WHITE PAPER

PLANNING, CLEANING, CONNECTION AND MEASUREMENT: KEY ASPECTS IN THE CORRECT INSTALLATION OF FIBRE OPTIC CABLING

High-speed fibre optic links, which are installed mainly in LAN backbones and data centres, merit special attention if they are to provide the desired long-term transmission capacity: from careful planning of the loss budget and selection of suitable products through correct installation and acceptance testing to maintenance of the fibre optic cabling installed, connector cleanliness is of crucial importance.

Optical performance is adversely affected by connectors which have been contaminated, worn or scratched as a result of improper use, since this increases insertion loss (IL) and reduces return loss. As a consequence the optical transmission link may no longer provide the desired transmission rate or may not function at all.

Standard attenuation values set too low

One reason for this lies in the transmission line attenuation values required by the standards which are based on all too conservative calculations. Three examples are given below:

1. For the transmission of a 10-Gbps Ethernet signal on an 850 nm OM2 fibre, a loss on the transmission line of 1.8 dB inclusive of fibres is permitted by EN 50173-1:2011. Therefore, in a 4-connector link, there are just under 0.45 dB available for each connection. Unfortunately however, the standard permits an insertion loss of 0.5 dB maximum for 95% of all detachable FO connections. Losses even up to a level of 0.75 dB are permissible for the remaining 5%.

2. As regards 40- and 100-Gbps transmissions via OM3 / OM4 fibres, the standard IEEE 802.3ba:2010 specifies transmission line insertion losses of maximum 1.9 (OM3) / 1.5 dB (OM4) respectively, inclusive of fibres. This leaves just 1.5 / around 1.0 dB for all connections.

3. In the case of Fibre-to-the-Home (FTTH) networks the connection from the building entry point as far as the fibre optic wall outlet in the apartment may feature a maximum attenuation of 1.2 dB.

When it comes to ensuring good transmissions, all of these values – especially from a long term point of view – are only just sufficient. In the event of any contamination or wear, fault-free transmission will no longer be guaranteed.

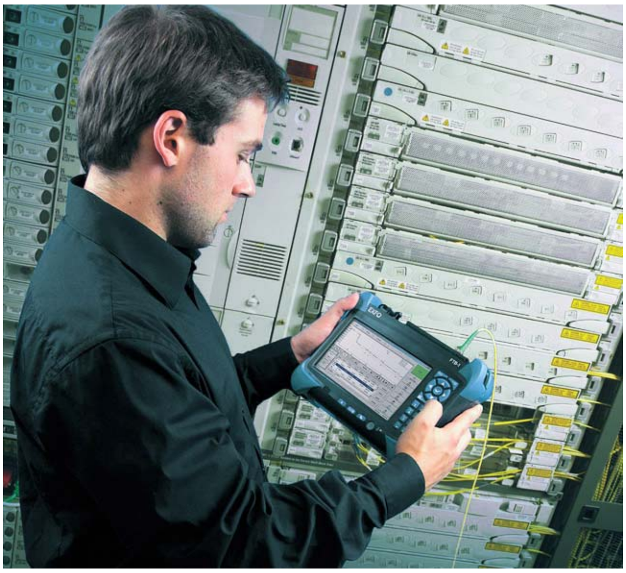

Image 1: OTDR testing a section of FO cabling. © EXFO/Opternus

These examples still do not take into account any additional loss contributions that may occur due to splices. In the interests of avoiding any further aggravation of the problem posed by what is, in any event, a marginal loss budget, higher optical performance requirements than those set in the standards should be stipulated in tenders and when selecting detachable FO connections. Among other things the use of FO cables pre-fabricated with connectors may be appropriate; as a matter of principle, they should be housed in protective sleeves.

More stringent IL limits recommended

The insertion loss (IL) values specified in EN 50173-1:2011 and ISO/IEC 11801:2010 for detachable FO connections apply to each plugged connection (“round-robin” principle). This means, for example, that even the connection of a patch cable to an installation cable fitted with connectors – whether preassembled or with pigtails spliced on – should not exceed the specified values in order to comply with the insertion loss for the whole transmission link stipulated in the standards (see for example EN 51073-1:2011, Tables F4 and F5).

As explained above, these values are “minimum requirements” at best. Measurement standard ISO/IEC 14763-3, on the other hand, is more demanding, as it specifies defined basic conditions. In particular it stipulates that the measuring cable should have a “master connector” (reference connector) of high centricity.

Table 4 of ISO/IEC 14763-3, moreover, specifies more stringent insertion loss values for detachable FO connections between the master connector and the connector of the link to be measured than EN 50173-1:2011 above. For SC connectors with multimode fibres these are a maximum of 0.3 dB, 0.5 dB with single-mode fibres.

Datwyler takes the view that these lower IL values should also apply to other standardised connectors which are in fact all expressly permitted in the cabling standards. This refers particularly to the LCD (IEC 61754-20) and MPO (IEC 61754-7) connectors for data centre cabling systems mentioned in Part 5 of EN 50173:2011. As explained above, in order to guarantee reliable transmission for data rates greater than 10-Gbps insertion loss values should if possible be kept even lower than those specified in ISO/IEC 14763-3.

Two measurement methods

Standard ISO/IEC 14763-3 above describes the “Testing of optical fibre cabling” for application-neutral cabling. It explains basic terminology, requirements, test set-ups and measurement methods.

This standard basically provides two methods of acceptance testing: measurement with an attenuation meter or using an OTDR (see Image 2 and 3 on the right). The advantage of OTDR measurement is that an experienced installer can also immediately use the results for troubleshooting and defect rectification.

High reflections as a warning signal

OTDR measurement also provides information on reflections and therefore covers events which cannot be recorded with an attenuation meter. It is interesting that the values for reflection loss (RL) in the application-neutral cabling standards are kept very moderate: > 20 dB for multimode and > 35 dB for single-mode cables.

These low RL requirements should only be seen in the context of the transmission components (VSCEL) used in the LAN. Low RL figures mean relatively high reflection. The transmission performance of LAN-specific laser diodes essential for data rates ≥ 1Gbps is virtually unaffected by reflection.

The laser diodes in metro and wide area networks (FP and DFB lasers), on the other hand, react very sensitively to reflection at connectors. For this reason APC connectors with high return flow values are almost invariably used in MAN and WAN.

Low reflection loss figures are always a sign of poor connector transfer and indicate installation flaws. These could be contaminated connectors, an air gap between the fibre cores or scratched or otherwise worn end faces.

Taking measurements

The “3 jumper” method has become widespread for measurement using an attenuation meter (Image 2). This involves carrying out zero adjustment with three relatively short cables (launch cord, field calibration cord and tail cord). During measurement the field calibration cord is replaced by the device under test. If the light source of the attenuation meter has no specified mode distribution (EF = encircled flux, LMD mode excitation in accordance with Annex A of ISO/IEC 14763-3), the launch cord must be wound on a defined mandrel. This ensures that the specified mode distribution is achieved.

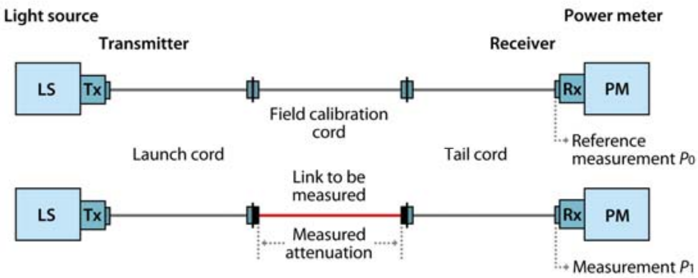

Image 2: Measuring with attenuation meter.

Measurement using OTDR (Image 3) must also be carried out with a launch cord and tail cord. For launch and tail the standard stipulates at least 75 metres for multimode fibres and 150 metres for single-mode fibres. Under certain conditions a bilateral (bidirectional) OTDR measurement is required to determine the effective attenuation value. This helps during the occurrence of apparent signal amplifications known as gainers, produced when different fibres are connected, when smaller fibre cores are spliced to larger ones or when different types of fibre are connected.

Image 3: Measurement with OTDR.

In both test methods the measuring cords must contain fibres with the same nominal values as the device being tested. In multimode cables the nominal values are the core and sheath diameter, in single-mode cables the mode field diameter and sheath diameter, and in both the numerical aperture.

In single-mode connections installation flaws can be detected by taking measurements in two different wavelength ranges (1310 nm and 1550 nm or greater). Such testing is therefore frequently required for single-mode fibres.

Always nice and clean

Clean FO connections are not only an important prerequisite for successful acceptance testing. If fibre optic links are to have a long life, the fibre optic connectors must always be kept clean and be carefully cleaned during each mating process. If treated with care FO connectors can easily be used for up to 1000 mating cycles. Without cleaning, however, they can be permanently damaged, even completely ruined, during the very first mating process.

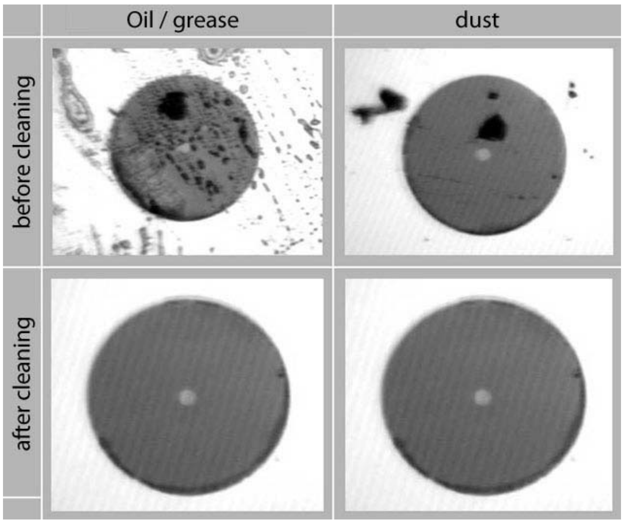

Image 4: Examples of contaminated and cleaned connector end faces.

This topic is so important that it has found its way into cabling standards. In ISO/IEC 11801 under "General Requirements" 10.3.1 it states that: "Optical fibre adapters and connectors should be protected from dust and other contaminants, specifically while they are in an unmated state. End faces of connectors shall be inspected according to ISO/IEC 14763-3 and subsequently cleaned when necessary, prior to connection."

Requirements under standard

Section 5.3.2 of ISO/IEC 14763-3 dated September 2010 says the following on this subject: "Dust, dirt and other contaminants at the interfaces to the cabling under test or at interfaces of the test cords and at the interface to the test equipment may produce misleading results and in some cases damage the cabling under test."

It goes on to state that: "Connector end faces on the test cords shall be inspected in accordance with Annex B which is derived from IEC 61300-3-35. If they are dirty or contaminated they should be cleaned following the recommendations of Annex H and re-inspected with Annex B. If the connectors on the test cords are damaged and/or fail to meet the requirements of Annex B, the test cords shall be replaced."

February 2011 even saw the publication of a technical report devoted exclusively to "Fibre optic connector cleaning methods" (IEC/TR 62627-01:2010).

Typical instances of contamination

Instances of contamination of FO connectors may occur as a result of the connector face coming into contact with the skin (sebaceous matter etc.), following contact with another connector face that has already been contaminated or with dust and dirt from the environment, for example, if the test plugs are put down on an adjacent surface (see Image 4 on the left).

If a connector has been in contact with a contaminated mating connector, it will invariably be necessary to carefully clean both connectors and the coupling. At the same time it is advantageous if the FO cabling has been installed using extendable splice boxes such as, for instance, with Datwyler OV-A models, since these make cleaning the internal connectors and the adapters considerably easier. Splice box enclosures painted black have proved helpful as dust and dirt are easier to detect against a black background.

Professional cleaning tools

FO connectors can be cleaned with isopropyl alcohol (98%) and lint-free cloths, for example Kimwipes Lite. When cleaning with ultra-pure alcohol, care must be taken to remove every last trace of the cleaning agent.

However, tools that have been specially developed for cleaning FO connectors are better. For the best optical performance professional on-site cleaning equipment as featured in Datwyler's fibre optic accessories portfolio (see table below) is particularly suitable.

	Description	Specification	Article No.	Pcs.
	Reel Cleaner	for FO connectors	1411400	1
	Replacement reel	for Reel Cleaner	14114101	6
	FO connector cleaning device	through MPO adapter	415627	1
	FO connector cleaning device	through 2.5 mm adapter	415628	1
	FO connector cleaning device	through 1.25 mm adapter	415629	1
	Cleaning rod	for 2.5 mm adapter	1411404	10
	Cleaning rod	for 1.25 mm adapter	1411405	10

Acceptance test with microscope

Correct cleaning is of particular importance when it comes to the acceptance test. In practical operation, a number of individual tests are generally carried out in series. It has happened, for example, that a fully connected splice box is tested using OTDR without the people conducting the test (who are frequently working under considerable time constraints) cleaning the test connector for the launching fibres and pigtails between measuring operations or carrying out repeat checks on the status of the connector. However, if the face of the test connector has been contaminated in the course of a test of this kind, this dirt will spread to all other connectors in the subsequent tests.

The connector end face will also wear if both connectors of a detachable FO connection and the FO adapter are not kept clean at all times.

This will definitely lead to unsatisfactory test results. In the case of acceptance tests with OTDR, contaminated connectors often demonstrate high losses and unusually high levels of back reflection. Smaller Return Loss (RL) values also occur with contaminated single-mode APC connectors. In a worst case scenario the connectors to be tested will suffer lasting damage, and this also applies to the test connectors (see Image 5 below).

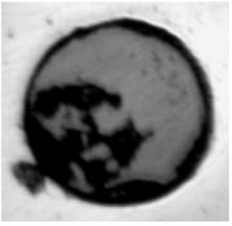

Image 5: The black marks on this optical fibre are damages such as may also frequently occur in relation to on-site connector assemblies.

For this reason the on-site fibre optic specialists should, prior to each patching operation, use a microscope with a minimum 200x magnifying capability to assess the cleanliness of the fibres and connectors. For health and safety reasons a video microscope is recommended for this which will protect the installer's eyes against any laser light that may emanate from the fibre. In addition, a device of this kind has the advantage of enabling the connector to be observed through the FO coupling. This means that it is not necessary to decouple each connection individually. It is also possible to store the images for documentation purposes.

Software controversial

Some suppliers of video microscopes also offer special software for assessing connector end face quality. However this software is the subject of debate on the market since the pass/fail criteria depend to a large extent on the software. A trained eye on its own should be able to appraise the end face of the connector when greatly magnified by the microscope.

So that the FO connectors and adapters do not become recontaminated once they have been cleaned, it is important to ensure that the dust caps supplied with these items are always in position whenever they are not actually connected. For SCD adapters Datwyler can supply optional self-closing shutters (see Image 6 above).

Conclusion

From what has been said above it is evident that in tenders and when selecting detachable FO connections optical performance should be subject to more stringent requirements than those stipulated in the standards in order to ensure sufficient long-term attenuation reserves. The aspects dealt with also show that the cleanliness of FO connections is an important guarantee of successful acceptance testing and continuously functioning transmission.

Within the confines of a White Paper it is of course virtually impossible to portray the complex interrelationships between the requirements of a standard, actual implementation and successful acceptance testing. That is why Datwyler provides regular training courses in fibre optic cable systems, which treat the whole range of issues in more detail and allow extra time for questions. As a rule Datwyler collaborates with expert partners when dealing with splicing and measuring.

You will find further information on content and registration at
www.cabling.datwyler.com / Training

