A Record Energy Efficient QSFP ELS for Co-Packaged Optics

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Abstract *We demonstrate an uncooled pigtailed-QSFP ELS employing an 8-channel (4-λ × 2) CWDM TOSA for Co-Packaged Optics. When operating 100 mW for all 8 channels, the ELS achieves a record high power conversion efficiency of 14.3 % at a housing temperature of 55 ºC.*

Introduction

Co-Packaged Optics (CPO) has been expected to expand the bandwidth and save the power consumption for data centre interconnects (DCIs). CPO has a unique packaging structure where high-density optical transceivers are mounted together with a switch application specific integrated circuit (ASIC) on the same substrate [1]. A wide bandwidth switch ASIC consumes a large amount of power and accordingly generates the heat. Since the optical transceivers and the ASIC are arranged very close, it is concerned that the thermal radiation of the ASIC increases an operating temperature of the optical transceiver and deteriorates the characteristics. To avoid such a technical issue, silicon photonics (SiPh) transceivers has been developed with two different laser source options. An 800-Gb/s SiPh transceiver was demonstrated with the usage of two redundant internal laser sources per optical channel [2]. A 1-Tb/s SiPh optical transceiver was demonstrated with the usage of an external laser source (ELS) employing 16-wavelength distributed feedback (DFB) laser array [3].

The CPO collaboration ELS guidance document describes that an ELS is placed at a front panel by using a small form factor (SFF) where QSFP-DD, OSFP and OBO, which have been standardized and widely employed for optical transceivers, are proposed [4]. The ELS modules have 8-channel optical outputs in compliant with 400GBASE-FR4 or 400GBASE-DR4. 400GBASE-FR4 requires the wavelength allocation of 4-wavelength (λ) coarse wavelength division multiplexing (CWDM) (i.e., 1271 nm, 1291 nm, 1311 nm, and 1331 nm) × 2, or 400GBASE-DR4 requires the wavelength of 1310 nm for 8-channels. The operating range of fibre-coupled power is specified from 23 dBm to 27 dBm (i.e., 200 mW to 500 mW) at the operating temperature ranging from 20 °C to 70 °C.

To realize high optical output power, Inoue et al. demonstrated a 1.3-µm semiconductor optical amplifier (SOA)-integrated distributed feedback (DFB) laser which exhibits the optical power of 350 mW at 45 °C with a power conversion efficiency (PCE) of >25 % [5]. Gokhale et al. demonstrated continous wave (CW) DFB lasers which exhibit a PCE of 25 % at at 100 mW with a 1-mm cavity design and a PCE of 20 % at 200 mW with a 2-mm cavity design [6].

Johnson et al. reported an 8-channel CWDM ELS using a double-height QSFP-DD housing [7]. The ELS exhibited fibre-coupled optical power of 100 mW at a case temperature up to 50 °C where the power consumption of the transmitter optical subassembly (TOSA) was ~6.2 W with a PCE of ~12.9 %. The power consumption of the ELS was as high as ~7.7 W at a case temperature of 55 °C whereby the PCE was ~10 %.

To save the link power in DCIs, it is highly demanded to realize a higher PCE for an ELS. We have demonstrated an 8-channel CWDM TOSA and a pigtailed-QSFP ELS which exhibits a fibre-coupled optical power of >100 mW per channel at an LD bias current of 400 mA over the operating housing temperature ranging from 0 ºC to 55 ºC [8,9].

In this paper, we demonstrate a record energy efficient uncooled QSFP ELS which exhibits a record PCE of 14.3 % at a housing temperature of 55 °C. By optimiing the optical coupling and the thermal disspation structures of the TOSA, the ELS realizes the fibre-coupled power of >100 mW per channel with an LD bias current of 300 mA at a housing temperature of 55 ºC. We describe the design and characteristics of the uncooled pigtailed-QSFP ELS.

8-channel CWDM TOSA

Fig. 1 shows a schematic top view for the 8-channel CWDM TOSA structure. Wavelength-selected SOA-integrated DFB-LDs are mounted on a substrate. The launched laser beam from the SOA-integrated DFB-LD is coupled to a polarization maintaining fibre (PMF) by a focusing lens through an optical isolator. By adopting a new focusing lens, the optical coupling efficiency is increased from ~70 % to ~85 %. We also adopted a new substrate which has a higher thermal conductivity and hence the temperature

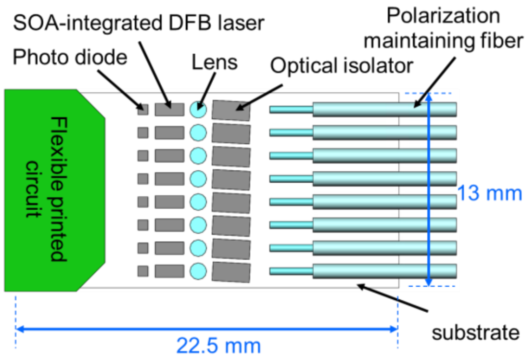

Fig. 1: Schematic top view for the 8-channel CWDM TOSA structure.

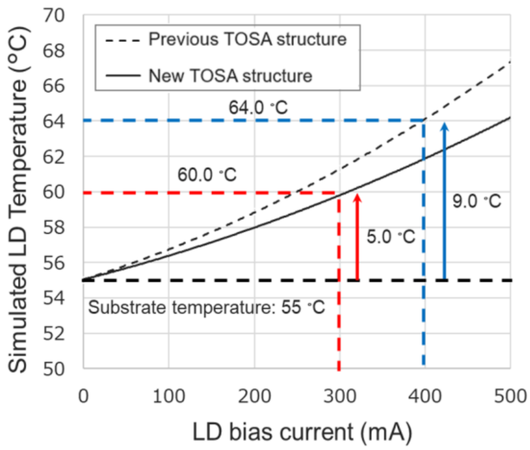

Fig. 2 Simulated LD temperature characteristics as a function of LD bias current.

difference between the LD and the bottom surface of the substrate is decreased in comparison with our former work reported in Ref. 9. Fig. 2 shows simulated LD temperature characteristics as a function of LD bias current where an LD pitch size is 1.2 mm. The characteristics for the previous TOSA structure and the new TOSA structure are shown with a dotted curve and a solid curve, respectively. By increasing the optical coupling efficiency, an LD

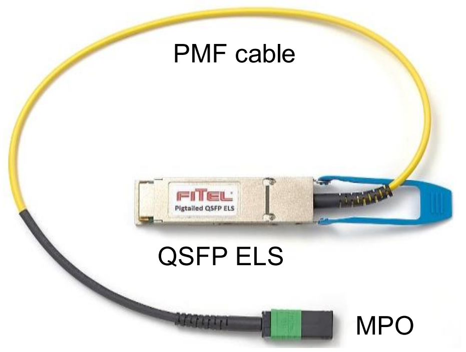

Fig. 4: Photograph of the pigtailed-QSFP ELS

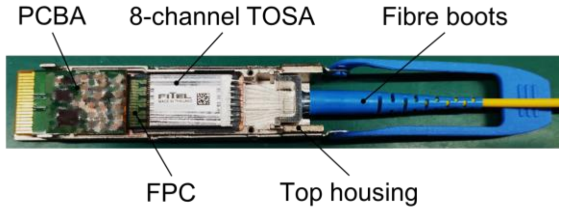

Fig. 5: Photograph of an inner structure for the pigtailed-QSFP ELS integrated with the TOSA.

bias current is decreased from 400 mA to 300 mA. Such suppression of the LD bias current contributes to make the LD temperature lower. In fact, the temperature increase of the new TOSA structure is as small as 5.0 °C in the LD bias current ranging from 0 mA to 300 mA. A lower LD bias current contributes making a PCE of the LD higher.

Fig. 3 shows fibre-coupled optical power and LD voltage characteristics as a function of LD bias current at a case temperature of 25 °C and 55 °C, respectively. To obtain the fibre-coupled optical power of >100 mW for all channels, an LD bias current is sufficient within 300 mA over the case temperature range. When operating all 8 channels simultaneously, the TOSA achieves the power consumption of 3.7 W and a high PCE of 21.6 % even with the optical coupling loss.

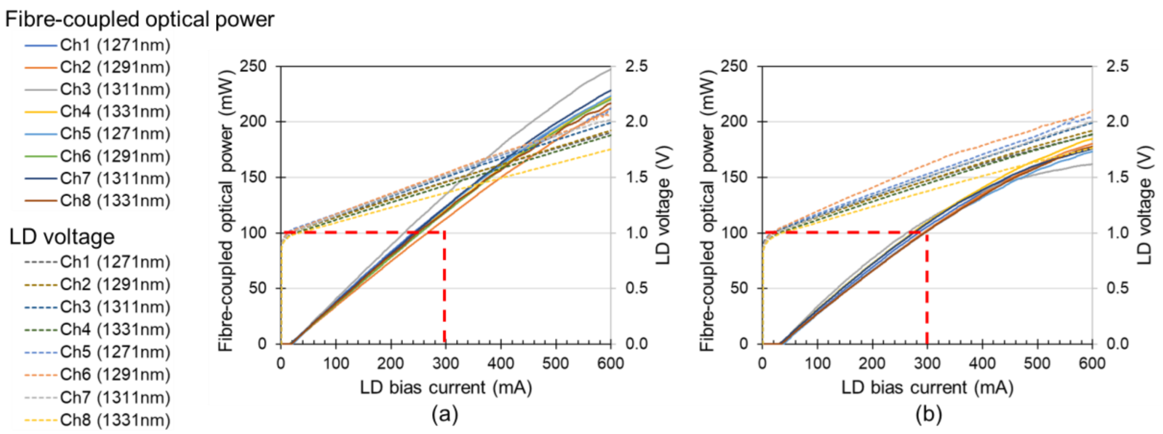

Fig. 3: Fibre-coupled optical power and LD voltage characteristics as a function of LD bias current at a case temperature of 25 °C and 55 °C, respectively. (a) 25 °C. (b) 55 °C.

Pigtailed-QSFP ELS

Fig. 4 shows a photograph of the pigtailed-QSFP ELS. The pigtailed 8-lane PMF cable is fully covered by a protective tube. The length of the pigtailed PMF cable is as short as 300 mm and a standard 12-lane MPO connector is attached at the fibre end. The polarization orientation of the laser beams is aligned to the horizontal slow axis of the PMFs.

Fig. 5 shows a photograph of an inner structure for the pigtailed-QSFP ELS integrated with the TOSA. The bottom surface of the TOSA substrate is thermally connected to the top housing, in order to suppress the difference between the case temperature of the TOSA and the housing temperature of the QSFP ELS. The temperature difference between the case of the TOSA and the top of housing is suppressed as low as 0.7 °C. Therefore, the QSFP ELS can maintain a very similar characteristics with the TOSA.The 8-channel CWDM TOSA is built in a standard QSFP housing together with a printed circuit board assembly (PCBA) which can control the LDs with the auto power control (APC) and auto current control (ACC) modes and monitor the driving status through the inter-integrated circuit (I^2C) bus interface. The TOSA is electrically connected to the PCBA by a flexible printed circuit (FPC).

Fig. 6 shows a block diagram for the LD driving circuitries. The PCBA has LD driver circuitries as well as a power supply regulator, microcontroller unit (MCU) and a temperature sensor. The LD driver circuitries employ DC/DC converters. To save the power consumption, the DC/DC converters reduce a supply voltage of 3.3 V to the maximum LD driving voltage, which enables supplying an LD current of 500 mA sufficiently.

Fig. 7 shows calculated and measured power consumption as a function of LD bias current for the pigtailed-QSFP ELS. The calculated characteristic is shown with a dotted line and the measured results are shown with open circle plots. As can be seen from the graph, the measured result has a good agreement with the calculated result and a lower LD bias current obviously contributes reducing the power consumption. When all LDs are operated with an LD bias current of 300 mA to obtain the fibre-coupled power of >100 mW at a housing temperature of 55 °C, the power consumption of the ELS measures 5.6 W whereby a record PCE of 14.3 % is realized. At a housing temperature of 50 °C, the LD bias current can be reduced to 290 mA and hence the power consumption measures 5.4 W whereby the PCE is as high as 14.8 %. The LD bias current decrease results realizing the lower power consumption and the higher PCE.

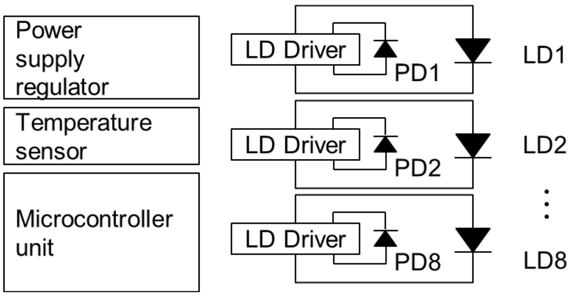

Fig. 6: Block diagram for the driving circuitries.

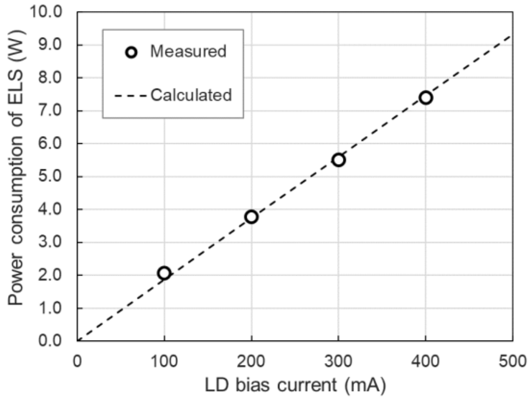

Fig. 7: Calculated and measured power consumption as a function of LD bias current for the pigtailed-QSFP ELS.

For example, if the bias current can be reduced to <250 mA, the power consumption will be <5.0 W and the PCE will be >16.0 %.

Conclusions

We described a record energy efficient uncooled QSFP ELS which exhibits the PCE of 14.3 % when operating all 8 channels with fibre-coupled optical power of 100 mW at a housing temperature of 55 °C.

The new TOSA adopted a new focusing lens to increase the optical coupling efficiency from ~70 % to ~85 %. The TOSA also adopted a new substrate which has a higher thermal conductivity to suppress the temperature difference between the LD and the bottom surface of the substrate. Owing to these improvements, the LD bias current is reduced within 300 mA over the case temperature range. At a case temperature of 55 °C, the power consumption of the TOSA measures 3.7 W and a PCE of the TOSA is as high as 21.6 % even with the optical coupling loss.

The pigtailed-QSFP ELS exhibits the fibre-coupled power of >100 mW for all channels with an LD bias current of 300 mA at a housing temperature of 55 °C. The PCE is 14.8 % and 14.3 % at a housing temperature of 50 °C and 55 °C, respectively. In order to further increase the PCE, it is expected to further reduce the LD bias current.

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