16-ch 50Gbps 1060-nm Single-mode Bottom-emitting Metal-aperture VCSEL Array through 5km-long SMF

(D3) Liang Dong*, Xiaodong Gu, and Fumio Koyama
Laboratory for Future Interdisciplinary Research of Science and Technology, Tokyo Institute of Technology
*: dong.l.ab@m.titech.ac.jp

1. Introduction

For high-speed transmission, signal attenuation caused by the electrical wiring becomes a large issue. Co-packaged optics (CPO) are focusing on the high-integrated electrical-optical connection. Optical devices can be placed much closer to the switch ASICs within the package, which brings low power consumption and small footprint. Thanks to the high-speed and low-power consumption of VCSELs, CPO transceivers based on VCSEL array and multi-core fiber (MCF) are expected to play an important role in future datacenter and edge computing networks because of their ultrahigh data rates density per space.

In this paper, we demonstrate a 16-ch bottom-emitting MA VCSEL array based on a full 3-inch wafer process. It has a good uniformity of single-mode operation and modulation bandwidth. The 50Gbps transmission through 5km-long standard 1,300nm SMF is exhibited.

2. Device structure

Figure 1(a) shows the conceptional schematic of 16-ch VCSEL CPO transceiver with 19 core-MCF(Multi Core Fiber). The schematic of bottom-emitting metal-aperture VCSEL is shown in Fig. 1(b). The boundaries between oxidation aperture and metal contact are as small as 1 μm to realize the transverse resonance [1]. The photo of 16-ch bottom-emitting VCSEL array is shown in Fig. 1(c). The chip size is as small as 0.16 mm^2. Thus, the data rate density per area is as large as 2.5 Tbps/mm^2. The distance between each adjacent channels is 40 μm and a multi-core fiber is fabricated with the same hexagonal layout.

3. Results and discussions

Thanks to the full 3-inch wafer process, all 16 channels in the array show similar performance. The superimposed 16-ch I-V-L curves are shown in Fig. 2(a). The operation voltage at 6mA is as low as 2.2 V. The single-mode output power is typically 3 mW. The threshold current is 0.6 mA. Single-mode operations are obtained with a high SMSR over 40 dB as shown in Fig. 2(b).

The eye patterns for all 16 channels are shown in Fig. 3(a). For back-to-back transmission, eye patterns are clearly open at 25 Gbps with the extinction ratio of 5 dB. The total modulation speed of this 16-ch VCSEL is 400 Gbps per module.

In previous research, based on the calculation results, bandwidth enhancement was expected after transmission in standard SMF due to the pulse compression [2,3]. We carried out the eye pattern measurements after 5-km 1,300nm standard SMF(G652) transmission. We observed eye opening at 50 Gbps (NRZ) and 70 Gbps (PAM4) without pre-equalization shown in Fig. 3(b). The bandwidth and distance product is over 250 Gbps・km which is 25 time larger than 850 nm VCSEL/MMF links.

4. Conclusion

We demonstrate the 16-ch bottom-emitting VCSEL array with metal-aperture structure. The total modulation speed is over 400 Gbps per module, resulting in 2.5 Tbps/mm^2. After 5km SMF transmission, we show the 50 Gbps (NRZ) and 70 Gbps (PAM4). We expect to realize a 100 Gbps (PAM4) transmission per channels and then the total bandwidth will reach at 1.6 Tbps per module. Further scalability up to 3.2 Tbps or 6.4 Tbps could be expected increasing the number of MCFs.

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References

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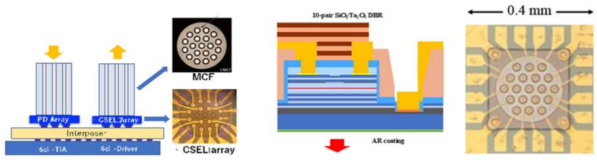

Fig. 1 (a) Schematic of VCSEL CPO transceiver, (b) Schematic of 1060nm bottom emitting metal aperture VCSEL, (c) Photo of 16-ch VCSEL array.

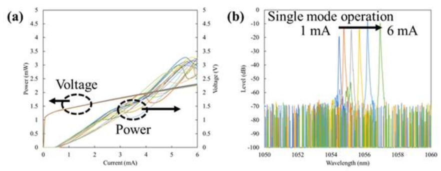

Fig. 2. (a) Superimposed IL characteristics of 16-ch array and (b) Lasing spectra at different currents.

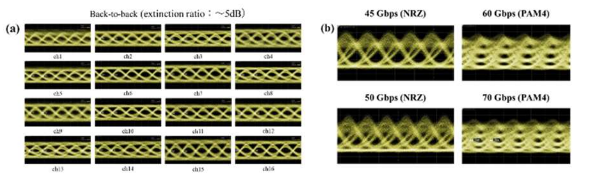

Fig. 3. (a) Eye pattern at 25 Gbps for all 16 channels. (b) Eye patterns after 5-km SMF transmission.