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Ultra Low Loss and Large Effective Area Fiber for Next Generation Submarine Networks

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The transition to higher bit rate (40 Gb/s and 100 Gb/s) transmission systems in submarine networks is imminent. At the 2010 SubOptic conference in Yokohama, Japan, it was clear that the industry anticipates that 40 Gb/s submarine terminal equipment will have several advantages, such as increased capacity, reduced cost, power dissipation and floor space per transmitted bit. Major submarine transmission system vendors presented their views of the requirements for 40 and 100 Gb/s implementation and one theme was consistently present in those presentations: 40 and 100 Gb/s will require higher optical signal to noise ratio (OSNR) compared to existing 10 Gb/s systems. There are several technologies that have been employed to reduce the need for higher OSNR. Forward Error Correction (FEC) is a mature technology that is moving toward its third generation and promises a 2.8 dB coding gain improvement. Coherent detection together with polarization multiplexing is widely seen as a technology of choice for 100 Gb/s systems. It reduces the required OSNR (up to 2.7 dB) and may be employed in high end 40 Gb/s transponders, but its cost effectiveness is uncertain. Finally, distributed Raman amplification that is used in terrestrial and unrepeatered submarine networks to improve OSNR is unlikely to be adopted in the repeatered links due to the electric power requirements.

In addition to hardware improvements, another way to improve OSNR is to use optical fiber with lower attenuation and larger effective area (A_{eff}). OSNR is proportional to the launched power and inversely proportional to the loss of the optical fiber between two repeaters. Larger A_{eff} reduces fiber nonlinearity that enables the launch of higher optical power. Lower fiber attenuation reduces the span loss (product of fiber length between repeaters and fiber attenuation). A simple figure of merit (FOM) can show how the combined improvement of fiber attenuation and A_{eff} will increase OSNR. According to this FOM and the example cited in this paper, depending on system configuration, it is conceivable to gain up to 3.5 dB in OSNR. This is comparable to the improvements gained by next generation FEC or coherent detection with polarization multiplexing. In practice all three methods (FEC, coherent detection and Ultra Low Loss large A_{eff} fiber) could be used to achieve 40 Gb/s and 100 Gb/s transmission over transoceanic distances.

Corning's submarine optical fiber development has been focused on improving fiber attenuation for quite some time. Corning introduced ultra low attenuation Vascade® EX1000 fiber in 2006. This low attenuation fiber, with typical attenuation of less than 0.170 dB/km, A_{eff} of 76 square micron (mm²) and good Raman efficiency, was designed for unrepeatered submarine systems. Corning Vascade EX1000 is a silica core fiber that does not have germanium doping, known for its higher Rayleigh scattering (unlike in vast majority of conventional telecommunication fibers). Even though the design seems simple, the manufacturing process is more complex compared to conventional fibers and that is why Corning is one of only two fiber suppliers to offer this type of product.

Vascade EX1000 fiber was deployed in 2007 by Faroese Telecom in a 400 km unrepeatered link connecting Faroe Island to Shetland Island in the North Atlantic Ocean. This submarine link supported capacity of 19 channels at 10 Gb/s on a single fiber without the use of remote optically pumped amplifiers. This ultra-long distance became possible due to the use of advanced Raman amplification over ultra low attenuation optical fiber.

Since the introduction of Vascade EX1000 fiber, Corning continued to work on improving fiber attributes that enable higher OSNR in submarine systems. The next logical step was to increase A_{eff} in fibers with ultra low attenuation. In May 2010, Corning introduced Vascade® EX2000 optical fiber, an ultra low loss and large effective area silica core fiber.

Vascade EX2000 optical fiber has a typical effective area of 112 μm^2 and typical attenuation of 0.162 dB/km at 1550 nm. In repeatered systems, these attribute improvements allow extended system reach at 40 and 100 Gb/s. This advanced fiber could be used in the next-generation dispersion-managed fiber solution, Vascade® R2000 fiber solution which combines positive (Vascade EX2000 fiber) and negative dispersion fiber (Vascade® S1000 fiber) in a single span. In unrepeatered submarine networks, Vascade EX2000 fiber enables the use of higher launch power which results in longer system reach. The table below summarizes the key attributes of Vascade EX2000 fiber.

Fiber Parameter	Units	Typical value
Attenuation (1550 nm)	dB/km	0.162
Dispersion (1550 nm)	ps/nm/km	20.4
Dispersion Slope (1550 nm)	$Ps/nm^2/km$	0.06
Mode Field Diameter (1550 nm)	mm	11.9
Effective Area (A_{eff})	mm^2	112

Table 1. Summary of key Vascade EX2000 fiber attributes

As the transition to very high data rates in submarine networks continues, submarine system vendors have clearly indicated the need for improved system OSNR. As a result, opportunities to improve OSNR through silica core optical fibers with both ultra low attenuation and large effective area are attractive as they present opportunities for cost-effective, simplified submarine system that can support 40 Gb/s and 100 Gb/s.

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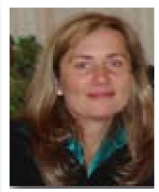

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Sergey Ten was born in Rostov-on-Don, Russia and graduated with honors from the physics department of Moscow State University. He earned his Ph.D. from the University of Arizona in 1996 and joined Corning in 1997 as a Senior Scientist, concentrating on the physics of light propagation in optical fibers. Sergey worked for Tyco Submarine Systems Ltd. in 2000-2001 and in 2001, he re-joined Corning Incorporated as the manager of the transmission test bed group, investigating high data rate transmission in optical fibers focusing on the nonlinear and linear impairments in all types of optical networks. He has authored 45 journal and conference articles and holds 11 patents in the field of optical communications. Currently, he is a manager of the New Business and Technology Development Group concentrating his efforts on the development of new fibers for telecom and non-telecom applications.