Novel Ultra Low Loss & Large Effective Area G.654.E Fibre in Terrestrial Application

Lei Zhang, Jihong Zhu, Jing Li, Honghai Wang, Ruichun Wang, R. Matai, Jie Luo
Key Laboratory of Optical Fiber and Cable Manufacture Technology, Wuhan 430073, China
Yangtze Optical Fiber and Cable Joint Stock Limited Company, Wuhan 430073, China
zhanglei@yofc.com

Abstract: The paper introduced latest ITU-T G.654.E fiber sepecification and typical G.654.E profile design. Our novel ultra low loss & large effective area fiber attenuation and cabling performance were also discussed. in the recent two G.654.E terrestrial cable projects of china, the PCVD G.654.E fiber shows the huge advantages of link attenuation and effective area than standard G.652.D fiber. G.654.E industry chain is matured and can be promoted in terrestrial network.

OCIS codes: (060.2280) Fiber design and fabrication; (060.2270) Fiber characterization

1. Introduction

In the next generation high speed 400G/400G+ communication, attenuation and nonlinear effect will be the bottlenecks for the system. Relative research [1,2] has shown that larger effective (110～130um^2) area can play the same role as ultra low attenuation (less than 0.174dB/km) in high speed and large capacity system. Larger effective area (Aeff. for short) can support higher launch power into the fiber which is good for improving OSNR. Lower loss can increase the output optical signal-to-noise (OSNR) and Q-factor of transmission system for the same distances, or extends the transmission reach. By reducing Rayleigh scattering [3], optical fiber attenuation can be lower to 0.14-0.15dB/km [4]. At the same time, ultra low loss technology can be transfer into large Aeff. fibre design and manufacturing. In theory, ultra low loss & large effective area fiber is best choice for next generation 400G/beyond 400G communication.

Large effective fiber shows huge potential capacity in terrestrial applications, but it still has two bottlenecks: no terrestrial G.654 fiber & cable specification and the maturity of terrestrial G.654 fiber & cable industry chain. It is well known large Aeff. G.654 fibers are widely used in transoceanic cable system, but the terrestrial cable installation, application and service environments are quite different from submarine cable. So it requires more performance optimization or special specifications for terrestrial large Aeff fiber and a new terrestrial G.654 specification also can help the novel G.654 fiber's promotion on land. On the other hand, purchase amounts of terrestrial cables are much larger than submarine cables'; network operators are also more sensitive in terrestrial fiber & cable's price. More fiber and cable vendors can avoid the risk of supply chain and lower the purchase cost. The maturity of terrestrial G.654 fiber & cable industry chain decides the application schedule of large Aeff. fiber in long haul terrestrial network.

Recently, with the effort of fiber & cable companies, above problems have been solved. First of all, the latest ITU-T G.654.E specification for terrestrial cable has been released. In other hand, as the important force in optical fiber field, Chinese companies ramp up the R&D of G.654.E fiber and also achieve key breakthroughs in recent two years, several companies have released their G.654 fiber products. Based on the above two foundations, two biggest Chinese network operators have build their G.654.E terrestrial long haul net since 2016: China Unicom have finish the building of two terrestrial G654 cable, 72km cable link in Xinjiang is 1st commercial G.654.E terrestrial cable in china and 400km cable link in Shandong will test 400G transmission on G.654.E fiber[6]; China mobile is building the longest (about 1500km) terrestrial G.654.E cable from Beijing to Nanjing in china, about 20000Fkm PCVD ultra low loss and large effective area fiber have been cabled and the project will be done before the end of 2017, 400G system will also be tested on the G.654.E fiber. Our ultra low loss & large Aeff. fiber combines large effective area, ultra low loss and bending insensitive together and have been used in these projects.

In this paper, we introduced our latest work in terrestrial long haul cable application and also review the G.654.E fiber specification and fiber & cable manufacturing progress in china market. And the key fiber and cable performances for terrestrial application are also discussed.

2. Latest G.654.E specification and G.654.E fiber design

In fiber profile design, several profiles can fulfill low loss or ultra low loss G.654.E fiber by different deposition process. Figure 1 depicts the five typical profile designs for G.654.E fiber. Profile a) & b) are typical designs for

ultra low loss & large Aeff. fiber, the "Pure silica Core" technology[3] can reduce the rayleigh scattering and lower the fiber attention below 0.17dB/km and four companies have released ultra low loss G.654.E fiber in the world. While c), d) and e) are typical profiles of low loss fiber G.654.E fiber. By reducing Ge doped in the core and adopt special annealing and coating process, low loss & large Aeff. fiber (Aeff. 110-130um2) can be made as profile c), d) & e), 4-5 companies can make low loss G654.E fiber in large quantity in china market[6].

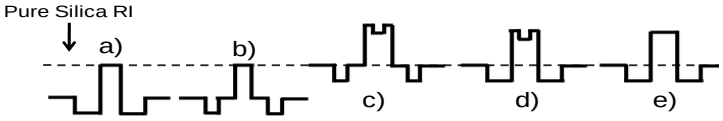

Fig. 1 Typical G.654.E design: a) & b) is pure silica core; c), d) & e) is conventional Ge doped concept.

As shown in table 1, we compared our ultra low loss & large effective fiber parameters and ITU-T G.654 series specification. Specified for long haul terrestrial cable application, new ITU-T G.654.E fiber specification pays more attention to macrobending, fiber effective area and dispersion. The relative tight macrobending specification is required for terrestrial cable deployment and service condition. Fiber effective area and dispersion requirements are designed for high speed and large capacity transmission system. New ITU-T G.654.E specification has listed not only the upper limitation, but also the range of dispersion coefficient and slope@1550nm, it means it will be easier to design and optimize dispersion compensation in transmission system. G.654.E has relative smaller MFD range, it means Aeff. 110～130um^2 is proposed to use in terrestrial cable.

Table.1 ITU-T G.654 series specification and PCVD G.654.E datasheet

		G.654.B	G.654.D	G.654.E	PCVD-A110	PCVD-A130
Mode field diameter	Nominal@1550nm [um]	9.5-13.0	11.5-15.0	11.5-12.5	11.8	12.8
	Tolerance	±0.7	±0.7	±0.7	±0.4	±0.4
Cable attenuation	1550nm [dB/km]	≤0.22	≤0.20	≤0.23	≤0.17	≤0.17
Macrobending R30mm-100turns	1550nm [dB]	TBD	TBD	TBD	≤0.1	≤0.1
	1625nm [dB]	≤0.50	≤2.0	≤0.1	≤0.005	≤0.005
Dispersion Coeff.	1550nm [ps/nm/km]	≤22	≤23	17-23	17-23	17-23
Dispersion Slope	1550nm [ps/nm^2*km]	≤0.070	≤0.070	0.050-0.070	0.050-0.070	0.050-0.070

**TBD: To Be Determined.*

Our ultra low loss G.654.E fiber have two series, A110 and A130, which fiber nominal Aeff.@1550nm is 110um^2 and 130um^2, respectively[7]. Both of them meet or beyond the G.654.E specification and they have tighter limitation on MFD, attenuation and macrobending. Especially, as shown in figure 2, our fibers' macrobending performance not only meets the G.654.E specification, but also exceed G.657.A1 macrobending level at D20-1turn. With the help of special trench assistant and coating process, our fiber also have excellent micro bending performance at all wavelength.

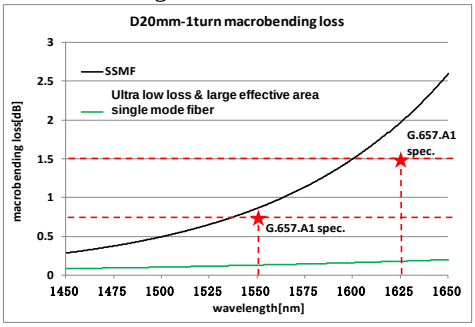

Fig.2 Macro-bending comparison

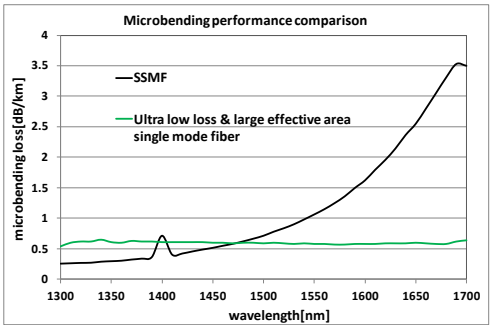

Fig.3 Micro-bending loss comparison

3. PCVD G.654.E cable performances in terrestrial long-haul projects

In 2015 OFC, we released our ultra low loss and large Aeff. fiber product. And then we provided our 1st generation ultra low loss & large Aeff. fiber (nominal Aeff. is 110um^2) to China Unicom in 2015. Table 3 shows our 1st generation fiber's performance in China Unicom projects. Thanks to the larger MFD matching, splicing loss can be

lower to 0.01dB/point, so the link attenuation can be lower to 0.172～0.174dB/km, while about 0.02dB/km lower than standard G.652.D fiber.

Table. 3 performance comparison of 1st Gen. PCVD and standard G.652.D fiber

	1st Gen. A110 Fiber in Xinjiang Link	Standard G.652
Aeff. @1550nm [um^2]	110	80
Fiber Att.@1550 [dB/km]	0.166	0.185
Cable Att. @1550 [dB/km]	0.169	0.186
Splicing loss [dB/point]	0.01	0.02
Loss increase in the link [dB/km]	0.003-0.005	0.008-0.012
72km link Att. [dB/km]	0.172-0.174	0.194-0.198

In the middle of 2016, we release our 2nd generation ultra low loss technology and the fiber typical attenuation can be lower from 0.166dB/km to 0.159dB/km. As the fiber vendor and cabling company, about 20,000Fkm ultra low loss & large Aeff. fiber was cabled for China mobile's 1500km long haul terrestrial link from Beijing to Nanjing of China. Figure 4 shows the attenuation change before/after the cabling process. The typical attenuation of cable is about 0.163dB/km in this case. In normal condition, the link attenuation will be below 0.170dB/km. China mobile will finish the cable deployment and test the 400G in 1500km link before the end of 2017. To my knowledge, it will be the longest terrestrial long haul G.654.E link in the world. We will follow the work and give the latest upgrade in the next year's OFC.

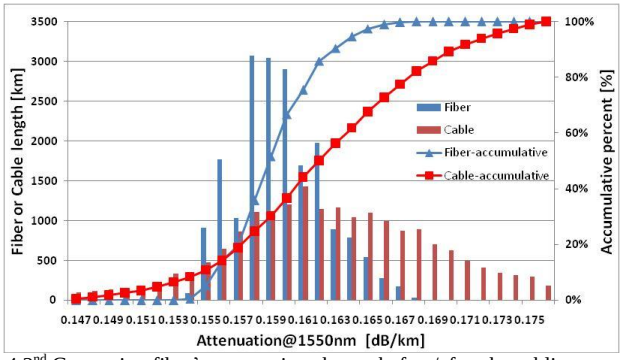

Fig. 4 2nd Generation fiber's attenuation change before/after the cabling process

4. Conclusions

In this paper, we presented our ultra low loss and large effective area G.654.E fiber's performance in latest long haul terrestrial network. We also review the latest ITU-T G.654.E specification from terestrial application view. Based on the latest G.654.E fiber and cable promotion results of china , G.654.E fiber and cable have come into an integrity and matured industry chain. G.654.E fiber can be rapidly promoted in terrestrial long haul network for next generation 400G or beyond 400G system.

5. Acknowledgement

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6. References

[1] Chengliang Zhang, et al. "Demonstration of Real-time 1.2 Tb/s Transmissions over 4 Types of Fiber with Nyquist WDM Prototype System". 2014OFC, W2A.21, (2014).
[2] Runhan Wang, et al. "Single Mode Optical Fiber with Large Effective Area for Long Haul Applications". International Wire & Cable Symposium Proceedings of the 61th IWCS, (2012).
[3] Sergey ten. "Ultra low loss optical fiber technology".2016OFC, Th4E.5, (2016).
[4] S. Makovejs, et al. "Record low loss (0.146dB/km) attenuation ultra-large Aeff optical fiber for submarine applications". 2015OFC, Th5A.2, (2015).
[5] M. Hirono, et al. "Record low loss (0.146dB/km) attenuation ultra-large Aeff optical fiber for submarine applications". 2015OFC, Th5A.2, (2015).
[6] Shikui Shen, et al. "G.654 fibre and cable evaluation for terrestrial high bitrate transport application". 2016IWCS, 470-475, (2016).
[7] Hongyan Zhou, et al. "A Bending-insensitive Ultra Low Loss and Large Effective Area Fibre for Long Haul Transmission". 2016OFC, Tu3G.2, (2016).