Silicon Photonics for 800G and Beyond

[invited]

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Abstract: Future optical transceivers will rely on silicon photonics to address the increasing need for high capacity density and energy efficiency. We review its applications in 800G and beyond and highlight the challenges ahead. © 2022 II-VI Incorporated

1. Introduction

Network traffic has experienced compounding annual growth rates between 25% and 80% across a diverse set of regions and applications in the past two decades [1] and is expected to continue into the foreseeable future. In order to meet the rising demand, future datacenter interconnects will require low-cost and small-from-factor optical transceivers with a capacity of 800G and beyond. Multi-source agreements (MSAs) have already been established for 800G optical transceivers, including DR8 and 2xFR4 [2-3] with next-generation 1.6T transceivers already being discussed [4]. The current market is dominated by 100G/lane transceivers that are based on compound semiconductor electro-absorption modulators (EAMs). The scalability of EAM technology to higher capacity density is questionable due to the packaging challenges associated with growing channel numbers. Over the last two decades, silicon photonics (SiPh) has emerged as a disruptive opto-electronic technology that can meet the increasing demands on capacity density, integration, and energy efficiency [5]. Recent reports of SiPh-based 400G transceivers [6-8] and 200G/lane Mach-Zehnder modulators (MZMs) [9-11] demonstrate the potential of SiPh for applications in 1.6T and beyond.

2. Datacom transceivers evolution

Figure 1 shows the remarkable progress of optical transceivers over the past three decades. The capacity increased from 1G to 800G in about 25 years, resulting in a capacity doubling every 30 months. Likewise, the energy per bit started from 800 pJ in 1G transceivers and has dropped down to 25 pJ for 800G modules (Figure 2). While this achievement is remarkable, it is to be noted that the efficiency increase cannot improve at the same pace as capacity. From 100G to 800G, the energy efficiency only increases about 30%. In order to further increase the energy efficiency, optical transceivers will need to be assembled on the same substrate as the switch ICs in co-packaged optics (CPO) or near packaged optics (NPO) formats, but there are tremendous challenges ahead. It is difficult to achieve high-power lasers, high-channel count SiPh chips, and large-size substrates with high yield required for CPO or NPO to be viable. In addition, technical challenges remain in flip-chip processing, mechanical assembly, heat dispassion, and RF signal routing and integrity.

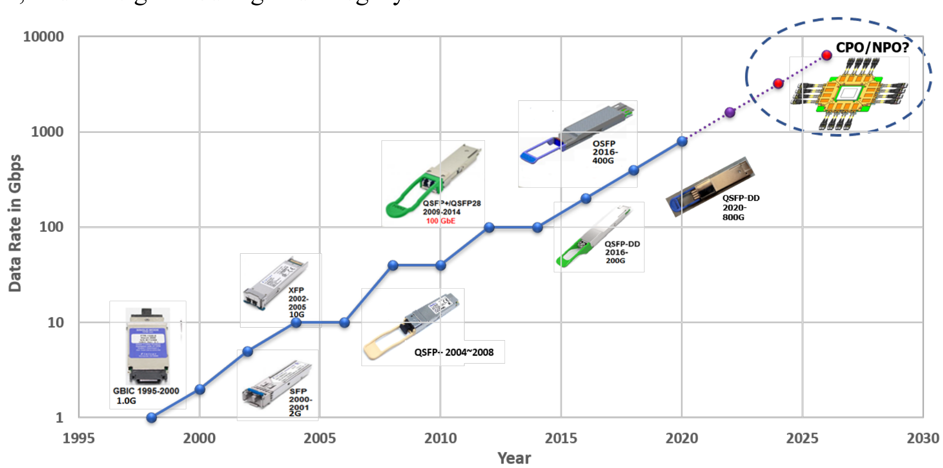


Fig. 1. Datacenter transceiver evolution. The inset pictures show II-VI (Finisar) transceivers.

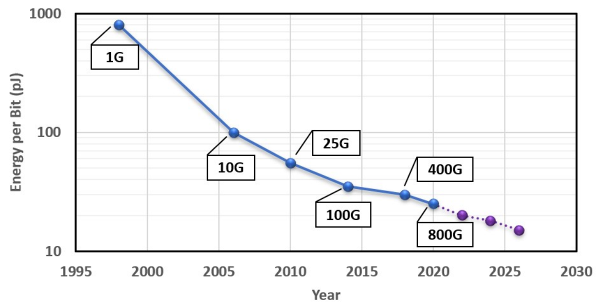
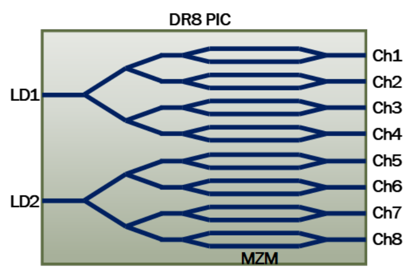


Fig. 2. Energy per bit for commercial datacom transceivers.

3. SiPh for 800G and beyond

Although heterogeneously integrated SiPh lasers are feasible [8], most SiPh-based transceivers employ external CW laser diodes (LDs). For 800G DR8, one laser can be shared by four (or eight) silicon MZMs to deliver 100G per channel, shown in Fig. 3(a). A loss budget based on the literature review [6-11] is tabled in Fig. 3(b) for each PIC element. An intrinsic loss of 9 dB occurs for the one-to-four splitting and biasing the MZMs at quadrature. The excess loss is estimated to be about 7 dB, including coupling losses, propagation loss and monitor tap loss. With this amount of total loss, the CW laser needs to provide a power of >16 dBm to fulfill the Tx specification for 800G DR8 modules. To scale up to 1.6T DR16, more laser diodes or more splitting may be employed, depending on the available laser power.



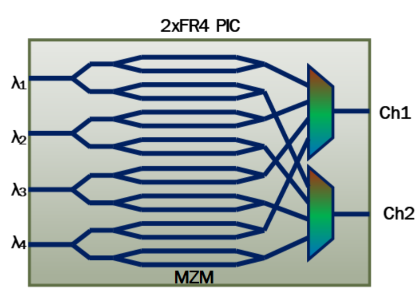
(a)

DR8 Tx	Loss (dB)
Laser-PIC coupling	1.50
1:4 splitting	6.20
MZM WG	3.00
MZM modulation	3.00
WG Routing	0.50
Monitor PD tap	0.20
PIC-fiber coupling	1.50
Total Loss	**15.90**

(b)

Fig. 3. Silicon PIC for DR8-type transceivers. (a) Circuit for Tx; and (b) Estimated loss for PIC.

FR4-type transceivers are based on a four-channel coarse wavelength-division multiplexing (CWDM) scheme. For 800G 2xFR4 modules, four CW lasers with different wavelengths are needed and each one can drive two MZMs as exhibited in Fig. 4(a). Due to the multiplexing, an additional mux loss of 1.5 dB is added in the power budget [Fig. 4(b)]. For 1.6T 4xFR4, one laser can be shared by four MZMs. To scale up the capacity, reducing the excess loss and increasing the PIC yield will be the key challenges.



(a)

2xFR4 Tx	Loss (dB)
Laser-PIC coupling	1.50
1:2 splitting	3.10
MZM WG	3.00
MZM modulation	3.00
WG Routing	0.50
Monitor PD tap	0.20
CWDM Mux	1.50
PIC-fiber coupling	1.50
Total Loss	**14.30**

(b)

Fig. 4. Silicon PIC for 2xFR4-type transceivers. (a) Circuit for Tx; and (b) Estimated loss for PIC.

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