New Innovation has Arrived:

Corning® SMF-28® ULL Fiber with Advanced Bend

Ultra-Low Loss Combined with Bend Resistance and 200-Micron Outer Diameter for Long-Reach, High-Capacity Terrestrial Networks

WP8152
Issued: September 2021

Evolution of SMF-28 ULL fiber

Corning® SMF-28® ULL fiber was first introduced in 2007 in response to the emergence of coherent systems, in which fiber attenuation is one of the critical system parameters. Since its inception, SMF-28 ULL fiber aimed to deliver superior performance for terrestrial long-haul networks operating at higher data rates via a continuous reduction in fiber attenuation. Today, channel rates have reached 800 Gb/s, which intensifies the need for the lowest possible fiber attenuation to meet more stringent Optical Signal to Noise Ratio (OSNR) requirements. In 2021 Corning announced SMF-28 ULL fiber with advanced bend, which represents an evolutionary improvement to its attenuation and bend performance - these improvements are summarized in Table 1.

	SMF-28® ULL Fiber	SMF-28® ULL Fiber with Advanced Bend
ITU-T Fiber Category	G.652.B & G.654.C	**G.654.C**
Effective Area μm^2	82	82
Attenuation (dB/km)	≤0.17 (1550 nm) ≤0.19 (1625 nm)	**≤ 0.16 (1550 nm) ≤ 0.18 (1625 nm)**
Applications	Terrestrial Long-Haul	**Terrestrial Long-Haul; Subsea Backhaul; Metro DCI**
Outer Diameter (μm)	242 & 200	242 & 200
Bend Resistance	Regular	**Meets or exceeds fiber macrobend loss requirements of ITU-T G.657.A1**
Cable Cutoff (λ) nm	≤1260 | ≤1520 (G.654)	≤1520

Table 1. Evolution of SMF-28 ULL Fiber Characteristics

SMF-28 ULL fiber with advanced bend represents a new industry benchmark for long-haul terrestrial fibers. First, it has the lowest ever attenuation specification for terrestrial fibers -0.16 dB/km maximum attenuation at 1550 nm and 0.18 dB/km at 1625 nm. Second, it has an improved bend specification, which meets the fiber macrobend loss requirements of the ITU-T G.657.A1. Finally, it retains both 242 and 200 micron coating outer diameter variants with the same optical performance specifications. As a result, SMF-28 ULL fiber with advanced bend is especially appealing for high-density cables (ex. microcables), which have gained a significant amount of interest over the recent years, particularly in the environments with duct space constraints. This fiber can be used in a wide range of applications, spanning from more traditional terrestrial long-haul networks [1, 2] to inter-campus data center interconnects, terrestrial extension of subsea routes, and quantum communications [3]. SMF-28 ULL fiber with advanced bend is available in a variety of cable designs (loose-tube, aerial, ribbon, microcables) and is suitable for many deployment conditions (from direct burial to duct and aerial).

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The Power of Ultra-Low Loss

Data traffic continues to grow across networks worldwide, driven by heavy use of high-resolution video-on-demand and video conferencing and emerging applications such as, virtual and artificial reality, distance learning, and 5G. The structure of data traffic is also changing from asymmetric to symmetric, a feature which is particularly pronounced in video conferencing, where the amount of received data is comparable to the amount of data sent. In other words, Internet users are no longer only content consumers, but also content generators. To respond to customer needs for higher bandwidth and network resilience, it is vital to increase the capacity per fiber pair. This can be achieved using higher-order (and OSNR-hungry) modulation formats and higher spectral bandwidth, such as expanded C-band and L-band. The ultra-low attenuation of SMF-28 ULL fiber allows an increase in OSNR for both C and C+L band systems and enables significant reach extension (up to 2 times reach compared to a generic single mode ITU-T G.652 fiber and up to 1.5 times reach compared to more recent ITU-T G.652 fibers, such as SMF-28® Ultra fiber as shown in Figure 1).

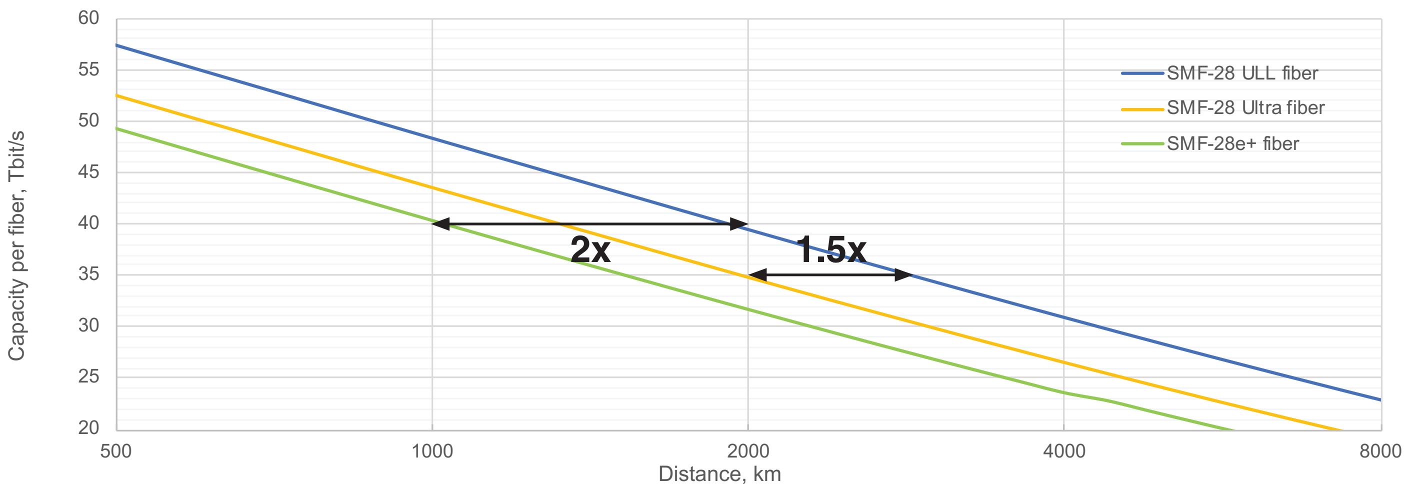

Figure 1. Maximum Reach for SMF-28 ULL Fiber, SMF-28 Ultra Fiber and Generic G.652 Fiber, Calculated at Different Transmission Capacity Values

Another benefit of SMF-28 ULL fiber with advanced bend is higher achievable transmission capacity per fiber, which is estimated to be 5 Tbit/s higher (12 – 20% increase) when compared against SMF-28 Ultra fiber and 8 Tbit/s higher (20 – 35 % increase) when compared against generic G.652 fiber. This is a significant improvement, particularly for terrestrial extensions of subsea routes (subsea backhaul Figure 2), which have recently gained prominence in an effort to achieve network cost reduction. Given that the value of each Gb/s worth of submarine data traffic is very high to start with, the use of an ultra-low-loss fiber on land helps to protect precious subsea transmission performance and significantly improve the cost effectiveness of the combined PoP-PoP network (PoP: Point of Presence).

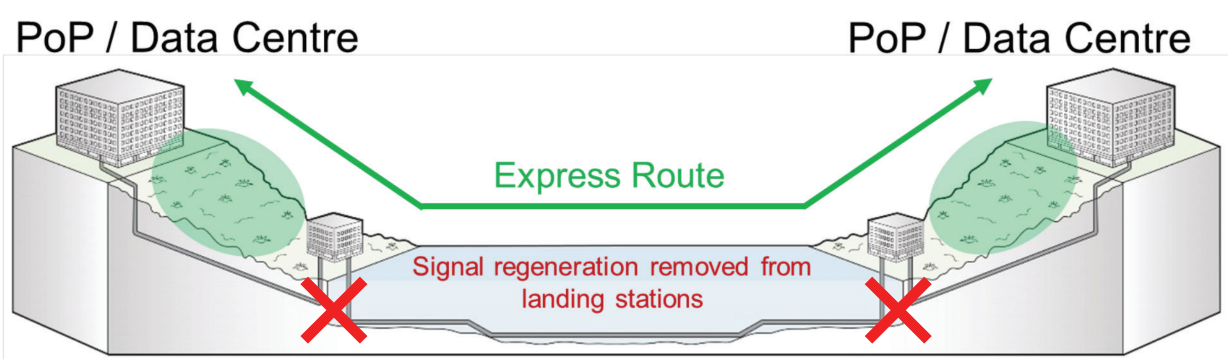

Figure 2. Subsea Backhaul Design Schematic

Enhanced Optical Fiber Bend Resistance

Why does bend matter for long-haul networks?

In most cable designs the fiber path deviates from a straight line because of the stranding process and excess fiber length. Moreover, after the applied load on cables and temperature changes during cable exploitation the curvature of the fiber becomes randomly distributed along the fiber (Figure 3). As a result, the fiber becomes subject to multiple macrobend and microbend events, which cumulatively increase total fiber attenuation. Increasing the number of strength elements and tube inner diameter in the cable reduces the impact of macrobend loss but also increases the weight, outer diameter, and cost of the cable. Therefore, the use of bend-resistant fibers significantly reduces the impacts of bend-induced loss on cable attenuation, paving the way for lighter, smaller form factor, more reliable cables, and maintaining ultra-low attenuation. In fact, many modern best-in-class cables used today are specifically designed to operate with fibers that require G.657.A1 bend compatibility.

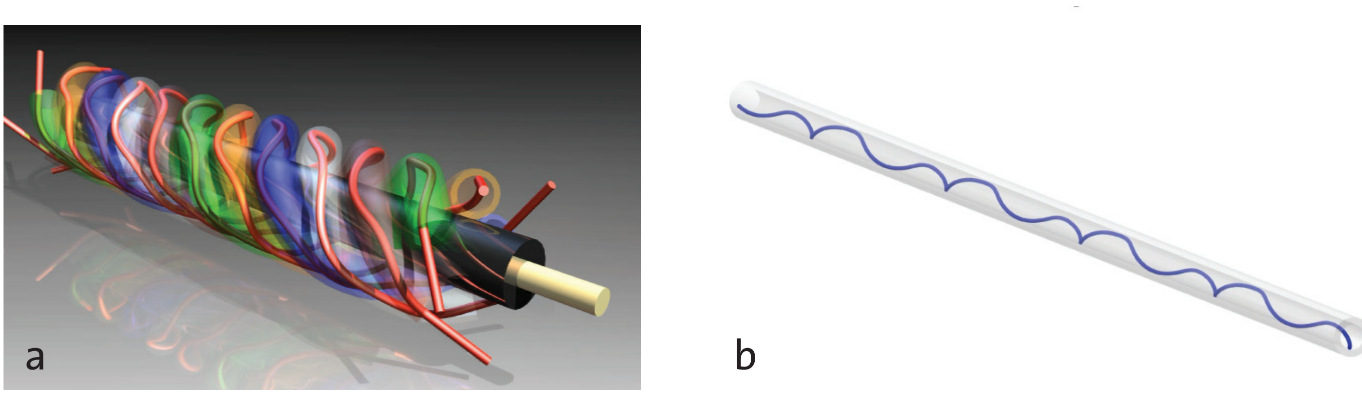

Figure 3. Simulated Picture of Fiber Curvature Under Environmental Conditions (Stress, Low Temperature)
(a) Along the Cable Length; (b) Inside the Loose Tube

Fiber with G.657.A1 compliant bend also helps cable deployment to be less susceptible to installation errors (for example in splice closures as shown in Figure 4a), ultimately leading to superior network resilience. Undesirable bends are also quite common in aerial cable deployments (Figure 4b) and fiber with G.657.A1 bend capability can help to mitigate the risk of high attenuation due to such bend events as well.

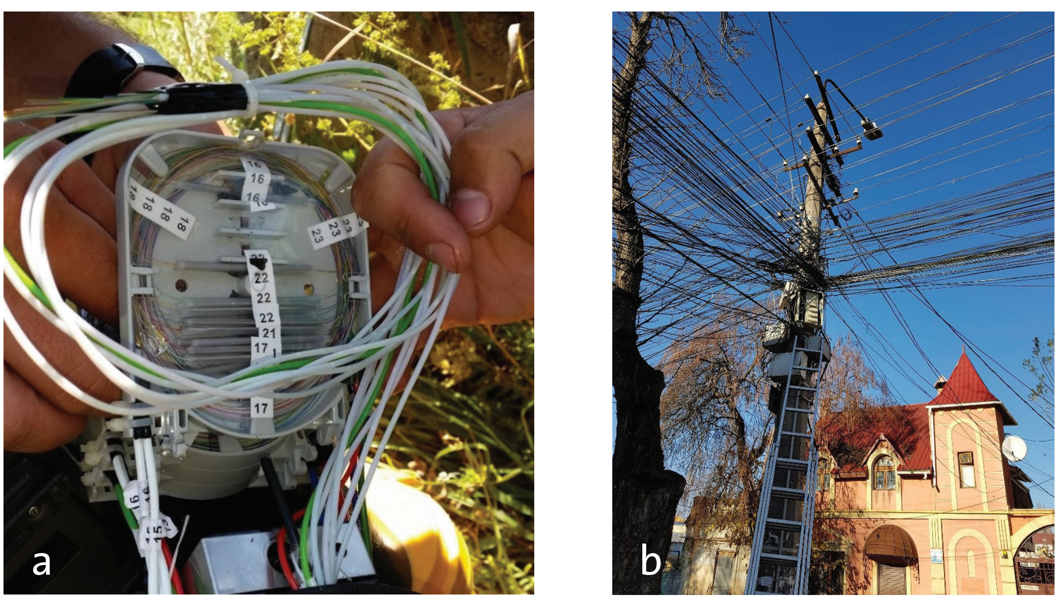

Figure 4. Examples of Installation Error Leading to Undesirably Tight Fiber Bending
a) Small Bend Radius in Splice Closures b) Aerial Cable Deployment

Smaller Form Factor – Value for 200 Micron Option

Industry desire for more efficient duct space utilization has led to interest in high-density optical cables in metro, regional, and long-haul networks. In such high-density solutions, microducts provide mechanical protection for the microcables that are deployed within these microducts. Such protection enables a reduction in cable weight and cross-sectional area by removing excess cable materials. The use of fibers with 200-micron outer diameter, compared to more conventional fibers with 240-250 micron outer diameters, allows for a significant reduction in cable form factor and weight, leading to an increase in fiber density by up to 50%. Figure 5 illustrates how one can increase the cabled fiber count from 96 to 144 using 200-micron fibers with the same cable form factor or, conversely, to reduce cable outer diameter. Microcables are air-blown rather than pulled into ducts, and air blowing has proven to be an effective technology to deploy cables at high speed. The most important parameter for achieving longer air blowing distance and higher installation speed is the ratio of cable outer diameter to the duct size. Hence, lighter and smaller cables can provide a significant improvement to both the deployment speed and distance.

The use of SMF-28 ULL fiber with advanced bend and 200-micron outer diameter provides ultra-low attenuation in high-density cables and decreases cable deployment cost. SMF-28 ULL fiber with advanced bend can be used in cables designed for standard single-mode fibers or bend-improved fibers like SMF-28 Ultra or SMF-28 Ultra 200 fibers, including hybrid cables with more than one fiber type.

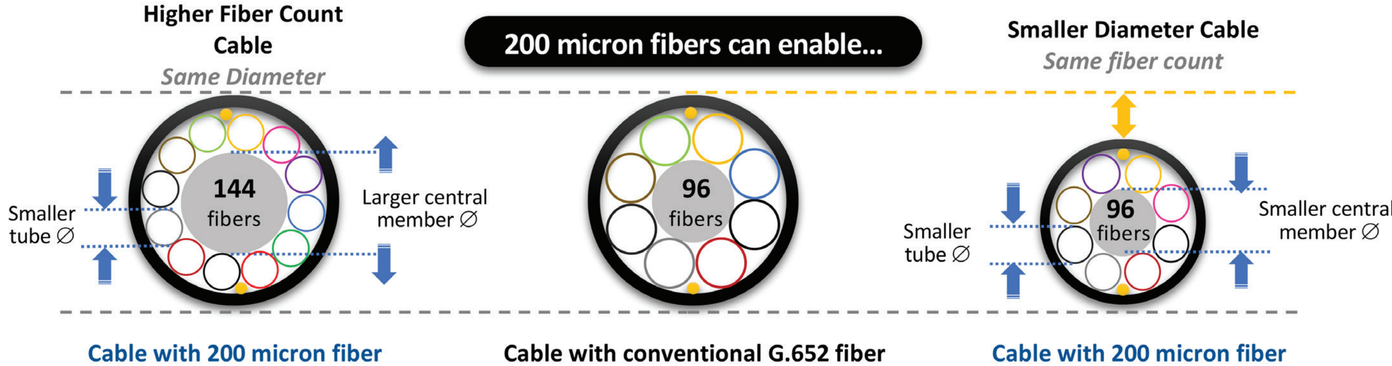

Figure 5. Fiber with Smaller Outer Diameter Enables Higher Fiber Count for the Same Cable Diameter or a Reduction in Outer Cable Diameter with the Same Amount of the Fibers

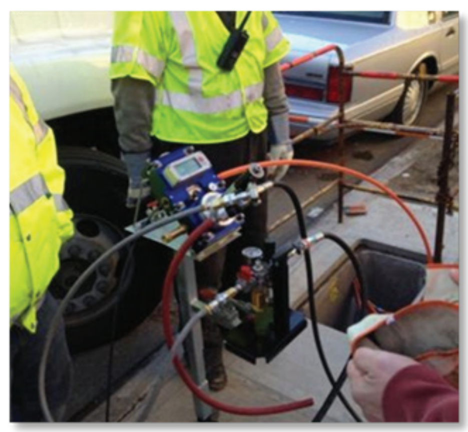

Figure 6. Air Blowing Light-weight Microcables Provides a Fast and Efficient Way of Increasing Transmission Capacity

Summary

At the 2021 Optical Fiber Communication Conference (OFC), Corning achieved an industry milestone; announcing a record-low attenuation in the 80 μm² fiber category with a demonstration of SMF-28 ULL fiber at 0.152 dB/km at 1550 nm. This together with the introduction of SMF-28 ULL fiber with advanced bend are prime example of Corning's continuous innovation within its long-haul fiber portfolio. SMF-28 ULL fiber with advanced bend features industry-leading attenuation specifications and is complemented by better bend resistance and a smaller, 200-micron outer diameter to provide superior transmission performance and packing density performance in long-haul terrestrial networks. SMF-28 ULL fiber with advanced bend is the fiber of choice for high-performance (optically-amplified and unrepeatered) networks. It also provides significant techno-economic benefits in emerging applications, such as Quantum Key Distribution and terrestrial extensions of subsea routes. Finally, this fiber is suitable for use in a wide-range cable designs, including high-density cable solutions.

References

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[2] Tezadov Y., Otradnov S., Korotkov N., Makovejs S. et. al. Record Unrepeatered 400G 16QAM Signal Transmission over 526 km of Terrestrial Ultra-Low Loss Optical Fiber. 2020 European Conference on Optical Communications (ECOC)

[3] Pittaluga, M., Minder, M., Lucamarini, M. et. al. 600-km Repeater-like Quantum Communications with Dual-band Stabilization. Nat. Photon. 15, 530–535 (2021)

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