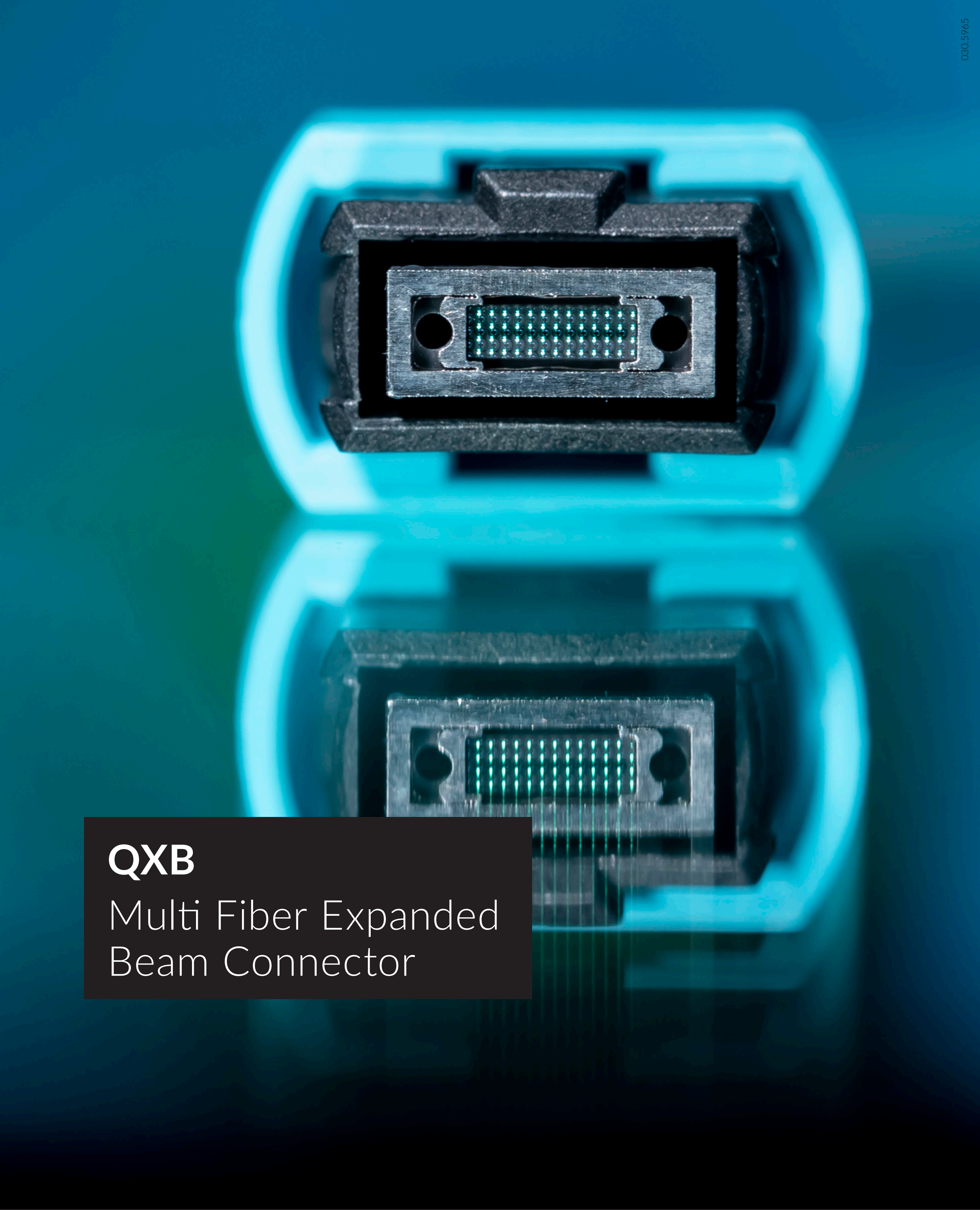

QXB

Multi Fiber Expanded Beam Connector

White Paper

September 2018 – English

R&M

030.5965

Currently MPO type multifiber connectors with 8, 12 and 24 fibers are widely used in many applications. They all have in common the necessity to be perfectly clean in order to ensure optimal signal transmission. 80% of the problems during installation and maintenance can be traced back to contamination, leading to deployment delays and excess costs of installation.

The optical multifiber connector for next generation optical networks has to guarantee long term reproducible performance and ideally should not need cleaning and inspection anymore.

R&M addresses challenges with a steady stream of new ideas. To provide stimuli, the company showcases its ideas for future connectivity in the form of connector studies such as the QXB. It is the outcome of a wide study in the search for high performance and the resilience against contamination by using the expanded beam technology.

Traditional optical connectors based on physical contact

Traditional optical connectors (single fiber e.g. LC and multifiber e.g. MPO) are based on physical contact (PC). In regular optical fiber links the fiber cores are aligned to each other and brought to physical contact with enough force to planarize the front ends and to eliminate any possible air gap. In the ideal case this creates a continuous propagating media where light can travel as if there was no medium discontinuity at all.

The drawbacks of physical contact are the high requirements to achieve optical performance: the cores must be perfectly aligned; the fiber ends must have a smooth optical polish and preferably be inspected and cleaned if needed before each mating. This intensive cleaning is to ensure the absence of any kind of dirt or debris, lest they may obstruct the passage of light or permanently damage the fiber face when trapped and pressed between the two fibers with the high forces usually used to mate optical fibers. In the case of multi-fiber connectors, the problems only get compounded by the laws of probability. Additionally, scaling to highly integrated connectors with 24, 32 or more fibers becomes a mechanical challenge for the connector design as the force required to mate them is proportional to the amount of fibers and not negligible at about 1N per fiber.

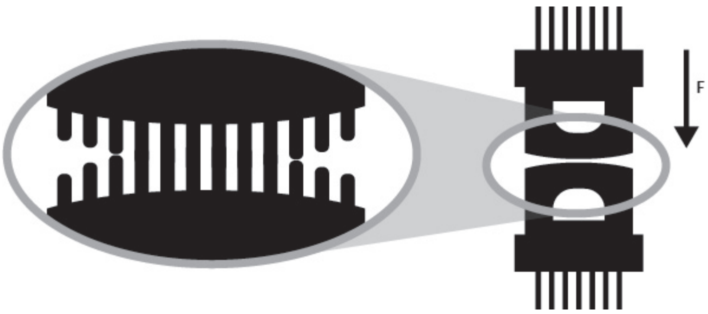

Figure 1
Ferrule front face geometry and fiber height difference. The force F is to ensure planarization and ensure physical contact of all optical fibers.

This high force is meant to ensure the planarization of not only the individual fiber tips but also the ferrule front face as this is not as commonly thought a flat surface but rather a curve as illustrated in Figure 1 .

The polish process produces a curved end-face for multifiber connectors with the center fibers protruding more than those on the edge of the connector. The maximum height difference is specified in standard EN 50377-15-1:2011.

Multifiber connectors are often used in applications where the access for cleaning, testing and inspection is difficult or in which the interruption of the service can be critical or unacceptable.   There are several devices available in the market that are designed for cleaning, testing and inspecting connectors that are difficult to access. Nevertheless, achieving satisfactory conditions for all fibers of one connector at the same time remains challenging.

Expanded beam connectors

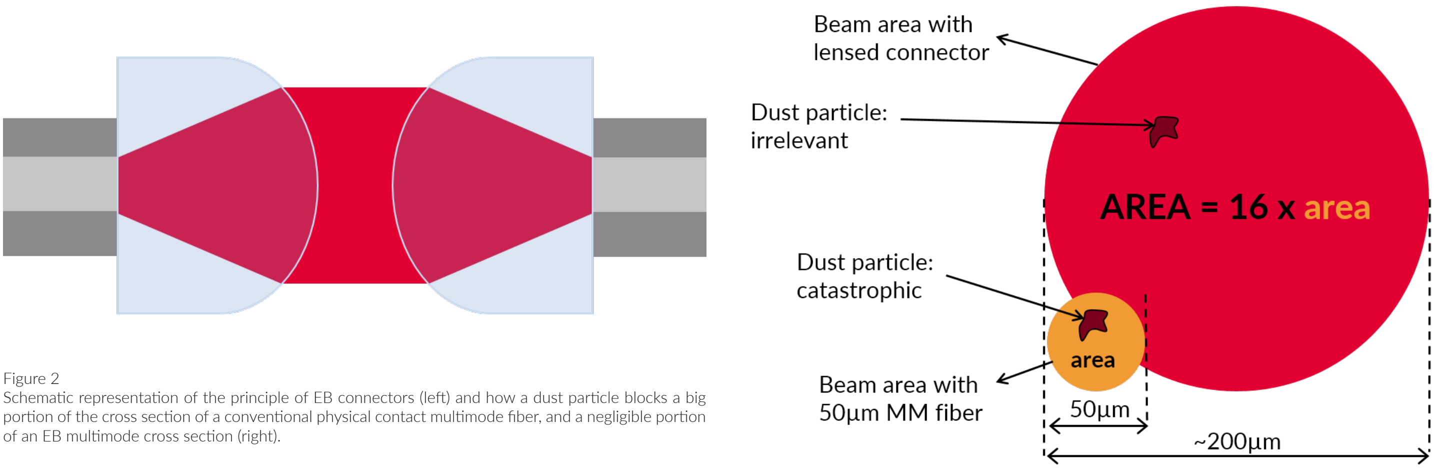

Figure 2
Schematic representation of the principle of EB connectors (left) and how a dust particle blocks a big portion of the cross section of a conventional physical contact multimode fiber, and a negligible portion of an EB multimode cross section (right).

The QXB connector is a strong candidate to solve these challenges for the next generation of optical fiber connectors. The working principle of the QXB connector is the expanded beam (EB) technology by means of micro lenses as shown in Figure 2 . The light is expanded and collimated by the first lens and focused again into the fiber on the second connector. The lenses are kept at a constant distance, thus making the light travel through an air gap. This non-contact principle is the same whether single mode (SM) or multimode (MM) transmission is used. This expanded beam working principle is already known and proven in applications like harsh environment and high power, mainly using ball lenses in single fiber products. The advances of the micro lens array technology open the door to new high density and multi fiber applications.

Benefits

One of the main benefits of expanded beam connectors is their insensitivity to contamination leading to a significant improvement in terms of reliability and mating repeatability, compared to standard physical contact connectors.

The contamination insensitivity principle is explained on the right side of Figure 2. It is obvious that a dust particle of the shown size has a catastrophic impact on the optical performance in the standard MM case, due to the light being blocked by this particle. By expanding the beam by a multiple of the initial diameter (from 50 to 200 µm in the MM case) the same particle has negligible impact on the light transmission.

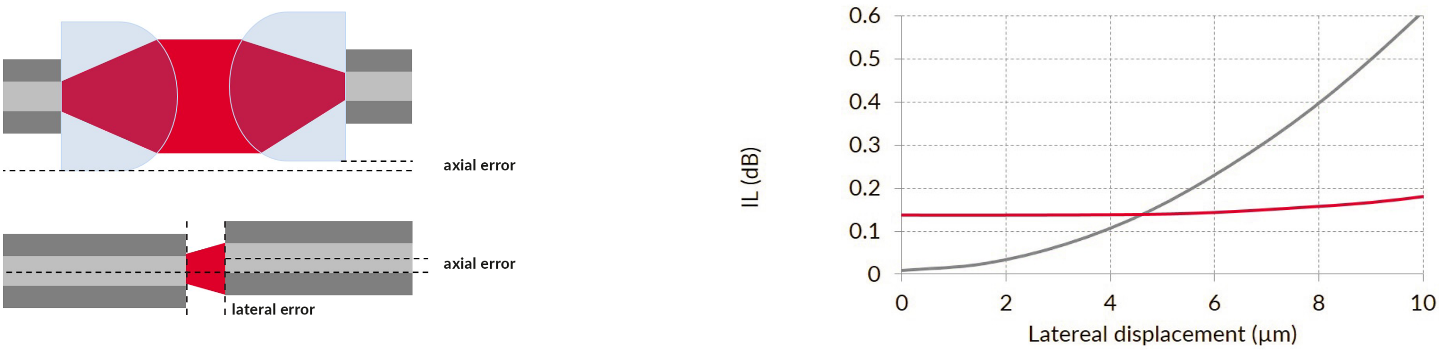

Figure 3
Schematic representation of the lateral and axial misalignment. Comparison of QXB and PC connectors (left). Numerical calculations of IL values for a connexion between OM4 fibers (blue) and QXB connectors (red) as a function of the lateral (i.e. radial) misalignment (right).

Another advantage of the EB technology is the increased tolerance against lateral misalignment shown in Figure 3. This lateral offset can occur if particles are located on the pins or the holes of the ferrule which can offset the original intended mating position.

A mechanical consequence of the non-contact principle is the minimal mating force needed to ensure mating reliability and stability of the connector. This is of great importance for multi-fiber connectors since in conventional MPO connectors, as shown in Figure 1, the mating force is proportional to the number of fibers and is not negligible at approximately 1N per fiber. This fact results in additional challenges for the mechanical design of the connector and for the operator at high fiber counts (i.e. 24 and above). Consequently, one further advantage of the non-contact QXB connectors is their scalability to high fiber counts. Even 48 or 64 fiber become feasible without an increase of the mating force.

All these benefit lead to an improvement of the handling and to a significant reduction of installation and maintenance time of multifiber connectors for all possible applications.

R&Ms approach – QXB

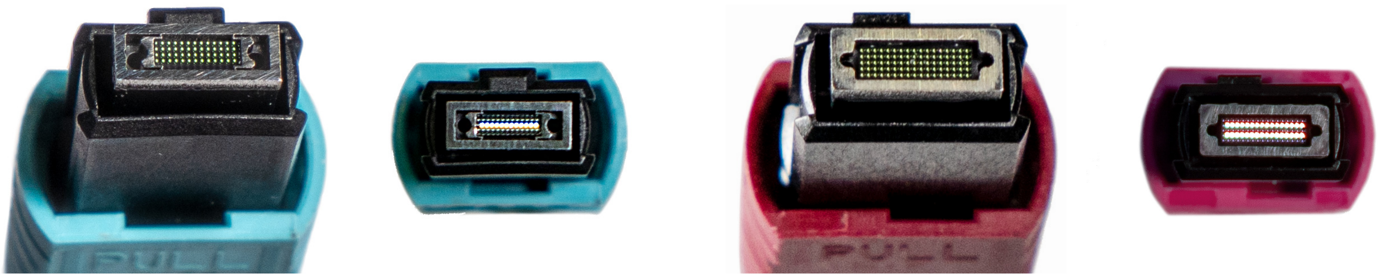

Figure 4
QXB Connectors in their 12 fiber MM and 32 Fiber MM versions

a. R&Ms expanded beam technology is built on the established MPO platform for multi-fiber connectors and is using the same footprint, adaptors and panels as the existing MPO products. The starting points are conventional MPO MM and SM ferrules for 8, 12, 16, 24, 32 fibers,

   The advantage of building on this existing MPO platform is the availability of the components and the broad market acceptance. Consequently, all existing MPO platforms of all different manufacturers can be used and there is no requirement for a new network layout. Even if the QXB connector is not compatible with PC connectors, the integration time and the costs for the migration to this new technology are therefore minimized.

b. The core optical element of the new connector is a glass micro lens array made of ultra-high purity fused silica, the same material as the fibers themselves. This is fabricated in a well-established wafer based lithographic process and diced to the needed size for 8,12, 16, 24 or 32 fibers. R&Ms proprietary optical design is optimized for the different types of fibers and wavelengths.

The advantage of using glass lenses is the optimal match of the optical refractive index to the optical fiber, leading to unprecedented return losses, which is not the case for polymer materials. The high temperature stability and durability of glass micro-lens arrays as well as their availability in high volumes, make them a very attractive choice for this application.

c. In the MM case, the area of beam is expanded by a factor of 16 to a beam diameter of 200 µm. In the SM case, we chose to expand the beam area by a factor of 30, to a beam diameter of 60 µm. Thanks to these values, QXB excels in its proven insensitivity to contamination.

d. In order to minimize the reflection loss at the lens-to-air interface, an anti-reflection (AR) coating is applied to the curved lens surface. This coating is optimized to the wavelength of 850 nm in the MM case and to 1310 nm and 1550 nm in the SM case. The coating process is well-established and used for glass optical components.

e. The process of alignment of the micro-lens array, the fibers and the ferrule is a critical step that directly determines the optical performance. R&M decided to use active optical alignment (AOA) of the lens array to the fibers and ferrule. AOA is an established technology, industry equipment for high volume production is available and results in a fast, automated and reliable process. The process is independent on the array size and thus on the fiber count of the connector.

f. Once mated the distance lens-to-lens in the adaptor is kept at minimum. This distance is controlled by a metal frame surrounding the lens which is attached to the ferrule and serves also as protection of the lens array. There is physical contact in the adaptor only at the frame surface. Therefore, a minimal contact force, given by the spring of the connector, is kept at low constant value independent of the fiber count.

g. In order to prevent a mixing with standard MPOs a new keying system is introduced.

QXB Technical Data

Optical Performance

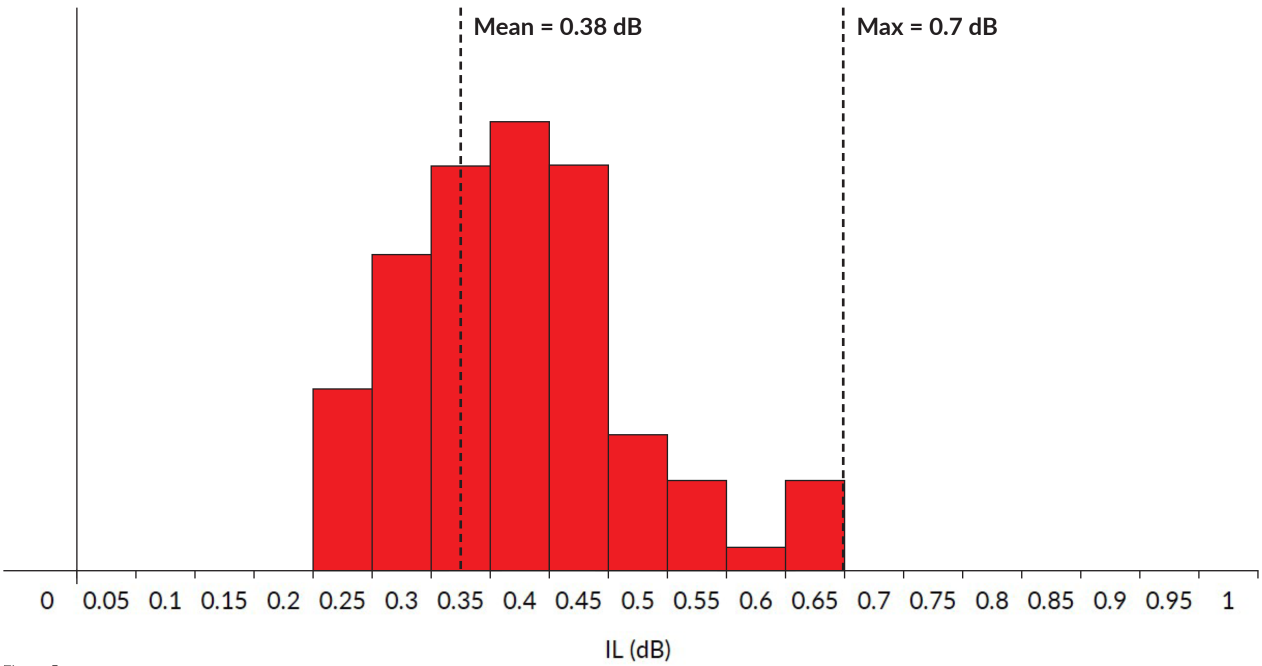

Figure 5
Histogram showing IL (dB) values resulting of a set of randomly mated QXB MM connectors. These connectors have been fabricated with bend insensitive ribbon OM4 fiber, in which the encircled flux condition has been guaranteed at the entrance of the in-coupling QXB cable.

Figure 5 shows a histogram with the IL values of a series of randomly mated 12-channel MM QXB prototypes. In a stable industrial process, we envision mean values around 0.3 dB and maximum values of 0.5 dB. The return loss (RL) values are stable and lower than -35 dB.

A further improvement of these values can be reached by a reduction of the tolerances of the arrangement of the fibers within the ferrule itself. This would require the development of a more precise ferrule in a joint development with a ferrule maker, was out of the scope of this study.

Insensitivity to contamination

The biggest benefit of the QXB connector, the insensitivity against contamination, was quantified and tested in a series of experiments, where office dust was used as contaminant. Expanded beam connectors have been compared to standard MPO connectors. The experiments were made as follows for both, QXB and MPO:

Step 1
A set of connectors were prepared and cleaned for the tests. Pictures, IL and RL measurements were taken in this initial ideal state of random pairs of connectors. For simplicity, we named in each pair the in-coupling connector "A" and the out-coupling "B". A typical example is shown in Figures 6a and 7a.

Step 2
For each pair of connectors, only connector A was contaminated and then mated with connector B. IL and RL measurements were then made and finally an image was taken. In this way, the contamination migration can be appreciated in each respective connector B in Figures 6b and Figure 7b.

Step 3
A simple clean air high pressure burst was the applied either to fibers (for the MPO contamination experiments) or to the lenses (QXB contamination experiments). An image was recorded and subsequently IL and RL were measured. This is shown in Figures 6c and 7c.

Step 4
A conventional wet-dry cleaning process was applied on all the fibers (MPO) or lenses (QXB). Images were recorded and IL and RL measurements were performed. A typical result is shown in Figures 6d and 7d.

Following the above described procedure, ten randomly mated MPO connectors as well as ten randomly mated QXB connectors we analyzed. Typical results are shown in Figures 6 and 7, while the full set of data will be published elsewhere.

The first striking conclusion of these measurements resides on the contamination migration. In the case of MPO connectors, the migration is notorious (Figure 6b), while in the case of QXB it is practically non-existent (Figure 7b). The reason behind this behavior lies in the physical contact nature of the MPO connectors and the non-physical-contact nature of the QXB connectors. For this very same reason, permanent damage appears in the MPO (Figure 6d) while the QXB B-connector shows no contamination nor damage at all (Figures 7b, c and d).

The way in which contamination affects the performance of both types of connectors can be seen by comparing the original performance (columns (a) of Figures 6 and 7) with that after applying contamination (columns (b) of the same Figures). The MPOs typically see their IL multiplied by a factor greater than 10, while the QXBs IL is typically multiplied for a factor of only 1.1. Additionally, the RL values also suffer an unacceptable change in the case of the standard MPO, because under these contamination conditions an air-gap appears between the fibers with the subsequent increase of the RL values. In the case of the QXB, the RL is not affected at all, and the fluctuation in the measured value corresponds only to the uncertainty of the measurement derived mostly from the instrument noise.

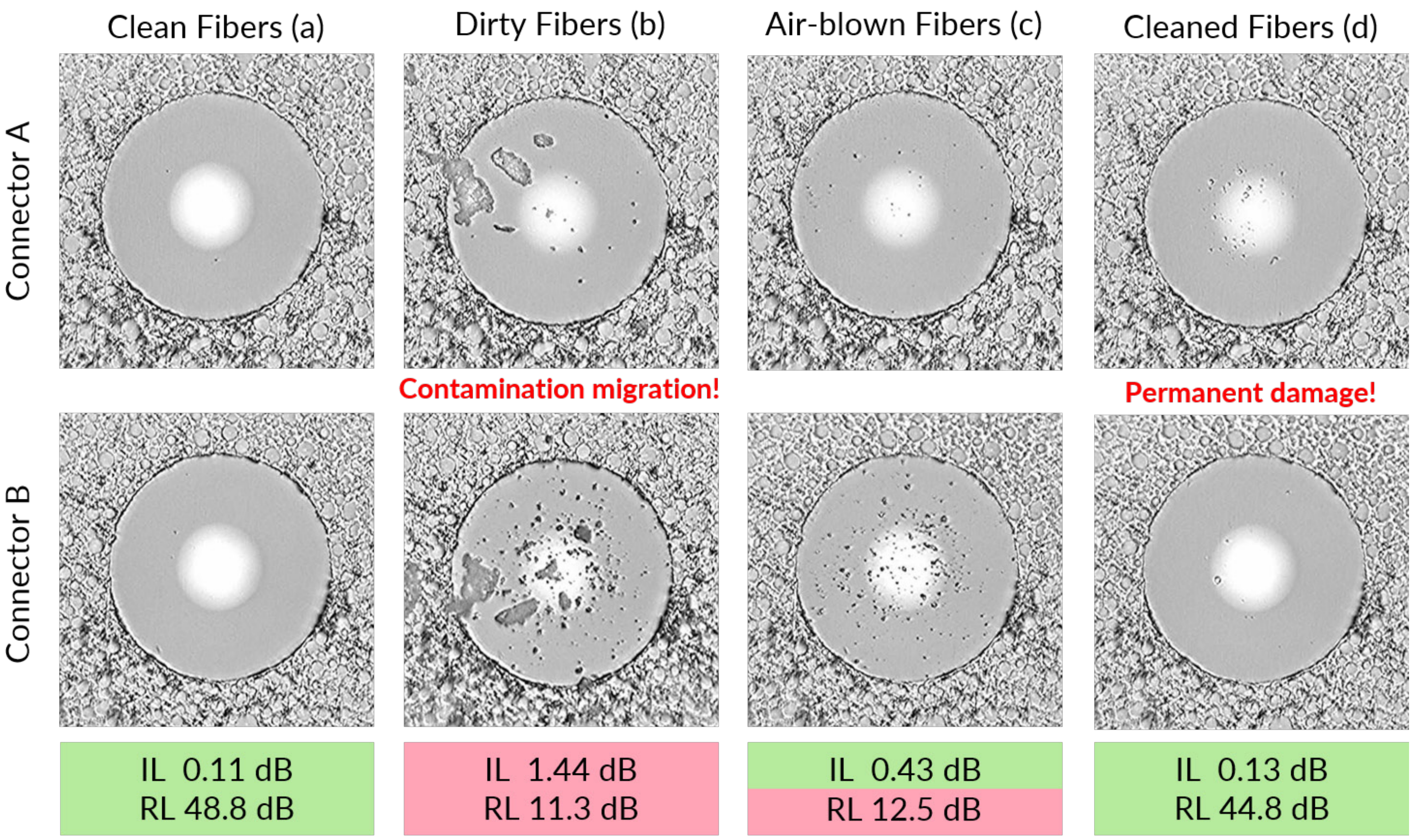

Figure 6
Typical results of the MPO contamination sensitivity test described in the text featuring a big overall change in the IL and RL. (a) Initial status of the fibers, (b) contamination on a fiber in connector A and transfer to a fiber in connector B, (c) status of the fibers upon blowing with high pressure clean air, (d) permanent damage appreciated on the fibers after wet and dry cleaning.

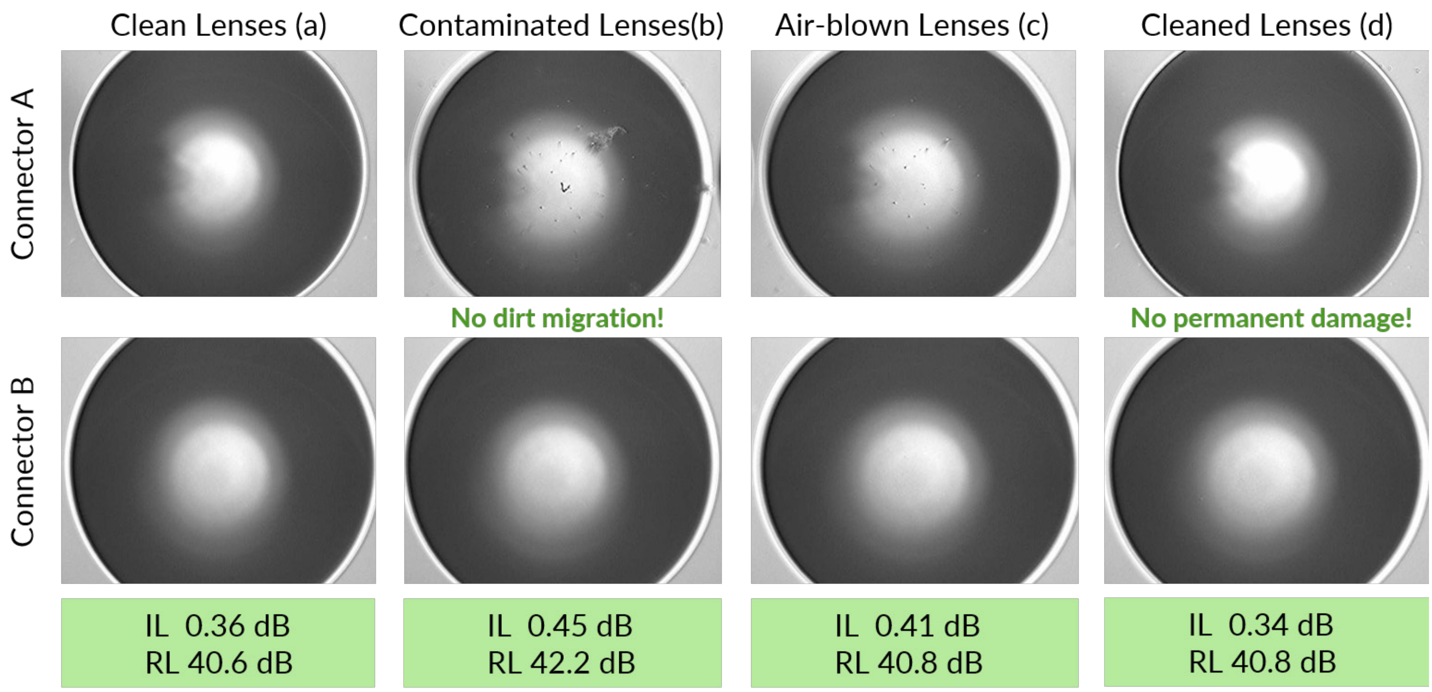

Figure 7
Typical results of the QXB contamination sensitivity test described in the text featuring a very small overall change in the IL and RL. (a) Initial status of the lenses, (b) contamination on a lens in connector A and negligible transfer to a lens in connector B, (c) status of the lenses upon blowing with high pressure clean air, (d) no permanent damage appreciated at all on the lenses after wet and dry cleaning.

Mating reliability & durability

The mating durability and mating reliability of the QXB has been also measured and compared to that of high quality MPOs for benchmarking.

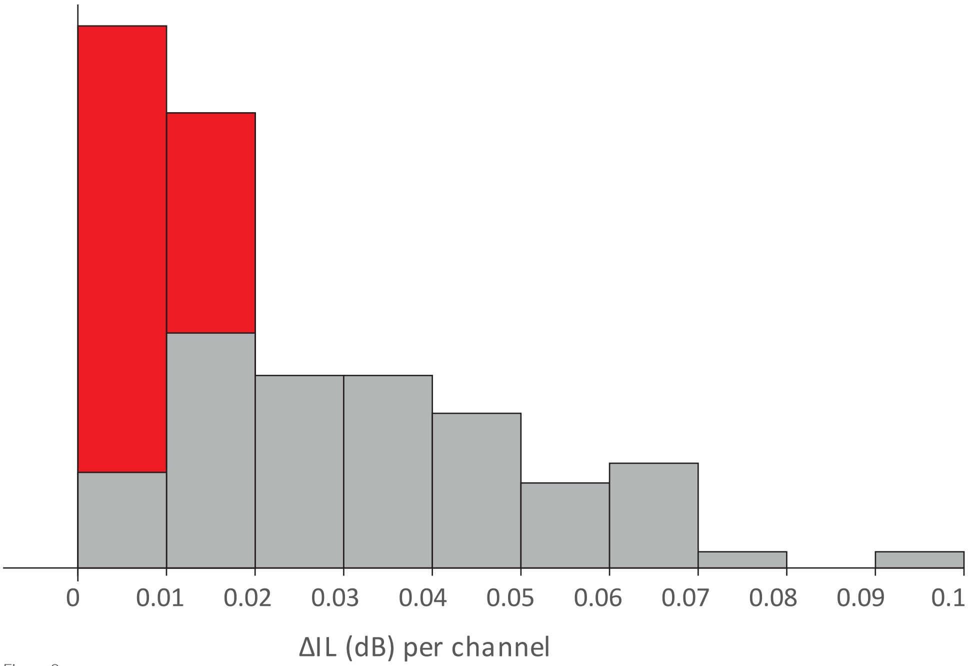

Figure 8
Mating reliability (max Δ IL)

Mating reliability is assessed by comparing ΔIL values of 15 samples randomly chosen during 10 times mating and measuring each time. The plot in- Figure 8 shows the maximum ΔIL recorded for the 5 samples. It should be mentioned, that the MPOs have been cleaned each time before measuring while QXB connectors where not cleaned. The QXB connector shows an outstanding reliability as compared to a typical MPO connector.

The mating durability testing is performed by measuring 100 mating cycles (see Figure 9). Also, here MPOs have been cleaned and inspected for each measurement while QXB connector have been measured without cleaning. The plots in Figure 9 show the ΔIL values for 3 different connectors of each type measured every 25 cycles for the first 100 mating's. The very low values for QXB connector (in green) demonstrate the high mating reliability and durability of this new connector technology.

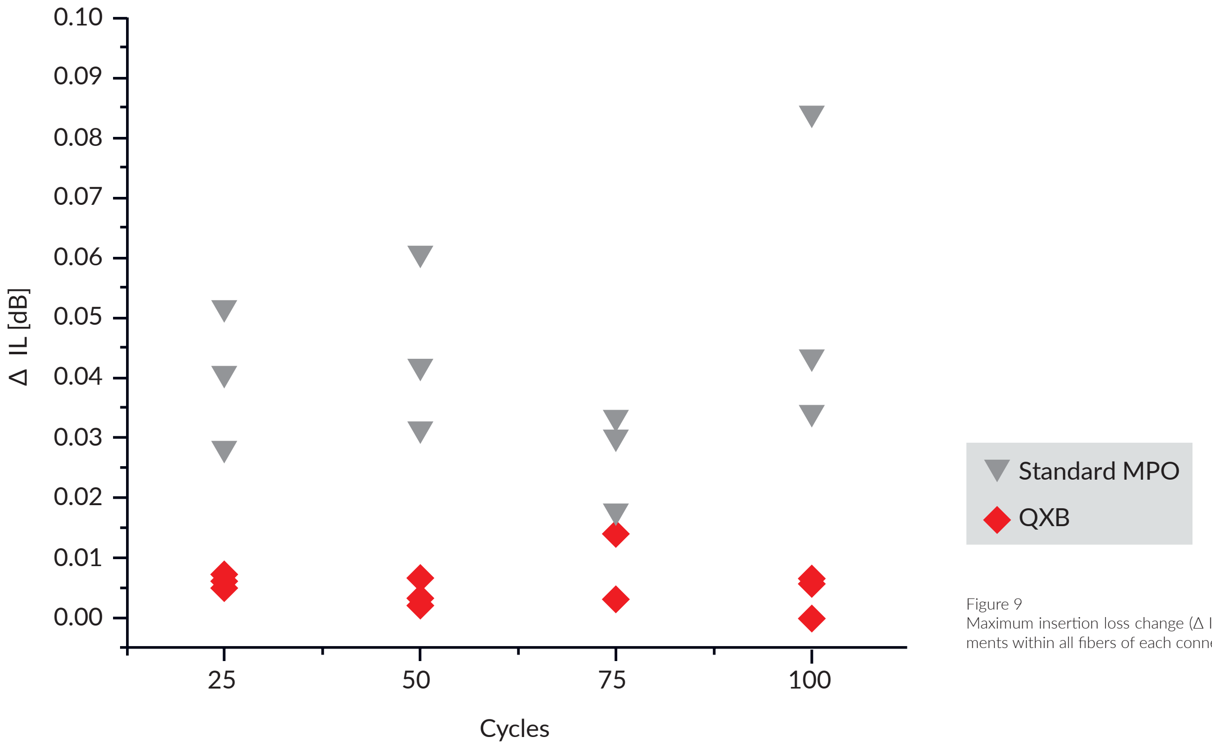

Figure 9
Maximum insertion loss change (Δ IL) of the mating durability experiments within all fibers of each connector tested.

In order to test the extended mating durability, the mating of QXB connectors was carried out up to 1000 mating cycles (see Figure 10). We observed no degradation of the ΔIL values.

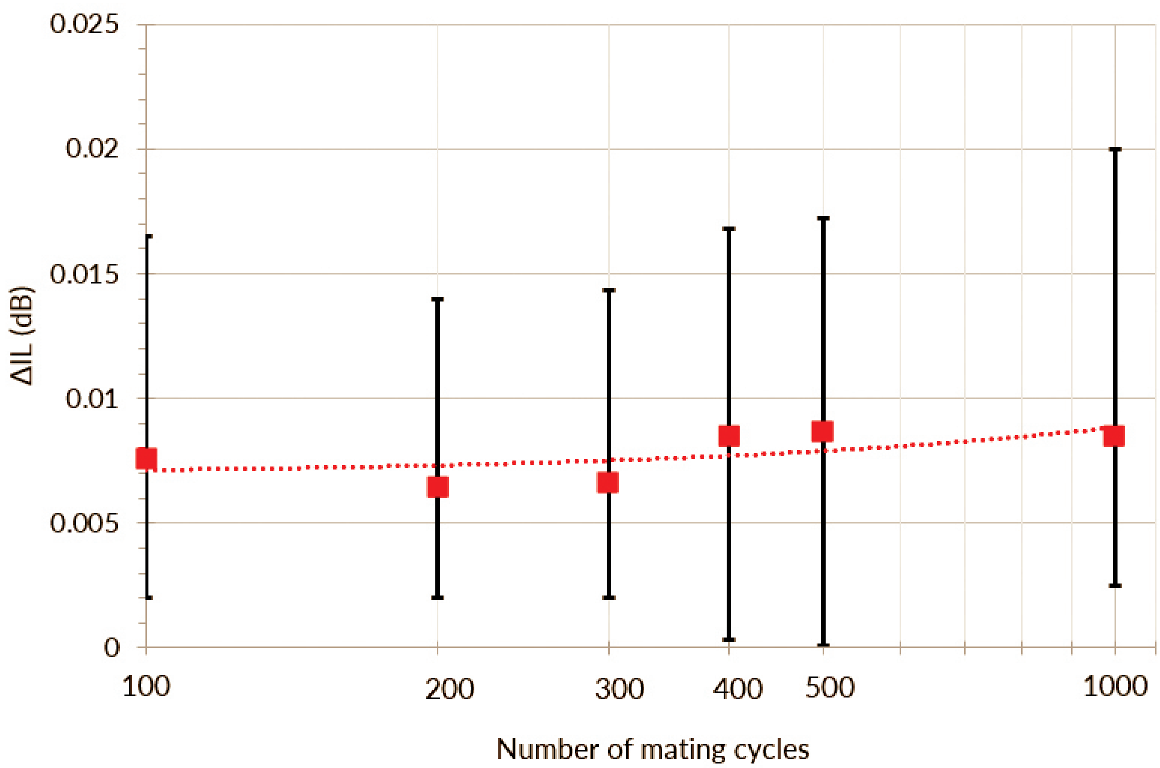

Figure 10
Extended mating durability of QXB connector. The bar shows the range of variation of the results for the individual channels of the connector while the square marks the average ΔIL of the connector. The dotted line is a linear fit of the global averages.

QXB Technology summary

Feature	Advantage	Customer value
MPO footprint	• Existing platforms and network layout can be still used	• Low migration cost • Use of existing DC layouts • No new operational skills requi-red • Fast rollout possibility
Glass micro lenses	• Perfect match of refractive index to fiber • AR coating is well established technology which allows a wide are of wavelength capability • AR glass coatings are very robust	• Excellent IL/RL values • High reliability, failure cost reduc-tion
No physical contact	• Low mating force. • Mating force independent of fiber count. • Easy scalability to high fiber counts	• Comfortable operation • Longer connector life • Contamination insensitivity • No contamination transfer bet-ween connector surfaces
Active optical alignment of lens to fiber array	• Automated, highly reliable and precise manufacturing process for both MM and SM applica-tions	• Optimized optical performance • Low installation failure risk