Ensuring Low Splice Loss

With High Quality Fibers

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Low fusion splice loss and ease of splicing are important needs for successful, low cost cable installations and growth to faster networks. To ensure low splice loss, one must begin with high quality fiber. OFS recommends proper fiber selection to help in achieving low splice loss and in making cables easier to splice.

Field installation of optical fiber cables can be challenging even under the best circumstances. Many times, craft personnel are called on to join cable ends together in adverse weather conditions or rough terrain and difficult to reach locations, as in "bucket" trucks for aerial cable splicing. Placing extra burden on these highly trained professionals by complicating their task is unproductive and costly to the network owners. What they really need are fibers that are simple to prepare for splicing and that easily and accurately splice together without remakes, and with long-term reliability.

Next to performance and price, specifications that affect field splicing are typically afterthoughts. Yet installation costs continue to increase as craft wages tend to grow from year to year. It only makes sense that fibers that help minimize the time spent on each splicing task will dramatically improve productivity and lower installation costs.

Fiber Parameters for Improved Splice Performance?

Fiber data sheets contain many important parameters that can be used to estimate signal performance and hence a fiber's value in your network. Generally speaking, core/cladding concentricity error, mode field diameter tolerance, outside diameter tolerance and fiber curl are the important fiber parameters that affect splicing performance. Prioritizing your fiber spec needs for splicing depends on the choice of using single-fiber or mass fusion splicing.

With single fiber fusion splicing and to some extent, mass fusion splicing, the loss performance is based on the core/cladding concentricity error. In fact, 99% of single-mode fiber splice loss can be attributed to the probability distribution of core/clad concentricity error, according to Stephen Mettler, OSP industry consultant and author of Optical Fiber Splices and Connectors.[1] In mass fusion splicing, fibers are aligned using their cladding diameter as a guide. Thus, for mass fusion splicing, fiber outside diameter and outside diameter tolerance are the most important values. OFS' fibers, including AllWave® and TrueWave® fibers, have industry leading specifications on core/clad concentricity error and cladding diameter geometry tolerances.

Parameters beyond geometry

Besides fiber geometry considerations, parameters that impact splice preparation such as coating strippability, and operational performance such as fiber curl, can have time saving impact as well. Before a splice is made one must free the fibers from the cable and strip back the protective acrylic coatings so that the bare glass is exposed to the fusion splicer. Clean and easy strippability of this coating is a bonus feature. OFS' fibers feature high performance DLux® coatings for excellent environmental performance and long-term reliability. This protective coating is easily removed for splicing and connectorization. Also, OFS' internal qualification criteria exceeds Telecordia GR-20 requirements for coating strippability, helping to reduce the time operators spend stripping fibers or ribbons and cleaning their stripping tools.

Fiber curl is another key parameter that affects both splice performance and set-up times. Fiber curl affects the way that the fiber lays in the V-grooves of the fusion splicer. Low fiber curl can impact setup or splice remakes. OFS maintains industry leading specifications on fiber curl.

Splice performance of like and mixed fiber types

The excellent splice performance of OFS fibers and ribbons are summarized in Table 1and Table 2. respectively The splices used to develop Table 1 were prepared with the Fitel S176, a commercial, core-alignment single-fiber fusion splicer and measured using bi-directional OTDR. Table 1 results are from a "5x5" analysis of fusion splices where 10 spools are randomly selected from different manufacturing lots and separated into two groups of fiber. Spools from one group are then spliced with each spool from the other group, resulting in 25 total splices

	OFS AllWave Fiber	**OFS Matched Clad**	**OFS Depressed Clad**	**OFS TrueWave RS Fiber**	**OFS TrueWave *REACH* Fiber**
OFS AllWave Fiber	**0.01**	**~0.03**	**0.03**	**0.10**	**0.10**
OFS Matched Clad		**0.03**	**~0.03**	**~0.10**	**~0.10**
OFS Depressed Clad			**0.03**	**~0.10**	**~0.10**
OFS TrueWave RS Fiber				**0.03**	**0.05**
OFS TrueWave *REACH* Fiber					**0.03**

Table 1. Average 1550 nm splice loss of OFS fibers using commercially available, core-alignment single-fiber fusion splicer and bi-directional OTDR measurements. Expected values for some combinations are preceded by **~.**

It should be noted that any individual splice loss can vary somewhat from the average numbers specified in this table and do not represent absolute maximum splice loss specifications. Also, these splice losses are reported for 1550 nm wavelengths. Splice loss at 1310 nm wavelengths can vary from values measured at 1550 nm, but should result in similar low-loss values when optimized. There are other variables such as equipment and level of splicing expertise that also affect results. The most important aspects of splicing are having equipment that is in good condition and using the most up to date software that matches the fibers being spliced together.

When splicing non-similar fibers together, mode field diameter mismatch becomes a limiting parameter to achieving low splice loss performance. Also, since different fibers have difference core refractive index profiles and concentrations of dopants, arc temperature and time dependence becomes extremely important. It is best to work with individual splicer manufacturers to establish the correct settings for splicing of mixed fiber types such as AllWave® fiber to TrueWave® RS fiber.

Table 2 contains recent results obtained by mass fusion splicing of 24 fibers using the Fitel S199M24, a commercial, cladding-alignment mass fusion splicer and measured using bi-directional OTDR. A two-step arc method was used to achieve the results in Table 2, and a limited number of fibers were used, but it shows the promise of low loss with commercially available equipment and current OFS fibers. Again, individual splice loss in the field can vary somewhat from the average numbers reported in this table. As indicated earlier, the cladding outside diameter tolerance control is the most important fiber parameter affecting mass fusion splicing results. OFS fibers lead the industry in this specification.

	OFS AllWave Fiber	**OFS Matched Clad**	**OFS TrueWave RS Fiber**
OFS AllWave Fiber	**0.02**	**~0.02**	**0.05**
OFS Matched Clad		**0.02**	**~0.05**
OFS TrueWave RS Fiber			**0.05**

Table 2. Average 1550 nm splice loss of OFS 24-fiber ribbons using commercially available, mass-fiber fusion splicer and bi-directional OTDR measurements.[2] Expected values for some combinations are preceded by ~.

One Way versus Two Way OTDR and OTDR "Gainers"

The most accurate way to measure splice loss is by using bi-directional or two-way optical time domain reflectometry (OTDR) measurement. The average of the splice loss in both directions gives the best indication of loss performance. Indeed, FOTP-61, "Measurement of Fiber or Cable Attenuation Using an OTDR," indicates that fiber splice loss must be measured from both directions with an OTDR for an accurate splice loss measurement of single-mode fiber. This is because of a phenomenon known as a "gainer". In a one-way OTDR, slight mismatches in the amount of backscattered light from the fiber preceding the splice and the fiber after the splice can result in an OTDR trace that looks as though light was gained after going through the splice. If the fiber after the splice backscatters more light than the fiber before the splice plus the light lost at the splice itself, then the OTDR trace will look as though light was "gained" as illustrated in Figure 1a. An OTDR trace in the opposite direction (Figure 1b) will reveal an exaggerated loss from the same splice (since in this direction the fiber preceding the splice now backscatters more light than both the fiber after the splice). Thus, the average of the two OTDR traces will result in the true splice loss.

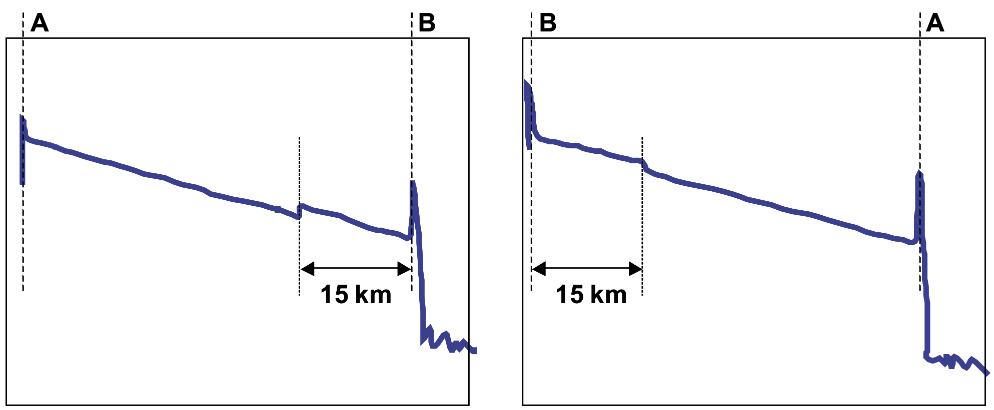

Figure 1. Illustrations of an OTDR splice "gainer". (a) "Gainer" or increase in backscattered power observed at a splice ~15 km from end terminal B. (b) Exaggerated loss in reverse OTDR observed at splice ~15 km from end terminal B. True splice loss is the average of the "gainer" and exaggerated loss.

Often one is tempted to use one-way OTDR measurements to evaluate splice and end-to-end losses. This saves time and expenses compared to the two-way OTDR measurements. However, the actual loss of any individual splice is difficult to assess by this method. One problem is the occurrence of "gainers" as described above. The other is the issue surrounding MFD tolerance. Specifically, the dimensional tolerance of MFD of any given fiber type is the major contributing factor to one way OTDR measurement errors of "splice loss". Specifically, a mismatch in mode field diameter that is within the MFD tolerance of a given fiber can create a loss that masks the true loss of the splice. Maximum MFD tolerance error for one-way OTDR measurements can be evaluated using,

$$One\,way\,OTDR\,error = 10 \cdot \log\left(\frac{MFD + tolerance}{MFD - tolerance}\right)$$

where MFD+tolerance is the maximum MFD for a given fiber, while MFD-tolerance is the minimum MFD. For example, a fiber with a MFD spec of 9.2 ± 0.4 µm has a one-way OTDR error of 0.38 dB. So, unless the requirements for the system are such that a "splice loss" measurement of 0.38 dB is tolerable, a one-way OTDR measurement would be insufficient for this system and an over statement of the true end-to-end system loss. As such, many in the telecommunications installations business have evolved to two way OTDR acceptance criteria for splice loss.

Conclusions

When evaluating optical fibers, it is important to ask about the parameters that affect splice performance such as low core/cladding concentricity error. For mass fusion splicing, a low value for cladding diameter tolerance is needed, as well. Other geometrical and coating specifications that help both loss performance and operator ease of use are mode field diameter tolerance, fiber curl and coating strippability. OFS has industry leading specifications across all of these parameters to insure the low splice loss performance you need for your optical networks.

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[1] C. Miller, S. Mettler and I. White, Optical Fiber Splices and Connectors, (Marcel Dekker, Inc., New York, 1986).
[2] T. Liang, et al., "24-Fiber Mass Fusion Splicing Based on Two Step Arc Power Process," NFOEC 2003.

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