Optical and Mechanical Resilience of Reduced Coating Diameter Fibers

Application Note

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Introduction

Miniaturization of cables and associated hardware is a major trend in the optical fiber cable telecommunications industry. This is born out of a necessity to improve installation efficiency and accelerate penetration of fast optical fiber-based bandwidth service coverage to subscriber areas which are difficult to reach or costly to service. Urban areas can be especially challenging for network operators when trying to deploy high fiber-count cables in underground duct infrastructure. Smaller diameter, high fiber-density micro cables offer several distinct advantages: more efficient duct utilization, easier handling and faster installation. Smaller and more lightweight cables can be deployed quickly and more efficiently by blowing into smaller duct sizes. Additionally, smaller form factor cable and hardware can help to reduce costs associated with packaging, storage, and freight. The new generation of micro cables require smaller diameter optical fibers that occupy less space and offer greater optical transmission resilience in confined spaces. Reduced coating diameter fibers started to emerge early in the last decade and any initial concerns in the industry about the standardization and multiple sourcing of these products have been addressed by the modification IEC 60793-2-50 in 2018 to include 200 micron coating diameter as an option. Reduced diameter fiber options are now offered by the majority of market-leading fiber suppliers.

Corning's first reduced coating diameter product was SMF-28® Ultra 200 fiber which features a reduced coating diameter of 200 microns that is optimal for high fiber-density outside plant cabling (OSP) and provides 100% ITU-T G.652.D backwards compatibility with enhanced bending capability [1]. In response to the growing market acceptance of lower coating diameter product and the increased need for higher fiber-count, densely packed cables across all application spaces, Corning is expanding its suite of reduced coating diameter products. This application note explains some of the key features of these advanced fiber types and shows how to maintain the mechanical and optical properties of the fiber through cable processing.

For example, Corning recently introduced SMF-28® ULL Optical Fiber with 200 micron coating diameter, which combines ultra-low attenuation and a reduced coating diameter to support ultra-low-loss high-density cable designs for long-haul deployments. SMF-28 ULL is a single-mode fiber designed for terrestrial applications and is ITU-T G.652.B and G.654.C compatible. SMF-28 ULL fiber enables service providers to transmit information across longer distances, achieve higher capacity per fiber, lower the number of active equipment sites, and reduce installation and maintenance costs. Offering a smaller diameter of SMF-28 ULL fiber to the market enables the potential for outstanding optical performance at even lower cost per bit operation. This paper provides guidance in optical cable processing to achieve these benefits whilst suppressing potential glass damaging mechanisms that might otherwise be aggravated by the reduced thickness of the surrounding coating.

As the market continues to demand higher fiber-count cables, Corning will continue to position itself for future telecommunication growth, enabling our customers to install market leading optical fibers into their networks.

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Reduced Diameter Fiber Coating

Conventional single-mode optical fibers that have become the foundation of modern-day optical telecommunication networks feature a protective coating layer with a nominal outside diameter of between 242 micron to 250 micron depending on application. Since Corning developed the first low-loss fibers in the 1970s, optical fiber technologies have evolved tremendously. Enhancements in both glass and coating technologies have improved optical transmission capabilities and the protective qualities of coating that preserve the optical and mechanical properties of the fiber. For decades, Corning's optical fibers have been mechanically durable and optically reliable across numerous outside cabling applications deployed worldwide. Corning has also developed fibers with a reduced diameter coating to enable the development of smaller diameter, high fiber-density cables [2]. These fibers have glass technology which helps advance the optical performance levels of the fiber and an optimized coating which maintains its protective functions despite the reduction in coating thickness. Figure 1 illustrates that Corning's dual layer CPC® protective coating performs two main functions for SMF-28 Ultra 200 fiber (Corning's first reduced diameter product): 1) The softer inner layer which has a lower Young's modulus and low glass transition temperature, preserves the fiber's optical performance properties during its operational lifetime, 2) the hard outer layer serves to protect the inner coating layer and the glass from mechanical damage during processing, installation, and expected service life. The smaller form factor of ~30% compared to 242 microns presents the opportunity for significant increase in the fiber density of cables and network capacity in a space constrained environment.

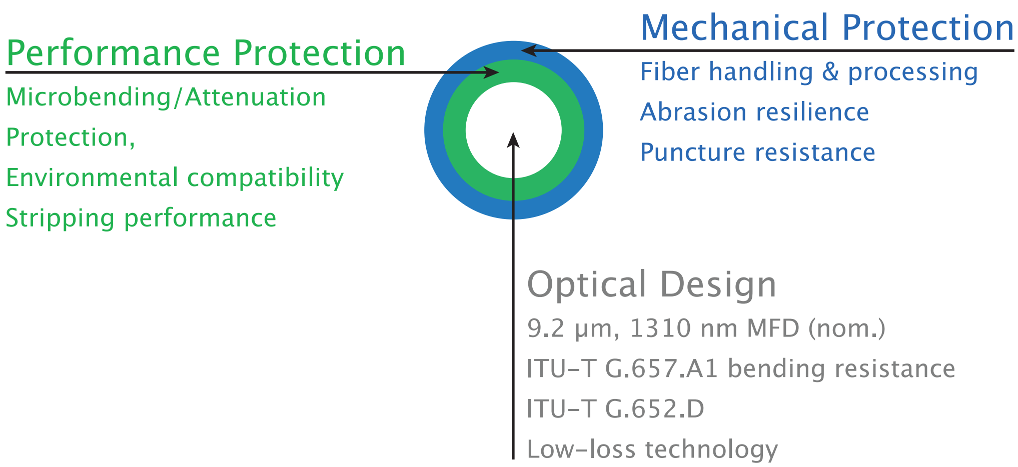

Figure 1 . Two main principle functions of the dual-layer Corning CPC® protective coating and key design aspects of the central glass fiber for SMF-28® Ultra 200.

Mechanical Protection and Fiber Handling Properties

The mechanical protective qualities of the fiber coating are dependent on the properties of the outer coating layer. To achieve the desired levels of coating toughness requires the outer coating to have high fracture toughness and sufficient radial thickness to protect the glass from damage during handling and cable processing, and to remain effective during its operational lifetime. Corning has studied the coating toughness properties over many years to understand how to design advantaged materials that enable reduced diameter fiber to be deployed in the interest of higher fiber density and maximizing network capacity [3,4].

The polymer material for the outer layer of the current generation of Corning's CPC® coating system was designed to have higher puncture resilience than the preceding versions. However, an optical fiber with a 200 micron coating diameter will have lower puncture resistance than an equivalent fiber with a ~242 micron coating layer because of the reduced thickness of the outer material. With the consequential reduction in protection, a cabler might expect to see more breaks per kilometer that can be attributed to process related puncture mechanisms. However, the as-drawn strength of Corning's 200 micron fiber products is in fact unchanged from the ~242 micron versions as the reduction in the outer coating dimension does not change this property. Assuming the absence of an external mechanism that could cause glass damage through the coating, an elevated break rate should not be observed for processes designed to operate reduced diameter coating fiber.

Some of the external damage mechanisms that could be more impactful for a fiber with lower coating diameter and that need particular attention paid to control are as follows: whip (i.e. penetration of the coating from flailing fiber ends), abrasion from an uneven fiber contact surface, abrasion from fiber running across a frozen contact surface, puncture by dirt or accumulated debris captured between the fiber and a contact surface, and manual handling during equipment thread-up.

After several years of experience running reduced coating diameter fiber since introduction in 2014, Corning has reviewed cable factory break rates in one of the global factories where both conventional and reduced coating diameter fiber is processed in large volumes. Equivalent low break rates are found to be achievable in both the coloring and buffering processes for both versions of the product. With increased attention to cleaning of the fiber contact surfaces of the production lines (pulleys, rollers and guide dies) and better housekeeping in the general vicinity of the manufacturing equipment, the reduction in the coating diameter does not necessarily introduce an increased break rate.

Based on these experiences, some suggestions that could assist a cable maker when starting to process reduced coating diameter fiber for the first time are as follows;

- Consider increasing the frequency of line cleaning and component inspection. In addition to routine cleaning and inspection regimes for each shift, less frequent but regular, deep-clean of each machine with fiber contact surfaces is suggested. Fiber contact surfaces that are found to be damaged in a manner that could nick the fiber coating should be replaced immediately, all rotating parts that contact the fiber should be checked to ensure that they are not freezing, and line operators should be educated on the importance of completing the cleaning regimes thoroughly.
- Tighter specifications for fiber contact part surface finishes should be considered.
- Use reduced diameter mechanical grade fiber, rather than conventional diameter mechanical grade fiber, for the setting up of lines that will be processing reduced diameter fiber. Please contact your Corning account manager to receive the necessary mechanical grade materials to perform these set-ups.

Corning SMF-28® Ultra 200 fibers were also tested to measure coating strip force against existing requirements for conventional fibers in accordance with the sectional requirements of IEC 60793-2-50 for type B fibers [5]. Figure 3 shows the peak and average measured coating strip force for conventional coating diameter and 200 micron fibers using the same coating type. These two particular studies agree well with fiber and cable processing and handling trials, during which no changes to any fiber handling or fiber processing practices were deemed necessary, other than the required use of smaller sized machine tooling to make best use of the smaller form factor.

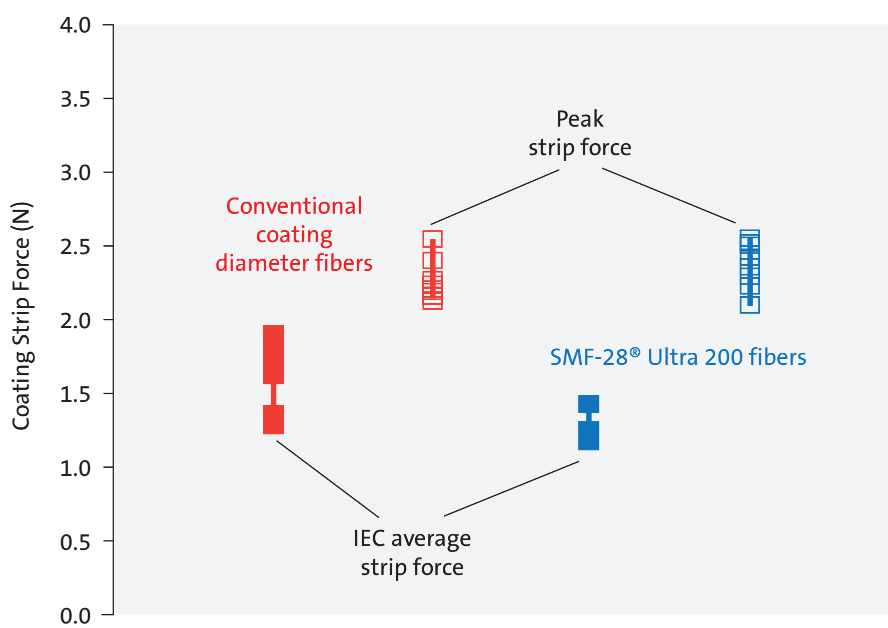

Figure 3. Comparison of coating strip force: Conventional coating diameter vs. 200 micron fibers.

As the tensile strength and mechanical reliability properties of optical fiber are determined by the glass and distribution of lower strength flaws present in the cladding surface, reduced coating diameter fiber products share the same mechanical specifications as conventional products. Furthermore, fiber strength and reliability models developed by Corning continue to apply for reduced coating diameter fiber. The applied stress guidelines that set out safe stress limits for tensile stress and bending stress applications that demand near zero failure risk or managed risk, continue to hold [6].

Fusion Splicing: Performance Compatibility

The fusion splicing performance of SMF-28® Ultra 200 fiber, when spliced to conventional ITU-T G.652.D fiber types, is equivalent to same fiber splicing between conventional coating diameter products due to the same and shared mode-field diameter (MFD) specifications of 9.2 ± 0.4 micron at 1310 nm and 10.4 ± 0.5 micron at 1550 nm. The adoption of ITU-T G.657.A1 fibers in high fiber-count outside plant cables, which feature smaller MFD, has been deferred by some network operators due to perceived concerns over splice compatibility with the existing network installed base of legacy ITU-T G.652 fibers. Earlier versions of ITU-T G.657 fibers derived some enhanced optical bending resistance from their smaller MFD, which is typically 8.6 - 8.8 microns and smaller than legacy ITU-T G.652 fibers that have a nominal MFD of 9.2 micron. SMF-28 Ultra 200 fiber specifications, while surpassing the requirements of ITU-T G.657.A1, are based on well-established industry international standards: ITU-T G.652.D and has a nominal MFD of 9.2 micron which maintains MFD consistency with legacy ITU-T G.652.D fibers to alleviate concerns over MFD compatibility during cable jointing and termination in the field.

When splicing reduced coating diameter products, some caution needs to be taken to ensure that the coating layer is stripped to a sufficiently long distance, such that only the fully stripped portion of the fiber lies within the V-groove holding mechanism of the fusion splicer. This is particularly true if attempting to splice conventional coating diameter to reduced coating diameter product as the effect of the coating in the two V-grooves will be different and could lead to a core alignment issue. Corning Application Engineers have observed that not all single fiber strippers strip 200 micron fibers as cleanly as ~242 micron fibers. Therefore, extra care should be taken to ensure all coating is removed with an alcohol wipe before attempting to splice. Alternatively, tools are available that are optimized for 200 micron removal and may be selected for maximum performance with low diameter coated fiber. The same concerns exist in regards to handling ribbonized 200 micron fibers. Care must be taken to ensure no matrix material (which bonds the 200 micron ribbon) 'overhangs' affecting the quality of the splice.

During fusion splicing studies of Corning SMF-28 Ultra 200 fiber, using both core- and cladding-alignment modes and standard splicing recipes found on all the commercially available splicing machines tested, a typical splice loss of 0.02 ~ 0.03 dB was achievable. SMF-28® Ultra 200 fiber is identifiable as an ITU-T G.652.D single-mode fiber with all splicing machines tested – including independent studies conducted by a well-known fusion splicer equipment manufacturer. The results in Figures 4 and 5 are considered representative for SMF-28 Ultra 200 fibers.

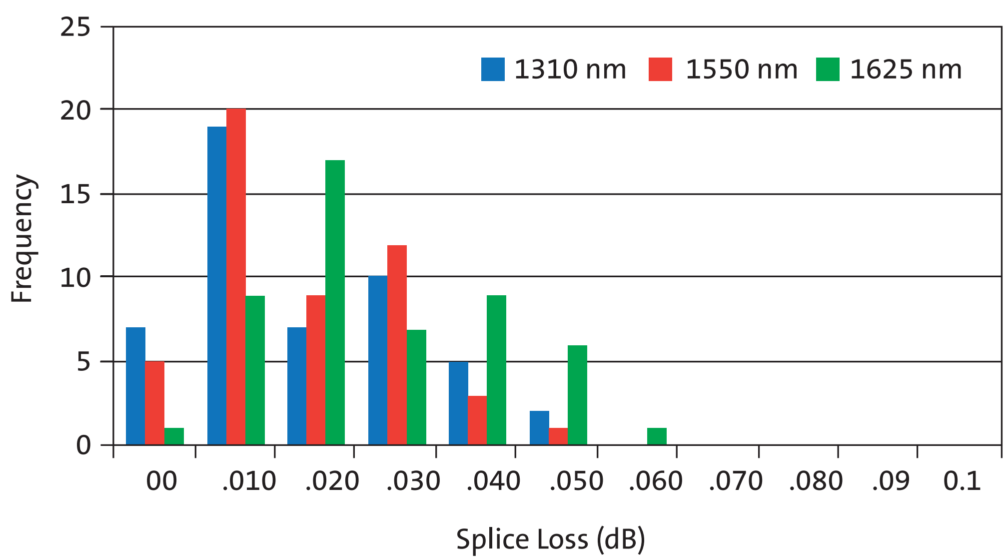

Figure 4. Representative splice loss of Corning SMF-28® Ultra 200 fiber spliced to itself.

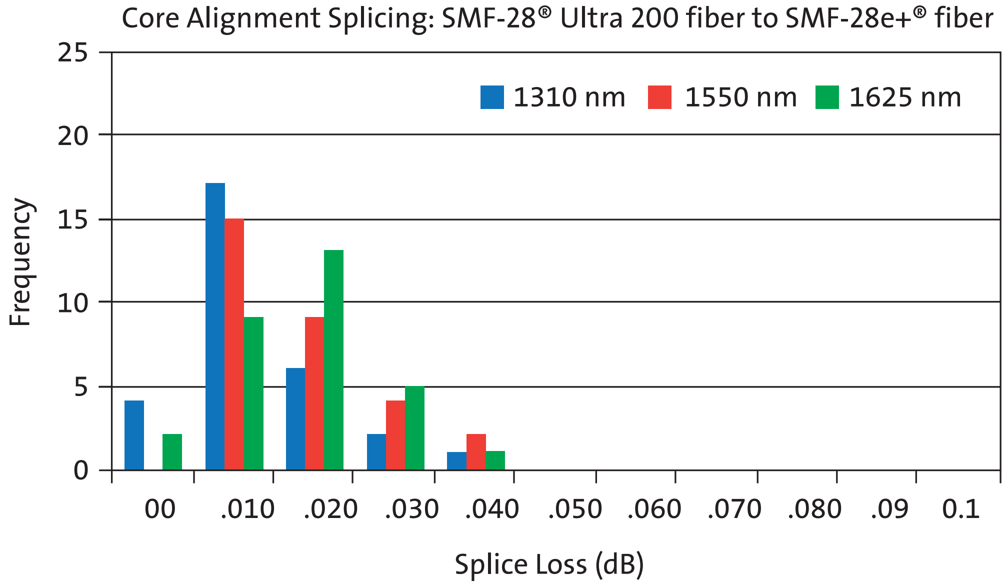

Figure 5. Representative splice loss of Corning SMF-28® Ultra 200 fiber spliced to SMF-28e+® fiber.

Summary

Reduced coating diameter optical fiber products have successfully enabled the introduction of densely packed mini-cables for more space efficient fiber deployment in access networks. Having proven their value over the previous decade, this concept is now being extended to other application spaces. As a result, Corning is increasing the number of products that are being made available in the smaller form version. With a strong track record, those experiences from the earlier generation of products have been collected to provide information and recommendations for cablers and installers who may be experiencing reduced diameter coating fiber for the first time. With correct procedures in place, Corning's reduced coating diameter fiber can be operated with the same confidence as derived from Corning's conventional coating diameter products.

References

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