Development of Four-Core MCFs with Standard Cladding Diameter from High-Core-Count MCFs

Kazuhiko Aikawa, Takuya Oda, Shota Kajikawa, Kohei Ozaki, Mayu Iizuka, Katsuhiro Takenaga, Akito Nishimura, and Kentaro Ichii

Fujikura Ltd., 1440, Mutsuzaki, Sakura, Chiba, 285-8550, Japan.

kazuhiko.aikawa@jp.fujikura.com

Abstract: We developed multiple-core filters (MCFs) with more than 30 cores and conducted transmission tests. Currently, we aim to commercialize four-core MCFs with a standard cladding diameter by conducting trials using MCF cables, and related technologies. © 2023 The Author(s)

1. Introduction

Space-division multiplexing (SDM) is expected to significantly improve the transmission capacity and spectral efficiency of optical communication systems. We developed high-core-count MCFs with more than 30 cores and conducted transmission tests between 2015 and 2017 [1-4]. Recently, a four-core MCF (4c-MCF) with a standard cladding diameter of 125 μm has exhibited potential for practical application at an early stage [5]. In this study, we reviewed the design of high-core-count MCFs with more than 30 cores in the initial stage of MCF development. We also studied MCF-related technologies for enlarging the preform size to reduce the fabrication cost, performance of the splice loss using arc fusion splicers and connectors, and trial results for the actual application of the MCF.

2. Design and fabrication of high core count MCF

In this study, we fabricated a 32-core fiber with its schematic structure (a) and cross-sectional view (b) shown in Fig 1 [2]. Two types of cores, H and L, were employed to suppress crosstalk (XT). The characteristics of the MCF at 1550 nm are summarized in Table 1. The average A_{eff} was 81.8 μm^2 at 1550 nm. The 32-core MCF demonstrated unidirectional transmission over 1644.8 km of PDM-16QAM 20-WDM signals. The distance was more than three times longer for a dense SDM with more than 30 spatial multiplicities [3].

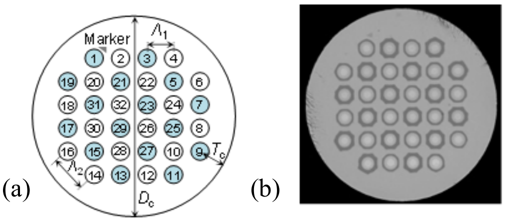


Fig. 1. Schematic structure (a) and cross-sectional view (b) of the 32-core MCF.

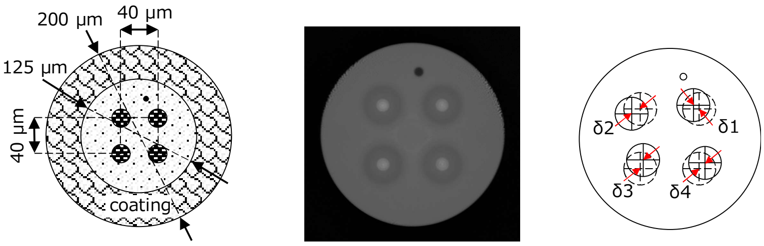
λ =1550 nm

Items	Unit	Core H	Core L
Attenuation	dB/km	0.221	0.213
A_{eff}	μm^2	82.1	81.5
PMD	ps/√km	0.13	0.10

Table 1. Optical characteristics of the 32-core MCF.

3. Four-core MCF with standard cladding diameter

Four-core MCFs with standard cladding diameter have sufficient mechanical reliability and compatibility with other devices [5]. However, the cost of MCF remains a problem for practical applications. Compared with single-mode fibers (SMFs), MCFs require several unique manufacturing processes, such as a drilling method for the cladding of the MCF. Fig. 2 (a) shows the design of the manufactured MCF [6]. The volume of the drawing preform was estimated to be 625 km in fiber length. Fig. 2 (b) shows a photograph of the manufactured MCF. A step-index core was employed. The optical characteristics were in compliance with ITU-T G.657. A1. The inter-core total XT was less than –36 dB/km at 1550 nm. The optical characteristics of the fabricated MCF were tested using cabling. We fabricated an air-blown-wrapping tube cable (AB-WTC^{TM}) with 288 4c-MCFs [6]. Figure 3 shows the histogram of δ for all cores and δ of each length position, respectively. The average and standard deviation of δ were calculated as 0.08 and 0.06 μm, respectively.



(a) (b) (c)

(a) Design of the MCF. (b) Picture of the manufactured MCF.
(c) Conceptual diagram of core misalignment.
Fig. 2 Geometric properties of the MCF.

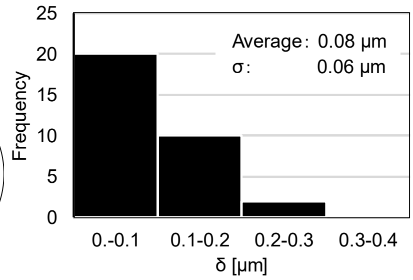


Fig. 3 Histogram of δ for all cores.

4. MCF related technologies

MCF-related technologies such as fan-in/fan-out (FI/FO) devices, connectors, and splicing are required for the single-core fiber (SCF) systems. Figure 4 shows the structure of the fabricated FI/FO device [7]. The ferrules for the MCF and fiber bundle were made of plastic via injection molding. The four cores were arranged in a square lattice of pitch 40 μm. The MCF was then inserted into the round-holed ferrule. The fiber bundle was fabricated by inserting four SCF bundles into a D-shaped ferrule hole. Figure 5 shows the IL measurement results, which were 0.24 dB/each at 1310 nm and 0.26 dB/each at 1550 nm on average.

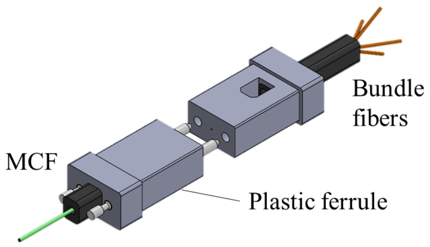


Fig. 4 Structure of the FI/FO device.

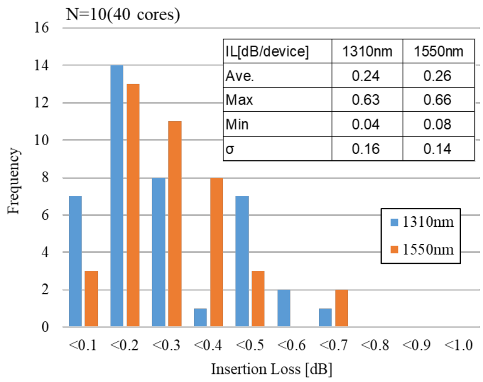


Fig.5 Insertion loss of 10 FI/FO devices.

The fusion splicing of the MCF was conducted using a rotary-centering fusion splicer, as shown in Fig. 6. Table 2 presents the results of comparing the MCF connection losses between different production lots and connections from the same lot [8]. By confirming the fusion characteristics of MCFs from different production lots, we found that the eccentricity of each core of the 4c-MCF and the rotation alignment angle of the fusion machine could be controlled to a level that had almost no effect on the splice loss. was suggested.

Fig. 6 Specialty fiber fusion splicer FSM-100P.

λ =1550 nm

Items	Same lot	Different lot
Sample size	72 (18 splices)	72 (18 splices)
Ave.	0.06	0.07
Max.	0.12	0.18
σ	0.03	0.03

Table 2. Splice loss results with similar and different MCF lots.

5. Deployment of MCF link for demonstration

Figure 7 shows a diagram of the constructed MCF link [9,10]. Approximately 800 m from a patch panel (PP) to another PP was connected through an MCF cable via fan-out devices and SCF cables. An MCF cable was laid in a microduct with a 15-mm OD along the duct pathway. The cable was laid in the middle of the route to two buildings. Subsequently, each MCF pigtail of the fan-out device was spliced with each MCF in the cable. The SCFs attached to the fan-out devices were spliced into an SCF cable. Finally, these fan-out devices were accommodated in fiber enclosures. The average value of the measured link loss showed good agreement with the predicted value, and no change in loss owing to installation was observed.

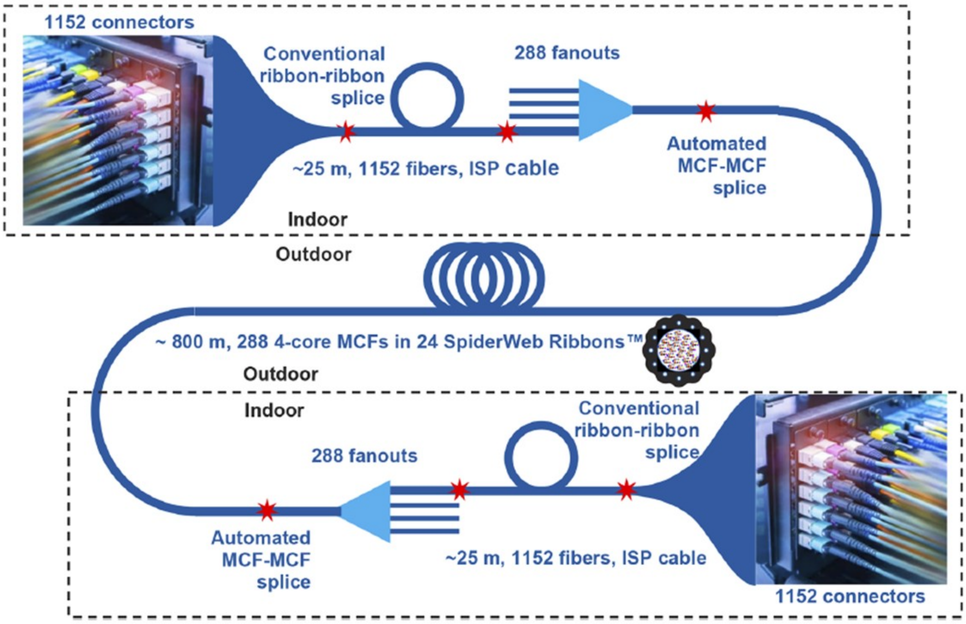


Fig. 7. Diagram of constructed MCF link.

6. Conclusion

High-core-count MCFs with more than 30 cores and a four-core MCF with a standard cladding diameter were reviewed in this study. Technologies related to MCF are also reviewed. Related MCF technologies, including design and production technologies of the MCF, FI/FO devices, connectors, and fusion splicers, were studied. We confirmed the feasibility of the practical application of 4c-MCF using these technologies.

7. References

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