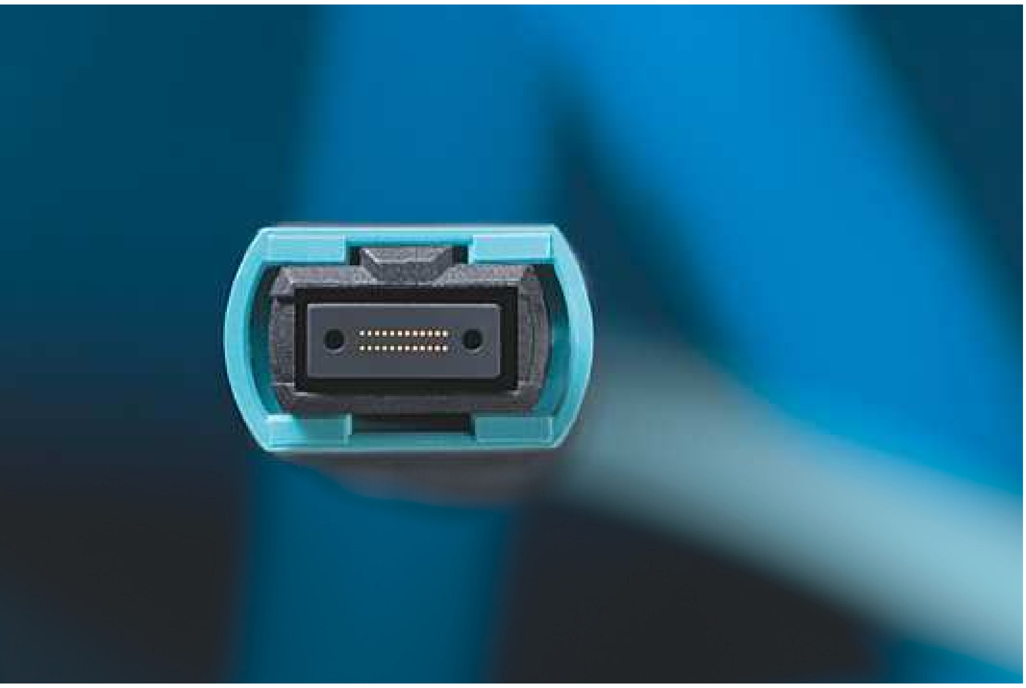
White Paper



MPO/MTP® – Introduction to Parallel Optics Technology

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Convincing cabling solutions

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MTO and MTP® – Introduction to Parallel Optics Technology

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Multi-fiber connectors now becoming the standard

The number of network connections in data centers is on the rise. Data centers have to achieve ultra-high density in cabling to accommodate all this cabling in the first place. Multimode fiber optics is the medium of the future for satisfying the growing need for transmission speed and data volume over short distances. Parallel optics technology is what you get if you combine both trends – cabling density and the use of fiber optics. It is a suitable solution for high-performance data networks in data centers. New multi-fiber connectors bring together 12 or 24 fibers in a single interface just as compact as an RJ45 connector. Ultra-parallel connections involve tougher requirements in terms of quality, the components and the handling of the connectors. The multi-fiber push-on (MPO) technology and especially the MTP® connectors from the manufacturer US Conec in connection with Elite® ferrules have proven to be a practical solution. R&M has pushed for further advances in this technology, setting new quality standards in the finish of the fiber endfaces in particular. These endfaces far outperform the standard and ensure lasting reliability and total transmission quality. The groundwork is laid for a broad introduction of the MPO technology in data centers, where pre-terminated solutions are generally employed anyway.

Application:	Data center networks, 10 and 40/100 Gigabit Ethernet
Technology:	Multimode fiber optic cabling
Format:	White Paper
Subjects:	Multi-fiber connectors, MPO/MTP® connectors, Elite® ferrules, performance, precision of fiber endfaces, core dip, fiber protrusion, plug and play with pre-terminated trunk cables, 10GBASE-SR, 40GBASE-SR4, 100GBASE-SR10, EIA/TIA 604-5, IEC 61754-7, EN 50377-15-1:2011
Objective:	To orient readers on MPO technology and inform them about quality and performance criteria, about the use of advanced high-density fiber optic technologies in data centers and about planning, purchasing and operations. R&M's stance on MPO/MTP®.
Target group:	Data centers, data center planners, installers, network managers
Authors:	Pirmin Koller, Dr. Thomas Wellinger
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This white paper provides introductory information on parallel optics and MPO technology. It presents performance and quality criteria and is meant as an initial orientation for decision makers in helping them plan their fiber optics strategy and select their connection technology.

1. Data centers present and future

The need for ever-greater bandwidths continues unabated. Data centers must respond early to provide sufficient capacities and plan for upcoming requirements. This chapter explains the reasons for the relentless growth in bandwidth and describes possible solutions to it.

1.1. Bandwidth as the driving force

The data quantity transmitted worldwide is growing exponentially. It will quadruple in the next four years alone. The network outfitter Cisco issued that forecast in June 2011. It said just under one zettabyte (1,000,000,000,000,000,000,000 bytes) of data will be transmitted over IP networks in 2015. The worldwide IP data traffic from businesses will triple in this same period and reach 10.1 exabytes a month in 2015. IP data traffic is currently increasing at a rate of 32 percent a year.

There are many different reasons for this rapid growth in bandwidth demand. For one thing, private use of the Internet is constantly increasing. From 2001 to 2010 alone, the number of Internet users increased from 37 percent to 72 percent, thus nearly doubling. At the same time, people want ever-faster access. The flood of data is being pushed to ever-greater volumes with flat rates and Internet telephony, cloud computing and online navigation, mobile Internet with smart phones or tablet computers and video on demand. In the business realm, the upsurge in bandwidth is being driven by cloud computing services, group-wide networking, remote access to company networks, remote sessions and in particular by data-hungry video conferences.

The data volumes currently demanded in backbone cabling can still be handled with 10 Gigabit Ethernet (GbE), but the forecast trends will require the introduction of the next technologies, 40 GbE and 100 GbE (Figure 1).

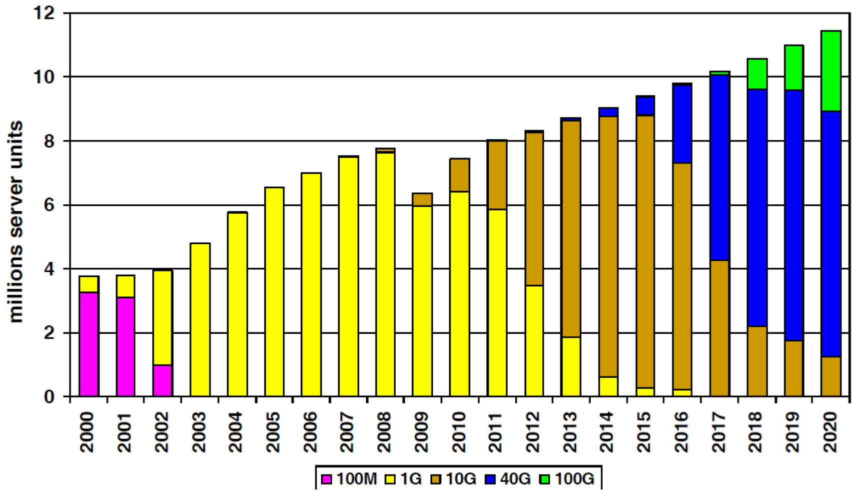

Figure 1: Trend over time of Ethernet technologies (Source: IEEE, 2011)

1.2. 10 GbE as the status quo

There is no way around the migration to 40 and 100 GbE. As Figure 1 shows, 40 GbE will be broadly introduced within five years at the latest and 100 GbE will follow just two years later. Data center managers therefore have to lay the groundwork today and adapt their infrastructure to meet these future requirements. This raises the question of how they should pick the connection technology in terms of performance and total cost of ownership (TCO). Here is an all too brief assessment of the current situation.

The crucial criteria for selecting the right interface are costs and the product of bandwidth to length. This value is a product of bandwidth and the transmission distance and underscores the compromise between signal bandwidth and the length of the link over which the signal can be transmitted. Data centers currently have a mix of copper cables and fiber optics. Links anywhere from 15 to 550 meters in length can be achieved depending on the cable type used (copper/FO). The table below briefly summarizes the existing transmission technologies, cable types and maximum achievable links. The definitions are based on the standards IEEE 802.3ak (Twinax) and 802.3an (twisted pair) for copper and 802.3ae for fiber optics.

Transmission technology	**Cable type**		**Maximum distance**
10GBASE-CX4	Copper, Twinax		15 m
10GBASE-T	Copper, twisted pair	Cat. 5e	50 m
		Cat. 6a/7	100 m
10GBASE-LX4	FO, 1310 nm	Multimode	300 m
		Singlemode	10 km
10GBASE-SR	FO, 850 nm	Multimode OM1/OM2	33/82 m
		Multimode OM3	300 m
		Multimode OM4	550 m*
10GBASE-LR	FO, 1310 nm	Singlemode	10 km
10GBASE-ER	FO, 1550 nm	Singlemode	40 km
10GBASE-SW	FO, 850 nm	Multimode OM1/OM2	33/82 m
		Multimode OM3	300 m
		Multimode OM4	550 m
10GBASE-LW	FO, 1310 nm	Singlemode	10 km
10GBASE-EW	FO, 1550 nm	Singlemode	40 km
* The OM4 solution over 550 meters is not standardized within the IEEE.			

Table 1: 10 GbE – Transmission technologies, cable types and maximum achievable distances. The transmission technologies and cable types most significant for data centers are shown against a gray background.

Links ranging in length from a few meters to several hundred meters have to be implemented in data centers and singlemode solutions are usually much more expensive than multimode ones. The table can therefore be reduced to the two transmission technologies 10GBASE-CX4 and 10GBASE-T for copper and 10GBASE-SR for fiber optics.

1.3. 40/100 GbE in the not too distant future

The new transmission technologies 40 GbE and 100 GbE were enacted in June 2010 with the standard 802.3ba. To achieve practical lengths for these large bandwidths, too, data centers have to operate several of the existing copper cables or optical fibers parallel to each other. Once again there are varying transmission technologies and distances resulting from this situation, both dependent on cable type. The table below provides an overview:

Transmission technology	Cable type	Signal routing	Maximum distance
40GBASE-KR4	PCB (bus)	4 x 10 Gb/s	1 m
40GBASE-CR4	Copper, Twinax	4 x 10 Gb/s	7 m
40GBASE-SR4	Multimode, OM3	4 x 10 Gb/s	100 m
	Multimode, OM4		150 m
40GBASE-LR4	Singlemode	4 x 10 Gb/s (CWDM)	10 km
100GBASE-CR10	Copper, Twinax	10 x 10 Gb/s	7 m
100GBASE-SR10	Multimode, OM3	10 x 10 Gb/s	100 m
	Multimode, OM4		150 m
100GBASE-LR4	Singlemode	4 x 25 Gb/s (DWDM)	10 km
100GBASE-ER4	Singlemode	4 x 25 Gb/s (DWDM)	40 km

Table 2: 40/100 GbE – Transmission technologies, cable types and maximum achievable distances. The transmission technologies and cable types most significant for data centers are shown against a gray background.

It quickly becomes apparent that the use of copper cables for transmission of 40/100 GbE is critical. Lines seven meters in length pose problems but so too does the laying of ten lines parallel to each other. Given the cramped space in cable runs and the difficulty of cooling them, the use of copper seems questionable. In the connection area, too, Twinax cables need more space than multi-fiber connectors (MPO/MTP®, refer to Chapter 2) for optical fibers. From today's perspective, the use of copper cables -- whether as Twinax or as twisted pair Cat. 7 – does not appear to be a reasonable approach, technically or economically.

Category OM3 and OM4 optical fibers are the compelling solution for future-safe cabling in data centers given their much longer transmission distances and more compact design. OM3 has a link length of 100 meters so it supports about 85 percent of all data center channels depending on architecture and size; OM4 fibers have a link length of 150 meters so they cover nearly 100 percent of the required reach.

Note: According to IEEE 802.3ae, the link length for OM3 fibers with 10 GbE is 300 meters. Although the OM4 fibers are not standardized, they can support solutions involving lengths of up to 550 meters. Although with 40 GbE and 100 GbE, only 10 Gb/s are transmitted per fiber because of the parallel optical architecture, 802.3ba defines only 100 meters for OM3 and 150 meters for OM4. That is because the requirements for the active components have become more lenient. They were reduced to cut the total costs of the link. Tolerances are greater especially for jitter. The link length has therefore had to be shortened so the admissible total budget for jitter would not be exceeded. Jitter is the time variation of a periodic signal in the transmission of bits. It is caused, for example, by noise in electronics or by dispersion in optical fibers.

2. Components and solutions for 40/100 GbE

It is clear from Chapter 1 that data centers have to start now with preparing their passive infrastructure for 40/100 GbE. This chapter describes the components they need to do so.

2.1. OM3/OM4 – Laser-optimized multimode optical fibers

For OM3 and OM4, these components are laser-optimized 50/125 µm multimode optical fibers. Whereas OM1 and OM2 fibers are operated with LEDs as signal sources, lasers are used for category OM3 and OM4 fibers. These lasers are generally vertical-cavity surface-emitting lasers (VCSELs). This type of laser is considerably cheaper than, for example, Fabry-Perot lasers or distributed feedback lasers. Lasers have the advantage of being able to transmit data at higher rates, unlike LEDs which are limited to a maximum frequency of 622 Mb/s. Lasers are more concentrated than LEDs in their coupling in the fiber core. That means interference has a much bigger impact on transmission characteristics there than in LED-fed fibers.

Conventional multimode fibers often exhibit iimpairments of the refractive index profile in the fiber core. These impairments include flat tops and peaks but especially centerline dips, which look like a notch in the refractive index profile. The laser signal concentrates a large part of the total power on the fiber core so deformations in the ideal transmission signal occur there, which increases the bit error ratio. This, in turn, leads to a bad net data rate or can even go so far as to cause the transmission to fail. With laser-optimized fibers, the refractive index profile is improved in comparison with conventional multimode fibers, so no centerline dips occur. Figure 2 shows the interconnections:

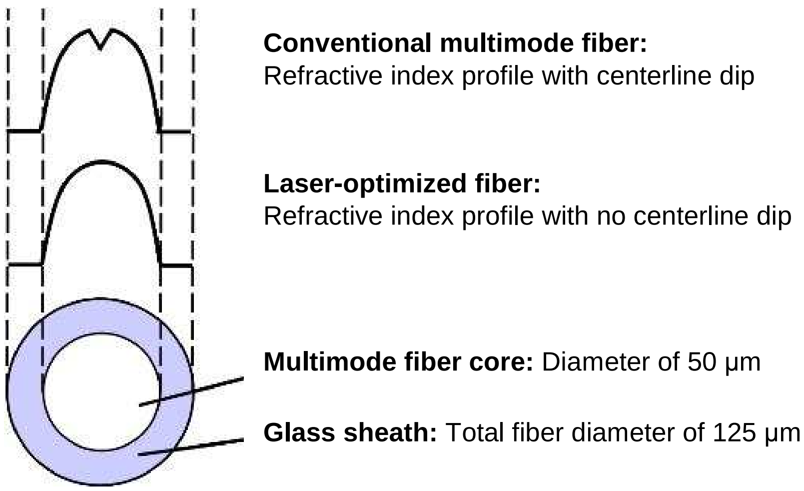

Figure 2: Laser-optimized fibers with improved refractive index profile

Category OM3 and OM4 laser-optimized fibers are prerequisite for achieving sufficiently high ranges through the use of lasers as the signal source. R&M offers a number of laser-optimized OM3 and OM4 cables, for installation and pre-terminated. Maximum distances and maximum transmission reliability are therefore guaranteed.

2.2. Parallel optical channels

As noted in Chapter 1.3, the 802.3ba standard defines the parallel operation of four OM3/OM4 fibers for 40 GbE in 40GBASE-SR4 and the parallel operation of ten OM3/OM4 fibers for 100 GbE in 100GBASE-SR10. Two fibers have to be used per link because this arrangement is full duplex operation, i.e. simultaneous transmission in both directions. Therefore the number of fibers increases to eight for 40GBASE-SR4 and to 20 for 100GBASE-SR10.

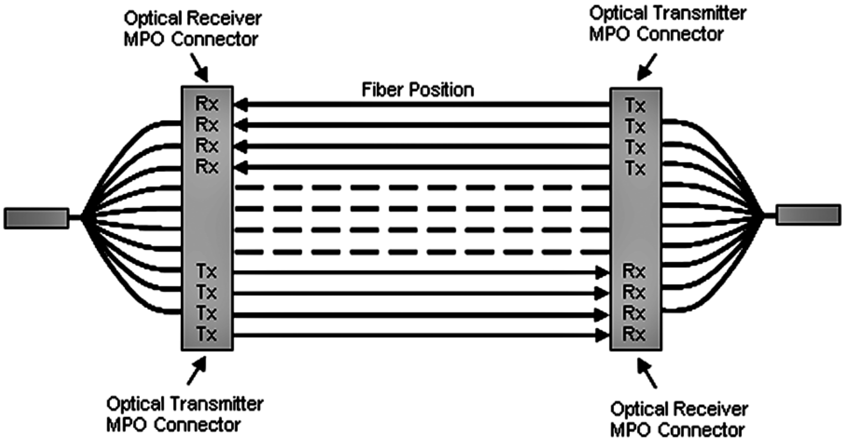

Figure 3: Parallel optical channel for 40 GbE with eight fibers used

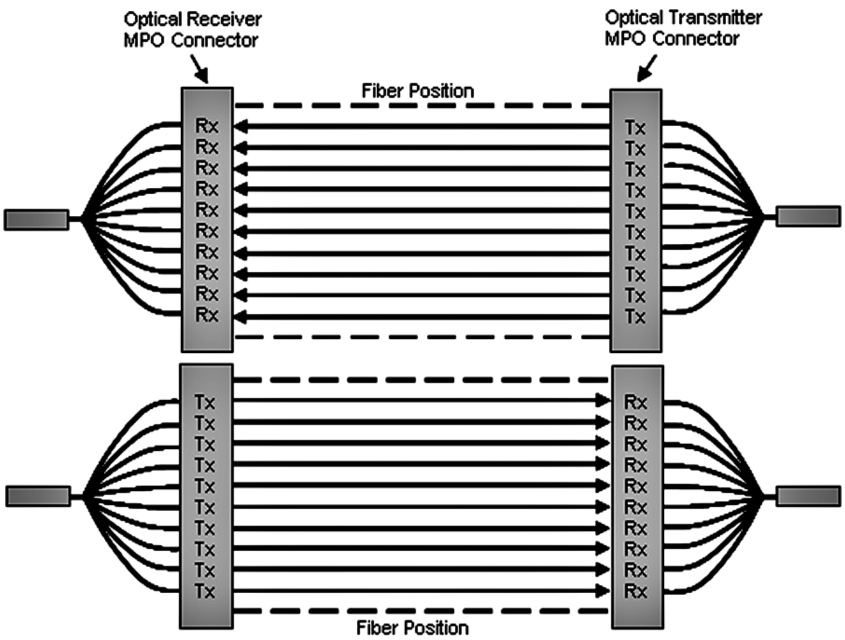

Figure 4: Parallel optical channel for 100 GbE with twenty fibers used

As Figures 3 and 4 show, four fibers remain unused in each case in connection with 12-fiber and 24-fiber cables and MPO/MTP®connectors (refer to Chapter 2). In the parallel optical link, the signal is split, transmitted over separate fibers and then joined again. That means the individual signals have to arrive at the receiver at the same time. Any skew in signal components has to be kept within tight tolerances. This fact alone means a combination of single fibers is prohibited for parallel optical connections. Trunk cables pre-terminated with MPO/MTP® connectors are therefore the best choice for reliable transmission. The following chapters will thoroughly cover these two subjects – MPO/MTP® connectors and trunk cables.

2.3. MPO/MTP® – Multi-fiber connectors for high port density

As shown in the previous chapter, parallel optical channels with multi-fiber multimode optical fibers of the categories OM3 and OM4 are used for implementing 40 GbE and 100 GbE. The small diameter of the optical fibers poses no problems in laying the lines, but the ports suddenly have to accommodate four or even ten times the number of connectors. This large number of connectors can no longer be covered with conventional individual connectors. That is why the 802.3ba standard incorporated the MPO multi-fiber connector for 40GBASE-SR4 and 100GBASE-SR10. It can contact 12 or 24 fibers in the tiniest of spaces. This chapter describes this type of connector and explains how it differs from the much improved MTP® connectors of the kind R&M offers.

2.3.1. MPO connectors: structure and function

The MPO connector (known as multi-fiber push-on and also as multi-path push-on) is a multi-fiber connector defined according to IEC 61754-7 and TIA/EIA 604-5 that can accommodate up to 72 fibers in the tiniest of spaces, comparable to an RJ45 connector. MPO connectors are most commonly used for 12 or 24 fibers (Figure 5).

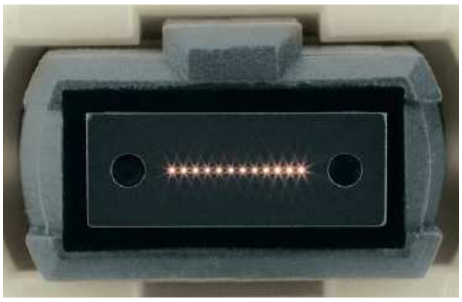

Figure 5: MPO connector for accommodating 12 fibers

As explained in Chapter 1.5 on parallel optical connections, eight fibers are needed for 40 GbE and 20 for 100 GbE. That means four contacts remain non-interconnected in each case. The diagrams below (Figure 6) show the connection pattern:

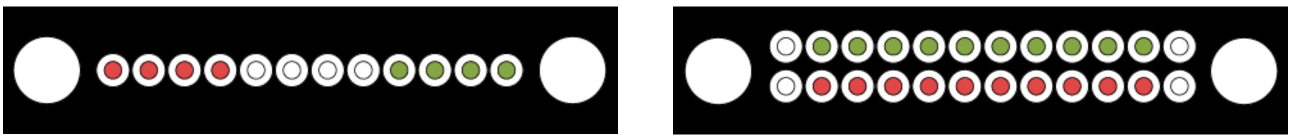

Figure 6: Diagram of MPO connectors, 12-fold (left) and 24-fold (right). The fibers for sending and receiving are color-coded, red and green, respectively.

The push-pull interlock with sliding sleeve and two alignment pins are meant to position the MPO connector exactly for more than 1000 insertion cycles. As with every connector, the quality of the connection for the MPO connector depends on the precision of the contacting. In this case, however, that precision must be executed 12-fold or 24-fold. The tough requirements put on the MPO are what made it essential for R&M to be able to understand and control the optimum endface geometry for low insertion loss (IL) and return loss (RL).

The fibers are usually glued into holes within the ferrule body. Such holes have to be larger than the fiber itself to allow the fiber to be fed through so there is always a certain amount of play in the hole. This play causes two errors that are crucial for attenuation:

- **Angle error (angle of deviation):**
  The fiber is not exactly parallel in the hole but at an angle of deviation. The fibers are therefore inclined when they come into contact with each other in the connector and are also radially offset in relationship to each other. The fibers are also subject to greater mechanical loading.
- **Radial displacement (concentricity):**
  The two fiber cores in a connector do not touch each other fully but somewhat offset in relationship to each other. This is referred to as concentricity. The true cylindrical center is taken and rotated once around the reference center. This results in a new cylinder whose diameter is defined as the concentricity value. In accordance with EN 50377-15-1, the concentricity of fiber holes in the MPO ferrule is allowed to be no more than 5 µm.
  One often talks about eccentricity, too, in connection with radial displacement. This is a vector indicating the distance of the true radial center of the cylinder from the reference center and the direction of deviation. To determine the concentricity, the true cylinder center is rotated once around the reference center. This value is therefore twice as big as the value for eccentricity but contains no information about the direction of deviation.

In both cases, the consequences are higher insertion loss and return loss because part of the light is decoupled or reflected instead of being transmitted.

MPO connectors (and the MTP® connectors described below) are no longer terminated on site because of the delicate multi-fiber structure and narrow tolerances involved. MPO/MTP® connectors are therefore sold already terminated together with trunk cables. With this arrangement, customers have to plan line lengths precisely but are also assured top quality and short installation times. R&M offers a number of different cable types that are sold completely terminated and with further improved MTP® connectors (see next section).

2.3.2. MTP® connectors with Elite® ferrules from R&M

Fibers are glued directly into the plastic body of the ferrule with MPO connectors, making reworking later on difficult and putting limits on manufacturing accuracy. Angle errors and radial displacement can be reduced only to a certain degree.

To achieve lower tolerances and better attenuation values, the American connectivity specialist US Conec developed the MTP® connector (MTP = mechanical transfer push-on). It has better optical and mechanical quality than the MPO. Unlike the MPO connector, an MTP® connector consists of a housing and a separate MT ferrule (MT = mechanical transfer). The MTP® connector differs from the MPO in various ways. e.g. rounded pins and oval shaped compression springs. These features prevent scratches during plug-in and protect the fibers in the transition area from connector to cable. This design makes the connectors highly stable mechanically. The MT ferrule is a multi-fiber ferrule in which the fiber alignment depends on the eccentricity and positioning of the fibers and the holes drilled in the centering pins. The centering pins help control fiber alignment during insertion.

Since the housing is detachable, the ferrules can undergo interferometric measurements and subsequent processing during the manufacturing process. In addition, the gender of the connector (male/female) can be changed at the last minute on site. A further advance from UC Conec is that the ferrules can be moved longitudinally in the housing. That allows the user to define the applied pressure.

A further improvement is the multimode (MM) MT Elite® ferrule. It has about 50 percent less insertion loss and the same return loss as the MM MT standard ferrule, which typically has 0.1 dB insertion loss. Tighter process tolerances are what led to these better values.

Series of measurements from the R&M Laboratory confirm the advantages of the R&M Elite® ferrule. The histograms in Figure 7 and Table 3 illustrate the qualitative differences of the two ferrule models. The random-mated measurements with R&M MTP® patch cords were carried out in accordance with IEC 61300-3-45, one group with Standard and another with Elite® ferrules. Thus, connections with R&M MTP® Elite plugs, for example, have a 50 percent probability of exhibiting insertion loss of just 0.06 dB or less. There is a probability of 95 percent that these same connections will have optical losses of 0.18 dB or less.

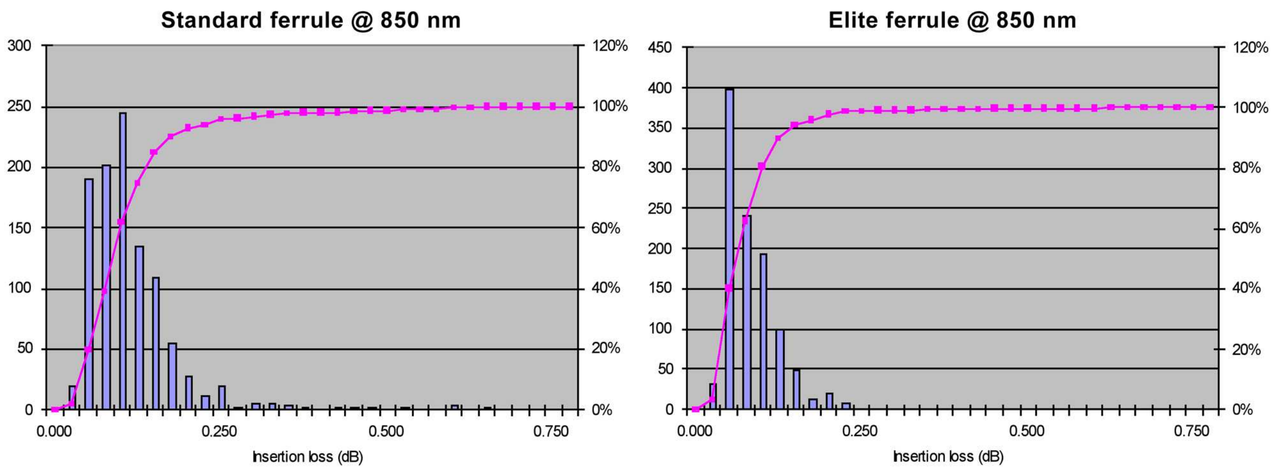

Figure 7: Insertion loss characteristic of Standard (left) and Elite ferrules (right) from the series of R&M measurements

Ferrule type	50%	95%
Standard	≤ 0.09 dB	≤ 0.25 dB
Elite®	≤ 0.06 dB	≤ 0.18 dB

Table 3: 50% and 95% values for Standard and Elite® ferrules

For its own MPO solutions, R&M makes exclusive use of MTP® connectors with Elite® ferrules. However, it has further improved the already good measured values in a finishing process specially developed for the purpose. In other words, R&M not only ratcheted up the EN-specified tolerances for the endface geometry of MPO connectors but also defined new parameters. Finishing is done in a special high-end production line.

The criteria R&M sets for each processing step and parameter and for the statistical processes in quality management are basically more stringent than the relevant standards in order to guarantee users maximum operational reliability.

For instance, the EN 50377-15-1 requires that fibers in MPO/MTP® connectors protrude at least one µm beyond the end of the ferrule and have physical contact with their counterpart. The reason is that the ferrule of an MPO/MTP® has an extremely large contacting surface area. This large area equally distributes the spring power pressing the ferrules together across all fibers in each connector. If fibers are too short, there is a risk that just the surfaces of the two ferrules that are stuck together will come into contact with each other, thus preventing the two fibers from touching. Fiber height is therefore a critical factor for connection performance.

At the same time, all fiber heights in an MPO/MTP® connector also have to be within a certain range. This range is defined as the distance between the shortest and the longest fiber and naturally has to be minimized to ensure that all fibers touch in a connection. The situation is exacerbated by the fact that the fiber heights are not linear arrangements. Variation in fiber heights arises during the polishing of fiber endfaces and can only be reduced by working with extreme care using high-quality polishing equipment and suitable polishing agents. Although operators should always try to keep all fibers at the same height during polishing they will not fully succeed in avoiding a certain deviation in the sub-micrometer range. R&M has optimized this work step in such a way as to reduce the tight tolerances in EN 50377-15-1 yet again by 1 to 3.5 µm (Figure 8).

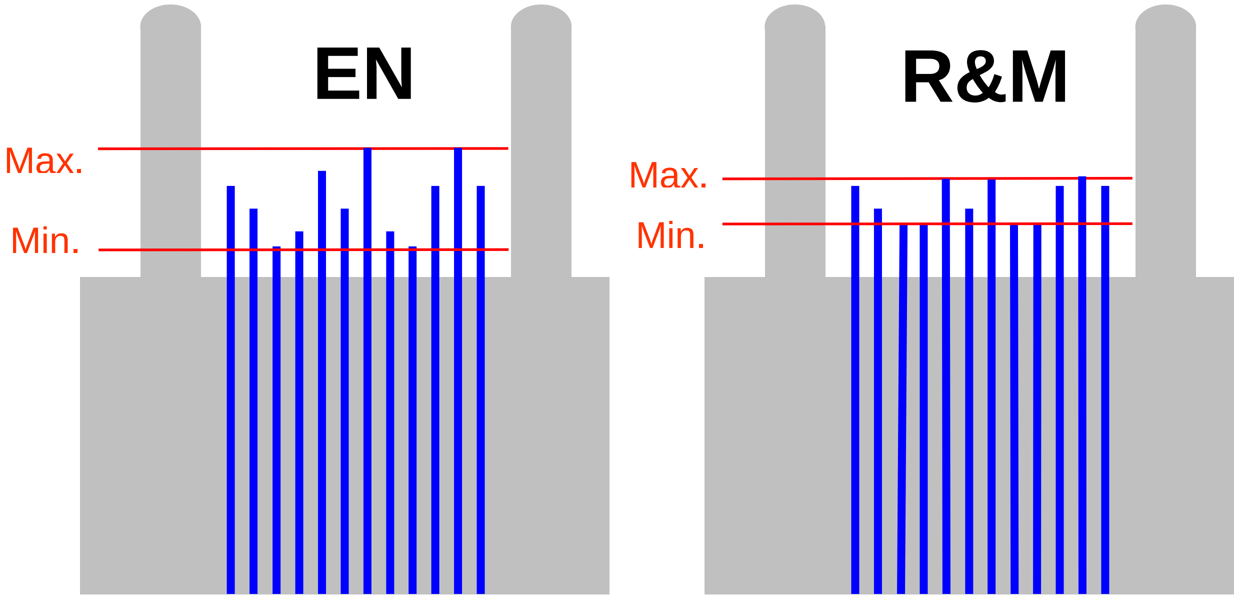

Figure 8: Fiber protrusion – minimum and maximum deviations according to EN 50377-15-1 and the much tighter tolerances set by R&M

But one not only has to keep in mind the height differences between all 12 or 24 fibers but also between the two adjoining fibers in each case. As mentioned above, the spring power is ideally distributed evenly across all fibers. At the same time, fibers become compressed if subjected to pressure. If a short fiber is flanked by two adjoining higher fibers, there is a chance it will not contact its counterpart in the other connector and thus increase the amount of insertion loss and return loss.

Particular attention must be paid to what is called core dip. This is the place where the fibers come into contact with each other in a connection and is a major factor in determining insertion loss and return loss. Core dip is a dip in the fiber core, as illustrated in Figure 9. It occurs during polishing because the core is somewhat softer than the fiber sheath due to its allocated purpose. EN 50377-15-1 says the depth of the core dip is not allowed to be more than 100 nm.

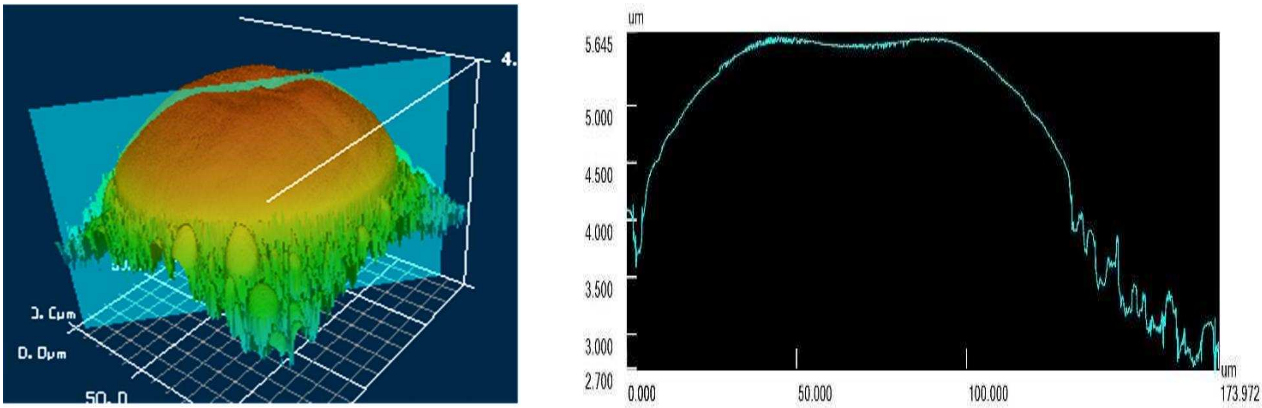

Figure 9: (Left) 3-D image of a fiber endface measured with a laser-scanning microscope. (Right) Profile of the same fiber.

In the case of a 24-fiber MPO/MTP® connector for 100GbE applications, the problem of optimum geometry becomes even more complex because these models have two rows with twelve fibers each that have to be polished. Optimizing the polish geometry is the prerequisite for ensuring the high quality of the connectors. But 100 percent testing during production is what guarantees compliance with these tolerances.

Further parameters

Besides fiber height and core dip, there are further parameters of crucial importance for the surface quality of fiber endfaces and thus for the transmission properties and longevity of a connector. Ferrule radius and fiber radius are two examples. Instead of focusing on just one value here, you must examine the geometry as a whole during production and quality control.

Refer to the white paper "Manufacturer-Neutral Quality Grades for Fibre-Optic Connectors" for further detailed information on the requirements FO connectors must meet and on the tough standards at R&M for production and quality control. You can download this white paper at www.rdm.com, under "Service/ Downloads".

100% tested = 100% quality

The tight tolerances R&M set are tougher than those in EN 50377-15-1 and ensure the top quality of the connectors. But 100 percent testing during production is what guarantees compliance with these tolerances. R&M therefore subjects all connector endfaces to an **interferometric inspection** (Figure 10). Defective ferrules are reworked until they comply with the specified tolerances.

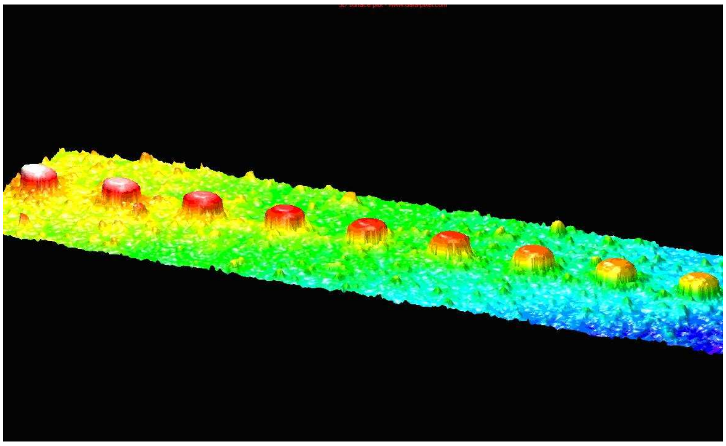

Figure 10: Interferometric test on connector endfaces

The **insertion loss and return loss** of all connectors are also checked. To reduce the insertion loss of connectors, the offset of two connected fibers must be as small as possible. R&M likewise measures the internal **polarity of the fibers in** all MPO/MTP® cables to be sure that it is correct. Polarity refers to how the fibers are connected, e.g. fiber Tx1 (transmitting channel 1) leads to Rx1 (receiving channel 1), Tx2 to Rx2, Tx3 to Rx3, etc.

2.3.3. Trunk cables

On-site termination of an MPO/MTP® connector with 12, 24 or even up to 72 fibers is obviously no longer possible. In other words, if you use MPO connectors you also have to use trunk cables (Figure 11) delivered already cut to length and terminated.

This approach requires greater care in planning but has a number of advantages:

- **Higher quality:**
  Higher quality can usually be achieved with factory termination and testing of each individual product. A test certificate issued by the factory also serves as long-term documentation and as quality control.
- **Minimal skew:**
  The smallest possible skew between the four or ten parallel fibers is crucial to the success of a parallel optical connection. Only then can the information be successfully synchronized and assembled again at the destination. The skew can be measured and minimized with factory-terminated trunk cables.
- **Shorter installation time:**
  The pre-terminated MPO cable system can be incorporated and immediately plugged in with its plug and play design. This design greatly reduces the installation time.
- **Better protection:**
  All termination is done in the factory, so cables and connectors are completely protected from ambient influences. FO lines lying about in the open in splice trays are exposed at least to the ambient air and may age more rapidly as a result.
- **Smaller volume of cable:**
  Smaller diameters can be achieved in the production of MPO cabling from FO loose tube cables. The situation changes accordingly: Cable volume decreases, conditions for air-conditioning in data centers improve and the fire load declines.
- **Lower total costs:**
  In splice solutions, a number of not always clearly predictable factors set costs soaring, e.g. splicing involving much time and equipment, skilled labor, meters of cable, pigtails, splice trays, splice pro-

tection and holders. By comparison, pre-terminated trunk cables not only have technical advantages but also usually involve lower total costs than splice solutions.

Figure 11: Pre-terminated cabling with MPO trunk cables from R&M simplifies the development, expansion, and consolidation of data centers.

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Convincing cabling solutions

3. The components in the system

MPO/MTP® connectors and trunk cables are central components of a parallel optical link. This connection decides whether the insertion loss exceeds the attenuation budget and whether the return loss is high enough. But in the end, the desired bandwidth can only be reached if all components in a parallel optical link satisfy the highest requirements, not just briefly after installation but for years beyond that.

R&M delivers top-quality, well-coordinated components for the entire link, which combine minimum insertion loss and maximum return loss with convenient installation characteristics and longevity.

Consult the white paper "Application of MPO Technology – Migration to 40/100 Gigabit Ethernet" for detailed information on setting up a parallel optical connection. This document contains details on the components, the planning of the structure and the attenuation budget. You can download this white paper at www.rdm.com, under "Service/Downloads".

4. Summary

The need for bandwidth continues to rise steadily and the next technologies are already waiting in the wings with 40 GbE and 100 GbE. Data centers will make broad use of FO lines even though copper solutions involving parallel twisted-pair cables will continue to be justified for short links. A look in the labs where engineers are already working meticulously on 1000 GbE confirms this general trend all the more.

With the currently available category OM3 and OM4 multimode FO lines, the required bandwidths can only be implemented using parallel optical connections. Single-mode fiber optics are only feasible for longer links for economic reasons. There is a big choice of the necessary passive and active components available and as installation increases, the market prices will continue falling.

Given the technical and economic advantages, managers in data centers should get an early start in converting their infrastructure to parallel optical systems based on MPO/MTP®. Anyone wanting to install a new system or upgrade an old one will opt for this technology anyway. The fear of fixed lengths of pre-terminated trunk cable is certainly not wholly unjustified. You can rid yourself of this fear, however, if you plan well with a partner you can trust. Moreover, trunk cables have definite quality and cost advantages over splice solutions.

R&M is a reliable partner for you. Not only can it supply you with all components in top quality, it also assists you competently with all questions involving planning, installation and maintenance.