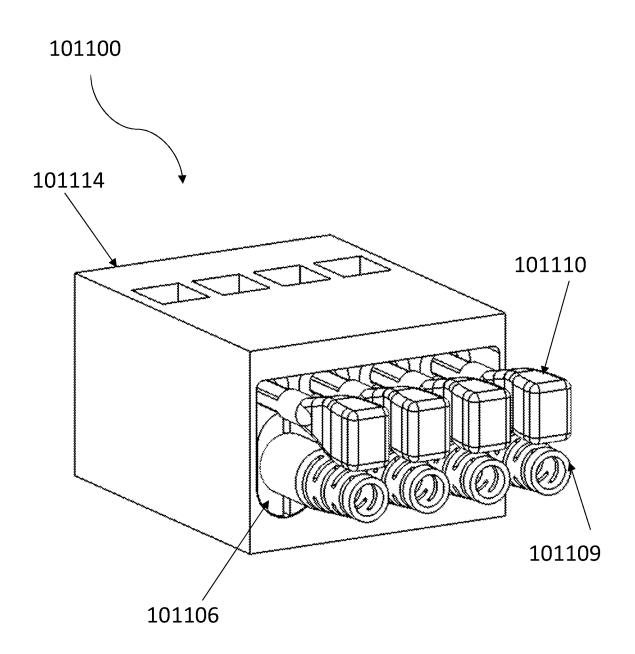


FIG.60

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FIG. 62A

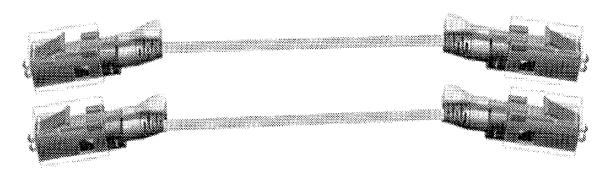


FIG. 62B

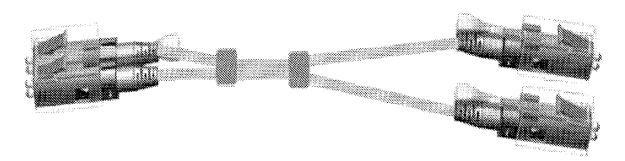


FIG. 62C

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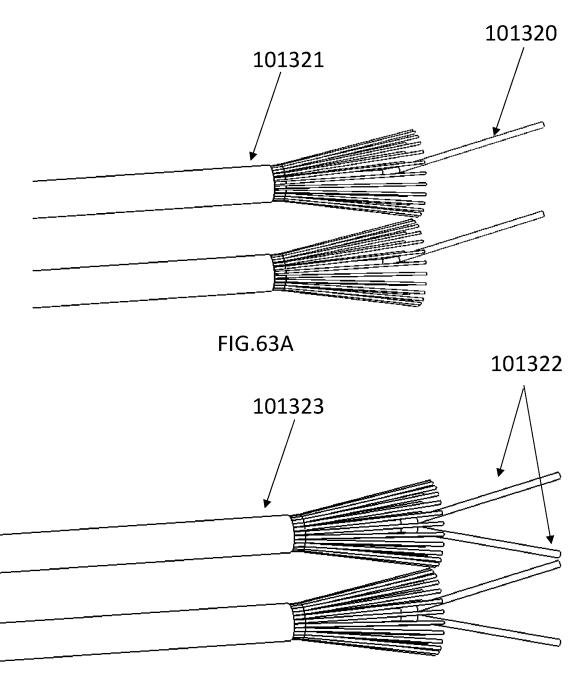


FIG.63B

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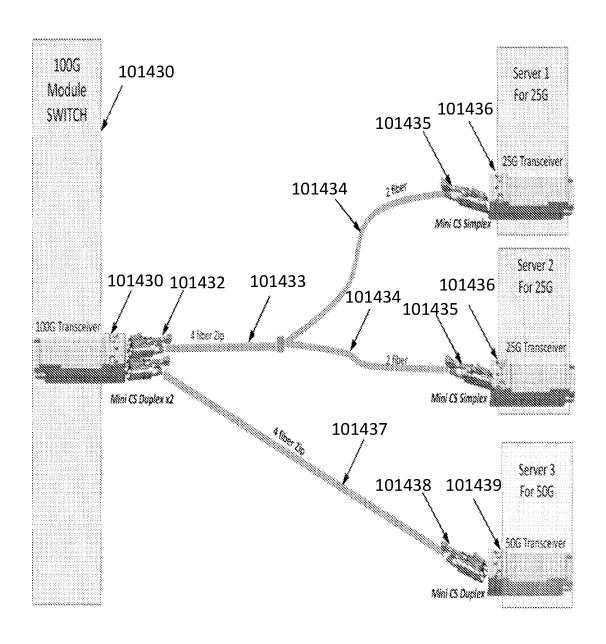


FIG.64

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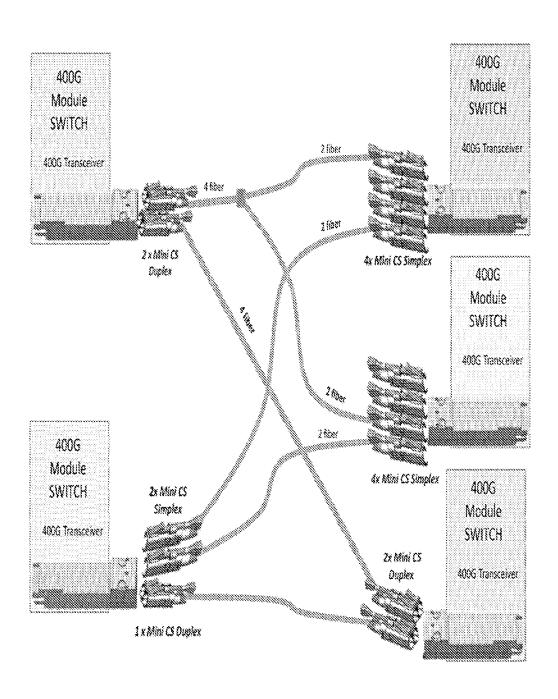
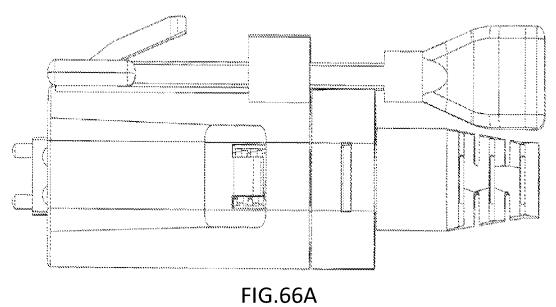
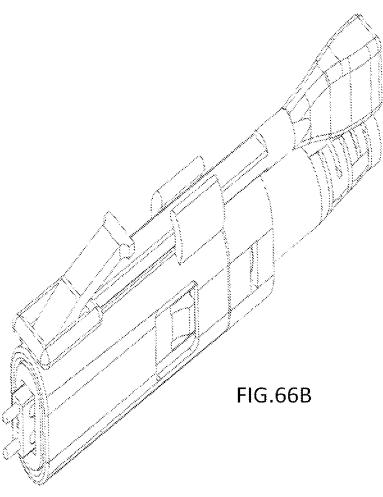


FIG.65

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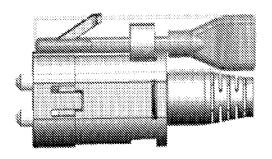


FIG.67A

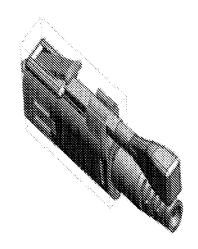


FIG.67B

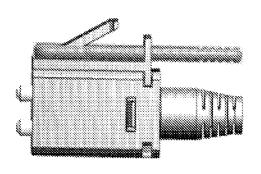


FIG.67C

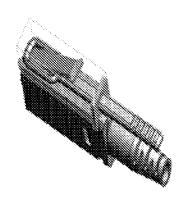
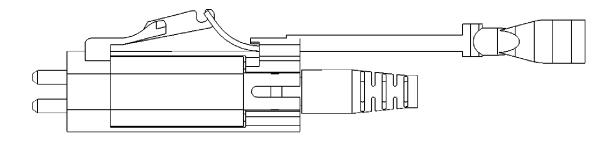


FIG.67D

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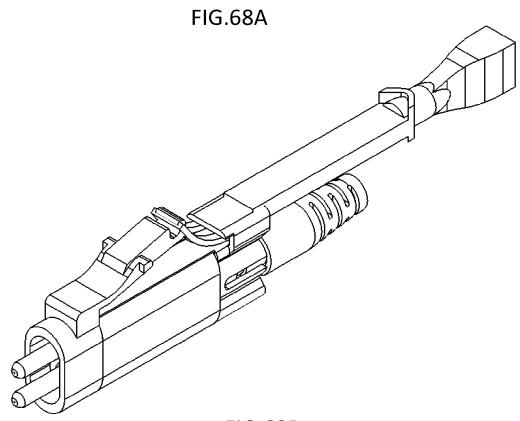


FIG.68B

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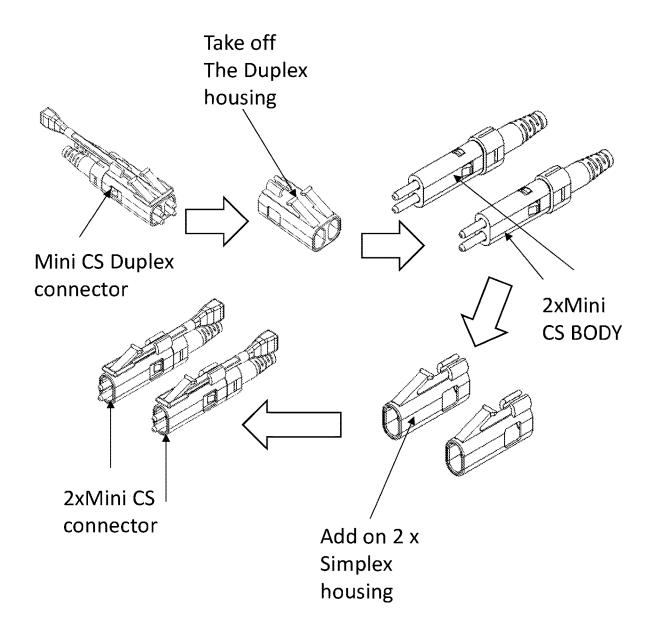


FIG.69

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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 10 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. 20 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- 25 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 30 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, 35 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 55 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 60 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 65 the same footprint previously used for a smaller number of connectors in order to provide backward compatibility with

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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;

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- FIG. 1B is a perspective view of a prior art standard 6.25 mm pitch LC adapter;
 - FIG. 1C is a top view of the prior art adapter of FIG. 1B;
- FIG. 1D is a front view of the prior art adapter of FIG. 1B, showing the 6.25 mm pitch;
- FIG. 2A is a perspective view of a prior art LC duplex connector;
- FIG. 2B is a perspective view of a prior art LC duplex connector with a remote release pull tab;
- FIG. 2C is a top view of a prior art LC connector used in 10 27A. the embodiments shown in FIGS. 2A and 2B;
- FIG. 2D is a side view of the prior art LC connector of FIG. 2C;
- FIG. 3 is an exploded view of one embodiment of a connector:
- FIG. 4 is a perspective view of one embodiment of a
- FIG. 5 is a perspective view of one embodiment of a connector with the outer housing removed from the front
- 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 25 connector;
- FIG. 9 is another perspective view of one embodiment of a quad connector:
 - FIG. 10 shows various embodiments of adapter types;
- FIG. 11A is a side view of a connector connected to an 30 adapter;
- FIG. 11B is a side view of a connector being removed from an adapter;
- FIG. 12A is a side view of the outer housing of a connector being removed;
- FIG. 12B 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. 14A-C are illustrative examples of cable manage- 40 ment using various embodiments of connectors;
- FIG. 15A-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. 45
- FIG. 17 is another illustrative example of using a cable management system using multiple fiber strands per jacket.
- FIGS. 18A-B are various views of one embodiment of a MT connector.
- FIGS. 19A-D are illustrative examples of possible alter- 50 native connector designs.
- FIG. 20 shows moving two connectors from a duplex connector to two simplex connectors.
- FIG. 21A is an exploded view of a micro optical connector according to an embodiment.
- FIG. 21B is a perspective view of the assembled micro optical connector of FIG. 21A.
- FIG. 22 is a front view of the micro optical connector of FIG. 21B showing overall connector dimensions and ferrule pitch.
- FIG. 23A is a cross-sectional view of the micro optical connector of FIG. 21B latched into the adapter of FIG. 24.
- FIG. 23B is a cross-sectional view of the micro optical connectors of FIG. 21B unlatched from the adapter of FIG.
- FIG. 24 is an exploded view of an adapter for the micro optical connectors of FIG. 21B.

- FIG. 25A is a cross-sectional view of the adapter of FIG. 24, assembled.
- FIG. 25B 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. 27A is an isometric view of the front body of the micro optical connector of FIG. 21A.
- FIG. 27B is a right side view of the front body of FIG.
- FIG. 28A is an isometric view of the back body of the
- micro optical connector of FIG. 21A. FIG. 28B is a side view of the back body of FIG. 28A.
- FIG. 29A is an isometric view of the outer housing of the 15 micro optical connector of FIG. 21A.
 - FIG. 29B is a front view of the outer housing of FIG. 29A.
 - FIG. 29C is a cross-sectional view of the outer housing of FIG. 29A showing the top of an orientation protrusion.
- FIG. **29**D is an inner view of the outer housing of FIG. 20 29A:
 - FIG. 29E 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. 21B.
 - FIG. 32A is cross-sectional view of a prior art connector showing a latch gap.
 - FIG. 32B is a cross-sectional view of the micro optical connector of FIG. 21B latched (left) and unlatched (right) within the adapter of FIG. 24, assembled.
 - FIG. 33A depicts the micro optical connector of FIG. 21B in a QSFP footprint, depicting dimensions in millimeters.
- FIG. 33B depicts the micro optical connectors of FIG. 35 21B in an SFP footprint, depicting dimensions in millime-
 - FIG. 34A-34C depicts adapter hooks interacting with the micro optical connectors of FIG. 21B before (FIG. 34A), during (FIG. 34B), and after (FIG. 34C) latching.
 - FIG. 35A-FIG. 35C depicts the micro optical connector of FIG. 21B side flap operation before (FIG. 35A), during (FIG. 35B), and after (FIG. 35C) latching.
 - FIG. 36A depicts plural micro optical connectors in a transceiver.
 - FIG. 36B is a front view of the transceiver of FIG. 36A.
 - 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. 40A, 40B, and 40C depict a technique for reversing polarity of the optical connector of FIG. 37.
- FIG. 41 is an exploded view of a micro optical connector 55 according to a further embodiment.
 - FIG. 42A 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 60 optical connector of FIG. 41.
 - FIGS. 44A, 44B, and 44C are isometric views of the outer housings that may be used with any of the micro optical connectors of FIGS. 21A, 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.

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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** 5 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 15 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 ²⁰ 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 manage- ³⁰ ment using various embodiments of connectors;

FIG. 63A-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. ³⁵

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 alter- ⁴⁰ native 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 50 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 55 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 60 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 6

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. 1A 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. 1B 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. 1C is a top view of the adapter 106 of FIG. 1B. 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. 1D, which shows a front view of the adapter 106.

FIG. 2A 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. 2B 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. 2C and 2D 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.

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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 $_{15}$ 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 20 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 40 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 45 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 60 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 65 re-inserted into the outer housing. This allows for a change in the polarity of the front body **502**, as shown by the arrow

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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.

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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 20 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 25 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 30 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 twoferrule capacity housings. In this manner, cables may be flexibly reconfigured to match the capacity of a mating 35 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 40 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 45 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 50 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 55 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 60 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

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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. 11A, in one embodiment 1100A, 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 1100A. Accordingly, in some embodiments, the receptacle 1114 may have a receptacle hook 1115, which is flexible and can secure the connector 1100A 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 1100A into the receptacle.

Additionally, or alternatively, in some embodiments, such as that shown in FIG. 11B, a connector 11001B 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. 11B, as the connector 1100B 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. 12A and 12B, 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. 12A. 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

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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 15 in FIGS. 14A through 14C 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. 20 21B, 37, and 41, to be discussed in detail below. FIG. 14A 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 25 be bundled and reduce the risk of entanglement with additional cables. FIG. 14B 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 30 move and be connected independently. FIG. 14C shows an embodiment in which a duplex connector like that of FIGS. 6 and 14A is connected to two separate individual connectors. Through the variable housing configurations depicted above in FIG. 10, the cable of FIG. 14A can be reconfigured 35 as the cables of either 14B or FIG. 14C.

In addition to binding existing fiber cables, some embodiments herein may utilize a new four fiber zip cable. Referring now to FIG. 15A, a conventional zip cable (i.e., one with a single fiber strand 1520 per jacket 1521) is shown in 40 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 45 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 pos- 50 sible, such as, for example, that shown in FIGS. 18A-18B and FIGS. 19A-19D. 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 55 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 60 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 65 inserted into another transceiver (e.g., 50G transceiver) 1639.

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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. 18A-18B, and the optical connectors of FIGS. 21, 37,

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. 19A-19D 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. 19A-19B, 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. 19C-19D. 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. 14A to a connector as shown in FIG. 14C. 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. 21A depicts an embodiment of an optical connector 2100, shown in exploded view while 21B depicts the optical connector 2100 in an assembled view. Optical connector 5 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 10 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 15 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 20 "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, 25 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 35 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 40 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. 29A and 29B, isometric and front views of the outer housing 2110 are shown. As seen in the front view of FIG. 29B and the cross-sectional view of FIG. 29C, connector orientation protrusions 2910 are provided within the interior of the outer housing 2110. Connector protrusion 50 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 55 inserted into the outer housing 2110, the outer housing locking surface 2114, best seen in FIG. 27C, engages the connector orientation protrusion 2910, seen in an inside view of the outer housing in FIG. 29D, labelled as "Flap A", flexing the connector flap 2103 outwardly from the outer 60 housing body 2110, depicted in the inset of FIG. 29C. The flap protrusion mating location is indicated as "mating place B" in FIG. 29D. Once the locking surface 2114 passes beyond the orientation protrusion, the connector flap returns to its original position (FIG. 29A), and the protrusion 2910 engages locking surface 2114 and any withdrawal of the front body assembly from the outer housing 2110 is pre14

vented as the proximal end face of the connector flap 2103 is stopped by protrusion 2910.

FIGS. 35A-35C 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. 35B. 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. 35C, 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. 28A and 28B, 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. 27A and 27B) 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. 28A, 28B) of back body 2130 by spring tension. As seen in the assembled cross-sectional views of FIGS. 23A and 23B, 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. 27A and 27B, 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. 21B, 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. 27A and 27B (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

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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 20 transceiver optical receptacle is depicted in FIG. 36B (holding optical connectors 2100); as seen in FIG. 36B, the connection environment is substantially similar to one-half of an adapter 2400.

Turning to FIG. 24, further size reductions in the overall 25 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. 21B. As seen in FIG. 30, receptacle hooks 2302 include an inner surface 3110. The adapter housing 2402 further includes 40 connector alignment slots 2403 that mate with connector alignment key 2105 of FIG. 21A. 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 45 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 connec- 50 tion 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 55 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. 60 21B. 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. 21A. The connectors 2100 are received through connector opening of the receptacle housing which 65 also includes flex tab, cutout, mount plate and panel hook. To assemble the receptacle alignment assembly in the recep16

tacle 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. 25A and 25B. 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. 32B and 34A-C. Prior to latching (FIG. 34A), 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. 32A. As seen in FIG. 32A, 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. 25A. Connector alignment keys 2105 are positioned within connector alignment slots 2403. As seen in the cross-sectional view of FIG. 23A, 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. 33B. 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. 33A. 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

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optical connector of FIG. 21A 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

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. 21A, described above. A ferrule flange alignment slot 3817 is also provided.

In FIG. 39, the back body 3730 is depicted, showing 25 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, 30 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. 40A-40C, the assembled front body 3715 may be removed from the outer housing 3710, rotated 35 180° as indicated by the arrow (FIG. 40B), and re-inserted into the outer housing (FIG. 40C). 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 40 previously with respect to FIGS. 35A-35C, 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. 21A 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 50 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. 42A, 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. 42B. 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 65 breakage or disconnection of the front body and the back body 4030.

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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. 42B. 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. 44A-44C, may be used with any of the optical connectors depicted in FIGS. 21, 37, and 41 or earlier embodiments. In FIG. 44A, 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. 44B 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. 44C 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. 5 embodiment make it possible for the four connectors to fit in the profile of FIG. 52.

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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 10 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 20 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 ments, 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), 30 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 embodi- 35 ment, 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 40 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 45 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 50 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 60 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. 65 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-

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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 wherein the connector 10400 is assembled. In some embodi- 25 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 55 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

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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 5 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 10 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, 20 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 25 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 35 body **101106** and boot **101109**). However, unlike FIG. **58**, the embodiment shown here utilizes four individual pushpull 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 benefi- 45 cial with regard to reducing the burden of cabling in a data center environment. Illustrative embodiments shown in FIGS. 62A through 62C depict cable configurations that can be used to reduce the complexity of optical cables in a compact environment. FIG. 62A shows two duplex cables 50 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. 62B is an illustrative example, of how easily an embodiment can separate into two individual connectors by unbinding the cables and thus 55 quickly and easily creating two independent fiber optic channels that can move independently. FIG. 62C shows an embodiment in which a duplex connector like that of FIGS. **56** and **62**A is connected to two separate individual connec-

In addition to binding existing fiber cables, some embodiments herein may utilize a new four fiber zip cable. Referring now to FIG. 63A, 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 65 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.

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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. 66A-66B, 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. 66A-66B).

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

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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 10

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 15 "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 20 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 25 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" 35 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" 40 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 45 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 50 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 55 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 60 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 65 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

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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

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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 lock- 5 ing 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, 15 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 20 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 25 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 30 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 35 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 40 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 50 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 55 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 60 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 65 walls defines a latch opening, wherein the second part comprises opposing inner side wall sections, each of the

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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 con-

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- figured 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 5 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 10 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, 20 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 35 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 40 connector height.

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- 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;	multi-fiber ferrule plurality of optical fiber connector
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,	Transverse axis Transverse axis Transverse axis Transverse axis Transverse axis Transverse axis Plurality of optical fibers spaced along the transverse axis in a row Perrule exposed through front end portion, fibers spaced along transverse axis in a row Connector housing (green)

Case 1:23-cv-00083-JPM Document 40 Filed 02/01/24 Page 680 of 759 PageID #: 2317

U.S. Patent No. 11,307,369	MMC
a depressible latch above the top portion of the connector housing; and	depressible latch
an elongate arm connected to the connector housing above the top portion and configured to be pulled to actuate the depressible latch;	DirectConecTM Push-Pull Boot Technology Depressible latch DirectConec(TM) Push-Pull boot functions by using boot to pull the arm and thereby depress latch Top portion of connector housing Connector

Case 1:23-cv-00083-JPM Document 40 Filed 02/01/24 Page 681 of 759 PageID #: 2318

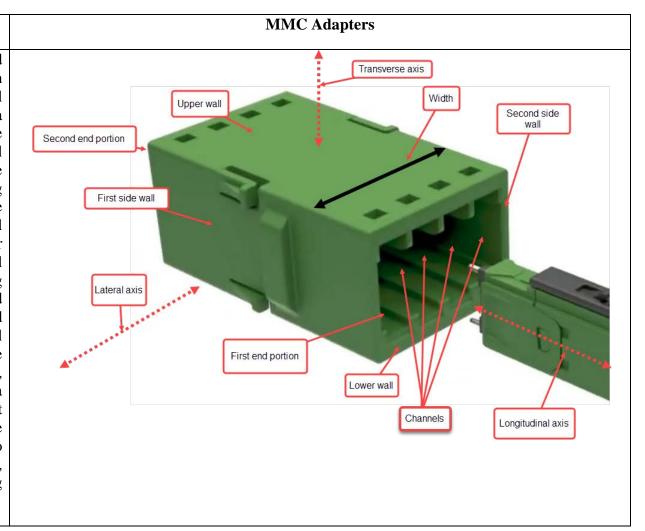
U.S. Patent No. 11,307,369	MMC
wherein the connector housing comprises a guide connecting the elongate arm to the optical fiber connector.	Guide of connector housing connected to arm

EXHIBIT O

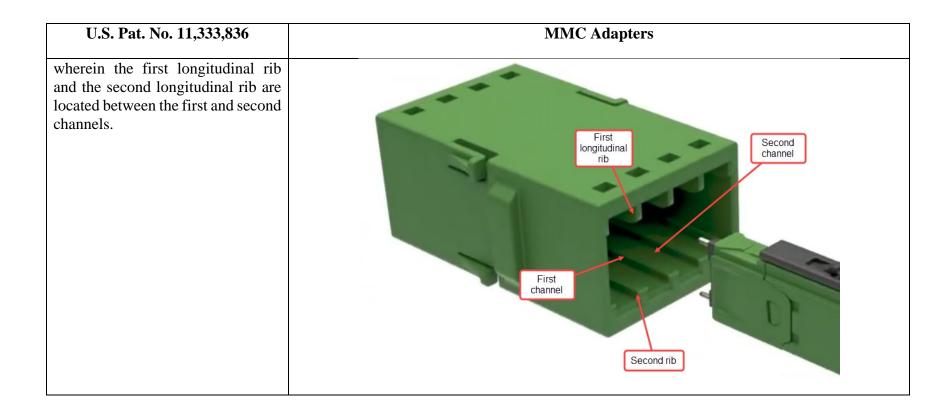
U.S. Pat. No. 11,333,836	MMC Adapters
1. An adapter for mating with optical fiber connectors, the adapter comprising:	Adapter

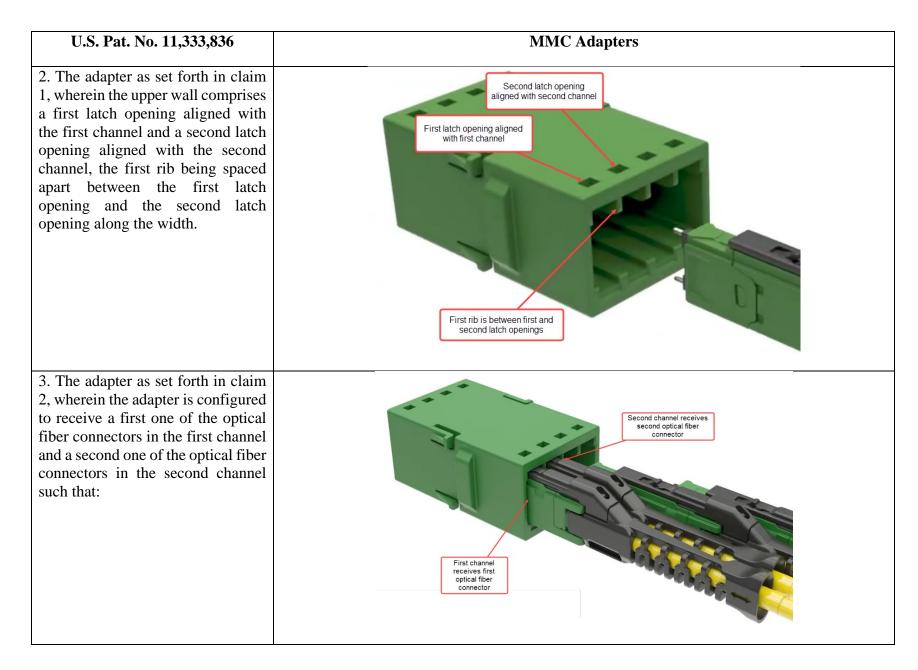
U.S. Pat. No. 11,333,836

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 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

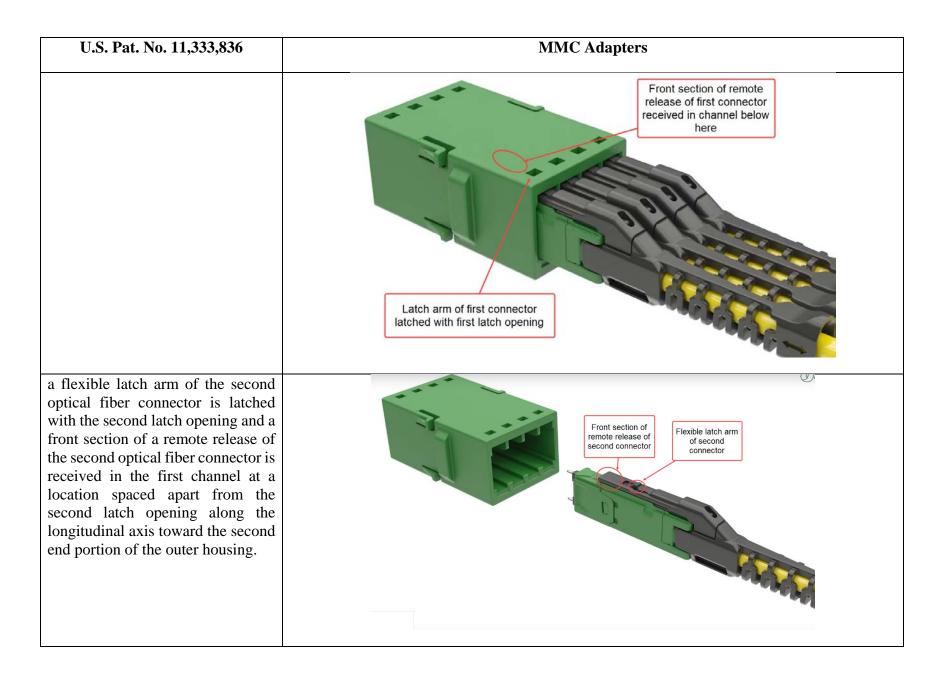


U.S. Pat. No. 11,333,836 **MMC Adapters** a first longitudinal rib formed on the inner surface of the upper wall at a location spaced apart along the width of the outer housing between the first side wall and the second First Transverse side wall and a second rib formed longitudinal gap on the inner 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, Second rib





U.S. Pat. No. 11,333,836 **MMC Adapters** a flexible latch arm of the first optical fiber connector is latched Front section of with the first latch opening and a remote release of first connector front section of a remote release of the first optical fiber connector is received in the first channel at a Flexible latch arm of first connector location spaced apart from the first latch opening along the longitudinal axis toward the second end portion of the outer housing; and



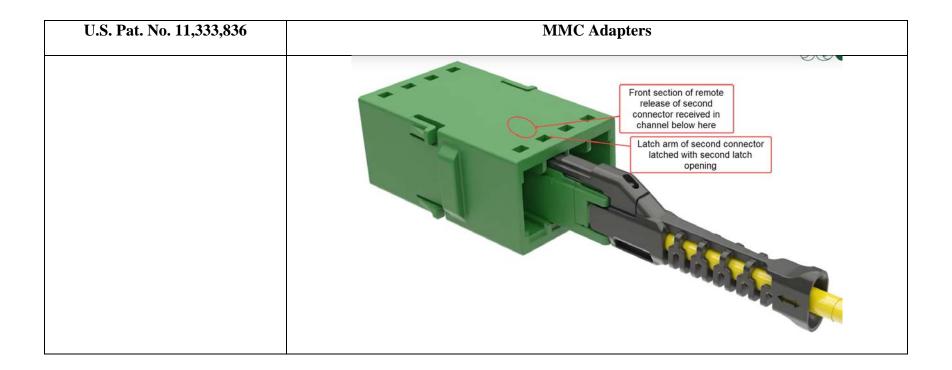
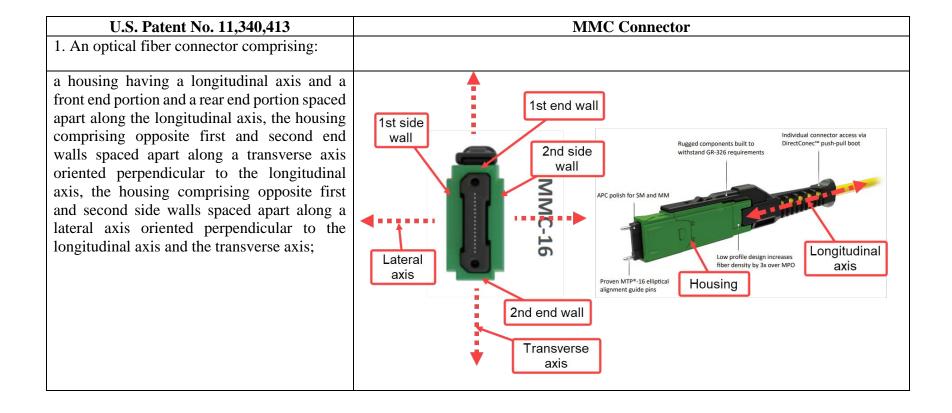
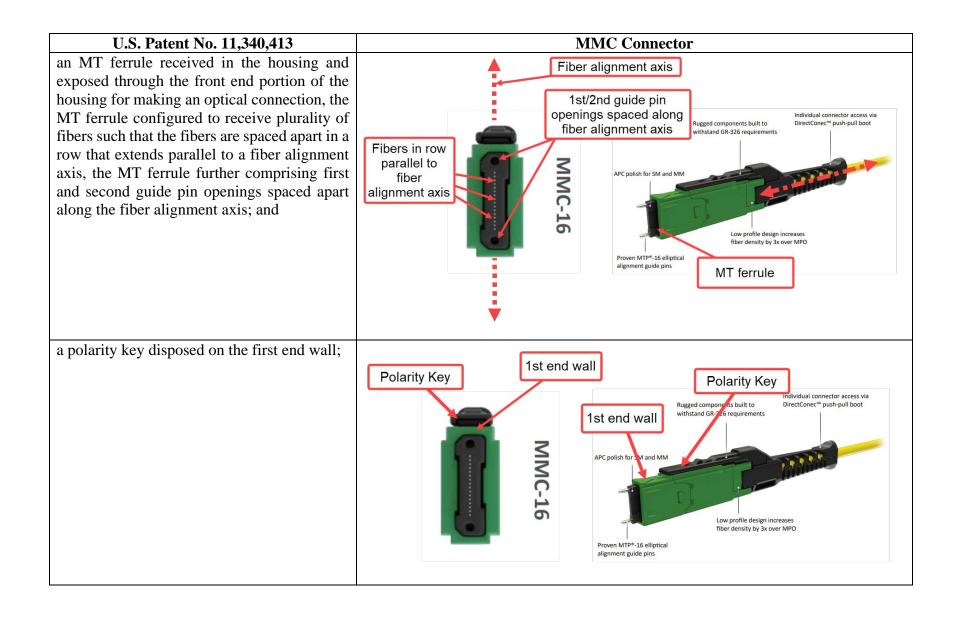
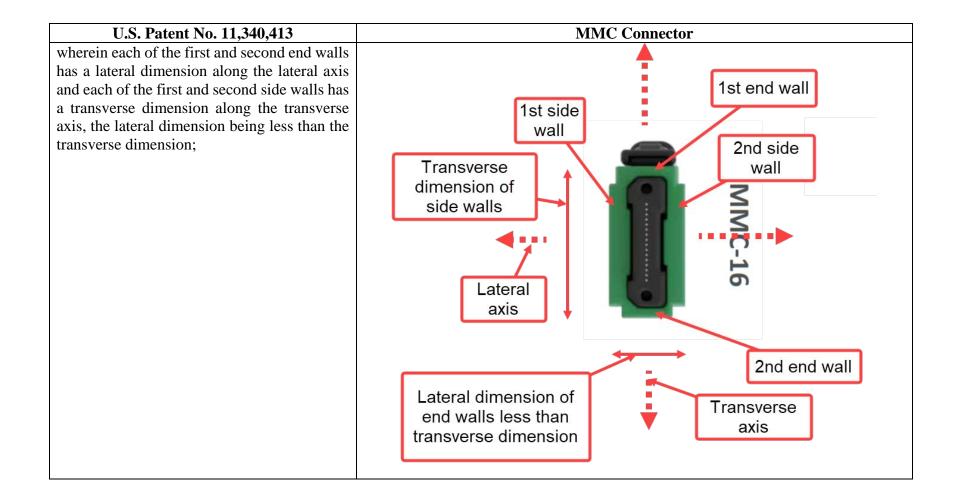


EXHIBIT P







U.S. Patent No. 11,340,413

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.

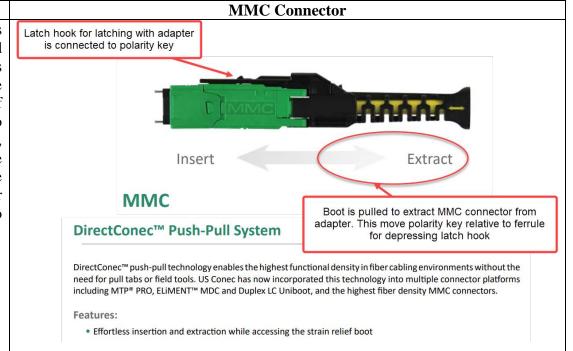
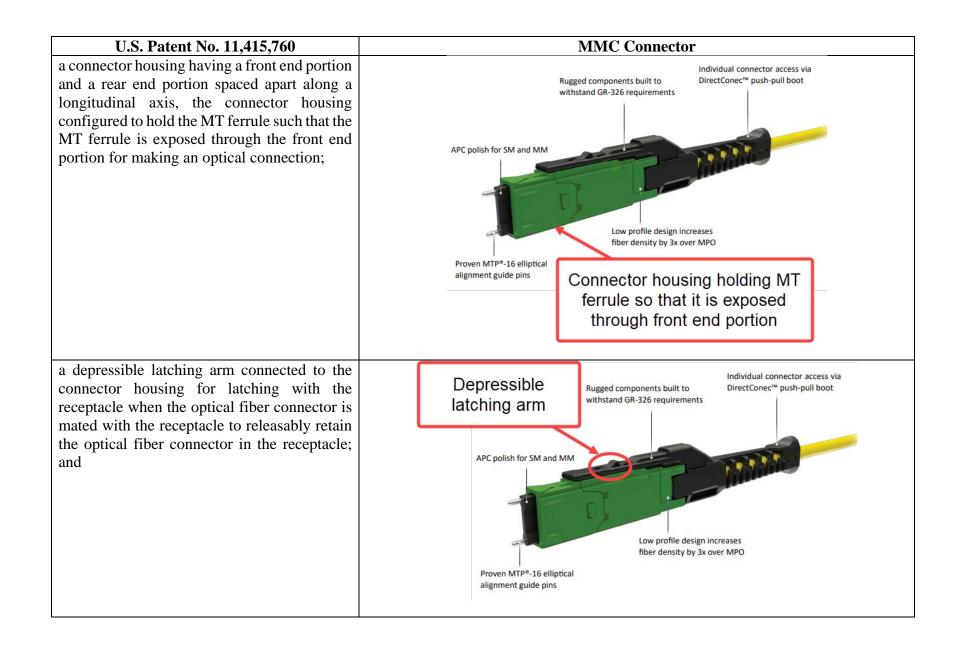
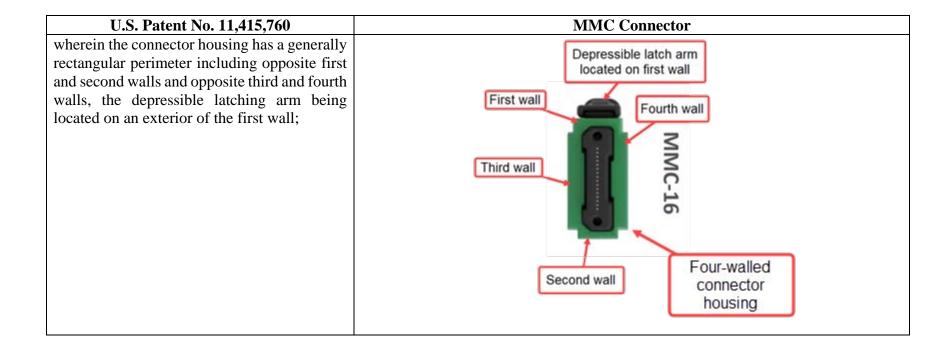


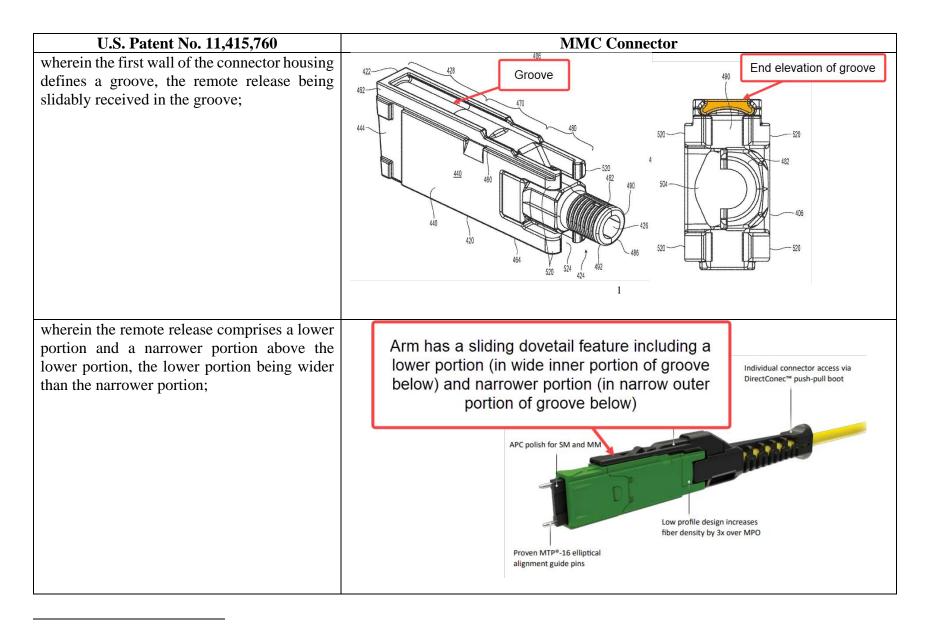
EXHIBIT Q

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;	Rugged components built to withstand GR-326 requirements APC polish for SM and MM Low profile design increases fiber density by 3x over MPO Proven MTP*-16 elliptical alignment guide pins Connector



MMC Connector U.S. Patent No. 11,415,760 a remote release connected to the connector Remote release housing for movement relative to the connector housing along the longitudinal axis, Individual connector access via the remote release being configured to be Rugged components built to DirectConec™ push-pull boot pulled rearward along the longitudinal axis to withstand GR-326 requirements depress the depressible latching arm for releasing the optical fiber connector from the receptacle; APC polish for SM and MM Low profile design increases fiber density by 3x over MPO Proven MTP®-16 elliptical alignment guide pins





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.

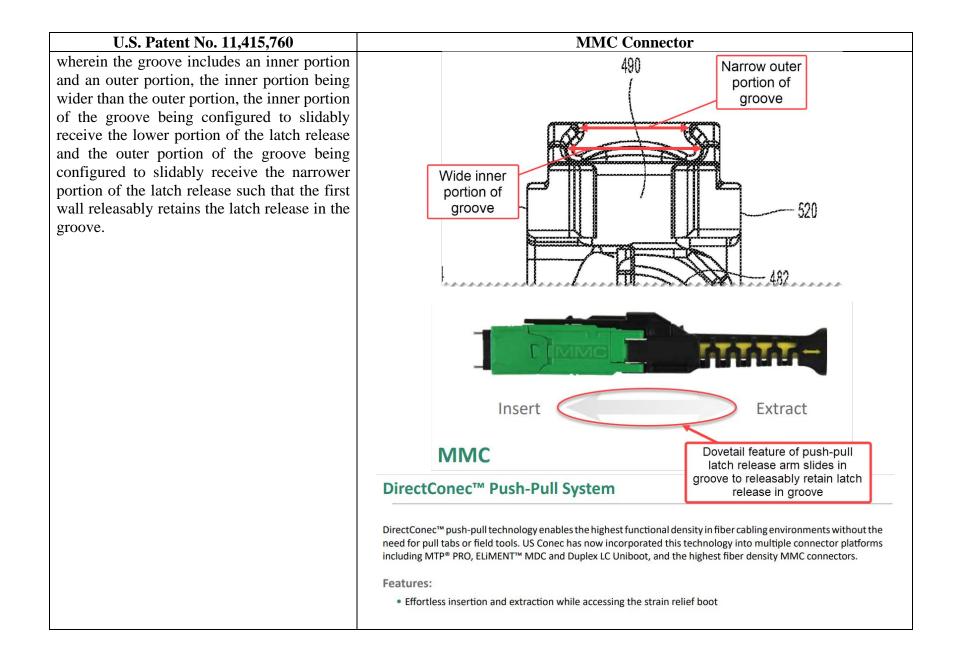
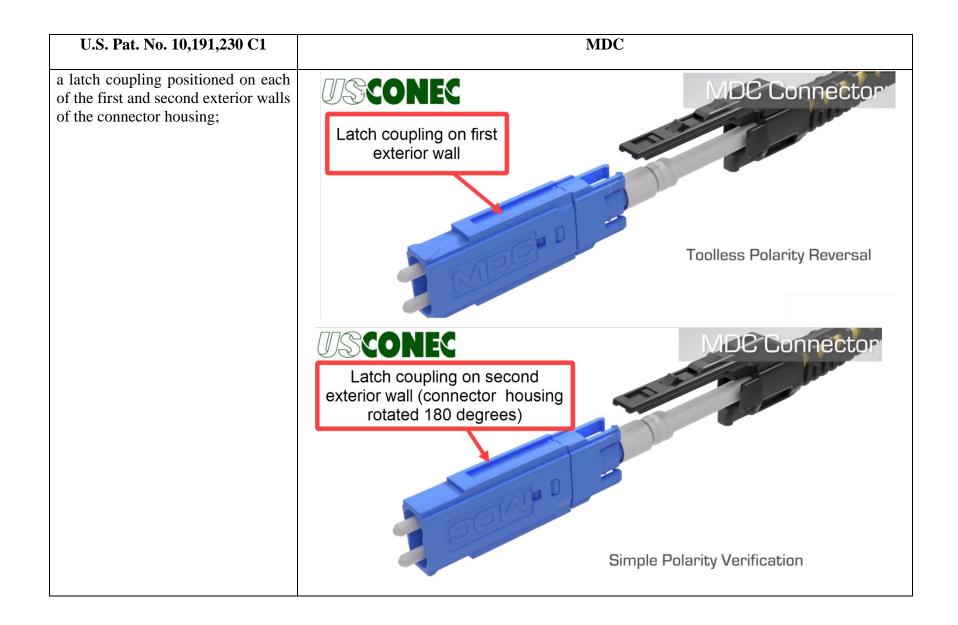
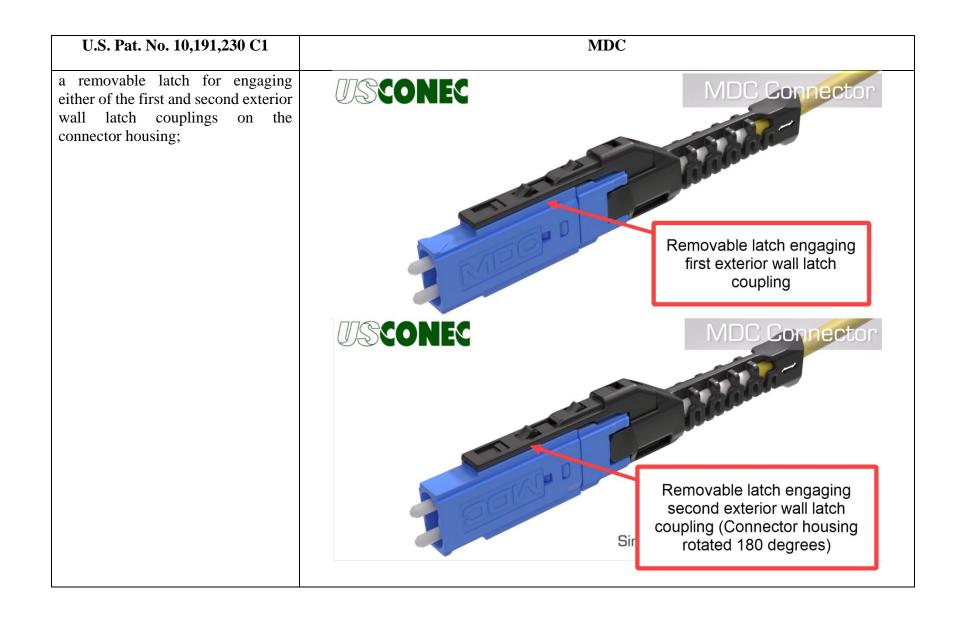


EXHIBIT R

U.S. Pat. No. 10,191,230 C1	MDC	
1. A reversible polarity fiber optic connector comprising:		1111
	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.	fiber optic connector
at least first and second optical ferrules;	First ferrule	MDC Connector
	Second	Toolless Polarity Reversal

MDC U.S. Pat. No. 10,191,230 C1 a connector housing having a USCONEC MDC Connector longitudinal axis and comprising an exterior portion at least partially First exterior wall surrounding the first and second above ferrules Yellow highlight optical ferrules such that the exterior shows how portion extends 360 degrees portion extends 360° about space circumferentially with respect to the longitudinal axis about a space in which each of the first and second optical ferrules are received, the First ferrule Toolless Polarity Reversal exterior portion comprising a first exterior wall positioned above the Space Connector housing first and second optical ferrules and receives (blue) a second exterior wall positioned ferrules Second exterior wall beneath ferrules beneath the first and second optical Second ferrule ferrules;





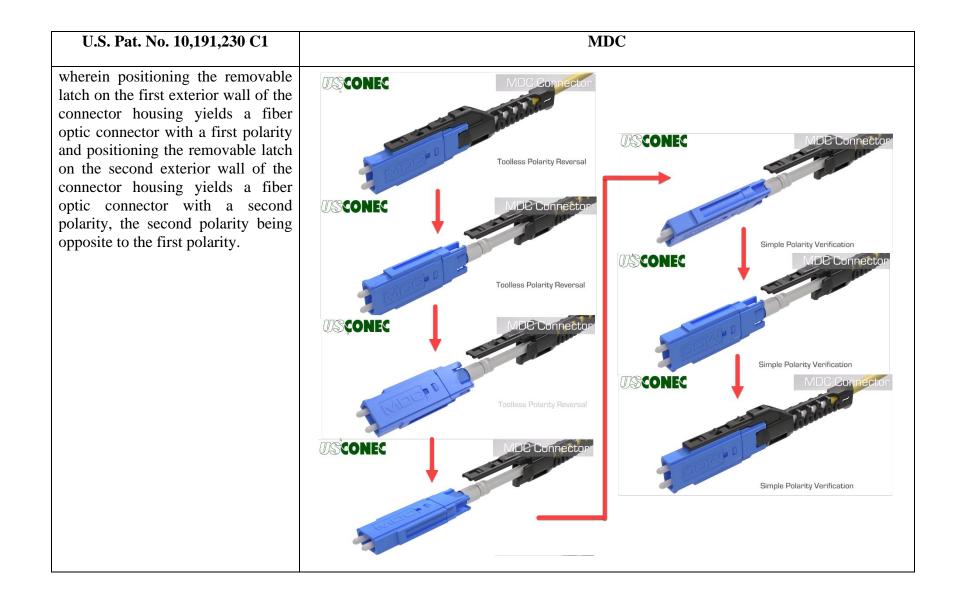
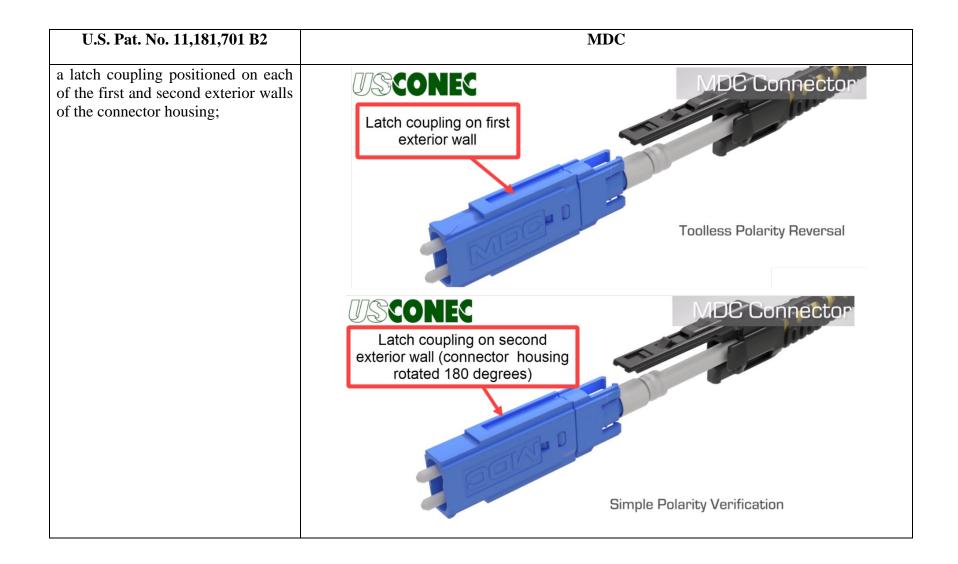
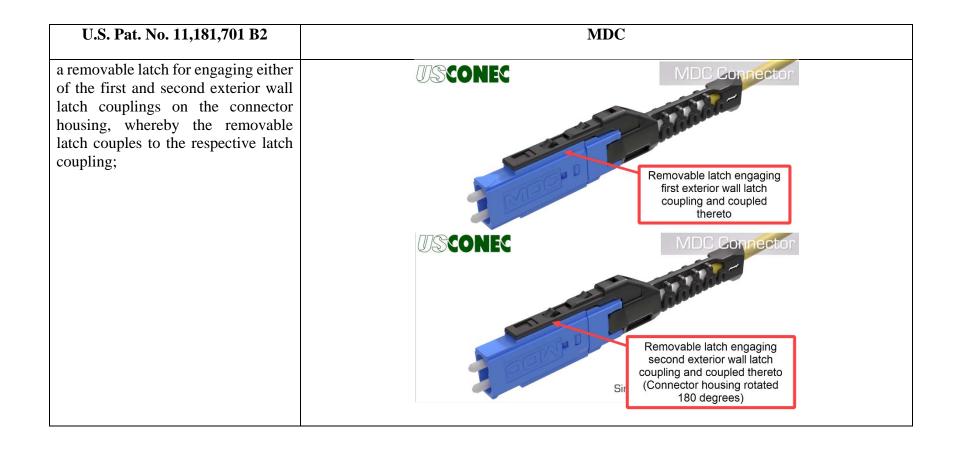
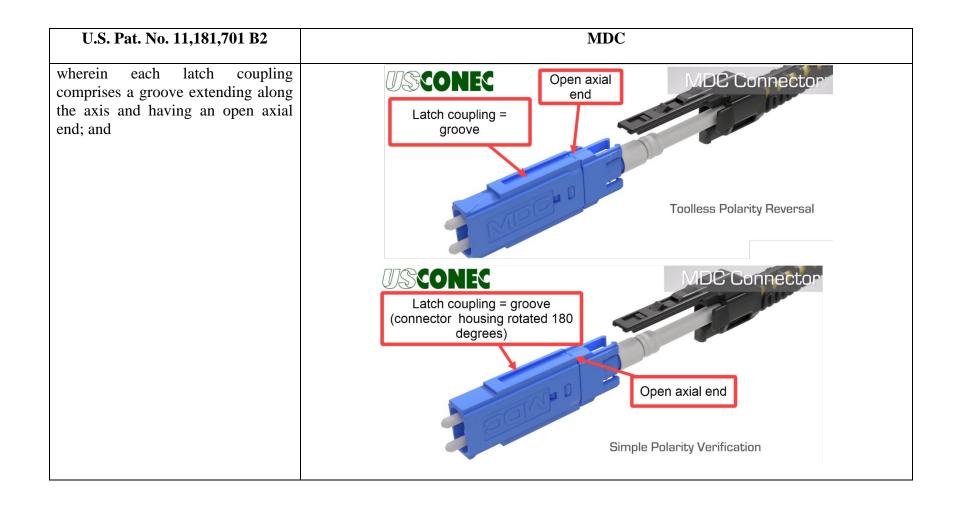


EXHIBIT S

MDC	
First ferrule	MDC Connector
Second ferrule	Toolless Polarity Reversal Fiber optic connector
	Toolless Polarity Reversal Connector housing (blue)
	First ferrule Second ferrule Yellow highlight shows how exterior portion circumscribes space receiving ferrules Space receiving ferrules







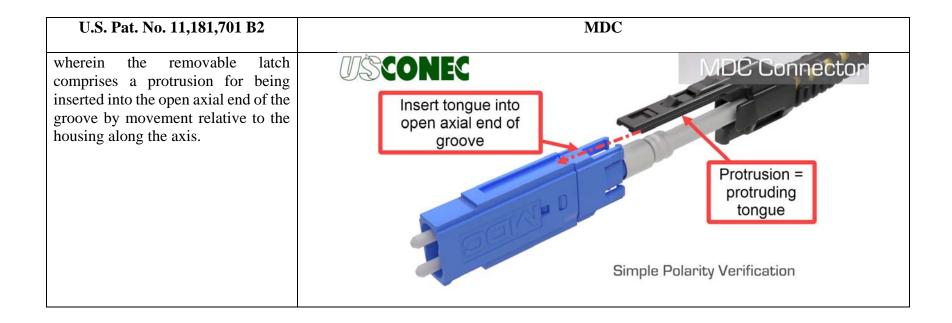
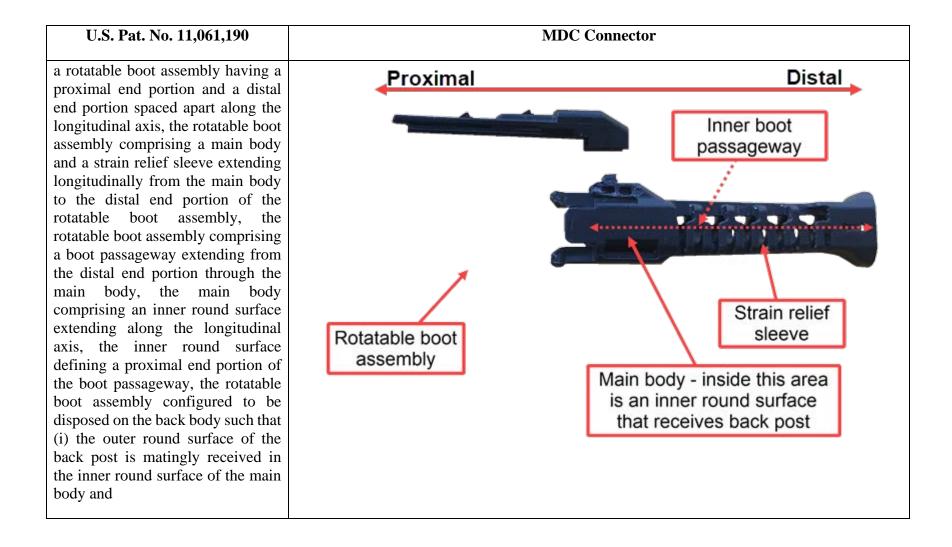
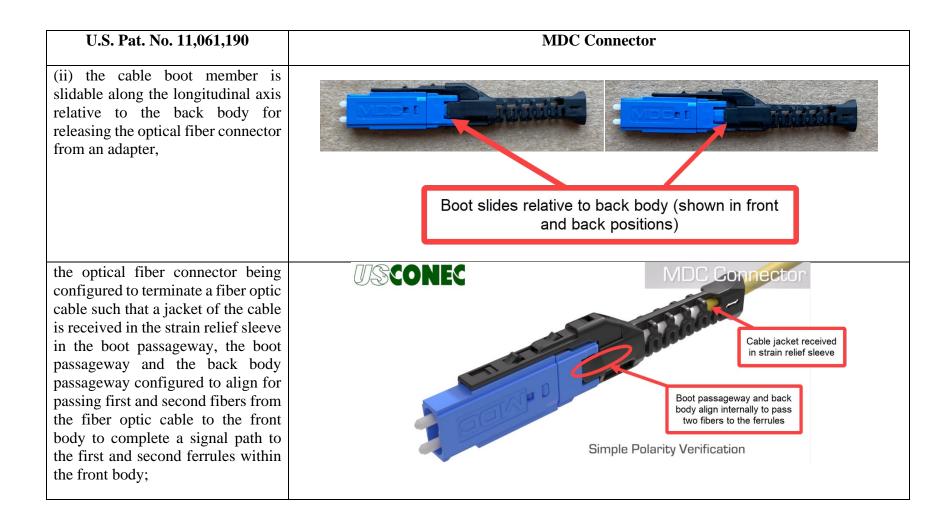
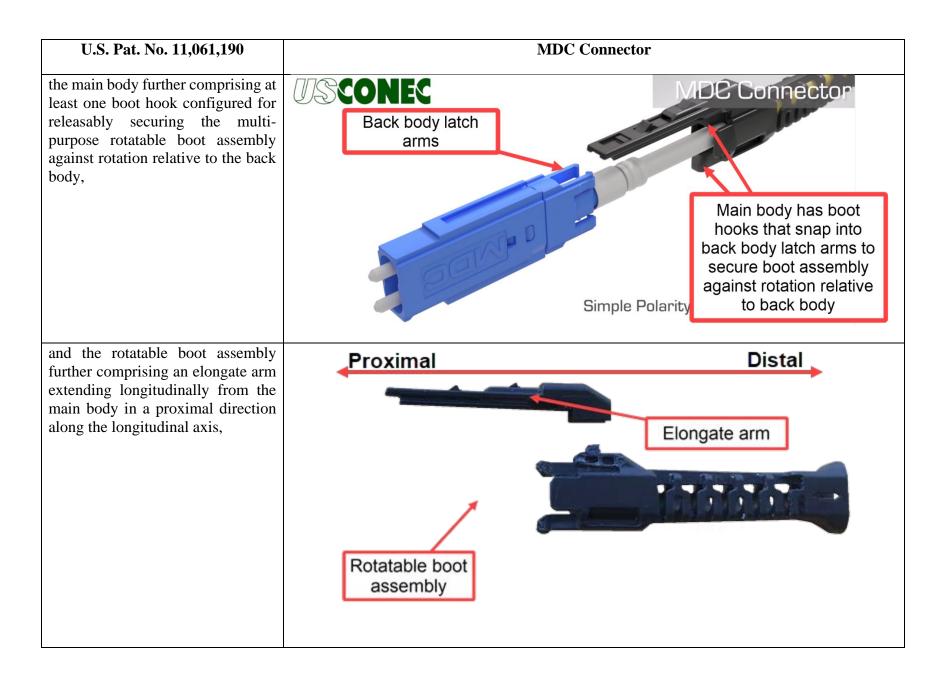


EXHIBIT T

U.S. Pat. No. 11,061,190	MDC Connector
1. An optical fiber connector comprising:	
a front body configured to hold first and second ferrules;	1st/2nd 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	Proximal Latches on proximal end portion of back body couple back body to to front body here Distal Cylindrical back post with outer round surface, defines back body passageway



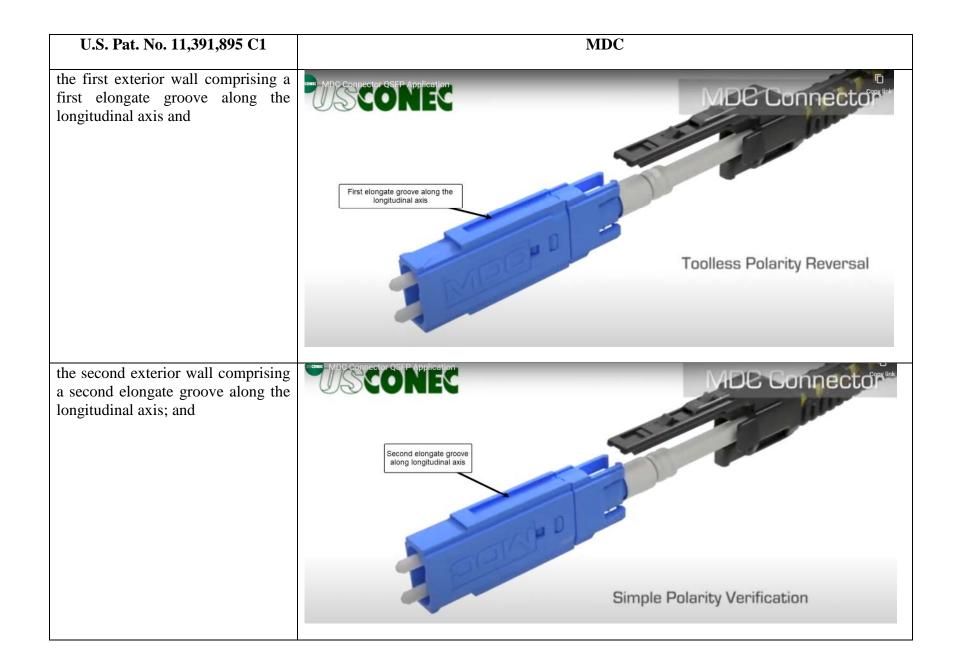




U.S. Pat. No. 11,061,190	MDC Connector
the elongate arm being configured for selectively setting the optical fiber connector to each of a first polarity and a second polarity.	Boot assembly is rotatable so that arm attaches to either top or bottom of housing, whereby elongate arm selectively configures 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,	Toolless Polarity Reversal Connector housing First wall Longitudinal axis



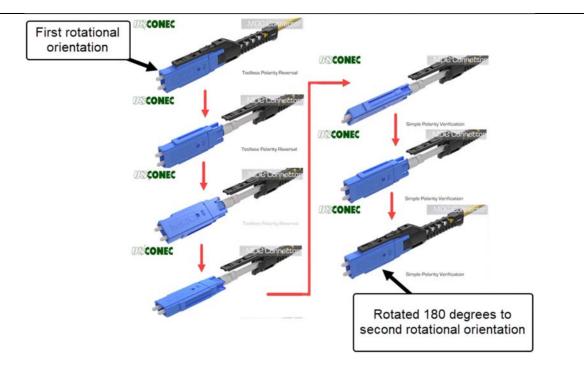
U.S. Pat. No. 11,391,895 C1 MDC polarity change element CONEC ADE Connector ink comprising a key portion and a Key Portion tongue, the tongue being configured to be slidably received in a selected one of each of the first elongate groove and the second elongate Polarity change element groove to selectively and releasably position the polarity change element Tongue portion configured to be slidably received in either the first or on a corresponding one of the first second elongate groove exterior wall and the second exterior wall such that the key portion is externally positioned on the Simple Polarity Verification respective one of the first exterior wall and the second exterior wall, Tongue received in first Tongue received in second elongate groove; key elongate groove; key portion portion on first exterior on second exterior wall Toolless Polarity Reversal Simple Polarity Verification

U.S. Pat. No. 11,391,895 C1 MDC wherein positioning the polarity Key portion on first Key portion on second change element on the first exterior exterior wall establishes exterior wall establishes first polarity configuration second polarity configuration wall such that the key portion is externally positioned on the first exterior wall configures the fiber optic connector in a first polarity Toolless Polarity Reversal configuration and positioning the Simple Polarity Verification 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

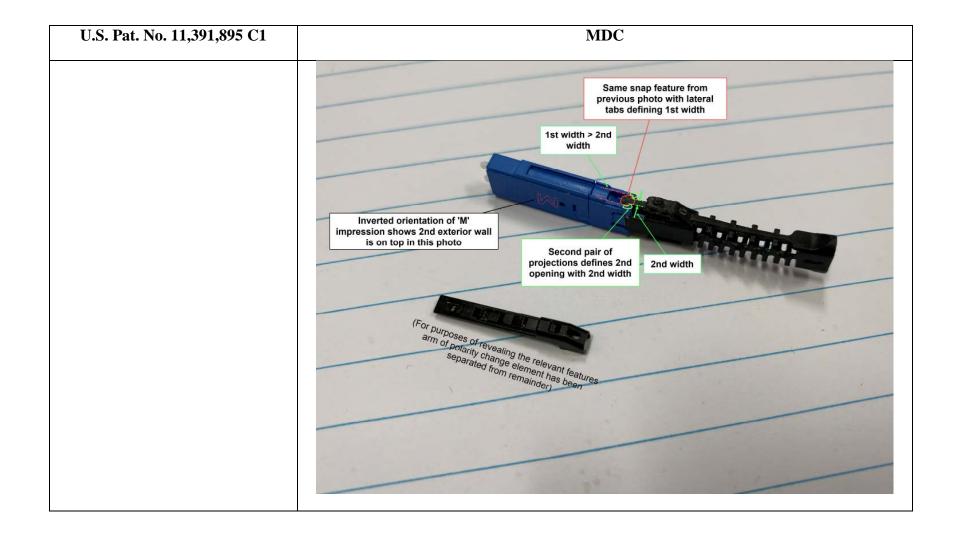
wherein the fiber optic connector is configured to be plugged into a mating receptacle with the connector housing in a first rotational orientation about the longitudinal axis when the fiber optic connector is in the first polarity configuration and the fiber optic connector is configured to be plugged 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° ;

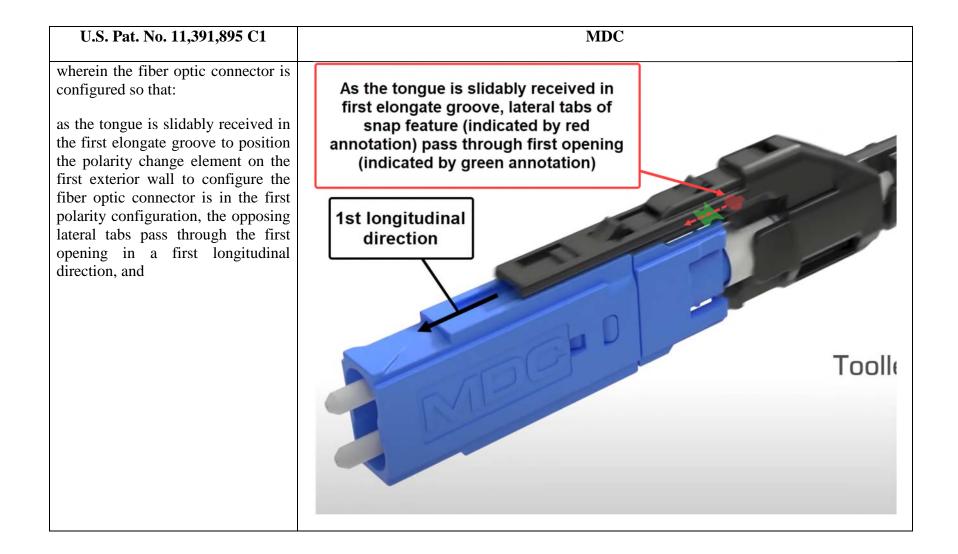
MDC



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 1st width comprises opposing lateral tabs Snap feature has opposing lateral defining a first width and the tabs defining 1st connector housing includes a first width pair of projections adjacent the first elongate groove and a second pair of projections adjacent the second Orientation of 'M' impression elongate groove, the first pair of shows first exterior wall is on top in this photo projections separated by a first opening having a second width and the second pair of projections First pair of projections defines 1st opening with separated by a second opening 2nd width 2nd width having the second width, the first width being greater than the second (For purposes of revealing the relevant features separated from remainder) width;

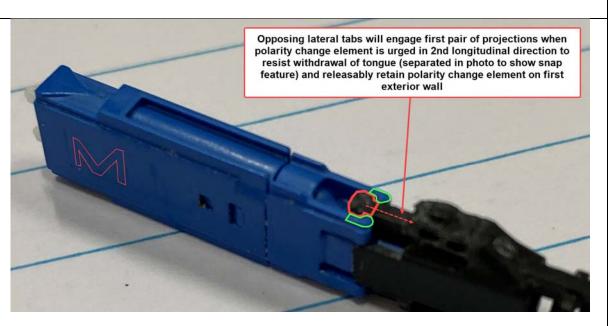


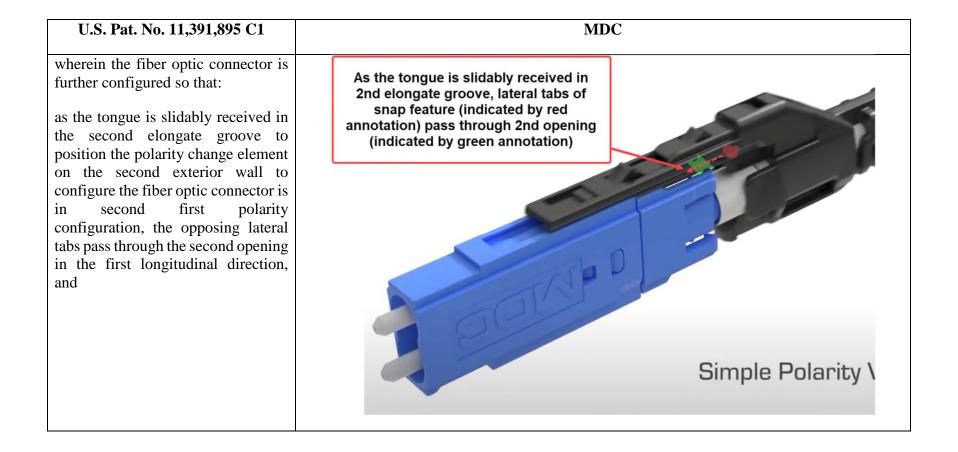


U.S. Pat. No. 11,391,895 C1

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

MDC





U.S. Pat. No. 11,391,895 C1

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.



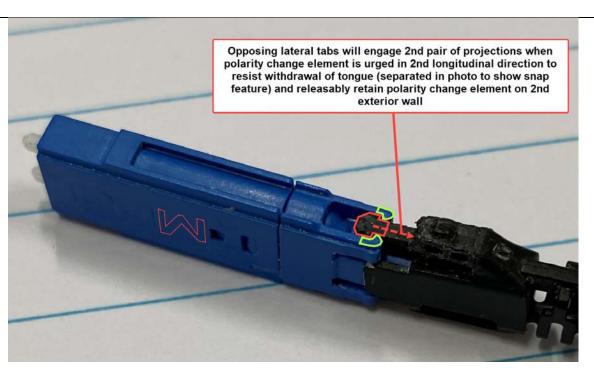


EXHIBIT V

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	Adapter housing 2nd end portion Non-behind-the-wall ports

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;	x2 ferrule alignment sleeves between each pair of ports

U.S. Pat. No. 11,435,535 MDC/MDC Jr. Adapter wherein the adapter housing is configured to receive a behind-thewall optical connector in each behind-the-wall port and a nonbehind-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 Behind-the-wall ports receive behind the wall connectors. 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 non-behind-the-wall of the connector in received in the nonbehind-the-wall port; Non-behind-the-wall ports receive non-behind-the-wall connectors

U.S. Pat. No. 11,435,535 MDC/MDC Jr. Adapter wherein the adapter is configured to Adapter retains the behind-the-wall retain the two types of connector in the behind-the-wall connectors in the port and the non-behind-the-wall respective ports to connector in the non-behind-themake an optical connection between wall port such that an optical them connection is made between the plurality of ferrules of the behindthe-wall connector and the plurality of ferrules of the non-behind-thewall connector in the adapter housing;

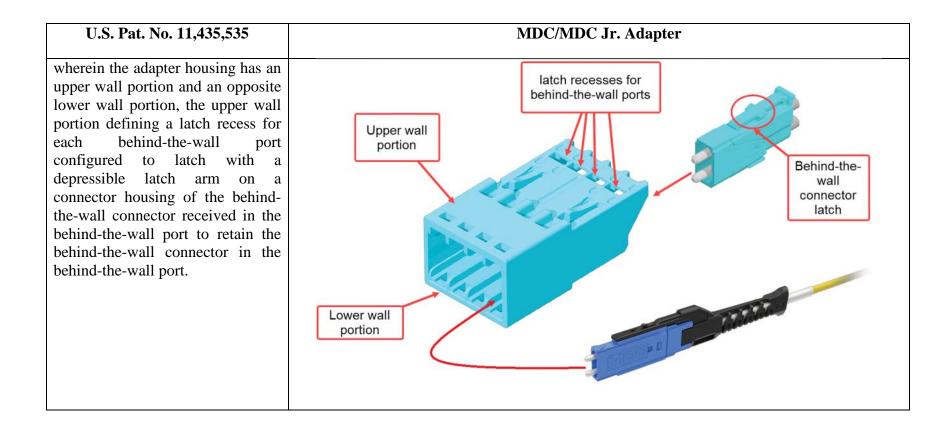
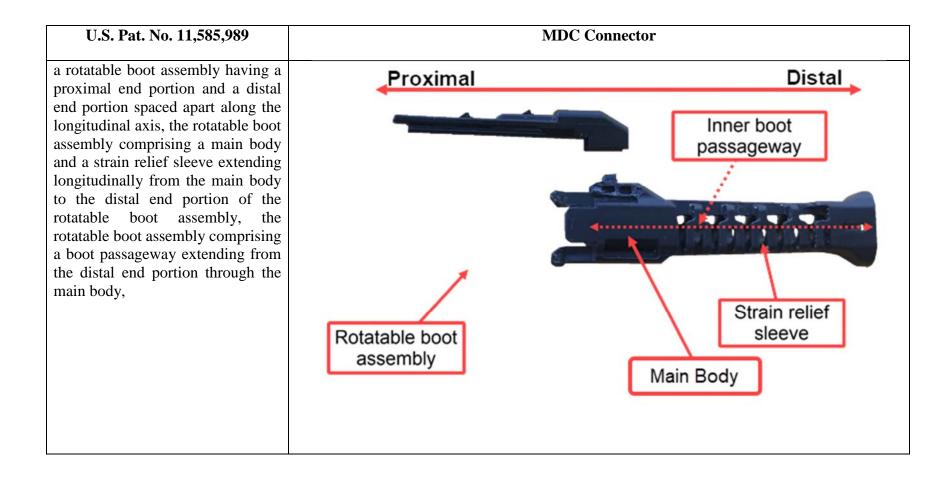
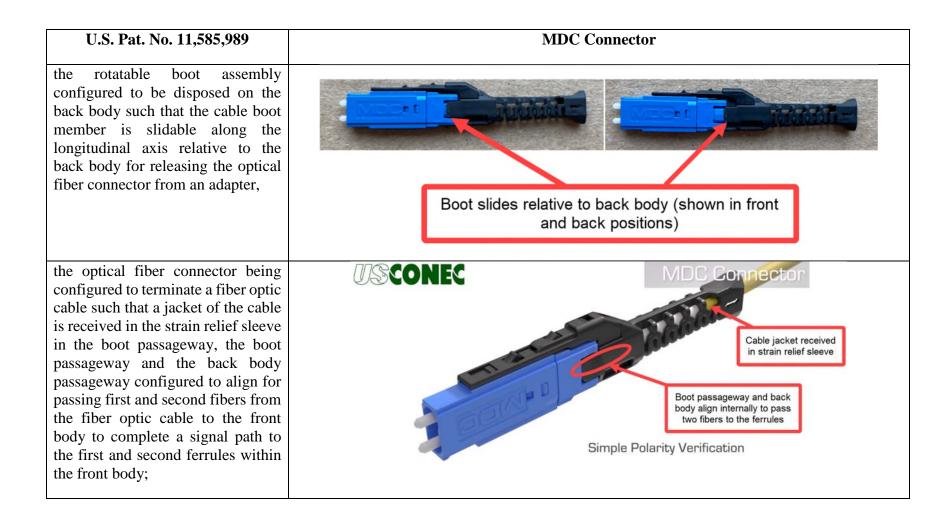
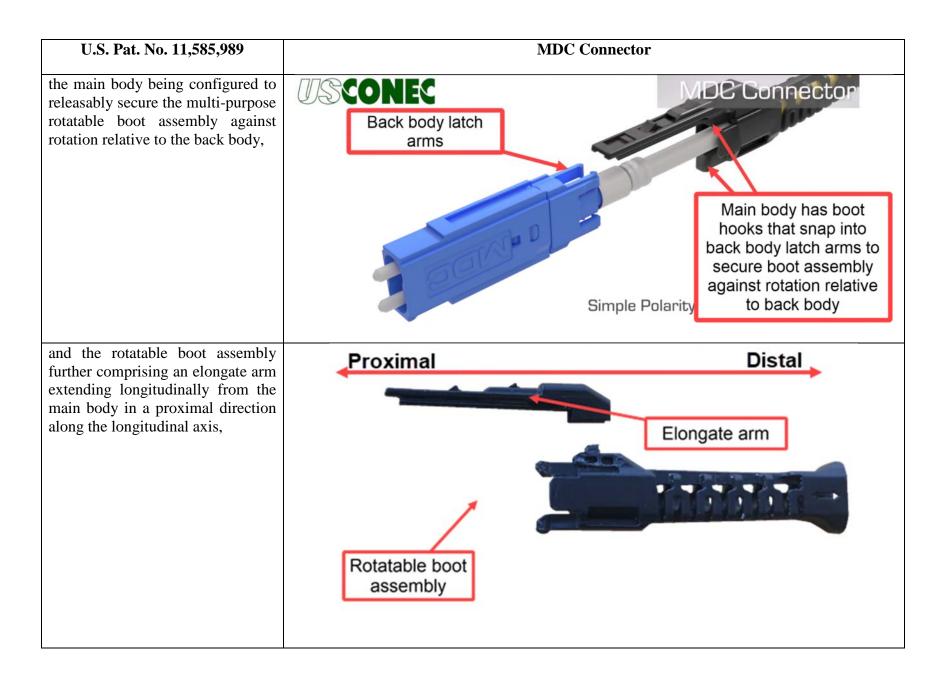


EXHIBIT W

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;	1st/2nd 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	PTOXIIIIai







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

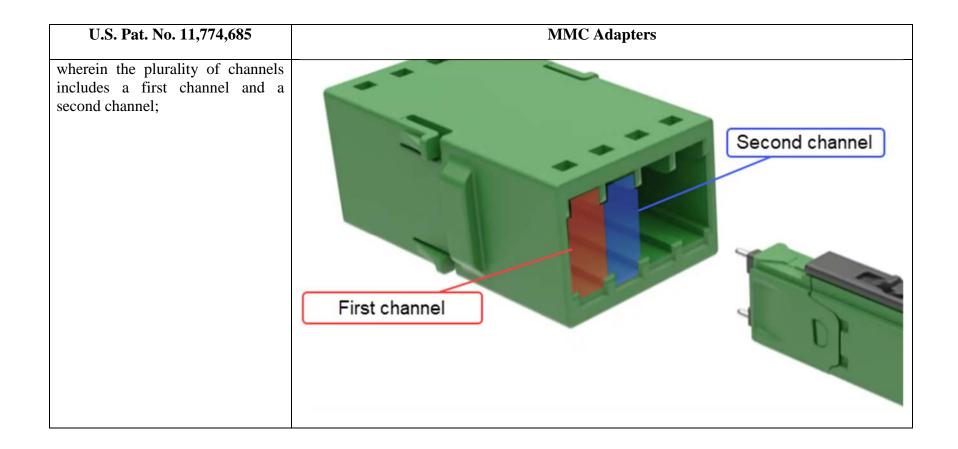
EXHIBIT X

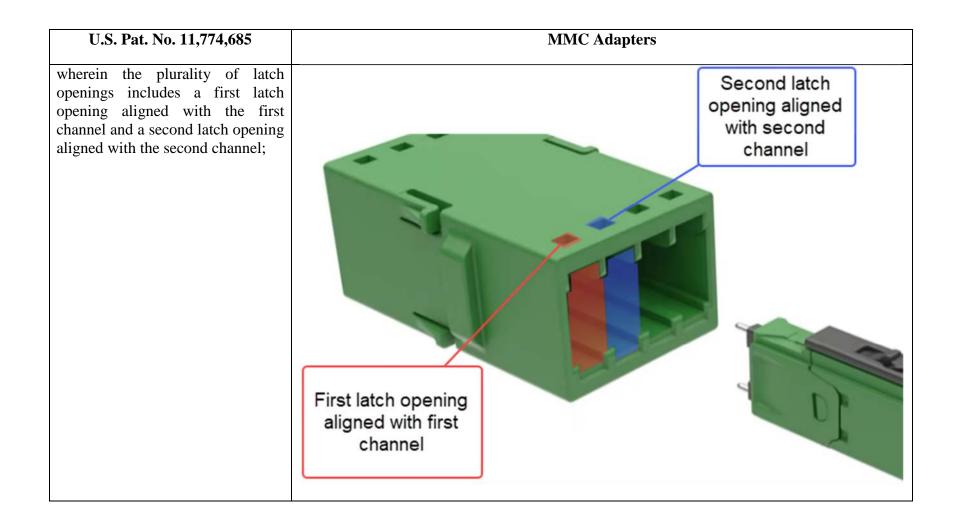
U.S. Pat. No. 11,774,685 **MMC Adapters** 1. An adapter for mating with a Remote release front section configured to plurality of optical fiber connectors, slide rearward (to the right in the drawing) each of the plurality of optical fiber along the flexible latch arm to depress it connectors comprising a connector housing holding multiple optical DECONEC fibers, a flexible latch arm having a Flexible latch arm with front (left) end front end and a rear end spaced and rear (right end) 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: Adapter One of four identical connectors that can be mated with the adapter

MMC Adapters U.S. Pat. No. 11,774,685 an outer housing having a first end Transverse axis portion and a second end portion spaced apart along a longitudinal Width axis and a first side wall and a Second side second side wall spaced apart along Second end portion a width, the outer housing defining a plurality of channels side-by-side along the width of the outer First side wall 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 Latch openings for longitudinal axis into the plurality latching with flexible of channels through the first end latch arms of portion to mate the adapter with the connectors plurality of optical fiber connectors First end portion for making an optical connection to Lower wall the optical fibers via the adapter, the outer housing comprising an upper Channels Longitudinal axis wall and a lower wall spaced apart along 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 DirectConec™ of optical fiber connectors such that the front sections of the remote Push-Pull Boot 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; Each channel receives a connector so that the front section of the remote release is inside the channel forward of the latch opening



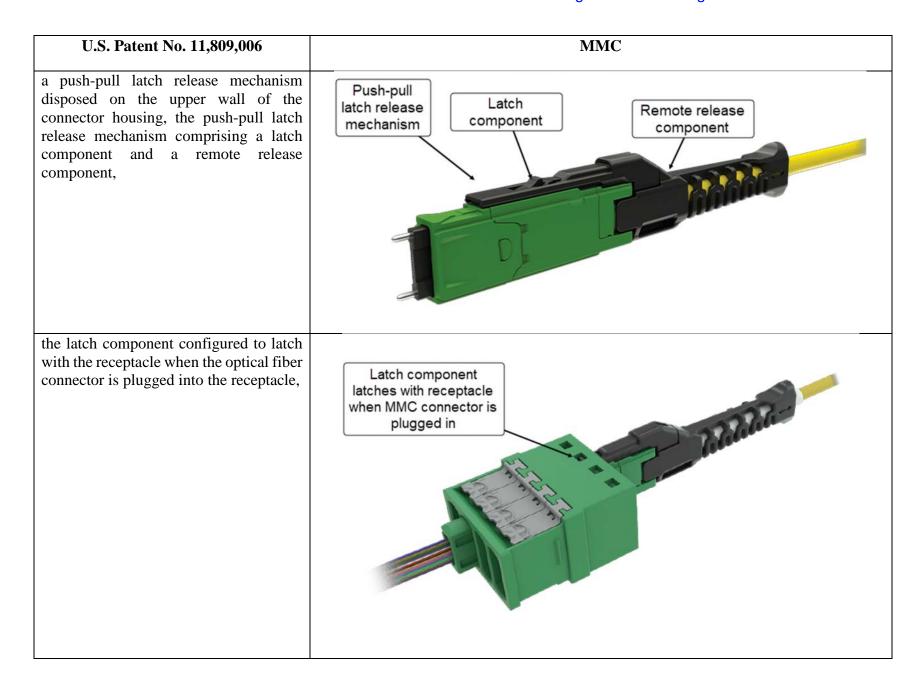


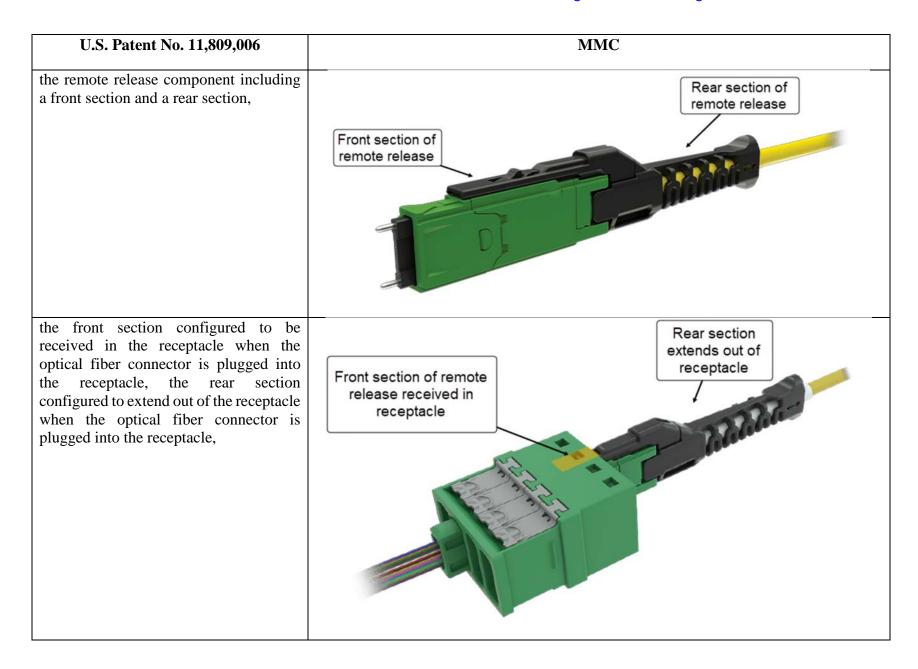
U.S. Pat. No. 11,774,685 **MMC Adapters** wherein the upper wall comprises a first longitudinal rib projecting inwardly along the transverse axis toward the lower wall and the lower comprises wall second First longitudinal rib projecting inwardly Transverse longitudinal gap along the transverse axis 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. Second rib

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,	Connector Housing (green) Right side Connector width

U.S. Patent No. 11,809,006	MMC
the upper side of the connector housing defining a groove;	Highlighted portion of connector housing defines 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	Fibers spaced apart along connector height Ferrule





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.	To unlatch, remote release component is pulled backward and front section slides in groove to actuate (depress) the latch

CERTIFICATE OF SERVICE

The undersigned hereby certifies that on February 1, 2024, a copy of the foregoing

document was served on the counsel listed below in the manner indicated:

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