Connection Characteristics of Coupled Multi-core-Fiber Connectors

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1. Introduction

Currently, single-mode fiber (SMF) is mainly used for optical-fiber communications, and it has become clear that the transmission capacity of a single SMF has reached its limit, namely, 100 Tbit/s. To attain greater capacity than that limit, "space division multiplexing" (SDM) using multi-core fiber (MCF), which has multiple cores in a single optical fiber, is attracting attention. MCF currently being researched can be broadly classified as two types: "uncoupled multi-core fiber" (UC-MCF), in which each core acts as an independent transmission path, and "coupled multi-core fiber" (C-MCF), in which optical signals on adjacent cores are coupled and transmitted in multimode. C-MCF is more suitable for long-distance signal transmission than UC-MCF.

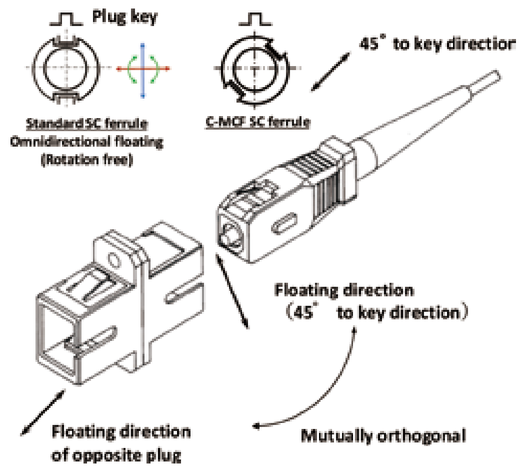
When MCF is used as a transmission line, however, optical connectors that can be detached and connected are required. We previously developed an SC-type optical connector to connect UC-MCFs and confirmed that it has sufficient performance for practical use[1]. However, the connection characteristics of C-MCF connectors have not been reported. In this study, we used a random-mated connectors specified by the International Electrotechnical Commission (IEC) to measure the attenuation of an SC-type C-MCF connector. We then compared the measured attenuation with our previously reported simulation results[2] that show the relation between lateral misalignment and attenuation determined by electromagnetic-field analysis of a C-MCF connector.

2. Structure of SC-type MCF connector

Since optical connectors are usually used to connect optical fiber cables, it is necessary to consider the possibility that an external force of several dozen newtons may act on the optical cable. When such a force interacts with the optical connector, the plug housing can deform by more than 10 μm, which by far exceeds the alignment tolerance of SMF. To solve this problem, a floating mechanism, which offers tolerance between the ferrule and the plug housing, is widely used. Unlike SMF, MCF has cores located away from the center of the fiber, so angular precision around the ferrule axis is required when connecting MCFs. However, angular precision and the ferrule-float structure are mutually contradictory requirements. To solve that contradiction, an SC-type MCF connector with an Oldham's coupling mechanism was proposed[3]. SC-type MCF connectors have sufficient mechanical performance for use in communication networks; namely, they satisfy transmission tests under tensile load such as IEC 61300-3-51[4].

The structure of an SC-type MCF connector is shown in Figure 1. The ferrule of the connector "floats" in all directions; that is, it rotates freely inside the plug housing. On the other hand, the MCF ferrule has a narrower keyway, so it floats in one direction only, and its rotation is restricted. In the case of C-MCF, as shown in Figure 1, the ferrule is designed to float at 45° from the key direction in a manner that creates a structure that forms an Oldham's coupling mechanism when the plug is placed opposite the ferrule.

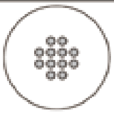
Figure 1



3. Results of experiment

We attempted to measure the attenuation that occurs when some of the transmitted light leaks from a connection point and thereby reduces optical power at that point of the optical fiber. Since optical signals on separate cores in a C-MCF are combined, it is not possible to measure the attenuation of each core as in the case of UC-MCF. In this study, we measured attenuation of random-mated connectors (according to IEC 61300-3-34) by using a coupled 12-core fiber (C-12CF) with a specification as listed in Table 1. As for the measurements, we evaluated the connection characteristics for all combinations of ten master optical connectors and nine optical connectors connected to the masters. For the measurements, ten C-12CFs with SC-type

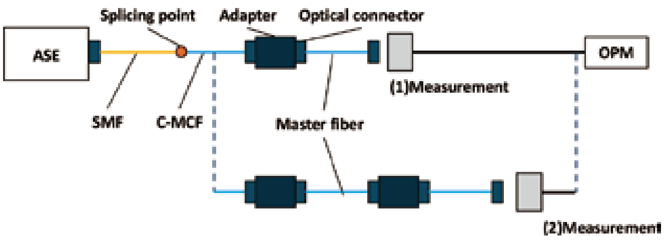
■ Table

Parameter	C-12CF
Cross section	
Core material	S_iO_2
Cladding OD	125 μm
Core radius	4.8 μm
Core pitch	15.5 μm
Core Δ	−0.35 %

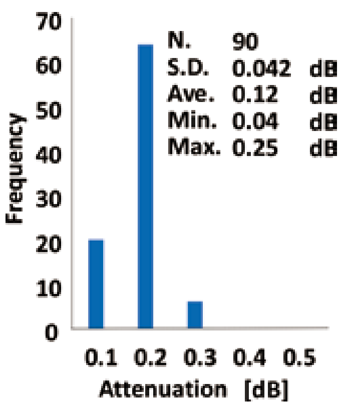
optical connectors on both ends were fabricated, and an ASE light source (wavelength of 1520 to 1570 nm) was used. The setup used for measuring attenuation of the random-mated connectors is shown schematically in Figure 2. For the optical-connector plug, an SC-type optical connector[3] for C-MCF, with an Oldham coupling mechanism as described in Section 2, was used.

Measured attenuation of the C-12CF connector is shown in Figure 3. As for 90 measured connection points, average, minimum, and maximum attenuation were respectively 0.12 dB, 0.04 dB, and 0.25 dB. These results satisfy Grade B (97% less than 0.25 dB) of the optical interface standard for optical connectors (IEC 61755-1). However, as shown in Figure 4, the dominant factor in attenuation is lateral misalignment. According to the simulation results for attenuation of C-12CF shown in Figure 5[2], estimated lateral misalignment of the C-12CF connectors is 0.4 to 1.4 μm. Compared to SMFs, C-MCFs have higher bending loss[5], so changes in the arrangement of the measurement setup can cause fluctuations in optical power, and as shown in Figure 5, changes in mode can cause changes in attenuation. It is therefore necessary to continue studying methods for accurately measuring attenuation.

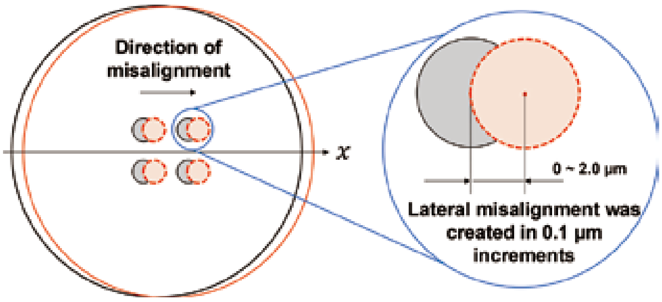
■ Figure 2



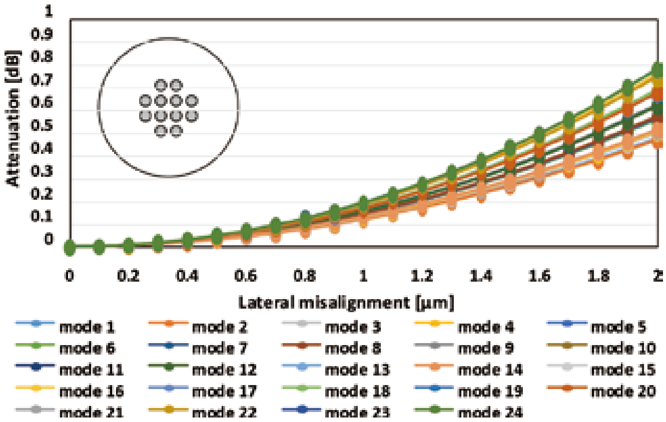
■ Figure 3



■ Figure 4



■ Figure 5



4. Conclusion

We measured attenuation, one of the important characteristics of C-MCF connectors, of the C-12CF optical connectors by random-mated connection test and found that average attenuation was 0.12 dB. The measured attenuation satisfies Grade B in IEC 61755-1, and that result indicates that the performance of the C-12CF optical connectors is sufficient for use in optical communication networks. In addition, compared to previously reported simulation results for attenuation obtained by electromagnetic-field analysis of C-MCF connectors, lateral misalignment of the C-12CF connectors is 0.4 to 1.4 μm. Moreover, changes in the arrangement of the C-MCF measurement setup may cause fluctuations in optical power and mode switching, so a method for accurately measuring attenuation must be further investigated.

Acknowledgements

This work was supported by NICT-commissioned research project No. 01010.

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