Guidance on splicing and field measurements of bend-insensitive fibers for FTTH deployments

Application Note

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Introduction

This application note provides general recommendations on fusion splicing and on post-installation testing of ITU-T G.657 A and B type bend insensitive fibers, such as ClearCurve® single-mode optical fiber, for FTTH deployments and recommendations to overcome compatibility issues that may exist with some types of fusion splicing equipment. Historically, the introduction of any new fiber, such as a non-zero dispersion shifted fiber (NZDSF) or the more recent ITU-T G.657 fibers, requires a simultaneous review of splicer compatibility. Bend insensitive fibers that are ITU-T G.657.B compliant and capable of coping with challenging MDU/FTTH deployments -with tight bending down to 5 mm radius- may require adoption of minor changes to splicing and test procedures to achieve optimum performance and measurement accuracy. This application note also provides guidance for correct interpretation of splice loss performance from measurements made by OTDR.

Bend Insensitive Fiber, Design approaches - Compatibility with G.652.D

Different fiber design technologies exist to achieve varying degrees of macrobending improvement over standard ITU-T G.652.D fiber types. All bend improved fibers feature a slightly smaller mode field diameter (MFD) than the average MFD of a typical ITU-T G.652.D fiber. Some fibers utilize a ring of additional dopant to yield a depressed cladding or an optical trench. A more sophisticated approach, as used in ClearCurve single-mode optical fiber, is to engineer nanoStructures™ into the fiber cladding as trapping mechanisms to confine the light in the core. Each nano-structure is a tiny inert air-filled pocket arranged in an annulus in the cladding around the core. The result is class leading bending capability - down to 5 mm radius - well in excess of the requirements of ITU-T G.657.B, while also delivering 100% compliance and compatibility with ITU-T G.652.D.

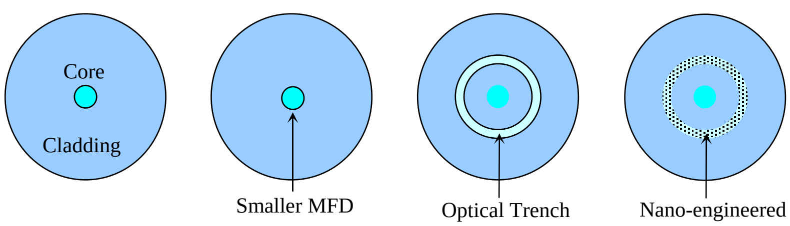

Figure 1. Different design approaches for delivering enhanced macrobend performance in single-mode optical fiber.

Splicing bend-insensitive fibers – Fusion Splice Machine Compatibility

While **all** ITU-T G.657 fiber designs are fully capable of being spliced with existing splicer equipment, new fiber design features may lead to fiber recognition issues with some fusion splicers, in particular those that rely on core detection techniques. As a result, both bend tolerant ITU-T G.657.B fibers that feature chemically doped optical trenches and bend insensitive fiber types such as ClearCurve® single-mode optical fiber may not always be correctly identified by certain makes/models of fusion splice machine. In many splicer models, optical core detection techniques are used to identify the type of single-mode fiber, and to then align the fibers to minimize splice loss due to core off-set. The optical core detection system also checks the cleave quality and angle, as well as providing an alarm if end-face dust contamination is detected. For a splicer working in core alignment mode, fibers featuring an optical trench or nano-structure design in the cladding can sometimes cause the splice machine to incorrectly identify the fiber type, have difficulty in determining the location of the core or mistakenly interpret the design features as a cleave quality/angle problems or dirt/dust on the fiber end-face.

Corning has extensively investigated the splice performance of G.657 fibers with leading fusion splicing equipment manufactures and has concluded that bend insensitive fibers such as Corning® ClearCurve® fiber can be spliced normally using a cladding alignment program, either by using a standard single-mode splicing recipe or a standard multimode splicing program: the choice of single-mode or multimode program is splicer dependent and hence Corning has formulated guidelines as illustrated in Table 1. Splicing equipment using V-groove fiber alignment is not affected by the differences between G.652 and G.657 fibers and so ClearCurve single-mode fiber can be used with the standard built-in programs for single-mode fiber.

Table 1, illustrates the splicing guidelines for some of the fusion splice equipment which have been tested by Corning, in some cases in collaborative studies with the splicer manufacturers. In some cases the splicer manufactures have issued specific firmware upgrades and or additional programs for automated splicing of ClearCurve single-mode fiber. For further details please contact a Corning representative or your fusion splicer supplier representative.

Table 1. Examples of fusion splicer equipment tested in splicing ITU-T G.657 A/B and ClearCurve® single-mode fiber.

Manufacturer	**Splicer Model**	**ClearCurve® Program or Software/Firmware available**	**Recommended Setting Splice Program Settings**
Corning Cable Systems	OptiSplice One	Yes	ClearCurve® Program
	OptiSplice LID	Yes	ClearCurve® Program
	X77i	No	Single Mode
	M90i	No	Single Mode
Fujikura	FSM-40S	No	MM1 program (multimode program)
	FSM-50S	No	MM1 program (multimode program)
	FSM 17S	No	Single Mode
	FSM 11R/S	Yes	Single Mode
	FSM 50R	No	Single Mode
Sumitomo	Type-25	No	Single Mode
	Type-65	No	Single Mode
Fitel	S175	Yes	ClearCurve® Program or Multimode Program

Note: Availability of software/firmware updates may vary by region or model version. If your specific make/model of fusion splicer is not listed please contact your representative

Splice loss measurement and evaluating results

ITU-T G.652 fibers are commonly used in the outside plant leading up to the home. Indoors, the use of ITU-T G.657 fiber cables is now becoming the norm, with operators increasingly transitioning towards the most bend insensitive fibers like ClearCurve single-mode fiber in order to protect the network and minimize operational expenditure associated with maintenance of failing links. Consequently at the outdoor indoor cabling transition point, there will be a heterogeneous ITU-T G.652 to ITU-T G.657 splice connection.

Due to the MFD difference between ITU-T G.657.A/B and ITU-T G.652 fiber types, the measured loss of a heterogeneous splice, depending on the measurement technique, may appear greater than the actual value. The most accurate methods for evaluating splice losses are the use of a light source and power meter for end-to-end measurement, or a bidirectional measurement (measuring from both ends of the link) using an OTDR, as per international standards such as IEC 60793-1-40. While these approaches are certainly the most accurate, another method, that is commonly used to estimate homogenous splices in other parts of the optical fiber network, is the unidirectional OTDR measurement which is made from one fiber end only. In an effort to save time and cost, some FTTH network installers have come to rely upon unidirectional OTDR estimates. However, due to the MFD mismatch at the ITU-T G.652 to ITU-T G.657 interface, the unidirectional OTDR measurement technique may incorrectly estimate excessive splice loss.

This occurs because an OTDR only measures the amount of light that is backscattered by the fiber; it does not directly measure attenuation or splice loss. The fraction of light backscattered at a point in the fiber is inversely proportional to the MFD at that point. Therefore, unidirectional OTDR studies of splice loss can be inaccurate in the case of splices at the point of a fiber MFD mismatch, where the backscatter fraction changes abruptly. Hence FTTH deployments utilizing ITU-T G.657.A/B fibers and employing unidirectional estimates, must consider the wider variances than can exist when splicing heterogeneously to the ITU-T G.652 install base. The chart below, Figure 2, illustrates the calculated difference between unidirectional estimates and bidirectional splice loss measurements based on the MFD.

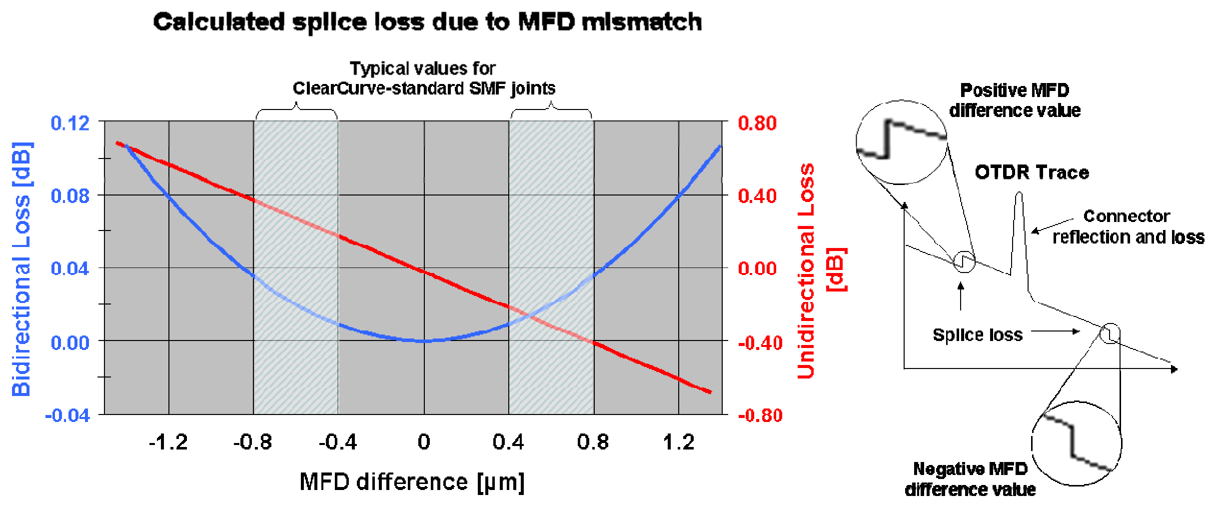

Figure 2. Comparison between bidirectional and unidirectional splice loss measurements.

Unidirectional OTDR traces, shown in the far right of Figure 2, will register a “step-loss” or “step-gain”, depending on the direction of measurement, which is a measure of both the splice loss and the artificial loss/gain due to MFD mismatch that may exist between the fibers at the splice;

Larger MFD ⇒ Smaller MFD = step “gain”

Smaller MFD ⇒ Larger MFD = step “loss”

In FTTH installations a unidirectional OTDR measurement is typically taken from the open end of the indoor G.657 fiber cable back towards the central office and the G.652 fiber cable in the outside plant. Hence, it is typical to record a step loss at the G.657 to G.652 fiber splice interface. The magnitude of this unidirectional step loss recorded by the OTDR, however, cannot be considered to be the actual splice loss value, since the differences in MFD that can exist between G.657 and G.652 fiber will over-estimate the loss by up to 0.7 dB, whereas the actual splice loss will typically be less than 0.1 dB. Therefore, any splice loss acceptance criteria based on unidirectional OTDR estimates must be increased to reflect wider MFD variances characteristic of heterogeneous splices featuring G.657A/B to G.652 types compared to homogenous fiber splices.

Splice Results
Actual splice loss values of 0.1 dB or below, as in accordance with standards recommendations, such as Telcordia GR-20, are commonly regarded as satisfactory for most network application requirements, including FTTH type deployments. Corning has conducted extensive fusion splicing performance studies of ClearCurve single-mode fiber employing a wide range of commercially available fusion splicers and using established fiber preparation practices. Figure 4 compares the typical splice loss performance of ClearCurve single-mode fiber to the splice loss performance of other ITU-T G.657 fibers and ITU-T G.652 in a standard MDU/FTTH installation (featuring 4 splice points), while also illustrating the bend loss performance of ClearCurve single-mode fiber relative to the other less bend insensitive fiber types in this standard installation (featuring twelve 90 degree bends of 5 mm radius). Here we see that the average splice loss of ClearCurve-to-ClearCurve fiber and ClearCurve-to-ITU-T G.652 fibers is typically 0.05 dB and 0.06 dB respectively, based on cladding alignment splicing.

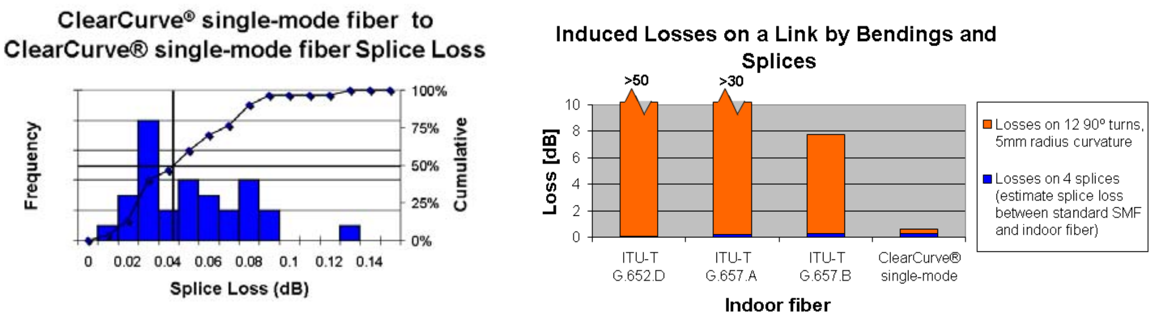

Figure 4. ClearCurve® single-mode fiber splices results and bend performance relative to other fiber types.

Although the average splice loss of homogenous and heterogeneous ClearCurve single-mode fiber splices is slightly higher than typical homogeneous ITU-T G.652 fiber splices, the overall ClearCurve singled-mode fiber splice performance is comparable to heterogeneous splicing of most other ITU-T G.657A/B to ITU-T G.652 fibers. Most importantly in Figure 4, we see that for all fibers the bend losses in a standard MDU installation are the overriding loss factor, such that splice loss performance of <0.1 dB is more than sufficient for this application. However, it is also evident that the greater bend insensitivity of ClearCurve single-mode fiber can tolerate much tighter bending and thereby protect of the overall insertion loss budget over the lifetime of the network.

Summary
Corning ClearCurve bend insensitive single-mode fiber is compatible with existing and commercially available splicer equipment. By conducting extensive fusion splicing performance studies on ClearCurve single-mode fiber, Corning has developed a set of guidelines for ClearCurve fiber splicing. In the absence of a dedicated ClearCurve fiber program or in the event of a fiber type detection error being reported on a single-mode splicing program in common with other ITU-T G.657.B compatible fibers, it is often beneficial to use a cladding alignment program or a multimode splicing program as an alternative. This is also true of other G.657.B compliant fibers. Corning's extensive studies have shown satisfactory ClearCurve

single-mode fiber splicing performance yielding a typical average loss of <0.06 dB when splicing using a multimode or cladding alignment splicing program.

Splice loss measurement of ITU-T G.657.A/B fibers also requires specific consideration. Although the splice loss of heterogeneous ITU-T G.657.A/B to ITU-T G.652 fibers are typically <0.1 dB, the larger MFD differences that can exist between ITU-T G.657A/B and ITU-T G.652 fiber types require a wider acceptance criteria for any splice loss estimates made via single ended, or unidirectional OTDR methods. While unidirectional methods offer time and cost savings over bidirectional or end-to-end light source and power meter measurements, such methods can yield erroneously high splice loss results when used to estimate heterogeneous splices.

ClearCurve single-mode fiber maybe spliced and tested using conventional methods developed for ITU-T G.657 A/B fiber types. As a result, installation of ClearCurve single-mode fiber, in single- and multi-dwelling units (MDUs) for FTTH deployments, can reduce installation and maintenance costs by allowing the use of more simplified cable installation practices while providing unrivalled protection from optical power budget failure throughout the lifetime of the system.

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