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著者(和文)	DONG LIANG, 顧 曉冬, 小山 二三夫
Authors(English)	Liang Dong, Xiaodong Gu, Fumio Koyama
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1060nm Single-mode Bottom Emitting VCSEL Array for Multi-core Fiber Co-packaged Optics Transceivers

(D2) 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

With the fast development of 5G, cloud computing, streaming and social networking, the Internet traffic keeps a high growth rate. Co-packaged optics (CPO) has been attracting much attention in data centers and edge computing networks since CPO brings optics much closer to switch ASICs in a single package, so that power consumption could be saved by reducing the reach [1]. A VCSEL gives us high-speed and low-power consumption [2], which will meet requirements in CPO.

In this paper, we demonstrate 16-ch bottom emitting VCSEL arrays with intra-cavity metal-aperture structure based on a full 3-inch wafer process, exhibiting the single-mode operation with a large mode field diameter for the low loss direct lens-less coupling to MCF.

2. Device structure

The photo of the 16-ch bottom emitting VCSEL array chip is shown in Fig. 1(a). The VCSEL array is fabricated by a full 3-inch wafer foundry process. The total chip size is as small as $1 \times 1 \text{ mm}^2$. The 16-ch VCSELs are arranged under the hexagonal layout with spacing of $40 \mu\text{m}$ as matched to the core layout of MCF. The schematic of bottom emitting MA-VCSEL is shown in Fig. 1(b). The GaAs substrate was polished with a thickness of below $100 \mu\text{m}$. Then, AR coating was carried out on the substrate back surface to reduce the reflection for direct coupling to MCF.

3. Results and discussions

The superimposed IL characteristics of all 16-ch VCSELs are shown in Fig. 2(a). The series resistance is as small as 80Ω thanks to a large oxide aperture of around $6 \mu\text{m}$. The threshold current is as low as 0.7 mA . Slope efficiency is approximately 0.3 W/A which could be improved by adjusting the pairs of DBR.

The lasing spectra of the 16-ch VCSEL array are shown in Fig. 2(b). The devices show single mode operations for the entire current range from 2 mA to 10 mA , thanks to the transverse resonance in the intra-cavity metal-aperture structure. The side mode suppression ratio is over 30 dB .

We also realized the bandwidth enhancement of single mode VCSEL array with intra-cavity metal-aperture by the modification of a DBR layer structure to enhance the transverse resonance. The small signal modulation response of the bottom emitting MA-VCSEL array is shown in Fig. 3 in comparison with conventional multi-mode 1060 nm VCSEL. The

modulation bandwidth is increased from 14 GHz to 22 GHz thanks to the transverse coupled cavity effect.

4. Conclusion

We demonstrated 16-ch bottom emitting MA-VCSEL based on full 3-inch wafer process, enabling flip-chip bonding for use in compact CPO transceivers. The spacing between each adjacent VCSELs is $40 \mu\text{m}$ and the total size of chip is as small as 1 mm^2 . With the intra-cavity metal-aperture, single mode operations were obtained with large oxidation apertures of $6 \mu\text{m}$, which is important for high reliability. Also, the bandwidth enhancement was observed thanks to the coupled cavity effect.

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References

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- [2] A. Larsson, IEEE J. Sel. Top. Quantum Electron. 17, 1552 (2011).

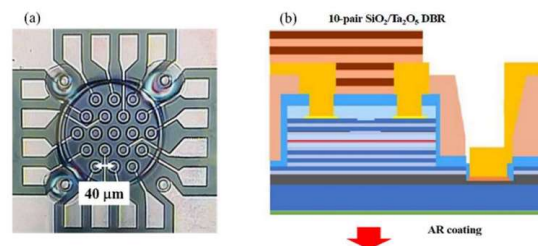


Fig. 2 (a) Photo of 16-ch bottom emitting VCSEL array and (b) schematic of bottom emitting VCSEL with intra-cavity metal aperture.

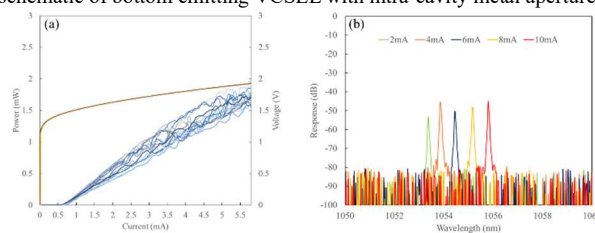


Fig. 3. (a) Superimposed IL characteristics of 16-ch array and (b) Lasing spectra at different currents.

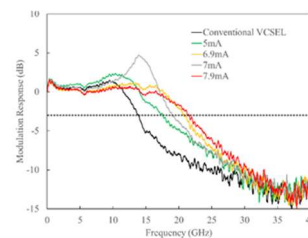


Fig. 5. Small signal modulation response of bottom emitting MA-VCSEL array in comparison with conventional multi-mode VCSEL.