Corning® TXF® Optical Fiber Fusion Splicing & Installation Recommendations

Application Note

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Introduction

As Corning® TXF® optical fiber becomes more prevalent in the marketplace, system designers need access to accurate information such as splice loss performance and compatibility with the existing fiber products. TXF optical fiber combines both ultra-low loss and larger effective area to allow high-data-rate transmission to be achieved over longer spans and extended reach. As fibers become more advanced, understanding of critical parameters such as splicing conditions and procedures, compatibility with fiber assemblies such as pigtails and jumper cables, hardware component selection, and OTDR testing becomes more important. Long-haul networks with TXF fiber can be designed more efficiently, removing the need of amplification sites to be placed in remote territories and minimizing the number of regenerators needed, even as higher data-rate upgrades with more stringent Optical Signal to Noise Ratio (OSNR) requirements are planned.

Effects of Splicing TXF Fiber with Standard Single-mode Fiber

When splicing TXF fiber with standard single-mode fiber, a question that arises is ''what is the impact of heterogeneous (different fiber types) splices?'' The driving force behind this question is the mode field diameter (MFD) differences between fibers.

Mode Field Diameter (MFD) Effect on Splice Loss

MFD is a measurement in micrometers (μm) of the light-carrying region of an optical fiber, determined by the power distribution of light traveling down the fiber at a particular wavelength. When fibers with different MFDs are spliced together, a MFD mismatch occurs at the splice point. The splice loss contributed by the MFD mismatch can be estimated using the following relationship:

$$\text{LOSS} = 20\text{LOG}\frac{1}{2}\left(\frac{MFD1}{MFD2}+\frac{MFD2}{MFD1}\right)\text{ dB} \quad \text{(Eq. 1)}$$

TXF fiber is a large effective area single-mode fiber that is fully complaint with ITU-T G.654.E and is also compatible with G.652 and G.657 type fibers. The larger effective area design of G.654.E fiber leads to slightly high splice loss when TXF fiber is spliced to G.652 and G.657 fiber types.

For example, estimated splicing loss between Corning's TXF fiber and SMF-28® Ultra fiber is shown as follows: TXF fiber has nominal MFD of 12.4 μm at 1550 nm, and SMF-28 Ultra fiber has a nominal MFD of 10.4 μm at 1550 nm. By inserting the given MFDs in equation 1, the theoretical splice loss due to MFD mismatch only can be calculated. The calculated splice loss contributed by the MFD difference is 0.13 dB.

OTDR Bi-Directional

MFD differences also affect the Optical Time Domain Reflectometer (OTDR) displayed trace. The unidirectional splice measurement between G.652 fiber into TXF fiber exhibits an ‘‘exaggerated loss,’’ reported as a positive value caused by MFD mismatch. The measurement from TXF fiber into G.652 fiber would be expected to be a “gainer” reported as a negative value, also caused by MFD mismatch. A generalized view of this relationship can be seen in Figure 1 below:

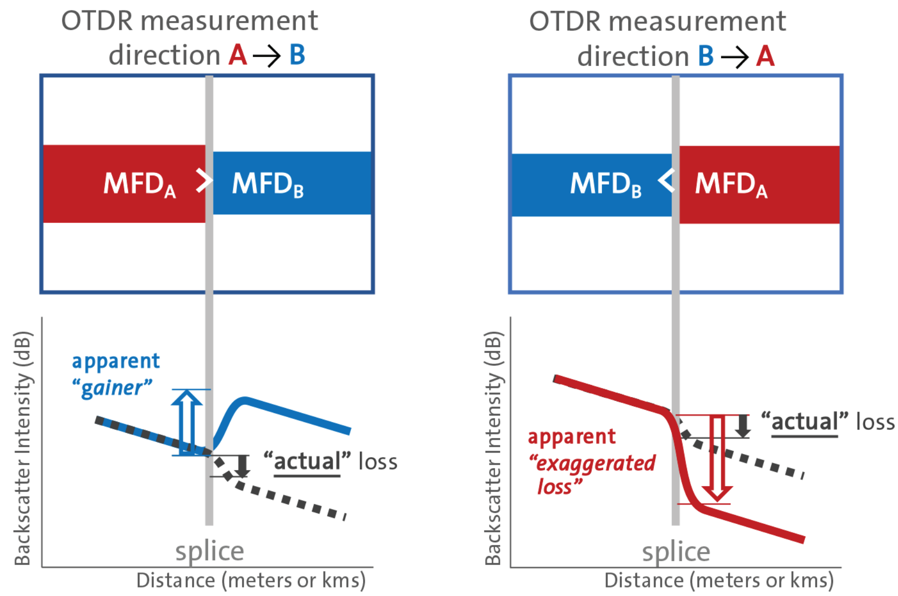

Figure 1. Illustration of OTDR backscatter trace behavior at splice location between fibers of different MFD; a) Larger MFD → Smaller MFD, b) Smaller MFD → Larger MFD

Gainers, where the trace at the splice appears to spike upwards, and exaggerated losses result from the change in the proportion of light back-scattered by TXF fiber compared to G.652 fiber; values are not necessarily an indication of poor splice loss. Bi-directional average of the measurement from both sides is required to deliver an accurate assessment of the actual splice loss.

Splicing Performance Across Common Types of Single-mode Fibers

Corning conducted fusion splicing trials with common types of single-mode fiber to demonstrate the compatibility of TXF fiber. Results from this study can be seen in Table 1.

Table 1: Splicing Corning TXF® optical fiber to different types of Corning standard single-mode fibers

			OTDR Bi-directional Measured Splice Loss			
Product-Splice Combination with TXF Fiber	ITU-T Classification	Mode Field Diameter (µm)	Avg. Splice Loss at 1550 nm (dB)	Avg. Splice Loss at 1625 nm (dB)	Max. Splice Loss at 1550 nm (dB)	Max. Splice Loss at 1625 nm (dB)
TXF® fiber	G.654.E	12.4 ± 0.5	0.02	0.01	0.05	0.04
Vascade® EX2000 fiber	G.654.B/D	11.9 ± 0.5	0.02	0.02	0.04	0.04
SMF-28® ULL fiber	G.654.C	10.5 ± 0.5	0.08	0.06	0.10	0.08
SMF-28® Ultra fiber	G.652.D, G.657.A1	10.4 ± 0.5	0.15	0.13	0.25	0.22
LEAF® fiber	G.655	9.6 ± 0.4	0.21	0.17	0.27	0.21
ClearCurve® LBL fiber	G.657.A2/B2	9.6 ± 0.5	0.29	0.26	0.37	0.33

The performance of the splice is directly connected to the MFD (and effective area) of the fiber which is being spliced with TXF fiber. Similar MFDs obtain a better splice performance because they are not subject to high MFD mismatch. Further details may be found in Corning Application Note AN3060, Guidance for OTDR Assessment of Fusion Spliced Single-mode Fibers.

Older Fusion Splicing Machine Settings

Some older types of fusion splicing machines (that pre-date the industry standards work related to the development of ITU-T G.654.E type fibers in 2016) may fail to correctly recognize G.654.E with large MFD (large effective area) values, which may result in various machine error messages during fusion splice operations:

- Erroneous fusion splicer error messages reporting of dirt or debris on the fiber end face
- Difficulty in aligning the fibers using a core alignment program
- Incorrect diagnosis of post-splice fiber geometry
- And/or inaccurate estimation of splice loss

Recommend using the following guidance and settings shown in Table 2 to minimize these errors:

- Adjust fiber parameters, such as mode field diameter (refer to fiber specifications)
- Instead use a multimode splicing program that uses fiber cladding alignment
- Contact the fusion splicer machine manufacturer or service vendor for instructions on how to update the firmware or software on the device

Table 2: Recommended fusion splicing settings to optimize TXF fiber splicing performance

Program	Cleave limit	Loss limit	Arc power	Arc time	Cleaning arc	Rearc time
SM AUTO settings	2.0°	0.20 dB	Auto	Auto (2.5 sec)	150 ms	800 ms

Visual Appearance During Fusion Splicing

A faint fusion line can be detected when the completed splice is visually inspected using the high magnification imaging system associated with a fusion splicer. Figures 2a and 2b are images of typical homogenous and heterogeneous fiber splices. The faint fusion line associated with homogenous splice and the black and white lines associated with the heterogeneous splice are both a result of small refractive index differences created by the fusing process that are detectable by a splicer's imaging system. These lines may confuse the splicer's assessment algorithm, but the lines are not an indication of a poor splice. Splices with these faint fusion lines consistently pass the splicer's strength proof test and do not represent any functional concern.

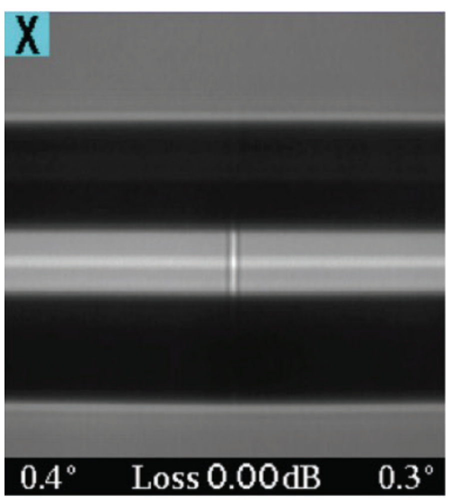

Figure (2a). Homogeneous Splice

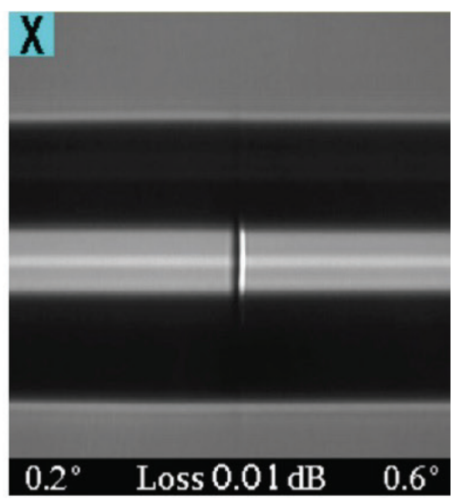

Figure (2b). Heterogeneous Splice

Hardware Component Selection

During cable installation, it is a common practice to splice fiber ends. Fiber bend occurs when excess fiber is looped inside the splice tray after splicing. Loss due to this methodology is considered in TXF fiber specifications where minimum bend radius of 30 mm is specified to reflect typical splice tray dimensions, and 100 turns represent total excess fiber from all the splice enclosures between repeaters, and a maximum 0.1 dB loss towards macro-bending is allocated in the power budget. This specification replicates the requirement of Recommendation ITU-T G.654.E. TXF fiber may incur higher macrobending loss than G.652.D fiber in tighter bend deployments.

Using Single-mode Fiber Assemblies in TXF Fiber Routes

Because the pigtail and jumpers are only a few meters in length, and therefore have no practical impact on the power loss throughout the link, either of itself or by the splice loss incurred, the industry has not favored introducing matching pigtails and jumpers made from TXF fiber to overcome the higher heterogeneous splice loss. The addition of a second category of pigtails and jumpers, for use only in TXF fiber networks, would place an alternative burden on the installer who would need to carry both types of pigtails and jumpers and ensure that they were correctly employed when switching from standard single-mode fiber to TXF Fiber and back again. Carrying both types of pigtail and jumpers could increase the potential of mix-ups and occasional elevations in the uni-directional traces would be more difficult to diagnose than the across-the-board elevation observed, and for the most part understood, today when making heterogeneous splices.

Table 3 compares the use of TXF fiber pigtails and jumper cables in TXF fiber routes. Typical splice and connector values are used to compare the expected performance differences of the two systems for this simulation.

Table 3. Typical performance of using single-mode vs TXF fiber for pigtails and jumper cables

Budget Item	**Single-mode fiber case**		**TXF fiber case**	
	dB	Spliced fiber	dB	Spliced fiber
EDFA to Pigtail Splice	0.02	SM to SM	0.15	SM to TXF fiber
Pigtail to Jumper Connection at Backplane	0.25	SM to SM	0.28	TXF fiber to TXF fiber
Jumper Connection at Fiber Distribution Frame	0.25	SM to SM	0.28	TXF fiber to TXF fiber
Splice point at Splice Bay	0.02	SM to SM	0.02	TXF fiber to TXF fiber
Splice to OSP cable	0.15	SM to TXF fiber	0.02	TXF fiber to TXF fiber
Total at Site A (1-5)	**069**		**0.75**	
Splice to OSP cable	0.15	SM to TX fiber	0.02	TXF fiber to TXF fiber
Splice point at Splice Bay	0.02	SM to SM	0.02	TXF fiber to TXF fiber
Jumper Connection at Fiber Distribution Frame	0.25	SM to SM	0.28	TXF fiber to TXF fiber
Jumper to Pigtail Connection at Backplane	0.25	SM to SM	0.28	TXF fiber to TXF fiber
Fiber-Detector Pigtail	Assumed SM pigtails to detector loss equivalent to TXF fiber detector loss			
Total at Site B (6-10)	**0.67**		**0.60**	
Total Loss at Site A & B	**1.36**		**1.35**	

In conclusion, there is no advantage to using TXF fiber assemblies instead of single-mode fiber assemblies. It is generally accepted that the one-off excess loss does not impact the loss of the entire link sufficiently to justify the use of customized patch-cords that are different for every project and the logistical difficulties of maintaining and separating inventories that this would entail.

Summary

Corning has completed a fusion splicing study for TXF fiber showcasing expected performance when conducting homogeneous and heterogeneous splicing using standard single-mode splicing parameters on commercially available fusion splicers. The results from this report confirm that TXF fiber can be readily spliced to a variety of optical fiber types while maintaining low splice loss performance. It is recommended to use bi-directional OTDR loss measurements to accurately measure splice performance, especially when splicing heterogeneous fiber combinations. Additionally, recommend adherence to ITU-T G.654.E bend specifications and standard single-mode pigtails / jumper cables during installation.

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