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CS[®] - the Next Generation connector for 200G/400G Deployments

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Executive Summary

The demand for higher network bandwidth in data centers has been increasing significantly in the advent of social media, video streaming and increased number of smartphone users. In order to cater for emergence of next generation application and technology such 5G, Cloud Services, 4K Videos and the Internet of Thing (IoT), Data Centers around the world are growing in numbers, floor space and bandwidth capacity. This is most evident in 2016 whereby Data Centers around the world started to upgrade their links from 40Gbps to 100Gbps links (refer to table below). It is forecasted that from 2016~2022, transceiver revenue will increase at a CAGR of 39%, mainly fueled by new data center builds, expansion and also retrofitting of existing data centers and finally, adoption of enterprise data centers. In fact, transceiver vendors are currently expanding their manufacturing capacity to keep pace with the demand for 100Gbps modules.

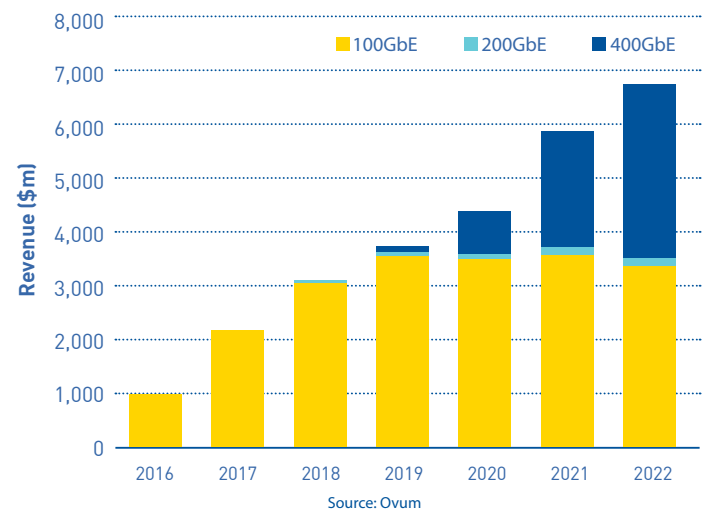
The highest number of equipment connections are the server interconnects in data centers. The significant increase in bandwidth consumption requires cost effective solutions. Network uplinks need to move to higher speeds to match server speeds which is transferring from 10Gbps to 25Gbps and most recently the adoption of PAM4. The IEEE has released a new standard titled IEEE 802.3.bs-2017 "IEEE Standard for Ethernet Amendment 10: Media Access Control Parameters, Physical Layers and Management Parameters for 200Gbps and 400Gbps Operation". The initial target to support capacity growth was to introduce a 400Gbps solution, but a 200Gbps capability was added to support a cost and performance optimized migration path towards 400Gbps. Nevertheless, the 100Gbps transceiver alone is expected to grow at a CAGR of 53% out of the total transceiver (100G, 200G & 400G) growth of CAGR of 63%. This is due to the fact that 200G & 400G transceivers will start to be commercially adopted starting 2019 and will start taking away the market share from the 100Gbps transceivers, but only slightly.

Traditionally data center interconnects were single wavelengths transmitted using Multimode or Singlemode fibers but recent technology drivers have been pushing the use of multi-wavelength technology in Singlemode fibers. In 2016, CWDM4 technology, in line with the adoption of 100Gbps transceivers, grew to have equivalent market share with PSM4. With the commercial adoption of 200Gbps & 400Gbps starting in 2019, market volumes will be driven by both parallel (SR4, PSM4, or DR4) and multi-wavelength (FR4, LR4, or CWDM) technologies.

Next-generation data centers upgrades

Zone	2012-2015	2016-2018
Server ports	10Gbps	25Gbps
Server footprint density	1 server=1RU	4 servers per "sled"
Intra-Data Center switch fabric	40Gbps	100Gbps
WAN DCI traffic	Multiwavelength	Multi-WDM system

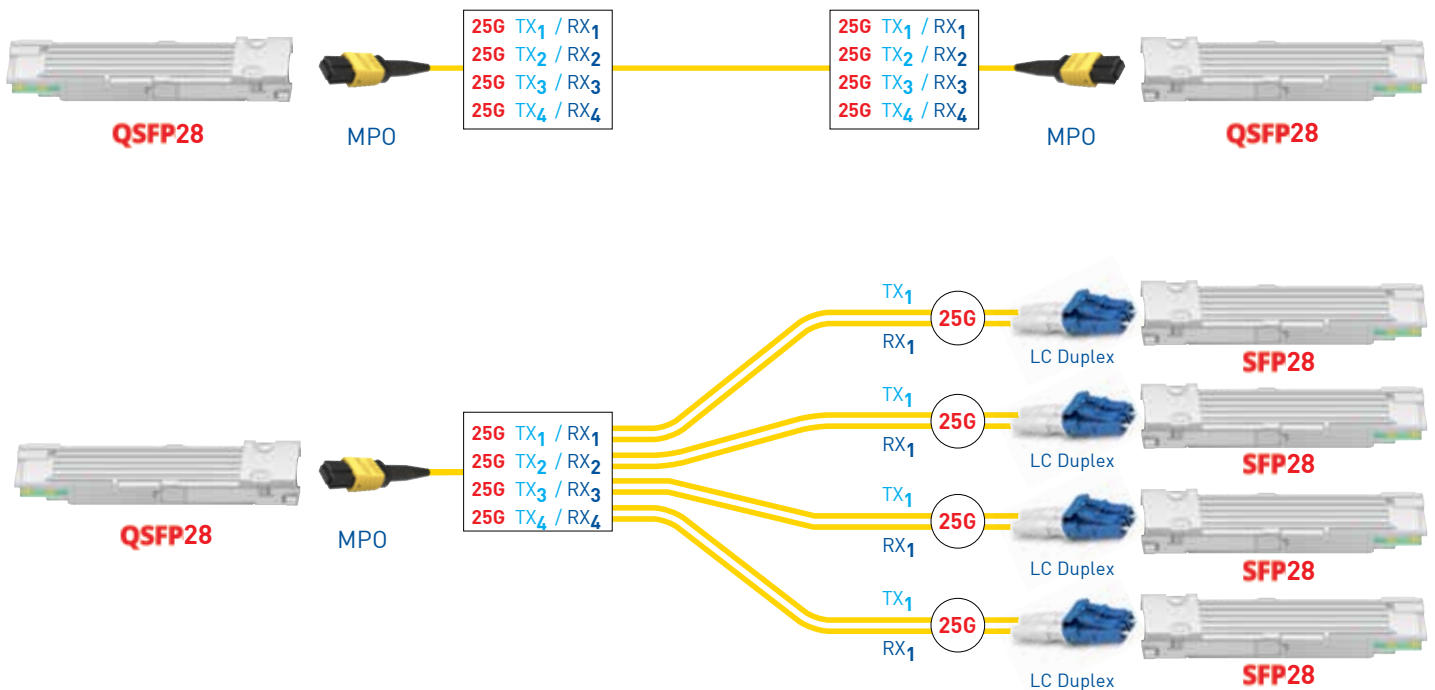
Total revenue for 100G, 200G, and 400G transceivers



Parallel vs Duplex Connectivity

A good comparison of a parallel and duplex connectivity structure is the PSM4 transceiver link vs the CWDM4 link structure. Both these architectures carry a 100GbE signal over four separate 25GbE channels. PSM4 transceiver link uses a parallel connectivity structure while the CWDM4 uses a duplex structure. The 100G PSM4 uses eight single mode fibers, with four to transmit and four to receive at 25Gbps each. All four of these lanes are identical and independent.

Two QSFP28 transceivers can be connected via a single MPO to MPO jumper for a full 100Gbps transmission, or each of the independent links can be distributed to four separate 25GbE SFP28 transceivers. The parallel architecture allows for flexible network connectivity and gradual network upgrade pathway. One advantage of the parallel fiber technologies over multi-wavelength technology in the data center is the ability to breakout the four parallel fibers into single fibers to different switches or servers without the use of fan-out modules.



Rather than using independent fiber lanes, the 100G CWDM4 transmits four different wavelengths, with each wavelength carrying 25G optical signal. The four wavelengths are transmitted through a single pair of fiber by using optical multiplexer and de-multiplexer.

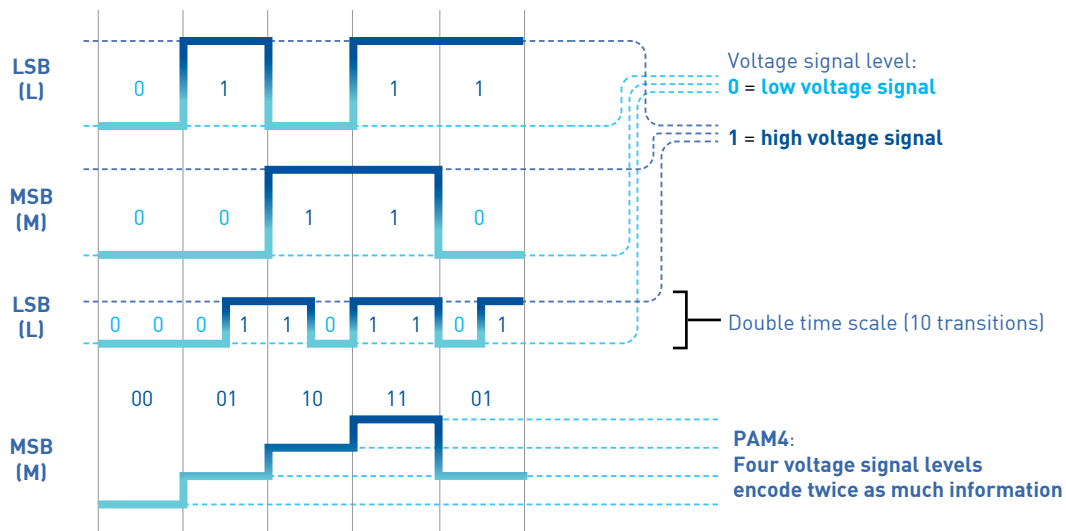


The Industry Standardizes IEEE 802.3bs Transmission

There are two versions of the IEEE 802.3bs transmission standards which are the 25Gbps over sixteen electrical lanes and 50Gbps through eight electrical lanes. The 25Gbps transmission standard is an existing infrastructure that will be used to ease transition to higher speeds. The eight electrical lane with 50Gbps is being developed to increase transmission efficiency by halving the connectivity requirement.

To enable transmission speeds of 400Gbps based on eight electrical lane interface 50Gbps serializer/deserializer (SERDES) rate is essential.

The non-return-to-zero modulation (NRZ) encoding scheme which streams 0s and 1s in a single lane electrical interface is a barrier to speeds higher than 25Gbps. An IEEE 802.3 task force was formed in May 2016 to develop a single-lane 50Gbps Ethernet standard using an encoding scheme called PAM4 (4-level Pulse Amplitude Modulation). PAM4 encoding scheme provides four signal levels compared to the two levels of NRZ, thus doubling the bit rate. This is achieved by dividing the least significant bit (LSB) signal level in half and adds it to the signal of the most significant bit (MSB).

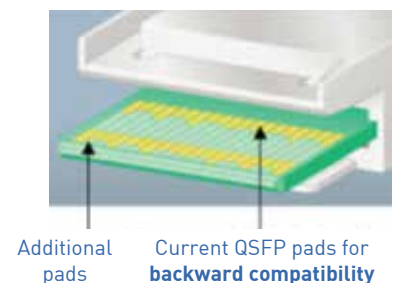
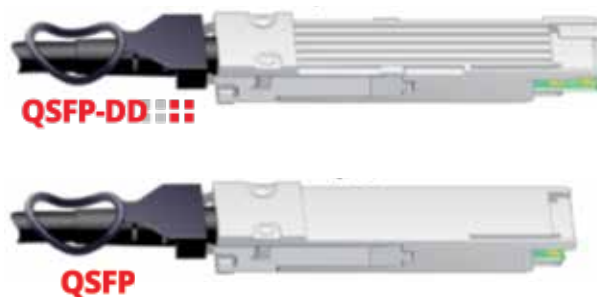


QSFP-DD

In early 2016, a group of thirteen industry leaders came under the QSFP-DD Multi Source Agreement (MSA) to develop a high-speed, double-density Quad Small Form Factor Pluggable (QSFP-DD) interface. The QSFP-DD, which is a pluggable transceiver, with an additional row of contacts to provide for an eight lane electrical interface, is introduced while maintaining the footprint

to allow backward compatibility with the standard QSFP form factor. Each of the eight lanes of the QSFP-DD can operate up to 25Gbps NRZ modulation or 50Gbps PAM4 modulation, thus providing bandwidth of up to 200Gbps or 400Gbps aggregate. The backwards compatibility of the QSFP-DD allows for easy adoption of the new module type and accelerate overall network migration.

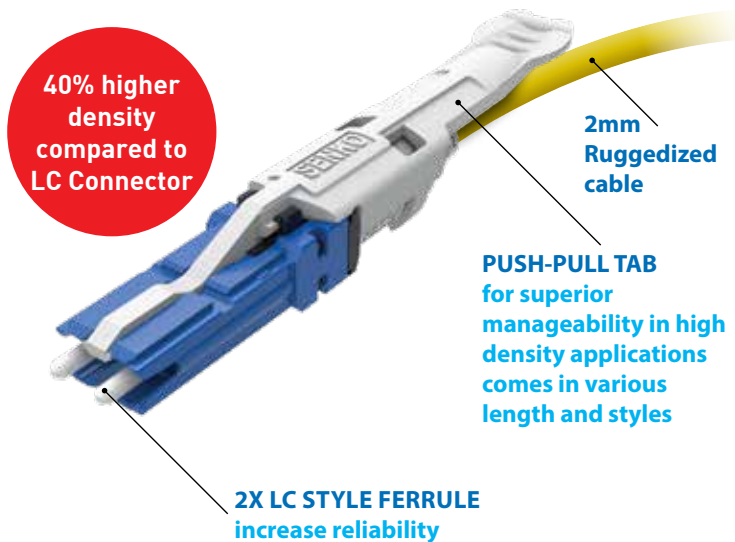
UP TO
400G



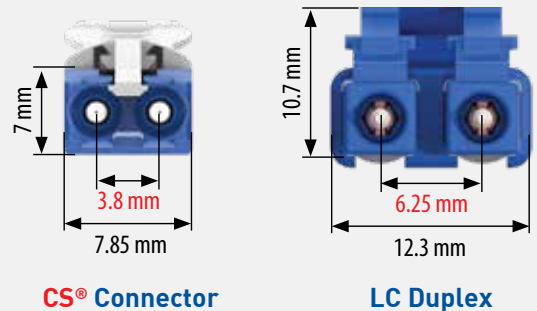
CS® Connector

The CS® connector is operated with push-pull coupling mechanism has two cylindrical, spring-loaded butting 1.25mm ferrules, within a single housing. The CS® connector's two ferrules are pitched at 3.8mm apart, which is the minimum possible spacing to meet the TOSA and ROSA optics requirement. Furthermore, CS® has an advantage in height over LC connector. The LC's latching lever design requires

adequate vertical spacing between adapters to get physical access to the release lever. The CS® connector comes with push pull tab which allows the adapters to be more densely stacked vertically. CS® can more than double the density in the patch panel compared to LC, with the features of narrower adapter width and denser vertical stacking of the CS® adapter.



CS® Connector compared to an LC connector



The CS® connector is designed to be available in OM3, OM4, and OM5 Multi-mode, as well as Single-mode and Single-mode APC varieties. The connector design utilizes current industry processes for ferrule polishing, cleaning and visual qualification techniques. In addition, the connector also uses existing materials capable of Extended Service Life qualifications. As the CS® connector is designed for application in data centers, telecoms, and enterprise industry, the connector is tested against standard performance qualifications.

The main industry standard testing performed on the CS® connector are:



GR-326:

Generic requirements for Single-mode optical connectors and jumper assemblies



IEC 6130-3-34:

Fiber optic interconnecting devices and passive components – Basic test and measurement procedures – Attenuation of random mated connectors (Grade B)



TIA 568:

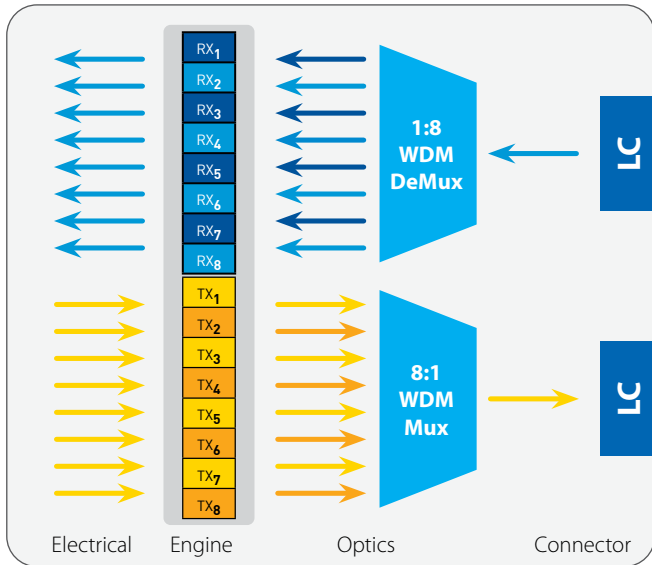
Structured cabling system standards for commercial buildings, and between buildings in campus environments.



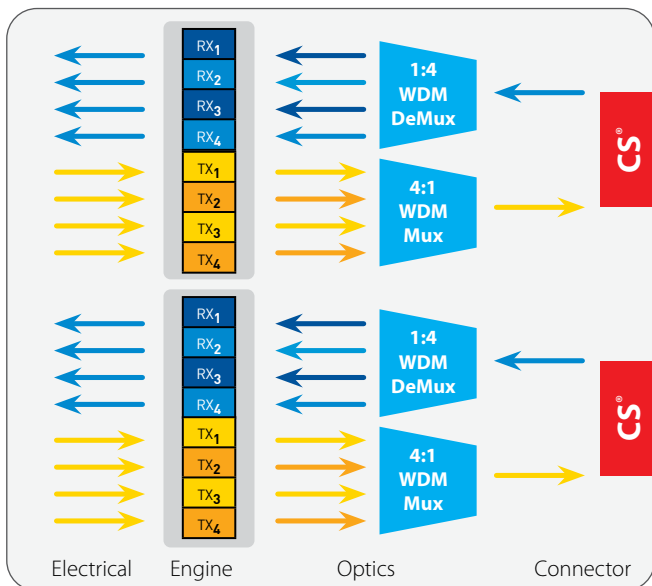
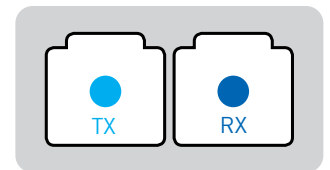
CS® Connector with QSFP-DD/OSFP

LC duplex connectors are currently used for connection in standard QSFP transceiver modules, especially for WDM base duplex modules. Although LC duplex connectors can still be used in QSFP-DD transceiver modules, the transmission bandwidth is either limited to a single WDM engine design either using a 1:4 Mux/DeMux to reach a 200GbE transmission or a 1:8 Mux/DeMux to reach a 400GbE. This increases the transceiver cost and cooling requirement on the transceiver. A new connector type is required to double the

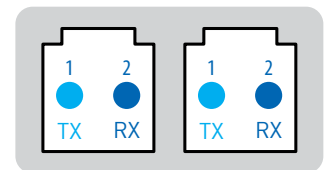
connectivity to the QSFP-DD while maintaining the same connector footprint. The smaller connector footprint of CS® connectors allows two of them to be fitted within a QSFP-DD module, which LC duplex connectors cannot accomplish. This allows for a dual WDM engine design using a 1:4 Mux/DeMux to reach a 2x100GbE transmission or a 2x200GbE transmission on a single QSFP-DD transceiver. In addition to QSFP-DD transceivers, the CS connector is also compatible with OSFP and COBO modules.



LC Duplex



CS® Duplex



CS® Connector enables two duplexes in a single QSFP-DD/OSFP transceiver

CS[®] Connector used in QSFP-DD and OSFP transceivers to increase port density in 100/200G applications

The most common types of QSFP28 transceivers based on four lane multiplexing are LR4 and CWDM4.

LR4 has the advantage in telecom applications because it is interoperable with most other 100G equipment and transceiver form-factors supporting LR4. CWDM4 has the advantage in large scale data center applications due to lower cost and power consumption.

	CWDM4	LR4
Wavelengths	1270, 1290, 1310, 1330nm	1295.56, 1300.05, 1304.58, 1309.14nm
Distance	2 km	10 km
Form factor Support	QSFP28, QSFP-DD	CFP, CFP2, QSFP28, QSFP-DD

Two CS connectors can fit in to the same front panel space of a QSFP-DD/OSFP transceiver as a single duplex LC connector or multimode MPO ribbon cable would usually fit. When using CS connectors in a QSFP28-DD transceiver, this gives the possibility to double the port density of a 100G switch. A 128-port switch would usually require 4U when using standard QSFP28 transceivers. Using the CS connector in a QSFP28-DD transceiver instead solves the task in 2U, and halves the required real estate saving space and money. The transceiver uses two CS connectors in the front interface in the same space where normally a single duplex LC connector would be situated.

LC Duplex connector

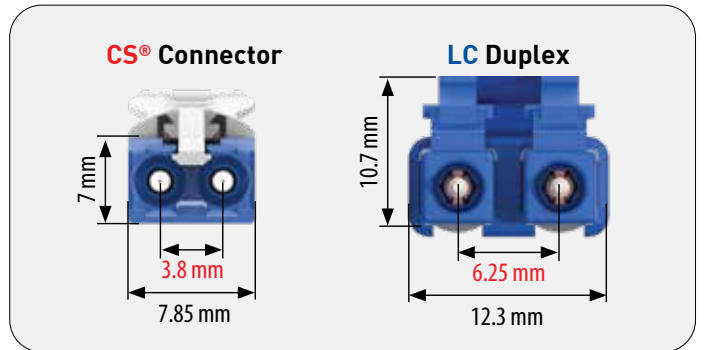
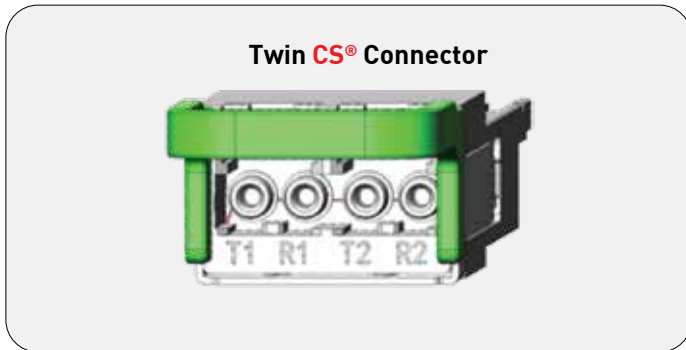


Twin CS[®] connector



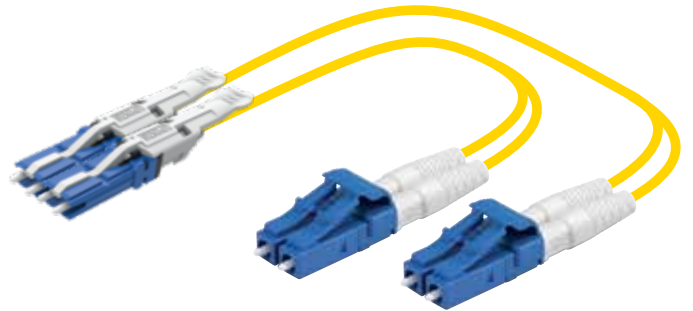
Two CS[®] connectors can fit in to the same space as a single duplex LC connector

This approach of replacing a single duplex LC connector with two CS connectors has been adopted in QSFP-DD and OSFP modules and means that two transceivers are effectively sandwiched together inside one single module to create two transceivers in one.



Using CS® connector in a QSFP-DD or OSFP transceiver doubles the optical port density

Simple CS to duplex LC cables are then used to connect the QSFP-DD/OSFP transceivers to standard QSFP28 transceivers in other equipment.



LC 128 ports in 4RU

A rack panel with four rows of ports. Each row has 32 ports. A blue double-headed arrow indicates the height is 4RU.

Two QSFP28 transceivers connected by a green and black cable.

one QSFP28 to 1x QSFP28

CS® 64 Ports in 2RU

A rack panel with two rows of ports. Each row has 32 ports. A red double-headed arrow indicates the height is 2RU.

Two QSFP28 transceivers connected by a green and black cable.

one QDD/OSFP to two QSFP28s

CS® Connector in 400G switches for 100G applications

One of the challenges for both QSFP-DD and OSFP form factors is the support of legacy 100G interconnections. If the switch uses QSFP28 connectors, then a QSFP-DD transceiver can be used in this port. If OSFPs are used, then QSFP-DD to OSFP converters exist therefore allowing a QSFP-DD to be used in OSFP ports as well.

The CS connectors in the QSFP-DD and OSFP transceivers increases this efficiency by a factor of 2 and at the same time offers important interoperability to legacy CWDM4 and LR4 form factors. Less switch ports are required which prolongs the lifetime of the switch or enables larger networks to be built.

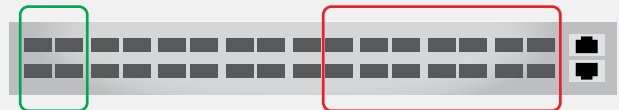
Example Configurations

Using 400G QSFP-DDs and 100G QSFP28s



4x 400G ports + 28x 100G ports

Using 400G QSFP-DDs and 2x100G QSFP-DD



4x 400G ports + 14x 100G ports

The example configurations above show the comparisons between using 100G QSFP28 transceivers in a 400G switch versus using QSFP28-DDs. When using a QSFP28-DD with CS Connectors instead of a standard QSFP28 transceiver, the result is that only half of the 400G ports are used for 100G traffic due to CS connectors providing double density in QSFP-DDs. This more efficient use of the switch or router ports increases its life-time.

CS® Connector in 400G switches for 200G applications

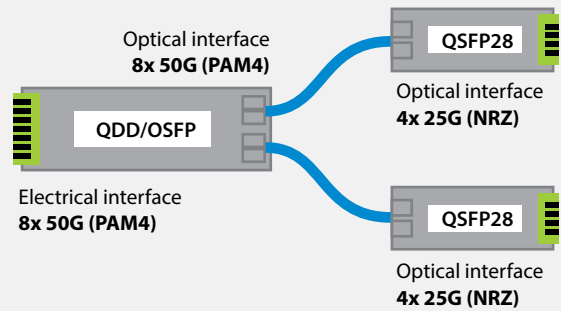
The same advantages are present in 200G scenarios using PAM4 modulation. By this, a 2x 200G port can be hosted in a 400G switch port. Modern 400G switches and transceivers can be set to support both 100G and 200G applications. The three diagrams show how a 400G QSFP-DD/OSFP transceiver can be used in a 400G switch in three modes.

MODE 1

In Mode 1, it can be used for 100G connectivity.

With two CS Connectors the transceiver can connect to two independent QSFP28 transceivers and therefore doubles the capacity of the port from a single 100G connection to 2x 100G connections.

2x 100G in 400G switch using QDD/OSFP to 2x QSFP28

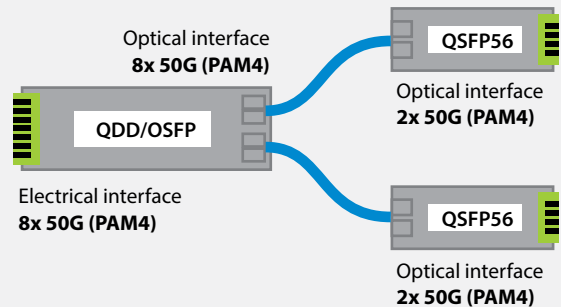


MODE 2

In Mode 2 it can be used for 200G connectivity.

Again, with two CS Connectors in the transceiver it can connect to two separate 200G QSFP56 transceivers and therefore doubling the capacity of the port from a single 200G connection to two 200G connections.

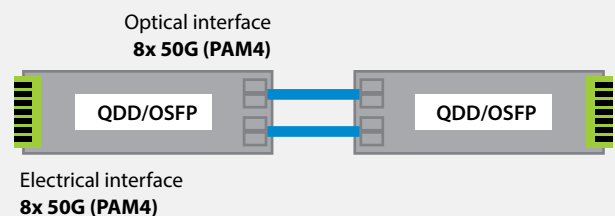
2x 200G in 400G switch using QDD/OSFP to 2x QSFP56



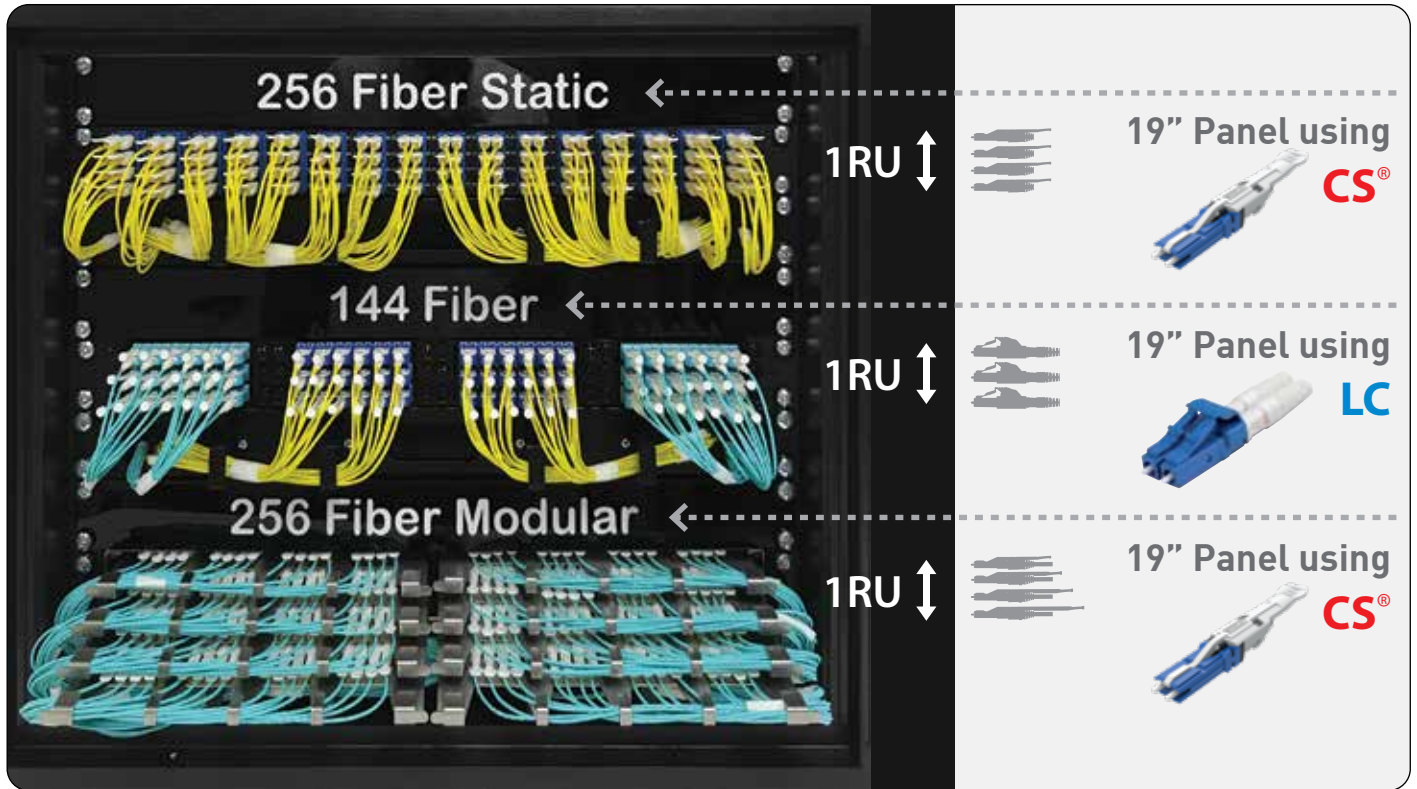
MODE 3

Finally, in Mode 3 the QSFP-DD/OSFP transceiver can be connected to another QSFP-DD/OSFP using 2xCS Connectors for 2x 200G connectivity. This means that the transceiver can either be used in three independent configurations depending on the type of traffic it needs to connect to. Or it is a seamless part of the network upgrade from 100 to 200 to 400G connectivity.

400G to 400G using QDD/OSFP to OSFP

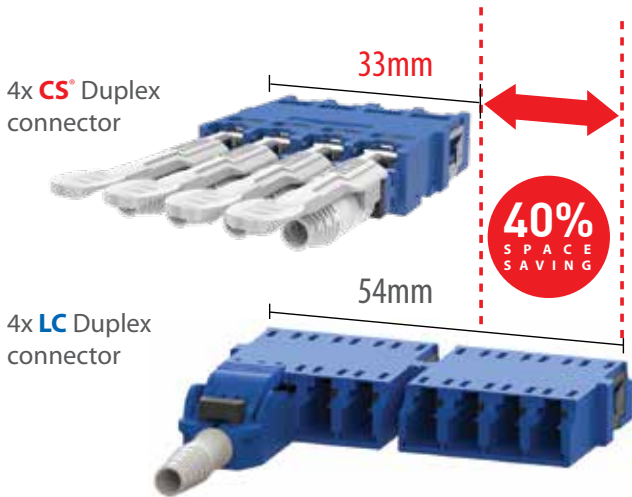


CS® Connector doubles the density of standard Cross-Connect Patch Panel



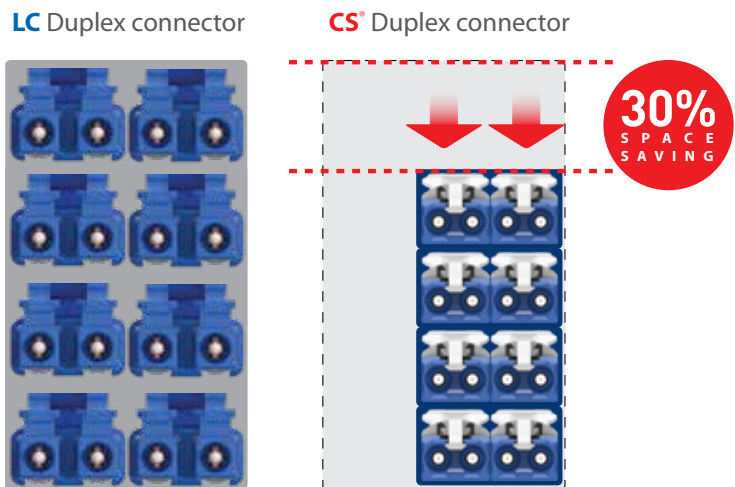
40% size reduction compared to LC Duplex

40% size reduction compared to LC Duplex



30% vertical density reduction compared to LC Duplex

30% vertical density reduction compared to LC Duplex



The CS® connector has a 40% width reduction compared to the standard duplex LC connector. On a 1RU 19" rack, four rows of CS® connectors can be connected with 21 CS® Dual Channel (4-fiber) adapters per row. This results in 336-fiber connections. In comparison, standard duplex LC connector can only achieve 96 fibers terminations in the same 1RU footprint.

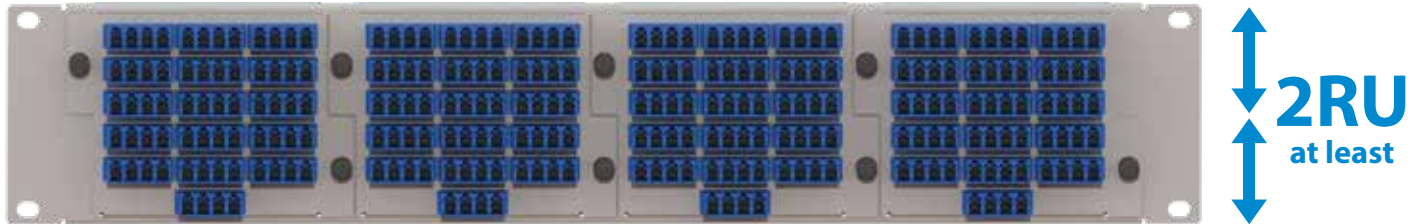
CS® Duplex - Maximum 4x 21 adapters in 1RU - 336 fiber connections



CS® Duplex - 4x 64 fiber silk screened cassette modules 256 fiber connections

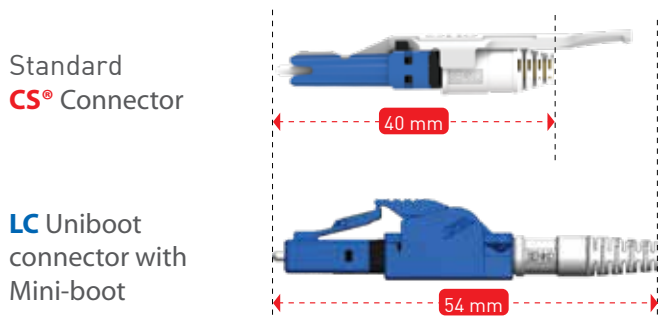


LC 128CH/256F Cassette Panel in 2RU

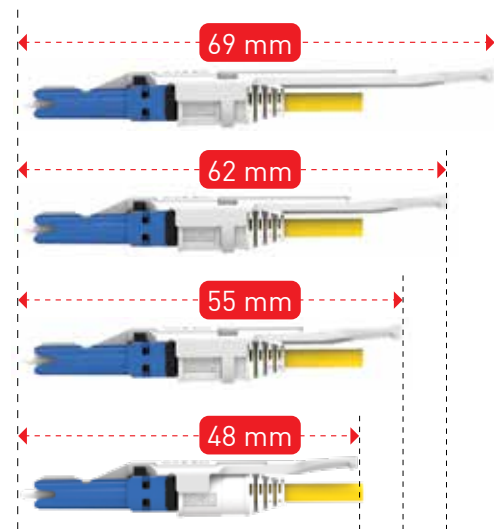


In addition to the smaller connector footprint, the length of the connector from ferrule tip to boot is also much shorter compared to an LC connector. Compared to SENKO's shortest LC Uniboot connector with a Mini-boot, the CS® connector is more than 14mm shorter. This improves the connector mechanical strength as well as reduces the front-of-shelf space requirement for boot and cord management. The embedded push-pull tab design enables the patch panel design to be further compacted without increasing the risk of physically

affecting adjacent connectors during mating or de-mating operations. This allows CS® adapters on a patch panel to be vertically compacted as well. In addition, the push-pull tab can also be used for identification purposes through color coding or clipping identification tags onto the tab. There are four tab lengths available to enable the connector tabs to be staggered with four CS® adapter stacked in a 1RU patch panel.

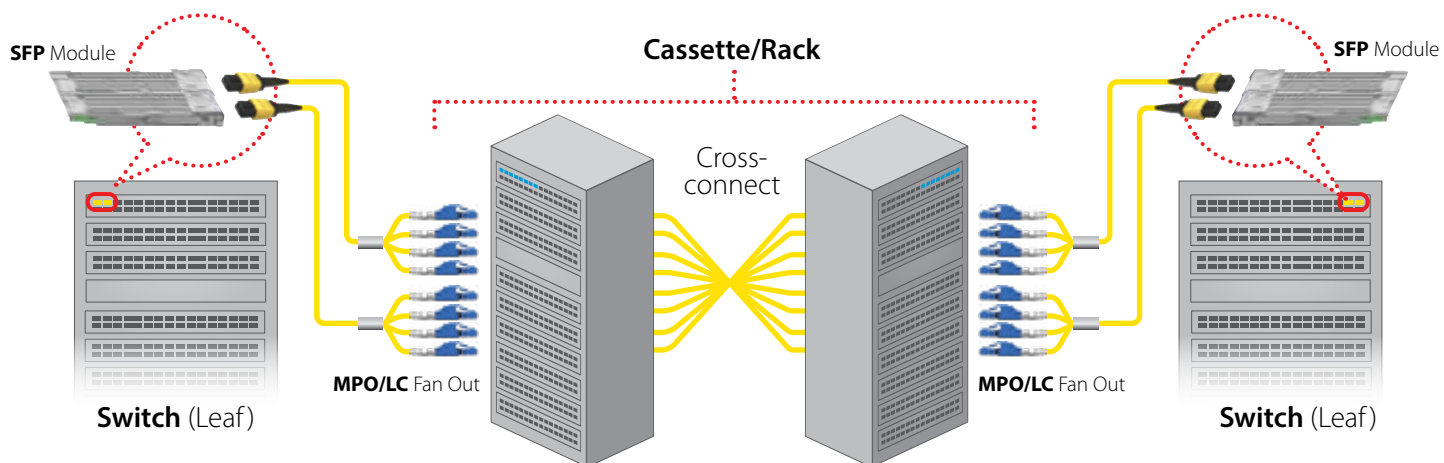


- Less space requirements for patching shelf depth
- Allows for better cabling routing management
- Saving of more than 14mm front-of-shelf space
- Four push-pull tab length

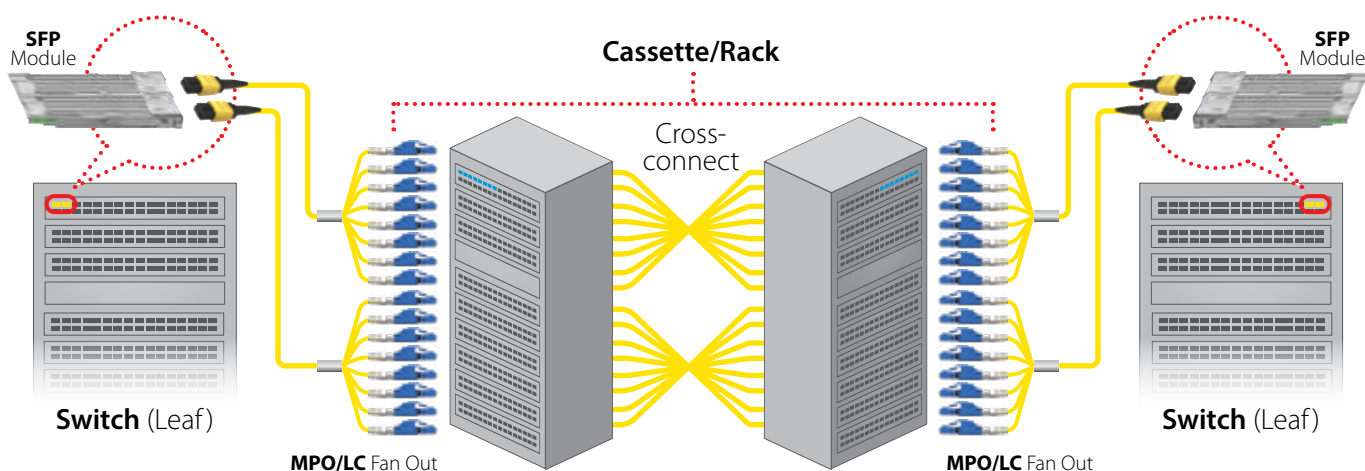


In a parallel transmission system, the most common method used to allocate bandwidth between switches is through an MPO fan-out to LC connectors in a cross-connect patch panel that is connected to another LC connector which is then fan-in back into an MPO connector.

Current 4-lane based transceiver case



Potential 8-lane based transceiver case



The 8-lane based QSFP-DD and OSFP transceivers doubles the switch capacity from the existing 4-lane based transceiver such as QSFP, which can also double the number of fiber connections compared to the current deployed patching structures. A standard 1RU switch has 32 transceiver ports. With the traditional 4-lane transceivers, the maximum fiber counts per transceiver is 8 fibers, which equates total fiber counts to 256 fibers in 32 ports switches. The 8-lane based transceivers would go up to 16 fibers per module using MPO-16 or MPO-24 connectors, which is also referred to as an MPO-12 two row in the TIA standards. This equates to a maximum of 512 fibers in 32-port switch, With a 4x64-fiber cassette modules, a 1RU patch panel

can have 256 fiber connections. This perfectly aligns with the fiber port requirement of a 1RU switch with 32 new generation QSFP-DD or OSFP transceivers which requires 512 fiber terminations. If we compared with LC, CS can save at least 2RU spacing in this application. Furthermore on the patch panel, the reduced width of the CS allows the same cassette with that originally holds horizontally 12 LC connectors to have 16F horizontally thus allowing the same 19' front panel to be reused. The data center will not need to replace the existing 19' racking but instead just need to replace the LC cassettes with the CS cassettes in order to seamlessly migrate to 400G applications.

128CH/256F 1RU Patch Panel CS®

Supports 1 switches

128CH/256F 1RU Patch Panel LC

At least 2RU

Diagram details: The top section shows a QSFP SR4, PSM4, DR4 Transceiver connected to an MPO 4 Channel (8 fibers) cable, which is then connected to 4x CS® Connectors (8 fibers) on a patch panel. The bottom section shows a QSFP SR4, PSM4, DR4 Transceiver connected to an MPO 4 Channel (8 fibers) cable, which is then connected to 4x LC Duplex (8 fibers) on a patch panel. A transceiver switch is shown in the middle, labeled 128CH/256F 32-port Transceiver switch. A small diagram at the bottom left shows fiber allocation on an MPO-12 with TX and RX ports.

256CH/512F 2RU Patch Panel CS®

Supports 1 switches

256CH/512F 4RU Patch Panel LC

At least 4RU

Diagram details: The top section shows QSFP-DD Dual PSM4/SR4 SR8 Transceivers connected to an MPO 8 Channel (16 fibers) cable, which is then connected to 8x CS® Connectors (16 fibers) on a patch panel. The bottom section shows QSFP-DD Dual PSM4/SR4 SR8 Transceivers connected to an MPO 8 Channel (16 fibers) cable, which is then connected to 8x LC Duplex (16 fibers) on a patch panel. A transceiver switch is shown in the middle, labeled 256CH/512F 32-port Transceiver Switch. A small diagram at the bottom left shows fiber allocation on an MPO-24 and MPO-16 with TX and RX ports.

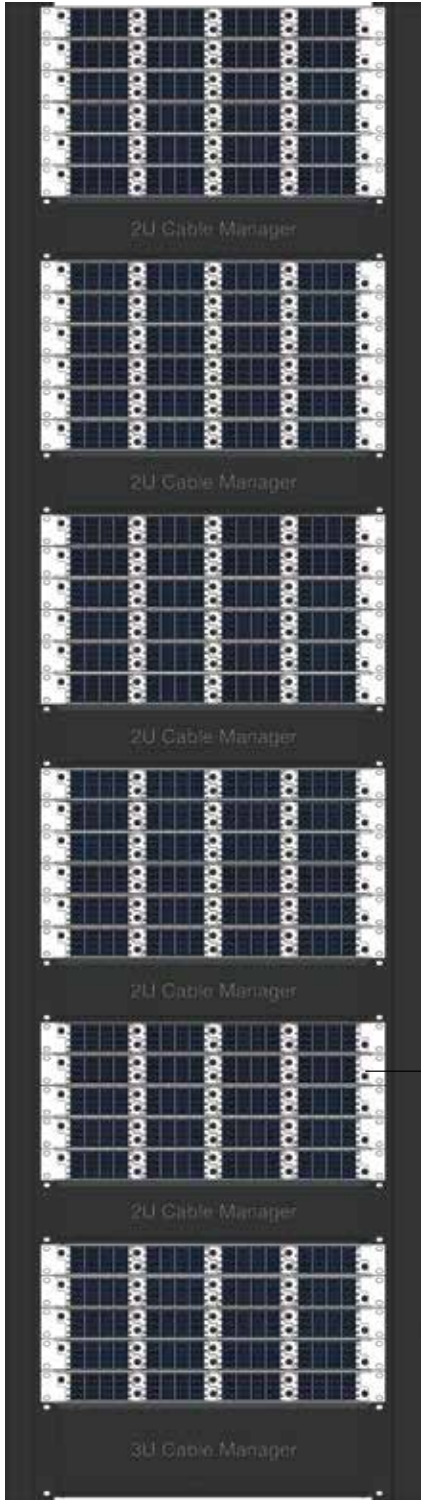
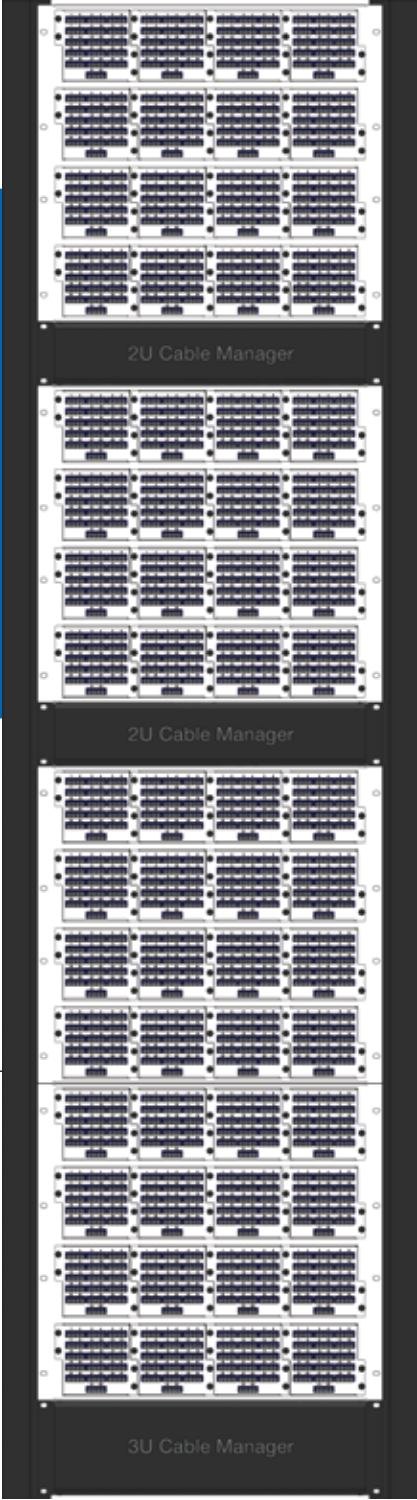
A standard 45RU 19" rack with cable slack managers can have a total capacity of 8704 CS® connector ports compared to 4096 LC connector ports. The use of CS® connector more than doubles the capacity of a standard rack. The CS connector is suitable to be deployed in any location that requires a high density cross-connect termination from hyperscale data centers to shelter data centers, as well as telecoms central offices.

LC 45RU Rack

CS® 45RU Rack

with **LC**
 512CH LC Patch Panel
 4 set can fit in 45RU

Total Capacity
2048 CH
4096 F
 (single sided rack/cabinet)



with **CS®**
 128CH LC Patch Panel
 34 set can fit in 45RU

Total Capacity
4352 CH
8704 F
 (single sided rack/cabinet)

More than double the LC capacity

Generic **LC**

Total **7RU** Cable Management Space

CS® CONNECTOR

Total **13RU** Cable Management Space

**Note that the 3 RU wire manager is installed on the bottom rack base plate and the remaining 1 RU space at the bottom of the rack.*

Summary

SENKO is at the leading edge of high quality connector development to meet the industry's insatiable hunger for higher bandwidth. The introduction of the CS® connector is critical to the implementation of 200/400GbE networks and beyond. The use of industry standard 1.25mm ferrule and manufacturing processes, as well as the backward compatible QSFP-DD design enables a seamless network migration to the new model type while reducing the connectivity footprint. The compact design of the CS® connector more than doubles the channel capacity of racks which translates to significant savings where rack space is a premium.

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Biography



Tiger (Takuya) Ninomiya graduated with his Master's Degree in International Communication from Aoyama Gakuin University in 2012 and joined SENKO Advanced Components. He was transferred to the Fiber Optics Division as a sales representative in Tokyo office in 2013. In 2016, Tiger was transferred to SENKO's Business Development Division in Massachusetts.

Tiger is currently representing SENKO in the MSA and Consortiums for the development of QSFP-DD, OSFP, SFP-DD and COBO. He is also the product line manager for the CS* connector and continuously innovating new products to further develop data center connectivity technology.



David Malicoat is currently an Emerging Technology Specialist at SENKO Advanced Components. He started his career in the telecommunications field working for GTE Lenkurt in the R&D team that was exploring optics. Shortly afterwards he joined HP, and he held several engineering, and system architect positions in the enterprise server business. In 2010, he joined the newly formed Advanced Technology Group in the networking business, and his focus was on next the generation network architectures, and emerging optical technologies for the data center. He drove the data center optical transceiver product line roadmap for 25/100Gbps and beyond. He is an active member of the IEEE 802.3 working groups. David currently represents SENKO at IEEE 802.3 meetings, in MSAs, and consortiums for the development QSFP-DD, OSFP, SFP-DD and COBO.



Dr. Bernard HL Lee is currently the Regional Technology Director at SENKO Advanced Components. He started his career in optical communications when he was appointed as a Senior Research Office for the European Union IST project known as DAVID in 2000. In 2003, he joined Telekom Malaysia R&D where he has held various technical and management positions there including the Head of Photonic Network Research and also Head of Innovation and Communications. Bernard then joined the parent company, Telekom Malaysia (TM) in 2010 as the Assistant General Manager of the Group Business Strategy Division where he oversees the company's business direction. Bernard obtained his RCDD accreditation in 2016. Bernard is also a member of the International Electrotechnical Commission (IEC), the Institute of Engineering and Technology (IET) and was also the Director of the Board of the Fiber-To-The-Home Council APAC. He is currently the Malaysia Country Chair for BICSI Southeast Asia.



Sean Davies is the Director of Sales at Eoptolink covering the Americas. He joined the Telecommunication industry in 2000 at then start-up Transmode Systems AB (now a part of Infinera). His focus has been predominantly on xWDM transmission systems where he was responsible for bringing CWDM and later DWDM in to several of the major telecom operators in the UK. More recently, he was co-founder of Smartoptics and responsible for sales development, OEM relationships and latterly marketing and digital communications. At Eoptolink Sean is working with the major OEM switch vendors and DC operators to design in next generation 100/200/400G transceiver solutions.



Dirk Lutz is an optical transmission and transceivers expert with a passion for making things simple. His experience coupled with the flexibility of Eoptolink allows him to offer unique solutions to the problems facing today's data-center operators and network design engineers. Previously, Dirk was Co-Founder and CTO at Smartoptics where he managed the technical developments of the company. Smartoptics revolutionized the cooperate data-center connectivity industry with Open-Line and disaggregated DWDM Networking. Before co-founding Smartoptics, Dirk was a founding member of Transmode Systems, now a part of Infinera.

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