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Invited paper

Prospect of chip scale silicon photonics transceiver for high density multi-mode wiring system

Kazuhiko Kurata*, Yasuyuki Suzuki, Mitsuru Kurihara, Masatoshi Tokushima, Yasuhiko Hagihara, Ichiro Ogura, Takahiro Nakamura

Photonics Electronics Technology Research Association (PETRA), Japan

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ABSTRACT

We propose high density multi-mode wiring system with chip scale silicon photonics transceiver. After review of concept and a discussion of overall design principles, design of a chip scale optical transceiver named Optical I/O core using silicon photonics is described.Experimental results with connected multimode fiber are presented. Finally, applications of optical I/O core and future prospects are introduced.

1. Introduction

Performance of recent IT/NW equipment is dramatically increasing. To secure enough bandwidth for off chip interconnection has become a vital factor. The electrical I/O bandwidth for off-card and off-module interconnect used in data communication is fast approaching an I/O bottleneck [1]. Optical interconnection technology has been expected to solve this problem even for shorter distances. Optical interconnection offers the added advantage of providing high-speed, high-density and low power consumption. To realize optical interconnection, industrial drivers such as lowest cost and mass production technology is a bigger challenge. Silicon photonics technology is one of the more attractive options. High speed beyond 25 Gbps and small size Si-photonics transmitter and receiver devices and Photonics Integrated Circuits (PIC) are fabricated by precise silicon wafer fabrication processes [2]. It is very suitable for very small optical transceivers and mass production. To relaise such modules, fabrication and assembly techniques will required to incorporate silicon photonics. Generally, optical coupling adjustment is a challenging step in manufacturing of optical wiring systems. This difficulty forces use of expensive parts and precision assembly procedure. Usually, single mode transmission line is applied in an optical transceiver using silicon photonics technology. In this case, less than 1 μm alignment accuracy is required between optical transceiver and optical transmission line. It is considered that applying multimode transmission lines is more desirable to get low cost and high productivity using commercialized equipment. In this paper, we propose high density multi-mode wiring system with chip scale silicon photonics transceiver. After review of concept and a discussion of overall design principles, design of a chip scale optical transceiver named Optical I/O core using silicon photonics is described. Experimental results with connected multimode fiber are presented. Finally, applications of optical I/O core and future prospects are introduced.

2. Multimode transmission line using silicon photonics transceiver

Demand for optical interconnection exists not only in high end IT/NW equipment but also several short reach interconnections such as consumer or industrial applications that require higher speed, noise reduction and low weight. Large potential applications for huge scale production will exist in these short reach interconnections in the near future. Almost all optical interconnection needs for transmission lengths less than 300 m are satisfied by using multimode transmission. Optical interconnection using silicon photonics should be optimized to these short length interconnections to accelerate deployment in these areas. High precision alignment is a serious challenge to realizing lower cost optical interconnection. Applying multimode transmission configurations is considered suitable for relaxing optical coupling requirement. Therefore, we propose multimode optical interconnection for silicon photonics transceiver. The advantage of Si photonics is that different types of photonics integrated circuit can be fabricated using the same process rule. Single

* Corresponding author.
E-mail address: k-urata@petra-jp.org (K. Kurata).

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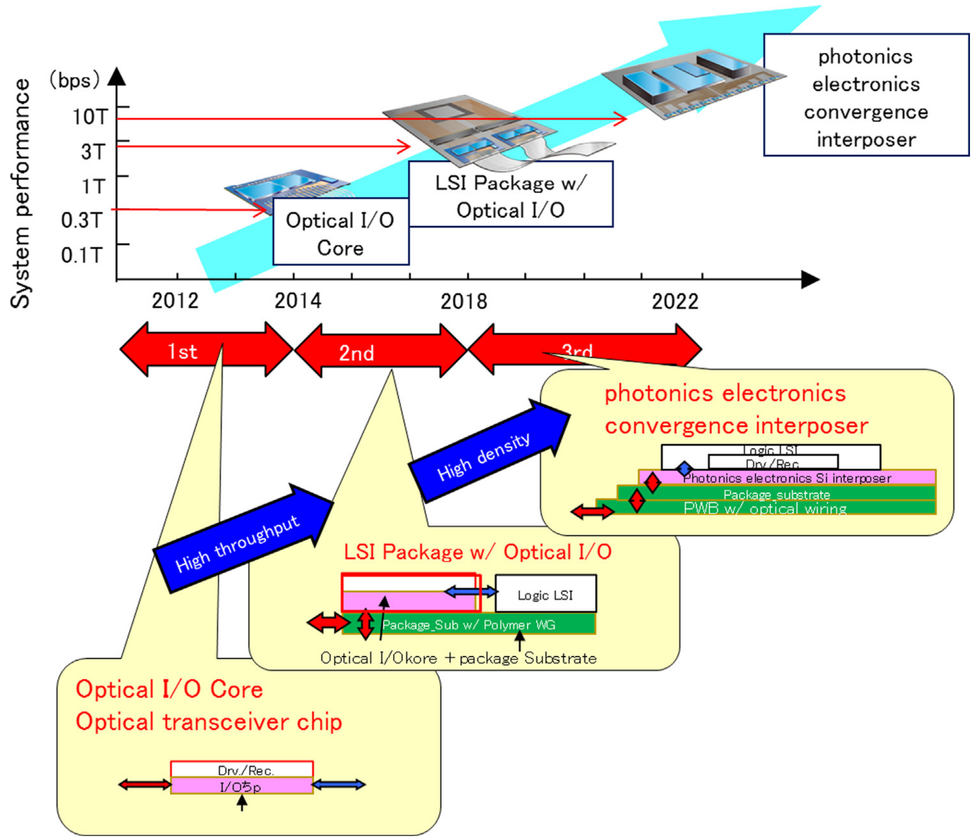

Fig. 1. PETRA roadmap.

mode applications such as WDM/Switches for long reach may be merged to enough volume short range applications. In this case, reasonable lower cost optical transmission from short reach to long reach up to 2 km can be realized using unified processes for high volume manufacture. Silicon photonics technology becomes the focus of development to attain high density and low power consumption optical transceiver. Optical transceiver functions of compatible size with electrical I/O have to be attained to overcome the I/O bottleneck. A roadmap of the PETRA project is shown in Fig. 1 [3]. In this technology, miniature optical transceivers can be built into a LSI package, whereby the optical transceiver function can be fabricated on a silicon interposer using standard silicon processing equipment. On the other hand, more expensive LSI fabrication equipment is necessary to get photonics integrated circuit. This means that large scale production is necessary for cost effectiveness.

3. Applied wavelength and optical coupling tolerance target

For applying multimode optical coupling to silicon photonics, applicable wavelength and optical coupling tolerance are discussed below.

3.1. Applicable wavelength

Wavelengths longer than 1 μm and more specifically, 1.3 and 1.5 μm are typically used for silicon photonics due to the higher transparency of silicon above these wavelengths. Currently, transmission at 1.3 and 1.5 μm exhibits low propagation loss [4]. On the other hand, optical fibers tailored to wavelengths of 0.85 μm and 1.3 μm are already established in industrial standards. Experimental results at 25 Gbps and 820 m transmission have been reported by using graded index (GI) fiber optimized to 1.3 μm [5]. According to eye safety specifications, higher optical powers at wavelengths around 1.3 μm are permitted compared to 0.85 μm. This will allow a wide dynamic range over 25 Gbps transmission to be achieved in the future. Additionally, polymer waveguides and plastic optical fibers are also applicable in short reach interconnection. Applicable transmission materials are shown in Table 1. For these reasons, we designed an I/O optical core for silicon photonics devices operating at 1.3 μm wavelength.

3.2. Target of optical coupling tolerance

In the history of optical communication, cost reduction has been a major challenge due to the precision needed in coupling of light to and from optical fiber and components. Generally, an accuracy of 1/10 of core size of the fiber is needed for stable optical connection. The need for precise alignment requires special equipment, in particular machines for active alignment that need precise parts thereby contributing to the higher cost. On the other hand, mounting accuracy of commercialized mounting machines has advanced roughly from 2 to 10 μm in flip chip bonding machine. Fig. 2 shows relation of accuracy and productivity in commercialized mounting equipment. Required optical coupling tolerance is also indicated. For coupling to multimode optical fiber with a coupling tolerance of about 10 μm, high precision flip chip bonding machines may be used. By developing new optical coupling structures, a target tolerance between optical transceiver and optical transmission materials of less than 10 μm may be easily achieved in our Si optical I/O core [6].