# whitepaper

## FUNDAMENTALS OF GRADES APPLICABLE TO OPTICAL CONNECTIONS

FOLAN
DATA & TELECOM INFRASTRUCTURE

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# INTRODUCTION

The large-scale development of high-performance fibre-optic networks requires increasing severity in the choice of passive components which make up their infrastructures. The optical fibre in itself is a source of losses in signals' transmissions (insertion loss or attenuation). However, points of connection are the most sensitive to losses.

Hence, reducing potential losses at connections remains the main objective to be reached. This means that the use of high-quality connectors is increasingly vital. In fact, maintaining long-term performances and the reliability of the network depend on this factor.

Knowing the fundamentals of the grades applicable to optical connections is essential to be able to choose properly the components which make the connections.
Standards, unique to all component manufacturers, ensure their mutual compatibility.

This "white paper" is for all users of fibre-optic networks (designers, installation engineers, and operators). It supplies all the necessary information for choosing the products adapted to different fibre-optic networks while at the same time limiting the many causes of losses at connections.



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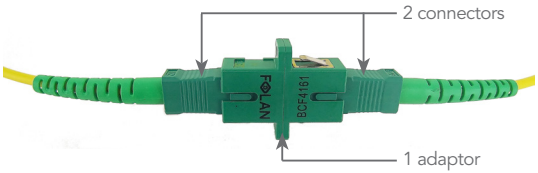
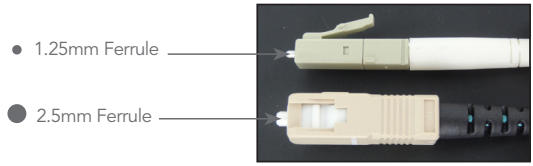
## 1/ OPTICAL CONNECTORS : the main source of losses in optical network

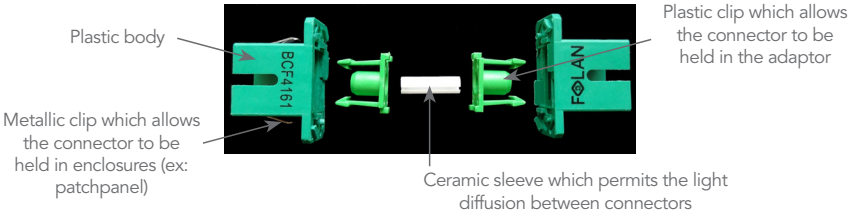
An optical connection is made up of an adaptor and two connectors.




Connectors contain ferrules (measuring 1.25 or 2.5mm). These ensure the precise connection and positioning of the two ends of the fibre.

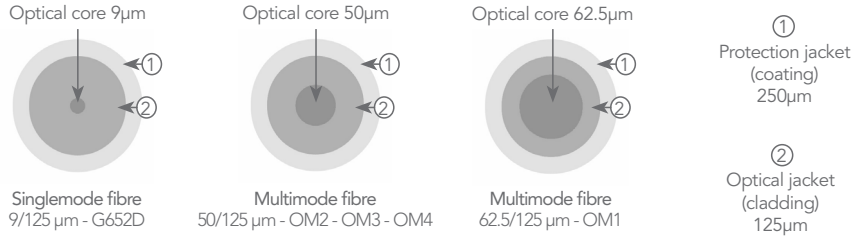



Optical connectors are joined using an adaptor which ensures their alignment.




To reduce losses in transmission (i.e. : to limit light losses at connections points), the two ferrules must be joined together with great precision.

Indeed, the extremely small dimensions of the fibre-optic cores area (area where the transmission takes place, of 9µm for singlemode fibres and 62.5 or 50µm for OM1, OM2, OM3 and OM4 multimode fibres) demand great mechanical and optical precision regarding the optical components (connectors and adaptors) which ensure connections between the fibres.



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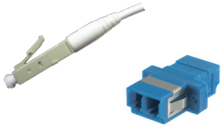
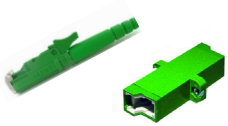
| STANDARDS OF THE MOST WIDELY-USED FIBRE-OPTIC CONNECTIONS | | | |
|---|---|---|---|
| SC | IEC 61754-4 | 2.5mm ferrule<br>Push-pull locking<br>Plastic |  |
| ST | IEC 61754-2 | 2.5mm ferrule<br>Bayonet locking<br>Metal |  |
| MU | IEC 61754-6 | 1.25mm ferrule<br>Push-pull locking<br>Plastic |  |
| MTP | IEC 61754-7 | For ribbon fibres<br>Capacity from 4 to 72 fibres |  |
| FC | IEC 61753-13 | 2.5mm ferrule<br>Screw-locking<br>Metal |  |
| MTRJ | IEC 61751-18 | Duplex connector (2 fibres) |  |
| LC | IEC 61751-20 | 1.25mm ferrule<br>SFF (Small Form Factor)<br>Push-pull locking<br>Plastic |  |
| E2000 | IEC 61753-1-1 | 1.25mm ferrule<br>Push-pull locking<br>Plastic<br>Protective shutter “anti-dust” |  |



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## 2/ INTRINSIC AND EXTRINSIC LOSSES

**Intrinsic losses**, produced only by the fibre, are generally caused by differences in core diameters, different refraction indexes according to the materials used, or the fibre being off-centre (when the core is not in a central position).

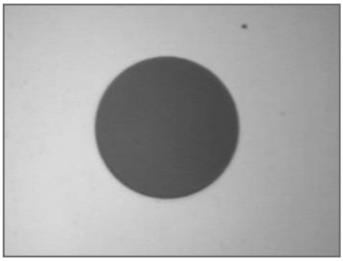
**Extrinsic losses** are the result of various parameters related to optical connections (connectors and adaptors):

- Precision of the connector's ferrule geometry - ***Fig 2***
- Adaptor's geometry, elasticity and sleeve material
- State of the connector optical surface (roughness, dirt or humidity) - ***Fig 1***
- Fiber off-centeredness or centring in the connector's ferrule - ***Fig 2***
- Dimensions of the fibre cores' adjustment areas - ***Fig 3***
- Angular misalignment - ***Fig 4***

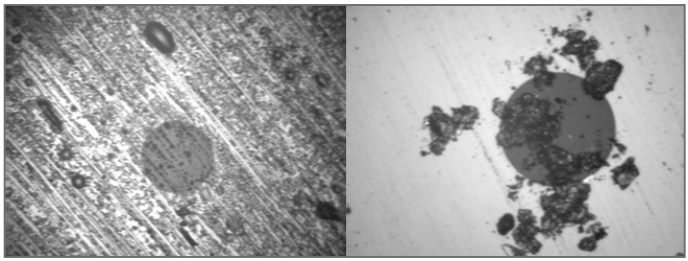
…

These extrinsic losses are higher in fibre optic networks. More than 70% of transmission losses are due to extrinsic losses. They must therefore be reduced to a minimum, for example: by polishing correctly the connectors in order to minimize the losses brought by roughness and dust.

**Fig 1 - Inspection of the state of connector surface (by microscope)**



Acceptable optical surface



Soiled optical surfaces (dust, damp, finger-marks)





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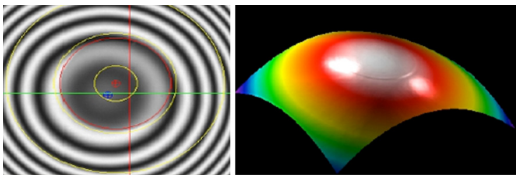
**Fig 2 - Inspections of the 3D geometry of the end of the fibre and of the connector's ferrule (by interferometer):**

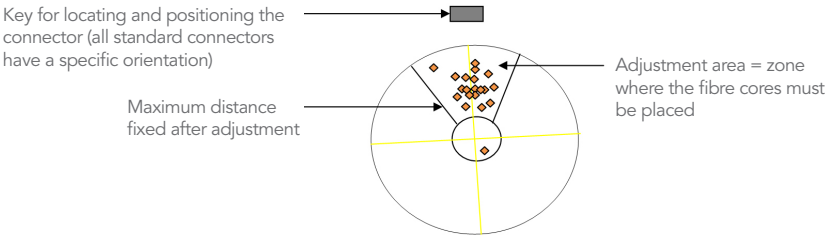
- View of the radius of the convex surface,
- Off-centredness of the Apex (axis of the fibre) in relation to the highest point of the ferrule,
- Angular position of the Apex,
- Differences of roughness between the fibre and the ferrule,
- Fibre height



3D reconstitution of the optical surface

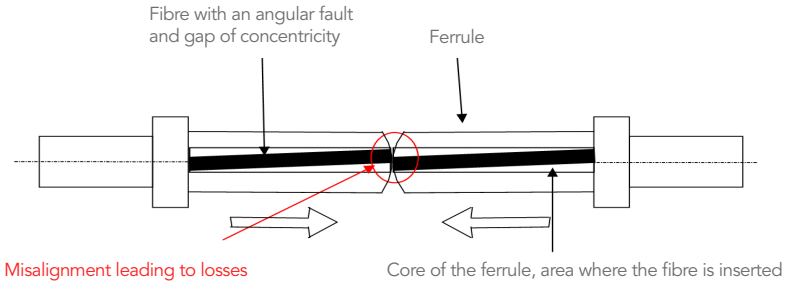
**Fig 3 - Ferrules adjustment areas**

The ferrules adjustment is an important operation in the manufacturing phase for optimum results. This operation is also called "Tuning". To optimize the attenuation due to extrinsic losses, the fibre-core must be positioned in an area defined as follows:




Adjustment doesn't change the fibre position in the ferrule. The ferrule support is rotated within the connector in such way that the fiber are positioned in the defined area (see above). The adjustment aims to minimize the difference in alignement of optical cores when the connectors are combined.

**Fig 4 – Misalignment and concentricity**



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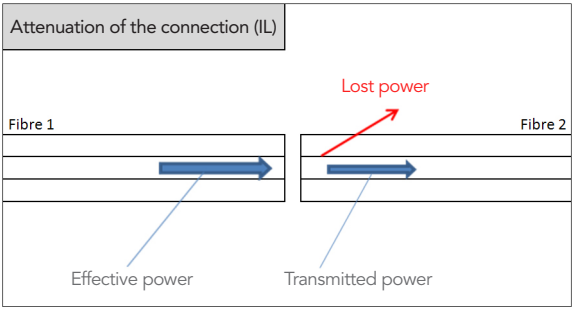
## 3/ CONNECTING POINT CHARACTERISTICS

The two parameters which enable a connection to be defined are:

**- IL : Insertion losses (in dB, decibels)**

Losses engendered at the connection point (core misalignment, quality of the optical surfaces, gap between the cores).

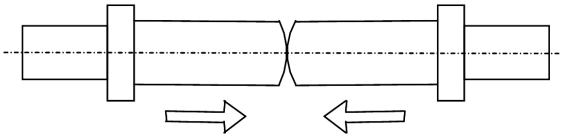
Insertion losses are calculated from the difference between the power emitted and the power received beyond the connection point. The lower the IL value is, the smaller are the losses.

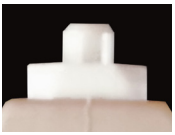



**- RL : Reflection or reflectance losses (in dB, decibels)**

The reflectance is the quantity of light reflected back to its source when a connection is made.
The reflectance value s intimately linked to the techniques used in the polishing of the optical surfaces:

• **PC polishing** : Physical Contact,
The ferrule is polished to form a convex surface to ensure contact between the two fibres at the highest point of the ferrule.





PC (Physical Contact)

• **UPC polishing** : Ultra Physical Contact
The ferrule is convex and the polishing is of better quality (optimal point of contact).



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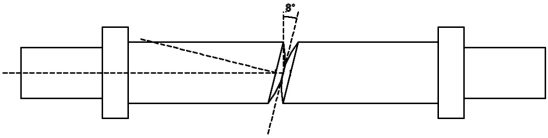
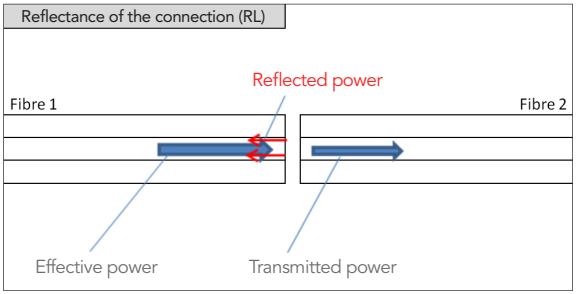
• **APC polishing** : Angle Physical Contact
A higher level of performance is reached with this polishing technique: here, the convex surface is polished with an angle of 8° from the perpendicular of the fibre. One part of the light signal is still partly reflected, but with a wider angle than the acceptance angle of the fibre.This part of the light (also called « modes ») is dispersed by refraction. Hence there is no return of these modes to the transmitter through the fibre.




APC ( Angled Physical Contact)




At each connection between two fibres, the eccentricity, the scratches and the dirts induce that a part of light emitted are reflected (red arrow).

The higher the RL value is, the weaker is the reflection.



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## 4/ GRADES OF PERFORMANCE ACCORDING TO IEC 61753

The grades classification and testing methods defined in the IEC are really helpful in the choice of patchcords, pigtails and optical adaptors.
Optical performances are partially defined in IEC 61753.

The IEC 61755-3-1 (PC connector, 2.5mm ferrule) and IEC 61755-3-2 (APC connector, 2.5mm ferrule) standards define the geometric criteria of the connectors for each grade.
These standards also detail the dimensions of the adjustment area of the fibre cores according to the expected grade.

| | Insertion loss | Attenuation value in random* connections (according to the IEC 61300-3-34 procedure) | |
|---|---|---|---|
| | | MEAN IL | MAX IL |
| SINGLEMODE | Grade A | IL≤0,07 dB | IL≤0,15 dB, 97% |
| | Grade B | IL≤0,12 dB | IL≤0,25 dB, 97% |
| | Grade C | IL≤0,25 dB | IL≤0,50 dB, 97% |
| | Grade D | IL≤0,50 dB | IL≤1,00 dB, 97% |

| | Reflectance | Reflectance value in random* connections (according to IEC 61300-3-6 procedure) |
|---|---|---|
| SINGLEMODE | Grade 1 | RL≥60 dB (coupled) et RL≥55 dB (non-coupled) |
| | Grade 2 | RL≥45 dB |
| | Grade 3 | RL≥35 dB |
| | Grade 4 | RL≥26 dB |

**Random connections: the connectors of a predetermined batch are not coupled with a reference connector (Master) but with another connector of the same batch. Measurements are taken on the connector/adaptor/connector unit.*

| Logical combinations | Grade A | Grade B | Grade C | Grade D |
|---|---|---|---|---|
| Grade 1 | x | x | x | |
| Grade 2 | x | x | x | (x) |
| Grade 3 | | | | x |
| Grade 4 | | | | (x) |

Grade 1 corresponds to APC-type polishing.
Grades 2 to 4 correspond to PC-type polishing.
SPC or UPC finishes are usually used but do not correpond to any standard, although more restrictive.





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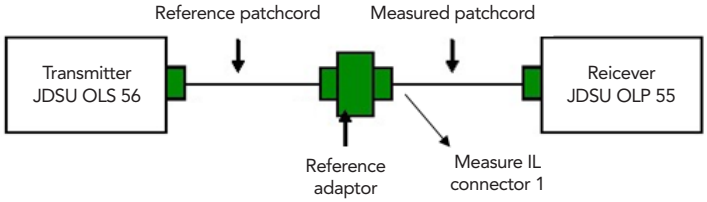
## 5/ GRADES OF PERFORMANCE ACCORDING TO FOLAN

FOLAN offers a range of connection components based on grades to help manufacturers, operators and installers in the choice of the components best suited for the application in question.
The best connectors will have excellent performance only if it is coupled to an identical quality adaptor.

FOLAN can manufacture according to all standard grades but chose to standardize the values in the table below in its production to optimize the cost/quality ratio:

| | | |
|---|---|---|
| SINGLEMODE | Loss of insertion | Attenuation value with reference measuring (according to IEC 61300-3-34 method B procedure) |
| | | MAX IL |
| | Grade B FOLAN | IL≤0,25 dB |
| | Grade D FOLAN | IL≤0,50 dB |
| MULTIMODE | Grade M FOLAN | IL≤0,50 dB |

The measurement method used by FOLAN is the **insertion method B from the standard IEC 61300-3-4** with reference measuring. The picture (see below) illustrates the assembly required for this type of measurement:




The measure is performed at **1550 nm for singlemode (SM) and 1300 nm for multimode (MM)**. The patchcord used for the measurement is a reference patchcord with negligible attenuation. A calibration measurement is done first with two reference patchcords and a reference adaptor. Then, one of the reference patchcords is replaced by the measured patchcord.

| | | |
|---|---|---|
| SINGLEMODE | Reflectance | Reflectance value (according to IEC 61300-3-6 procedure) |
| | Grade B FOLAN | APC type: RL≥60 dB (Grade 1 type)<br>UPC type: RL≥50 dB (Grade 1-2 type) |
| MULTIMODE | Grade M FOLAN | PC type: RL≥35 dB (Grade 3 type) |

FOLAN does not define the reflectance performance with Grades 1 to 4, as specified in the IEC 61753 standard.

In fact, for FOLAN, performances in terms of reflectance are directly expressed by detailing the type of polishing, which is more restrictive than the quoted PC, UPC and APC standards.

Adjusted or "tuned" connectors, produced by FOLAN are certified with an IL ≤0.2 dB.



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FOLAN produces master patchcords with grade A1 specifications generally used as reference patchcord. They are commonly used as standard value for measurements for a given set of connectors.

**Singlemode applications:**

- Grade B is recommended for high-performance telecom networks.
- Grade D is reserved for other applications.

**Multimode applications :**

Grade M is optimized for LAN applications.

**FOLAN guarantee:**

FOLAN guarantees connections entirely made with FOLAN components, for classic use:

- Grade B : 3-years guarantee
- Grade D : 1-year guarantee





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Do not hesitate to contact FOLAN during the different stages of the installation of your network. We will offer you the best combination of products to meet your customers' requirements. With its recognised expertise in fibre-optic infrastructures, whether company networks or telecom operators, FOLAN can also advise you on the specific needs of your network: connection of remote sites, optical distribution for large-scale LAN, links management in industrial environments, or Datacenter (Big Datas).

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