Single-Mode Fiber

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Single-Mode Fiber

Splicing and OTDR splice measurements

Application Note

VALUE
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Introduction

The continuous increase of bandwidth used by consumers, government and enterprises causes a rapidly expanding worldwide optical fiber telecommunications network. With the building of Fiber-To-The Home (FTTH) networks and a general move from long-haul to access networks the average installed length of optical fiber cable is decreasing. The combined effect is that the amount of fiber splices made each year increases even more than the fiber use.

Fibers can be connected to each other by fusion splicing, mechanical splicing and by the use of connectors. Of these three, fusion splicing is the commonly used method. Although fusion splicers have advanced in ease of use and speed, people who are responsible for and those who perform fusion splicing do need specific knowledge about fiber, splicing and testing of the results.

This Application Note explains all aspects of fusion splicing on Draka single-mode products, ESMF and BendBright-XS. This includes the testing of spliced fibers.

1. Fusion splicing of optical fibers

Fusion splicing is the method of joining two optical fibers end-to-end using heat. The goal is to join the two fibers together in such a way that optical signal passing through the fibers is not attenuated or reflected back by the splice. The splice and the region surrounding should be almost as strong as the fiber itself. The source of the necessary heat is usually an electric arc.

The following steps are necessary to splice optical fiber:

1. Clean the fiber
2. Stripping the coating off the two fibers that will be spliced together
3. Cleaning of the stripped fiber
4. Each fiber must be cleaved so that its end-face is perfectly flat and perpendicular to the axis of the fiber
5. Aligning of two end-faces of the fibers. This is normally done by the splicing machine by means of: fixed V-groove, optical core alignment, cladding alignment or local injection and detection of light (LID)
6. The two fibers are fused together
7. Visual inspection of the splice and splice loss estimation (available on most splicing machine). Redo the splice (step 1 to 7) in case an error is found
8. Check mechanical strength of the splice (normally done by the splicing machine)
9. The bare fiber area around the splice is protected with a splice protector

Alternatives to fusion splicing include using optical fiber connectors or mechanical splices both of which have in general higher insertion losses, lower reliability and higher return losses than fusion splicing.

2. Splicing Draka ESMF

Standard Single-Mode (SMF) fiber is the prevailing fiber for telecommunication applications carrying digitized voice, internet data, analog video and many other data. Enhanced Single-Mode Fiber (ESMF) is the standard Draka single-mode fiber and is also the most widely sold type of optical fiber by Draka.

Draka ESMF is made of highest quality silica glass that enables easy splicing. The excellent geometry parameters make sure that splice attenuation is very low and repeatable. This is proven in a large number of tests as well as proven field performance. Draka estimates that more than 5 million fiber splices are made using Draka ESMF each year.

Figure 1 shows the aggregated statistics of splice tests on Draka ESMF spliced to itself and to other fibers coming from various fiber vendors using different manufacturing process (Corning, OFS, and Fujikura) at 1550 nm. These splice tests were made with Fitel S177, Fujikura 50S and Sumitomo T39 splicers. It can be underlined that average values and statistic distribution widths are remarkably low and at the top-of-the-art level.

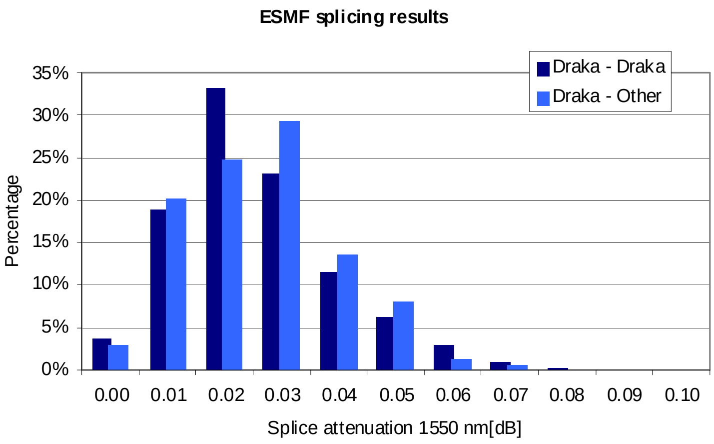

Fig. 1 Splice loss distribution of Draka ESMF

Especially since the incorporation of the Alcatel optical fiber division in 2004, Draka produces large volumes of this single-mode fiber in several factories all around the world. In combination with the APVD™ (Advanced Plasma Vapor Deposition) technique, Draka uses two different methods to produce the preforms (where fibers are drawn from). Those methods are called FCVD (Furnace Chemical Vapor Deposition, originally from Alcatel) and PCVD (Plasma Chemical Vapor Deposition, originally from Draka). Fibers from both types fully comply with all relevant international specifications (ITU G.652 and IEC 60793-2-50).

Modern fully automated splicers will recognize an inserted fiber and choose the right splicing program automatically. The splicing process is then shown on the splicer screen. For some machines that use profile or core alignment, the difference between fibers of different manufacturing methods may be visible on the screen of a splicing machine (see example picture, Figure 2).

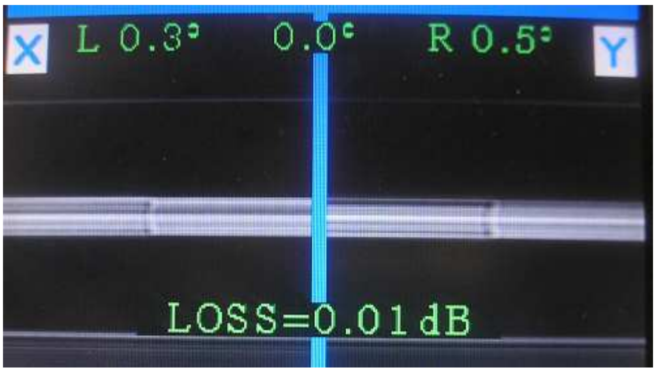

Fig. 2 Splicer screen showing fibers from different manufacturing process

This is because of the differences in refractive index and glass types. An FCVD fiber may looks different from an OVD (Outside Vapor Deposition) fiber that looks different from a VAD (Vapor Axial Deposition) fiber that may looks different to a PCVD fiber. This different appearance of the left and right fiber in the splicer display is normal so that there is no reason to reject the splice.

In the rare case that 1) a profile/core alignment splice machine reports an error due to the machines inability to properly recognize a fiber, and 2) a quick solution is needed, a quick fix can be to change the splice program from automatic (or SM) to MM. Herewith splicing machines do not need to recognize the fiber core and therefore can always splice every fiber. Due to the superb geometry parameters of Draka fiber, the increase in average splice loss is very limited, and the mechanical quality of the splice is not compromised. Because of the inconvenience not having valid splice estimation values in MM setting this method should be limited to "emergency use" and the failing splicer should undergo full maintenance as soon as possible.

A common practice in the field operation relates to a visual evaluation of the splice with the optical imaging system of the splicer. Presence of defects such as kinks, neck-downs, bubbles and vertical white/dark lines often correspond to a poor splice quality that can impact on splice loss, mechanical behavior or return loss.

When splicing fiber on some splicers, a presence of a light/dark circle (or halo) at the splice joint vicinity is sometimes visible (similar to those shown in the pictures, Figure 3). Depending on operator experience, such splice could be misinterpreted as a bad one that needs to be redone. Such halo-shaped features give no impact on splice quality in term of loss, mechanical resistance and return loss.

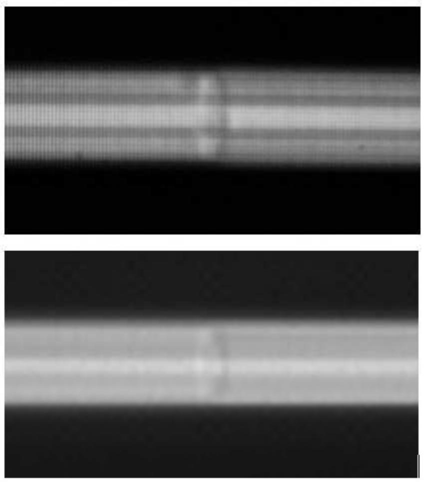

Fig. 3 Pictures of two splices between external (right) and Draka's fiber (left) for two different splicer models

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Due to the presence of dopants located in the cladding, a complex refractive index profile is produced close to the splice joint (along radial and longitudinal directions) during arc discharge and heat-induced diffusion. This visual feature originates from changes in the refractive index, during joint formation, that are caught up by the imaging system of the splicer. This may be seen on the screen of the splicer as a typical halo-like pattern. Due to the difference of the optical systems and imaging methods, the corresponding visibility can noticeably differ from one splicer to another.

3. Splicing Draka BendBright-XS SMF

Draka has been on the forefront in the development of bend-insensitive fibers. With the 2006 introduction of the BendBright-XS single-mode fiber (SMF), Draka has answered the growing market demand for bend-insensitive SMF driven by the mass deployment of Fiber-To-The Home (FTTH) access networks. For detailed information on characteristics and application of Draka BendBright-XS, a datasheet and Application Note are available on the Draka website (http://www.drakafiber.com).
The bending losses have been improved by two orders of magnitude thanks to the addition of a trench in the optical cladding. The trench is a perfectly delimited and homogeneous annular zone where the refractive index is lower than the refractive index of the optical cladding in the vicinity of the core.
Draka and all major splice machine manufacturers have conducted extensive splicing tests of BendBright-XS and have found all machines are capable of splicing BendBright-XS effectively. This includes splicing BendBright-XS to itself, to other bend-insensitive fibers, and to standard single-mode fibers.

Splice machines use either outside diameter (OD) or core/profile alignment. OD alignment machines whether single or mass fusion, are compatible with BendBright-XS. However, some single fiber core/profile alignment systems with auto recognition software may be confused by the new profile design. Because of the close vicinity of the core and the surrounding trench in BendBright-XS, some older machines do not have the program to discern the difference between the core and trench (See figure 4).

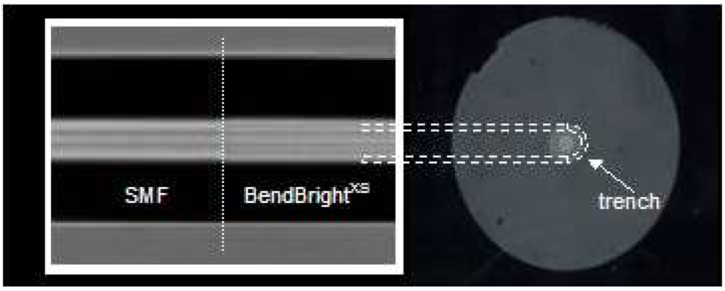

Fig. 4 The trench in BendBright-XS showing up on the fusion splicer visualization screen

When using an older profile/core alignment machine which does not have updated software for bend- insensitive fibers, including BendBright-XS, it is possible that the machine may not align correctly the fiber. If this is encountered, this can easily be overcame by simply adopting the machine setting. (see Table I).

Table I: Splice machine setting recommendations for BendBright-XS

	Model	Recommended program corresponding alignment method		Alternative setting
Fujikura	FSM-11S	Automatic mode	Fixed V-Groove	-
Fujikura	FSM-17S	Automatic mode	Fixed V-Groove	-
Fujikura	FSM-18S	Automatic mode	Fixed V-Groove	-
Fujikura	FSM-30S	SMF	Core alignment	MMF
Fujikura	FSM-40S	MMF	Cladding alignment	-
Fujikura	FSM 50S	BendBright-XS	Core alignment	Automatic mode
Fujikura	FSM 60S	BendBright-XS	Core alignment	Automatic mode
Furukawa Fitel	S122A	Standard SM	Fixed V-Groove	-
Furukawa Fitel	S175 (All version)	BendBright-XS (US only)	Cladding alignment	SM with clad alignment
Furukawa Fitel	S176	Standard SM with cladding alignment*	Cladding alignment	-
Furukawa Fitel	S177A	BendBright-XS	Core alignment	SM with clad alignment
Sumitomo	Type-25	SM settings	Fixed V-Groove	-
Sumitomo	Type-45	SM settings	Fixed V-Groove	-
Sumitomo	Type-37	SM Diameter Alignment*	Cladding alignment	-
Sumitomo	Type-39	BBxs Diam	Cladding alignment	-
Sumitomo	Type-65	Standard SM	Fixed V-Groove	-
Sumitomo	Type-66	Standard SM	Fixed V-Groove	-
Corning (Siecor)	M90i	MMF (VIDEO mode)	Cladding alignment	-
Corning (Siecor)	OptiSplice™ LID Micro	MMF (VIDEO unequal pairs)	Cladding alignment	-
Ericsson	RSU12	Standard SM	Fixed V-groove	
Ericsson	FSU995	Standard SM	Core alignment	-

* *Setting should be done by qualified personnel*

Table I lists most common splice machines on the market. It is intended to provide guidance and recommendations in case alternative settings are required. It should be noted that the splice machine manufacturers have already updated or are in the process of updating software to recognize BendBright-XS. Standard SM settings can be used for outside diameter/cladding alignment machines, including mass fusion splice machines.

Care should be taken when using splicing equipment that uses the LID (Light Injection and Detection) fiber alignment method. Because the transmission length between the injection and the detection points is rather small, the injected power might very well be propagated by the inside-trench area of the optical cladding instead of the fiber core. This effect could lead to fiber misalignment. Therefore it is advised to not use the LID alignment system.

In the case of older profile/core alignment splicers or LID based splicers (not reported in Table I) that have no suitable program for splicing BendBright-XS, a simple approach is to use the Multimode Fiber fusion program setting. This provides a lower temperature and a higher fusion time (without compromising the mechanical quality of the splice). Usually this program can be selected from the splicer's program library. Because of the inconvenience not having valid splice estimation values in MM setting this method should be limited to "emergency use" and the splicer should be updated with new software or preferably replaced by a more suitable machine.

As shown in the table I, for some splicers, best results are obtained by switching the alignment method from core/profile to cladding or diameter alignment. In Table I, core alignment machines that can be switched from core alignment to OD alignment are noted with an "*" This setting change should be performed by an experienced technician since it can result in total failure of the splicer when done improperly.

Do not hesitate to contact the local distributor of the splicing equipment for up-to-date information and updating procedures.

Splice test results:

As the BendBright-XS fiber design allows a backwards compatibility with already deployed fibers (standard G.652 single-mode fiber), it is also important to guarantee compatibility with existing deployment procedures. As far as fusion splicing operation is concerned, it is important to ensure that splicing conditions do not differ that much when BendBright-XS is spliced to another fiber. Two possible splicing cases can be thus distinguished:

- Splicing BendBright-XS to standard single-mode fibers
- Splicing BendBright-XS to itself

BendBright-XS to SMF

Splicing the trench-assisted BendBright-XS fiber to a standard SMF will occur frequently at the edge of an access network or when splicing fiber pigtails in passive components like power splitters. Although the optical field confining trench represents a very small part of the total fiber cross-section only, it does influence the softening temperature of the fiber end slightly. Most fusion splicers have suitable splice programs to perform splicing in a correct manner (See table II). Table III and Figure 5 show the result of splice test performed by Draka between different commercial available G.652.D fibers and BendBright-XS, performed with several fusion splicers.

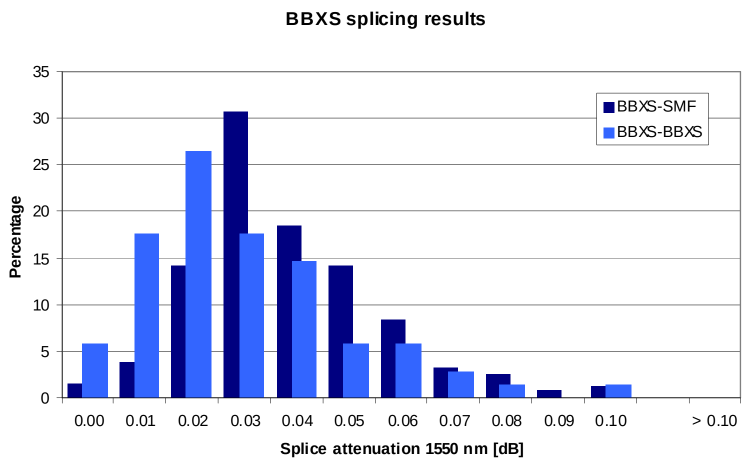

Fig. 5 Splice losses distribution of BendBright-XS at 1550 nm

Table II: Splice loss statistics for fusion splice tests BendBright-XS with commercial enhanced single-mode fibers (ITU-T G.652.D). Measurement performed with bidirectional OTDR method

Fusion Splicer Model	SETTINGS		1310 nm		1550 nm	
	Program	Alignment	Average	Standard Deviation	Average	Standard Deviation
			dB	dB	dB	dB
S177A	SM	Cladding	0.041	0.024	0.032	0.015
S177A	MM	Cladding	0.040	0.022	0.040	0.020
S175	SM	Cladding	0.044	0.023	0.038	0.034
T-39	SM	Cladding	0.043	0.023	0.041	0.019
FSM-50S	Auto	Core	0.039	0.026	0.047	0.023
FSM-11S	Auto	Fixed V-groove	0.056	0.025	0.052	0.021
FSM-17S	Auto	Fixed V-groove	0.030	0.019	0.030	0.014
FSM-40S	MM	Cladding	0.063	0.017	0.052	0.014

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BendBright-XS to BendBright-XS

Splicing BendBright-XS to itself works like splicing every other standard SMF. Given that spliced fibers have identical chemical compositions, splicing conditions are usually more relaxed than splicing with dissimilar fiber. As a result, fusion splicing usually exhibits better performance than when splicing with heterogeneous fibers. This is shown in table III and Figure 5 using different commercially available splicing machines. In any case, average splicing losses and distribution widths of the splice losses distributions are remarkably low.

Table III: Splice loss statistics for fusion splice tests BendBright-XS with itself. Measurement performed with bidirectional OTDR method

Fusion Splicer Model	SETTINGS		1310 nm		1550 nm	
	Program	Alignment	Average	Standard Deviation	Average	Standard Deviation
			dB	dB	dB	dB
S177A	SM	Cladding	0.026	0.034	0.019	0.035
S177A	MM	Cladding	0.047	0.023	0.038	0.013
S175	SM	Cladding	0.038	0.022	0.036	0.027
T-39	SM	Cladding	0.045	0.032	0.044	0.027
FSM-50S	Auto	Core	0.027	0.016	0.015	0.021
FSM-11S	Auto	Fixed V-groove	0.036	0.027	0.036	0.015
FSM-17S	Auto	Fixed V-groove	0.036	0.036	0.033	0.039
FSM-40S	MM	Cladding	0.066	0.031	0.053	0.024

4. OTDR measurements on splices

Optical Time Domain Reflectometers (OTDR, see example picture, Figure 6) are widely used in the telecommunication industry for testing bare and cabled fiber, including final link commissioning. OTDRs can measure the attenuation coefficient of fiber and are extremely useful to analyze discreet events in a link such as splice points or connector pairs. These instruments are also extremely useful in locating damaged or distressed cable or broken fibers.

Fig. 6 Example of OTDR for field use

OTDR is based on raylight scattering. A small fraction of the light is spread in all directions when it encounters in-homogeneities of the size of its wavelength. A small part of this light is captured by the core of the fiber and propagates backwards (see Figure.7). It is called backscattered light. It is a local phenomena and any variation of the backscattered level along the fiber is due to a defect or to an alteration of the properties at a local point.

When measuring, a light pulse is first injected into the fiber(s) under test. Then the OTDR measures the amount of backscattered light as a function to the time from the initial pulse.

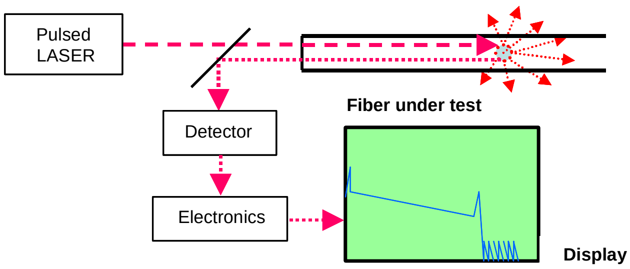

Fig. 7 Rayleigh backscattering basic principles

A representation of the OTDR power P(z) at wavelength λ backscattered by a point z along an optical fiber is [1]:

$$P(z) = C.\frac{\lambda^2}{MFD^2(z)}.P_i.\tau_W.10^{-\frac{2}{10}\alpha.z}$$

[1] where:

- Pi is the input OTDR pulse power
- τ_w is the input OTDR pulse width
- z is the distance from the origin
- α is the attenuation coefficient of the fiber (assumed constant to simplify the equation)
- MFD(z) is the fiber mode field diameter at point z
- C is a constant, which depends on several parameters such as the fiber material

Equation [1] shows the backscattered power depends on e.g. the pulse-width, the fiber attenuation coefficient and the MFD. The optical echo, as given by the above equation, is conventionally represented on a logarithmic graph: it therefore appears as a (theoretically) straight line, where the slope represents the attenuation coefficient of the fiber, α.

Combining fibers by means of mechanical or fusion splices may result in loss of the optical signal because of a number of aspects:

- radial offset of the core centers
- angular offset (tilt)
- axial offset (mechanical splices)
- mismatch of MFDs

This section focuses on the MFD mismatch because that is in most cases an important contributor to “apparent splice loss” displayed on an OTDR and it can cause confusion when measurement results are wrongly interpreted (See Section 5).

The true loss due to MFD mismatch is given by equation [2]:

$$Loss_{due\ to\ MFD\ Mismatch}\,[dB] = -20\,Log\left(2\frac{MFD_1.MFD_2}{MFD_1^2 + MFD_2^2}\right)$$

The induced (true) splice loss due to MFD difference is quite small, as shown in Figure 8. Typically this loss can be ignored due to its small order of magnitude. As an example, when MFD_1 = 9.2 µm and MFD_2 = 9.0 µm, the induced loss is only 0.002 dB.

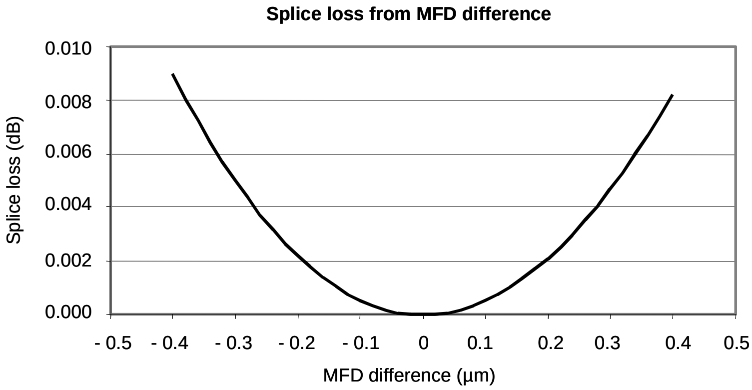

Fig. 8 True splice loss due to MFD difference

The specification of splice losses serves two goals. The first is to ensure that the optical link loss is within the loss budget as it is set by the optical transmission systems. The second goal is to ensure a mechanically stable and reliable fiber splice that will last as long as the fibers and the optical fiber cable.

To achieve the first goal a maximum average splice loss should be set. To comply with the system budget, a maximum individual splice loss is not needed, because the systems functionally depends on the total link loss, not on an individual splice.

Fig. 9 Illustration of field installation. In the foreground, a splicing machine and, in the background, a connection box.

The second goal, mechanical reliability of the splice, is not covered by attenuation alone. Mechanical reliability is assured by performing a splice proof test, which is performed automatically on most machines (see example picture, Figure 9) after the actual splicing is finished. This is to secure a minimum level of mechanical reliability. Worldwide specifications for splice loss on SM fiber do vary, but they agree on two main points:

- Splice loss specification should be based on averages
- The measurement of splice loss is done by averaging bi-directional OTDR measurements. This is described in more detail in section 5

5. Practical considerations on splice loss determination

During installation, the splice loss is estimated by the optical image processing system of the splicer unit. Based on this estimation, the splice can be approved or rejected. When commissioning an optical link, splice losses usually are checked again by OTDR testing from either one side or from two sides of the fiber link. Note, that for testing splices in networks with optical splitters, special procedures exists.

To determine the loss of a splice, in general two possibilities are available: power metering and OTDR. Since a power meter measures end to end loss, the OTDR is the only tool available to measure the loss of individual splices. With the OTDR technique, special care should be taken since OTDR’s do not directly measure splice loss. There is a special effect referred to as “Apparent Gain” and “Apparent Loss”, which are related to the OTDR principle of

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operation.

The OTDR backscatter power is very sensitive for the local MFD, as it can be seen from equation 1. This backscattered power is inversely proportional to the MFD of the fiber. Assuming all other parameters in equation 1 are equal, this means that in a fiber with smaller MFD, the backscattered power is higher than that in a fiber with larger MFD.

When fibers with different MFDs are spliced together, the backscatter power level just before and just after the splice will differ. When measuring from a fiber with a larger MFD into a fiber with a smaller MFD, the amount of light being backscattered from the fiber at the launch side of a splice is lower than that from the fiber at the other side of the splice. The OTDR may interpret this difference as an apparent increase in power. If the apparent increase in power is greater than the true loss of the splice itself, the OTDR trace shows an overall increase in optical power or apparent gain. Measured in the opposite direction (light is launched through the smaller MFD fiber into the larger MFD fiber), the OTDR trace for the same splice junction will show an exaggerated loss (apparent loss). This directionality is strictly because of the differing MFDs.

Especially in unidirectional measurements, this particular characteristic of OTDR testing may cause misinterpretations in case of MFD mismatch. Apparent gain and loss should not be misinterpreted with true optical loss. This commonly known phenomenon is an artifact of the unidirectional OTDR measurement which in general is well understood in the industry. Figure 10 shows an example of unidirectional measurement with apparent gain and loss.

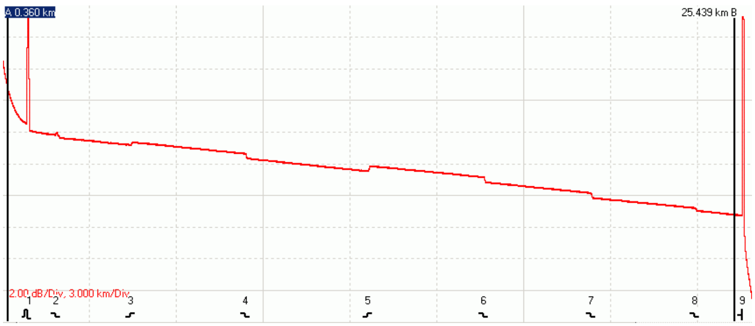

Fig. 10 Example of and OTDR for field use. Typical OTDR trace with splices, including “gainers”

The error in the unidirectional measurement (apparent gain/loss), is estimated by the following equation [3]:

$$Loss_{OTDR\ Error}\ [dB] = \left| 10\ Log\left(\frac{MFD_1}{MFD_2}\right) \right|$$

This apparent loss or gain does not have an effect on the system loss budget and should not be considered as true splice loss. In the previous example with MFD_1 = 9.2 µm and MFD_2 = 9.0 µm, the error in the measured unidirectional loss equals 0.1 dB, much larger than the true loss due to the MFD mismatch (0.002 dB), see Figure 11.

The splice effect displayed by the OTDR is a combination of the actual true splice loss and the apparent gain or loss resulting from the different MFDs. When no true loss is present, the effective gain and loss shown by both bidirectional OTDR traces are identical in size.

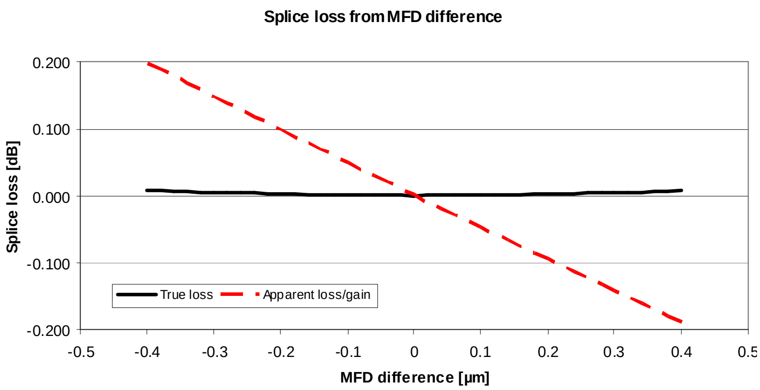

Fig. 11 Error in unidirectional OTDR measurements (apparent gain or loss) in comparison to true splice loss due to MFD difference

Normally some true loss will be present (e.g. because of offset, tilt, etc), because of which the effective gain and loss shown by the OTDR are asymmetric, as shown in Figure 11. From a unidirectional measurement this true loss can NOT be determined.

The apparent unidirectional splice loss as shown by the OTDR can than be written as equation [4]:

$$OTDR_{Splice\ Loss\,/\,Unidirectional\ Meas.}[dB] = True\ Splice\ Loss + Loss_{OTDR\ Error}$$

In bidirectional measurements $Loss_{OTDR\ Error}$ changes sign in case of dissimilar MFDs. From this, it’s clear that the true loss of a splice can only be determined by performing a bidirectional OTDR measurement and averaging both OTDR loss readings (see Figures 12 and 13), as standardized in the Int. Standard IEC 60793-1-40

(Measurement methods and test procedures – Attenuation) and the Industry test procedure EIA/TIA FOTP-61 (Measurement of Fiber or Cable).

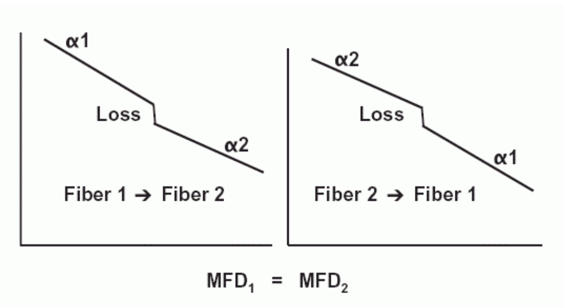

Fig. 12 Two bidirectional OTDR traces showing a splice between fibers with unequal fiber attenuations (α1 > α2) and a true splice loss. Because of the assumed equal mode fields both traces show the same true loss.

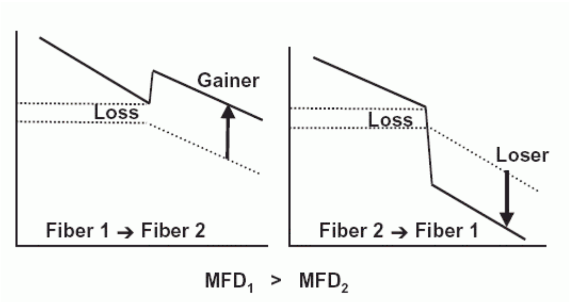

Fig. 13 The same two bidirectional OTDR traces, now assuming difference in mode ($MFD_1 > MFD_2$), causing an equal "Loser" and "Gainer", which - due to the presence of true loss - are unequally shown by the OTDR.

While the official procedure to determine true splice loss is the average of two bidirectional OTDR measurements, these two-way OTDR tests are not always possible (e.g. when one side of a spliced link is not accessible, or when the link is too long). In such a case the true splice loss can NOT be determined any more from the single OTDR trace and Draka recommends then to use alternative methods, which in general are less accurate.

One alternative method is to rely on the estimated splice loss given by the splicer in combination with a unidirectional OTDR check on the average attenuation per km of the total link. (In a unidirectional OTDR test a gainer splice is expected to be followed by a loser splice and vice versa).

A second alternative method is to use an optical power-meter. Taking into account the fiber linear attenuation, it gives the total loss of the link and the splices average loss.

In summary, the maximum apparent splice loss seen by unidirectional OTDR measurement can be calculated with equation [5]:

$$\text{Maximum } Loss_{OTDR\ Error}\ [dB] = \left| 10\ Log\left(\frac{MFD_{\max}}{MFD_{\min}} \right) \right|$$

Table IV: Examples of calculated apparent loss from MFD differences

MFD (µm)		Apparent Loss (dB)
Minimum	Maximum	
8.9	9.1	0.10
8.8	9.2	0.19
8.7	9.3	0.29
9.0	9.4	0.19
8.6	9.4	0.39
8.6	9.0	0.20

Table IV shows the apparent loss for some MFD differences. For Draka ESMF with a MFD_{1310} specified as 9.0 ± 0.4 µm, the worst case apparent loss/gain is 0.39 dB.

Finding two fibers opposite of each other that are on both limits of the MFD range is of course very unlikely to happen.

Unidirectional OTDR tests can be useful for making a first analysis of a link to select splices that should be redone. Taking into account that modern fiber can be spliced with low loss, a relatively high threshold (e.g. > 0.4 dB) should be set in order not to redo splices that will show as a gainer from the other side.

As OTDR measurements mostly are performed when all splice closures are closed and buried or mounted, redoing splices will require time consuming operations like traveling, road-guarding, equipment setting up, etc. Because these additional operations account for high additional costs, redoing of splices should be prevented as much as possible by selecting an adequate measurement strategy.

Conclusion

Draka ESMF fiber (G.652.D) can be spliced to itself and to other SMF complying to ITU G.652 with splice losses that very rarely will exceed 0.1 dB.

Same conclusion applies to BendBright-XS, Draka's bend-insensitive SMF introduced in 2006. The work carried out with the splicer manufacturers and the tests performed on the most popular machine are a guarantee. Draka's bend-insensitive SM fiber BendBright-XS can be spliced to itself and to other SMF without any decrease in splice quality.

Splice loss is measured by averaging bidirectional OTDR measurements.
Specification of splice loss should be based on average splice loss.

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