OPTICAL CONNECTOR PERFORMANCE AND 0.1dB CLASS

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Abstract: Aiming to satisfy optical network requirement in terms of performance and reliability, the technical performance of optical connectors is essential. Each connector performance depends on several parameters, which must be mastered during component manufacture and connector termination. DIAMOND produces every connector fulfilling all these strict conditions and can also provide its customers with optical products belonging to the 0.1dB class.

Performance in optical networks

The demand for real time information continues to grow placing high demands on today's communication networks. As a result there is an ongoing need to increase bandwidth throughout the entire network.
Dense Wavelength Division Multiplexing (DWDM) technology has become one of the most common methods for expanding network bandwidth. The use of DWDM allows to transmit multiple signals (wavelengths) in parallel on a single fiber. A direct impact of using DWDM is significantly higher power levels transmitted throughout the infrastructure (e.g. 64 channels {λ's} at 5mW = 320mW total transmitted power).
History has shown that most network failures occur at or within close proximity to a termination point. As a result component performance and reliability over time has become a critical factor in ensuring network performance.

The optical connector

The primary function of a connector is to provide a repeatable low loss connection between optical fibers. High performance (low loss IL_{max}. ≤ 0.1 dB) connectors must be able to minimize the factors, which lead to power loss over all environmental conditions. The primary drivers behind power loss are fiber-to-fiber core offset, fiber core angular misalignment, contamination at the optical interface, and lack (loss) of physical contact.

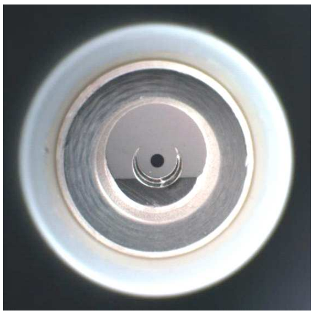

Fig.1: Front face 8° APC

In order to minimize the power loss at the optical interface, Diamond SA recommends to use a connector, which is able to provide very low eccentricity. (less than 0.15 microns). Material selection plays a critical role in maintaining the sub-micron tolerances noted above over a wide operating temperature range (typically –45ºC to 85ºC).
Fiber optic connectors are usually specified for a service life of 500 to 1,000 mating cycles and as a result, critical components in particular precision (alignment sleeves and ferrules components) are made of zirconia. Zirconia is an ideal material for these types of applications because unlike other materials (Bronze, steel, or plastic) it is a very hard and stable material (low coefficient of expansion), which can be manufactured to very tight tolerances.
The choice of ferrule and sleeve materials is also predominant for minimizing particulate contamination, which can accumulate during connector mating cycles.
Ensuring fiber-to-fiber physical contact, the last major factor behind power loss in optical connectors, is accomplished by maintaining proper connector end face geometry (Fig 1,2 and 3).

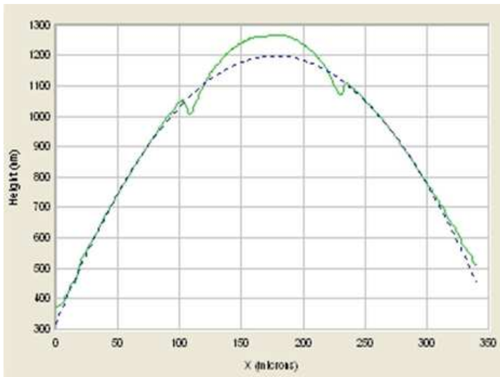

Fig. 2: 2D Section of a ferrule

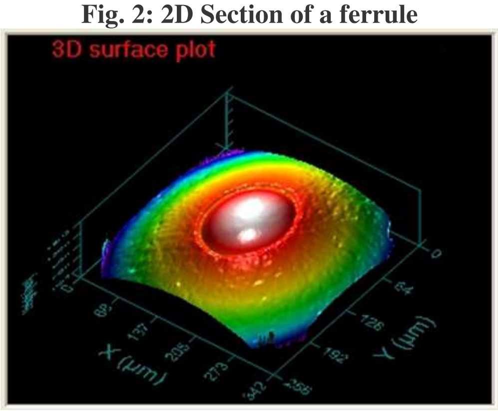

Fig. 3: 3D surface plot of a ferrule (interferometer measurement)

Diamond active core alignment

Diamond's high performance connectors are manufactured using only the highest quality materials coupled with our advanced fiber optic component manufacturing processes developed over the last 30 years. The goal is to reduce IL by minimizing fiber-to-fiber eccentricity. The result is a patented composite ferrule and the related "Active Core Alignment" technology.
The assembly process starts with the ferrule, which is made of a high quality zirconia sleeve and a titanium end face insert. The ferrule is then precision ground (< 0.5 µm OD tolerance) and drilled out to approximately 128µm. The fiber to be terminated is then stripped, cleaned, inserted and fixed into the ferrule by means of epoxy-glue. A circular crimping tool is then applied to the end face aiming to calibrate the drilled bore to the outside diameter (OD) of the fiber providing its pre-centering with respect to the OD of the ferrule (Fig. 4).

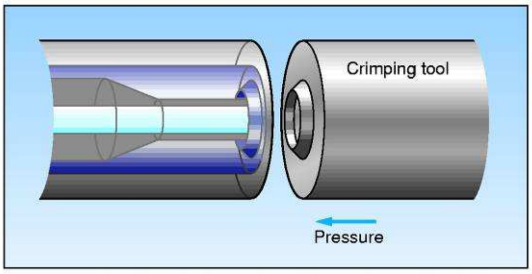

Fig. 4: Crimping process. The fiber is pre-centered with respect to the outside diameter of the ferrule

Once the epoxy is fully cured, the ferrule assembly is placed into a high precision measuring device, to determine fiber core eccentricity with respect to the ferrule OD. This measurement is performed by means of injecting visible incoherent light and rotating the ferrule over 360º facing a CCD camera to detect core position trough light spot displacement analysis.
The use of the computer assisted setup and the advanced active core alignment (ACA) software algorithm allows to precisely measure the eccentricity of the fiber core with respect to the ferrule OD.
(Fig. 5).

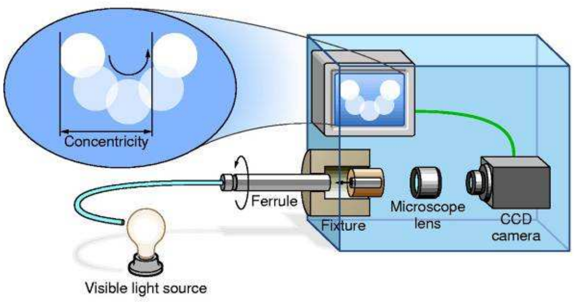

Fig. 5: Detection of the fiber core eccentricity with respect to the outside diameter of the ferrule

With this information and a 2nd crimping tool it is possible to reduce the fiber core eccentricity to <0.125µm (Fig. 6).

This process is used on both PC and APC terminations and the measurement results (eccentricity, tilt angle, IL, and RL) are automatically traceable for each termination.

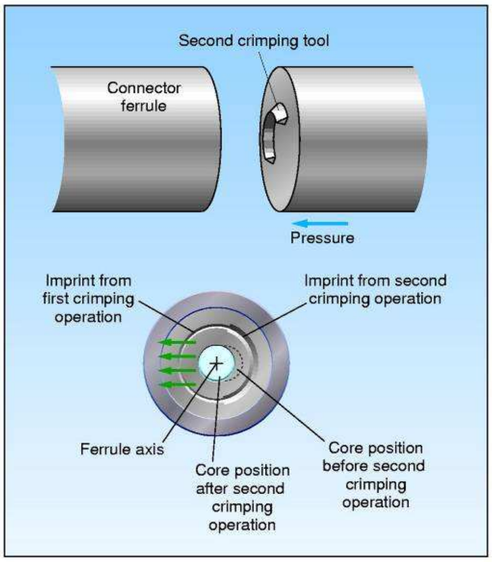

Fig. 6: second crimping process and definitive active core alignment process

Diamond's "actively aligned" connectors are available in most common connector housing styles (E-2000™, F-3000™LC, ST, SC, MU, FC, DIN, HMS, Fusion splice-on connectors, etc.) and are fully compatible with conventional ceramic connectors.

Diamond 0.1 dB class

The optical performance of a fiber optic connector can only be guaranteed by keeping several parameters under control such as:

- Ferrule diameter, form and hole concentricity;
- Polishing parameters;
- End face imperfections: scratches, pits and contamination;
- Insertion loss, Return Loss etc.

Aiming to achieve superior optical performance *(0.1dB first class connectors)* these parameters must be mastered during all relevant steps of the manufacturing and assembly process.

The result of an IL-measurement is highly influenced by major measurement uncertainties (reference connector and adapters, fiber MFD tolerances, uncertainties related to the measurement instrument) and cannot therefore be used as the unique criteria for the definition of performance grades for optical connectors.
The worldwide accepted IEC-61755 Standard series "Fiber optic connector optical interface" describes performance grades for connectors terminated on SM-fibers. These standard series define a set of prescribed conditions which must be maintained in order to satisfy certain requirements for the attenuation and return loss performance in a randomly mated pair of fibres.

If physical contact between the fibers is guaranteed, the most significant parameters affecting attenuation are, **lateral offset** and **angular misalignment**.
By maintaining specified limits on these parameters, the performance of the different classes can be guaranteed when connectors are randomly mated.

Resulting IL contour lines

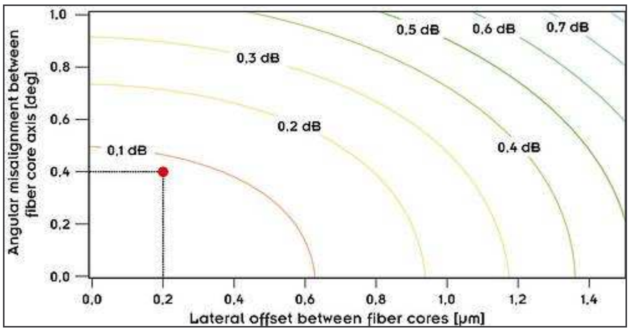

Fig. 7: IL contour lines of optical connections of SM fibers

The figure 7 shows resulting IL contour lines of optical connections of SM fibers. The red spot in this graph indicates a connection, where the lateral offset between the 2 fiber cores is 0.2µm and the overall fibre misalignment is 0.4 degree, resulting in an IL-value below 0.1 dB.

DIAMOND has always developed and produced fiber optical connectors according to these principles.
The eccentricity and tilt angle parameters of the connectors are rigorously taken under control and measured at 100% during the termination process, and all the stringent parameters of each connector that is produced are also recorded.
By insuring that each parameter is controlled during termination (fiber eccentricity < 0.125µm and tilt angle < 0,4°) the "0.1 dB class" can be guaranteed for randomly mated connectors.

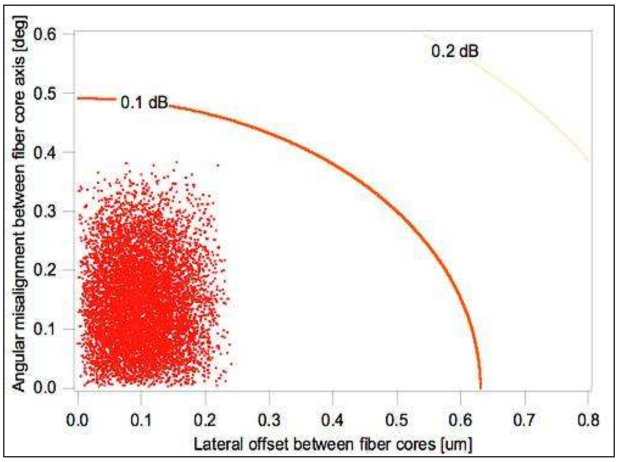

Fig. 8: Simulated results of the Diamond 0.1dB first class connectors

Simulated results of the "0.1dB First Class" connectors:

- 10.000 connectors with "0.1dB class" tolerances were mated numerically, the resulting fiber cores lateral offsets and angular misalignments were calculated, illustrated with red spots in the above graph (Monte-Carlo-Simulation);
- To be noted that all IL calculated values are located below the 0.1 dB level curve!

Conclusion

By controlling the tolerances of fiber core eccentricity and angular misalignment, Diamond is able to define an optical performance grade, with guaranteed random mated attenuation within "0.1dB first class".