A Single Mode Optical Fiber with Large Effective Area

Runhan Wang, Hongyan Zhou, Shengya Long

State Key Laboratory of Optical Fiber and Cable Manufacture Technology, Wuhan 430073, Hubei, China
Yangtze Optical Fiber and Cable Company Ltd. R&D center, R&D Department, Wuhan, Hubei, China

wangrunhan@yofc.com

Abstract: A single mode optical fiber with a ring core structure to obtain an enlarged effective area up to over 150μm^2 is reported. With a trench assisted refractive profile design and coating process optimization, the micro-bending performance is also improved.

1. Introduction

Demand for large transmission capacity has been increasing exponentially due to the rapid spread of Internet broadband services. Wavelength division multiplexing (WDM) at 100 Gb/s is expected soon in the most advanced commercial submarine systems, particularly in ultra-long-haul transoceanic cable transmission systems. Longer unrepeatered fiber span distance transmission can abandon repeaters or reduce repeaters amount, cutting down the system cost. Systems with 100Gb/s data rates have been extensively studied in the past several years for long-haul networks [1-3].

It is well understood that large effective area fiber is the optimal choice for the next generation ultra-long-haul, high speed and large capacity communication, because of its excellent transmission performance, improving optical signal-to-noise ratio (OSNR) and allowing longer transmission distance. For the design of large effective area fiber, controlling cable cutoff wavelength (λ_{CC}) and the micro-bending loss performance are key techniques. To meet the ITU-T G.654 recommendations, the λ_{CC} should be lower than 1530nm for practical applications. Then, it seems that the Aeff hardly reached 150μm^2 [4, 5]. So, how to fabricate an even larger effective area with a relative lower λ_{CC} is a great challenge. A trench assisted step index structure is a solution to improve the microbending sensitivity. And the improvement in coating process can also bring a better bend performance, such as employing a low modulus primary coating [2]. Further enlargement of Aeff would be limited by degradations of the macro-bending and micro-bending performance, because the light confinement in the core becomes weaker in larger-Aeff fiber.

In this paper, we reported a single mode optical fiber structure with large effective area. With improvements in refractive index profile design, the Aeff value can increase to above 150μm^2 while keeping the λ_{CC} still below 1530nm. The fiber has good microbending performance attributing to a trench assisted design and coating optimizations.

2. Fiber Design and Fabrication

To fabricate a standard 125/250μm (fiber/coating diameter) commercially-available large effective area fiber, a step core profile and a trench-assisted structure is generally adopted. For practical applications in the long distance transmission system, it is better to control the λ_{CC} <1530nm (ITU-T G.654 recommendations) for single mode transmission requirements. It has been reported that it is quite difficult to fabricate a fiber with Aeff > 155μm^2 but λ_{CC} <1550nm, based on a conventional step core structure profile [5]. To make a breakthrough in the λ_{CC} constraint for even larger Aeff fiber fabrication, we introduced a depress layer in fiber core to make a ring core structure. The electric field distribution of the ring core structure fiber and step core structure fiber at 1550nm are shown in the fig.1. The field in the step core structure fiber displays a Gaussian distribution. But, in the ring core structure fiber displays a non-Gaussian electric field shape, which results in a larger Aeff than the step core structure fiber. Table 1 exhibits typical Characteristics of fiber sample with ring core structure and large Aeff of ~150μm^2. It is obvious that the fiber complies with or exceeds ITU-T Rec. G654.D. It is also found that the ring core structure can bring lower λ_{CC} while keeping the same Aeff in contrast with the conventional step core structure. As revealed in fig.2, it allows a ~ 60nm reduction in λ_{CC} for fiber with Aeff around 150μm^2. Thus, it has still a great potential for the ring core structure fiber to increase Aeff up to 170μm^2 while still maintaining the λ_{CC} <1530nm.

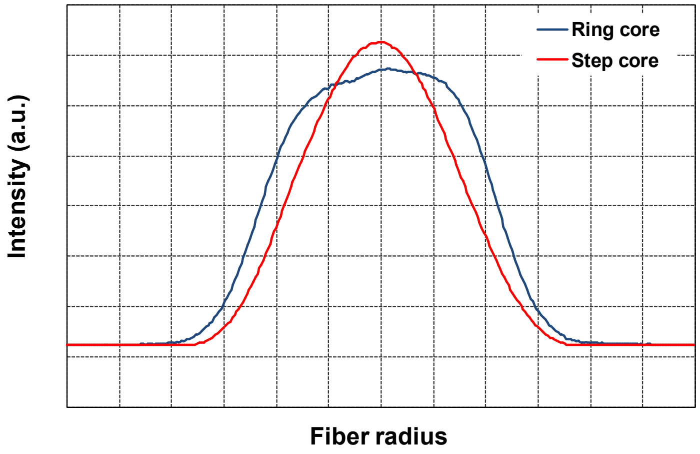

Fig.1. Electric field distribution of the ring core structure fiber and step core structure fiber

Table 1 Characteristics of large Aeff fiber sample with ring core structure

Characteristics	Unit	Wavelength (nm)	ITU-T Rec. G.654.D	SSMF	Large A_{eff} fiber
MFD	um	1550	11.5-15	10.2	13.5
A_{eff}	um^2	1550	\	81	152
Cable cutoff wavelength	nm	\	⩽1530	1180	1482
Attenuation	dB/km	1550	⩽0.20	0.19	0.183
Macro-bending loss (R30mm×100 turns)	dB	1625	⩽2.0	0.05	0.05
Dispersion	ps/nm/km	1550	⩽23	16.8	21.4
Dispersion slope	ps/nm^2/km	1550	⩽0.070	0.058	0.061
Zero dispersion wavelength	nm	\	\	1312	1282
PMD	ps/km$^{1/2}$	1550	⩽0.2	0.025	0.023

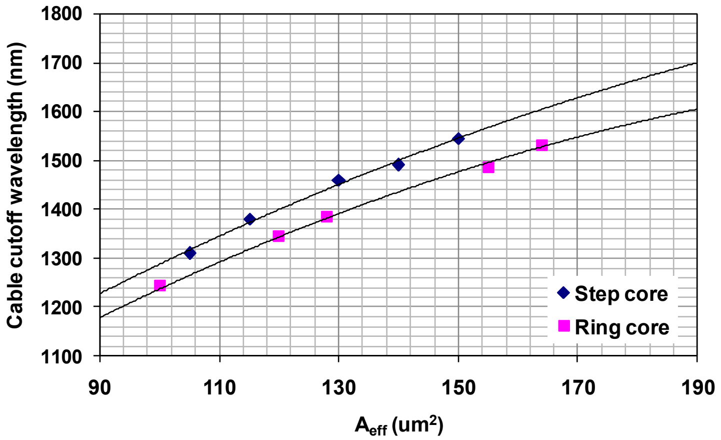

Fig.2. Improved cable cutoff wavelength performance of the ring core structure fiber

The micro-bending performance deterioration with the Aeff enlargement is another bottleneck for large effective area fiber design. The trench assisted structure is a mature bending insensitive design in G.657 fiber [6]. In our large Aeff fiber, it has displayed the same bending improved characteristic. As shown in the fig. 3, the micro-bending loss is reduced while the trench volume increases (The micro-bending losses are measured using the Method B of the IEC TR-62221 document). The Aeff of tested fiber sample samples are all around 150μm^2 and with the ring core structure refractive index profile.

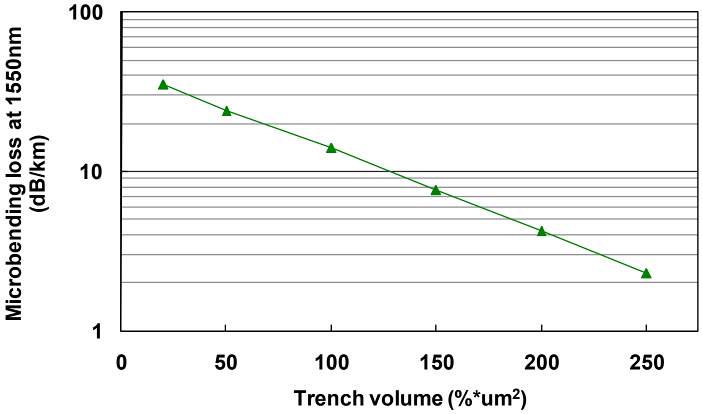

Fig.3. Relationship between microbending loss and trench volume

In order to further improve the micro-bending performance, coating process is also optimized. The in-situ modulus of the primary/secondary coatings is optimized. And the primary coating diameter is increased while still keeping a 250μm secondary coating diameter. Fig.4 exhibited the improved microbending performance with the optimized coating process. To accurately evaluate the effect of the coating process development, all fiber samples are produced with the same trench volume (with the same trench width and depth). For the fiber with Aeff around 150μm^2, the reduction of microbending induced loss has reached about 65%.

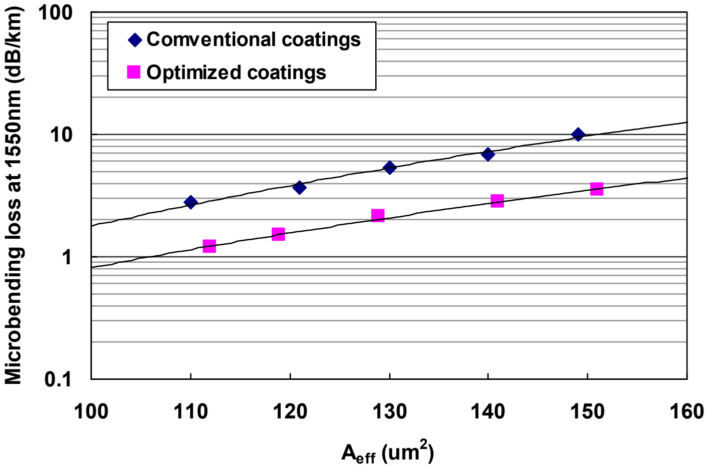

Fig.4. Improved microbending performance with optimized coatings

3. Conclusions

In this paper a single mode optical fiber with large effective area is fabricated. With the ring core structure, trench assisted design and optimized coating process, the Aeff reached up to over 150μm^2 while still keeping λ_{CC} below 1530nm and ideal microbending performance.

4. References

[1] V.A.J.M. Sleiffer et al , "A Comparison between SSMF and Large-Aeff Pure-Silica Core Fiber for Ultra Long-Haul 100G Transmission," Opt. Express, 19 ,2011,B710-B715

[2] Y. Yamamoto et al, "OSNR-Enhancing Pure-Silica-Core Fiber with Large Effective Area and Low Attenuation," OFC' 2010, paper OTuI2.

[3] W. Peng, I. Morita, and T. Tsuritani, "Transmission of Power-Efficient CO-OFDM Signal over 9360km of Ultra-Large-Area Fiber," OFC'2012, paper OTh3A.2

[4] M. Bigot-Astruc et al., "125um Glass Diameter Single-Mode Fiber with Aeff of 155um2," OFC'11, paper OTuJ2.

[5] M. Bigot-Astruc and P. Sillard, "Realizing Large Effective Area Fiber," OFC'12, paper OTh4l.

[6] Q. Han et al., "Large-Scale Production Technology for G.657 Fiber," Proc. 59th IWCS, (2010) ,pp. 114-116