Corning® SMF-28® Contour Fiber
Innovations in Single-mode Fiber Offering Increased Fiber Density Cables in Constrained Spaces

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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 has brought work-from-home and home-schooling to the forefront and networks have struggled to accommodate the demands brought about by these 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, one in which the public is unlikely to want to retreat from the life-style advantages of dropping the daily commute and maintaining contact with distant friends and families, 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.

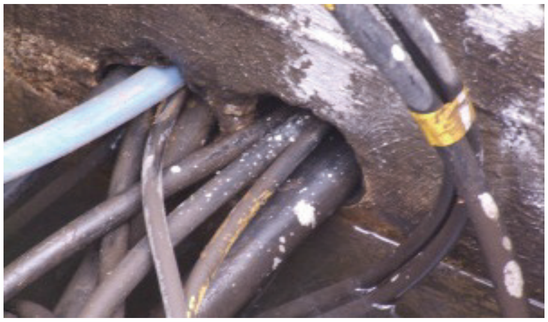


Figure 1. The Crowded Environment Close to the Subscribe

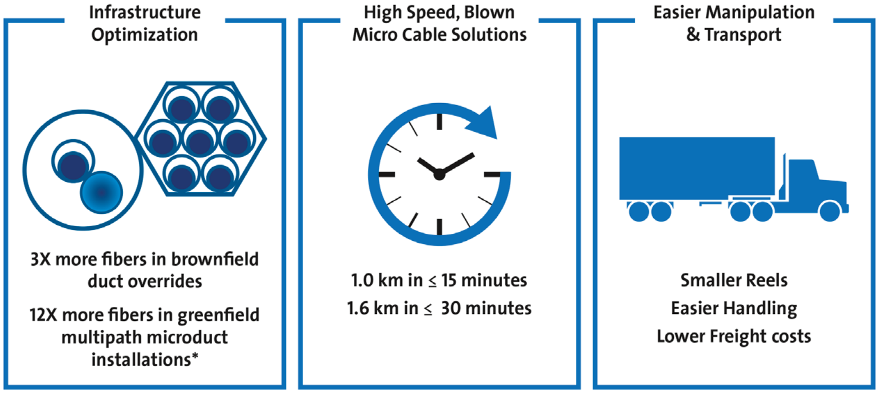
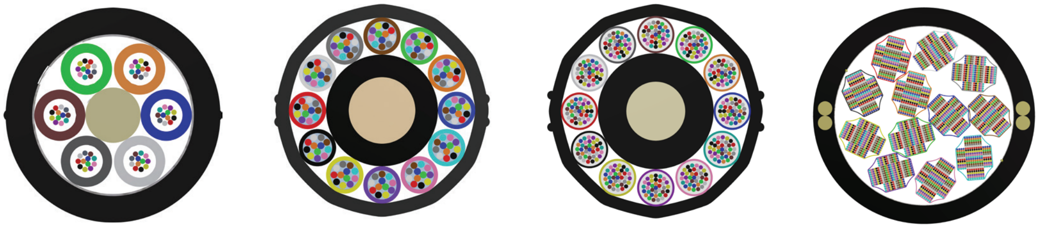


Figure 2. Blowing Light-Weight Microduct-Cables Provides a Fast, Efficient Way of Bringing Capacity On-Line

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 (m)	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.

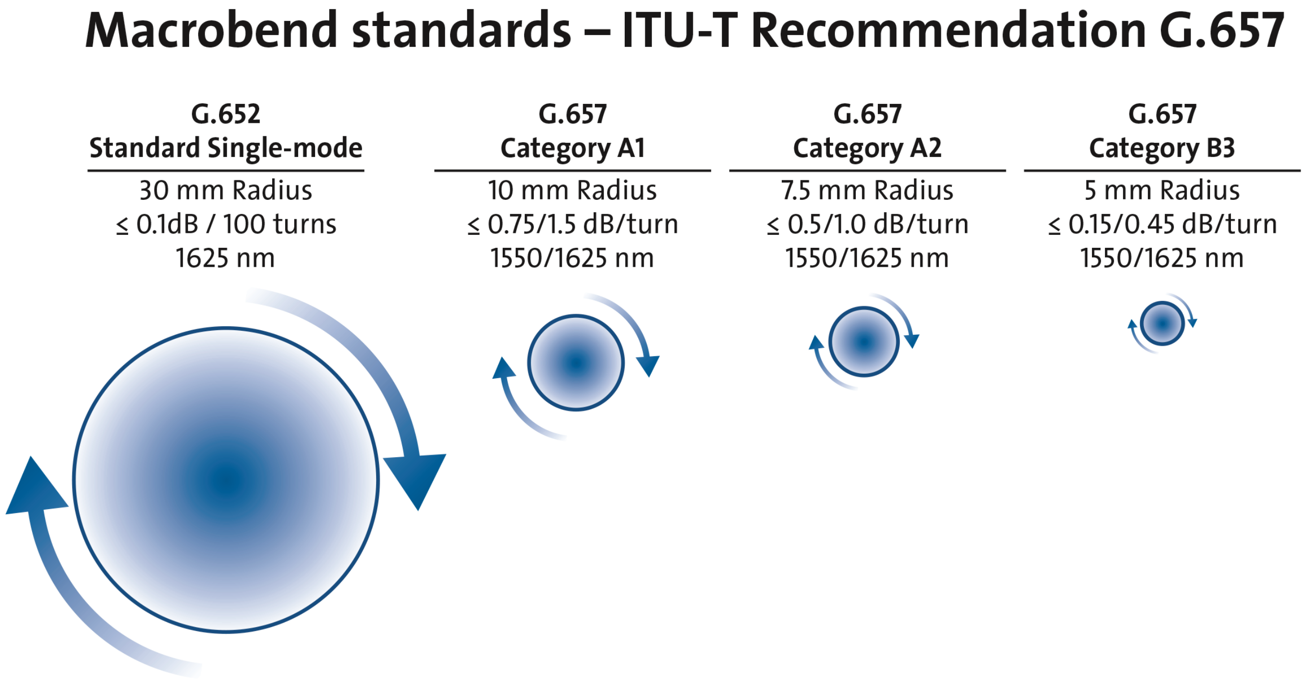


Figure 4. Tightest Bending Conditions Specified by the Different Fiber Categories of ITU-T Recommendation G.657 Compliant Optical Fiber

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.

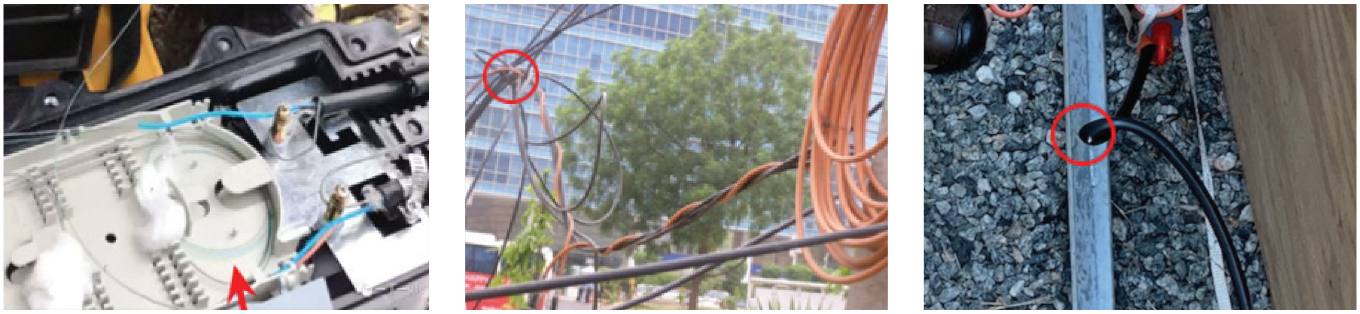


Figure 5. Examples of Installation Error Leading to Undesirable Tight Fiber Bending. Improved Resilience of G.657.A2 Compliant Fiber to Installation Errors Provides Superior Protection for the Network

In standards, bend resistance is always quantified in terms of macrobending as this test method is well defined, established and straightforward to replicate results. As macrobending performance improves and fibers move into the higher performing G.657 classes, improvements in microbending capability are also achieved. This property is critical in addressing the fundamental challenge for network operators discussed earlier, that of in-cable fiber density. Micro-cable 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. Low-loss G.657.A1 designs will incur microbending losses that negate the low attenuation advantage when packing exceeds current design limits. Selecting a G.657.A2 design greatly enhances microbending resilience, opening up the potential for even further downsizing of the cable and providing a path to even higher fiber counts than currently available.

Corning® SMF-28® Contour fiber incorporates Corning's well established low-loss technology, providing 10% lower attenuation across the operational spectrum compared to conventional G.652.D fiber. This performance translates to 20% increase in the area of potential network coverage. Network operators that want to take advantage of low loss in high density, innovative cable designs can be assured that attenuation performance is protected by the superior bending resistance provided by this product.

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 instead of a single-ended unidirectional assessment.

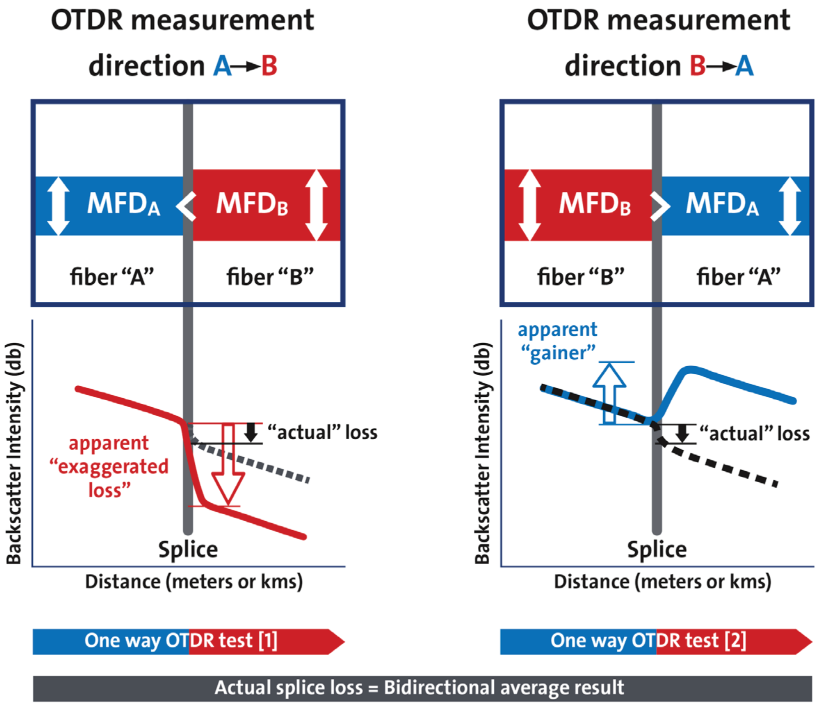


Figure 6. MFD Mismatch Leads to Misleading OTDR Traces and Potential for Expensive and Unnecessary Additional Work

SMF-28 Contour fiber is 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 to itself and to conventional G.652.D fiber.

Conclusions

SMF-28 Contour optical fiber provides the first ITU-T G.657.A2 compliant fiber featuring low-loss and with no compromise on MFD compatibility with the existing network. This unique combination of features offers cable designers the opportunity to provide network operators significantly increased optical fiber density with high fiber count, light-weight micro-cables. SMF-28 Contour fiber is available in both a standard 242 µm coating diameter format and a reduced 190 µm diameter format, the latter 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.

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