Loss performance of field-deployed high-density 1152-channel link constructed with 4-core multicore fiber cable

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Abstract: A cable link with 288 four-core multicore fibers and 288 pairs of fanout devices was deployed in the field and its losses were evaluated. No excess losses were observed from MCF-related components in field installation.

1. Introduction

Rising demands for data center (DC) services has created an urgent need for higher-capacity fiber-optic networks between DC buildings. Effective utilization of limited resources is necessary owing to space and time constraints. For instance, additional fiber cores can be placed in a limited duct space by increasing the core density per cable. Previous studies have been conducted using thinner cable and single-core fiber (SCF) approaches [1]. Recently, uncoupled multicore fiber (MCF) technology has been considered as an effective solution for further increasing the core density. Indeed, a four-core MCF (4c-MCF) with a standard cladding diameter of 125 μm exhibits potential for practical application at an early stage [2]; however there is minimal number of publications on the performance of field-deployed MCF links. Furthermore, previous reports had only considered a few 4c-MCFs in a cable [3], and there are no reports on the field performance of MCF links with practical fiber counts greater than 100.

In this study, we constructed a 1152-channel, 800-m-long MCF cable link in the test field and evaluated its loss performance. The cable was composed of 288 4c-MCFs, which achieved 5.2 times higher core density per cable than that of a conventional 1152-SCF cable. Following successful installation of the MCF cable in the duct, 288 pairs of fanout devices were fusion spliced at both ends of the MCF cable. The link loss of the constructed MCF link was measured using an optical loss test set (OLTS) at wavelengths of 1310 and 1550 nm. This loss was found to be consistent with the sum of the component losses, i.e., cable attenuation, insertion losses (ILs) of fanout devices, and splice losses. In other words, no excess losses were observed owing to field deployment. Section 2 reports the loss values for the individual MCF-related components. Section 3 describes the detailed procedures of field installation, measurement results, and discussions of link losses.

2. Loss performance of each component

2.1. MCF cable

We fabricated an Air-Blown Wrapping Tube Cable™ (AB-WTC) with 288 4c-MCFs [4]. The AB-WTC can be efficiently laid into microducts by blowing with compressed air. The 4c-MCFs used in this cable were designed with 125-μm cladding, 200-μm coating, and G.657.A1 compliant cores, respectively [5]. Figure 1 illustrates the cross-sections of the MCF cable schematic, photos of part of the fabricated MCF cable, and an end face of the 4c-MCF. Each core number of the MCF can be distinguished by placing a marker between two cores, closer to one of them to break the core pattern symmetry. This generates a polarity at both ends of the MCF. Polarity management of the MCF is required because it affects the uniform numbering of connected cores in the MCF-to-MCF connection [6]. The details of polarity management are described in Section 3. The outer diameter (OD) and cable weight of the MCF cable were 9.3 mm and 59 kg/km, respectively, which amount to 5.2 times higher core density and 81% less cable weight than a conventional 1152-SCF cable with a 21.3 mm OD and a cable weight of 313 kg/km [7]. The combination of AB-WTC and MCF enables cables with numerous core counts to be laid with high efficiency over long distances with less connection points, using minimal labor and time. Table 1 lists the measured attenuation values of the fabricated cable, wherein the average attenuation was 0.34 dB/km and 0.20 dB/km at 1310 nm and 1550 nm, respectively. There was negligible loss variation before and after the cabling process.

2.2. MCF splicing

The splice loss of the fabricated 4c-MCF was evaluated. A Fujikura FSM-100P splicer was employed for both test and field deployment, which can automatically detect and align the marker position, enabling the matching of MCF core numbers [4]. Figure 2 presents the experimental results of splice loss in the laboratory. An average splice loss of approximately 0.1 dB was obtained at both 1310 nm and 1550 nm wavelengths.

2.3. Fanout device

In total, 612 fanout devices were fabricated using a vanishing-core approach [8]. Figure 3 shows the IL distributions in these devices. The average IL was 0.3 dB/device at both 1310 nm and 1550 nm wavelengths.

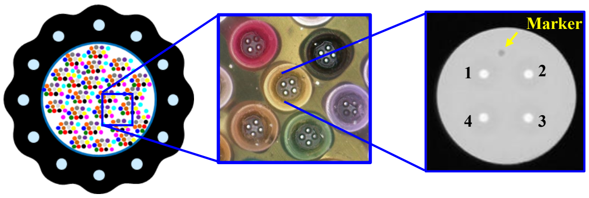
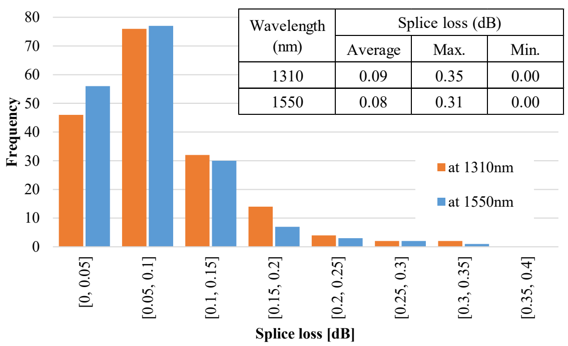


Fig. 1. Cross sectional view of fabricated MCF cable.

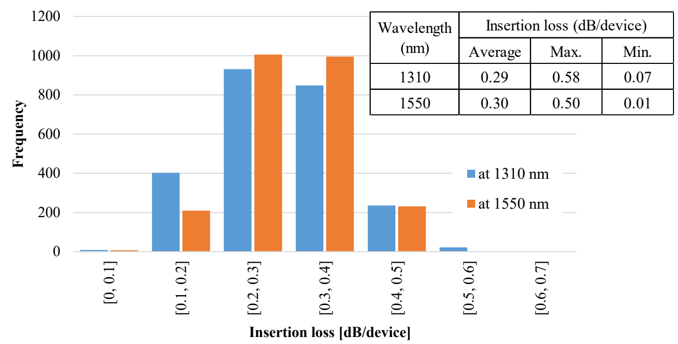
Table 1. Attenuation of MCF cable (1152 cores).

Wavelength (nm)	Attenuation (dB/km)			
	Average	Max.	Min.	Target
1310	0.34	0.37	0.31	≤ 0.4
1550	0.20	0.23	0.18	≤ 0.3



Wavelength (nm)	Splice loss (dB)		
	Average	Max.	Min.
1310	0.09	0.35	0.00
1550	0.08	0.31	0.00

Fig. 2. Splice loss measurement result of 4c-MCF (44 connections, 176 cores).



Wavelength (nm)	Insertion loss (dB/device)		
	Average	Max.	Min.
1310	0.29	0.58	0.07
1550	0.30	0.50	0.01

Fig. 3. ILs of the fanout devices (612 devices, 2448 channels).

3. MCF link construction and loss evaluation

Figure 4 displays a diagram of the constructed MCF link. Approximately 800 m from patch panel (PP) to PP was connected through the MCF cable via fanout devices and SCF cables. First, an MCF cable was laid in microducts with a 15-mm OD along the duct pathway, as shown in Fig. 5. The cable was laid from the middle of the route to Buildings A and B. Subsequently, each MCF pigtail of the fanout device was spliced with each MCF in the cable. The SCFs attached to the fanout devices were spliced to an SCF cable. Finally, these fanout devices were accommodated in fiber enclosures.

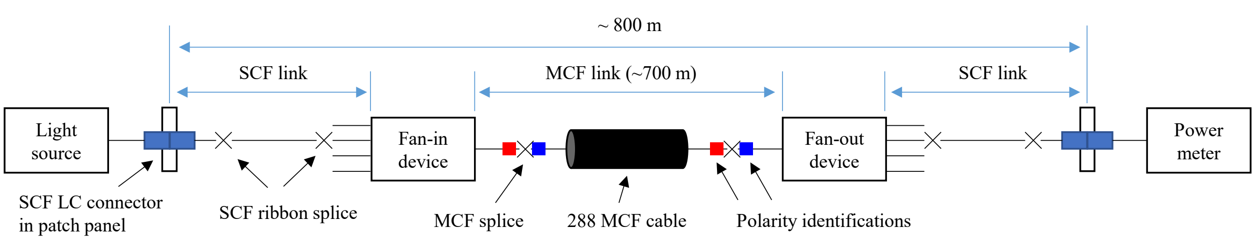


Fig. 4. Schematic of a field deployed, panel-to-panel MCF link with OLTS measurement setup.

Figure 6(a) shows the end faces of the 4c-MCF, definition of polarity, and labeling color for each end. For this trial run, the polarities of all 288 MCFs in the cable were aligned in the same direction to match the core numbers at all MCF-to-MCF connection points, as shown in Fig. 6(b). Polarity identifications were attached to the MCF cable and fanout devices. As shown in Fig. 7, red and blue tapes were attached to both ends of the MCF cable to identify their polarity states during installation. Similarly, red and blue jackets were attached to the MCF pigtails of the fanout devices. The cable and fanout devices were installed such that red and blue labels were mated, as shown in Fig. 4. In the field test, all ports were connected consistently owing to the polarity identification and highly accurate marker detection of the splicer. However, the greater the fiber count, the greater the burden of MCF polarity management in cable manufacturing and field installation, which needs to be reduced for practical usage.

The total link losses of the constructed MCF link were measured using the OLTS method. The test setup is shown in Fig. 4, and Fig. 8 presents the results, wherein out of the 1152 channels, 1102 had ILs of less than 3 dB. The investigation revealed that most defects occurred at the SCF LC connectors and the SCF splice points. The average measured ILs of the channels less than 3 dB were 1.46 dB at 1310 nm, and 1.17 dB at 1550 nm. To estimate the total link loss from individual components, we assumed the typical SCF LC connection loss as 0.1 dB/point, SCF ribbon splice loss as 0.05 dB/point, and IL of SCF cable as 0.01 dB for both wavelengths. The typical losses of the MCF-based components were estimated based on the average values described in Section 2. The estimated total link losses on average were 1.44 dB at 1310 nm and 1.32 dB at 1550 nm. These estimated values were close to those obtained using the OLTS. These results indicated that no excess losses were observed due to the MCF-based components in the field. Even when considering the maximum loss of each component, this system can be applied up to 8 km in 100GBASE-LR4 (optical link power budget: 6.3 dB) transmission [9]. Although inter-core crosstalk also needs to be considered for MCF transmission system, it is low enough to be negligible for O-band transmission up to 10 km [5].

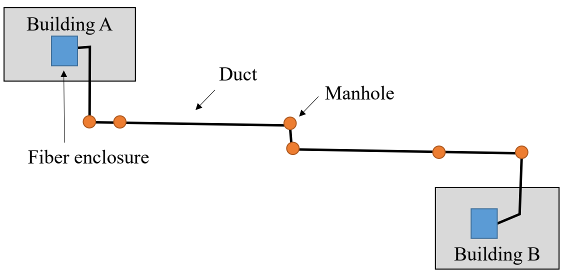


Fig. 5. Test sight map and duct pathway.

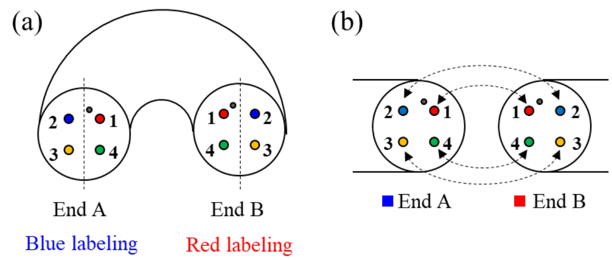


Fig. 6. (a) Definition of MCF polarity and labeling color. (b) Connected core numbers in MCF-to-MCF connection.

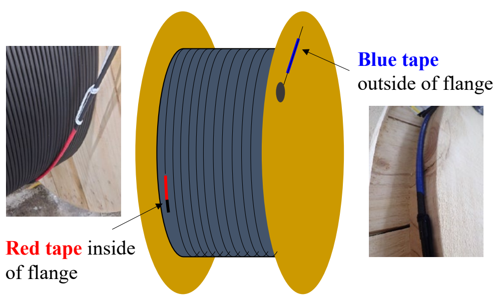


Fig. 7. MCF cable drum with polarity identifications.

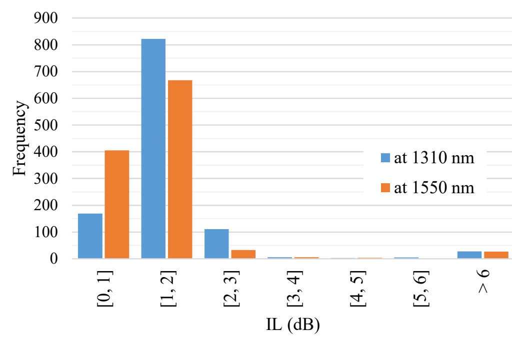


Fig. 8. OLTS result of the MCF link (1152 channels).

4. Conclusion

The loss in the field-deployed 288 4c-MCF link with 1152 channels was evaluated. No excess losses in the field deployment were observed for the MCF cable, fanout devices, and MCF splicing. These results support the applicability of high-density MCF links between buildings over short distances of approximately 8–10 km in O-band transmission without amplification. In addition to the specifications of individual MCF-related components, the management of core numbering should be considered for practical use in future studies.

5. References

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