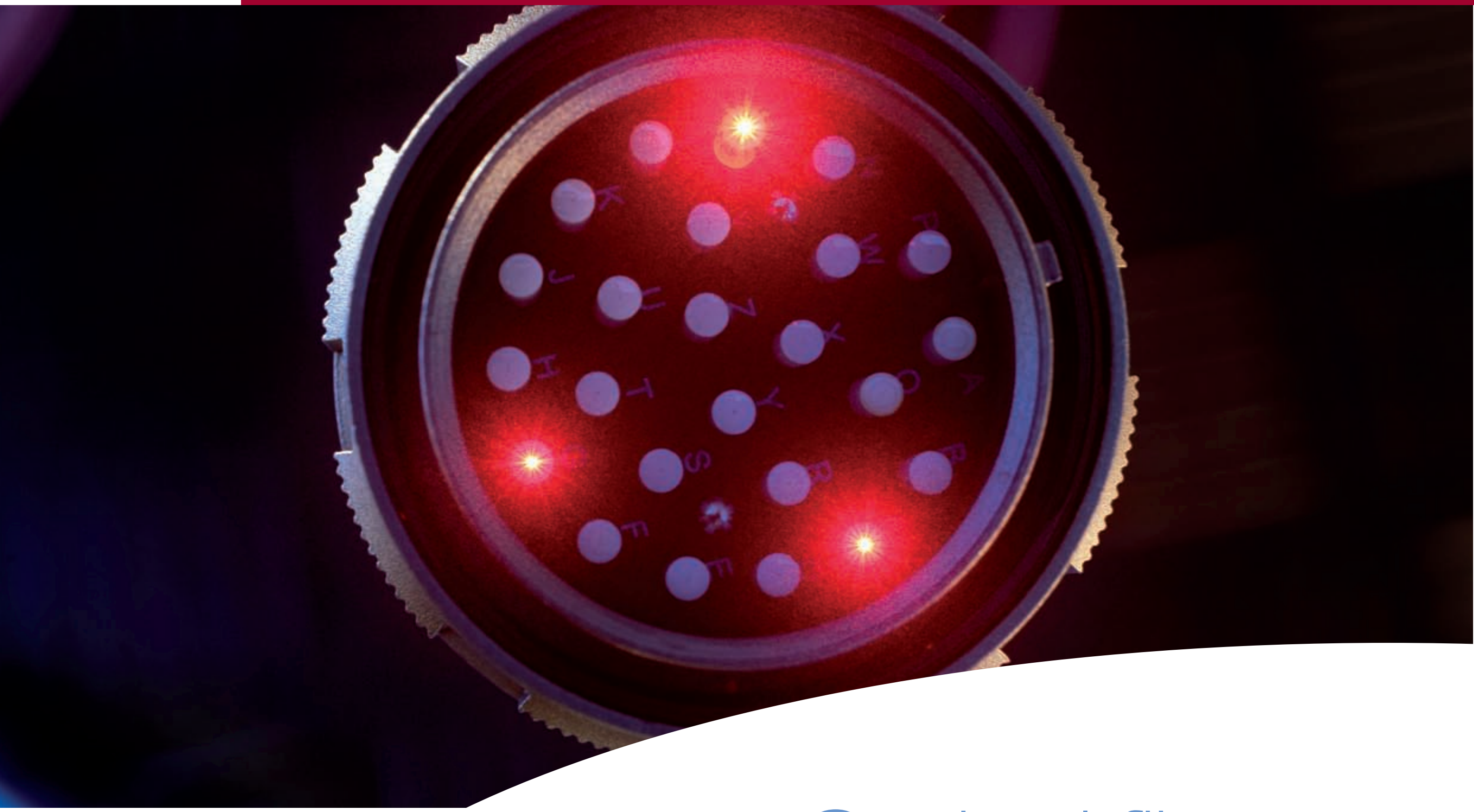


Optical fibre on aircraft

When the light speed serves data transmission

As more and more electronic systems are installed on aircraft, the quantity of electrical cable is inclined to increase significantly. Aeronautical electrical installations have been for many years based on copper conductors which are firstly expensive in terms of weight and secondly, have some constraints in relation to their characteristics such as Electro-Magnetic Interferences (EMI) and bandwidth limitations. The introduction by Airbus of aluminium wiring allowed saving weight but had no better effects on the characteristic constraints.

Therefore, electrical installation designs introduced the optical fibre technology instead of copper cables for data signal transmissions. The use of optical fibre provides large benefits in terms of a large bandwidth capacity, EMI insensibility, complete electrical isolations, signal attenuations lesser than electrical cables and last but not least, lightweight compared to an electrical cable (4kg/km).

Stéphane BOUYSSOU
Aircraft Electrical Installation
Electrical Standard Items
Airbus Engineering

What is an optical transmission assembly?

The principle is to convert the electrical signal to a light wave signal, then to transmit it through a physical pipe used as a wave guide, so called 'optical fibre'. Therefore, an optical fibre transmission assembly is composed of a transmitter, optical fibre, connectors and a receiver (figure 1).

As a reminder, light is characterized by its 'spectrum' which is the whole set of wavelengths from ultraviolet to the infrared (including visible light) and by its 'index of refraction (n)' which is an intrinsic property of a material corresponding to the ratio between the speed of light in vacuum and its speed in the material. When light encounters an environment, the light ray is reflected and refracted. The refracted ray (meaning transmitted inside the medium with a change of directions) depends on:
- The refraction index of the parameters which are the medium,
- The angle of the light ray (figures 2 and 3).

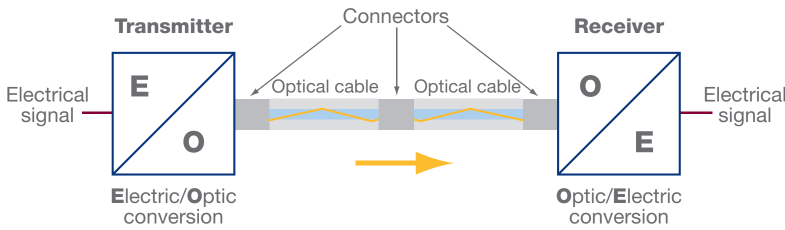
This is defined per the Snell Descartes Law: $n1 \sin \Theta 1 = n2 \sin \Theta 2$.
Another physical phenomenon is when an object bumps on a plane surface, its incidence ray angle is the same as the reflection ray angle.

To date, the optical fibre application in Airbus aircraft are:

Aircraft Family	A320	A330/A340	A380	A350
Cockpit Display System (CDS)			•	
Large displays (under development)				•
Head-Up Display (HUD)	•	•	•	•
On-board Airport Navigation System (OANS)	•	•	•	•
Taxi Aid Camera System (TACS)		•	•	•
Concentrator Multiplexing Video (CMV)			•	
Network Server System/On-board Information System (NSS/OIS)				•
Cabin Video Monitoring System (CVMS)			•	
Cockpit Door Surveillance System (CDSS)			•	
In-Flight Entertainment (IFE)		•	•	•

Aircraft Family	A320	A330/A340	A380	A350
Cable length*	Following chosen options	565 m*	2.4 km	TBD
Nombre of links	Following chosen options	41*	171	TBD

*average following chosen options



Optical transmission assembly

Figure 1

However, it is possible to obtain a complete reflexion (see figure 4) if the above both conditions are gathered, which will give us:
- n1 value > n2 value (n1 and n2 refraction value of both medium).
- Incident angle 1 trends towards 90° (low-angled beams).

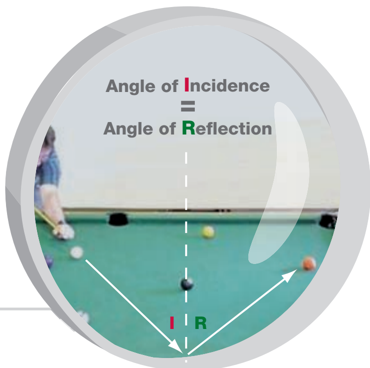
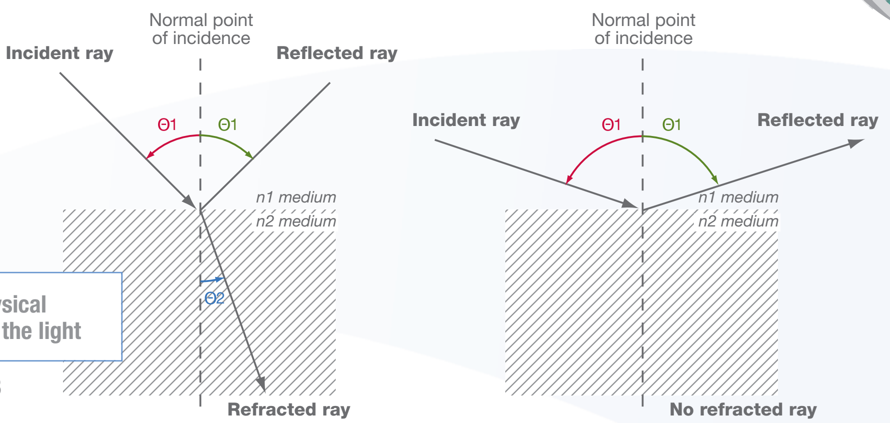


Figure 2



General physical behavior of the light

Figure 3

Condition for a complete reflection

Figure 4

information

Regarding optical fibre in telecommunication, cladding is one or more layers of material of a lower refractive index, in intimate contact with a core material of a higher refractive index. The cladding causes light to be confined to the core of the fibre by total internal reflection at the boundary between the two.

Optical fibre

An optical fibre is a wave guide allowing transmission of a reflected light signal between two equipments. This wave guide is made of two basic elements which are the core and the cladding. Each of them is composed of the same material with different refraction indexes which are chosen in order to have ‘ncore value > ncladding value’. Then the light is transmitted inside the core with a low angle to ensure the light wave will be totally reflected by the cladding and transmitted along the core (figure 5).
The fibre can be made out of Silica or Polymer. Airbus qualified a Silica (glass) optical fibre P/N ABS0963-003 Type LF (see figure 6).

Transmitter and receiver

The transmitter and receiver modules are included in the equipment using the optical fibre technology and manufactured directly by the equipment suppliers.

The transmitter has to convert electrical data signal to light data signal. The signal is specified by its power (<1mW) and its wave length. Wave lengths used by Airbus are 850nm and 1300nm (figure 7). The conversion is ensured by laser diodes or the Light Emitting Diode (LED) technology. At the end of the line, the receiver has to collect the light data signal and reverse it to electric data signal. This conversion is done using the Photodiode technology.

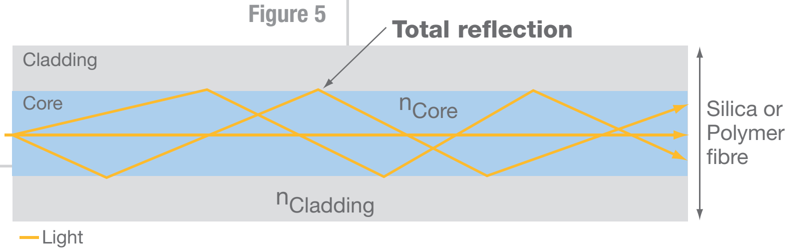
Optical contacts and connectors

The optical connector is a mechanical element which allows the connection of two optical fibre links. The optical fibre link is an optical fibre fitted with contacts at each end, allowing the installation of the optical cable in a connector. The connector implementation has to ensure the optical signal propagation with the minimum of attenuation. In consequence, the connectors have been designed to ensure a perfect alignment of both optical fibre contact end faces, but also a constant contact between both fibres whatever the environmental conditions (figure 8).

Two contacts, ABS1906-01 and ABS1379-003, allowing the installation of optical fibre in the connectors have been qualified by Airbus.

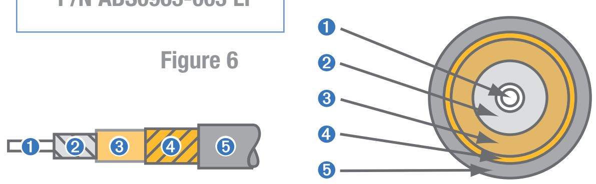
Fibre

Figure 5



Airbus Optical Fibre P/N ABS0963-003 LF

Figure 6



Jacket N°	ELEMENTS		MATERIAL	DIAMETER Ø
1	Fibre	Core Cladding	Silica	62.5 µm ± 3 µm 125 µm ± 2 µm
2	Primary coating		Silicone	400 µm ± 25 µm
3	Primary jacket		Copolymer OHAL high temperature	900 µm ± 50 µm
4	Mechanical strength braid		Polymer aromatic fibre braid	N/A
5	Outer jacket		Copolymer OHAL high temperature	1.8 µm ± 0.1 µm

µm: micrometre
1.000×10–6 m = 1.0000 µm

Light spectrum

Figure 7

CAUTION: Even in an infrared spectrum (not visible to the eye), the light ray could cause serious eye damage, therefore never look an optical fibre contact in front view.

The particularity of the optical contacts, compared to electrical contacts, is that they are ‘hermaphrodite’, meaning that the contact is the same on both sides of the connector. The contact alignment is ensured by a specific additional sleeve fitted in the female connector.

Since the A350 design, Airbus’ philosophy is to use only ABS1379-003 (the best one in terms of installation facilities, cleaning and installation on the optical fibre) and to design connectors in accordance with existing supports (rectangular, circular or square connectors, as shown in figure 9).

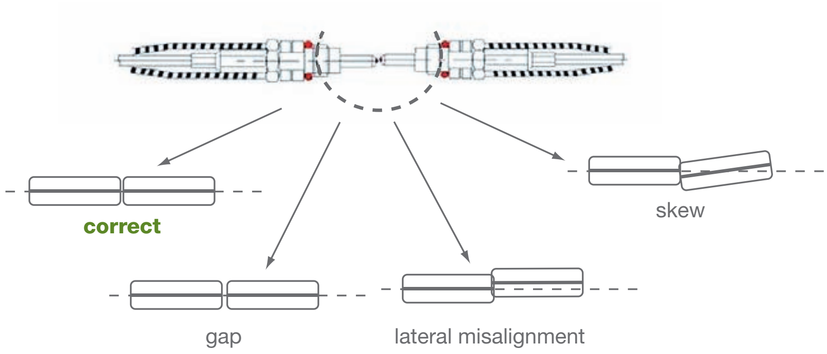
Optical link manufacturing

The manufacturing of an optical link consists in fitting the optical contacts on each side of the optical fibre. This process is complex due to some critical steps as the gluing of the ferrule with the fibre (contact robustness is highly dependent of this step) or the polishing (where the surface of the fibre needs to be plane). In case of a damaged optical fibre, operators have the possibility to order a new optical fibre link through Airbus Spares. Depending on the programme, the optical cable has its own Part Number (P/N) recorded in the Illustrated Parts Catalogue (IPC) and retrieved with the wire number as entry point (A350, A380, A340 TACS), or it is possible to request Airbus customers support to get the P/N associated to the wire number.

In addition, optical link manufacturing requires some specific tooling (oven, polish machine, interferometer, etc.). The on-shop process is described in the Process and Material Specification manual 01-05-63.

Optical fibre contact alignment

Figure 8



Airbus optical components

Figure 9

Usage of optical fibre for In-Flight Entertainment

Optical fibre installation and connection on the aircraft

Optical fibre can be routed alone but also on a bundle with electrical wire. Due to the optical cable specifications (-55° to 125°C), no optical cable is routed in fire or high temperature areas.
As for electrical wires, a minimum bend radius has to be respected due to the light's reflection properties. Indeed a short bend radius will modify the incidence angle of the light ray, thus the total reflection conditions will no longer be respected, resulting to some refraction of the light ray and attenuation of the signal (figure 10).

During maintenance actions on the aircraft or during its installation phase, the optical fibre should not be crushed at the attachment point. In case of over tightening, effects could occur on the fibre leading to an attenuation of the signal.

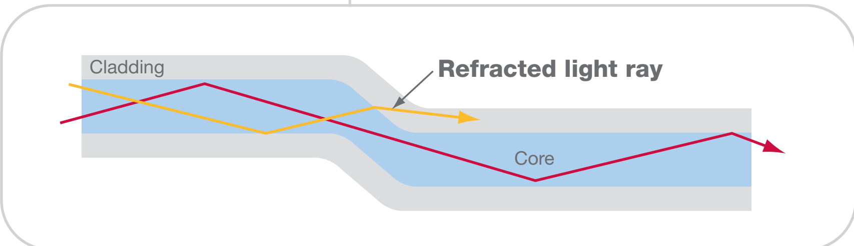
To prevent such attenuation, either bobbin or tape must firstly be applied at each attachment point of the optical fibre installation. Information concerning the installation of the optical fibre is available in the ESPM 20-33-11 (Electrical Standard Practices Manual).

A major difference with the electrical wiring installations with a high impact on the optical assembly performance concerns the cleanliness of the connection. Due to the diameter of the optical fibre's core (62.5µm, about the thickness of a human hair), contamination of the optical contact surface generates optical attenuations or even, a complete loss of the signal. This is why cleaning and protecting the optical cable contact surface is mandatory at each step of the optical fibre handling, to avoid contamination of the contact surface (figure 11). For the cleaning, Airbus proposes three techniques: Dry, wet and dry air cleaning, and two processes: Contact alone or contact fitted in a connector.

In addition, to allow the detection of an optical contact end face contaminated, a microscope with a minimum magnification of 200 can be used. All the above is widely detailed in ESPM 20-55-60.

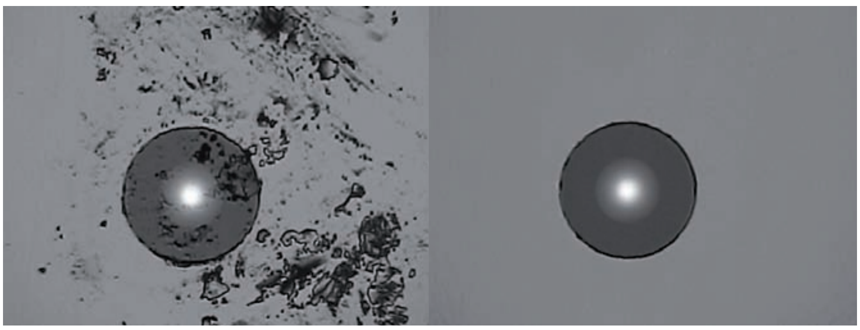
Over-bent radius effects

Figure 10



Optical fibre cleanliness

Figure 11



Dirty optical fibre

Clean optical fibre

Optical fibre troubleshooting and repair

In order to ease the operator's task for the optical fibre's malfunction troubleshooting, some specific tools were designed in strong partnership with the manufacturers. The troubleshooting is similar to one that would be done for an electrical cable, by performing a continuity check. It is performed using the Visual Fault Locator (visible light source emitter) or a Power Meter, with or without a calibrated light source (figure 12).

To determine where the default is located on the optical fibre line, the use of the Optical Time Domain Reflectometer (OTDR) is the most reliable and accurate way.

The OTDR LOR220, using the photon counting method (see the information box below), was specifically designed by Luciol Instruments to provide high precision measures in the aircraft environment and can be used on wing.

With one screenshot, the tool provides a curve showing the optical signal's attenuation at each distance point of the cable. By such, it is possible to find with high accuracy where the damage is localized on the line in order to perform the repair.

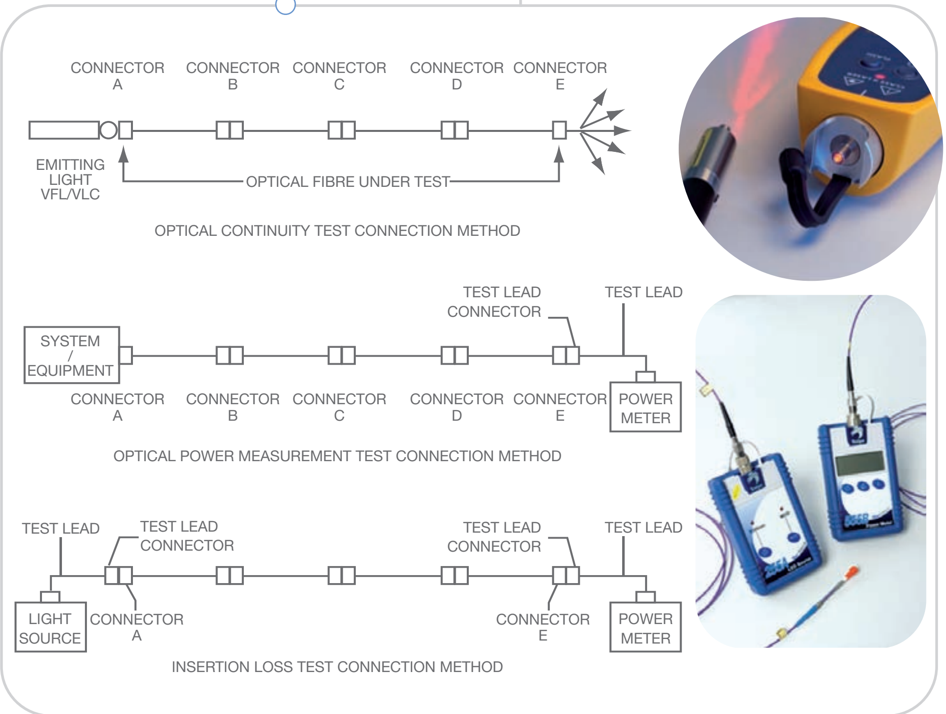
The displayed result curve (figure 13) allows to make the difference between the return loss (light reflection due to the optical line cut-off at the level of the connectors) and the insertion loss (signal attenuation resulting of the defect on the line). The OTDR offers the possibility to record the curve, allowing the operator to send the curve directly to Airbus specialists for interpretation.

Airbus broken optical fibre can be repaired. Airbus qualified a specific tooling developed by the manufacturer Diamonds allowing this kind of repairs called the 'Fusion Splice' which uses the fusion technology.

An electrical arc is generated welding two optical fibre ends facing each other (figure 14). The result is a complete continuity of the fibre. The tool kit contains also a 'tension test' system, checking the correct fusion of the cable. A kind of protective sleeve P/N ABS1632-003 - called 'crocodile' in relation to its shape and specifically designed for this application - is then glued on the splice to ensure a mechanical protection.

Extracted from the Electrical Standard Practices Manual (ESPM 20-52-25)

Figure 12

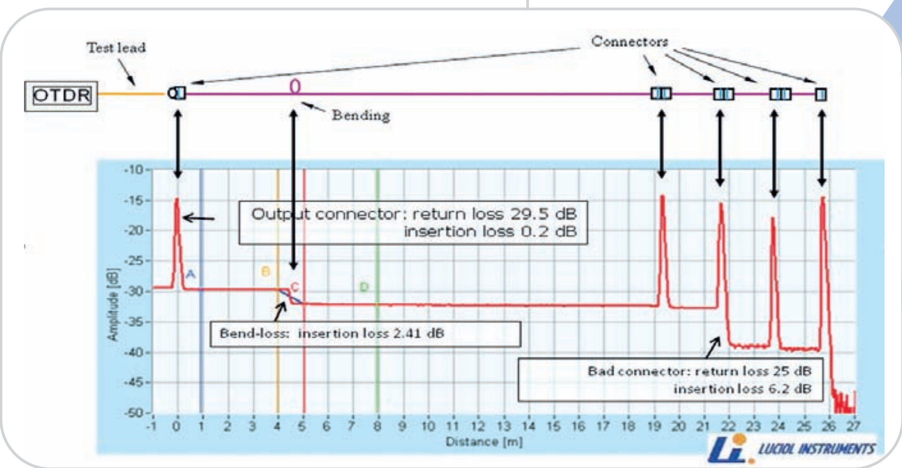


information

In physics, a photon is an elementary particle, the quantum of the electromagnetic interaction and the basic unit of light and all other forms of electromagnetic radiation.

Optical Time Domain Reflectometer (OTDR) screenshot

Figure 13



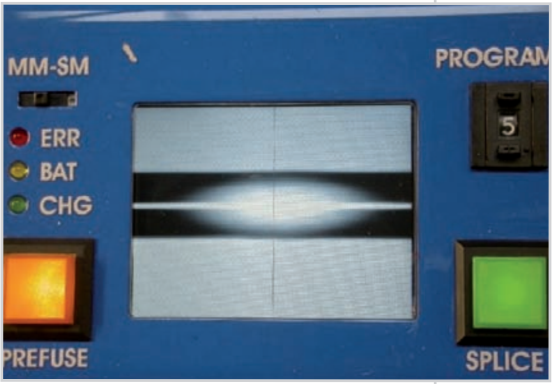
This permanent repair restores the full integrity and characteristics of the optical cable (losses introduced by the 'Fusion Splice' are less than 0.1dB).

A complete kit P/N 1047320 (figure 15) was designed containing the Fusion Splice tools including the complete gear (pliers, scissors, light, support plate, etc.) and the material necessary to perform the repair on-wing.

You may find information concerning the repair of an optical cable in the ESPM 20-53-28, but also available in Airbus SIL 20-030.

Fusion Splice technology

Figure 14



On-wing repair kit

Figure 15

CONTACT DETAILS

Stéphane BOUYSSOU
Aircraft Electrical Installation
Electrical Standard Items
Airbus Engineering
Tel: +33 (0)5 61 18 55 75
Fax: +33 (0)5 61 93 44 25
stephane.bouyssou@airbus.com

Conclusion

In the recent past years, the optical fibre was introduced in the aeronautics. This has required to develop components and associated processes/methods to maintain them during the aircraft's life-cycle, like any other previous copper or aluminium electrical cables. In the coming years, no doubt that continuous improvements and further developments will come to light.
The principles of optical fibre installations are similar to other technologies, copper and aluminium, but require the optical faces to be scrupulously clean. The continuous development of the optical fibre's use in the aeronautics requires new skills and competences for an airline electrician, likely to work on the systems using optical fibre.
A specific training course (Optical Fibre Inter-System Code XMOF) dedicated to optical fibre troubleshooting and maintenance has been developed by Airbus and will be available beginning of 2011 in the Airbus Training e-Catalogue.

AIRBUS