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1060nm Single-mode Bottom Emitting VCSEL Array for Multi-core Fiber Co-packaged Optics Transceivers

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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 filed 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 1x1 mm^2. The 16-ch VCSELs are arranged under the hexagonal layout with spacing of 40 μm 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 μm. 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 80 Ω thanks to a large oxide aperture of around 6 μm. 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 μm 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 μm, 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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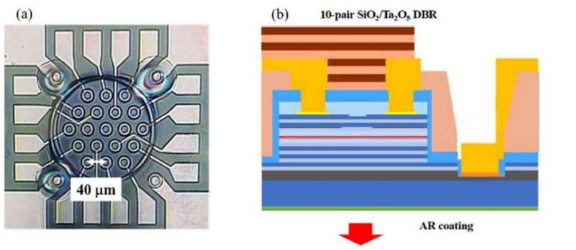

Fig. 2 (a) Photo of 16-ch bottom emitting VCSEL array and (b) schematic of bottom emitting VCSEL with intra-cavity metal aperture.

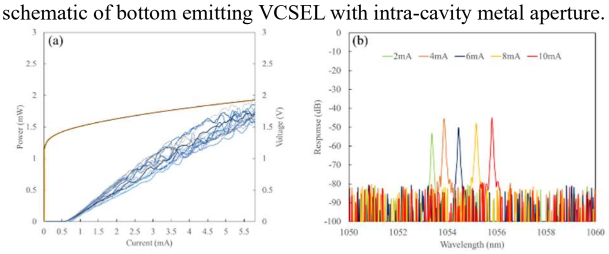

Fig. 3. (a) Superimposed IL characteristics of 16-ch array and (b) Lasing spectra at different currents.

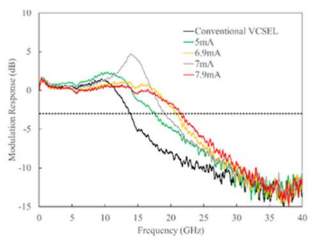

Fig. 5. Small signal modulation response of bottom emitting MA-VCSEL array in comparison with conventional multi-mode VCSEL.