Optical Connectivities for Multicore Fiber

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Abstract: Multicore fiber is proposed for use in space-division multiplexing for ultra-wide-band optical transmission systems. This paper introduces recent progress on multicore fiber connection technologies for simplex and multifiber connectors.
OCIS codes: (060.2340) Fiber optics components; (350.3950) Micro-optics

1. Introduction

Optical communication traffic continues to increase; however, the transmission capacity of conventional single-mode fiber has now reached around 100 Tbit/s, which is assumed to be the maximum possible value [1]. Space division multiplexing (SDM) is expected to be used for next-generation ultra-wide-band optical transmission. Multicore fiber (MCF) is a candidate SDM transmission medium [2], and standard outer diameter MCF is especially attractive because it is easy to apply to actual systems, moreover long-distance transmission experiments are also being conducted [3].

Optical connectors are essential for constructing optical networks. They are unique in that they require resistance from an external force. They should usually allow component deformation of around tens of microns, and so a core alignment accuracy of better than 1 μm is required. Optical connectors used in telecommunication systems have a ‘floating mechanism’ to eliminate the influence of deformation on connection stability. The most difficult issue for simplex connectors as regards connecting MCFs is finding a way to align each core when using a floating mechanism. The most difficult issue as regards multi-MCF connectors is how to adjust the orientation of each MCF. Achieving a stable physical contact (PC) connection is an issue common to both simplex and multifiber connectors.

This paper describes recent progress on MCF connection technologies.

2. Simplex MCF connectors

2.1. How to balance both floating and precise MCF angular alignment conditions with cylindrical ferrules

Single-mode optical connectors require an attenuation of less than 0.5 dB and a return loss of 40 dB or more. To realize these requirements with a butt joint mechanism, the fiber core offset should be less than 1 μm.

Optical connectors are attached to the fiber cables, so we sometimes have to consider an external force of tens of newtons. If such a force interacts with a small optical connector, the plug housing will be deformed by more than 10 μm, which is far greater than the alignment tolerance. We can use a ‘floating mechanism’ to solve this problem, however, a floating mechanism allows ferrule rotation. To solve this problem, an MU-type MCF connector with Oldham’s coupling mechanism was proposed [4]. The mechanical performance of this connector, for example in the ‘Test for transmission with applied tensile load’ (IEC 61300-2-51), makes it suitable for use in telecommunication networks [5]. It can be used for almost all optical interconnection applications including transceiver modules, however, the need for a precision Oldham’s coupling mechanism inside the plug increases the cost.

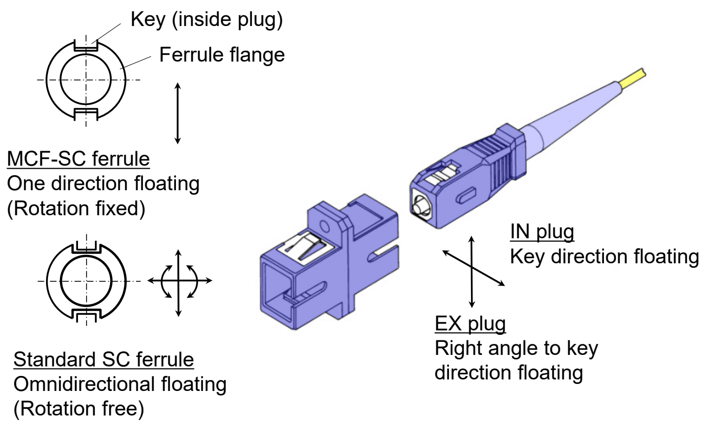
An MCF patch cord has a direction because each core ID must be connected to the same core ID. If the connection points are limited to cable to cable connections, it would be sufficient to have Oldham’s coupling mechanism in a connection point consisting of a pair of plugs. An SC-type MCF connector with a simplified structure is proposed as shown in Fig. 1 [6]. This MCF connector is constructed without increasing the number of components while maintaining the floating mechanism and has suitable mechanical characteristics [6].

2.2. Physical contact design for MCF connector

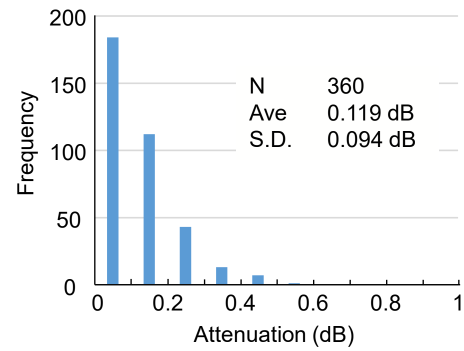
We can use PC technology for the MCF connector, however, the specifications of the ferrule endface geometry must be reconsidered because some cores are not located in the center of the fiber. The ferrule endface geometry has been standardized, e.g. IEC 61755-3-1, based on a microscopic deformation analysis of the ferrule endface [7]. The ferrule endface with 19-core MCF was also analyzed and it was confirmed that we can use PC connection for MCF [8].

It should be noted that if the fiber outer diameter is larger than the standard diameter of 125 μm, the adhesion area with the ferrule increases, and the fiber withdrawal would increase with temperature fluctuation. A 4-core MCF with a standard outer diameter the same as that of single mode fiber (SMF) was proposed [9]. The standard diameter

MCF is advantageous not only in terms of productivity, bending reliability and polishing conditions, but also because we can expect the fiber withdrawal to be the same as that of conventional SMF connectors. It is a great advantage that the same level of reliability can be expected for long-term use.



(a) Design principle



(b) Attenuation for random connection

Figure 1. MU-type multicore fiber connector, (a) design principle and (b) attenuation

3. Multi-MCF connectors

3.1. Precise individual angular alignment of MCF

The MT ferrule is generally used for multifiber connectors. It is aligned with two guide pins and holes and there is no MCF angular misalignment even with a floating ferrule. However, it is not easy to adjust the angular position of each MCF. Two angular alignment methods have been reported. One employs a single block using V-grooves [10], and the other consists of individual alignment using alignment blocks [11]. In both cases, the rotation alignment is realized in the block which is then inserted into the ferrule for completion. An attenuation of less than 1 dB for all cores has also been reported.

3.2. Ferrule endface polishing

In a commonly used multifiber connector polishing method, each fiber endface has a small radius of curvature. This fiber endface requires greater ferrule pressure than a normal MT ferrule to achieve contact for all the cores of each MCF with non-center cores. A new polishing method was reported that can realize an almost flat MCF endface and achieve PC connection for all the cores using the same ferrule pressure as with an MPO connector [11].

4. Insertion and return loss measurement procedure

Fan-in/fan-out (FIFO) devices are essential for measuring the optical performance of MCF connectors. The attenuation measurement procedure is almost the same as with multifiber connectors. However, for the return loss measurement, it is necessary to consider the reflection at the FIFO and connection points along the optical path. For the return loss measurement procedure, Optical time domain reflectometer (OTDR), optical low coherence reflectometer (OLCR) and optical continuous wave reflectometer (OCWR) methods are specified in IEC 61300-3-6. The OTDR method enables the return loss measurement of one connection point, however, it cannot measure connectors attached to short fibers. The OLCR method also enables one connection point measurement, however, it is difficult to realize a stable measurement because of the state of polarization instability along the long optical path of an FIFO device [6].

The OCWR method is widely used in product inspection because it can perform measurements both quickly and inexpensively. With the OCWR method, the measurement results include the reflection at the FIFO, optical switch and connection points along the optical path as shown in Fig. 2. In that case, the return loss of one MCF connection point RL can be calculated with eq. (1) where RL_0 is the measured return loss, RL_f is the return loss of the FIFO, and IL is the insertion loss of the FIFO.

$$RL = -10\log\left(10^{-\frac{RL_0}{10}} - 10^{-\frac{\mathrm{RL_f}-IL}{10}}\right) \tag{1}$$

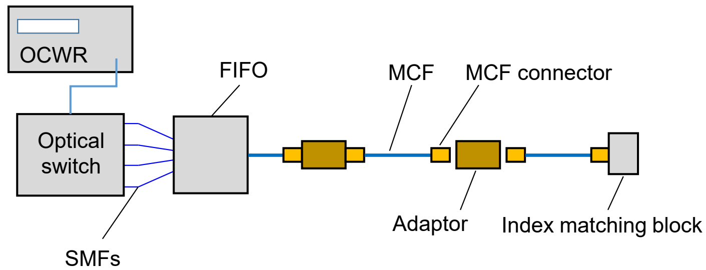


Figure 2. OCWR return loss measurement setup

It is confirmed that the calculation results and the measurement results by OTDR were in good agreement [6].

4. Summary

This paper described recent progress on multicore fiber (MCF) connection technologies. MCF connectors are realized that have good potential for practical use as both simplex and multifiber connectors. It is essential to specify the connection performance measurement procedure for the practical use of MCF connectors. A return loss measurement procedure using the OCWR method was also proposed.

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