PHOTONICS

FIBER OPTIC SOLUTIONS FOR DEMANDING APPLICATIONS

DIAMOND
the fiber meeting
Fiber Optics are being used increasingly in commercial applications because of it's bandwidth capacity, environmental durability, and it's ability to be deployed in numerous applications and markets. The light transmitted by fiber optics can be used as a power source, a digital signal transfer, or for analog analysis in sensing and measurement applications.

In the past optical fibers were used primarily in the data and telecom industries, but new research has resulted in many new applications for fiber optic components. These applications cover markets such as: Bio-medical, Measurement instruments, Laser delivery, Sensing.

Fiber optic solutions that satisfy the increasing demands for customer specific challenges and requirements, can only be offered from companies like Diamond who exhibit the following competencies thanks to a vertically integrated structure:

- **Mechanical:**
  - Integrated Ceramic production (pressing, sintering, machining)
  - Precision metal machining (drilling, milling, EDM), with expertise in hard metals, (Ti, WC, Kovar, stainless)
  - High quality plastic injection
  - Ultra-high precision lapping
  - Ultra-high precision drilling
  - Fiber-ferrule polishing

- **Optical:**
  - Fiber Active Core Alignment (A.C.A)
  - Active Polarization Orientation (A.P.O)
  - Expanded beam technology: contact (PS), non contact (X-beam, PSf)
  - Splice technology (MM, SM, PM, dissimilar fiber, PCF fibers)

- **Assembly:**
  - Epoxy Polymerization
  - Modules termination (Active or Passive, PM, PS)
  - Sealing (epoxy)
  - Active component alignment and laser welding
  - Clean room packaging

- **Measurement:**
  - High quality and reliable test and measurement of fiber optic components, in an accredited laboratory with the capability to simulate multiple environments.
DIAMOND TECHNOLOGIES FOR FIBER OPTICS

COMPOSITE FERRULE (CF)
Diamond technologies are all based on a composite ferrule. Instead of a full ceramic ferrule, Diamond has opted for a composite ferrule formed of a Zirconia ceramic sleeve and a Titanium metal insert.

Advantages:
➔ Custom drill sizes from 80µm to 800µm
➔ Superior Ultra polishing
➔ Allows plastic deformation for our Active Core Alignment
➔ Custom ferrules for multi-fiber technology
➔ Ultra-Low ferrule O.D. tolerances

ACTIVE CORE ALIGNMENT (ACA)
Insertion Loss mainly depends on two parameters; the lateral offset between the two fiber cores and the angular offset (between the two fiber core axis) according to the following formula:

\[ IL = K_1 d^2 + K_2 \theta^2 \]

Where:
\( K_1 \) A coefficient increasing quadratically inversely to Mode Field Diameter (MFD)
\( K_2 \) A coefficient not dependant to MFD
\( d \) The lateral offset, dependant on concentricity, ferrule and sleeve diameter tolerances
\( \theta \) The angular offset, dependant on fiber exit angles

Diamond’s Active Core Alignment, (ACA) is the technology Diamond utilizes to control these variables. During this process the endface is deformed, after the fiber has been polymerized in place, in order to center the core of the fiber with the mechanical axis of the ferrule.

Advantages:
➔ Ultra low Insertion Loss (IL)
  - 0.1dB Grade for SM Telecom fibers
  - Unbeatable low IL for small core diameters
➔ High Return Loss (RL)
➔ Applicable on PM fibers, outperforming IL performance of any other technology

Available in the following products:
➔ SM, 0.1dB grade, LW (low wavelength), PS (Power solutions), PM (Polarization maintaining), and X-Beam (Expanded Beam).
EXPANDED BEAM (EB)

Diamond uses different methods for expanded beam alignment, depending on the final use of the assembly. The main expanded beam types can be defined as following: spliced GRIN lenses, Ball lenses and spliced glass rod-, or endcap.

Spliced GRIN lens

Splicing a GRIN (Gradient Index) lens to expand a beam has been used by Diamond for more than 10 years, in order to improve power handling. A GRIN lens is spliced at the end of a SM fiber and it’s length is polished to result in a collimation of the SM beam. Two such connectors, when mated, achieve an exceptionally low IL.

Diamond proposes the SM Power Solution (PS) Optical Interface using this technology

Advantages:

➔ Lower Power density (20x)
➔ Collimated beam
➔ Low insertion loss

Available in the following products:

➔ Diamond Power Solution (PS) Optical Interface for contact connectors
➔ Custom products for sensor illumination without additional lens
Ball lens
A ferrule is placed behind a ball lens which is glued into a housing. Depending on the concentricity, the expanded beam exits the lens at a certain angle. To minimize this exit angle, Diamond uses the ACA process to minimize the exit beam angle.

Advantages:
➔ Easy field handling and cleaning
➔ Less sensitive to dust

Available in the following products:
➔ Diamond X-Beam (in conjunction with ACA for SM)

Spliced glass rod or end-cap
A glass rod can be spliced at the end of a SM fiber. This allows the beam to be expanded before it exits the glass, diminishing the power density at the glass-air interface. This technique is used for high power applications, at the injection or at the output to minimize the chances of burns at the interface. Diamond provides the SM Power Solution Freespace (PSf) Optical Interface using this technology.

Advantages:
➔ Lower Power density (60x)
➔ Compact

Available in the following products:
➔ Diamond Power Solution free space PSf Optical Interface for non-contact connectors
**POLARIZATION ORIENTATION (PO)**

Polarization plays an important role in the industrial photonics market. Sensors and communication systems have been designed using Polarization Maintaining or Polarizing fibers. Special connectors are required for such fibers, because their connection must be made with a certain orientation. Only connectors with an orientation key are capable of properly terminating these fibers.

The connector key for a Polarization Maintaining connector can be aligned to the stress members (Passive Polarization Orientation, PPO) or to the true optical axis (Active Polarization Orientation, APO).

**Advantages:**
- Ultra low Insertion Loss
- High Extinction Ratio
- High Return Loss

**Available in the following products:**
- Diamond Polarization Maintaining PM Optical Interface

**EPOXY Sealing (PM)**

In order to route a fiber assembly into facilities with different atmospheric pressures, a feedthrough needs to be utilized. These can be vacuum or high-pressure based and are defined normally by a leak test. Diamond has developed a technology using special epoxy polymerization and geometry to manufacture a feedthrough minimizing this leak rate and compatible with all optical fibers and optical interfaces.

**Advantages:**
- Low leak-rate
- Wide temperature range
- Easily Adaptable to various flange standards

**Available in the following products:**
- Vacuum Feedthrough (V-FT)
OPTICAL AND CONNECTOR INTERFACES

As a global company Diamond standardizes its products according to existing IEC standards. Each termination is composed of an optical interface and a connector interface. The following section lists the applicable standards for Diamond’s products. For complete information please refer to our website catalog.

CONNECTOR INTERFACES – IEC 61754

This standard is a collection of physical features on a connector assembly that defines a specified style. It consists of those minimum features that are functionally critical during the mating and un-mating sequences of the connector with its counterpart component. The interface defines the sizes, relative locations, and tolerances for each of the features. It includes references, definitions, and rules for creating and interpreting the standard drawings.

OPTICAL INTERFACES – IEC 61755

An optical interface standard is a multi-part collection of the requirements necessary in order to comply with the optical functionality specifications for a defined interface between two optical fibers. It consists of those essential features that are functionally critical to the optical attenuation and return loss performance of an optical interface in the mated condition. This standard provides general information on single-mode optical interfaces, defining the location of the fiber core in relation to the datum target and the following key parameters: lateral offset, end face separation, end face angle, end face high index layer condition.

<table>
<thead>
<tr>
<th>Connector Interface</th>
<th>Optical Interface</th>
<th>Standard</th>
<th>0.1 dB Grade</th>
<th>VIS/NIR</th>
<th>PS</th>
<th>PM</th>
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<tbody>
<tr>
<td>F-2000™</td>
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<td>SM</td>
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<tr>
<td>F-3000™</td>
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<td>MM</td>
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<td>AVIM</td>
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<td>Mini-AVIM</td>
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<td>SC</td>
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<td>ST™</td>
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<td>MU</td>
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<td>FISMA</td>
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<td>Diamond</td>
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</table>

* available on demand, but not qualified

In the following pages the emphasis is on Diamond Optical Interfaces. For details on Connector Interfaces and IEC standardized Optical Interfaces, please refer to our standard catalog.
0.1 dB GRADE - SM ULTRA LOW LOSS

The 0.1 dB Grade is Diamond’s proposal for a Grade A definition for IEC quality grade standards. At this time there is no formal definition for the Grade A in IEC standards, nevertheless, Diamond is promoting this quality grade under the 0.1 dB Grade name.

0.1 dB Grade Optical Interface:
➔ ACA, eccentricity < 0.125 µm
➔ Exit angle < 0.4°
➔ 0.1 dB Grade ferrules: low diameters tolerance (<0.2 µm)
➔ Ultra polish with 100% Endface inspection

This quality grade retains it’s name for the performance obtained with ITU G.652 D fiber which corresponds to a 0.1 dB at 97% limit, random mated according to IEC 61754-3-34.

Applications:
➔ High quality Networks
➔ High speed Networks
➔ High speed equipments

VIS/NIR - SM LOW WAVELENGTH

Small core fibers used mostly for visible and near infrared wavelengths (VIS/NIR), have not been addressed by standard groups. The A.C.A technology allows Diamond to provide the following specifications.

<table>
<thead>
<tr>
<th>VIS/NIR - SM Low Wavelength Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>WAVELENGTH (NA 0.12±0.02)</td>
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<tr>
<td>------------------------------</td>
</tr>
<tr>
<td>1060 - 980 nm</td>
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<tr>
<td>830 - 780 nm</td>
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<tr>
<td>735 nm</td>
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<tr>
<td>532 - 460 nm</td>
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<tr>
<td>405 nm</td>
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<tr>
<td>TEST CONDITIONS</td>
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<td>------------------------------</td>
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</tbody>
</table>

The previous values are intended on E-2000™. For other connectors, a slight increase up to 0.05 dB on the IL is due to the connectors interface.

VIS/NIR Optical Interface:
➔ 0.1 dB Grade ferrules with diameter tolerance < 0.2 µm
➔ ACA with Ultra low eccentricity < 0.125 µm
➔ Exit angle < 0.6°
➔ Ultra polish with 100% Endface inspection

Applications:
➔ Bio-Medical diagnostics and treatment
➔ Visible light laser
**PS · SM POWER SOLUTIONS**

The Power Solution optical interface is based on contact Expanded Beam GRIN lens technology. It has been qualified at 1310/1550nm using ITU G.652-D and ITU G.657-B3 fibers and at 980nm using Corning HI-1060 fiber. Its power rating is limited by the cleanliness of the connectors, but has been improved by a factor of 15x compared to standard connectors. Applications up to 3W CW for 1310/1550nm and 1W CW for HI-1060 have been validated.

### PS Optical Interface:
- 0.1dB Grade ferrules with diameter tolerance < 0.2µm
- ACA with low exit angle < 0.1°
- Eccentricity < 7µm, keyed
- Increased Mode field Diameter < ca. 35µm
- Ultra polish with 100% Endface inspection

### Applications:
- Raman (1310/1550nm) and EDFA (980nm) amplifiers
- 100G backbones
- High power (>300mW CW) networks
- Collimator replacements for detectors

### PSf · SM POWER SOLUTION – FREE SPACE

The PSf optical interface is designed for free space applications (injection or output) of high power intensities. It uses our Expanded Beam end-cap technology and diminishes the occurrence of fiber burn due to small particles at the interface.

### PSf · SM Power Solution Free space Specification

<table>
<thead>
<tr>
<th>OPTICAL SPECIFICATION</th>
<th>TEST CONDITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard spot diameter, D</td>
<td>B* MFD at 1/e2 or 13.5% at requested λ</td>
</tr>
<tr>
<td>Numerical aperture, NAb</td>
<td>&gt;80% NAb 1 dB below std. PM</td>
</tr>
<tr>
<td>Extinction Ratio, ER (Psf · PM)</td>
<td>Similar to IEC 61300-3-40</td>
</tr>
<tr>
<td>Ellipticity</td>
<td>&lt;15%</td>
</tr>
<tr>
<td>Eccentricity</td>
<td>&lt;5</td>
</tr>
<tr>
<td>Ferrule radius</td>
<td>&gt;40 [µm]</td>
</tr>
</tbody>
</table>

### Applications:
- High Power (>50mW) visible (400nm..600nm) laser source injection
- Free-space output for connector protection
**PM - SM POLARIZATION MAINTAINING**

The use of Diamond Active Polarization Orientation with a special Active Core Alignment process, avoids any residual stress in sensitive PM and PZ fibers, and allows us to achieve the below listed performances. These performances can vary depending on manufacturers.

**PM Optical Interface:**
- 0.1dB Grade ferrules with diameter tolerance < 0.2µm
- ACA with low eccentricity < 0.15
- Exit angle < 0.6°
- Active Polarization Orientation (APO) < ±2°
- Ultra polish with 100% Endface inspection

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![PM SM Polarisation Maintain Specification Table](image)

The previous values are intended on E-2000™. For other connectors, a slight increase up to 0.05dB on the IL is due to the connectors mechanical interface.

**Applications:**
- Interferometers for metrology or semiconductor industry
- Research & Development
SPECIAL INTERFACE PRODUCTS

Applications with fibers are not only based on physical contact, but also other types of interfaces. Light must be injected in fibers and must get out to illuminate a target too. In some cases, feedthrough to go through dissimilar ambient are necessary. The following products corresponds to the standardized solutions developed for these applications. Others are regularly designed or customized for specific applications.

MAS – MULTIPURPOSE ADAPTER SYSTEM
The Multipurpose Adapter System (MAS) is a hybrid flexible adapter. The Universal adapter is mounted on a chassis or used on a bench and is available in FC or Mini-AVIM. The other side of the adapter is changeable on the fly and is available in the following mechanical interfaces: E-2000™, SC, LSA DIN, ST™, F-3000™ (100% compatible with the LC), FC (wide and narrow key).

Interchangeable adapters (upper), Universal Adapter (lower)

Advantages:
➔ Easy use
➔ Low insertion loss
➔ Large choice of Mechanical Interface
➔ Easy cleaning of internal connectors

Applications:
➔ Measurement instruments
➔ Light sources

IMOD – INTERFACE MODULE
The Interface Module (IMOD) is used to terminate a connector for free space applications. Various options are available to fix the ferrule in a location optimal for your application.

Fig. 1 Without any stopper; for applications which does’t require specific tolerances or exact ferrule axial positioning.
Fig. 2 With ferrule ZrO2 cylinder stopper, for a good axial repeatability.
Fig. 3 With ferrule front face stopper, for superior axial repeatability.

These options can be adapted to most mechanical interface for PC, and APC versions, such as: E-2000™, SC, F-3000™, ST™, LSA (DIN), FC, Mini-AVIM.
**Advantages:**

➔ Easy implementation
➔ High Position reproducibility
➔ Long service life

**Applications:**

➔ Laser launch
➔ Instrument front panel connection
➔ Custom adapters

**V-FT – VACUUM FEEDTHROUGH**

Feedthroughs have been produced by Diamond for twenty years using a proven epoxy sealing technology. Diamond has standardized this sealing process and is now offering an off-the-shelf solution for the Vacuum Feedthroughs.

Diamond offers V-FT's based on a standard ConFlat (CF) flange, (DN16 size, OD 40mm). These flanges can be used with rubber seals for High Vacuum, or with one-time-use copper seals for Ultra-High Vacuum. Thanks to the MAS universal flange, most of the optical connectors can be mounted on the atmospheric side. Whereas on the vacuum side, due to the environment limitations, only the following connectors are available; AVIM, Mini-AVIM, FC, DMI, DIN (LSA).

**Advantages:**

➔ Low leak rate at wide temperature range
➔ Low Insertion Loss
➔ Fiber type independent
➔ Compatible with all Optical Interfaces
➔ Wide range of mechanical interface
➔ Wide range of flange accessories

**Applications:**

➔ Semiconductor Vacuum chamber
➔ Space pressurized vessels
➔ Vacuum fiber qualification
➔ Nuclear plant

**MAT – MAR**

Transmitter (MAT) and Receiver (MAR) modules are designed with an IMOD with the appropriate fitting to adapt to an active component. The MAT requires an optical component to focus the light source (Laser, LED) to the ferrule position in the housing. Depending on the type of fiber (SM, PM or MM) the active alignment device secured by laser welds on the fixing flange is designed to guarantee optimal performance. (E-2000™ is our termination of choice for these products).

**MAT**

- Zr O₂, split sleeve
- interchangeable color-code or mechanically-keyed frame
- precision ferrule stopper
- lens

Construction for LD source transmitters (3 axis alignment)

**Advantages:**

➔ Compact solution
➔ Precise Fiber core alignment
➔ SM, PM and MM
➔ Customizable

**Applications:**

➔ Transceivers for sensing
➔ Measurement instruments
➔ Laser launch device

**MAR**

- Zr O₂, for 1300 nm types
- metal for 780 nm types
- rigid sleeve

Construction for LED source transmitters and receivers (2 axis alignment)
SERVICES

LABORATORY
The test and calibration laboratory at DIAMOND SA has been accredited by the Swiss Accreditation Service SAS since March 2002. We are accredited as testing laboratory STS 333 for fiber optic components and as calibration laboratory SCS 101 for fiber optic measurement instruments in accordance with the standard ISO / IEC 17025:2005.
The accredited test and calibration laboratory STS 333 / SCS 101 performs measurements, tests and calibrations not only for DIAMOND SA, subsidiaries and DIAMOND representatives all over the world but also directly for external customers.
By the end of 2012, Diamond will have completed evaluation and qualification of optical connectors for the European Space Agency.

R&D
Solutions in the photonics market regularly requires customization for unique applications. As Diamond is vertically integrated, and has years of design experience and we can quickly develop the solutions necessary for your application. Diamond’s, computer aided engineering software and design tools facilitate the quick development of new products and production tools, as well as the prototyping and evaluation of new concepts, including the most up-to-date inspection techniques.