

Corning® SMF-28® Contour Fiber Single-mode Fiber Innovations for Increased Cable Density in Constrained Spaces

WP1850

Issued: May 2023

Issued: August 2022

ISO 9001 Registered

Introduction

Operators and cable makers have become accustomed in recent years to the benefits of single-mode fiber featuring enhanced bend resistance and low attenuation, the leading example being Corning® SMF-28® Ultra optical fiber. Compliant with ITU-T G.657.A1 and G.652.D, these fibers have been instrumental in firmly establishing micro-cables (as detailed in the IEC family specification 60794-5-10) as the preferred solution for accelerating the roll-out of massively increased network capacity and connectivity in recent years. The global COVID-19 pandemic brought work-from-home and home-schooling to the forefront and networks struggled to accommodate the demands brought about by those drivers, in addition to the growing enthusiasm of subscribers for video streaming and social communication platforms. As operators make plans to ensure networks are prepared for the future, technology that delivers durable capacity both quickly and efficiently will find favor.

The Connectivity Challenge

Cable designs, particularly for the high-connectivity access network, have already migrated from rugged, bulky, loose-tubed designs featuring multiple layers of protection to smaller, lighter, and more flexible miniaturized versions. Micro-cables are stripped of excess material that add to the cable's weight and cross-sectional area and leverage the mechanical protection of the microduct. This allows the fibers to be more tightly packed so that fiber counts can be numbered in hundreds and still be installed into small conventional ducts and microducts that more efficiently utilize the scarce available space (Figure 1) and help overcome the challenges of routing the cable to make the final connection at the subscriber.



Figure 1. The Crowded Environment Close to the Subscriber

CORNING

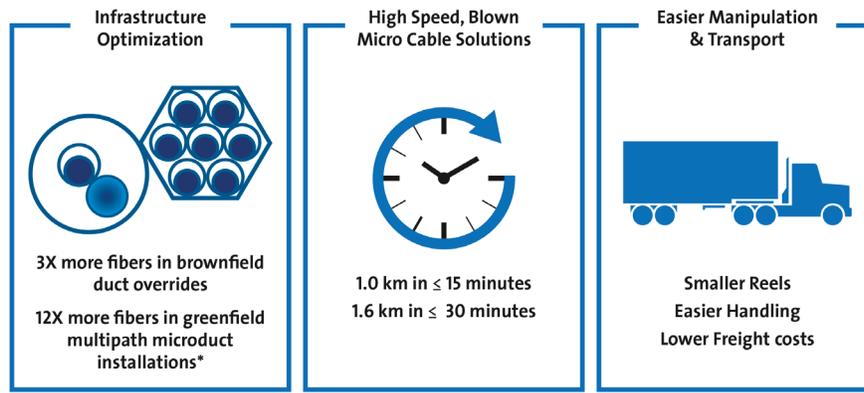


Figure 2. Blowing Light-Weight Microduct-Cables Provides a Fast, Efficient Way of Bringing Capacity On-Line

Air blowing of optical cables into purpose designed ducting (Figure 2) is an advantageous technique favored by many network operators. The method is fast to install with speeds of up to 3 km/hour possible for installing up to 1 km cable lengths using compressed air. Furthermore, lengths of up to 2 km are capable of being installed by this technique under the correct conditions. Factors such as bending of the duct and humidity can limit installation speed and distance. One of the most critical properties for achieving longer distance installation at high speed is the ratio of cable outer diameter to the duct size (bore). Microduct sizes of 14/10 mm (outer/bore diameter) for example impose a maximum cable size of ~ 8 mm, introducing a practical limit on fiber density. Microduct cables that provide greater fiber density and offer faster installation speed and reach can help to reduce installation time and cost so that large tranches of capacity may be quickly and efficiently brought into service.

An example of how micro-cables provide a fiber density advantage is presented below (Figure 3). Compare a traditional 72-fiber loose tube design with a 144-fiber micro-cable (enabled by low-loss G.657.A1 fiber), a 432-fiber high density mini-cable (enabled by low-loss G.657.A1 fiber with a 200 μm reduced coating diameter) and a 3,456-fiber ribbon-based micro-cable (also enabled by low-loss G.657.A1 fiber with a 200 μm reduced coating diameter) and observe the improvements made in fiber density.



Cable Design	Loose Tube	Micro-Cable	High Density Micro-Cable	Ribbon Based Micro-Cable
Fiber Diameter (μm)	242	242	200	200
Fiber Count	72	144	432	3,456
Cable Diameter (mm)	10.3	8.1	10.8	29
Relative Fiber Density	1	3.2	5.5	6.1

Figure 3. Examples of Increasing Fiber Count Cables (Illustrations Not to Scale) and Increasing Fiber Density

The challenge that the telecommunications industry now faces is how to increase the momentum generated by the emergence of high fiber density micro-cables. After around 10 years of cable design innovation enabled by moderately bend-enhanced fiber, the industry is ready for the next great leap forward. For this next advance, the focus has been returned to innovations in optical fiber.

Enhanced Optical Fiber Bend Resistance

ITU-T Recommendation G.657 classifies bend-resistant fibers into four categories, A1, A2, B2 and B3, primarily according to the minimum bending diameter specified (in addition, both category A types require full compliance of the fiber to ITU-T Recommendation G.652.D). Different levels of performance are illustrated in Figure 4.

Macrobend standards – ITU-T Recommendation G.657

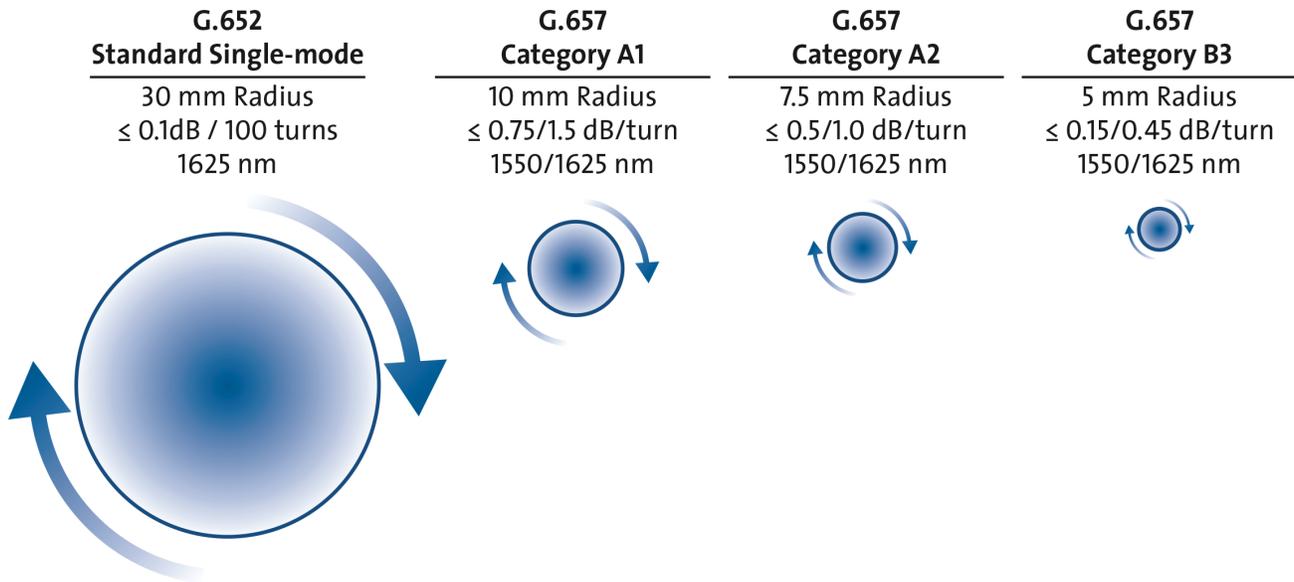


Figure 4. Tightest Bending Conditions Specified by the Different Fiber Categories of ITU-T Recommendation G.657 Compliant Optical Fiber

Crossing the threshold from A1 to A2 delivers several benefits to the network operator. The obvious benefit is assurance that fiber may be deployed in a tighter radius before optical losses begin to hinder transmission performance at longer wavelengths. In deployments that are close to the subscriber, for example in drop cables, such bends can be included by design to assist deployment around fixed frames and obstacles. Further upstream, enhanced bend resistance provides protection and insurance against unintended installation error. The challenge to increase fiber connectivity density applies not only to cable but also to inside cable joints, terminations and distribution cabinets. For example, failure to restrict fiber bend radii sufficiently during installation is more likely when the number of connections is high and risk continues to grow as new subscriber connections are added. Figure 5 shows several examples from field installations, including splice tray, aerial cable mounting and duct installation where sub-optimal fiber deployment results in fiber being forced into undesirably tight bends that can challenge the optical power budget. G.657.A2 fiber will tolerate more extreme installation errors that result in tight fiber bends before optical losses are incurred that might compromise performance. As network operators demand even more widespread and rapid roll-out of high-speed connectivity, it is inevitable that more inexperienced installers will be employed and errors will be incurred during deployment of time-sensitive projects.

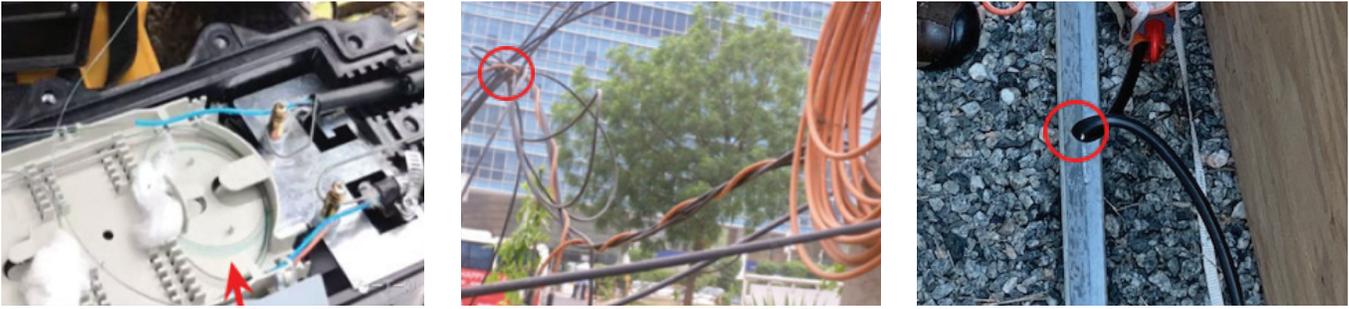


Figure 5. Examples of Installation Error Leading to Undesirable Tight Fiber Bending. Improved Resilience of G.657.A2 Compliant Fiber to Installation Errors Provides Superior Protection for the Network

In standards, bend resistance is always quantified in terms of macrobending as this test method is well defined, established and straightforward to replicate results. However, microbending performance, which is less readily characterized in standards, is also critical in addressing the fundamental challenge for network operators associated with in-cable fiber density. Microcable designs already pack fibers tightly within the cable structure. Simply bunching more of the same fibers into a more restricted space is not feasible to deliver step-change improvements in fiber density. In tightly packed conditions, fibers press against each other and against the tube wall, introducing steady loss of optical power along the fiber length by microbending. Most single-mode fibers, even those marketed as featuring improved bend resistance compared to standard G.652.D designs, will incur microbending losses that negate the low attenuation advantage when packing exceeds current design limits. Selecting one of the Corning® SMF-28® Contour fibers greatly enhances microbending resilience, opening up the potential for even further downsizing of the cable and providing a path to even higher fiber counts.

Corning® SMF-28® Fit fiber is well suited for high-density cable applications with its excellent microbend performance. It is G.657. A1 compliant and has G.657.A2-level macrobend performance at 7.5 and 10 mm bend radii. Corning® SMF-28® Contour Pro fiber incorporates Corning’s well established low-loss technology with full G.657.A2 compliance across all defined bend radii and excellent microbend performance. It delivers superior attenuation performance across the operational spectrum, which is well protected against microbending in even the most densely packed designs. This capability translates to 20% increase in the area of potential network coverage compared to conventional G.652.D optical fiber.

MFD - The Importance of Compatibility

Optical fibers that comply with the requirements of ITU-T G.657.A2 are not new. These emerged with the first issue of the ITU-T G.657 standard in 2006. Early G.657.A2 designs, such as Corning® ClearCurve® LBL fiber, derived superior bend resistance from a reduced mode field diameter (MFD) centered at 8.6 μm at 1310 nm. Although this design maintains compliance with ITU-T G.652.D (a pre-requisite for ITU-T G.657 Category A compliance), fibers with reduced MFD are dissimilar in this property to the majority of standard single-mode fiber installed in the network. This can lead to challenges with OTDR based splice performance checks if existing builds are extended with low MFD G.657.A2 fiber (Figure 6); more expensive and time consuming bi-directional OTDR link integrity measurements will be required

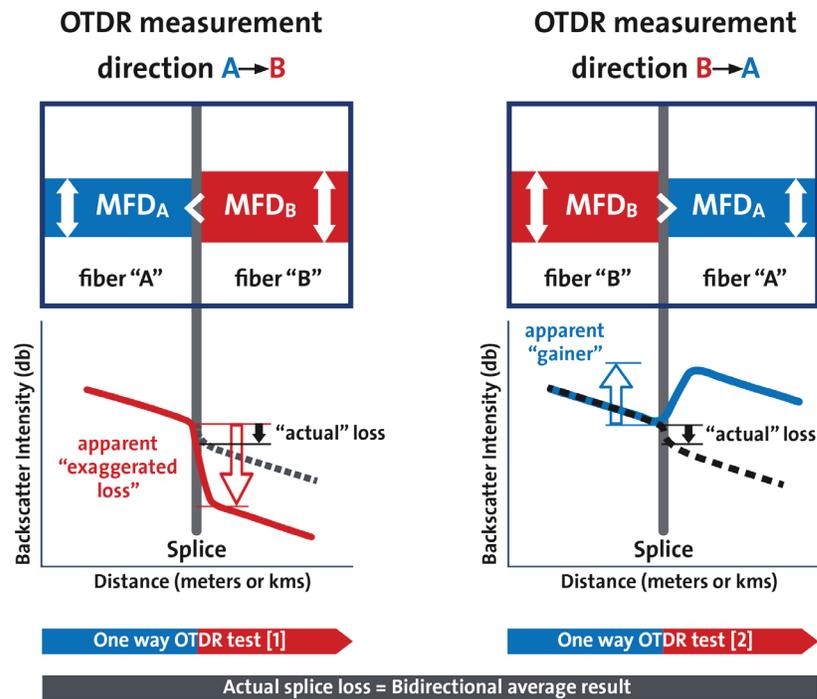


Figure 6. MFD Mismatch Leads to Misleading OTDR Traces and Potential for Expensive and Unnecessary Additional Work

SMF-28 Contour fibers are designed with a MFD of 9.2 μm , dramatically reducing the risk of MFD mismatch issues when splicing into the existing G.652.D network and allowing a confident assessment of splice quality to be determined with a single-ended measurement. Splicing studies performed by Corning, using widely deployed core alignment fusion splicers, demonstrated typical splice loss of 0.02 dB when spliced both homogeneously and to conventional G.652.D fiber.

Conclusions

SMF-28 Contour optical fibers combine excellent microbend and macrobend performance with a 9.2 μm MFD. These fibers offer cable designers the opportunity to provide network operators significantly increased optical fiber density with high fiber count, light-weight micro-cables with no compromise on MFD compatibility with the existing network. SMF-28 Contour fibers have a reduced 190 μm outer diameter, offering the opportunity for even greater fiber density micro-cables to be designed. These cables can be installed quickly, efficiently, and with improved resilience to error during network deployment providing much needed increases in communication network capacity and connections.

Corning Incorporated
www.corning.com/opticalfiber

One Riverfront Plaza
Corning, New York
USA

Phone: (607)248-2000
Email: cofic@corning.com

A listing of the trademarks of Corning Incorporated and its subsidiaries is available at <http://www.corning.com/worldwide/en/legal-notices.html>.

© 2023, Corning Incorporated