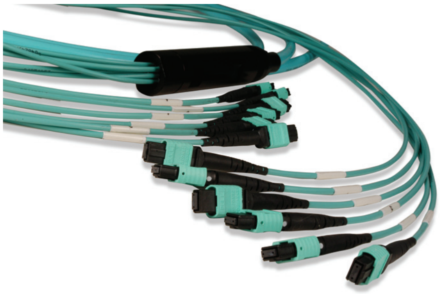
A Closer Look at Plug and Play MPO/MTP Assemblies

The Internet of Things (IoT) and Big Data are driving the need for more bandwidth and increased transmission speeds from 10 to 40 and 100 gigabit per second (Gb/s) within data center switch-to-switch backbone links to handle larger sets of complex data from multiple sources. New optical fiber technologies and standards have thankfully made it easier, more cost-effective and less complex to deploy high speed fiber backbone links.

Both 40 Gb/s (40GBASE-SR4) and 100 Gb/s (100GBASE-SR4) transmission are based on 8 multimode optical fibers – 4 transmitting and 4 receiving at 10 Gb/s or 25 Gb/s each. These applications use plug and play MPO/MTP Trunk Assemblies that enable faster deployment and ease of migration from 10 to 40 and 100 Gb/s. Even in 10 Gb/s applications, plug and play MPO/MTP-to-LC Hybrid Assemblies are used due to their easy plug and play deployment and ability to connect to MPO/MTP backbone cabling. These hybrid assemblies are also often used in 40 Gb/s link aggregation applications that aggregate four duplex LCs running 10 Gb/s.

With today's 40 and 100 Gb/s data center applications using the MPO/MTP interface, overall fiber cabling performance has become a critical factor, especially in the face of the more stringent channel insertion loss requirements of these next generation transmission speeds. Unfortunately, not all MPO/MTP assemblies are created equal, and selecting lower-cost versions from unproven sources can compromise performance and put any size and type of data center at risk of costly downtime. This article discusses and evaluates MPO/MTP Trunk Assemblies and MPO/MTP-to-LC Hybrid Assemblies to determine their viability in today's high speed fiber optic links.

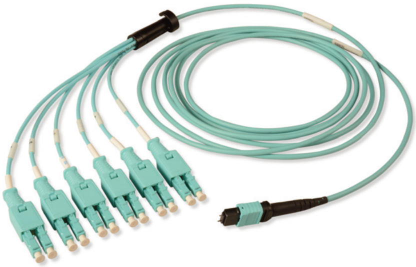
In a previous white paper, *A Closer Look at Fiber Optic Cable Assemblies*, Siemon evaluated the performance of LC laser optimized multimode OM3 fiber jumpers from various suppliers and the impact on network installation.



MPO/MTP Cable Assemblies

This white paper expands the focus to look at the performance of MPO/MTP laser optimized multimode OM3 trunk assemblies and MPO/MTP-to-LC laser optimized multimode OM3 hybrid assemblies. This study includes MPO/MTP Trunk Assemblies and MPO/MTP-to-LC Hybrid Assemblies from Siemon and four different generic assembly houses. Five samples of each assembly were purchased from each manufacturer through standard distribution channels. Siemon Labs tested each assembly to Siemon's specifications, as well as to TIA and IEC standards for end face geometry, cleanliness, optical performance and mechanical reliability. Siemon's specifications are more stringent to ensure superior performance and application assurance for today's high speed fiber applications.

The MPO/MTP Trunk Assemblies evaluated in this study were 24-fiber plenum-rated assemblies with 0.5 meter breakouts to two 12-fiber MPO/MTP connectors. The MPO/MTP-to-LC Hybrid Assemblies evaluated in this study were 12-fiber MPO/MTP hybrid assemblies with 0.5 meter breakouts to six duplex LCs. The evaluation tests included end face geometry, visual inspection, end face cleanliness, optical transmission performance and mechanical reliability.



MPO/MTP to LC Hybrid Assemblies

End Face Geometry

End face geometry is an essential characteristic of repeatable and reliable optical fiber connections. Overall performance of fiber optic connectivity depends on the mechanical characteristics that control alignment and physical contact of the fiber cores. End face geometry parameters for MPO/MTP connectivity include:

- Angle of the polish - Horizontal or X axis (RX and GX)
- Angle of the polish - Vertical or Y axis (RY and GY)
- Fiber Protrusion Height (H)
- Maximum Fiber Height Differential Among all Fibers (HA)
- Maximum Adjacent Fiber Height Differential (HB)

Figure 1 below shows the end face geometry parameters for MPO/MTP connectors as defined by IEC PAS 61755-3-31. All samples were subjected to an optical inspection to determine end face quality (contamination, scratches and defects) and then subjected to end face geometry analysis to confirm standards compliance. Samples were also subjected to end face geometry analysis per Siemon's more stringent specification.

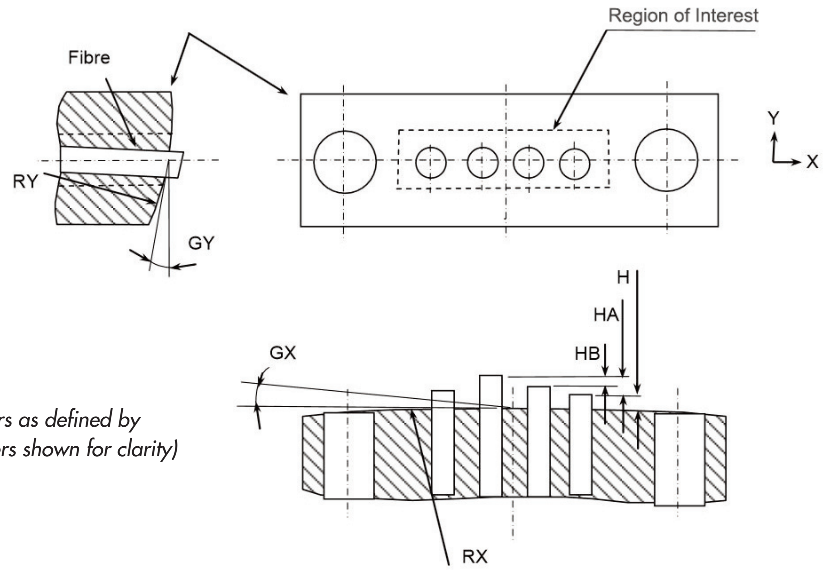


Figure 1: *End face geometry parameters as defined by IEC PAS 61755-3-31 (Note: Four fibers shown for clarity)*

Table 1 shows the results of the end face quality testing and geometric parameter compliance for the MPO/MTP Trunk Assemblies. Only two of the manufacturers had product that was compliant with the IEC standard for end face geometry—Manufacturer A2 and Siemon. The other three manufacturers had four or more failures, most of which can be attributed to a lack of fiber height control during the polishing process at the manufacturing stage.

Manufacturer	IEC PAS 61755-3-31					
	RX ≥2000mm	RY ≥5mm	GX/GY ≥0.2°	H 100nm to 3500nm	HA ≤500nm	HB ≤300nm
Siemon	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**
A1 (MPO)	Pass	Pass	Fail	Fail	Fail	Fail
A2 (MTP)	Pass	Pass	Pass	Pass	Pass	Pass
A3 (MTP)	Pass	Pass	Fail	Fail	Fail	Fail
A4 (MTP)	Pass	Pass	Fail*	Fail	Fail	Fail

Table 1: *End Face Geometry Test Results for MPO/MTP Trunk Assemblies*

** Siemon's more stringent specification*

Tables 2a and 2b show the results of end face quality testing and geometric parameter compliance for the MPO/MTP-to-LC Hybrid assemblies. Each of the sample hybrid assemblies was tested for end face geometry for both the MPO/MTP (Table 2a) and LC connector (Table 2b) ends. It is important to note that end face geometry testing for LC connectors differs from that of MPO/MTP connectors and includes the following parameters as described below and shown in Figure 2:

- Radius of Curvature (RoC): Measures the end-face spherical condition to ensure proper fiber to connector compression. The ROC range that allows for maximum connector performance is 7 to 25mm.
- Apex Offset: Measures the distance between the center of the fiber and the actual highest point of a polished connector. An excessive Apex Offset contributes to high insertion loss and reflection.
- Fiber Height: Measures the distance the fiber is extended out of or recessed into the ferrule, which must be in the -100nm to 50nm range.

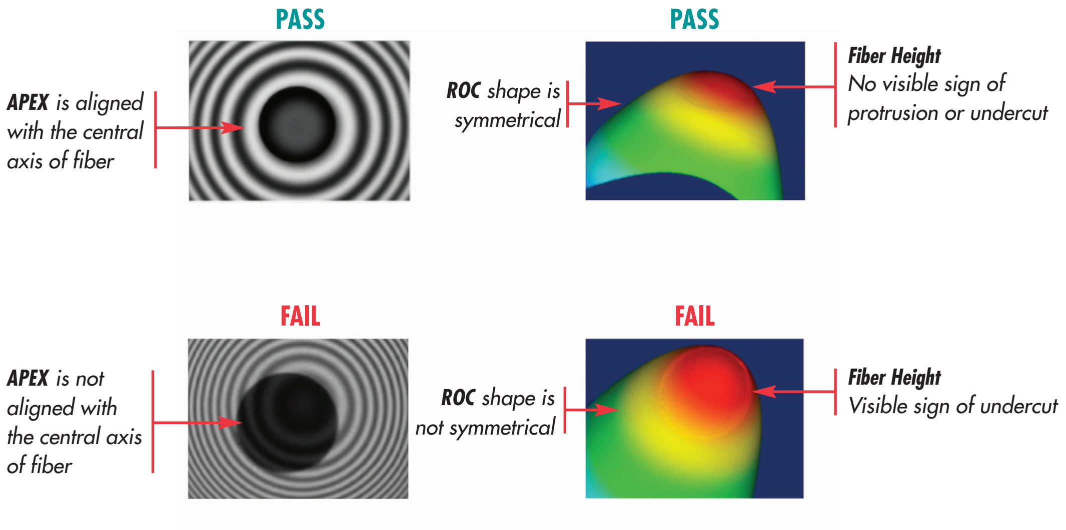


Figure 2: *LC End face geometry parameters as defined by IEC PAS 61755-3-1*

For the hybrid assemblies, Manufacturer A4 in particular had difficulty maintaining control of fiber height and differential fiber height for the MPO/MTP connector. Overall, end face geometry for the LC connectors on the assemblies was standards compliant with the exception of Manufacturer A1 and A4 for Apex Offset.

Table 2a: *End Face Geometry Test Results for MPO/MTP side of the MPO/MTP-to-LC Hybrid Assemblies*

Manufacturer	IEC PAS 61755-3-31					
	RX ≥2000mm	RY ≥5mm	GX/GY ≥0.2°	H 100nm to 3500nm	HA ≤500nm	HB ≤300nm
Siemon	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**
A1 (MPO)	Pass	Pass	Fail*	Fail	Pass	Pass
A2 (MTP)	Pass	Pass	Fail	Pass	Pass	Pass
A3 (MTP)	Pass	Pass	Fail	Fail	Pass	Pass
A4 (MTP)	Pass	Pass	Pass	Fail	Fail	Fail

** Siemon's more stringent specification*

Table 2b: *End Face Geometry Test Results for LC side of the MPO/MTP-to-LC Hybrid Assemblies*

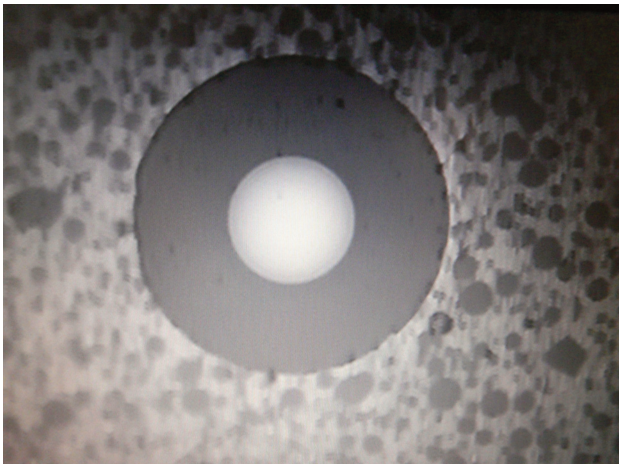
Manufacturer	IEC PAS 61755-3-1		
	ROC 5-30mm	Apex Offset ≥70μm	Fiber Height -100 – 500nm
Siemon	**Pass**	**Pass**	**Pass**
A1 (MPO)	Pass	Fail	Pass
A2 (MTP)	Pass	Fail*	Pass
A3 (MTP)	Pass	Fail*	Pass
A4 (MTP)	Pass	Fail	Pass

** Siemon's more stringent specification*

Visual Inspection & End Face Cleanliness

Surface defects and overall fiber end face cleanliness is critical to optical performance, but will not always be detected via end face geometry testing. A smooth but fractured fiber will not necessarily fail end face geometry inspection for angle of the polish and fiber height. The photographs in Figure 3 show the typical end face quality received for the various MPO/MTP Trunk Assemblies and the end face quality received for the sample from Manufacturer A3. While contamination was able to be removed from other samples during the fiber cleaning process, scratches and defects were unable to be removed from the A3 sample, which ultimately caused it to fail the parameter for end face worst case scratch/defect as shown in Table 3. A3 would have failed end face geometry testing regardless since it failed other parameters per IEC.

Typical End Face Quality After Cleaning



Manufacturer A3 End Face Quality After Cleaning

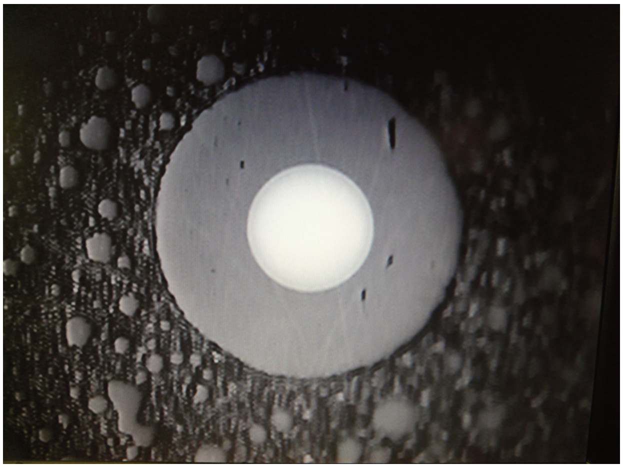


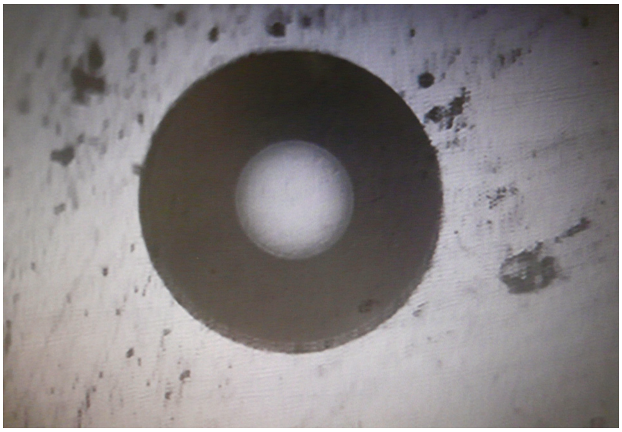
Figure 3: *End face Contamination and Surface Defects for MPO/MTP Trunk Assemblies (Note: One fiber end face shown for clarity)*

Manufacturer	IEC PAS 61755-3-31 EF worst case scratch/defect
Siemon	**Pass**
A1 (MPO)	Pass
A2 (MTP)	Pass
A3 (MTP)	Fail
A4 (MTP)	Pass

Table 3: *End Face Cleanliness for MPO/MTP Trunk Assemblies*

For the MPO/MTP-to-LC Hybrid Assemblies, the visual inspection of the fiber end faces showed typical contamination as shown in Figure 4. However, after proper fiber cleaning, the assemblies had an acceptable end face finish. All hybrid assemblies, including those from Siemon and from the assembly houses, ultimately passed end face contamination testing.

Typical End Face Quality



Typical End Face Quality After Cleaning

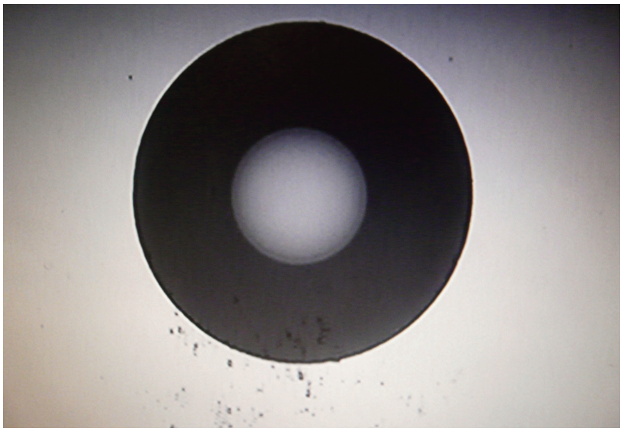


Figure 4: *End face Contamination and Surface Defects for MTP/MTP-to-LC Hybrid Assemblies*

In regards to connector end face cleanliness, there is a move within standards bodies to state that all fiber connectors “should” be inspected prior to testing and installation rather than the previously stated “shall” be inspected. Consequently, it is more vital than ever to provide customers with clean fiber terminations. During the factory termination process, it is Siemon’s policy to inspect all connector end faces for cleanliness following end face geometry and performance testing.

Optical Performance

Insertion loss is commonly used as the basis for acceptance testing of installed links and channels. Although return loss testing of installed cabling is not required by industry standards, it is a normative requirement for fiber connectors and assemblies. Return loss is critical to optical performance of links and channels because reflected optical signals can interfere with detecting the optical signal by degrading the signal to noise ratio. For these reasons, it is absolutely essential to ensure that optical fiber cables, components and assemblies are fully standards compliant for return loss and insertion loss with testing completed in both directions and at both the 850nm and 1300nm wavelengths designated for multimode fiber operation. Every Siemon plug and play MPO/MTP Trunk Assembly is 100% tested for insertion loss and return loss, in both directions for both wavelengths. Each assembly is serialized and traceable to factory test results for insertion loss and return loss.

All of the samples were tested for insertion loss and return loss against international standards IEC-61755-3-31, TIA 568.3-C and Siemon’s specification. Table 4 shows the results for the MPO/MTP Trunk Assemblies. The data shows that only two of the five manufacturers—A2 and Siemon—met the IEC and TIA specifications for return loss, with four out of five meeting the IEC and TIA insertion loss specifications. However, most industry professionals believe the IEC and TIA insertion loss specification of 0.75dB to be an outdated value as most MPO/MTP and LC connectors are in the range of 0.2dB to 0.5dB. Furthermore, an insertion loss of 0.75dB would eliminate the use of cross connects in 40/100 Gb/s applications where the maximum channel loss is only 1.9dB for OM3. In response, there is a movement within standards organizations to reduce the insertion loss specification from 0.75 to 0.5dB or lower.

Although only company A3 failed the 0.75dB insertion loss specification, both samples from A1 and A4 exhibited insertion loss values greater than 0.50dB, which is expected to be the maximum insertion loss specification in upcoming TIA standards. Only two of the five manufacturers of the assemblies—A2 and Siemon—met the tighter Siemon specification of 0.40dB for insertion loss. Another important factor emerging from the data is that the three other manufacturers who all failed the return loss specification for MPO/MTP Trunk Assembles also failed to meet the fiber height parameters in the MPO/MTP end face geometry testing. This emphasizes the need to have a stable, controlled manufacturing process for MPO/MTP connector polishing.

Table 4: *Insertion Loss and Return Loss Test Results for MPO/MTP Assemblies*

Manufacturer	IEC-61755-3-31 and TIA 568.3.-C.3		Siemon Spec	
	IL (0.75dB)	RL (20dB)	IL (0.40dB)	RL (20dB)
Siemon	**Pass**	**Pass**	**Pass**	**Pass**
A1	Pass	Fail	Fail	Fail
A2	Pass	Pass	Pass	Pass
A3	Fail	Fail	Fail	Fail
A4	Pass	Fail	Fail	Fail

As shown in Table 5a, for the MPO/MTP-to-LC Hybrid assemblies, Manufacturer A4 failed return loss testing for the MTP/MPO side of the assembly. This can be directly correlated to Manufacturer A4's difficulty maintaining control of fiber height and differential fiber height for the MPO/MTP connector as shown previously in Table 2a. For return loss testing, Manufacturer A1 failed testing for the LC side of the assembly as shown in Table 5b, which can be correlated to its failed Apex Offset testing shown previously in Table 2b.

Table 5a: *Insertion Loss and Return Loss Test Results for MPO/MTP Side of the MPO/MTP-to-LC Hybrid Assemblies*

Manufacturer	IEC-61755-3-31 and TIA 568.3.-C.3		Siemon Spec	
	IL (0.75dB)	RL (20dB)	IL (0.40dB)	RL (20dB)
Siemon	**Pass**	**Pass**	**Pass**	**Pass**
A1	Pass	Pass	Pass	Pass
A2	Pass	Pass	Pass	Pass
A3	Pass	Fail	Fail	Fail
A4	Pass	Fail	Fail	Fail

Table 5b: *Insertion Loss and Return Loss Test Results for LC Side of the MPO/MTP-to-LC Hybrid Assemblies*

Manufacturer	IEC-61755-3-31 and TIA 568.3.-C.3		Siemon Spec	
	IL (0.75dB)	RL (20dB)	IL (0.25dB)	RL (30dB)
Siemon	**Pass**	**Pass**	**Pass**	**Pass**
A1	Pass	Fail	Pass	Fail
A2	Pass	Pass	Fail	Fail
A3	Pass	Pass	Pass	Pass
A4	Pass	Pass	Fail	Pass

Mechanical Reliability

There are several tests required as part of industry standard specifications for mechanical reliability. Mechanical reliability parameters include Flex Testing, Torsion Testing, Pull Testing, Cable Retention, Impact Testing, Vibration Testing, Durability and Transmission with an Applied Load. These mechanical tests verify that a fiber assembly can endure the various conditions that may arise in a real-world installation, and that they can dependably withstand the internal stresses imposed by spring loaded physical contact over time in a variety of environmental conditions.

The MPO/MTP Assemblies and MPO/MTP-to-LC Hybrid Assemblies were all subjected to Cable Pull, Flex, Torsion and Retention as governed by International Standard TIA-568-C.3 and the following Fiber Optic Test Procedures (FOTPs):

- FOTP-6: Cable Pull, 50 Newtons @ 0 degrees for 5 seconds
- FOTP-1: Cable Flex, 4.9 Newtons, 100 cycles
- FOTP-36: Cable Torsion, 15 Newtons, 10 cycles
- FOTP-6: Cable Retention, 19.4 Newtons @ 90 degrees for 5 seconds

As shown in Table 6, all of the MPO/MTP Trunk Assembly samples from Manufacturer A1 failed the Cable Flex test and could therefore not be tested for Cable Torsion or Cable Retention. Two of the five samples from Manufacturer A4 failed the flex test, but the remaining three samples were compliant to Cable Torsion and Cable Retention testing.

Table 6: *Mechanical Reliability Test Results for MPO/MTP Trunk Assemblies*

Manufacturer	Cable Pull FOTP-6	Cable Flex FOTP-1	Cable Torsion FOTP-36	Cable Retention FOTP-6
Siemon	**Pass**	**Pass**	**Pass**	**Pass**
A1	Pass	Fail	N/A*	N/A*
A2	Pass	Pass	Pass	Pass
A3	Pass	Pass	Pass	Pass
A4	Pass	Fail	Pass**	Pass**

**All samples failed in the previous test*
*** Remaining three out of five samples in the group were compliant to the test*

The photos in Figure 5 show the failure for the MPO/MTP Trunk Assembly samples that failed the Cable Flex test. In this instance, the cable jacket pulled out of the rear of the crimp sleeve.

The MPO/MTP-to-LC Hybrid Assemblies were subjected to the same mechanical stress tests as the MPO/MTP Trunk Assemblies with the results shown in Table 7. All samples except for those from Siemon exhibited fiber failures occurring in either the Cable Pull and/or Cable Flex testing.

Manufacturer A1 After Cable Flex Test — **Manufacturer A4 After Cable Flex Test**

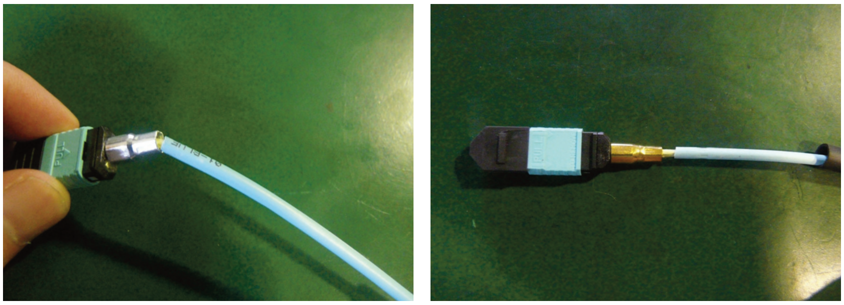


Figure 5: *Failed Cable Flex Test for Manufacturer A1 and A4 MPO/MTP Trunk Assemblies*

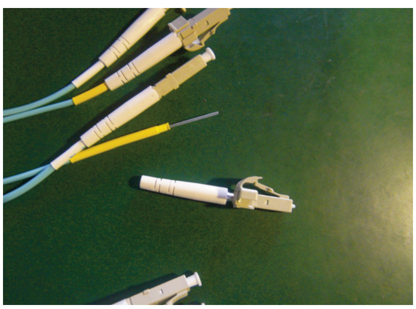
***Table 7:** Mechanical Reliability Test Results for MPO/MTP-to-LC Hybrid Assemblies*

Manufacturer	Cable Pull FOTP-6 MTP	Cable Pull FOTP-6 LC	Cable Flex FOTP-1 MTP	Cable Flex FOTP-1 LC	Cable Torsion FOTP-36 MTP	Cable Torsion FOTP-36 LC	Cable Retention FOTP-6 MTP	Cable Retention FOTP-6 LC
Siemon	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**
A1	Pass**	Fail	Fail	N/A*	N/A*	N/A*	N/A*	N/A*
A2	Pass	Fail	N/A*	N/A*	N/A*	N/A*	N/A*	N/A*
A3	Pass**	Fail	Fail	Pass**	Pass**	Fail	Pass**	Pass**
A4	Fail	Fail	N/A*	N/A*	N/A*	N/A*	N/A*	N/A*

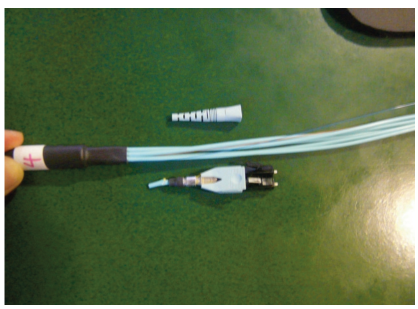
**All samples failed in the previous test*
*** Remaining samples in the group were compliant to the test*

The mechanical tests provide an indication as to whether the MPO/MTP-to-LC Hybrid Assemblies can withstand installation and maintenance without subject to failure or degradation in optical performance. It is evident that the construction of the breakout/furcation system of hybrid assemblies has a major impact on mechanical reliability.

Manufacturer A2 LC Side After Cable Pull Test— Fiber Broke in Connector



Manufacturer A3 MPO/MTP Side After Cable Pull Test—Fiber Broke in Connector



Manufacturer A4 After Cable Pull Test— Furcation Tube Separated from Breakout

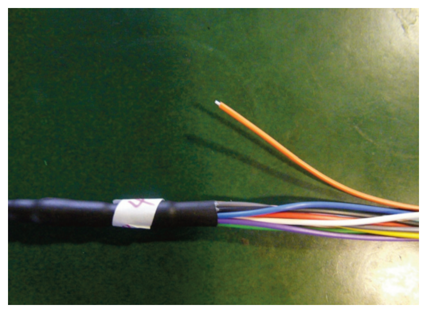


***Figure 6:** Failed Cable Pull and Cable Flex Tests for MPO/MTP-to-LC Hybrid Assemblies*

In Conclusion

This study highlights the importance of using high quality materials and instituting well-defined process controls throughout the manufacture of fiber optic MPO/MTP Trunk Assemblies and MPO/MTP-to-LC Hybrid Assemblies. While it is important for assemblies to pass optical transmission testing (Insertion Loss and Return Loss), it is also evident that end face geometry control during the polishing process is paramount in achieving acceptable optical performance in random mating situations. This study demonstrates the following:

- Strict control of the fiber connector polishing process during MPO/MTP termination has a direct correlation to end face geometry and the Return Loss performance.
- Current TIA insertion loss specification of 0.75dB is not adequate for low loss OM3 or higher installations and prevents use of cross connects in 40/100 Gb/s applications where the maximum channel loss is only 1.9dB. While all manufacturers met the TIA 0.75dB insertion loss spec, only Siemon and two other manufacturers met the more stringent insertion loss requirements.
- Design of fiber breakout and furcation sub units can have a significant impact on the ability of hybrid assemblies to with-stand real-life installation conditions.

Siemon places a high emphasis on all facets of fiber optic assembly performance, including using the highest quality materials and instituting rigorous process control over end face geometry, cleanliness and mechanical reliability to ensure superior optical performance.

As shown in Table 8 that summarizes the results of this study, generic MPO/MTP Trunk Assemblies and MPO/MTP-to-LC Hybrid Assemblies from cable assembly houses are more likely to fail critical performance parameters that can result in product failures and costly network down time. Siemon was the only manufacturer with both MPO/MTP Trunk Assemblies and MPO/MTP-to-LC Hybrid Assemblies to comply with ALL parameters for ALL tests because Siemon uses the highest quality components, consumables, test equipment and processes. With studies indicating the average cost per downtime incident at US $140K with the financial sector stating an average loss of US $540K, one should ask, are the savings from using substandard MPO/MTP Assemblies worth the risk?

Table 8: *Summary of Overall Results for End Face Geometry, Optical Performance and Mechanical Reliability**

Manufacturer	A1	A2	A3	A4	Siemon
MTP Trunks					
End Face Geometry	Fail	Pass	Fail	Fail	Pass
Optical Performance	Fail	Pass	Fail	Fail	Pass
Mechanical Reliability	Fail	Pass	Pass	Fail	Pass
MTP-LC Hybrid Assemblies					
End Face Geometry	Fail	Fail	Fail	Fail	Pass
Optical Performance	Fail	Pass	Fail	Fail	Pass
Mechanical Reliability	Fail	Fail	Fail	Fail	Pass

**Overall failure is based on failing one or more of the parameters for each test*

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