Variations in the Optical Characteristics of 200 µm and 250 µm Coated Multicore Fibres Owing to Cabling

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Abstract *The optical characteristics of cabled four-core multicore fibres (4CFs) with 200 µm and standard 250 µm coating diameters are compared, and are found to be identical. Effective bending diameter of 4CFs in a cable is estimated to be small, which leads to low crosstalk.*

Introduction

The demand for high-density and higher-bandwidth optical cables has been growing due to the significant increase in network traffic. Particularly, cables with smaller-diameter and higher-fibre-count optic cables are required to meet the growing demand. This is because the size of conduits connecting datacentre sites and the datacentre floor space available for storing cables are limited. One solution is a cable with intermittently bonded optical fibre ribbons. This type of ribbon can change its shape freely and be packed inside a cable. It also has the advantage of easy manual division into individual fibres. Furthermore, the fibres can be spliced with each other as well as a conventional rigid ribbon. To develop improved high-density cables, single-mode fibres (SMFs) with a 200 µm coating and a standard 125 µm cladding diameter (200-SMFs) have been developed. Standard SMFs have a coating diameter of 250 µm. The reduced coating diameter from 250 µm to 200 µm decreases the cross-sectional area per fibre by 36%. A cable with a fibre count of up to 6,912 has been developed by employing 200-SMFs. The cable diameter is kept as 33 mm, which can be easily accommodated into a 1.5 inch conduit[1].

Spatial division multiplexing (SDM) is a promising technology for significantly increasing the transmission capacity of each fibre, which is difficult using a standard SMF. Uncoupled single-mode multicore fibres (MCFs) have an advantage whereas signals transmitted in the core can be processed as independent parallel transmission channels due to their low crosstalk and does not require complex digital signal processing, such as MIMO, to compensate for the crosstalk. MCFs, particularly with a standard cladding diameter of 125 µm, are compatible with the current optical transmission systems and hence, are easy to incorporate in practical applications. MCFs can be a breakthrough for achieving much higher-density cables in datacom. Trench-assisted and step-index four-core MCFs with a 125 µm cladding diameter have been developed[2],[3]. However, these MCFs have a 250 µm coating, the same as standard SMFs. Recently, we have fabricated a four-core MCF (4CF) with a reduced 200 µm coating diameter and cabled it, which is a first to the best of our knowledge[4]. However, there still exist some concerns regarding the optical characteristic changes owing to the reduced coating diameter.

In this study, we compare attenuation and crosstalk of reduced 200 µm-coated 4CFs with those of standard 250 µm-coated 4CFs. Based on the optical characteristics comparison of before and post cabling process, we show that the 200 µm-coated 4CFs can be cabled without causing any significant deterioration in optical characteristics such as attenuation and crosstalk.

Prepared 4CFs

Standard SMFs (250-SMFs) have a cladding diameter of 125 µm and a 250 µm coating. Generally, reducing the coating diameter could lead to high microbending loss. Therefore, to achieve low microbending loss characteristics with high mechanical reliability despite the reduced coating thickness, resins of a 200 µm coated four-core fibre (200-4CF) for primary and secondary coatings have been optimized[5]. We prepared two-types of 4CFs, 200-4CFs and 250 µm-coated 4CFs (250-4CFs). Figure 1 shows the schematics of the cross-section of 250-4CF and 200-4CF, respectively. Both 4CFs had

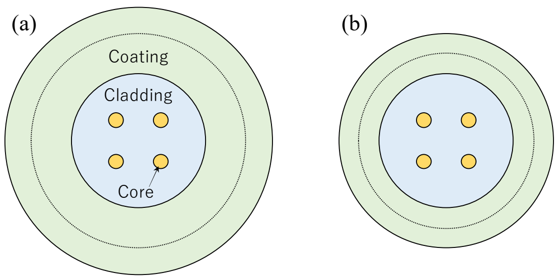

Fig. 1: Schematics of cross-section of prepared 4CFs (a) 250-4CF and (b) 200-4CF.

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Tab. 2: Measured characteristics of the prepared 4CFs.

Attributes	Wavelength [nm]	ITU-T G.657.A1	200-4CF	250-4CF
Attenuation [dB/km]	1310	< 0.4	0.34	0.33
	1550	< 0.3	0.19	0.19
MFD [μm]	1310	8.2-9.6	8.3	8.5
	1550	-	9.3	9.6
Macro-bending loss at φ30 mm [dB/10 turns]	1550	< 0.25	< 0.01	< 0.01
	1625	< 1.0	0.02	0.02
Zero-dispersion wavelength [nm]		1300–1324	1314	1315
Cutoff wavelength [μm]		< 1.26	1.21	1.20
Total crosstalk [dB/km]*	1310	-	–69	–67
	1550	-	–37	–33
Cladding diameter [μm]		124.3–125.7	124.9	125.0
Coating diameter [μm]		-	194	243
Core pitch [μm]		-	39.8	40.0

*Bending radius: 155 mm.

homogeneous cores with identical step-index profile without index trenches. The key advantage of employing a step-index profile is the ability to be manufactured using the VAD method without the requirement of fluorine dopant, thereby reducing the fabrication costs. Table 1 summarises the optical characteristics and measured dimensions of the prepared 4CFs compared to ITU-T G.657.A1 recommendations. Both 4CFs had 125 µm cladding, whereas the coatings of 200-4CF and 250-4CF were 194 µm and 243 µm, respectively. The 200-4CFs and 250-4CFs were compliant to ITU-T G.657.A1 recommendations. Compared with crosstalk of the 250-4CFs, crosstalk of the 200-4CFs was almost the same at 1310 nm and was smaller at 1550 nm. It is confirmed that the coating thickenss had a negligible effect on the crosstalk of a 4CF.

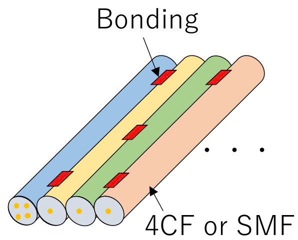

Fig. 2: Schematic diagram of the fabricated intermittently bonded optical fibre ribbon.

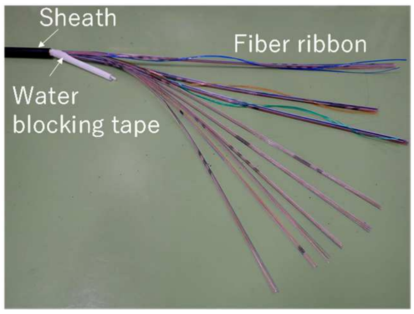

Fig. 3: Representation of the fabricated cable A.

Attenuation variation

Intermittently bonded optical fibre ribbons employing 4CFs and SMFs were fabricated. The ribbons were then cabled, and labelled as Cables A and B, having lengths of 5 km and 2 km, respectively. The bundle pitch and tension of the cables were the same as those of conventional cables. Cable A comprised of 288, 200 µm-coated fibres, 12 of which were 200-4CFs, and rest were 200-SMFs. Similary, Cable B comprised of 250 µm-coated fibres, 50 of whch were 250-4CFs and 90 fibres were 250-SMFs. The 200-SMFs and 250-SMFs were compliant to the ITU-T G.657.A1 recommendations. Figures 2 and 3 show a schematic of the ribbon and a physical view of cable A, respectively. We measured the attenuation of each SMF and core of every 4CF before cabling process (fibre condition) and after cabled, respectively. The cables were wound onto drums. Figures 4 and 5 show the attenuation before cabling process and after cabled for Cables A and B at 1310 nm and 1550 nm, respectively. The differences in the attenuation of 4CFs and SMFs before cabling could be attributed to the additional fabrication processes involved in producing 4CFs, such as the drilling process. We believe that the decrease in SMF attenuation at 1310 nm was primarily caused by measurement variability. The attenuation of both 4CFs after cabling process increased as compared to that before cabling process, which we believe is due to the micro-bending loss caused by fibre compression in the longitudinal direction of the cable. However, the average variation in attenuation of 200-4CFs and 250-4CFs was less than 0.01 dB/km at both 1310 nm and 1550 nm. Therefore, we can conclude that the difference in the coating diameters had a negligible impact on the attenuation.

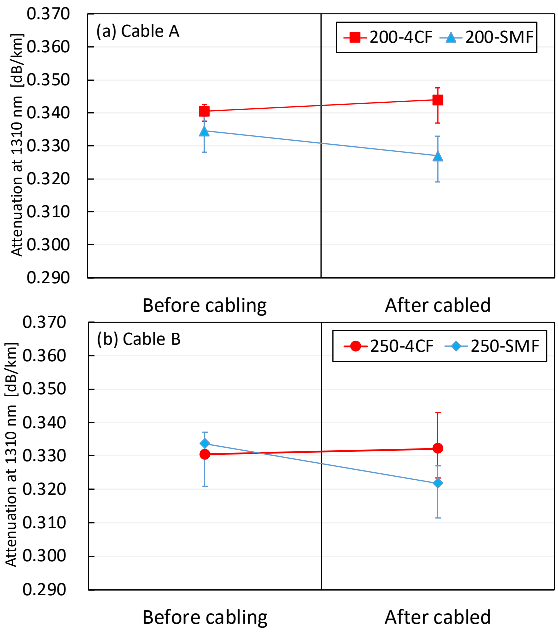

Fig. 4: Variation in attenuation of (a) Cable A and (b) Cable B at 1310 nm.

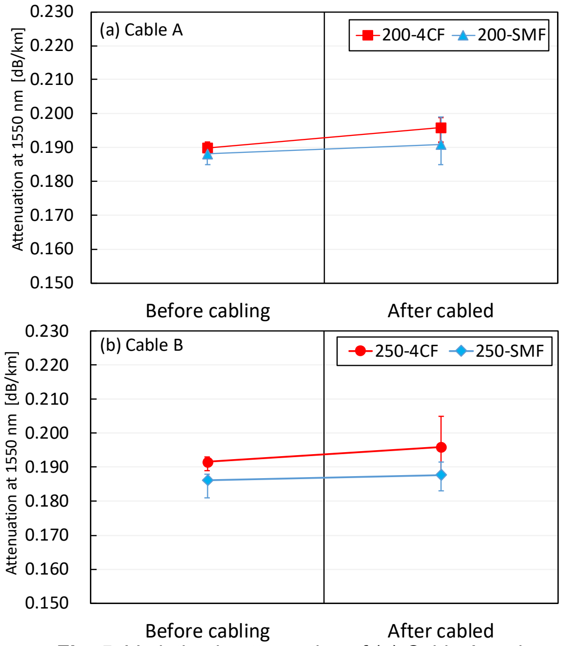

Fig. 5: Variation in attenuation of (a) Cable A and (b) Cable B at 1550 nm.

Crosstalk variation

If the crosstalk deteriorates due to cabling process, we must consider it in designig an MCF. We measured the crosstalk of 4CFs before cabling and after they were cabled. The cables were wound onto cable drums. The fibre spool radius of 4CFs before cabling was 155 mm. The cable drum radii for cables A and B were 500 and 600 mm, respectively. The crosstalk of a homogeneous MCF increases as the bending radius increases in the phase-matching region[6]. Therefore, the crosstalk of a cabled 4CF wound on a cable drum would be larger than before cabling. Figure 6 shows the measured core-to-core crosstalk increment after cabling, along with

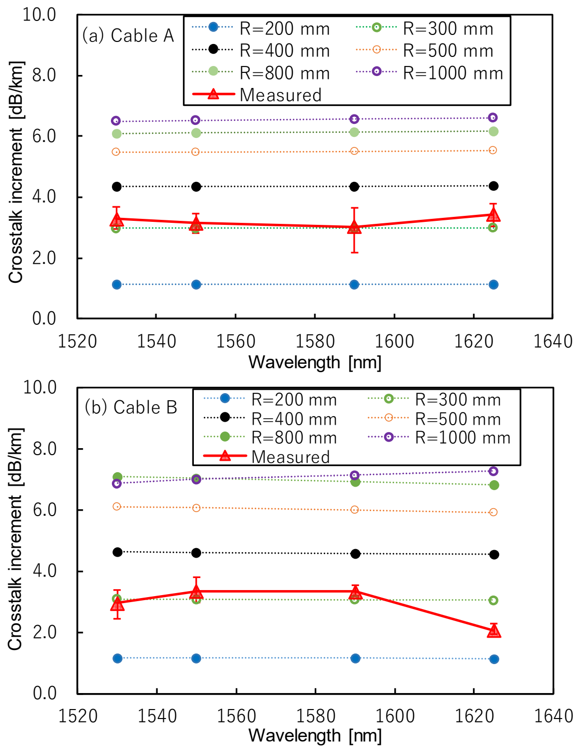

Fig. 6: Crosstalk increment after cabling as compared to before cabling for (a) Cable A (200-4CFs) and (b) Cable B (250-4CFs). Fibre spool radius of 4CFs before cabling was 155 mm.

the simulation results using multiple bending radii (R) assuming that all crosstalk variations are caused by variations in R. It was observed that the crosstalk increment in the 200-4CFs in Cable A and 250-4CFs in Cable B were almost identical. It was confirmed that coating diameter had minimal impact on the crosstalk behavior due to cabling. The crosstalk increment was smaller than the values simulated based on the assumption that R was the cable drum radii (500 or 600 mm), however, it matched well the assumption that R was approximately 300 mm for both cables. It can be explained that the fibres in the cable are deformed, which may have resulted in a smaller effective bending radius than cable drum radius, thereby leading to a suppressed crosstalk increment of 4CFs. Because the deformation is kept even after cable installation, crosstalk of 4CFs will be suppressed regardless of coating diameter.

Conclusions

In this study, we compared optical characteristics of cables with 200-4CFs and 250-4CFs employing intermittently bonded optical fibre ribbons. As a result, we confirmed that the 200-4CFs could be cabled with negligible attenuation increment as well as 250-4CFs and SMFs. Crosstalk of the cabled 200-4CFs and 250-4CFs was also evaluated. The crosstalk deterioration was smaller than the value expected from variations in the bending radius.

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