Fibre Innovation

Foundation of next-generation networks

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We are becoming used to living in a superconnected world. Our societies are changing thanks to social networks, cloud computing, video streaming, television, etc. However, the increasing number of bandwidth-hungry applications puts unprecedented pressure on networks from the backbone to the access level. As such, it is necessary to look at the world not from the perspective of the latest smartphone or "app", but from the fundamental technology at the foundation of this superconnectivity – optical fibre.

According to Infonetics, a significant increase is expected in the number of links operating at 40 G and 100 G by 2013. Delivering such high data rates means that the attenuation of optical fibre is a key concern. As per Infonetics, almost half of the network will still operate at 10 G, wherein maintaining low dispersion will be important to ensure a profitable link for the carrier.

Delivering high data rates: Low attenuation fibres and the OSNR challenge

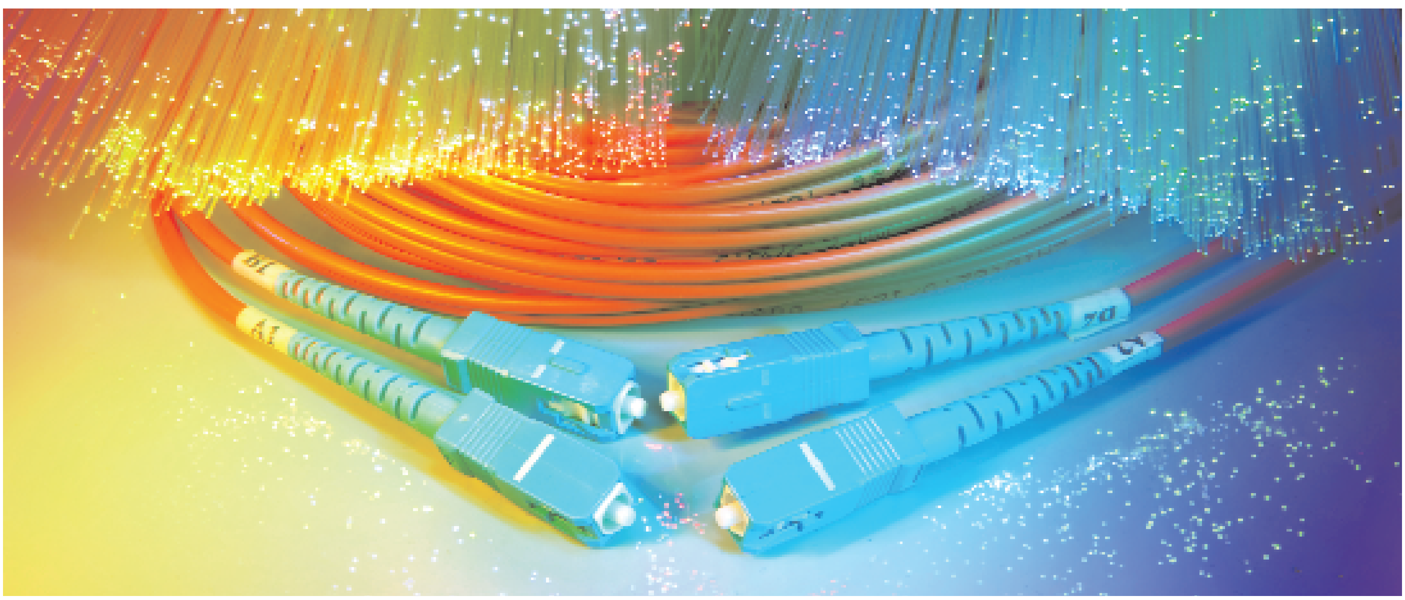
In the absence of system advancements, each tenfold increase in data rate, such as a move from 10 G to 100 G, requires a 10 dB increase in the optical signal-to-noise ratio (OSNR). Another challenge is that a transition from 10 G to 400 G will require 16 dB of OSNR gain. Recent advances in modulation formats, digital signal processing (DSP) and coherent systems have helped achieve OSNR gains of up to 6 dB, but for some network links, this may not be enough to deliver data rates beyond 100 G, nor does it meet the demand for low-cost non-coherent 100 G.

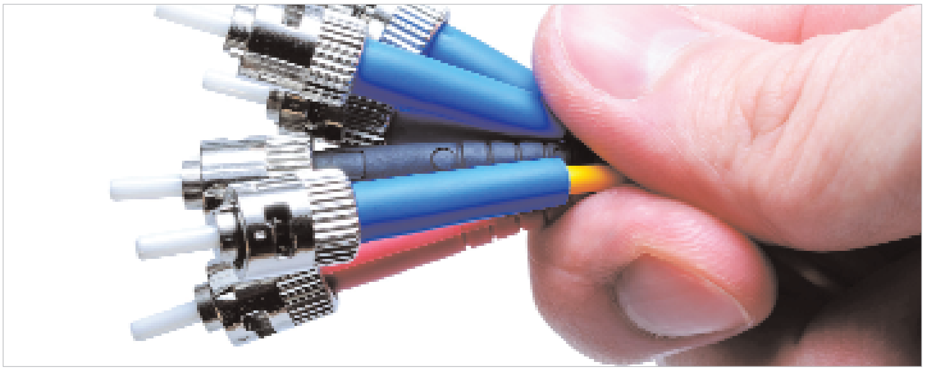
The OSNR of a system is proportional to the signal power in the fibre, which, in turn, is proportional to the effective area of the fibre. OSNR is also inversely proportional to the total signal attenuation of the system, which increases with the span length. Thus, to improve OSNR through fibre innovation, we must increase the fibre effective area and/or reduce fibre attenuation.

Reducing the attenuation will have no impact on the standards compliance of a fibre, but increasing the fibre's effective area can make it non-compliant with basic terrestrial ITU fibre standards like G.652 and G.655. New lower attenuation fibre, including some with larger effective areas, are already available and deliver significant OSNR gains as compared to G.652 and G.655 fibre.

Submarine networks are usually customised, greenfield deployments and, therefore, standards compliance is not a major concern. This enables the use of fibre with a large effective area such as Corning Vascade EX2000 fibre (110 um^2), which, coupled with a pure silica core to enable ultra-low loss (0.162 dB per km), can deliver up to a 5.4 dB OSNR gain over a 100 km length. A more recent submarine fibre, the Vascade EX3000 fibre, features an even larger effective area (≥145 um^2) and lower loss (0.16 dB per km), enabling up to 6.9 dB of gain over 100 km. This illustrates the role of optical fibre innovation in addressing the OSNR challenge.

In terrestrial systems, compliance with existing fibre standards becomes essential due to the need for backward compatibility with legacy networks. Thus, a significant increase in the effective area is not possible, and efforts must focus on reducing fibre loss to achieve OSNR gains.





Benefits of low attenuation fibre

A simple reduction in the attenuation of optical fibre can deliver OSNR gains that offer benefits in terms of network capacity, performance, cost as well as technology robustness.

Lower attenuation delivers a higher OSNR margin for upgrading to 40 G, 100 G and beyond. Upgrading a network link of 800 km or 1,000 km to a higher data rate can compromise its reach, forcing the addition of an optical-to-electric regeneration stage midway in the link at significant operator cost. However, the use of low-loss fibre is allowing operators to upgrade such networks with minimal or no compromise on the original link length.

Corning tested its Vascade EX3000 fibre in a 112 Gbps link, with 16 channels, over a length of 100 km and erbium doped fibre amplifier (EDFA) amplification only. The reach at this high data rate was an impressive 7,200 km, the longest distance recorded for this type of configuration, clearly demonstrating that low attenuation and a large effective area offer significant benefits in terms of reach at high data rates.

In another 100 G demonstration by Ciena using ultra-low attenuation SMF-28 ULL fibre, the company demonstrated a 1,500 km reach even while using long 125 km spans and EDFA only (no Raman amplification). This demonstration showed that ultra-low attenuation fibre can extend distances by 30-35 per cent.

In a network deployment in Europe, the Middle East and Africa, a carrier deployed a ring network across three cities using SMF-28 ULL fibre, with distances between each city ranging from 135 km to 145 km. Though it paid a premium for the innovative 48-fibre count cable, this ultra-low loss fibre gave a 4.8 dB advantage in span loss and avoided constructing three amplifier sites in remote areas that would be very costly to build, power and cool.

As each fibre was lit, the carrier made additional savings by avoiding the installation of three additional amplifiers. This resulted in initial savings (with one fibre pair lit) of almost $1.5 million and potential savings of over $8 million (excluding the net present value [NPV]), once the cable was fully lit. Thus, the carrier got a system with ultra-low loss fibre enabled advanced OSNR performance, which resulted in significant capex and opex savings.

The additional system margin allowed by low attenuation fibres can also be used to provide additional resilience to repairs. With each cable cut resulting in a loss of 0.2 dB, a 100 km cable with only 1 dB of spare system margin will go "dark" after five cuts. The use of a low attenuation fibre can enable at least an additional 3 dB of margin, enabling an additional 15 cuts, thus delaying cable replacement.

In access networks, despite the much shorter link distances, a simple reduction in attenuation on a G.652.D fibre can deliver additional reach, resulting in an increase of up to 20 per cent in subscriber, cabinet and antenna coverage area. Lower attenuation also provides an additional margin to facilitate network upgrades.

Lower dispersion in next-generation applications

While some networks are already operating at 40 G and 100 G speeds, a large number of networks remain at 10 G with some moving towards 40 G. For such routes with a low traffic demand, the use of low-cost non-coherent systems with in-line dispersion compensation, rather than advanced coherent 100 G systems, is the most cost-effective solution. In this case, non-zero dispersion-shifted G.655 fibre is the most efficient option.

Lower dispersion optical fibre enables the removal of dispersion compensation modules (DCMs). In a basic 560 km, eight-span 10G optical transmission link with G.652 fibre, switching to G.655 fibre would enable the removal of five DCMs required in the original architecture. This would also enable the use of lower-cost single-stage amplifiers at each of these points.

When the first fibre pair is lit, the equipment savings immediately cover the G.655 cable premium to yield net positive savings, which increase to $2 million (excluding NPV) once the 12 fibre pairs are lit. Hence, G.655 fibre continues to be adopted in certain applications.

Low dispersion G.655 fibre also offers key benefits for 100 G networks, wherein non-coherent 100 G systems are an attractive low-cost option. In a recent demonstration, ADVA Optical Networking has shown that the use of G.655 fibre can extend a non-coherent 100 G system's reach from 40 km on G.652 fibre to 200 km (with some amplification), enabling the application of low-cost non-coherent 100 G systems on regional networks.

Next-generation fibre is expected to provide the cost and performance gains required for future networks and ultimately enable a super-connected world.

Role of optical fibre in delivering networks of the future

Innovation and advances in optical fibre attributes make a significant difference to a network. Lower attenuation can deliver higher OSNR and optimised selection of the fibre type can offer lower costs and advanced network performance.

We are moving towards a superconnected world, which is driving capacity demand across access, metro and backbone networks. For a superconnected future, fibre innovation is critical. Next-generation fibre is expected to provide the cost and performance gains required for future networks and ultimately enable a superconnected world. ▲