High Power External Pluggable Laser Bank with Simultaneous Single Mode Optical & Electrical Connection

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Abstract: We demonstrate a pluggable laser bank module with 8-channel single-mode optical output and a maximum power of 18.5 dBm per channel. The hot pluggable module supports sufficient link-budget for a 1.6 Tb/s silicon photonic chip.
OCIS codes: (140.0140) Lasers and laser optics; (230.3120) Integrated optics devices; (060.2330) Fiber optics communications

1. Introduction

In recent years, low cost and large capacity optical interconnects for applications in inter- and intra- data centers, 5G mid-haul and access networks, etc. is a strong demand. Silicon photonic (SiPh) based multi-channel transmitter and receiver has been widely recognized as one of the main solutions for it, and lots of effort has been done by industry with promising progresses released [1-2].

One of the most significant challenge for SiPh transceiver is the lack of monolithically integrated optical source. Several solutions have been proposed for integrating laser in SiPh transceiver, such as flip-chip bonding [3], die or wafer bonding [4], and III-V direct growth on silicon substrate [5].Several on-board external light source modules have also been demonstrated [6].

In this paper, we demonstrate a high power external 8-channel pluggable laser bank (LB) module. A newly designed hot-pluggable optical and electrical (OE) adaptor is introduced, and it simultaneously build single mode optical and electrical connection between SiPh transceiver and the controlling printed circuit board (PCB).

2. Structure and optical device of the LB

The pluggable LB module structure is shown in Fig. 1(a). It has a standard SFP+ package, and unlike traditional pluggable optical transceiver, the optical output connector is located at the same side of the electrical connector. To be specific, a mechanical docking transmission (MT) ferrule fixed on top of the PCB gold finger by a newly designed structure.

Besides, as shown in Fig. 1(b), a fiber array (FA)-MT is used in the optical device of the LB to realize an 8-channel parallel space multiplexing optical output. A thermo-electrical cooler (TEC) and isolator is packaged in the optical device.

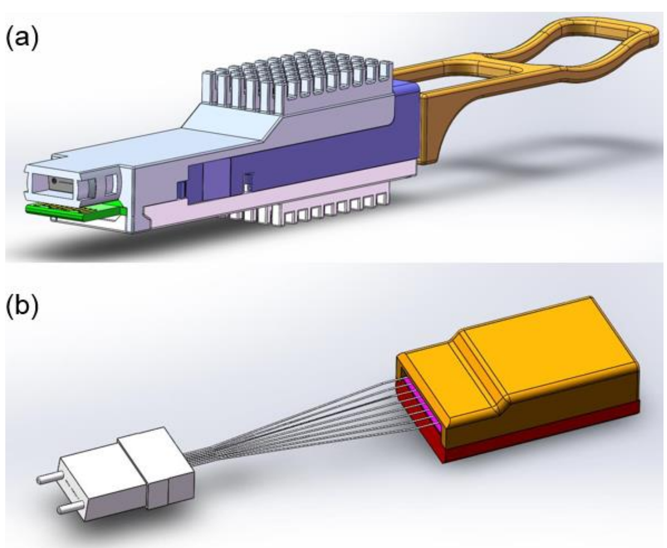

Fig. 1. Schematics of (a) the pluggable LB module and (b) the LB optical device.

Figure 2(a) presents the output spectra of the LB module. The emission wavelengths of the LB meet the standard of coarse wavelength division multiplexing (CWDM) 4. As shown in Fig. 2(b), the lasing-power-in-fiber per channel can reach as high as 18.5 dBm. However, in order to balance between performance and energy efficiency, the emission power is set at 17 dBm per channel and the total module power consumption of the module is 3 Watts, including that of a TEC.

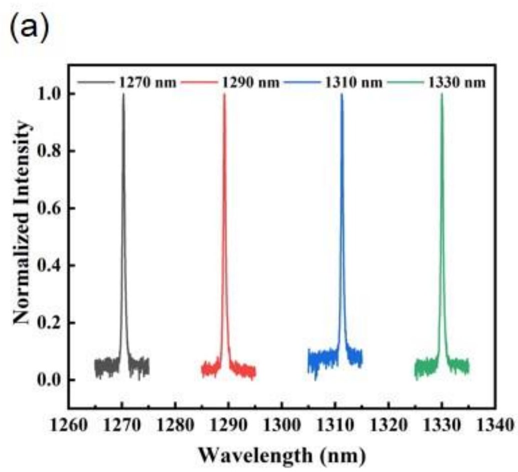

Fig. 2 (a) Optical spectra of the LB and (b) lasing-power-in-fiber as a function of current.

3. OE on-board adaptor

As shown in Fig.3(a), the integrated OE adaptor is mounted on a PCB, which satisfies an electrical and optical connections of standard SFP+ pluggable module and single mode multi-fiber push on. Once the LB obtains electrical power from the PCB when it is plugged into the OE adaptor, the output lasing power is simultaneously supplied to the on-board SiPh transceiver through the MT jumper fixed in the OE adaptor.

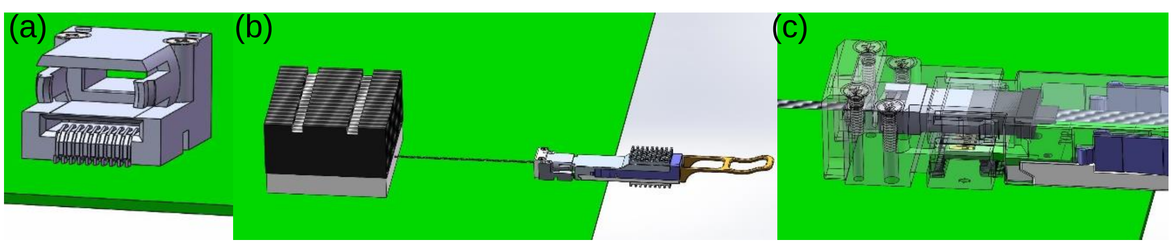

Fig. 3. Schematics of (a) on-board OE adaptor, (b) on-board SiPh transceiver and external LB module pair, (c) electrical and optical connection in OE adaptor.

It has to be highlighted that, compared with the internal integrated optical source of SiPh transceiver, the external packaged LB module has advantages of lower optical source cost, longer transceiver life time and easier thermal management.

The concept of laser 'bank', which refers that the lasing power from each laser die is shared by multiple SiPh modulators, is a promising way to reduce the optical source cost. By applying the external LB, low-cost and high-power quantum-well (QW) based distributed feedback (DFB) laser can be used since isolators can be easily integrated, the working temperature can be efficiently controlled and the coupling insertion loss can be cost-effectively minimized. Therefore, an 8-channel LB module can supply sufficient optical energy for a large capacity optical interconnection. The cost of optical source decreases by reducing both volume and unit price of laser die, which make it more attractive for industry mass production.

In the meantime, as the failure rates of the SiPh chip and III-V-based laser are significantly different, laser would more likely wear out before SiPh chip. An external LB can be easily exchange after its failure, without throwing away the whole on-board SiPh transceiver and disconnect the whole line-card while changing the on-board transceiver module. Therefore, the failure in time (FIT) per optical-link of an on-broad SiPh transceiver supposed to be longer than that of the traditional pluggable optical module.

The thermal management of the SiPh transceiver is critical as it partially decides the application scenario. If the performance stability and mature supply chain of QW-based laser is more preferred in a production solution, it would be a better solution to package SiPh chip and optical source separately in terms of board-level heat dissipation engineering. Typically, SiPh chip can work at a temperature higher than 80 ℃, while a QW-based laser will suffer severe performance degradation when its working temperature is over 70 ℃. Therefore, the thermal management would be easier by locating the SiPh chip in the mid-board close to serializer/deserializer (SerDers), taking advantage of lower electrical signal loss, while the broad-edge pluggable LB module can be exposed to cooler ambient.

On the other hand, unlike other reported on-board external optical source module solutions, the LB exchange procedure is as simple as that of the traditional pluggable optical transceiver, without disconnecting the whole line-card.

In terms of the repeatability of the on-board OE connector, a cycle plug-unplug test is still carrying on. So far, the optical insertion losses are all lower than 0.5 dB and its fluctuation is smaller than 0.35 dB.

4. Experimental results of 1.6 Tb/s data transmission

In this paper, the LB is used to supply a self-developed SiPh transceiver. Previously, we reported a 1.2 Tb/s travelling-wave Mach-Zehnder modulators (TW-MZMs) based SiPh transceiver [7]. In our current experiment, with each modulator working at 50 Gb/s or even 100 Gb/s, the total capacity of the transceiver is increased to 1.6 Tb/s.

Each output channel of the LB can be either shared to four TW-MZMs working at 50 Gb/s or two at 100 Gb/s. In the experiment, the self-developed SiPh transceiver worked at 106 Gb/s PAM-4. As shown in Fig. 4(a), the received electrical eye diagram is clear to distinguish the 4 levels. At an average received power of -7 dBm, the measured bit error rate (BER) is 2e-4, well below the KR4 FEC BER threshold, which is sustainable for the 400G-FR4 standard.

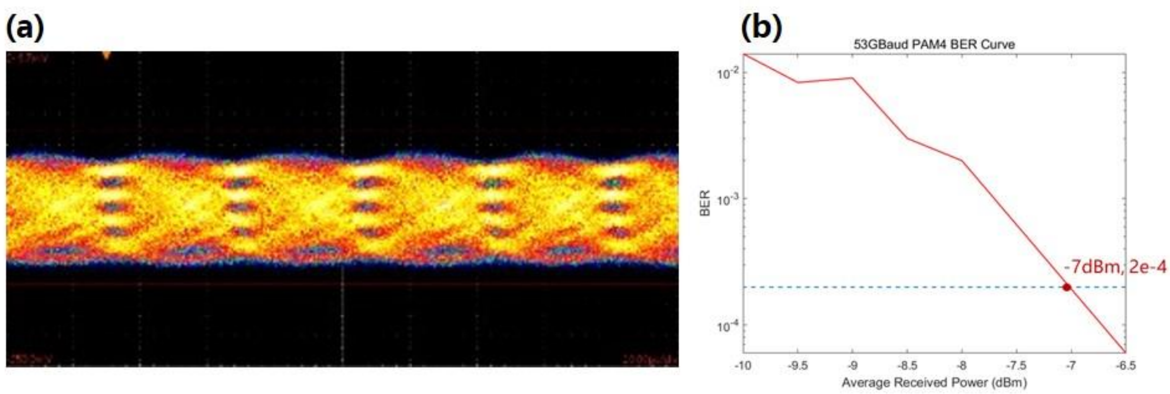

Fig. 3. (a) Electric eye diagram at 100 Gb/s and (2) BER as a function of average received power.

5. Conclusion

We demonstrate a high power external pluggable LB module which is able to supply sufficient optical energy for a self-developed SiPh transceiver with 1.6Tb/s capacity. The LB module is broad-edge hot pluggable and once it has been plugged, the optical connections are formed simultaneously with the on-board SiPh chip. Besides, its external packaging design makes remarkable contribution in the self-developed on-board SiPh optical interconnect system in terms of system maintain and heat dissipation engineering.

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