Development of Optical Wiring Technology for Optical Interconnects

Mitsuhiro Iwaya, Katsuki Suematsu*, Harumi Inaba*,*
Ryuichi Sugizaki, Kazuyuki Fuse*, Takuya Nishimoto*[2], Kenji Kamoto*[3]*

ABSTRACT We had developed elemental technologies for optical interconnects for its application in next generation high performance data server and others. To achieve complicated compact wiring, low loss and high reliability, we applied the small diameter and bend insensitive fiber, ThreadWave. We had also developed the optical connector housing which can be space-reduced and of high-density connection in anticipation of its combination with electrical wiring, achieving 3.2 times higher of connection density over conventional ratio. We had also simplified the assembling method of connectors with the goal of cost reducing and we had confirmed that, with the easy-assembled connectors, the optical characteristics required for the high-speed transmission could be maintained. We had developed an experimental model of blade server structure which is assembled of these elemental technologies, and achieved an installation of 2000-fiber-channels with the same size as the conventional electrical wiring.

1. INTRODUCTION

In recent years, along with the higher-performance of CPU and the increasing of data traffic, the data processing capacity required to the server has been dramatically increasing. Also, on the server construction, virtualization technology by consolidating multiple processes in one CPU is progressing, and the volume of data between CPUs and the memory capacity required are increasing. Based on this situation, in the future, it is estimated that the input-output of data processing will need several Tbps of the bandwidth and tens of Tbps of the transfer rate in total will be required in the interconnects which will transmit these multiple signals.

Meanwhile, the increase of the transmission capacity on the conventional electric transmission technology is about to face a limit in terms of the signal quality and the heat dissipation efficiency. As a new technology, the optical interconnects are expected to solve these problems.

Based on these backgrounds, we have been working through the development of elemental technologies for the optical interconnects such as optical modules, optical connectors and optical fibers [1].

This time, we had considered the optical interconnects technology which is intended to apply to the next generation high performance data server and others and we had developed wiring technique which can be implemented in higher-density and lower-cost than ever before. This is reported herein.

* FITEL Photonics Labs, R&D Div.
*[2] Yokohama R&D Labs, R&D Div.
*[3] FITEL Products Division, Telecommunications Company

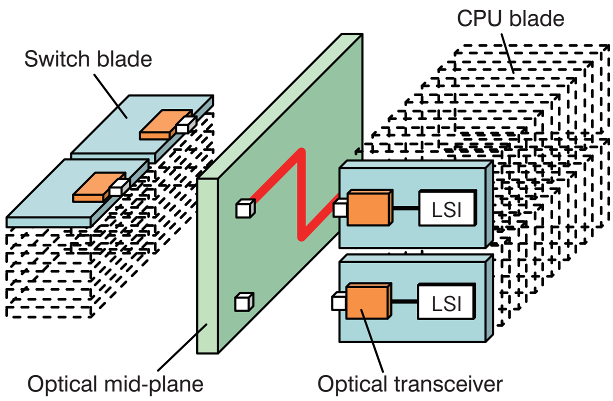


Figure 1 Structure of optical CPU blade server.

2. THE CONCEPT OF THE DEVELOPMENT

2.1. Development Subjects and Examination Items

For the assumed application, we set the high performance server in a blade server structure which has a high-density mounting. The schematic of the set server structure is shown in Figure 1. A mid-plane (circuit board) is placed in the center and the slots where blades can be inserted into are placed on the both sides of the mid-plane. In this development, we assumed that the structure in which the CPU blades, where optical transceivers are installed, can be inserted from the one side, and that each CPU blade can be connected to switch blades on the other side of the mid-plane. We also targeted that the server chassis size is the same as the conventional electric wiring server.

Since many blades are densely installed in a blade server, the connecting space allowed for one blade is limited. Also, considering power supply or low-speed electric signal transfer to the blades, the space allowed for optical signal connection is further decreased. To achieve multiple channel connections under such conditions, the drastic space-reduction and the high-concentration of the optical connectors and transmission media are required.

Additionally, the optical signal transmission media is required to allow the flexibility of the wiring design and the ease of installation. Also, from a repair and replacement viewpoint, it is desirable not to have an excessive integration.

Lastly, reducing costs of components and mounting process are important evaluation points for the realization of the optical interconnects. We tried to examine, this time, the cost reduction of the optical connection from both viewpoints of the component cost and the mounting process cost.

2.2. The Concept of the Development

In our development of the product and its evaluation, we proceeded following the concept below.

As mentioned above, we set a mid-plane type blade server as the assumed server structure where several CPU blades and switch blades can be interconnected. For the connection diagram of CPU blades and switch blades, we assumed two types, namely, one where CPU blade connects to several switch blades and one where one CPU blade connects to one switch blade, and we design so that these are placed together on the optical mid-plane.

An optical transceiver is installed on the CPU blade and optically connected to the optical mid-plane at the optical connector on the edge of the blade. Meanwhile, on the switch blade, in order to extract an arbitrary optical signal and to confirm the connection characteristics or the wiring of the mid-plane by loopback, the connectors are attached to the wirings of the optical connector on the edge of the blade and terminated. The number of the optical signal channels is set as 96 channels per blade.

We selected optical fiber as the optical transmission media. The advantages of the optical fiber applied to the blade server are:

1. Low crosstalk between channels,
2. Flexibility and ease of installation,
3. Production cost,
4. Ease of length standardization in the unit of module, by ribbon fiber such as 12-fiber ribbon and others.

Also, in this prototyping, we assumed that the structure where the optical fiber installation is only on one side of the mid-plane circuit board, this is the side where CPU blades are inserted in Figure 1.

The high-density connection of the optical signals is considered on the basis of a conventional mechanically transferable (MT) connector structure. Also, since optical components and electric components need to be connected simultaneously when the blade is inserted, we took a backplane (BP) optical connector housing.

For cost reduction, we are essentially trying to reduce the components cost and the assembling cost.

3. ELEMENTAL TECHNOLOGIES

3.1. Optical Fiber

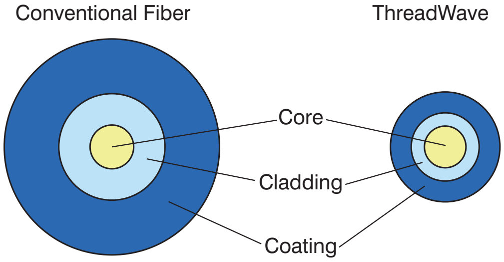
The strictest limitation of the high-density installation with optical fiber is the minimum bending radius. It is limited by long term reliability (failure rate) of the optical fiber and the optical signal loss when bending the optical fiber. The minimum bending radius R is around 30 mm for standard optical fiber. And even for so-called “bend insensitive fiber”, which inhibits bending loss by controlling refractive index profile of core and cladding, it is considered to be around 7.5 mm in terms of long term failure rate for the fiber.

On the other hand, to achieve complex optical fiber wiring on the mid- plane and maintaining minimum bending radius, it is desirable to have the space which is, at least, twice as high as the minimum bending radius on the mid-plane. However, it is difficult to have such space because the insertion length of the blades is specified if conventional electric components are used.

Also, to install as many as 2000 fibers efficiently, it is desirable that the optical fiber is as small and flexible as possible to avoid interference and generation of tensile force between optical fibers.

To meet such requirements, we used ThreadWave, the small diameter fiber of 50 μm core, 80 μm cladding and 125 μm coating in diameters [2]. The comparison between cross-section shapes of ThreadWave and standard fiber is shown in Figure 2. Figure 3 shows total failure in time (FIT) number of 2000 fibers with one turn loop of 5 mm radius plotted against the cladding diameter. The FIT at 80 μm cladding diameter is less than 1.0, the value shown in black solid line, and it is understandable that the ThreadWave has sufficient reliability to the small-radius bending. For the optical characteristics, as gaining the relative refractive-index difference Δ from 1% to 2% of the GI profile core, good characteristics as 0.1 dB or less of bending loss with one turn loop of 5 mm radius and 200 MHz-km or more of transmission band are achieved.

In this development, we assumed the total channel numbers of transmitter and receiver modules as up to 12 fibers and examine with 12-ribbon fibers of ThreadWave. The 12-ribbon fibers of ThreadWave has each fiber in 125 μm-pitch alignment and can reduce the cross-section area down to about one-quarter of 12-ribbon of standard fiber with 125 μm cladding diameter. In addition to that, thanks to its smaller diameters of cladding and coating, it is more flexible than standard ribbon fiber. With these characteristics, high-density and compact wiring can be achieved easily.



50	Core [μm]	50
125	Cladding [μm]	80
250	Coating [μm]	125

Figure 2 The comparison between cross-section size of ThreadWave and standard fiber.

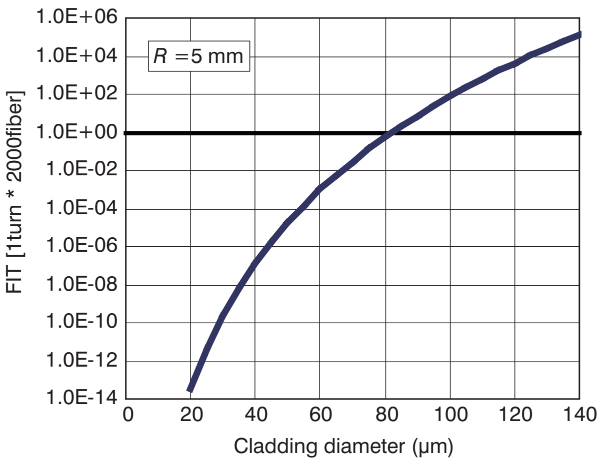


Figure 3 Cladding diameter of fiber and total FIT number.

3.2. Assembling Method of Optical Connectors

We used optical connector of MT ferrule which has the same size as the conventional one. The appropriate number of fibers for one MT is assumed as 24 fibers from the aspects of the balance with wiring density, ease of connection diagram designing between blades, and manufacturability.

For the alignment positioning of 24 fibers, “2 rows of 12 fibers” or “single row of 24 fibers” are available. We selected “single row of 24 fibers” to avoid increase in the rigidity with bending of vertically stacked ribbon fibers. This fiber alignment is shown in Figure 4.

We reviewed the manufacturing process of the MT connector to reduce the optical components cost and adopted no- polish quick assembly technique in this development. This is the technique where ribbon fiber is cut off by a cleaver and then fixed by adhesive after adjusting the position of the end faces of fiber and MT connector. It is possible to reduce manufacturing cost drastically by omitting the polishing process which exists in standard assembly process of MT connector.

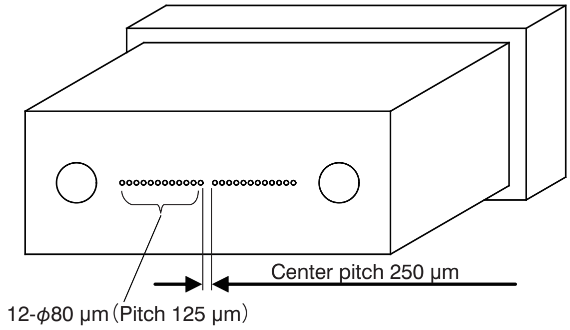


Figure 4 Fiber position of 24 MT ferrule.

3.3. Optical Connector Housing

As described before, for the blade server application, in order to connect the electric connectors and the optical connectors simultaneously when the blade is inserted, the backplane connector structure for optical connector housing is required. There is a multi-fiber push on backplane (MPO-BP) connector as a currently standard backplane optical connector. In case of MPO-BP connector, first a MPO connector is assembled with a MT ferrule inserted inside, and then this MPO connector is mounted on the BP housing. This process is shown in Figure 5. Although it has the advantage for such construction that the MPO connector is detachable from the BP housing and is easy to exchange or to replace, it is difficult to increase the mounting density of the MT connector because components are many and the size becomes large.

To solve such problems, we developed a new high-density backplane connector housing. The outline of its structure is shown in Figure 6. This connector has the structure where 4 pcs of the MT ferrules are aligned in 2x2-array and mounted directly to the backplane connector housing. With this connector structure, the number of necessary BP connector housing parts is drastically reduced as one set of housing is for 4-MT ferrules, as compared with the conventional requirement of one set for each. Also, we made the structure where each MT ferrule is mounted and fixed with minimum and simplified components. With this structure, the number of component parts for 4-MT ferrules is reduced in half and drastic reduction of the part’s cost is expected.

The front views (to scale) of the conventional MPO-BP connector housing and the new housing are shown in Figure 7 compared with the same scale. As shown in Figure 7, for the new housing, even though the entire size is slightly increased from the conventional MPO-BP connector housing, the installation density of the optical fiber has increased by 3.2 times because 4 pcs of MT ferrules are mounted. In addition, since 1 pc of MT ferrule has 24 fibers, 96 fibers can be connected at a time per one set of backplane connector.

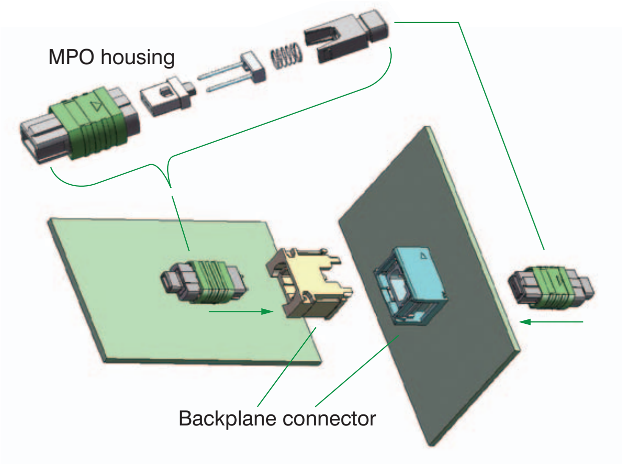


Figure 5 Conventional MPO type backplane connector.

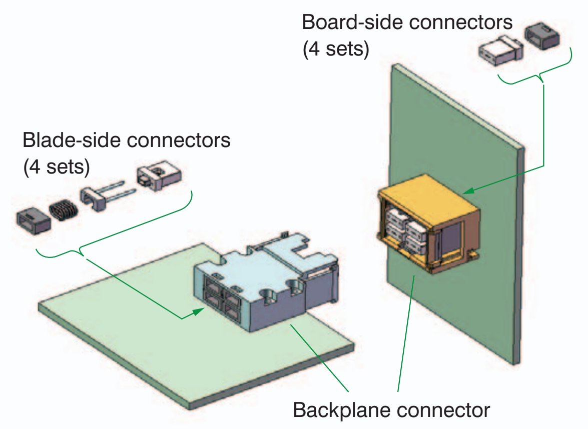
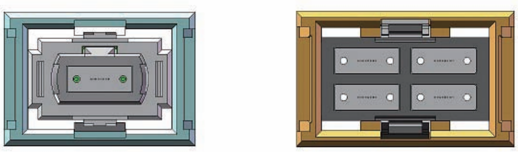


Figure 6 New backplane connector.



Conventional (MPO-BO)
24 fibers / 13 mm x 19 mm
(24-fiber MT x 1)

New housing
96 fibers / 14 mm x 22 mm
(24-fiber MT x 4)

Figure 7 Comparison of fiber density.

4. CHARACTERISTICS

4.1. Insertion Loss

The insertion loss distribution of quick assembly optical connector without index matching material is shown in Figure 8. On the data for connected sample number of N = 768, 0.29 dB of the average insertion loss and 0.79 dB of maximum insertion loss at 850 nm are obtained. Also, the insertion loss difference of matings with index matching material between end faces of the MT ferrules is shown in Figure 9.

From these results, we had confirmed that sufficient connecting characteristics can be obtained with the MT ferrules assembled with no-polish quick assembly technique without index matching. Also, it is understandable that insertion loss will be further reduced with proper index matching.

Also, equivalent insertion losses are obtained for both clipped mating of MT ferrules only and for 4 pcs of MT ferrules mounted in the new backplane housing, and hence, it is confirmed that the new developed housing can connect appropriately 4 pcs of MT ferrules at once.

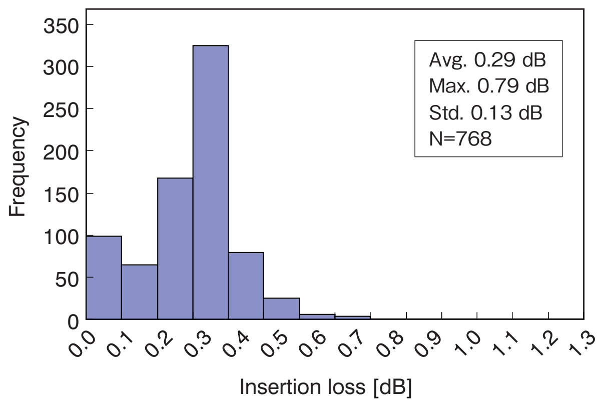


Figure 8 Insertion loss distribution of non-polish quick assembly MT connectors.

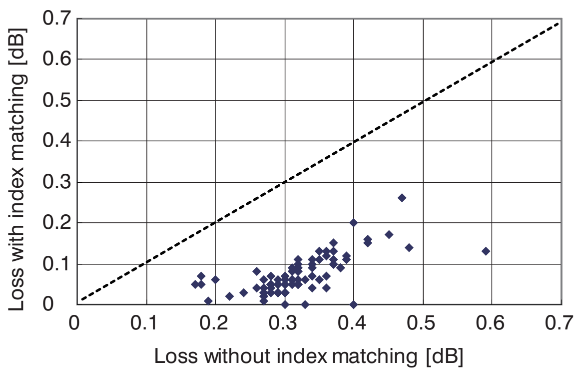


Figure 9 Insertion loss difference between matings with and without index matching.

4.2. Transmission Characteristics

We evaluated the 10 Gbps transmission characteristics of the quick assembly connector. Using 850 nm wavelength of VCSEL (vertical cavity surface emitting LASER), the signal of PRBS-7 (pseudo-random binary sequence 7) is generated and eye-pattern is observed. Observed eye-pattern is shown in Figure 10. As measurements are conducted on all 24 fibers, sufficient eye opening is obtained at all channels and it is considered that the quick assembly connector has sufficient characteristics for 10 Gbps transmission.

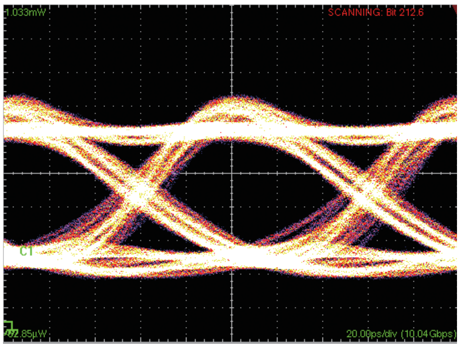


Figure 10 Eye-pattern diagram at 10 Gbps transmission.

5. EXPERIMENTAL MODEL OF BLADE SERVER

We had made an experimental model of blade server with the techniques described above. We achieved the size of 500 mm width x 500 mm height, which is almost equivalent to the conventional electric wiring blade server. For the depth, as we cannot make an easy comparison because a cooling fan is attached externally and the blade slots are simplified. However, since we designed the optical mid-plane so that its effective thickness remains the same as that of the one which only has electric connectors mounted on, it is expected that the server size will be equivalent to the conventional electric wiring type at end products.

On the mid-plane, there are 2000 fibers installed in total with ThreadWave 12-ribbon fibers, throughput performance of 20 Tbps is achieved when it is operated at 10 Gbps per channel.

6. CONCLUSION

We had developed a new optical interconnecting technology in expectation of its application to the next generation high performance data server. With the use of the small diameter fiber, ThreadWave, and the development of the new type backplane housing, we realized much higher-density connection over conventional optical interconnects technique, and compact and high capacity optical wiring. Also, by reviewing the components and the manufacturing processes, prospect for high reduction of mass-production cost is obtained.

In the future, consideration of further cost reduction, reliability evaluation of optical connection, and more detailed transmission characteristics evaluation are scheduled to proceed.

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1) Masayuki Iwase et al.: "Optical Components for High-Density Optical Inter-Connect System: OptoUnity®", Furukawa Electric Review No. 32 (2007), 26-33.
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