Corning® TXF™ Optical Fiber Featuring Ultra-Low-Loss and Large Effective Area for Extended Reach

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Introduction

Corning® TXF™ optical fiber is an innovative product designed to deliver increased reach for terrestrial long-haul networks operating at high data rates. As channel data rates continue to increase, with 100 Gb/s now commonplace in long-haul networks and with 200 Gb/s already deployed and 400 Gb/s emerging, network operators need to carefully consider the more stringent Optical Signal to Noise Ratio (OSNR) needed to upgrade to higher speed transmission. Corning's TXF fiber delivers significant OSNR advantage compared to conventional standard single-mode fiber, a consequence of a design that features ultra-low loss and large effective area.

Impact of Increasing Data Rate

Operators throughout the world face considerable challenges to keep up with the increasing capacity demands placed on their networks. Subscribers have become conditioned to expect reliable, responsive connections to data-heavy video content without encountering buffering, pixilation, or distortion. And, as the price of connected devices and subscriptions continues to fall, more customers are accessing content than ever before. Furthermore, the emergence of the Internet of Things (IoT), a network of connected and inter-communicating machines, sensors and wearable accessories that is expected to exceed 50 billion devices[1] by 2020, will require networks to evolve to deliver the capacity needed.

One obvious upgrade path that exists is through increasing the channel speed. Whereas formerly 10 Gb/s operation was dominant, long-haul networks are increasingly migrating to 100 Gb/s operation, with equipment to allow operation at 200 Gb/s available and 400 Gb/s emerging. Whilst the increase in capacity is valuable, it does not come without a cost. Higher speed protocols rely on the phase, amplitude, and polarization states of the signal to deliver improved data capacity. This places much more stringent demands on the OSNR, and error-free operation is only achieved with the signal power maintained well above the noise floor. A limit on reach is encountered once signal degradation due to loss and non-linear distortion accumulates beyond a particular threshold.

Theoretical studies have been carried out[2] to determine how the reach limit changes as the channel data rate increases. An illustration of the findings of such a study is provided in Figure 1 (note, actual reach achievable depends on the specific network design rules employed). Of particular interest is the reach reduction involved in upgrading from 100 Gb/s using PM-QPSK protocol to 200 Gb/s using PM-16QAM protocol. Whereas the 100 Gb/s reach limit of a few thousand km is generally irrelevant for a terrestrial network, at 200 Gb/s the limit drops to just several hundred km and therefore introduces a meaningful limit on transmission before costly signal regeneration is required. So, a network operator planning to migrate to faster protocols may need to incur significant capital outlay provisioning additional regeneration sites to address future capacity concerns.

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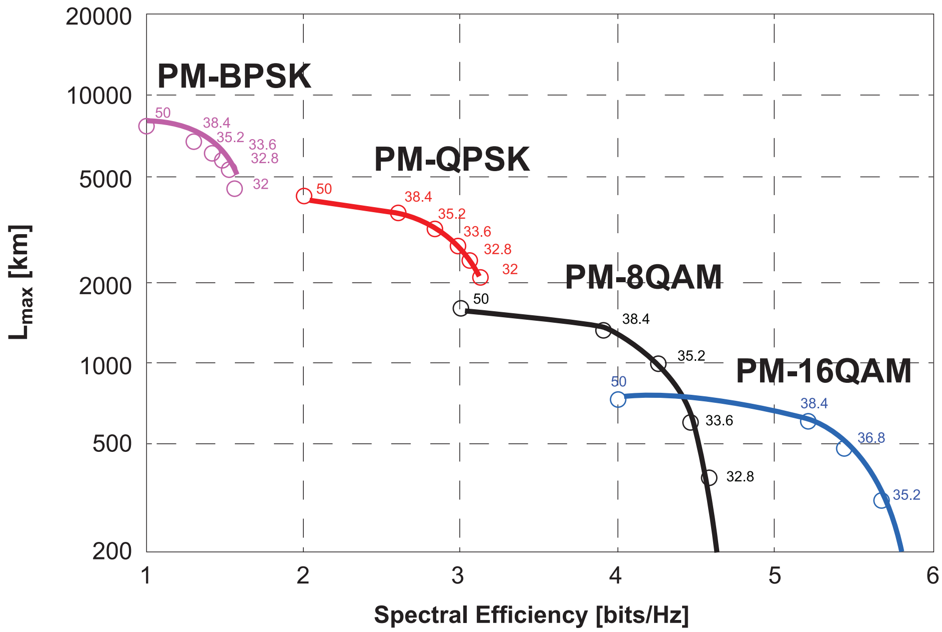

Figure 1. Impact on reach of upgrading to higher data rate protocols.

Fiber Attributes that Deliver OSNR Advantage

Fiber design can help mitigate against the decline in OSNR with distance and so extend the reach limit for higher data rate application. Two attributes are critical - ultra-low loss (also known as ultra-low attenuation) and a large effective area.

Conventional single-mode fiber has a germania-doped silica core and loss typically specified at ≤0.20 dB/km at 1550 nm. A low-loss fiber is generally considered to meet a specification ≤0.18 dB/km at 1550 nm and also features a germania-doped silica core with enhanced attenuation achieved through a superior manufacturing process. To achieve further improvement to ≤0.17 dB/km, a level generally referred to as ultra-low loss, it is necessary to migrate from a germania-doped core to a silica core. An ultra-low loss fiber maintains optical power in the core further, extending the distance before the signal strength approaches that of the noise floor. Expected typical attenuation of TXF fiber is 0.168 dB/km at 1550 nm.

A large effective area, created by increasing the size of the core region through which the optical signal propagates, allows higher power to be launched into the fiber. This is another means of extending the distance before the signal strength approaches that of the noise. A large effective area causes the optical power in the core to be more broadly spread and reduces the peak power density in the center, which is critical for wave division multiplexed (WDM) transmission operating over tens of channels. Once the power density exceeds a certain threshold, the signal is susceptible to reach limiting, non-linear distortions (e.g. Four Wave Mixing, Self Phase Modulation, Cross Phase Modulation). Spreading the optical power more broadly in the larger core means that higher launch power can be delivered before the non-linear threshold is reached. The typical effective area of TXF fiber is 125 μm^2.

A way to compare transmission performance of different fiber designs is to use the Figure of Merit (FOM) methodology[3], which determines dB advantage relative to a reference fiber (typically standard G.652.D optical fiber). This approach is illustrated in Figure 2 for several fiber designs developed for terrestrial long-haul transmission. FOM on the y-axis corresponds to an increase in Q-factor relative to standard G.652 fiber which can be translated into reach improvement. 1 dB advantage translates to ~25% reach increase, 2 dB to ~60% reach increase, and 3 dB - to ~100% reach increase. Modeling demonstrates that TXF fiber provides best-in-class transmission performance compared to other designs which have been developed for long-haul networks. As a result, TXF fiber can provide significantly more headroom for upgrades to higher data rates than alternative fiber types.

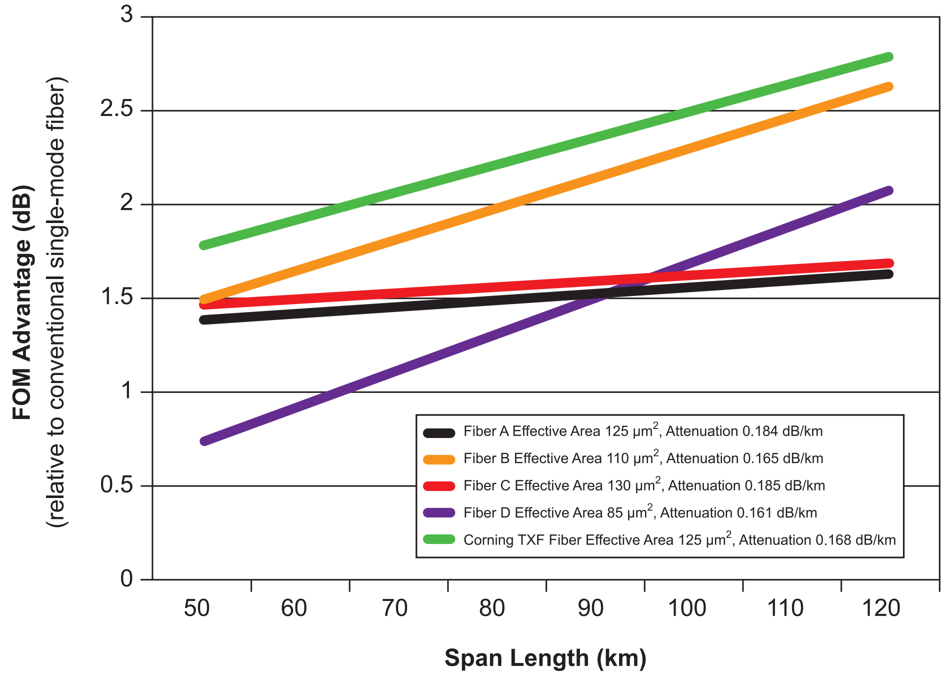

Figure 2. Corning TXF fiber performance advantage compared to other single-mode fiber designs targeted at terrestrial long-haul.

ITU-T Recommendation G.654

"ITU-T Recommendation G.654 – Characteristics of a Cut-Off Shifted Single-mode Optical Fiber and Cable" was introduced in 1988 and has been regularly revised since then. It describes the category of fibers with larger effective area than conventional G.652 compliant fibers, for which the cut-off wavelength is allowed to shift upwards, to just below the C-band around 1550 nm where loss is minimized. Conventional cut-off wavelength restrictions may be lifted as these fibers will not be operated in the higher-loss O-Band region around 1310 nm. The tables A to D of this standard are well established to describe fibers typically used in submarine cables, where low loss and large effective area are necessary to most efficiently provide links over trans-oceanic distances.

In September 2016, the latest revisions to G.654 were consented. This includes a new Table E to describe cut-off shifted fibers with large effective area primarily for use in extending reach at high data rates in terrestrial networks. Corning TXF fiber is compliant with ITU-T Recommendation G.654.E.

Conclusion

Corning's latest optical fiber innovation, TXF optical fiber is a G.654.E compliant product featuring ultra-low loss and large effective area. The fiber is designed to extend reach in long-haul networks, and is of particular value to network operators planning to increase capacity by upgrading to data rates beyond 100 Gb/s.

References

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