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High-density optical interconnection based on silicon photonics

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Abstract

Recent progress in the development of future high-density optical interconnects based on silicon photonics technology is presented. Optical interconnects by using on-package-type module between CPUs and the potential for use of wave-length-division-multiplex (WDM) toward a higher-amount of data transmission are discussed. The optical link test was successfully implemented using our proposed "bridge" structure.

1. Introduction

Optical interconnects are gradually being introduced into the inside of computing systems for large data transmission. While vertical-cavity surface-emitting laser (VCSEL) based photonic links provide a convenient and cost-effective solution to deliver aggregate data capacity to certain parts of a system as a supply form of board-edge-type modules and on-board-type modules, they may not be appropriate for higher-density optical interconnects beyond Tb/s-scale bandwidth.

On the other hand, there has been great progress has for transmitters and receivers toward high-performance optical links based on silicon photonics technology. The use of silicon as a photonic platform enables monolithic photonics-electronics integration and cost-effective solutions by using the current and mature silicon process. Furthermore, silicon photonics are expected as promising candidates to be introduced into the on-package-type optical modules near the CPU since they allow for a small foot print, high communication bandwidth, and low power consumption [1,2].

For on-package-type modules, it is important to reduce the distance between the CPU and silicon photonics to several centimeters to enhance power efficiency by eliminating the electrical equalizer [3]. In addition, attaching silicon photonics to the edge of a package substrate enables easier fiber attachment. To meet these requirements, several designs have been proposed so far even though they require wire bonding techniques that have density limitation and are affected by the deterioration of electrical transmission. Moreover, the bandwidth-density of these interconnects may be further scaled-up with the implementation of wavelength division multiplex (WDM) schemes. In this paper, we present recent progress in the development of silicon-photonics-based optical interconnects between CPUs. We propose and report on a "bridge" structure to realize the energy-efficient on-package-type-modules, and successful 25 Gbps operation between the fabricated silicon-photonics-based transmitter and receiver. We also present the recent results for WDM that we aim to introduce into the future optical interconnects.

2. CPU-CPU interconnection

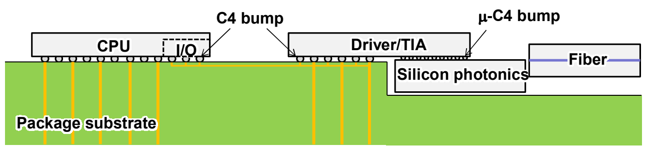

Fig. 1 Schematic image of on-package-type optical module

Figure 1 shows the proposed structure of silicon-photonics-based interconnection between CPUs (on-package-type) [4]. The structure consists of a driver/transimpedance amplifier (TIA) chip, a silicon-photonics chip and a package substrate with a trenched void. The hybrid assembly of the silicon photonics and driver/TIA chips is preferred because of the optimum design and process technology for the best performance and cost efficiency. For easy fiber assembly, the silicon photonics chip should be mounted face-up on the package substrate. On the other hand, the driver/TIA chip should be mounted face-down on the package substrate and connected by solder bumping for good signal and power integrities. In addition, to minimize the distance between the driver/TIA and photonic chips,

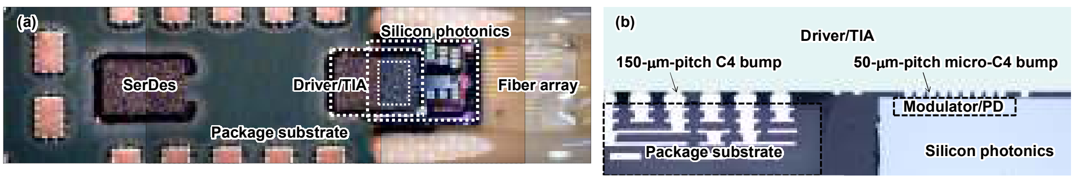

Fig. 2 Photos of fabricated transmitter

they should be connected face-to-face. To meet these requirements, our "bridge" structure has a trenched package substrate as shown in Fig. 2. The proposed structure enables establishing connection at all electrical interfaces via solder bumping and reducing the distance between the driver/TIA and photonic chips. Moreover, easy fiber assembly is possible for both facet-to-fiber and surface-to-fiber configurations.

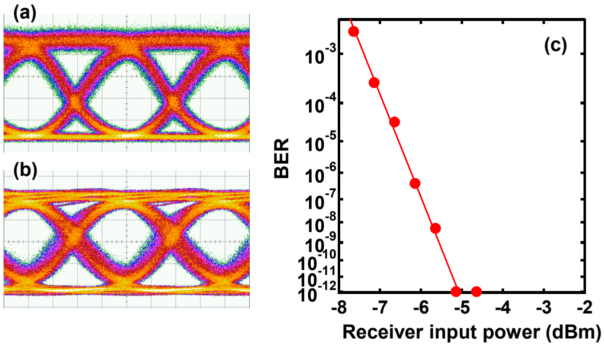

Fig. 3 Eye diagrams and BER measurements results

Figure 3 shows the results of link characterization by using the above-mentioned transmitter and receiver. Figure 3 (a) and (b) show the 25 Gbps eye diagrams for the transmitter (optical) and receiver (electrical), respectively: clear eye openings were achieved. The obtained dynamic extinction ratio was 11.6 dB. The bit error rate of the electrical signal from the TIA is shown in Fig. 3(c). Error-free operation was successfully achieved with an input power to the receiver of -5.9 dBm. The power consumption for this link including consideration of serializer will be discussed at the conference.

3. WDM technologies

A WDM scheme is promising as an efficient way of increasing the aggregated bandwidth in a small footprint. For WDM systems, a flatband spectral response is important since the wavelength control accuracy of the optical signals and temperature tolerance of optical components can be markedly relaxed [5]. Figure 4 shows the fabricated Demux optical filter based on the micro-ring assisted multiple delay lines. The proposed structure allows for a very compact size of 120 x 210 μm.

Fig. 4 Fabricated Demux filter

Figure 5 shows the measured spectra for the fabricated 1x4ch Demux optical filter. A clear flattened spectral response was clearly observed. Note that no thermal tuning is needed to adjust the phase of multiple filters. To investigate the spectral flatness, we also fabricated two conventional Demux filters with the same fabrication process. The shape factor that represents the degree of spectral flatness and defined as the bandwidth ratio of -1 to -10 dB was much higher than with the two conventional filters. To the best our knowledge, it was the largest shape factor among Si-wire-based optical Demux filters.

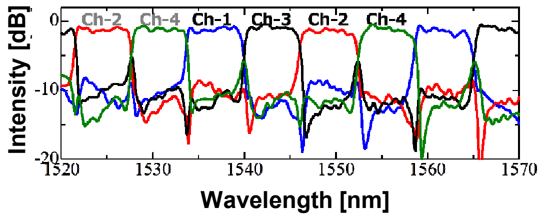

Fig. 5 Measured spectra for fabricated Demux filter

4. Conclusions

We described the recent progress in the development of optical interconnects based on silicon photonics technologies toward high-density CPU-CPU signal transmission. The optical link test was successfully implemented using our proposed "bridge" structure.

Acknowledgements

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