Multicore Fiber Fabricated by Modified Cylinder Method

Masanori Takahashi, Koichi Maeda, Ryuichi Sugizaki, and Masayoshi Tsukamoto
Furukawa Electric Co., Ltd.
6, Yawata-kaigandori, Ichihara, Chiba, 290-8555 Japan
masanori.takahashi@furukawaelectric.com

Abstract: MCF made by modified cylinder method (MCM) is demonstrated. Optimized cylinder with single hole show potentials for cost reduction and higher productivity. Attenuation loss of the MCF made by MCM is 0.190dB/km at 1550nm. © 2020 The Author(s)
OCIS codes: (060.2280) Fiber design and fabrication; (060.2430) Fibers, single-mode

1. Introduction

Space division multiplexing (SDM) transmission technology is attractive technology which overcomes the limit of the transmission capacity of the optical communication system using standard single-mode fiber (SMF). In recent years, SDM transmission technology using multicore fiber (MCF) has been actively developed, and many research have been reported. For example, high-capacity transmission using 19 core fibers [1, 2] has been reported. Furthermore, by combining mode multiplexing technology with each core of the MCF, more than 100 spatial multiplexing transmissions have been reported [3], and the transmission capacity per 1 fiber has been increased to more than 10 Pb/s. On the other hand, there are problems in applying these technologies to practical transmission systems. For example, most of these fibers have a cladding diameter of 200 μm or more, which far exceeds the standard cladding diameter of 125 μm of the SMF. When these fibers are used in the optical transmission systems, the requirements to ensure long-term mechanical reliability become more stringent. As MCFs suitable for practical optical transmission systems, MCFs with cladding diameter of 125 μm have been reported [4, 5]. The use of the MCF with standard 125μm cladding provides significant advantages in terms of matured techniques can be used for cleaving and connecting fibers, as well as cable structures.

Although MCFs with standard 125 μm cladding have attractive characteristics for practical applications, it is necessary to improve the productivity of the MCFs to realize SDM transmission systems using MCFs. Especially, cost reduction and improvement of productivity for mass production are important. For these purpose, it is essential to enlarge preforms. A drilling method is widely used as a fabrication technique of the MCFs. In addition to the drilling method, a stack and draw method have also been reported [6]. However, these methods have a problem in increasing the size of the preform. As new fabrication methods of MCFs, an over-cladding bundled rods method [7] and a slurry casting method [8] have been reported, however these methods have problems in the productivity and optical characteristics at this moment.

In this report, a new fabrication method of the MCFs have been investigated with the aim of overcoming disadvantages of the reported fabrication methods of the MCFs. MCFs are actually fabricated using preforms made by a modified cylinder method (MCM) which has a potential to enlarge preforms. Void ratio of the MCF preform is calculated, and effect of the void ratio on the core pitch deviation and the core non-circularity is investigated. In order to reduce void ratio, design of the preform made by the MCM is optimized, and the core pitch deviation and the core non-circularity are successfully reduced.

2. Design of MCF preforms made by modified cylinder method

The preforms for MCF made by the drilling method have an advantage on accuracy of dimensions. However, productivity on this method is limited by length of preforms and cost for making plural holes. In order to break the limiting factor for the drilling method, we propose the MCM utilizing cylinder with single non-circled hole. This cylinder can be obtained using similar technique to standard cylinders with round hole in the center. Since enlargement of the cladding material is easy by applying same approach as the method obtaining standard cylinders, the productivity of the cladding material made by the MCM is better than that of the drilling method.

Figure 1 shows an original design of 4-core MCF preforms made by the MCM. A cladding cylinder has a cross-shaped hole and a preform of a 4-core MCF is fabricated by inserting four core rods and a center cladding rod into the hole. The advantage of this design is good productivity in preparing preform due to the small number of the glass rods to be used. The disadvantage of this design is the large void ratio in the hole. Large void ratio will affect the core pitch deviation and the core non-circularity.

Figure 2 shows an approach of 4-core MCF preforms with reduced void ratio utilizing a cylinder with a cross shaped hole. By this approach, additional filler rods with small diameters are inserted to the air gap. The advantage of this approach is the reduced void ratio, and the core pitch deviation and the core non-circularity expected to be reduced. The disadvantage of this approach is the deterioration of productivity due to the increase in the number of the glass rods to be used.

Figure 3 shows an approach of 4-core MCF preforms optimized to reduce void ratio and to improve productivity. The advantages of this approach is to realize the good productivity due to the small number of the glass rods to be used, and low void ratio, simultaneously. The disadvantage of this approach is the need to precisely control the hole shape.

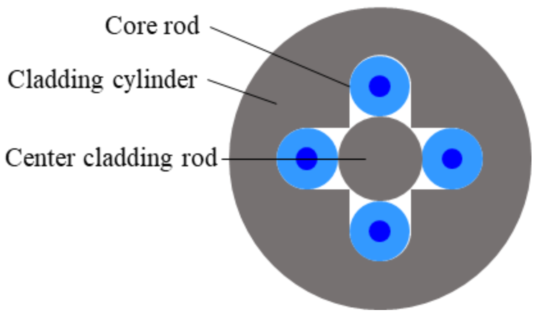


Fig. 1 Design of MCF preform using cross-shaped cylinder

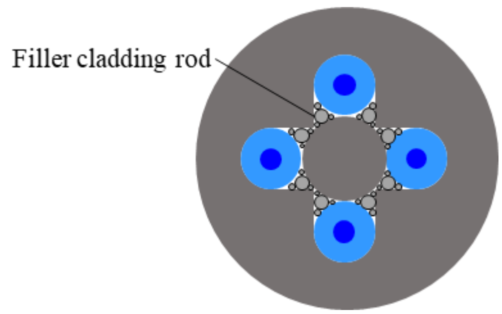
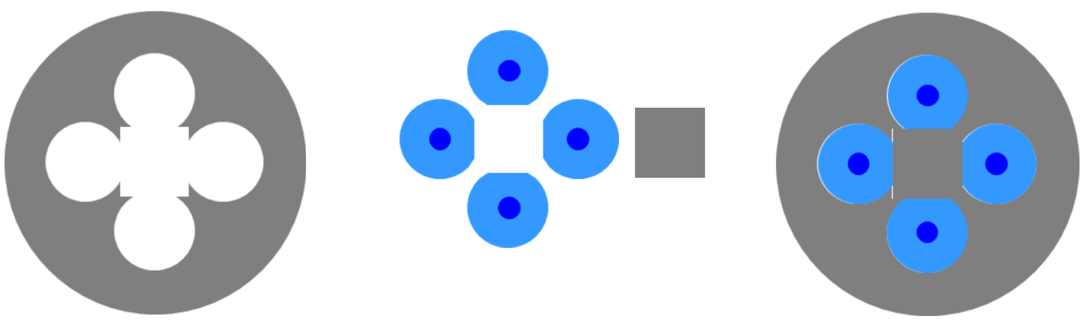


Fig. 2 Design of MCF preform using cross-shaped cylinder with low void ratio



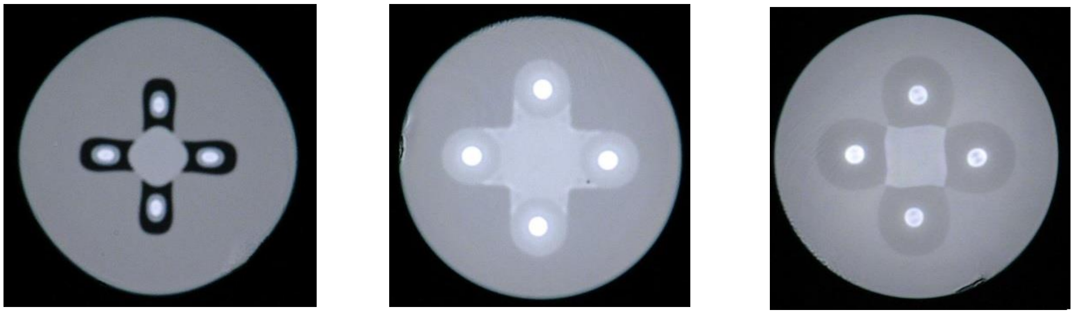
(a) Modified cross-shaped cylinder (b) Core and center cladding rod (c) Assembled preform

Fig. 3 Design of MCF preform using modified cross-shaped cylinder.

3. Characteristics of fabricated MCFs

4-core MCF fabricated using preforms with each approach is shown in figure 1 – 3, respectively. Figure 4 shows pictures of cross sections of the fabricated MCFs. Figure 5 and figure 6 show the core pitch deviation from the designed value of each MCF and the core non-circularity. In Figure 5 and figure 6, the void ratio is calculated from the ratio (A_1/A_0) of the area of the circle having the same diameter of the cladding (A_0) and the sum of the cross-sectional areas of the cladding cylinder, the core rods, and the center rod and filler rods inserted into the hole (A_1).

As shown in Figure 4 (a), large core non-circularity is observed in the MCF made from the preform with cross-shaped hole. On the other hand, as shown in figure 4 (b) and figure 4 (c), core non-circularity is reduced drastically in the MCFs made from the preforms with reduced void ratio. The void ratio of the preforms corresponds to the fiber (a), (b), and (c) of Figure 4 are 14.9%, 5.1%, and 2.4%, respectively. Figure 5 shows that the core pitch deviation of each fiber is improved as the void ratio decreases. The core pitch deviations of the fibers (a), (b), and (c) are 9.2 μm, 2.3 μm, and 1.7 μm, respectively. Figure 6 shows that the core non-circularity decreases as the void ratio decreases. The core non-circularities of fibers (a), (b) and (c) are 20.0%, 2.1% and 1.1%, respectively. Table 1 shows the characteristics of fabricated MCFs. In the fiber (a), the attenuation loss is remarkably increased due to the large core non-circularity. Although core rods which have the same design as G. 652 fiber are used for both fiber (b) and fiber (c), attenuation loss of the fiber (b) is increased. The reason of the loss increase can be considered to be the stress applied to the core in the fabrication process in addition to the non-circular core. On the other hand, low loss is obtained in the fiber (c) which has optimized preform design.



(a) Cross-shaped cylinder (b) Cross-shaped cylinder with filler cladding rods (c) Modified cross-shaped cylinder

Fig. 4 Picture of fabricated MCF

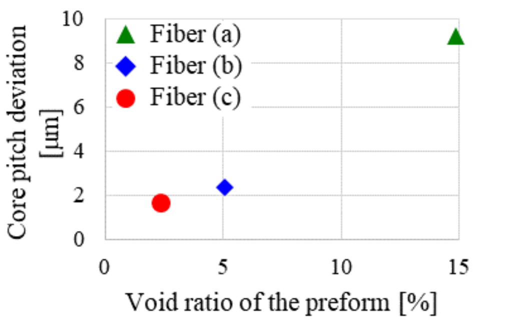


Fig.5 Effect of void ratio on core pitch deviation

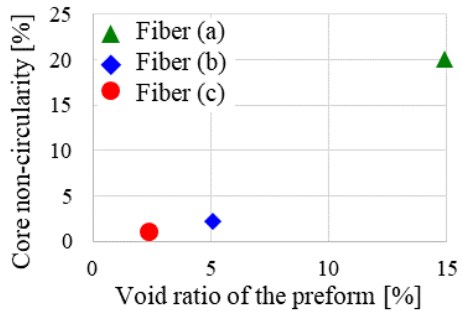


Fig. 6 Effect of void ratio on core non-circularity

Table 1. Characteristics of fabricated MCFs

		Fiber (a)	Fiber (b)	Fiber (c)
Cladding diameter	μm	124.9	124.8	124.9
Core pitch	μm	35.8	42.7	38.2
Attenuation loss @1550 nm	dB/km	0.853	0.412	0.190

4. Conclusion

Modified cylinder method which has good potential for higher productivity is developed as a new fabrication method for MCFs. Effect of the void ratio of the preform on the core pitch deviation and the core non-circularity is investigated. By optimizing the hole shape and the shape of the core rod and the center cladding rod, the void ratio of the preform is reduced. The core pitch deviation and core non-circularity are improved by this effect. Furthermore, attenuation loss is successfully reduced to 0.190 dB/km. This result shows a good feasibility to apply MCM for the future mass production process of the MCFs.

Acknowledgement

A part of this research is supported by the National Institute of Information and Communications Technology (NICT) Japan.

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