

High Precision 12-single-mode-fiber Multi-fiber Push-on Connector for Reference Use in Connector Evaluation

Ryo Koyama, Chisato Fukai, Yoshiteru Abe, Mitsuru Kihara, and Kazunori Katayama

Abstract

The data transfer speed between data communication equipment in datacenters has been increasing in recent years, and the use of multi-fiber optical links for the communication wiring in such buildings is expanding. In particular, the 12-fiber multi-fiber push-on (MPO) connector for single-mode fiber is expected to be widely used in the future, but an accurate evaluation method is necessary for its proper procurement. We introduce the high precision 12-fiber MPO connector developed as a reference for MPO connector evaluation.

Keywords: multi-fiber optical connector; reference connector; optical connector evaluation

1. Introduction

The data transfer speed between communication equipment has been increasing in communication facilities such as datacenters. Therefore, the use of multi-fiber optical links as opposed to single-fiber optical links is expanding in high speed communication links. Multi-fiber push-on (MPO) connectors, a type of optical connector developed by NTT, are most widely used as the interfaces of multi-fiber optical links in buildings. An example of the standard wiring of a datacenter is shown in **Fig. 1** [1]. In modern datacenters, high speed communication links such as 40 Gbit/s or 100 Gbit/s are widely used between the aggregation switches and spine switches, and their link speed continues to increase. Examples of the standard high speed communication links using the MPO connector are listed in **Table 1** [2–4]. Because inter-switch communication at a datacenter is expected to be over 100 Gbit/s in communication speed and over 100 m in wiring length, the 12-single-mode fiber

MPO connector is expected to be used more and more for high-speed communication optical wiring in buildings.

The structure of the MPO connector is shown in **Fig. 2**. The MPO connector consists of a male plug, which contains pre-inserted guide pins, a female plug with guide pin holes on the connector endface, and an adaptor that couples the plugs with a slide lock mechanism. To connect optical fibers, we have to align the positions of the fiber cores through which signal light passes in order to bring the fiber cores in contact with each other. In the MPO connector plug, the fibers are precisely arrayed and fixed into a mechanically transferable (MT) ferrule, and when one plug is connected to another one, the MT ferrule is aligned with the opposite MT ferrule by using the guide pins and the guide pin holes.

In an actual optical connector connection, it is difficult to perfectly match the positions of the fiber cores, and some of the signal light is consequently lost and not transmitted. This loss (connection loss)

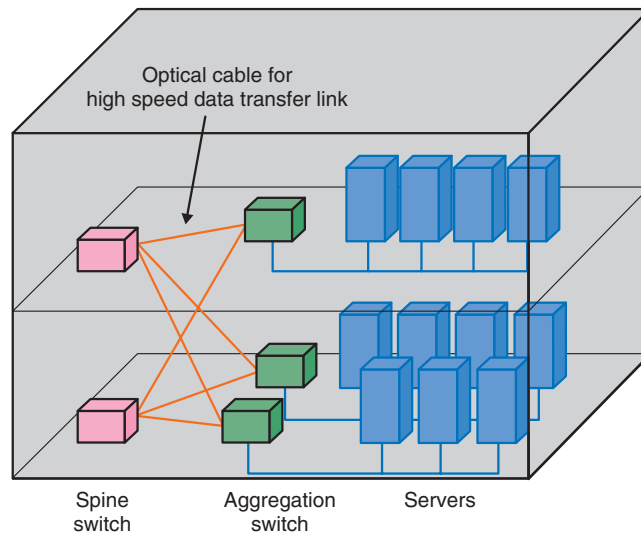
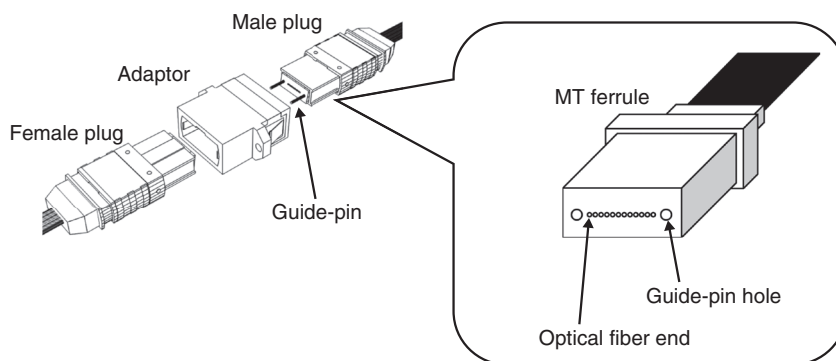


Fig. 1. Example of cabling for datacenter building.

Table 1. Examples of high speed data transfer links using MPO connector interface.

Data transfer speed	Specification name	Optical fiber	Number of fibers	Distance range
40 Gbit/s	40GBASE-SR4	Multi-mode fiber	12	150 m
100 Gbit/s	100GBASE-SR4	Multi-mode fiber	12	150 m
	100GBASE-PSM	Single-mode fiber	12	2 km
200 Gbit/s	200GBASE-SR4	Multi-mode fiber	12	100 m
	200GBASE-DR4	Single-mode fiber	12	500 m
400 Gbit/s	400GBASE-SR16	Multi-mode fiber	32	100 m
	400GBASE-DR4	Single-mode fiber	12	500 m



MT: mechanically transferable

Fig. 2. Structure of MPO connector.

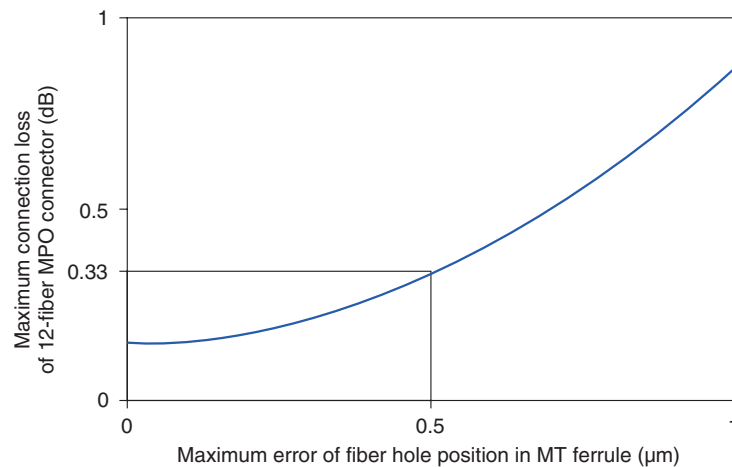


Fig. 3. Calculated connection loss in MPO connector.

affects the communication quality, so it is necessary to evaluate the connection loss. One evaluation method involves using a reference connector. The reference connector should be a highly accurate connector manufactured with less error than the standardized ideal design of an optical connector. This method is widely used because it is accurate based on the standardized design, and it guarantees the interoperability of the optical connectors.

However, there are no reference connectors currently available on the market for the MPO connector, so it is not possible to conduct an accurate evaluation as done for the conventional single-fiber optical connector. Consequently, there may be uncertainty about the measured connection loss between, for example, the manufacturer and the purchaser in the evaluation of the MPO connector. In addition, when the MPO connector is required to have a connection loss equivalent to the conventional single-mode-fiber optical connector, the connection loss of the MPO connector cannot be guaranteed.

We introduce here a high precision 12-single-mode-fiber MPO connector that we developed as a reference connector to achieve accurate evaluation of the 12-single-mode-fiber MPO connector. Our high precision MPO connector is the world's first 12-fiber MPO connector for single-mode fiber that meets the specifications of the International Electrotechnical Commission (IEC) reference connector.

2. High precision MPO connector

In the connection of optical connectors, any posi-

tional error of the fiber core will mainly affect the connection loss, so the target position of the fiber core is specified. However, the actual optical connector may have a deviation between the fiber core position and the target position due to a manufacturing error. The reference connector must therefore be a high precision connector with small error of the fiber core position. For example, the IEC specifies that the connection loss between reference connectors shall be no more than 0.2 dB, which means that the error of the fiber core position should be 0.5 μm or less [5].

There are two difficulties in achieving high precision multi-fiber connectors with a connection loss of 0.2 dB or less. One is the effect of manufacturing error. As mentioned above, in the MPO connector, the fiber cores are aligned by the MT ferrule, but the MT ferrule has a manufacturing error of 0.5 μm at maximum.

The connection loss of the MPO connector calculated based on the manufacturing error of the MT ferrule is given in **Fig. 3**. The figure shows that the connection loss of the MPO connector given the maximum 0.5-μm manufacturing error of the MT ferrule exceeds the target loss of 0.2 dB. It is difficult to reduce the manufacturing error to less than 0.5 μm with the current manufacturing technology, so in order to achieve a 12-core high precision connector, it is necessary to select connectors with a small manufacturing error from those manufactured with the maximum error of 0.5 μm.

The other difficulty lies in measuring the error of the fiber core positions in the MPO connector. In the MPO connector, fiber cores with a diameter of about

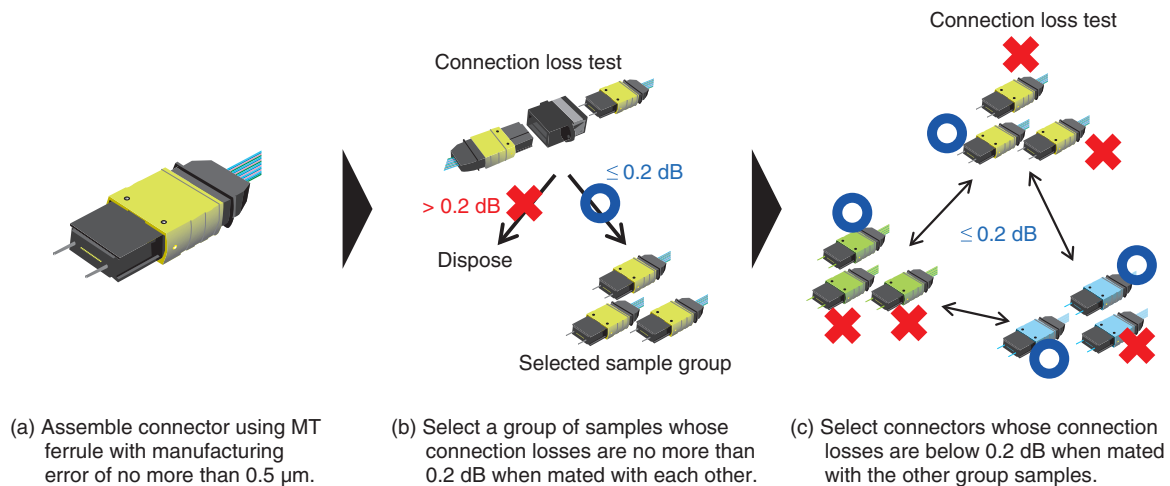


Fig. 4. Selection procedure for high precision MPO connectors.

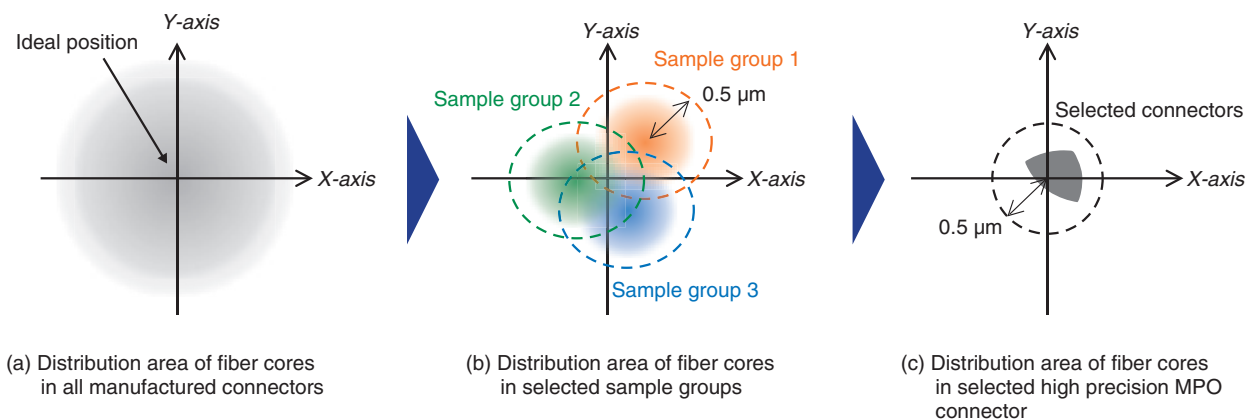


Fig. 5. Example of fiber core position of selected connector samples.

$10 \mu\text{m}$ are lined up in a 4.6-mm -wide area. The fiber core position cannot be measured accurately because of the large difference between the observation range and the size of the fiber core to be measured. For this reason, it is not possible to select connectors with a small manufacturing error based on the fiber core position itself.

The procedure for selecting connectors using connection loss when the actual fiber core position is unknown is shown in Fig. 4, and an example of the fiber core position in each procedure is shown in Fig. 5.

First, we manufacture an MPO connector using an MT ferrule with a manufacturing error of $0.5 \mu\text{m}$ or less. The fiber core position of the fabricated connec-

tor is distributed around the target position, as shown in Fig. 5(a), due to manufacturing error. Next, as shown in Fig. 4(b), we connect the fabricated MPO connectors together and select a sample group exhibiting a connection loss of 0.2 dB or less. Through selection, connectors whose fiber core position is in the range of $0.5 \mu\text{m}$ are extracted, although the center of the fiber core position will deviate from the ideal position, as shown in Fig. 5(b).

To select connectors with a fiber core position error of less than $0.5 \mu\text{m}$ from the ideal position, we prepared three sample groups and selected the connectors that had a connection loss of 0.2 dB when they were connected to the connectors of the other sample group. Although the fiber core position of each

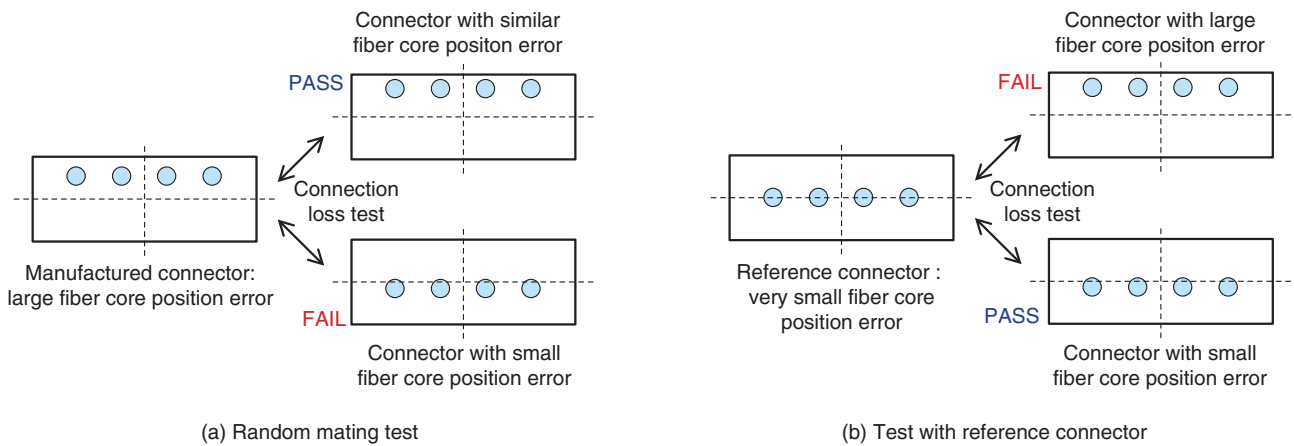


Fig. 6. Example of MPO connector evaluation methods.

Table 2. Reference connectors in major optical connectors.

Connector family	Standard	Requirement for fiber core position error	Requirement for connection loss
SC connectors	JIS C5973	Below 0.5 mm	Below 0.2 dB
MT connectors	JIS C5981	No requirement	Below 0.2 dB
MPO connectors	JIS C5982	No requirement	Below 0.3 dB
Our developed high precision MPO connector	—	Below 0.5 mm	Below 0.2 dB

JIS: Japanese Industrial Standards
 SC: subscriber connector

sample group is unknown, the range where the fiber core can exist can be estimated to determine whether it is 0.5 μm or less based on the fiber core position of the connector selected between each of the sample groups, as shown in Fig. 5(c). We are using this procedure to achieve a high precision MPO connector with a fiber core position of 0.5 μm or less for the first time in the world.

3. Application to MPO connector evaluation

Two widely used optical connector evaluation methods are depicted in Fig. 6. They are used to evaluate the connection losses and other characteristics of the connector. The random mating test method is used when connecting manufactured connectors to each other (Fig. 6(a)). As shown in the figure, the random mating test is not accurate when the fiber core positions have some deviation. Therefore, even if the connection loss was confirmed to be less than a specified value in the random mating test, the connec-

tion loss would not always be less than the specified value in actual equipment.

In the other method, the manufactured connectors are tested against a reference connector (Fig. 6(b)). Because the reference connector has low deviation of the fiber core position, this method can be performed accurately as shown in the figure, and interoperability between connectors is guaranteed.

However, even high precision reference connectors have a small deviation of the fiber core position. A comparison between the specifications of the reference connector in major optical connector standards and the developed high precision MPO connector is given in Table 2 [5–8]. The developed high precision MPO connector has the same deviation of the fiber core position and connection loss as those of the reference connector for single-mode subscriber connectors (SCs). Since the reference connector for a single-mode SC has been utilized in the practical evaluation of single-mode optical connectors for the last few decades, our developed high precision MPO connector

has a sufficiently small deviation for the reference connector for practical connector evaluation.

4. Summary and future work

We introduced our developed 12-single-mode-fiber high precision MPO connector to realize accurate connector evaluation of the 12-fiber MPO connector. The developed high precision MPO connector is the first in the world to meet the specifications of IEC's reference connector as a 12-fiber MPO connector for single-mode fibers. The accurate connector evaluation method enables fair competition among connector manufacturers and contributes to the proper procurement of MPO connectors in the NTT Group. We will continue to research a way to achieve a reference connector with more than 12 fibers by focusing on the technological trends of high speed communication.



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