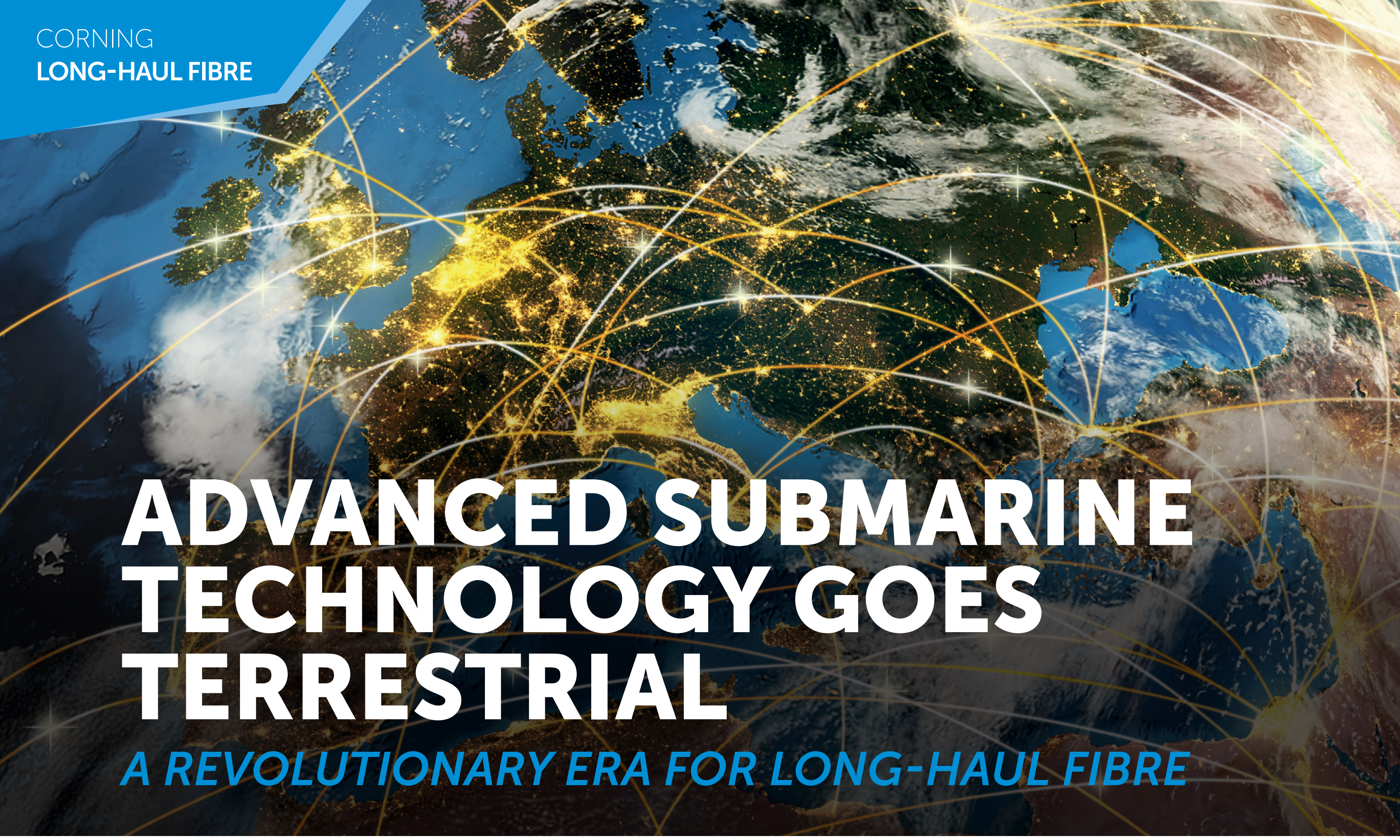


# ADVANCED SUBMARINE TECHNOLOGY GOES TERRESTRIAL

## *A REVOLUTIONARY ERA FOR LONG-HAUL FIBRE*

The exponential global bandwidth growth is catalysed by many factors, such as proliferation of video streaming from smart devices and an increasing trend to place mission-critical workloads into the cloud. Corning Optical Communications market and technology development managers **Dr. Hao Dong** and **Dr. Sergejs Makovejs** look at how long-haul network operators are now facing unprecedented pressure to undertake extensive network capacity expansions to keep pace with the growing bandwidth demand.

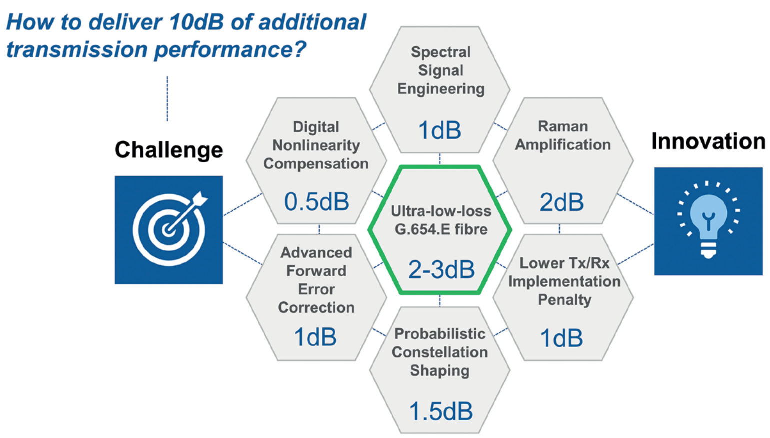
### THE CHALLENGE FOR LONG-HAUL

The capacity of fibre-based long-haul communication networks has become approximately 1000x greater over the last 20 years, with the most gain realised from the adoption of optical coherent technology since 2011. Coherent technology has created a capacity bonanza with data rate evolving from 10G to 100G, which has become the de facto standard globally. However, when the industry follows a capacity expansion trajectory to further evolve beyond 100G, the distances between amplifiers and regenerators become prohibitively short.

### AN ECO-SYSTEM VIEW

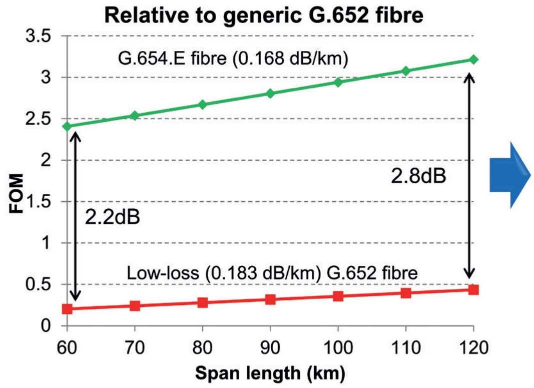
200G technology is expected to ramp up in the near future. For example, according to a recently published Telecom Optics and Components report by IHS Markit, approximately 90% of long-haul networks were based on 100G technology in 2016. By 2018, however, 30% of networks will adopt 200G and beyond technology. The report also predicts that this trend will continue. By 2022, 200G and beyond technology will account for nearly 54% of all deployed wavelength-division multiplexing (WDM) bandwidth in long-haul networks, making it very likely to repeat the success story of 100G.

However, the use of spectrally-efficient




*Source: Corning*

**Fig.1. Technology options available to deliver >100G capability**




| FOM (dB) | ~ Longer Reach (%) *Rule of Thumb* |
|---|---|
| 1 | 25 |
| 2 | 60 |
| 3 | 100 |

*Source: Corning*

**Fig.2 Recommendation ITU-T G.654.E fibre provides significant improvements in Figure of Merit (FOM).**

modulation, needed to achieve 200G and beyond speeds, requires higher optical signal-to-noise ratio (OSNR), which fundamentally translates into a shorter optical reach. For example, to upgrade the system from 100G to 200G, and to allow for additional headroom for subsequent upgrades in the future, the corresponding system should be able to provide 10dB of additional OSNR (Fig. 1). But how can the industry deliver such significant OSNR gain?

Traditionally, long-haul network operators performed system capacity upgrades either by deploying more advanced equipment or adding more fibre pairs in the cable. However, as the industry looks beyond 100G, and more challenging OSNR targets must be met, both equipment and fibre innovation should be pursued in parallel.

For example, such techniques as advanced forward error correction and probabilistic constellation shaping can provide approximately 2.5dB of OSNR gain, as shown in Fig. 1. Raman amplification and advanced laser and receiver designs can provide further OSNR improvements. However, an important conclusion from Fig. 1 is that even with the collective gain from different state-of-the-art transmission technologies, advanced electronics on its own cannot deliver 10dB of OSNR gain, and advanced fibre should be considered. An important simplification made in this analysis is that all OSNR gains can be linearly added together, but such a simplification should be reasonable for first-order estimation of the overall OSNR gain.

## G.654.E: SYNERGY BETWEEN LAND AND SEA

The OSNR is proportional to the optical power launched into the fibre, which, in turn, is proportional to the effective area of the fibre. OSNR is also inversely proportional to the total signal attenuation, which increases with the span length. Thus, to improve OSNR through fibre innovation, fibre effective area must be increased, and fibre attenuation must be reduced

In November 2016, Recommendation ITU-T G.654.E optical fibre standard was adopted for terrestrial applications, which brought many years of subsea technology innovation into the terrestrial space. A notable feature of G.654.E standard is its specification for large effective area (up to approximately 130μm²), which is critical in enabling higher optical power to be launched into the fibre, hence, achieving higher OSNR.

One practical challenge that the industry faced during G.654.E standardisation was the realisation that large effective area fibres are typically more susceptible to macrobend loss. Yet the engineering community believed that due to the complexity of terrestrial deployments, the new G.654.E macrobend specification should match the one of G.652 fibre. To reconcile the challenge of getting both large effective area and acceptable macrobend performance, the maximum allowable cable cut-off wavelength of the G.654.E standard was increased to 1530nm – the lower edge of the C-band. This means that G.654.E fibre is explicitly targeting C and L band applications, where fibre spectral attenuation is lowest and in-line amplification is readily available.

By incorporating the design features described above, fibre manufacturers have started to offer new G.654.E optical fibre solutions to the market. The broader industry now recognises that low attenuation, large effective-area fibre can extend the capacity and reach of terrestrial long-haul backbone networks.

How can the performance improvement that G.654.E fibre delivers to the long-haul terrestrial networks be quantified? Figure of Merit (FOM) is a reliable and well-accepted industry measure of relative transmission performance between the two fibres. The FOM includes the impact of key fibre attributes, such as attenuation, effective area, and chromatic dispersion. The beauty of FOM is that it is agnostic to specific network design rules, making it a fairly universal metric to determine relative transmission performance.

It is apparent from Fig.2 that G.654.E fibre (Corning® TXF™ fibre was used in this study) provides significant performance improvement relative to G.652 fibres. Depending on the amplifier span length, G.654.E fibre FOM was found to be at least 2dB (and in some cases almost 3dB) higher relative to commonly used low-loss G.652 fibre, therefore translating into a total reach extension of approximately 60 to 100%.

In the terrestrial long-haul environment, as transmission technology rapidly evolves into the post-100G era, the reliance solely on plug-in equipment upgrades is not sufficient anymore. The adoption of innovative and complementary equipment and fibre technologies will be needed to meet >100G transmission requirements. Enhanced transmission performance of G.654.E fibres will help to pave the way for a super-connected future. TXF fibre is Corning's G.654.E fibre solution. Building on Corning's technology and market leadership in both terrestrial and submarine fibre, TXF fibre incorporates many of the benefits of submarine fibre into a solution for the terrestrial high-data-rate fibre market.