

Mechanical Splice with Keyed Angle Cleave Fibers

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Business White Paper





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Introduction

Mechanical splices have been deployed in outside plant for over 20 years in the access network. They offer fast and easy installation without the capital investment and training expense of fusion equipment.

Standard perpendicular cleave mechanical splices have become well accepted for Fiber to the Home (FTTH) drop cable installations in Asia, Europe, and are beginning to be accepted North America, where service now includes voice, video, and data in digital format. The industry is trending toward digital, however standard video transmission in North America today is analog and installers/providers require higher reflection performance to maintain good signal quality in these networks.

Analog video transmission requires lower return loss. Industry standard test requirements such as Telcordia GR-765 [1] require ≥ 45 dB with an objective of ≥ 50 dB for

fiber optic splices used with for AMVSB (analog video). The IEC 61753-131-3 [2] splice performance standard, has a Grade 1 specification of ≥ 60 dB.

The specifications for return loss of ≥ 50 dB or ≥ 60 dB are difficult for conventional mechanical splices with perpendicular cleaves to meet across the full outside temperature range. Angle cleaving the fiber ends provides improved return loss compared to perpendicular cleave splicing, and is a viable technique for analog signal transmission systems.

The Cleave Angle Solution

Index Matching Gel

Perpendicular cleaved fibers have been traditionally used successfully along with index matching gel to improve the insertion loss and return loss of mechanical splices. At room temperature, a gelled angle fiber joint will exhibit very good return loss but one must be concerned about the outside plant conditions.

Index matching gel is typically a synthetic silicone fluid combined with a microscopic dispersion to produce thixotropic gel[3]. It is engineered to produce an optimum index match with optical fibers at room temperature. However, the gel's refractive index changes with temperature differently than that of glass. This change in index vs. temperature is commonly called dn/dT . Figure 1 below shows the relationship.

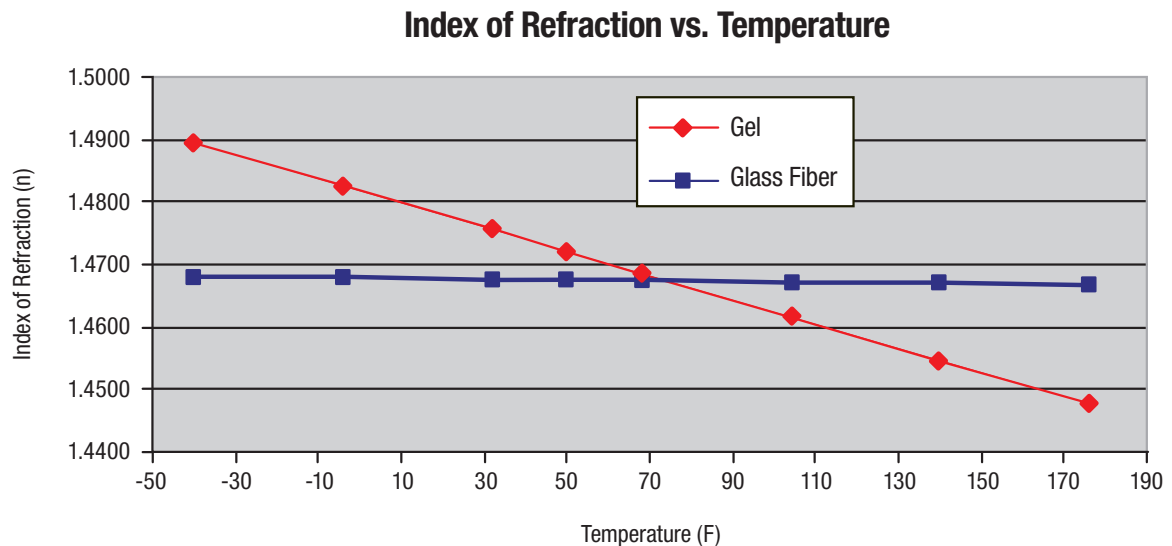


Figure 1 - Calculated Gel & Fiber Index of Refraction vs. Temperature

During temperature extremes a spliced joint having perpendicular cleaves and index matching gel can show return losses in the range of 40 dB. Index mismatch is not to be confused with instability. The gel itself is inert and stable across wide temperature ranges. Elevated time and temperature testing of index matching gels shows they offer superior stability[3]. This is supported by long term testing stability of mechanical splices which use index matching gels.

Return Loss vs. Dry Fiber Cleave Angle

One way to reduce the reflected light from a cleaved fiber is to angle the fiber end face. The angle reflects the light into the cladding where it is absorbed. The return loss vs. angle for a single fiber end face in air shows a predictable response, where higher angles return less light back down the core. Perpendicular cleaves create around 14.7 dB return loss and 8 degree angles result in 56 dB return loss. Figure 2 shows an image of an angled fiber end in air.

Measured reflection values for individual dry (non-gelled) cleaved fibers in air are shown in Figure 2 below. The results vary from theoretical [4] due to measurement capability (angle and reflection), along with cleaved fiber surface characteristics, and are limited by the noise floor of the reflection measurement instrument to -70 dB.

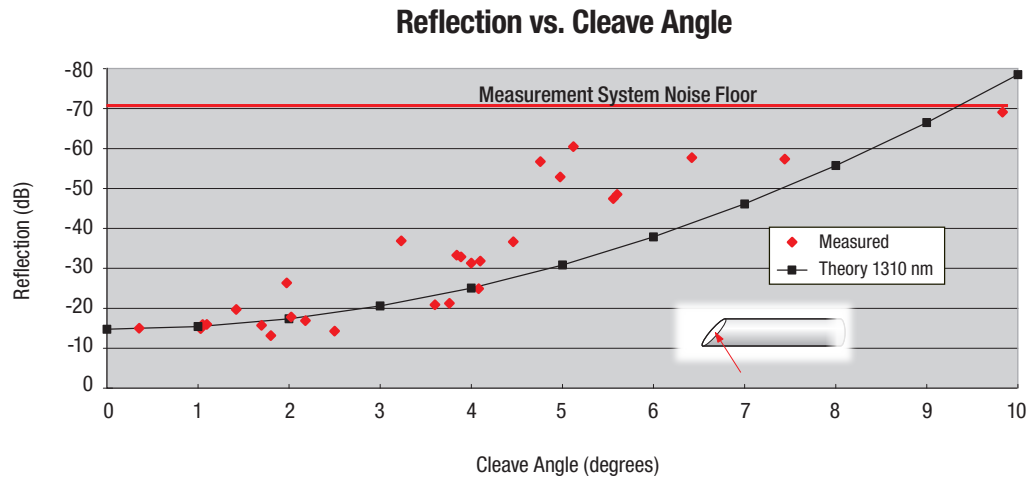


Figure 2 - Reflection vs. Cleave Angle of Single Fiber End in Air

Return Loss vs. Cleave Angle for a Pair of Fiber Ends Immersed in Index Match Gel

The return loss from a splice joint of fiber ends differs from the return loss from a single dry fiber in air discussed in the previous section, due to the multiple reflections which occur at the differing material interfaces. Interference between multiple reflections will be a complex function of temperature, geometry and wavelength and is beyond the scope of this publication. The maximum value for the return loss is presented here. Physical measurements of actual splices frequently show much less loss than this maximum. The improvement can vary during an experiment, but return loss due to multiple reflections from the glass interfaces will not exceed the calculated maximum.

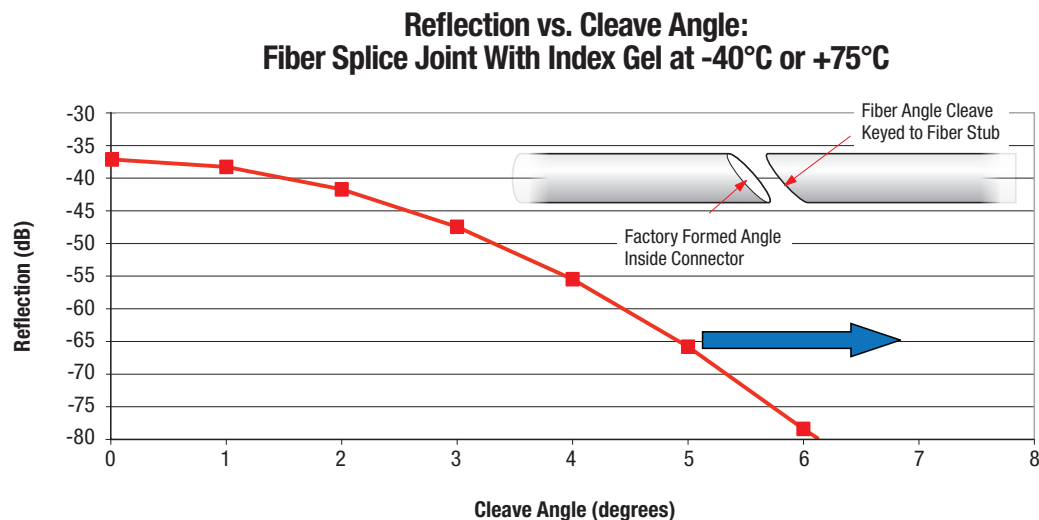


Figure 3 - Noise interference may be related to telco or power utility problems, or a combination of the two.

One way to compensate for the dn/dT difference at temperature extremes, between optical fiber and the index gel is to angle the fiber ends inside the splice. If a 7 degree angle cleaved fiber joint is immersed in index matching gel, the return loss is better than 60 dB at room temperatures. As the temperature goes toward the extremes of outside plant conditions, the gel's ability to index match will decrease slightly but the angle cleaved fiber ends send the small amount of reflected light into the cladding where it is extinguished.

As shown in Figure 3 above, if the cleave angle is a minimum of 5 degrees for both fibers, the return loss stays above 60 dB across the complete outside plant temperature range of -40°C to 75°C. If the two fibers which make up the joint have different angles, the lower angle will dominate the result.

With this knowledge, an optimum cleave angle for a gelled splice joint can be selected. In general, it is easier to make smaller cleave angles. Higher cleave angles result in greater variation, so this encourages selecting cleave angles which are not unnecessarily high. For example, if the cleave angle is ± 2 degrees, the nominal set-point for the cleaver should be 7 degrees, to maintain an angle above the 5 degree minimum.

Environmental Stability vs. Keyed Fiber Rotation

For optimum splice performance, one must also rotationally match the angle cleaved fibers. As one fiber is rotated relative to the other around their shared fiber axis, a small variable gap between the fiber cores is created. This is due to the edge of the fiber tips making first contact as shown in Figure 4 below.

We selected two different scenarios for mismatched angles for this study. Where no attempt is made to match the fiber ends, 180 degrees of rotational mismatches represents the worst case. Where crude techniques such as flags or finger grip on the fiber are used to maintain rotational keying of the fiber ends, a rotational mismatch of 45 degrees seems a reasonable worst case.

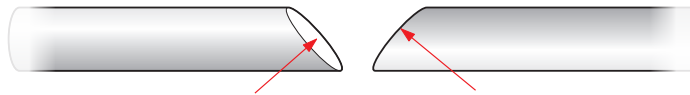


Figure 4 - Rotationally mismatched Fiber Ends (angle exaggerated for clarity).

Splice samples with 7 degree cleaves were assembled with 45 degree rotationally mismatched cleaved fiber ends. This produces a core gap of 5.9 μm . These samples showed slightly poorer return loss stability during temperature cycling to outside plant conditions from -40°C to 75°C, compared to fiber joints prepared with matched cleave-angles. Additional splice samples with 7 degree cleaves were assembled with 180 degree rotationally mismatched cleave fiber ends. This produces a core gap of 15.3 μm . These 180 degree mismatched samples showed noticeably poorer return loss stability, with all samples dipping below 60dB return loss during some portion of the temperature cycle test.

These experimental studies show that mismatch in the rotation of the fiber ends is undesirable for optimum performance of splices in extreme outside plant conditions.

Summary

Angle cleave mechanical splicing with keyed fiber ends can provide economical and attractive performance for consideration in sensitive network applications such as analog video in adverse temperature conditions.

References

1. Telcordia GR-765 “Generic Requirements for Single Fiber Single-Mode Optical Splices and Splicing Systems”.
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3. Joseph F. Braza Ph.D. and Joe C. Brooks III, “Index Matching Gel and Mechanical Fiber Splice Technology for FTTH” Proceedings of 2008 FTTH Conference Nashville, TN.
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