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Distance Capabilities for Corning's EDGE8™, EDGE™ and Plug & Play™ Pre-Terminated Connectivity Solutions

AEN162, Revision 3

This Application Engineering Note addresses the use of Corning De-Rating tables to aid system designers determine Ethernet and Fibre Channel transmission distance capabilities for Corning's pre-terminated optical connectivity solutions. For examples of fiber optic systems utilizing Base-12 pre-terminated connectivity solutions, please refer to AEN151 "Four-Channel Parallel Optic Connectivity Solutions Utilizing Base-12 Structured Cabling" and AEN152 "Four-channel Parallel to Duplex Optical Connectivity Solutions Utilizing Base-12 Structured Cabling". For Base-8 solutions, please refer to AEN156 "Connectivity Solutions Utilizing Base-8 Structured Cabling".

Transmission Standards

The Institute of Electrical and Electronic Engineers (IEEE) provides Ethernet standards and the International Committee for Information Technology Standards (INCITS) provides Fibre Channel standards. Each standard specifies a maximum channel length for different protocol data rates depending on fiber types and the associated channel loss. Both standard bodies use fiber transmission link models to account for the different loss penalties within the system to establish the maximum channel lengths for each protocol transmission speed. These models are a combination of electronics and connectivity power penalties used for a particular transmission protocol. Based on this, each data rate has a specific power budget that is used to determine system's capabilities.

The operating distances and channel insertion losses (CIL) are typically published in tabular format within the standard. It is difficult to show all the possible length combinations. Therefore, each standards committee must select how to display the output.

For most Ethernet protocols, the IEEE assumes a total connector loss budget of 1.5 dB; but in some cases, the assumption is only 1.0 dB. This budget can be divided into multiple connector pair if one chooses to. IEEE typically specifies a maximum discrete 0.75 dB connector mated pair insertion loss. For the 10GBase-SR protocol, they assumed a two connector mated pair system resulting in an overall connector loss of 1.5 dB for the link. From this assumption, a maximum achievable distance can be calculated with the standard model. For example, the IEEE states the maximum reach of OM3 fiber at 10GBASE-SR is 300 m with an overall channel insertion loss budget of 2.6 dB as shown in Figure 1. This value is a great guidance tool for providing a snapshot for a single system configuration. However, optical links have different lengths, number of mated connector pairs and design configurations.

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Paremeter	62.5 µm MMF			50 µm MMF			Unit
Modal bandwidth as measured at 850 nm	160	200	400	500	2000	4700	MHz.km
Power budget	7.3	7.3	7.3	7.3	7.3	7.3	dB
Operating distance	26	33	66	82	300	400	m
Channel insertion loss	1.6	1.6	1.7	1.8	2.6	2.9	dB
Allocation for penalties	4.7	4.8	5.1	5	4.7	4.4	dB
Additional insertion loss allowed	1	0.8	0.5	0.5	0.0	0.0	dB

Figure 1: 10G Ethernet (10GBase-SR) Table of Operating Distance & Loss Budgets

Historically for Fibre Channel protocols, the INCITS Technical Committee used the same normative guidance as IEEE; assuming a total connector loss budget of 1.5 dB. However, since the release of Fibre Channel Physical Interface 4 (FC-PI-4), instead of only assuming a default guidance with 1.5 dB total connector loss for the channel, INCITS started providing guidance on distance capabilities for various fiber types over a range of connector IL values from 1 dB to 3.0dB. 3.0dB, being the upper limit for connector IL.

Figure 2 shows the 8G Fibre Channel distance capabilities for various fiber types over a range of connector IL values. This method clearly demonstrates the tradeoff between distance and connector IL. Per the table, an 8GFC link over OM4 fiber can achieve a distance of 50 m with 3 dB of connector IL, or 220 m if the connector IL is limited to 1 dB.

Fiber Type	Distance (m)/Loss Budget (dB) Connection Loss				
	3.0 dB	**2.4 dB**	**2.0 dB**	**1.5 dB**	**1.0 dB**
M5F (OM4)	50/3.18	120/2.83	160/2.58	190/2.19	220/1.80
M5E (OM3)	35/3.13	110/2.80	125/2.45	150/2.04	180/1.65
M5 (OM2)	N/A	35/2.53	45/2.16	50/1.168	60/1.22

Figure 2: 8G Fibre Channel (800-SN) Table of Operating Distance vs. Loss Budgets

Even with the guidance provided by both standard bodies, a system designer will often run into cases where they need to implement links different from the ones assumed by the standards (e.g.: tapping applications or when cross-connecting multiple links). This creates a need for additional guidance, which is provided in the De-rating tables.

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Fiber Transmission Link Models

There is a trade-off between channel length and channel insertion loss. Reducing the channel length provides margin (dB) that can be used in the form of more connections while maintaining the required signal integrity. Likewise, by reducing the overall connector loss, we can add more connections in the system. Additionally, if components with improved connectivity loss parameters are utilized, then channel lengths that exceed standards specification can be achieved.

Structured cabling deployments often require elements that increase the channel insertion loss (IL) budgets of a given application. As an example, cross connects and optical taps can be valuable, even necessary; but result in increased channel IL.

Ethernet and Fibre Channel Standard committees have created models that show the trade-off between power penalties and supportable distances for different data rates.
The link models are based on a power budget calculation. Power penalties, sometimes referred to as AC penalties, are allocated for link impairments such as noise and dispersion. Power loss is also included to account for connectors and fiber attenuation. The power penalties and losses are added linearly in decibels to determine the total link penalty as a function of length. Additionally, a correction term is used to account for the interaction between penalties[2]. The models assume worst-case parameters for the components performance in the link, including the transceiver and physical media (cabling).

The models were developed as a tool to assist the Ethernet and Fibre Channel committees in understanding the potential tradeoffs between the various link penalties and as a baseline for discussion of link specifications. Using these models along with the consideration of the performance of the system components, systems designers can successfully balance the distance and loss in their networks. Figure 3 shows an example of a Standard Fiber Transmission Link Model for 10GBase-SR.

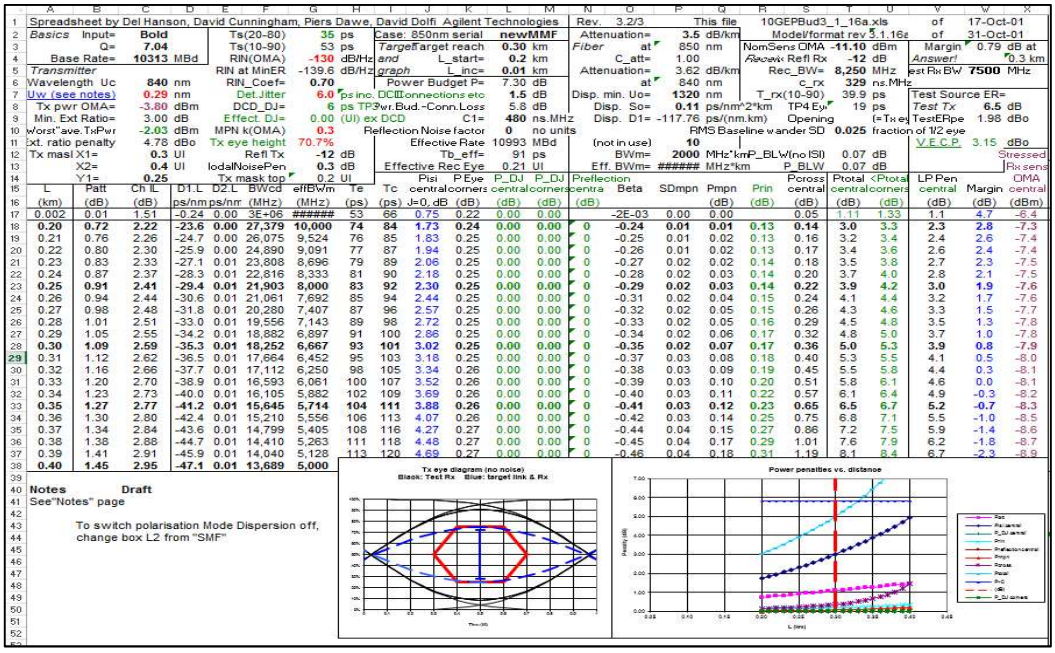

Figure 3: 10GBase-SR Fiber Transmission Link Model[1]

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Standards vs. Engineered Solution Models

A standard solution transmission model utilizes standards approved minimum compliant transceivers parameter for the different transmission protocols. A Multi-Source Agreement (MSA) guides the mechanical and electrical interface specifications for the transceiver ports, which is open to multiple vendors.

An engineered solution transmission model is based on vendor specific transceiver parameters for a specific transmission protocol. Engineered solutions normally provide channel distances longer than standard specified distances. The mechanical and electrical interface specifications are unique to the solutions vendor. i.e.: 40GBase-eSR4/CSR4/XSR4 for extended reach 40G parallel transmission and 40GBase-BiDi for bidirectional transmission. Corning has collaborated with engineered solution vendors to generate the maximum channel distances for different transmission protocols based on vendor specific transceiver parameters.

Corning De-Rating Tables

As mentioned above the values used in the standard solutions models assume worst-case transceiver performance parameters while engineered solutions models are based on vendor specific transceivers parameters. For both cases, Corning Optical Communication's connectivity parameters are used to calculate the maximum channel distances. Corning connectivity products provide consistently better performance than those used in the standard model. Additionally, the Corning De-Rating Tables give the designer a distance capability based on the number of components in the link, while ensuring that the integrity of the signal that arrives at the receiver is within the operating dynamic range, as verified by the models.

This is helpful to system designers who have links that are different from the ones assumed by the standards bodies. A designer wants the confidence that the link will work over a variety of channel conditions, and the Corning De-Rating Tables provide that assurance.

How to use the Corning De-Rating Tables

The information needed to extract the maximum channel distance for the different protocol data rates from the De-Rating table is listed below:

1) **Component Loss Specification**: Corning offers multiple loss specification for Multimode and single mode MTP®/LC modules and MTP/MTP mated pairs. EDGE8™ and EDGE™ multimode Ultra Low Loss modules have a loss specification of 0.35 dB, while the EDGE and Plug & Play™ Low loss modules have a loss specification of 0.5 dB. In the case of MTP/MTP mated pair, Corning's EDGE8 multimode MTP trunks have a 0.25 dB mated pair loss. EDGE multimode MTP trunks with manufacturing dates after September 2014 have 0.25 dB MTP mated pair loss; while trunks manufactured prior to this date have a 0.35 dB MTP mater pair loss. Plug & Play MTP trunks have a 0.35 dB mated pair loss.

2) **Fiber Type:** Standards recognized fiber types for protocol data rates covered are - Laser Optimized Multimode 50/125um OM3 and Laser Optimized Multimode 50/125um OM4 and Single mode (OS2).

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3) **Application Protocol and Data rate:** Ethernet and Fibre Channel protocol data rates for standard solutions and engineered solutions are covered. For specific guidance on Standards and Engineered link situations not published in this document, please contact Corning Optical Communications Technical Support line.

4) **Infrastructure connection count:** Number of MTP or module connections in the cabling infrastructure. For a cabling infrastructure with a mix of Modules and MTP connections typical in serial application, the MTP connections are counted as module connections. Conversion modules typical in parallel optics applications are counted as two MTP connections.

De-rating Tables

Each table provides the applicable protocols data rate distances capability. The first column of each table represents the cabled fiber type; the second column is the applicable data rates for the different protocols; the third column shows the protocol speed. Subsequent columns represent the number of MTP/LC modules or MTP mated pair count in the cabling infrastructure, starting from one through eight. The maximum distance capability in meters for a fiber type at a particular data rate can be read from the intersecting cell of the data rate row and the number of MTP/LC module or MTP mated pair count column in the cabling infrastructure.

De-rating Tables for Ethernet and Fibre Channel duplex and parallel applications can be found in **Appendix A**.

Sample of Infrastructure Layouts and Protocol Data Rate Channel Distances

In the infrastructure examples below, we used the De-Rating tables to determine the channel distances for applicable data rates based on fiber type and the number of MTP/LC modules or MTP/MTP mated pairs in the infrastructure. To support a protocol data rate, the De-Rating table distance should be greater than or equal to the infrastructure total cable length of the given fiber type.

Figure 4 shows a **two** MTP/LC module system. Assuming that this system has **OM4** fiber and Ultra Low Loss Modules (**0.35 dB** per module). Based on the information found in Table 1.2 the maximum distances for Ethernet protocols 1000Base-SX is 1170 meters, 10GBase-SR is 560 meters and 40GBase-BiDi is 200 meters. For Fibre Channel we would use Table 2.2 to determine the maximum distances; 4 GFC is 650 meters, 8 GFC is 285 meters, 16 GFC is 200 meters and 32 GFC is 130 meters.

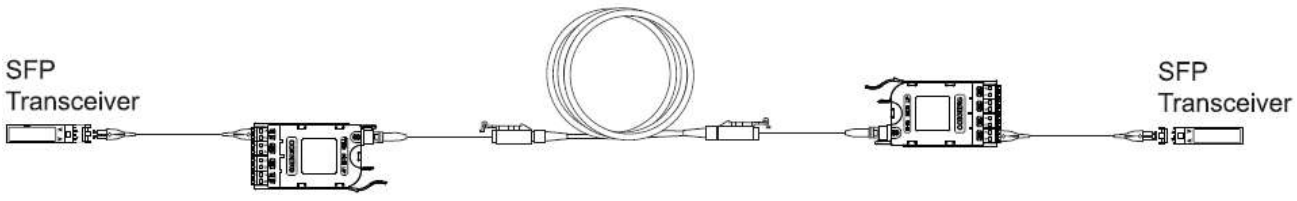

Figure 4: Two MTP/LC Module System

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Figure 5 shows a **six** MTP/LC module system. Assuming that this system has **OM3** fiber and Low Loss Modules **(0.50 dB** per module). Based on the information found in Table 1.1 the maximum distances for Ethernet protocols 1000Base-SX is 1010 meters, 10GBase-SR is 325 meters and 40GBase-BiDi is 105 meters. For Fibre Channel we would use Table 2.1 to determine the maximum distances; 4 GFC is 420 meters, 8 GFC is 175 meters, 16 GFC is 105 meters and 32 GFC is 75 meters.

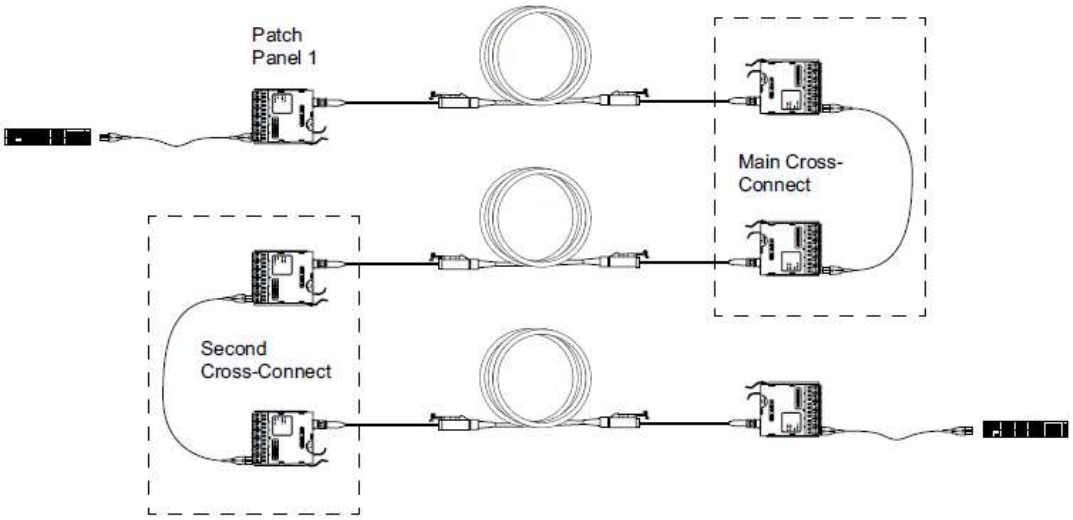

Figure 5: Six MTP/LC Module System

Figure 6 shows a **four** MTP/MTP adapter panel system. Assuming that this system has **OM3** fiber and Ultra Low Loss MTP mated pairs (**0.25 dB** per MTP mated pair). Based on the information found in Table 1.4 the maximum distances for Ethernet protocols 40GBase-SR4 is 145 meters, 40GBase-eSR4 is 325 meters and for 100GBase-SR4 is 85 meters. For Fibre Channel we would use Table 2.3 to determine the maximum distances for 128 GFC is 70 meters.

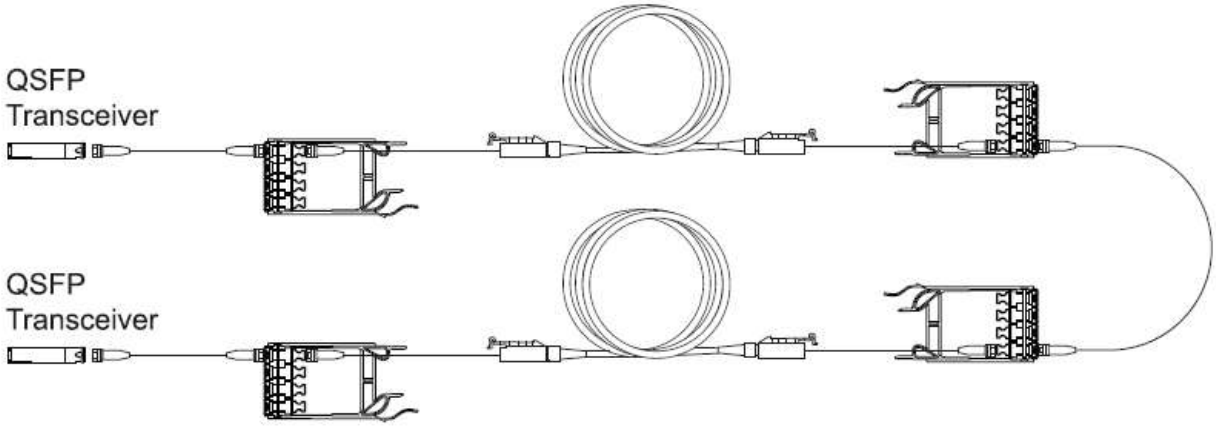

Figure 6: Four MTP/MTP Adapter Panels System

Figure 7 shows a two MTP®/MTP conversion module system (Conversion modules count at two MTP mated pair each). Assuming that this system has **OM4** fiber and Low Loss MTP mated pairs (**0.25 dB** per mated pair). Based on the information found in Table 1.4 the maximum

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distances for Ethernet protocols 40GBase-SR4 is 190 meters, 40GBase-eSR4 is 550 meters and for 100GBase-SR4 is 130 meters. For Fibre Channel we would use Table 2.4 to determine the maximum distances for 128 GFC is 105 meters.

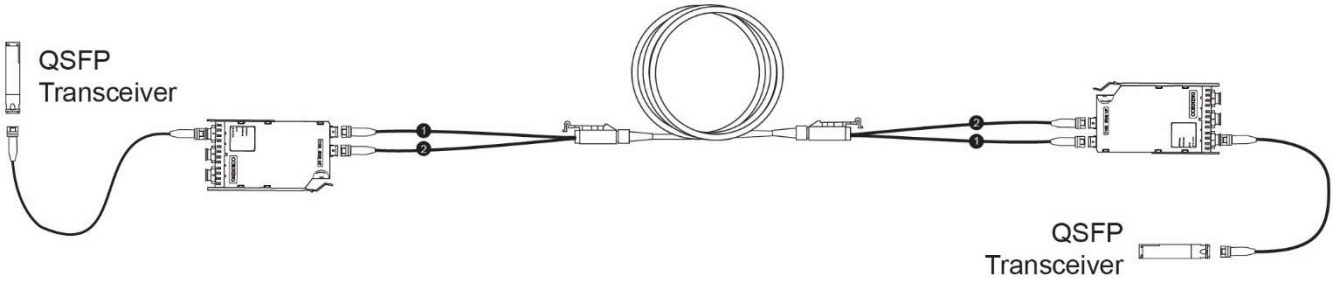

Figure 7: Two-MTP/MTP Conversion Module System (Four MTP/MTP Mated Pairs)

De-Rating Table for Optical Splitter/TAP module Application

Another connectivity component in the cabling infrastructure is the TAP modules for network monitoring and analytics. The TAP Modules contain an optical splitter that introduces additional loss into the channel due to splitting of the signal power into percentages of 50/50, 70/30 or 80/20. The split signals are channeled to two devices, the live device (switch/storage/server) and the monitoring device for signal analysis. Figure 8 depicts how the splitter inside the TAP module works.

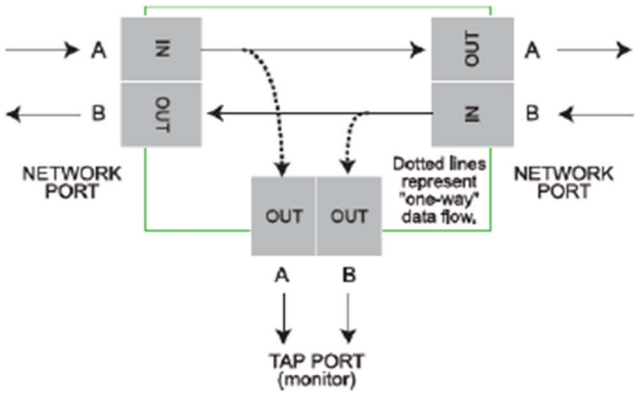

Figure 8: Optical Signal Split inside a Passive TAP module

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The inclusion of the splitter in the link inserts additional loss, which in turn reduces the loss margin and channel distance. Corning Optical TAP modules use a thin-film splitter technology for multimode applications offering better loss performance values. Integrating the optical splitter in the module component of the cabling infrastructure will further reduce loss compared to a non-integrated solution. Corning's De-Rating table provides maximum distances for different protocol data rates using TAP modules. The maximum live operating distances are provided for 50/50 and 70/30 split ratio TAPs for Ethernet applications and 70/30, and 80/20 split ratios TAPs for Fibre Channel applications. Due to the limitation of the monitor link length for unequal split taps and varying monitor equipment receiver sensitivity, the supportable monitor link lengths are addressed on a case-by-case basis for the different protocol data rates. Corning recommends the use of extended reach transceivers for 40/100G parallel transmission tap applications. For multimode Fibre Channel applications, the maximum distance of the monitor link shall not exceed 20 meters direct monitor equipment interconnection for all multimode applications. This guidance is based on the use of Virtual Instruments monitor/receiver devices. Please Contact Corning Optical Communications' Technical Support Line with any inquiry.

De-rating Tables for Ethernet and Fibre Channel duplex and parallel tapping applications can be found in **Appendix B**.

Corning partners with equipment and transceiver vendors to provide derating guidance for engineered and /or vendor specific higher Tx power / Rx sensitivity transceiver optics for extended reach applications and in support of tap monitoring. One such partnership is Corning's internal Foxconn Optical Interconnect (FIT) 100G BiDi transceiver evaluation with the EDGE8™ Tap Module using a 50:50 Split Ratio that demonstrated compliant performance up to 50 meters.
Refer to Appendix C for the white paper dedicated for the test setup and summary report.

Sample of Optical Splitter Infrastructure Layouts and Protocol Data Rate Channel Distances (live)

In the optical TAP infrastructure examples below, we used the optical De-Rating table to determine the channel distances of applicable data rates based on fiber type, one TAP module and the number of MTP/LC modules in the infrastructure.
To support a protocol data rate the De-Rating table distance for the live signal should be greater than or equal to the infrastructure total cable length of a given fiber type. For multimode Fibre Channel applications, the maximum distance of a monitor link cannot exceed 20 meters for any protocol regardless of the fiber type.

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Figure 9 shows a two MTP®/LC module system with one Integrated MTP/LC TAP Module and one MTP/LC Module. Assuming that this system has **OM4** fiber, **70/30** split and Low Loss Modules (**0.5 dB** per module). Based on the information found in Table 3.3 the maximum LIVE distance for Ethernet protocol 10GBase-SR is 525 meters. For Fibre Channel we would use Table 4.3 to determine the maximum LIVE distances; 4 GFC is 395 meters, 8 GFC is 190 meters, 16 GFC is 80 meters and 32 GFC is 70 meters.

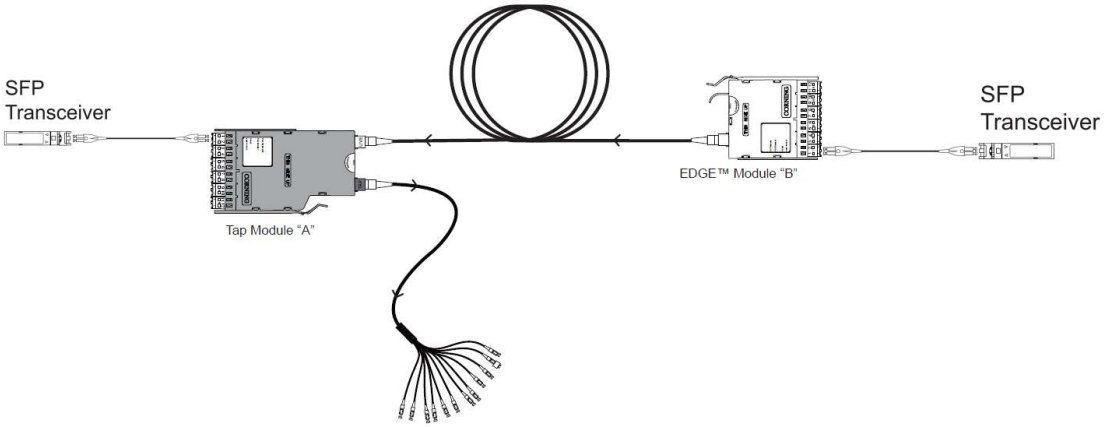

Figure 9: Two-Module System – 1 Integrated MTP/LC TAP Module and 1 MTP/LC Module

Figure 10 shows a two MTP/LC module system with one Integrated MTP/LC BiDi TAP Module and one MTP/LC Module. Assuming that this system has **OM4** fiber, **50/50** split and Low Loss Modules (**0.5 dB** per module). Based on the information found in Table 3.3 the maximum LIVE distance for 40GBase-BiDi is 120 meters.

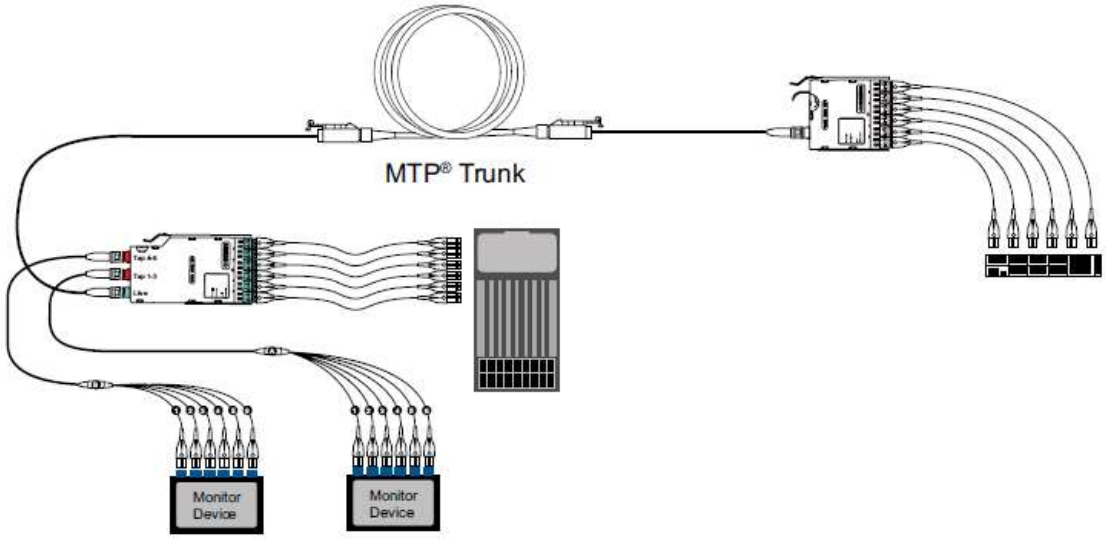

Figure 10: Two-Module System – 1 BiDi Integrated MTP/LC TAP Module and 1 MTP/LC Module

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The Corning De-Rating Tables offer system designers more flexibility when implementing fiber optics systems than the fixed maximum optical media transmission distances specified in the IEEE and Fibre Channel standards, and engineered solutions. The De-Rating tables provides the maximum supportable channel length in which a system can operate based on the fiber type, protocol data rate and number of connections. The values in the De-Rating Tables are derived using the IEEE and INCITS fiber transmission link models, which considers the relationship among all the relevant parameters of the system but with the optical performance parameters based on Corning Optical Communications' pre-terminated connectivity solutions. In evaluating the inter-dependencies of these many parameters, the De-Rating Tables have been developed to provide a series of operating points for channels of a specific fiber type and data rate when utilizing Corning products.

These tables are great reference documents for system designers because they complement the standard values provided by the IEEE, INCITS or engineered solution maximum distance specifications. A designer wants the confidence that a link will work when their system is different from those assumed by the standards or engineered solutions.

The maximum operating distances specified on the De-Rating table are contingent upon standard recommended cable installation practices devoid of any external impairment such as attenuation resulting from improper installation or dirty connections. The distances are also contingent upon passing an end-to-end power through test of the link loss budget based on the optical and connectivity component specifications. For guidance on how to build a link loss budget for Corning's Pre-terminated Systems, please refer to AEN115 "EDGE™ and Plug & Play™ Link Loss Budget Determination".

For questions concerning supportable distances for protocol data rates or engineered solutions not covered in this document, please contact Corning Optical Communications' Technical Support Line at 1-800-743-2671 or dutyeng@corning.com.

References:

1. IEEE (2002, April 9) P802.3ae 10Gb/s Ethernet Task Force - Serial PMD Documents. Retrieved from http://www.ieee802.org/3/ae/public/adhoc/serial_pmd/documents/10GEPBud3_1_16a.xls
2. Cunningham, D. & Dawe, P. (2002) Review of the 10Gigabit Ethernet Link Model Retrieved from http://www.avagotech.com/docs/AV02-2485EN

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Appendix A
De-rating Tables for Ethernet and Fibre Channel
Duplex and parallel applications

Table 1.1: Ethernet Duplex - Maximum Distance Capability for Systems with Multimode Low Loss/Single mode Standard loss MTP®/LC Modules (0.5/1.0) dB

Ethernet - Duplex - Maximum Distance Capability (All Distances in Meters)									
Fiber Type	Data Rate Protocol	Speed	Number of (MM/SM) Low/Std. loss MTP/LC Modules (0.5 /1.0)dB in the System						
			1	2	3	4	5	6	7	8
OM3	1000Base-SX	1 GbE	1145	1115	1090	1065	1040	1010	990	970
	10GBase-SR	10 GbE	325	325	325	325	325	325	325	325
	25Gbase-SR	25 GbE	85	85	85	80	80	75	65	60
	40G Bidi	40GbE	110	110	110	110	110	105	105	100
	100G Bidi	100GbE	100	95	95	90	85	80	75	70
	100G SWDM4	100GbE	70	70	70	70	70	70	70	70
OM4	1000Base-SX	1 GbE	1175	1150	1125	1105	1075	1050	1030	1010
	10GBase-SR	10 GbE	560	555	550	540	530	520	520	515
	25Gbase-SR	25 GbE	130	130	125	120	115	110	95	90
	25Gbase-eSR	25 GbE	330	326	322	319	315	311	308	304
	40G Bidi	40 GbE	200	200	200	190	185	175	170	165
	100G Bidi	100GbE	145	135	130	125	120	115	105	100
	100G SWDM4	100GbE	100	100	100	100	100	100	100	100
OS2	100G CWDM4	100GbE	2000	2000	2000	2000	2000	1250	350	N/A
	10GBase-LR	10 GbE	11750	10500	9250	8000	6750	5500	4250	3000
	25Gbase-LR	25 GbE	12100	10800	9700	8500	7400	6200	5000	3800
	40GBase-LR4	40GbE	11750	10250	9250	8000	6750	5750	4500	3500
	100GBase-LR4	100GbE	11750	10250	9000	7750	6500	5250	4000	2750

Table 1.2: Ethernet Duplex - Maximum Distance Capability for Systems with Multimode / Single mode Ultra Low Loss MTP/LC Modules (0.35/0.6) dB

Ethernet - Duplex - Maximum Distance Capability (All Distances in Meters)									
Fiber Type	Data Rate Protocol	Speed	Number of (MM/SM) Ultra Low Loss MTP/LC Modules (0.35/0.6) dB in the System						
			1	2	3	4	5	6	7	8
OM3-ULL	1000Base-SX	1 GbE	1155	1135	1115	1095	1070	1045	1020	1000
	10GBase-SR	10 GbE	325	325	325	325	325	325	325	325
	25Gbase-SR	25 GbE	85	85	85	85	85	80	75	65
	40G Bidi	40GbE	110	110	110	110	110	110	105	105
	100G Bidi	100GbE	105	100	95	95	90	90	85	80
	100G SWDM4	100GbE	70	70	70	70	70	70	70	70
OM4-ULL	1000Base-SX	1 GbE	1190	1170	1150	1130	1110	1085	1060	1030
	10GBase-SR	10 GbE	565	560	555	550	540	535	525	520
	25Gbase-SR	25 GbE	130	130	130	125	125	120	110	100
	25Gbase-eSR	25 GbE	333	330	326	323	320	316	313	309
	40G Bidi	40GbE	200	200	200	200	195	185	180	175
	100G Bidi	100GbE	150	145	140	135	130	125	120	115
	100G SWDM4	100GbE	100	100	100	100	100	100	100	100
OS2-ULL	100G CWDM4	100GbE	2000	2000	2000	2000	2000	2000	2000	2000
	10GBase-LR	10 GbE	12500	11750	11000	10250	9750	9000	8500	7750
	25Gbase-LR	25 GbE	12700	12000	11300	10700	10100	9500	8900	8300
	40GBase-LR4	40GbE	12500	11500	10750	10250	9500	9000	8250	7750
	100GBase-LR4	100GbE	12500	11500	10750	10250	9500	8750	8000	7500

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Table 1.3: Ethernet Parallel - Maximum Distance Capability for Systems with Multimode Low Loss MTP® Mated Pairs (0.35) dB

Ethernet - Parallel - Maximum Distance Capability (All Distances in Meters)									
Fiber Type	Data Rate Protocol	Speed	Number of (MM) Low loss MTP Mated pairs (0.35)dB in the System						
			1	2	3	4	5	6	7	8
OM3	40GBase-SR4	40 GbE	160	145	135	125	120	105	95	90
	40GBase-eSR4	40 GbE	325	325	325	325	325	325	325	325
	100GBase-SR10	100 GbE	160	145	135	125	120	105	95	90
	100GBase-SR4	100 GbE	85	85	85	80	80	75	65	60
OM4	40GBase-SR4	40 GbE	210	195	180	165	145	125	125	120
	40GBase-eSR4	40 GbE	560	555	545	535	530	520	515	510
	100GBase-SR10	100 GbE	210	195	180	165	145	125	125	120
	100GBase-SR4	100 GbE	130	130	125	120	115	110	95	90

Table 1.4: Ethernet Parallel - Maximum Distance Capability for Systems with Multimode/Single mode Ultra Low Loss (ULL) MTP Mated Pairs (0.25/0.35) dB

Ethernet - Parallel - Maximum Distance Capability (All Distances in Meters)									
Fiber Type	Data Rate Protocol	Speed	Number of (MM/SM) Ultra Low Loss (ULL) MTP Mated pairs (0.25/.35)dB in the System						
			1	2	3	4	5	6	7	8
OM3-ULL	40GBase-SR4	40 GbE	165	160	150	145	140	130	125	125
	40GBase-eSR4	40 GbE	325	325	325	325	325	325	325	325
	100GBase-SR10	100 GbE	165	160	150	145	140	130	125	125
	100GBase-SR4	100 GbE	85	85	85	85	85	85	80	80
OM4-ULL	40GBase-SR4	40 GbE	220	210	200	190	185	170	165	150
	40GBase-eSR4	40 GbE	565	560	555	550	545	540	535	530
	100GBase-SR10	100 GbE	220	210	200	190	185	170	165	150
	100GBase-SR4	100 GbE	130	130	130	130	130	125	120	115
	100GBase-eSR4	100 GbE	334	330	328	325	323	321	319	316
OS2-ULL	40G-PLR4	40 GbE	12750	12250	11750	11250	11000	10500	10250	9750
	100G PSM4	100G	500	500	500	500	500	500	500	500

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Table 2.1: Fibre Channel Duplex - Maximum Distance Capability for Systems with Multimode Low Loss/ Single mode Standard loss MTP®/LC Modules (0.5/1.0) dB

Fibre Channel - Duplex - Maximum Distance Capability (All Distances in Meters)									
Fiber Type	Data Rate Protocol	Speed	Number of (MM/SM) Low/Std. Loss MTP/LC Modules (0.5/1.0) dB in the System						
			1	2	3	4	5	6	7	8
OM3	400-M5E-SN-I	4 GFC	540	515	490	470	445	420	400	390
	800-M5E-SN-I	8 GFC	215	215	210	195	185	175	165	155
	1200-M5E-SN-I	10 GFC	325	325	325	325	325	325	325	325
	1600-M5E-SN-I	16 GFC	150	140	135	125	115	105	95	90
	3200-M5E-SN-I	32 GFC	80	80	80	80	80	75	65	60
	6400-M5E-SN-I	64 GFC	75	75	75	75	75	70	70	70
OM4	400-M5F-SN-I	4 GFC	655	625	595	570	540	510	490	470
	800-M5F-SN-I	8 GFC	290	275	260	250	235	220	210	200
	1200-M5F-SN-I	10 GFC	560	555	550	540	530	520	520	515
	1600-M5F-SN-I	16 GFC	205	190	180	170	155	140	130	120
	3200-M5F-SN-I	32 GFC	130	130	125	120	115	110	95	85
	6400-M5F-SN-I	64 GFC	115	115	115	115	110	105	100	95
OS2	800-SM-LC-L	8 GFC	12150	10400	9050	7550	6150	4800	3500	2200
	1600-SM-LC-L	16 GFC	11750	10250	9050	7700	6350	5000	3750	2400
	3200-SM-LC-L	32 GFC	11850	10400	9250	8000	6750	5500	4350	3100

Table 2.2: Fibre Channel Duplex - Maximum Distance Capability for Systems with Multimode/Single mode Ultra Low Loss (ULL) MTP/LC Modules (0.35/0.6) dB

Fibre Channel - Duplex - Maximum Distance Capability (All Distances in Meters)									
Fiber Type	Data Rate Protocol	Speed	Number of (MM/SM) Ultra Low Loss (ULL) MTP/LC Modules (0.35/0.6) dB in the System						
			1	2	3	4	5	6	7	8
OM3-ULL	400-M5E-SN-I	4 GFC	550	535	515	495	475	455	430	410
	800-M5E-SN-I	8 GFC	215	215	215	210	200	190	180	170
	1200-M5E-SN-I	10 GFC	325	325	325	325	325	325	325	325
	1600-M5E-SN-I	16 GFC	155	150	145	135	130	120	110	100
	3200-M5E-SN-I	32 GFC	80	80	80	80	80	80	75	65
	6400-M5E-SN-I	64 GFC	75	75	75	75	75	75	70	65
OM4-ULL	400-M5F-SN-I	4 GFC	670	650	625	605	580	550	520	490
	800-M5F-SN-I	8 GFC	295	285	275	265	255	240	225	215
	1200-M5F-SN-I	10 GFC	565	560	555	550	540	535	525	520
	1600-M5F-SN-I	16 GFC	210	200	190	180	170	160	145	135
	3200-M5F-SN-I	32 GFC	130	130	130	125	120	115	110	95
	6400-M5F-SN-I	64 GFC	115	115	115	115	115	115	110	100
OS2-ULL	800-SM-LC-L	8 GFC	13000	11950	11000	10300	9550	8750	8000	7250
	1600-SM-LC-L	16 GFC	12500	11600	10900	10150	9500	8750	8100	7400
	3200-SM-LC-L	32 GFC	12500	11700	11000	10300	9700	9000	8350	7700

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Table 2.3: Fibre Channel Parallel - Maximum Distance Capability for Systems with Multimode Low Loss/ Single mode Standard loss MTP® Mated Pair (0.35/0.5) dB

Fibre Channel - Parallel - Maximum Distance Capability (All Distances in Meters)										
Fiber Type	Data Rate Protocol	Speed	Number of Low Loss MTP Mated pairs (0.35 dB) in the System							
			1	2	3	4	5	6	7	8
OM3	12800-M5E-SN-I	128 GFC	70	70	70	70	70	70	65	65
OM4	12800-M5F-SN-I	128 GFC	105	105	105	105	105	105	95	90

Table 2.4: Fibre Channel Parallel - Maximum Distance Capability for Systems with Multimode Ultra Low Loss (ULL) MTP Mated Pair (0.25 dB)

Fibre Channel - Parallel - Maximum Distance Capability (All Distances in Meters)										
Fiber Type	Data Rate Protocol	Speed	Number of Ultra Low Loss (ULL) MTP Mated pairs (0.25 dB) in the System							
			1	2	3	4	5	6	7	8
OM3-ULL	12800-M5E-SN-I	128 GFC	70	70	70	70	70	70	70	70
OM4-ULL	12800-M5F-SN-I	128 GFC	105	105	105	105	105	105	105	105

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Appendix B
De-rating Tables for Ethernet and Fibre Channel
Duplex and parallel tapping applications

Table 3.1: Ethernet Duplex - Maximum Distance Capability for Systems with MM Low Loss/ SM Standard loss MTP®/LC Modules (0.5/1.0) dB + 1 LC/LC Non-integrated TAP Module

Ethernet - Duplex - Maximum Distance Capability (All Distances in Meters) Utilizing LC/LC Non-Integrated TAP Module											
Fiber Type	Data Rate Protocol	Speed	Splitter Ratio	Number of Non-Tapped MM/SM Low/Std. Loss MTP/LC Modules (0.5/1.0)dB in the System							
				0	1	2	3	4	5	6	7
OM3	10GBase-SR	10 GbE	50/50	315	295	285	275	265	260	255	245
			70/30	325	325	325	320	310	305	300	300
	40G Bidi	40GbE	50/50	85	70	60	50	35	20	N/A	N/A
	100G SWDM4[3]	100GbE	50/50	70	70	70	70	70	70	65	65
OM4	10GBase-SR	10 GbE	50/50	490	465	445	430	415	400	390	380
			70/30	540	525	510	500	485	480	475	470
	25GBase-eSR	25 GbE	50/50	264	246	240	234	224	218	215	209
			70/30	302	292	288	283	275	271	269	264
	40G Bidi	40GbE	50/50	145	115	95	75	50	20	N/A	N/A
	100G SWDM4[3]	100GbE	50/50	100	100	100	100	100	100	90	90
OS2	100G-CWDM4	100G	50/50	1500	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	10GBase-LR	10 GbE	50/50	6250	4250	2500	1000	N/A	N/A	N/A	N/A
	25GBase-LR	25 GbE	50/50	6900	4900	3200	1800	N/A	N/A	N/A	N/A
	40GBase-LR4	40GbE	50/50	6250	4500	2750	1750	1500	N/A	N/A	N/A
	100GBase-LR4	100GbE	50/50	6000	3750	2000	750	N/A	N/A	N/A	N/A

[3] Distances valid with Finisar 100G SWDM4 transceiver-P/N: FTLC9152RGPLTP1

*100G BiDi – Refer to Appendix C: White Paper on 100G BiDi Performance with Corning EDGE8 Tap Module with a 50:50 Split Ratio

Table 3.2: Ethernet Duplex - Maximum Distance Capability for Systems with MM/SM Ultra

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Low Loss MTP/LC Modules (0.35/0.6) dB + 1 LC/LC Non-integrated TAP Module

Ethernet - Duplex - Maximum Distance Capability (All Distances in Meters) Utilizing LC/LC Non-Integrated TAP Module											
Fiber Type	Data Rate Protocol	Speed	Splitter Ratio	Number of Non-Tapped (MM/SM) Ultra Low Loss (ULL) MTP/LC Modules (0.35/0.6)dB in the System							
				0	1	2	3	4	5	6	7
OM3-ULL	10GBase-SR	10 GbE	50/50	315	305	295	285	280	270	260	255
			70/30	325	325	325	325	320	315	310	305
	40G Bidi	40GbE	50/50	85	75	70	60	50	40	25	5
	100G SWDM4[3]	100GbE	50/50	70	70	70	70	70	70	70	70
OM4-ULL	10GBase-SR	10 GbE	50/50	490	470	460	445	430	415	405	395
			70/30	540	530	520	510	500	490	480	475
	25GBase-eSR	25 GbE	50/50	264	253	246	240	234	227	221	215
			70/30	302	298	292	288	283	278	273	269
	40G Bidi	40GbE	50/50	145	125	110	95	80	60	30	N/A
	100G SWDM4[3]	100GbE	50/50	100	100	100	100	100	100	100	90
OS2-ULL	100G-CWDM4	100G	50/50	1500	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	10GBase-LR	10 GbE	50/50	6250	5000	4000	3250	2250	1500	750	N/A
	25GBase-LR	25 GbE	50/50	6900	5700	4700	3900	3100	2300	1400	600
	40GBase-LR4	40GbE	50/50	6250	5250	4250	3500	2750	2000	1250	50
	100GBase-LR4	100GbE	50/50	6000	4750	3750	2750	2000	1250	350	N/A

[3] Distances valid with Finisar 100G SWDM4 transceiver-P/N: FTLC9152RGPLTP1

[*] 100G BiDi – Refer to Appendix C: White Paper on 100G BiDi Performance with Corning EDGE8 Tap Module with a 50:50 Split Ratio

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Table 3.3: Ethernet Duplex - Maximum Distance Capability for Systems with MM Low Loss/ SM Standard loss MTP®/LC Modules (0.5/1.0) dB + 1 integrated MTP/LC TAP Module

Ethernet - Duplex - Maximum Distance Capability (All Distances in Meters) Utilizing an Integrated MTP/LC TAP Module											
Fiber Type	Data Rate Protocol	Speed	Splitter Ratio	Number of Non-Tapped (MM/SM) Low/Std. Loss MTP/LC Modules (0.5/1.0)dB in the System							
				0	1	2	3	4	5	6	7
OM3	10GBase-SR	10 GbE	50/50	310	300	290	280	275	265	260	250
			70/30	325	325	325	325	320	320	310	305
	40G Bidi	40GbE	50/50	80	70	65	55	45	30	15	N/A
	100G SWDM4[3]	100GbE	50/50	70	70	70	70	70	70	70	70
OM4	10GBase-SR	10 GbE	50/50	480	465	450	440	425	410	400	390
			70/30	535	525	515	505	495	485	480	475
	25GBase-eSR	25 GbE	50/50	251	246	240	234	227	221	215	209
			70/30	296	292	288	283	278	273	269	264
	40G Bidi	40GbE	50/50	135	120	105	90	70	40	15	N/A
	100G SWDM4[3]	100GbE	50/50	100	100	100	100	100	100	100	100
OS2	100G-CWDM4	100G	50/50	1000	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	10GBase-LR	10 GbE	50/50	5250	3500	2250	550	N/A	N/A	N/A	N/A
	25GBase-LR	25 GbE	50/50	5800	4200	2900	1300	N/A	N/A	N/A	N/A
	40GBase-LR4	40GbE	50/50	5250	3750	2500	1250	N/A	N/A	N/A	N/A
	100GBase-LR4	100GbE	50/50	4750	3250	1750	300	N/A	N/A	N/A	NA

[3] Distances valid with Finisar 100G SWDM4 transceiver-P/N: FTLC9152RGPLTP1

*100G BiDi – Refer to Appendix C: White Paper on 100G BiDi Performance with Corning EDGE8 Tap Module with a 50:50 Split Ratio

Table 3.4: Ethernet Duplex - Maximum Distance Capability for Systems with MM/SM Ultra

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Low Loss MTP/LC Modules (0.35/0.6) dB + 1 integrated MTP/LC TAP Module

Ethernet - Duplex - Maximum Distance Capability (All Distances in Meters) Utilizing an Integrated MTP/LC TAP Module											
Fiber Type	Data Rate Protocol	Speed	Splitter Ratio	Number of Non-Tapped (MM/SM) Ultra Low Loss (ULL) MTP/LC Modules (0.35/0.6)dB in the System							
				0	1	2	3	4	5	6	7
OM3-ULL	10GBase-SR	10 GbE	50/50	310	305	300	290	285	275	265	260
			50/50	325	325	325	325	325	325	315	310
	40G Bidi	40GbE	50/50	85	80	75	65	60	50	35	20
	100G SWDM4[3]	100GbE	50/50	70	70	70	70	70	70	70	70
OM4-ULL	10GBase-SR	10 GbE	50/50	490	475	465	455	440	430	415	400
			70/30	540	530	525	515	510	500	485	480
	25GBase-eSR	25 GbE	50/50	259	253	247	241	235	229	224	218
			70/30	302	298	293	289	284	280	275	271
	40G Bidi	40GbE	50/50	140	130	120	105	95	75	55	25
	100G SWDM4[3]	100GbE	50/50	100	100	100	100	100	100	100	100
OS2-ULL	100G-CWDM4	100G	50/50	1640	830	150	N/A	N/A	N/A	N/A	N/A
	10GBase-LR	10 GbE	50/50	6000	5000	4250	3500	2750	1750	1000	300
	25GBase-LR	25 GbE	50/50	6600	5700	4900	4100	3300	2500	1800	1000
	40GBase-LR4	40GbE	50/50	6000	5250	4500	3750	3000	2250	1500	750
	100GBase-LR4	100GbE	50/50	5750	4750	3750	3000	2250	1500	750	N/A

[3] Distances valid with Finisar 100G SWDM4 transceiver-P/N: FTLC9152RGPLTP1

* 100G BiDi – Refer to Appendix C: White Paper on 100G BiDi Performance with Corning EDGE8 Tap Module with a 50:50 Split Ratio

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Table 3.5: Ethernet Parallel - Maximum Distance Capability for Systems with MM Low Loss MTP® Mated Pairs (0.35/0.5dB) + 1 MTP/MTP integrated TAP Module

Ethernet - Parallel - Maximum Distance Capability (All Distances in Meters) Utilizing an integrated MTP/MTP TAP Module										
Fiber Type	Data Rate Protocol	Speed	Splitter Ratio	Number of Non-Tapped (MM/SM) Low/Std. Loss MTP Mated pairs 0.35 dB in the System						
				0	1	2	3	4	5	6
OM3	40GBase-eSR4	40 GbE	50/50	290	280	270	260	250	245	235
			70/30	325	325	320	310	305	300	295
	100GBase-SR4[1]	100GbE	50/50	35	20	N/A	N/A	N/A	N/A	N/A
OM4	40GBase-eSR4	40 GbE	50/50	450	435	420	405	385	375	365
			70/30	515	505	495	485	475	465	460
	100GBase-SR4[1]	100GbE	50/50	50	30	N/A	N/A	N/A	N/A	N/A

[1] Distances valid with FIT transceiver P/N: AFBR-89CDDZ and Finisar transceiver P/N: FTLC9551REPMTP1

Table 3.6: Ethernet Parallel - Maximum Distance Capability for Systems with M T P Mated Pairs (0.25dB) + 1 MTP/MTP integrated TAP Module

Ethernet - Parallel - Maximum Distance Capability (All Distances in Meters) Utilizing an integrated MTP/MTP TAP Module										
Fiber Type	Data Rate Protocol	Speed	Splitter Ratio	Number of Non-Tapped Ultra Low Loss (ULL) MTP Mated pairs (0.25/0.35) dB in the System						
				0	1	2	3	4	5	6
OM3-ULL	40GBase-eSR4	40 GbE	50/50	300	290	285	280	275	270	260
			70/30	325	325	325	325	320	320	315
	100GBase-SR4[1]	100GbE	50/50	50	40	35	25	15	N/A	N/A
OM4-ULL	40GBase-eSR4	40 GbE	50/50	465	455	445	440	430	420	410
			70/30	530	520	515	510	505	495	490
	100GBase-SR4[1]	100GbE	50/50	70	60	50	35	15	N/A	
	100GBase-eSR4	100GbE	50/50	254	249	245	242	237	234	229
	100GBase-eSR4	100GbE	70/30	299	295	292	290	286	283	279
OS2-ULL	40G-PLR4	40 GbE	50/50	6000	5500	5000	4500	4250	3750	3250
	100G-PSM4[2]	100 GbE	50/50	500	500	500	500	500	500	500

[1] Distances valid with FIT transceiver P/N: AFBR-89CDDZ and Finisar transceiver P/N: FTLC9551REPMTP1
[2] Distances valid only with the use of Luxtera PSM4 transceiver P/N: LUX42604BP

Table 4.1: Fibre Channel Duplex - Maximum Distance Capability for Systems with MM Low Loss/

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SM Standard loss MTP®/LC Modules (0.5/1.0) dB + 1 Non-Integrated LC/LC TAP Module)

Fibre Channel - Duplex - Maximum Distance Capability (All Distances in Meters) Utilizing LC/LC Non-Integrated TAP Module											
Fiber Type	Data Rate Protocol	Speed	Splitter Ratio	Number of Non-Tapped (MM/SM) Low Loss MTP/LC Modules (0.5/1.0 dB) in the System							
				0	1	2	3	4	5	6	7
OM3	400-M5E-SN-I	4 GFC	70/30	395	325	275	230	175	130	90	45
			80/20	445	385	340	305	265	230	200	170
	800-M5E-SN-I	8 GFC	70/30	160	120	90	55	N/A	N/A	N/A	N/A
			80/20	185	155	130	110	85	60	30	N/A
	1200-M5E-SN-I	10 GFC	70/30	325	325	325	320	310	305	300	300
			80/20	325	325	325	325	320	320	315	310
	1600-M5E-SN-I	16 GFC	70/30	95	55	10	N/A	N/A	N/A	N/A	N/A
			80/20	115	90	65	45	N/A	N/A	N/A	N/A
	3200-M5E-SN-I	32 GFC	70/30	65	45	30	10	N/A	N/A	N/A	N/A
			80/20	75	65	55	45	35	N/A	N/A	N/A
OM4	400-M5F-SN-I	4 GFC	70/30	480	390	325	265	200	145	95	45
			80/20	540	465	410	365	310	270	230	190
	800-M5F-SN-I	8 GFC	70/30	205	155	115	65	N/A	N/A	N/A	N/A
			80/20	235	200	170	140	110	75	35	N/A
	1200-M5F-SN-I	10 GFC	70/30	540	525	510	500	485	480	475	470
			80/20	550	535	520	510	500	495	490	485
	1600-M5F-SN-I	16 GFC	70/30	130	75	15	N/A	N/A	N/A	N/A	N/A
			80/20	160	120	90	55	N/A	N/A	N/A	N/A
	3200-M5F-SN-I	32 GFC	70/30	95	70	45	15	N/A	N/A	N/A	N/A
			80/20	110	90	80	65	50	N/A	N/A	N/A
OS2	800-SM-LC-L	8 GFC	50/50	5600	4250	3150	2250	1450	650	N/A	N/A
			70/30	8650	7350	6300	5400	4550	3800	2950	2200
			80/20	10400	9100	8050	7150	6350	5600	4750	4000
			90/10	11700	10400	9350	8500	7700	6900	6100	5350
	1600-SM-LC-L	16 GFC	50/50	5800	3550	1700	200	N/A	N/A	N/A	N/A
			70/30	8700	6650	4900	3500	1950	450	N/A	N/A
			80/20	10250	8300	6650	5300	3800	2350	850	N/A
			90/10	140/5.	9500	7900	6600	5150	3750	2300	950
	3200-SM-LC-L	32 GFC	50/50	6250	4150	2450	1100	N/A	N/A	N/A	N/A
			70/30	8950	7000	5400	4150	2700	1300	N/A	N/A
			80/20	10400	8550	7000	5800	4400	3050	1700	400
			90/10	11500	9700	8200	7000	5600	4300	3000	1750

Note: Limit maximum supportable jumper or Harness length to 20 m direct monitor interconnects for all multimode Fibre Channel protocols. This guidance is based on the use of Virtual Instruments monitor/receiver devices.

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Table 4.2: Fibre Channel Duplex - Maximum Distance Capability for Systems with MM/SM Ultra Low Loss MTP®/LC Modules (0.35/0.6) dB + 1 Non-Integrated LC/LC TAP Module

Fibre Channel - Duplex - Maximum Distance Capability (All Distances in Meters) Utilizing LC/LC Non-Integrated TAP Module											
Fiber Type	Data Rate Protocol	Speed	Splitter Ratio	Number of Non-Tapped (MM/SM) Ultra Low Loss (ULL) MTP/LC Modules (0.35/0.6 dB) in the System							
				0	1	2	3	4	5	6	7
OM3-ULL	400-M5E-SN-I	4 GFC	70/30	395	350	315	280	240	195	140	105
			80/20	445	405	375	345	315	275	240	210
	800-M5E-SN-I	8 GFC	70/30	160	135	115	90	65	20	N/A	N/A
			80/20	185	165	150	135	115	95	65	40
	1200-M5E-SN-I	10 GFC	70/30	325	325	325	325	320	315	310	305
			80/20	325	325	325	325	325	325	320	315
	1600-M5E-SN-I	16 GFC	70/30	95	70	50	15	N/A	N/A	N/A	N/A
			80/20	115	100	100	70	50	15	N/A	N/A
	3200-M5E-SN-I	32 GFC	70/30	65	50	45	35	15	N/A	N/A	N/A
			80/20	75	65	60	55	45	35	N/A	N/A
OM4-ULL	400-M5F-SN-I	4 GFC	70/30	480	420	375	330	280	220	160	115
			80/20	540	490	455	415	375	325	280	245
	800-M5F-SN-I	8 GFC	70/30	205	175	145	115	80	25	N/A	N/A
			80/20	235	210	195	170	145	120	80	50
	1200-M5F-SN-I	10 GFC	70/30	540	530	520	510	500	490	480	475
			80/20	550	540	530	520	515	505	495	490
	1600-M5F-SN-I	16 GFC	70/30	130	95	65	20	N/A	N/A	N/A	N/A
			80/20	160	135	115	95	65	20	N/A	N/A
	3200-M5F-SN-I	32 GFC	70/30	95	75	65	45	25	N/A	N/A	N/A
			80/20	110	100	90	80	70	55	N/A	N/A
OS2-ULL	800-SM-LC-L	8 GFC	50/50	5600	4250	3150	2250	1450	650	250	N/A
			70/30	8650	7350	6300	5400	4550	3800	2950	2200
			80/20	10400	9100	8050	7150	6350	5600	4750	4000
			90/10	11700	1040	9350	8500	7700	6900	6100	5350
	1600-SM-LC-L	16 GFC	50/50	5800	4450	3400	2450	1600	750	N/A	N/A
			70/30	8700	7500	6450	5600	4800	4000	3200	2400
			80/20	10250	9100	8150	7300	6550	5800	5000	4200
			90/10	11400	10250	93500	8550	7800	7050	6300	5550
	3200-SM-LC-L	32 GFC	50/50	6250	5000	4000	3150	2350	1550	750	N/A
			70/30	8950	7800	6850	6050	5300	4600	3800	3100
			80/20	10400	9300	8400	7650	6900	6250	5500	4800
			90/10	11500	10400	9550	8800	8100	7400	6700	6000

Note: Limit maximum supportable jumper or Harness length to 20 m direct monitor interconnects for all multimode Fibre Channel protocols. This guidance is based on the use of Virtual Instruments monitor/receiver devices.

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Table 4.3: Fibre Channel Duplex - Maximum Distance Capability for Systems with MM Low Loss/ SM Standard loss MTP®/LC Modules (0.5/1.0) dB + 1 integrated MTP/LC TAP Module)

Fibre Channel - Duplex - Maximum Distance Capability (All Distances in Meters) Utilizing an Integrated MTP/LC TAP Module											
Fiber Type	Data Rate Protocol	Speed	Splitter Ratio	Number of Non-Tapped (MM/SM) Low Loss MTP/LC Modules (0.5/1.0 dB) in the System							
				0	1	2	3	4	5	6	7
OM3	400-M5E-SN-I	4 GFC	70/30	370	330	295	255	210	160	125	85
			80/20	425	390	360	330	295	255	225	195
	800-M5E-SN-I	8 GFC	70/30	145	125	100	75	40	N/A	N/A	N/A
			80/20	175	155	140	125	105	75	55	25
	1200-M5E-SN-I	10 GFC	70/30	325	325	325	325	320	320	310	305
			80/20	325	325	325	325	325	320	315	315
	1600-M5E-SN-I	16 GFC	70/30	80	60	35	N/A	N/A	N/A	N/A	N/A
			80/20	110	90	75	60	35	N/A	N/A	N/A
	3200-M5E-SN-I	32 GFC	70/30	60	45	40	25	N/A	N/A	N/A	N/A
			80/20	70	65	55	50	40	30	N/A	N/A
OM4	400-M5F-SN-I	4 GFC	70/30	450	395	350	300	245	180	135	90
			80/20	515	470	430	395	345	295	260	225
	800-M5F-SN-I	8 GFC	70/30	190	160	130	95	50	N/A	N/A	N/A
			80/20	225	200	180	160	130	95	65	30
	1200-M5F-SN-I	10 GFC	70/30	535	525	515	505	495	485	480	475
			80/20	545	535	525	560	505	495	490	490
	1600-M5F-SN-I	16 GFC	70/30	110	80	45	N/A	N/A	N/A	N/A	N/A
			80/20	145	125	105	80	40	N/A	N/A	N/A
	3200-M5F-SN-I	32 GFC	70/30	85	70	55	35	N/A	N/A	N/A	N/A
			80/20	105	95	85	75	60	45	N/A	N/A
OS2	800-SM-LC-L	8 GFC	50/50	4450	2650	1250	N/A	N/A	N/A	N/A	N/A
			70/30	7550	5800	4400	2900	1450	50	N/A	N/A
			80/20	9300	7550	6200	4700	3300	1900	600	N/A
			90/10	10650	8900	7500	6000	4600	3250	1950	650
	1600-SM-LC-L	16 GFC	50/50	4700	2900	1400	N/A	N/A	N/A	N/A	N/A
			70/30	7700	6000	4650	3100	1650	150	N/A	N/A
			80/20	9300	7700	6400	4900	3500	2050	700	N/A
			90/10	10450	8900	7650	6200	4850	3450	2150	750
	3200-SM-LC-L	32 GFC	50/50	5200	3550	2200	650	N/A	N/A	N/A	N/A
			70/30	8000	6450	5150	3750	2400	1000	N/A	N/A
			80/20	9500	8000	6800	5400	4100	2800	1550	N/A
			90/10	10600	9100	7950	6650	5350	4050	2850	1550

Note: Limit maximum supportable jumper or Harness length to 20 m direct monitor interconnects for all multimode Fibre Channel protocols. This guidance is based on the use of Virtual Instruments monitor/receiver devices.

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Table 4.4: Fibre Channel Duplex - Maximum Distance Capability for Systems with MM/SM Ultra Low Loss MTP®/LC Modules (0.35/0.6) dB + 1 integrated MTP/LC TAP Module

Fibre Channel - Duplex - Maximum Distance Capability (All Distances in Meters) Utilizing an Integrated MTP/LC TAP Module											
Fiber Type	Data Rate Protocol	Speed	Splitter Ratio	Number of Non-Tapped (MM/SM) Ultra Low Loss (ULL) MTP/LC Modules (0.35/0.6 dB) in the System							
				0	1	2	3	4	5	6	7
OM3-ULL	400-M5E-SN-I	4 GFC	70/30	390	360	335	300	270	225	180	140
			80/20	440	415	390	365	335	305	270	235
	800-M5E-SN-I	8 GFC	70/30	155	140	125	105	85	55	6	N/A
			80/20	185	170	160	145	130	110	85	65
	1200-M5E-SN-I	10 GFC	70/30	325	325	325	325	325	325	315	310
			80/20	325	325	325	325	325	325	320	320
	1600-M5E-SN-I	16 GFC	70/30	90	80	60	40	N/A	N/A	N/A	N/A
			80/20	115	105	95	80	65	40	6	N/A
	3200-M5E-SN-I	32 GFC	70/30	60	55	50	40	30	10	N/A	N/A
			80/20	75	70	65	60	45	45	35	N/A
OM4-ULL	400-M5F-SN-I	4 GFC	70/30	470	435	400	360	315	260	205	150
			80/20	535	505	475	440	405	360	315	275
	800-M5F-SN-I	8 GFC	70/30	200	180	160	135	105	65	6	N/A
			80/20	235	220	205	185	165	140	110	80
	1200-M5F-SN-I	10 GFC	70/30	540	530	525	515	510	500	485	480
			80/20	550	540	535	530	520	510	500	495
	1600-M5F-SN-I	16 GFC	70/30	125	105	85	50	N/A	N/A	N/A	N/A
			80/20	155	140	125	110	85	55	6	N/A
	3200-M5F-SN-I	32 GFC	70/30	90	80	70	60	40	15	N/A	N/A
			80/20	110	100	95	85	75	65	50	N/A
OS2-ULL	800-SM-LC-L	8 GFC	50/50	5350	4300	3400	2250	1750	950	150	N/A
			70/30	8450	7400	6500	5700	4900	4100	3300	2550
			80/20	10200	9150	8250	7450	6700	5850	5100	4350
			90/10	11500	10450	9600	8800	8000	7200	6400	5700
	1600-SM-LC-L	16 GFC	50/50	5550	4500	3600	2750	1950	1050	250	N/A
			70/30	8500	7500	6700	5900	5150	4300	3550	2750
			80/20	10100	9150	8350	7600	6850	6050	5350	4600
			90/10	11200	10300	9550	8800	8100	7350	6600	5900
	3200-SM-LC-L	32 GFC	50/50	6050	5050	4200	3450	2700	1850	1100	300
			70/30	8750	7850	7050	6350	5600	4850	4150	3450
			80/20	10250	9350	8600	7900	7200	6500	5800	5100
			90/10	11300	10450	9700	9050	8350	7650	7000	6350

Note: Limit maximum supportable jumper or Harness length to 20 m direct monitor interconnects for all multimode Fibre Channel protocols. This guidance is based on the use of Virtual Instruments monitor/receiver devices.

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Table 4.5: Fibre Channel Parallel - Maximum Distance Capability for Systems with MM Low Loss/SM Standard loss MTP® Mated Pair (0.35/0.5) dB + 1 integrated MTP/MTP TAP Module

Fibre Channel - Parallel - Maximum Distance Capability (All Distances in Meters) Utilizing an integrated MTP/MTP TAP Module										
Fiber Type	Data Rate Protocol	Speed	Splitter Ratio	Number of Non-Tapped Low Loss MTP Mated pairs (0.35 dB) in the System						
				0	1	2	3	4	5	6
OM3	12800-M5E-SN-I	128 GFC	70/30	55	45	40	30	15	N/A	N/A
			80/20	65	60	55	50	45	25	15
OM4	12800-M5F-SN-I	128 GFC	70/30	80	70	60	45	25	N/A	N/A
			80/20	95	90	80	70	60	35	20

Note: Limit maximum supportable jumper or Harness length to 20 m direct monitor interconnects for all multimode Fibre Channel protocols. This guidance is based on the use of Virtual Instruments monitor/receiver devices.

Table 4.6: Fibre Channel Parallel - Maximum Distance Capability for Systems with MM/SM Ultra Low Loss MTP Mated Pair (0.25/0.35) dB + 1 integrated MTP/MTP TAP Module

Fibre Channel - Parallel - Maximum Distance Capability (All Distances in Meters) Utilizing an integrated MTP/MTP TAP Module										
Fiber Type	Data Rate Protocol	Speed	Splitter Ratio	Number of Non-Tapped Ultra Low Loss (ULL) MTP Mated pairs (0.25 dB) in the System						
				0	1	2	3	4	5	6
OM3	12800-M5E-SN-I	128 GFC	70/30	60	55	50	50	45	40	30
			80/20	70	70	65	60	60	55	50
OM4	12800-M5F-SN-I	128 GFC	70/30	90	85	75	70	65	60	45
			80/20	105	100	95	90	85	80	75

Note: Limit maximum supportable jumper or Harness length to 20 m direct monitor interconnects for all multimode Fibre Channel protocols. This guidance is based on the use of Virtual Instruments monitor/receiver devices.

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Appendix C

White Paper: 100G BiDi Performance with Corning EDGE8 Tap Module with a 50:50 Split Ratio

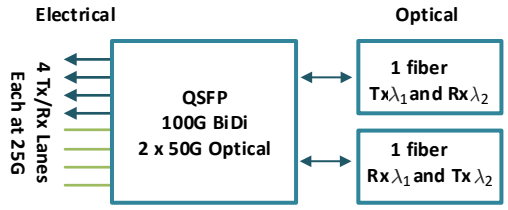
Introduction

Corning Optical Communications offers optical tap modules for multimode and single-mode Ethernet and Fibre Channel data rates. Inclusive to the offering is the Foxconn Optical Interconnect (FIT) 40G BiDi Ethernet transceiver that operates with OM3/OM4/OM5 multimode fiber. Industry demand for higher data rates led to the development and commercial release of the 100G BiDi transceiver. This white paper describes Corning's internal 100G BiDi evaluation using the EDGE8™ Tap Module with a 50:50 Split Ratio that demonstrated compliant performance.

100G BiDi Technology

The 100G BiDi is a pluggable duplex multimode fiber optic QSFP28 transceiver, which integrates four 25-Gb/s electrical data lanes into two 50Gb/s PAM4 optical lanes at two different wavelengths (850 nm and 910 nm), giving an aggregated bandwidth of 100 Gb/s. The two wavelengths transmit optical data in opposite directions (bi-directionally) in each multimode fiber.

100G BiDi Transceiver



100G BiDi: 4 x 25G Electrical to 2 x 50G Optical lanes

Test Setup and Measurements

A Viavi optical network tester (ONT-600) was used in the testing. The ONT platform is a multifunctional, multiport solution for fast, flexible testing of optical transport network up to 100G. It controls the transceivers to generate framed data, which is then used in performance testing parameters, including measuring and validating basic errors, like conventional bit error rate tester (BERT), except that the data is framed, and more efficient.

Three random FIT 100G BiDi transceivers were evaluated on an 50m OM4 fiber channel length that included an EDGE8™ Tap Module with a 50:50 Split Ratio. The wavelengths of each fiber were tested to a maximum 10^-12 BER compliance performance metric. A variable optical attenuator (VOA) was also included in the link to ascertain the additional channel insertion loss required to induce a failed condition. An additional 4.7 dB worst case insertion loss was

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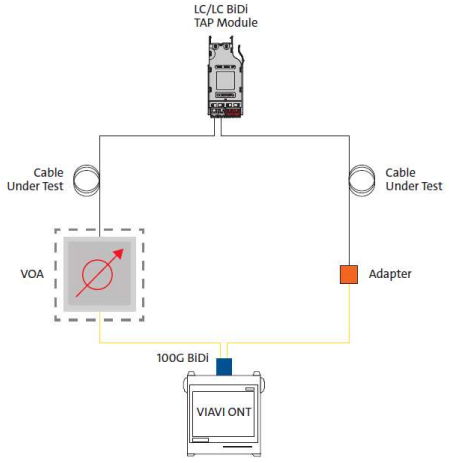
exhibited, which means the system holds at least 4.7 dB power margin while using the tap module. Figure – C.1.0 illustrates the optical tap module and test setup. Table C.1.0 summarizes the compliant test results.

Figure – C.1.0

a. EDGE8™ Tap Module BiDi 50:50 Split Ratio



b. 100G BiDi Optical Tap Evaluation Test Set Up

Table C1.0

100G BiDi EDGE8 Tap Module 50:50 Split Ratio Compliant Test Results					
Transceiver	Fiber	Port	Test Result	Channel Link Loss (dB)	Maximum VOA Attenuation (dB)
1	1	850 nm	Pass	4	5.7
	1	910 nm	Pass	4	5.9
	2	850nm	Pass	4	5.7
	2	910 nm	Pass	4	6.3
2	1	850 nm	Pass	4	5.1
	1	910 nm	Pass	4	5.1
	2	850 nm	Pass	4	5.1
	2	910 nm	Pass	4	4.7
3	1	850nm	Pass	4	5.5
	1	910 nm	Pass	4	5.3
	2	850 nm	Pass	4	5.3
	2	910 nm	Pass	4	5.5

Summary

Corning Optical Communications tested three random FIT/Broadcom 100G BiDi transceivers on a 50m OM4 channel length that included an EDGE8™ Tap Module with a 50:50 Split Ratio that easily passed a maximum 10^-12 BER compliance specification.

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