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High-Speed Optical Transceiver and Systems for Optical Interconnects

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Abstract: Demand for higher data throughput and higher interconnect densities in servers and routers for IT network systems is growing quickly. Optical interconnects have both speed and high-density. There are more developments in optical interconnection, and we outline those from Japan with an opt-electronics package point of view.

OCIS codes: (230.0230) Optical devices; (200.4650) Optical interconnects;

1. Introduction

The key advantage of an optical interconnection is that optical wiring, such as an optical fiber or optical waveguide, is used. The first motive for using an optical interconnection is to provide high throughput data transmission/achieve high throughput beyond the speed of electrical transmission. Active optical cable (AOC) has recently been used for rack-to-rack interconnection. Both AOC and an electrical cable can be used with the same board design. However, in this interconnection when it is used at high-bit rates there are problems in on-board electrical connections. The most challenging ones relate to the design of the characteristics of electric parts such as the printed wiring board (PWB) and the interposer. The presence of/ multi reflection at the connection point of the logic LSI, electrical connector, and optical transceiver depends on the PWB design. To enable the on-board electrical connection to be used to for high-speed transmission, on-board optical interconnection is expected. Additional components such as optical transceivers and optical connectors have to be merged in the circuit board without sacrificing board space or increasing the total manufacturing cost. However, the data throughput of a back plane in routers and servers is well over Tbps. This requires data transmission rates of over 10 Gbps per port. Recently, researchers have focused on making an optical interconnection that not only provides high throughput but also a rack configuration that provides efficient cooling. Various concepts of optical components (transceiver, wiring, and connector) for optical interconnection have been investigated and several components are being developed. We outline several activities that have recently been taking place in Japan.

2. Optical Transceiver

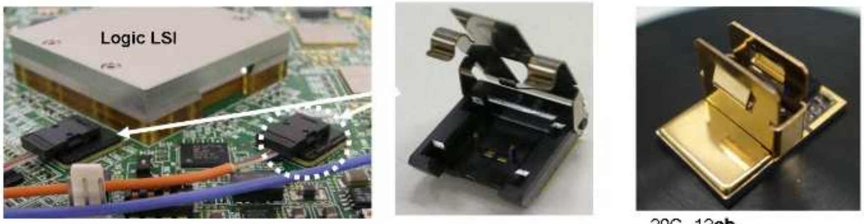
(1) Merge logic LSI and optical transceiver

The optical I/O should be placed on or near the LSI package to minimize the length of the electrical signal lines and thus eliminate increased power consumption. Using a short transmission line simplifies the electrical IO buffer, and it has low output amplitude and low power consumption that eliminates the additional wave-shape compensation circuit. Optical transceivers with power consumption of less than 20 mW/ch/Gbps are used today. In this case, an optical interconnection has a lower power consumption than the electrical interconnection under comparatively long interconnections between boards or over a back plane. The reduced power consumption enables the design of smaller optical transceivers. The size of the transceiver is mainly decided by thermal considerations, but the low power consumption means that a transceiver that is the same size as a small LSI package of an optical transceiver can be designed. An example of a multi-channel optical transceiver that is the size of a small coin [1][2] .

(2) Higher bit-rate operation over 10 Gbps

We also developed a quad 10-Gb/s optical transceiver with 0.85-µm vertical-cavity surface-emitting lasers (VCSELs) [2]. The next-generation transmission rate will be over 10 Gb/s per channel. An optical interconnect with a 1-µm-range wave-length is expected because the higher speed and reliability [3][4] of a 1-µm-range In-

GaAs/GaAsP quantum well (QW) VCSELs [5] surpasses the performance of 0.85-µm GaAs ones. Other factors that give the 1-µm-range VCSELs an advantage in transmission performance over/faster transmission than the 0.85-µm devices are the higher eye safety limit and the smaller chromatic dispersion in multi-mode fiber. We also developed a new form factor for 12-channel 20-Gb/s transmitters and receivers with 1-µm-range VCSELs. An example of a multi-channel optical transceiver with a size of a small coin is shown in Fig. 1.



10G、4chTransceiver

20G、12ch Transmitter/Receiver

Figure 1 Small high-through put optical transceiver

3. Optical wiring on PWB (printed wiring board) and back plane.

In general, an optical connector is attached at the edge of the board and each optical I/O is connected through an optical back plane in board-to-board interconnection. The placement of optical wires and optical connectors on the PWB should be considered. Optical wiring needs to be merged in the PWB by using a polymer waveguide. Several polymer waveguides have already been developed, but problems remain in the development of methods for optical coupling between the optical transceiver and the waveguide. High-density optical wiring and coupling will become a vital factor. The trends in board-to-board (B2B) and chip-to-chip (C2C) optical interconnection are shown in Figure 2. This is the result of discussions in the opt-electronics technology committee at the Japan Institute of Electronics Packaging (JIEP) in 2008 [6].

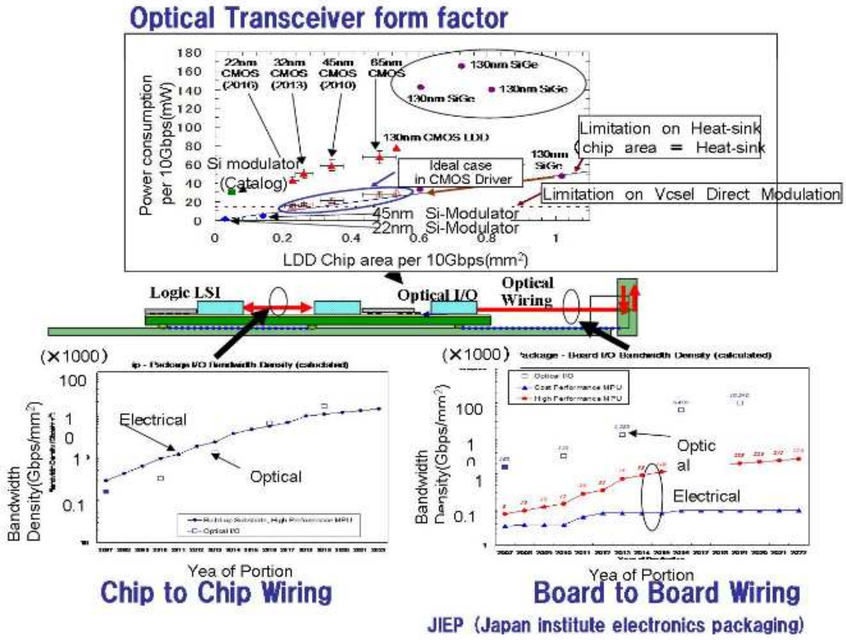


Figure 2 Trends in board-to-board (B2B) and chip-to-chip (C2C) optical interconnection

The efficiency per wiring pitch expressed as bandwidth-density (Gbps/mm2) is an important guideline to compare optical and electrical interconnection. To achieve higher optical density transceiver compared to that of electrical interconnection is needed to introduce optical interconnect in systems. In optical transceiver, chip scale packaging is the ideal direction to merge optics into electrical packaging. The relation between the chip-scale optical transceiver and power consumption should be considered. As shown in Figure 2, the current optical wiring has higher bandwidth density than electrical interconnection for B2B and on board interconnections. Development should focus on reducing cost and increasing density. On the other hand, higher density optical wiring is needed in C2C interconnection before it becomes a more attractive solution than electrical ones. Currently, although the transceiver is constrained by the power consumption of the laser driver IC, the size of the transmitter will finally reach the limit set by the power consumption of the VCSEL. This limitation might be overcome by CMOS-photonics using an on-chip optical modulator that can be driven by low voltage and optimized by separate placement of the light source [7]. The packaging technology such as opt-electrical integrated packaging or the optical coupling structure/methods merged in package is thus an important factor that will be offered in the near future. This is also reported at LEOS 2008.

As mentioned above, the current optical wiring has a higher bandwidth density for B2B. There is the possible use of a cooling friendly rack by alternative from back-plane to optical front wiring [8]. Figure 3 shows the outline of an optical front wiring rack. A very large cooling space can be created at the backside of the rack. Using a low-power fan enabled the air heated during the operation of the LSI to flow out through a cooling area. Doing this reduces the total power consumption of systems such as the server. This investigation was done in collaboration with Japanese manufacturers belonging to the Japan Electronics Packaging and Circuits Assosiation (JPCA).

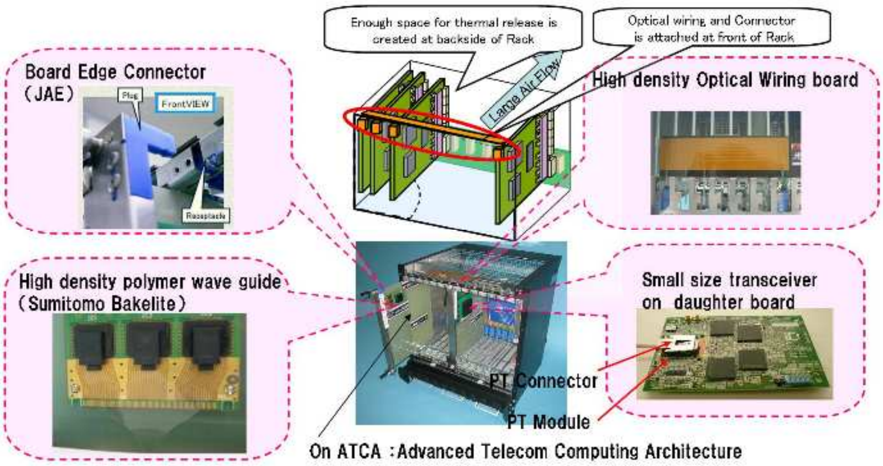


Figure 3 Proposed optical wiring rack

Conclusion and Acknowledgements

We have focused on recent activities in Japan on optical interconnection. I hope you get a good feeling for research done in Japan on optical interconnection, and also that we can collaborate on an international level. I greatly thank the members of JIEP and JPCA.

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