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Multimode MPO and SN-MT Connectors with APC Endface: When and Why to Use Them

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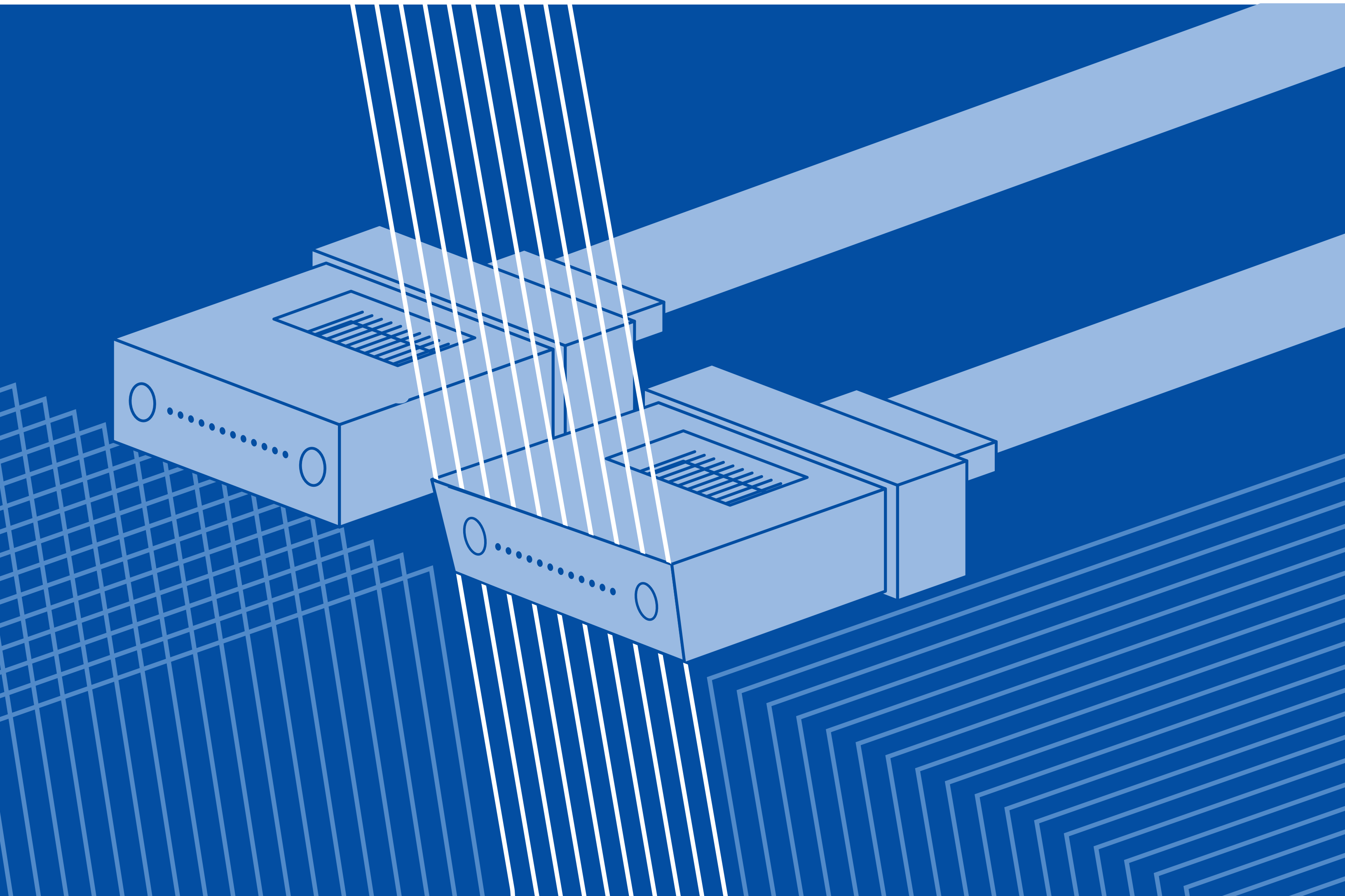

Multimode MPO and SN-MT Connectors with APC Endface: When and Why to Use Them

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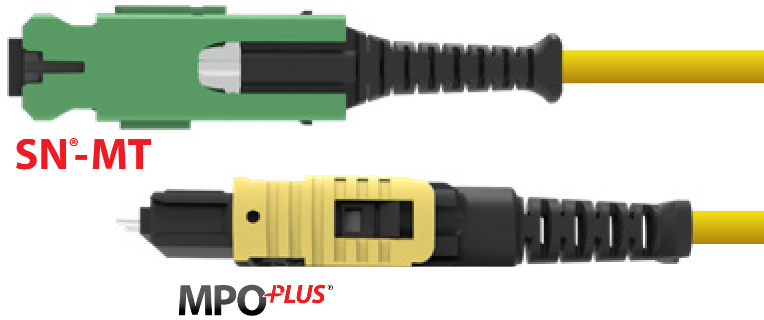
1.0 Where and Why MPO and SN-MT Connectors Are Gaining Popularity Today



MPO (Multi-Fiber Push-On) connectors are high-density fiber optic connectors designed to carry multiple fibers—typically 12 or more—within a single interface. They support both single-mode (SM) and multimode (MM) fibers and are widely used in space-constrained environments requiring high fiber counts. Traditionally, MM MPOs use UPC (Ultra Physical Contact) polishing, while SM MPOs use APC (Angled Physical Contact) polishing. Demand for 100G, 400G, and 800G transmission rates continues to rise, prompting transceiver manufacturers to adopt MM MPO interfaces. This trend reflects the evolving needs of data centers and AI factories, where operators seek fiber solutions that combine cost efficiency, high density, and performance. MM MPOs deliver the compact, high-bandwidth interconnects these high-performance applications require.

MM fiber links are popular in data centers due to their cost-effectiveness over short distances. These links support parallel optics architectures using VCSEL arrays, which are simpler and more power-efficient than their silicon photonic alternatives. While the energy savings from VCSELs are modest in transceivers with DSPs (Digital Signal Processors), in Linear Pluggable Optics (LPO) —which eliminate the DSP—VCSELs help reduce overall power consumption from ~20 pJ/bit to ~12.5 pJ/bit: a savings of roughly 40%.

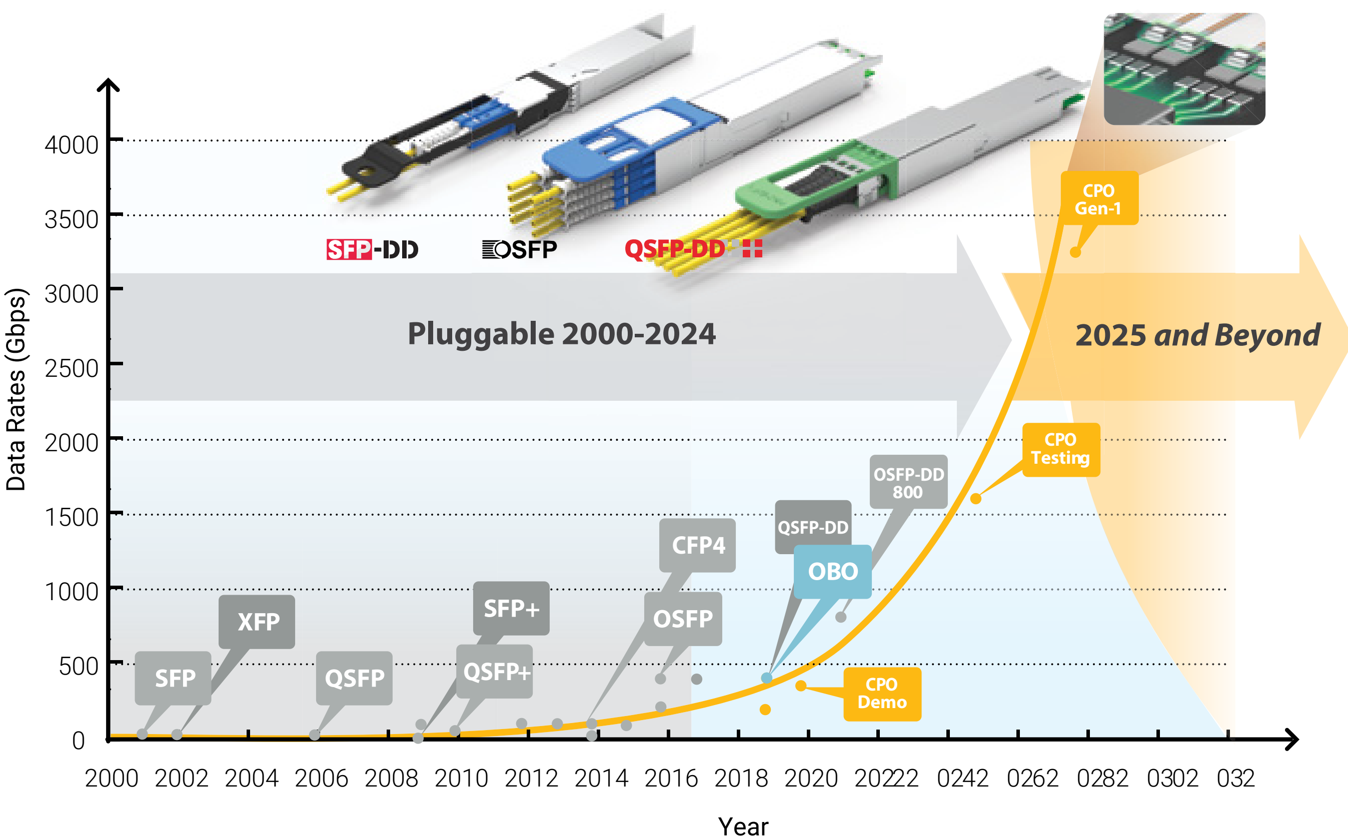


Figure 1: *Increase in Data Rates and Types of Transceivers - Shifting from Pluggable to CPO*

Angled MPO connectors help improve system performance in PAM4 and PAM8 links by minimizing back reflection caused by poor physical contact between optical fiber end faces. Compared to UPC connectors, APC interfaces are more tolerant of contamination and end face geometry deviations. This is why many transceiver vendors now specify APC connectors—even for multimode MPO.

Reflecting the growing relevance of multimode multifiber APC solutions, the IEC formed a new discussion group during its April 2025 technical meeting to develop a formal specification under the designation IEC 62664-1-16 ED1. This upcoming standard, titled *Fibre optic connector product specifications – MPO-APC multimode connectors – one fibre row, 16 fibres wide – Category C*, defines performance and interface requirements for MPO-APC connectors that terminate IEC 60793-2-10 category A1-OM2b to A1-OM5b fibers. The initiative aims to address the increasing demand for standardized MM APC multifiber connectors in high-speed, high-density applications.

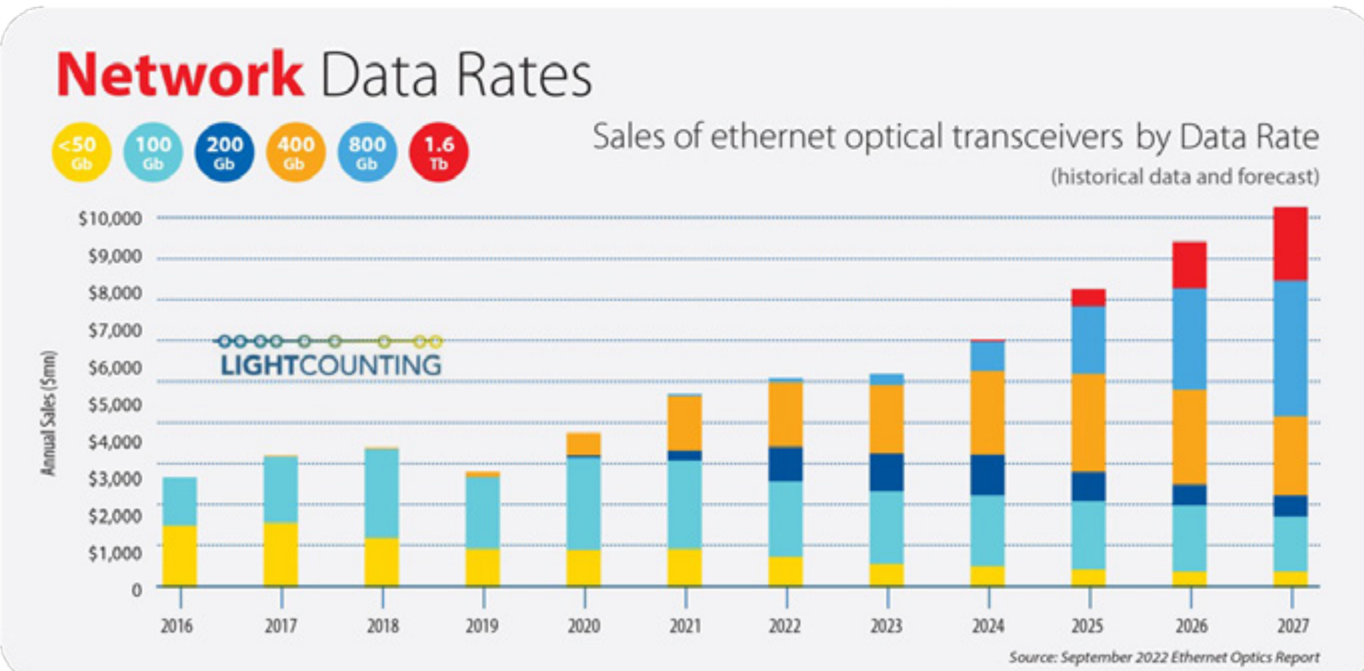


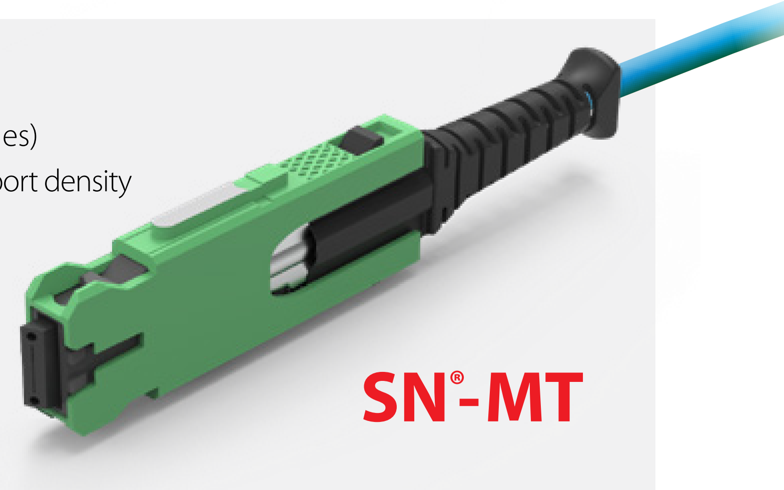
Figure 2: *Data Rates*

Hyperscale data centers, operated by companies such as Google, Amazon (AWS), Microsoft (Azure), Meta, Apple and others, are currently migrating from 400G to 800G while planning 1.6T interconnects. These facilities support massive volumes of traffic for cloud computing, AI, and big data. The demand for more bandwidth, lower latency, and energy efficiency continues to fuel the adoption of compact, high-density interconnect solutions.

One such innovation is the SN-MT connector, a very small form factor (VSFF) connector introduced by SENKO. It retains MPO's multi-fiber capability in a significantly smaller footprint optimized for next-gen transceivers like 800G DR8 and SR8.

Key features of SN-MT:

- Supports up to 16 fibers (or 32 in dual-row ferrules)
- Smaller footprint than MPO/MTP, enabling higher port density
- Push-pull latching for easier handling
- Lower insertion loss and improved reliability
- Compatible with both SM and MM (OM4 and above)
- MM SN-MT uses only APC polishing



SN-MT is emerging as a compelling alternative to MPO, offering superior space efficiency and better scalability for future networks. As MM MPO and SN-MT interfaces become standard in high-speed transceivers, they enable ultra-high data rates—especially in dense, short-reach applications like hyperscale and enterprise data centers. Leading companies such as Cisco, Broadcom, Arista, NVIDIA (Mellanox), Huawei, Intel, and II-VI (Finisar) offer transceivers with MM MPO interfaces, many of which now require APC mating connectors. Some can tolerate return losses as poor as 12 dB—worse than a bare fiber-air interface—yet performance does degrade under these extreme reflection conditions, which angled connectors help avoid.

Predictable, low-latency performance continues to grow as a critical requirement in modern AI and machine learning (AI/ML). As multiple compute and accelerator units collaborate on inference tasks across a backend fabric, a signal propagation delay of approximately 5 nanoseconds per meter must be considered within the scope of the total latency budget. This constraint inherently limits the maximum physical reach of GPU interconnect systems. Conveniently, multimode links are well-suited to these short-reach environments. For example, an 800G-SR8 link supports distances up to 100 meters, which is typically more than adequate for applications within a data center machine room or server cluster.

This paper compares flat and angled multimode connectors through simulation, measurements, and real-world transmission testing. We model return loss (RL) as a function of end face angle and validate this with empirical measurements on angled MPO connectors. Transmission tests show that flat connectors perform well when clean and properly aligned, but RL degradation from end face contamination or defects can enable reflected light to interfere with transmitters. Angled connectors consistently achieve high RL (>45 dB) even when unmated, reducing the risk of such interference and improving system stability.

2.0 Do Multimode MPOs and SN-MTs Need to Be Angled (APC)

Multimode fiber operates at shorter wavelengths (850 nm) than single-mode fiber (typically 1310 nm and above), and these shorter wavelengths see fewer problems from back reflections. MM MT ferrule design anticipates flat end face polishing, and so lacks the lateral offset used in SM MT ferrules to compensate for lateral misalignment. This raises concerns that angled polishing can cause alignment issues in multi-fiber interfaces and increase insertion loss.

SN®-MT APC

PAM4 and PAM8 systems are characterized primarily based on overall signal integrity rather than lateral ferrule alignment and reflection control alone. Traditional PAM4 and PAM8 modulation schemes prioritize low insertion loss, modal dispersion control, and clean fiber interfaces. Therefore, proper cleaning and maintenance of low-loss fiber links are critical for performance, and theoretically, APC interfaces are not required. However, more and more MM QSFP-DD and OSFP transceiver manufacturers advocate for angle polished MM MPOs.

This trend is supported by margin considerations in current high-speed standards. For instance, the IEEE 802.3df standard defines the 800GBASE-VR8 physical interface, which uses eight lanes of 100 Gb/s PAM4 signaling over OM4 fiber and supports reaches of up to 50 meters. The specification includes transmitter and receiver parameters such as Transmitter Dispersion Eye Closure Quaternary (TDECQ) and Transmitter Eye Closure Quaternary (TECQ), which quantify signal degradation and margin. Even at the highest allowed TDECQ, the required minimum transmitter optical modulation amplitude (TxOMA) is 0 dBm (1 mW) —a level that standard 100G VCSELs comfortably achieve. This performance leaves sufficient headroom for losses, validating the feasibility of PAM4-based MM links despite the variability introduced by connector style.

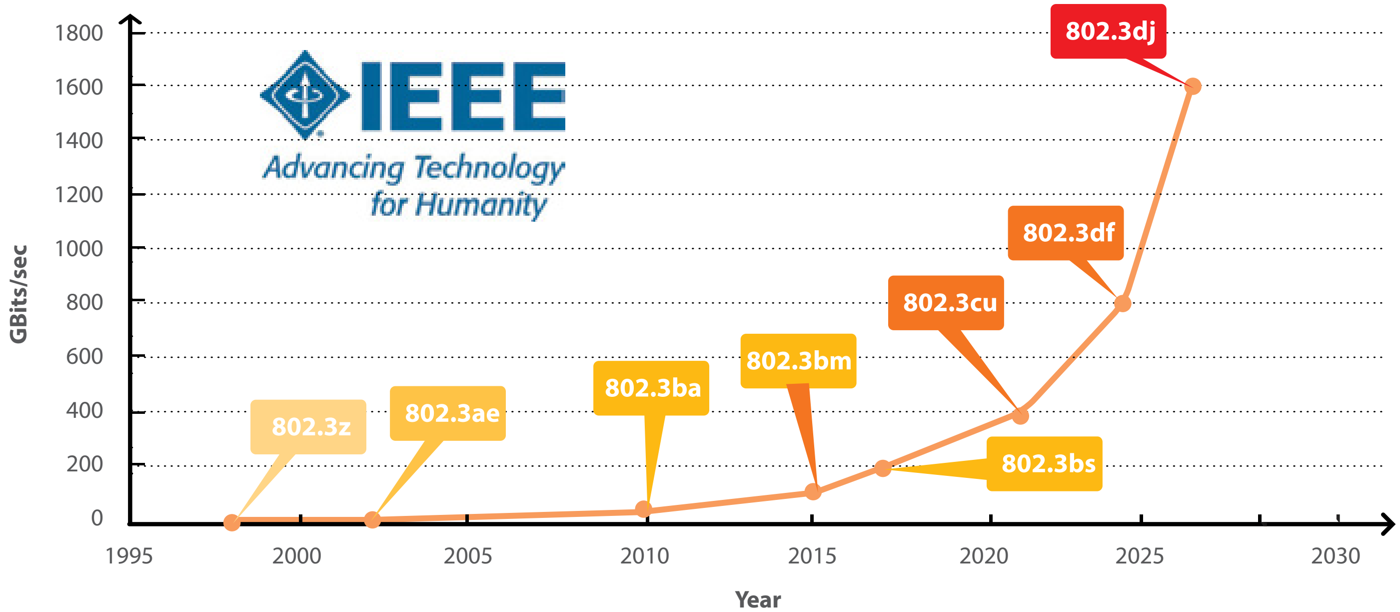


Figure 3: *Progression of IEEE standard optical transceiver speeds over time.*

IEEE standards serve to mirror changing market needs and advancing technologies. In that sense, Figure 2 narrates the dramatic growth in bandwidth needs of data centers, a testament to the impressive progress made in the components technologies industry to maintain pace.

However, component bandwidth cannot keep up indefinitely or easily, especially with current-generation oxide-aperture VCSELs. As we continue to push toward higher lane rates of 200G and beyond, the physical limitations of multimode links will become more pronounced. While low insertion loss and proper alignment will remain critical, the relevance of minimized back reflection may become critical to ensure signal integrity under tighter link budgets. In this context, adopting APC-polished multimode connectors could offer a long-term advantage.

Using APC-polished MM connectors offers additional margin and futureproof performance in next-gen networks. Even though current systems don't mandate APC use, designers increasingly view APC interfaces as a strategic investment that enables cleaner signaling and better system resilience under shrinking link budgets where every decibel counts. As bandwidth grows exponentially, incorporating APC connector end faces will facilitate the seamless transition to the data rates of the future, enabling clean and robust systems and signaling as the challenges posed by modal noise, dispersion, and crosstalk intensify.

SENKO collaborated with leading transceiver manufacturers to evaluate signal integrity and assess optical losses in MM APC versus MM PC connections. Additionally, SENKO evaluated the assumption that MM MT ferrules require lateral offsets to compensate for misalignment using data gathered from these studies. In this paper, we also present analytical findings and offer recommendations on industry direction, based on the latest developments from standards organizations such as IEC and TIA.

3.0 What Causes Return Loss in MM Fiber

The main contributor to return loss on MM fiber is the Fresnel reflection at the fiber-air interface. When light travels from a higher index (glass core) to a lower index (air at the fiber tip), part of the signal is reflected back into the fiber. If we assume an end face plane perpendicular to the direction of incident light—as is the case with flat polishing like UPC—the reflection coefficient R is given by:

Fresnel Reflection Coefficient:

$$R = \left(\frac{n_1 - n_2}{n_1 + n_2}\right)^2$$

- *n1 is the refractive index of the fiber core (≈1.47 for multimode fiber)*
- *n2 is the refractive index of air (≈1.00)*

noted that most OM5-compatible transceivers can handle even higher amounts of reflection—about 5% (12 dB return loss). For comparison, if the connector surface is not flat but has an APC polish with an 8-degree angle, the calculation becomes more complex, but the return loss is greater, in the range of 30 dB to 40 dB, which corresponds to 0.01% to 0.001% reflection on average.

Other factors, such as microbend losses (caused by tiny, microscopic deformations of the optical fiber that scatter light into the cladding), macrobend losses (where higher-order modes "leak out" when the fiber is bent beyond the minimum specified bend radius), and losses from mode mixing, are negligible. This is because OM5 graded-index fiber compensates for these effects through its radially varying refractive index, which helps reduce all forms and causes of modal dispersion.

However, high-speed multimode systems (100G, 400G, 800G) that use PAM4 and PAM8 signaling may be more sensitive to return loss due to increased susceptibility to noise. It is difficult to predict the effects of back reflections on Bit Error Rates (BER) in these high-speed multimode systems with theoretical calculations; therefore, a series of experimental results were analyzed.

4.0 Experimental Results

It is known that SM MT ferrules include a built-in lateral offset in the fiber row to compensate for potential misalignment when mating angled connectors. To evaluate whether any performance differences arise between SM and MM ferrules when using OM4 fiber with VCSEL sources and 8-degree angled polishing, we manufactured MM MPO cables using SM MT ferrules in one batch and MM MT ferrules in a second batch. Ten cables of each type were constructed. However, the test results showed no difference in insertion loss (IL) between SM ferrules with MM fiber (MPO/APC) and MM ferrules with MM fiber (MPO/APC). This indicates that the integrity of the VCSEL signal beam is not significantly affected by the estimated 1–2 µm lateral offset difference between ferrule types. MM fibers have a graded-index profile with a nominal core diameter of 50 µm and a numerical aperture (NA) of 0.2. The relatively large NA may help ensure that optical coupling between fibers tolerates minor lateral shifts such as these with no measurable IL-related signal degradation. Therefore, for MM/APC applications, our data suggest no clear requirement to use SM ferrules with a built-in lateral offset or to develop a custom MM ferrule with such a feature. We find standard MM ferrules suitable for both MPO/APC and SN-MT/APC connectors in multimode systems.

Second, we constructed an additional number of MM 16-fiber MPO connectors with both UPC and APC end face finishes and tested them to evaluate the impact of the nominal 8° angled polish on return loss. The return loss of the 16-fiber mated UPC connectors was measured, and all values ranged between 39 dB and 55 dB, indicating that physical contact was achieved across all fibers. There was minimal variation in return loss among individual fiber channels within each connector, suggesting the polishing process produced consistent end face geometry and fiber protrusion.

Next, we evaluated return loss among the 16-fiber MPO/APC connectors. When mated, these APC connectors exhibited RL values ranging from 50 dB to 57 dB, significantly higher compared to their UPC counterparts. This improvement can be attributed to the 8° angled endface, which reduces back reflections by directing reflected light away from the fiber core as shown in (2).

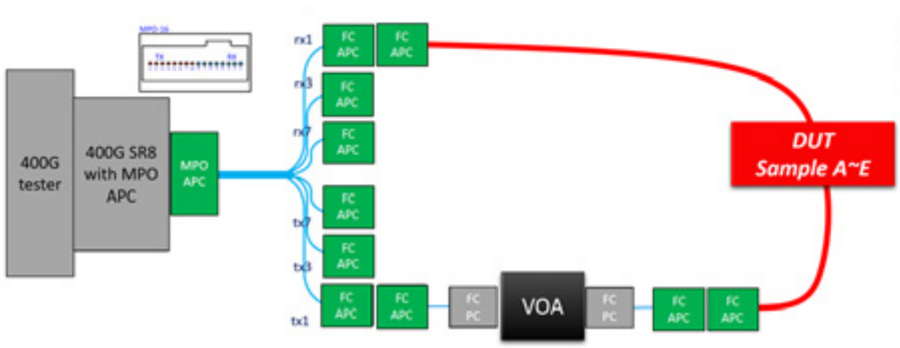
To simulate worst-case conditions where physical contact between fiber end faces is not achieved, the APC 16-fiber connectors were then unmated and left in free space, creating a glass-to-air interface. This scenario may occur in the field due to contamination, over-polishing, improper endface geometry, or handling errors. Even in this unmated state, the APC connectors maintained return loss values between 49 dB and 55 dB, demonstrating the effectiveness of the 8° angle in suppressing reflections under non-contact conditions. In contrast, unmated UPC connectors typically exhibit a return loss of approximately 14.7 dB, assuming a clean interface. This is consistent with standard Fresnel reflection at a glass-to-air boundary as modeled by (1). These results underscore the benefit of the 8° angled polish in APC connectors for maintaining high return loss even in the absence of physical contact.

The third set of tests focused on the impact of MPO interconnect back reflection on transmission performance. MPO connections with controlled reflection values ranging from -10 dB to a no-reflection condition were evaluated. The no-reflection condition was achieved using a self optical loopback within the 400G QSFP-DD SR8 transceiver system. The specific reflection levels tested were -10 dB, -12 dB, -15 dB, -20 dB, -25 dB, -30 dB and they were controlled using a variable optical attenuator (VOA). Insertion losses were measured and all tests normalized according to these values. All measurements used an MPO UPC 16-fiber ferrule.

The bit error rate (BER) is plotted as a function of reflection level. Transmission testing was performed using a 400G-SR8 transceiver, with the test setup illustrated in Figures 1 and 2. A 400G test instrument drove the AOI 400G QSFP-DD SR8 transceiver and recorded cumulative BER over 2-minute intervals. The transceiver's medium-dependent interface (MDI) featured a 16-fiber UPC ferrule. A fanout cable with a 16-fiber MPO UPC connector on one end and sixteen FC/APC connectors on the other formed the interface between the transceiver and the rest of the test system. Four transmitting lanes were tested sequentially, each connected one at a time to the setup. A VOA was inserted after the test fiber to control reflection, and a multimode optical switch (X) alternated between a power meter (PM) for optical power monitoring and the FC/APC return path to the receiver. The same receiver lane was used throughout to ensure consistency within results.

Testing BER and BER Curve

Connect known IL and RL to SR8 to observe performance



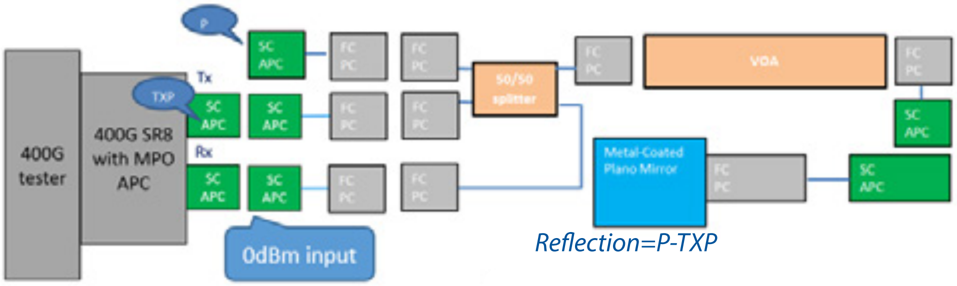
Test Conditions:

- Module: AOI 400G QSFP-DD SR8
- Temp (°C): 35
- SN: #41
- Voltage: 3.3V
- DUT Sample A-E:
  A - No reflection, self optical loopback
  B - with -20dB reflection fiber
  C - with -25dB reflection fiber
  E - with -30dB reflection fiber

Figure 4: *Test apparatus measuring BER at variable reflection level*

Testing BER and BER Curve

Test Diagram with Reflection



Test Diagram with No Reflection

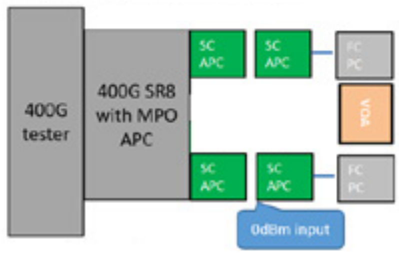


Figure 5: *Test apparatus measuring extreme reflection conditions*

Test Conditions:

- Module: 400G SR8
- Temp (°C): 35
- SN: #41
- Voltage: 3.3V
- Using metal coated Plano Mirror for back refection. ADjust the loss of VOA to get a different reflection

Test Result:

-10dB, 012dB and -15dB reflection causes obvious deterioration of BER

The test setup is shown below in Figures 4 and 5. Figure 6 plots the bit error rate (BER) in the optical signal as a function of back reflection level. BER is defined as the number of bit errors divided by the total number of bits for which transmission was attempted, expressed as a metric in units of errors per bit. The y-axis in Figure 6 is logarithmic (e.g. a y-value of 1.00E-06 errors/bit corresponds to a BER of 10^{-6} errors/bit). Each curve represents BER measurements taken under a specific back reflection level (e.g., -10 dB, -20 dB), using an optical loopback within the AOI 400G QSFP-DD SR8 transceiver. BER was measured using the transceiver's internal diagnostics, which reports errors per channel.

Due to sample limitations, BER consistency across channels was not ideal. However, the results clearly show a trend: as reflection increases (i.e., becomes less negative), BER performance deteriorates. Significant degradation is observed when back reflection exceeds -15 dB. It is important to note that even at -10 dB reflection, the measured BER remains below the maximum acceptable levels before forward error correction (FEC) occurs (referred to as the "pre-FEC threshold," such that the system can still correct all errors and deliver error-free data. This indicates acceptable performance even under these extreme conditions.

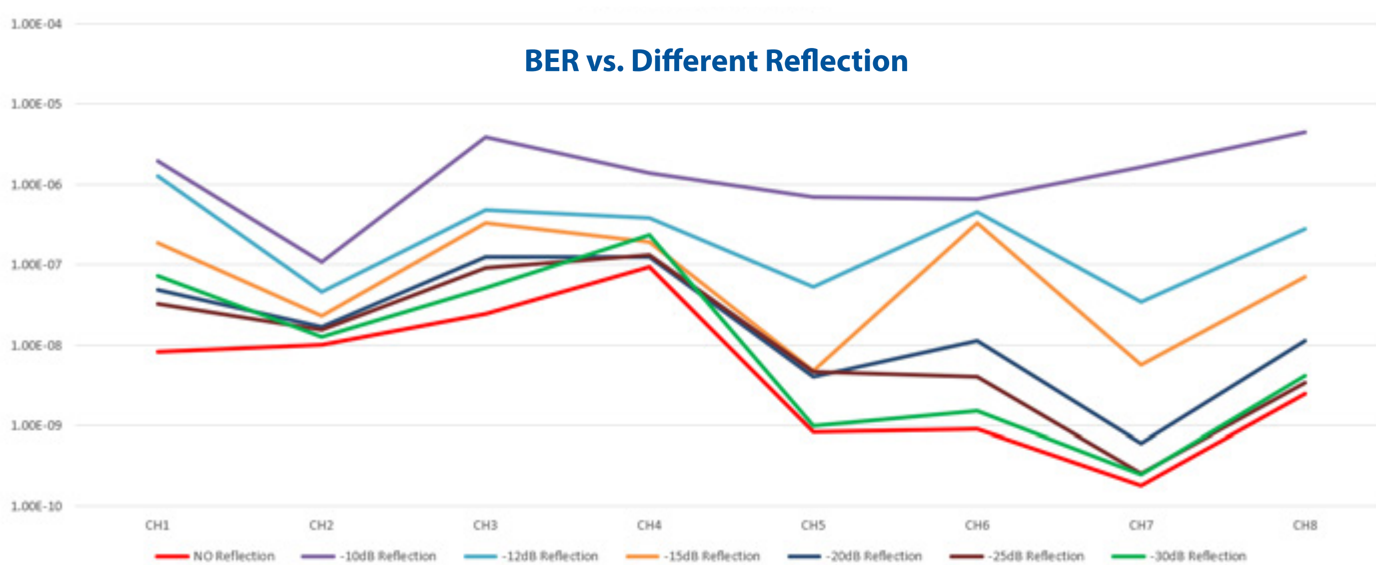


Figure 6 *MT Plot of BER against optical reflection level*

5.0 Conclusion and Summary

Recent developments across the industry from transceiver manufacturers, test data, and emerging standards clearly point toward a growing need for MM MPO and SN-MT connectors with APC end faces in today's 400G networks and beyond. In high-speed data center environments using PAM4 signaling, UPC MM connectors risk degraded system performance due to insufficient return loss (RL), especially in the presence of (unfortunately) common conditions such as contamination or air gaps. APC connectors effectively mitigate this risk and consistently deliver high RL and improve protection against BER degradation, even under less than ideal conditions.

The IEC has acknowledged this shift with IEC 62664-1-16 ED1, a forthcoming standard that will define performance and interface requirements for MM MPO APC connectors with one fiber row and 16 fibers wide. This move reflects the market's increasing demand for standardized, high-density APC connector solutions in high-speed environments. The TIA, in line with these trends, now formally includes green color coding for multimode APC ferrule connectors in the ANSI/TIA-568.3-E standard, referencing TIA-598-D for fiber color conventions.

Our test data reinforces this industry direction:

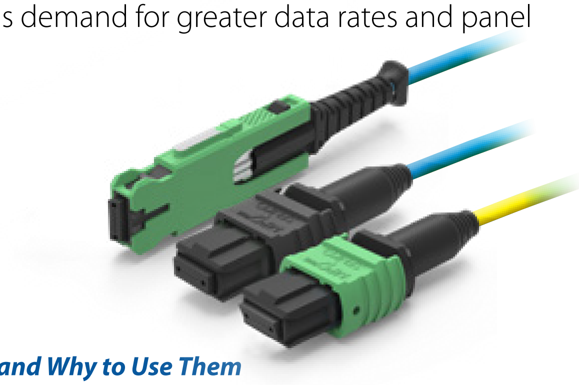
- Reflections worse than -15 dB show noticeable BER degradation in MM systems
- Lower reflection levels (e.g., -25 dB to -30 dB or "no reflection" conditions) significantly improve BER, approaching 1.00E-09 errors per bit. While our data showed systems with -10 dB reflection displayed BER values that still met pre-FEC thresholds, APC connectors offer a significant performance safety margin and represent the future-proofed solution.
- Variations between channels (e.g., CH6, CH7) suggest that optical imbalance or transceiver sensitivity can exacerbate BER under high reflectance conditions, possibly exceeding the pre-FEC thresholds in certain conditions. Although the test sample size was limited, observed trends were internally consistent and aligned with expected PAM4 behavior.

In summary, MM MPO/APC connectors deliver measurable BER improvement in high-speed systems by ensuring higher return loss, making them a future-ready option for next-generation network deployments.

SENKO is prepared to support this transition. We have assigned part numbers, validated polishing processes, manufactured reference test cables, and conducted extensive random-mating and reflection testing. Our solutions are ready to help customers maintain BER performance as demand for greater data rates and panel density continue to rise.

For more information or technical consultation, contact your SENKO representative.

Contact SENKO



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Biography

Andrei Vankov, is an Application Engineer at SENKO Advanced Components. He received his BS from Thomas Edison State College and his MSEE from Pennsylvania State University. He began his career in 1993 at Sumitomo Electric Lightwave Corp as a Fiber Optic Manufacturing Engineer where he worked on active and passive components using Kaizen methods in Yokohama, Japan. As a Senior Optical Design Engineer in Franklin, MA (founded as Advanced Interconnect) Andrei Vankov developed various passive optical components and packaging integration to meet Telcordia industry standards. He designed optical interconnects, including optical backplanes (MTP, HBMT, PHD, OGI), and a fiber optic SMPTE compatible Broadcast Connector for HD applications. In 2013-2020 Andrei worked at Nokia division Radio Frequency Systems (RFS) where he provided leadership for an LTE RAN launch project team. Andrei holds several US and European Patents in fiber optics interconnect technology.

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