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High-speed and Single mode 850nm Intracavity Metal Aperture VCSEL with Transverse Coupled Cavity Effect

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1. Introduction: Vertical cavity surface emitting lasers (VCSELs) have exhibited the advantages of low cost, ease of fabrication into arrays, small footprint, wafer-scale testing, and low power consumption [1, 2]. Therefore, VCSELs are attracting much attention for use in data center networks. The network traffic in data centers is increasing rapidly and hence the development of high speed VCSELs is a key issue. The modulation bandwidth of VCSELs is typically less than ~ 20 GHz due to the limited intrinsic carrier-photon resonance (CPR). We propose and demonstrate intracavity metal aperture VCSELs (MA-VCSEL) with a rectangular shaped oxide aperture. The fabrication process is exactly same as intracavity contact VCSELs. We found that the intracavity metal contact causes the transverse resonance [3] which provides the modulation bandwidth enhancement.
2. Device Structure: Figure 1 (a) illustrates the schematic structure of the fabricated single-mode MA-VCSEL. The size of an active region oxidation aperture is $9 \times 10 \mu\text{m}^2$, as shown in Fig.1(b) which is large enough for high reliabilities. We found that two lateral boundaries cause the transverse resonance as shown in Fig. 1(c).

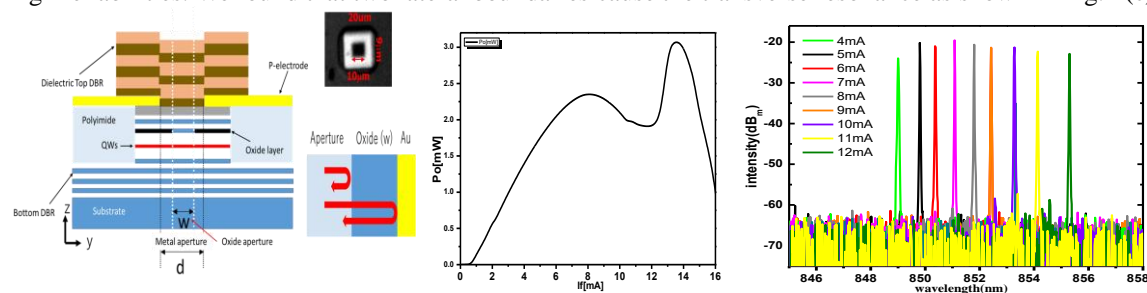


Fig.1. Schematic and top-view of infrared image of oxide aperture Fig.2. L-I curve for MA-VCSEL. Fig.3. Spectra measured

3. Results and discussions: The L-I curves of two fabricated devices were measured; one is for metal-aperture-VCSEL (MA-VCSEL) with a distance of less than $2 \mu\text{m}$ between the oxide aperture and metal aperture and the other one is conventional VCSEL (C-VCSEL) with a distance larger than $2 \mu\text{m}$ for comparison. Fig. 2 illustrates the L-I curve of MA-VCSEL with distance of $1.5 - 2 \mu\text{m}$ with oxide aperture size $9 \times 10 \mu\text{m}^2$. A kink appeared in the L-I curve as optical feedback induced from the metal boundary is coupled into the primary VCSEL cavity. The lasing spectra of the MA-VCSEL was measured a single-mode operation was obtained in the entire current range with SMSR of more than 40 dB as shown in Fig. 3. Figure 4 shows the measured NFP at 9mA bias current. currents. The mode field diameter is as large as $10 \mu\text{m}$ which is equal to the oxide aperture size. The small signal modulation response in MA-VCSEL is shown in Fig.5 the modulation bandwidth is over 20 GHz while it is 10 GHz for conventional VCSELs.

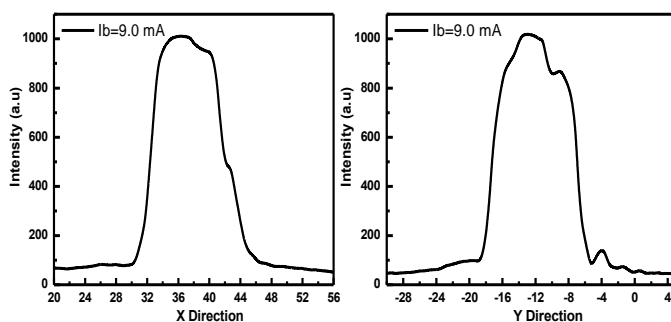


Fig. 4. NFP of MA-VCSEL in the X (a) and Y (b) directions

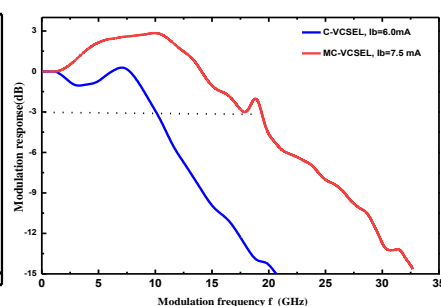


Fig. 5. Small signal modulation response of MA-VCSEL

4. Conclusions: In conclusion, we proposed and demonstrated the novel concept of high-speed and single-mode VCSELs with a large mode-field diameter. The mode field diameter is as large as $10 \mu\text{m}$ for single mode operations in the entire current range. The bandwidth can be double thanks to the coupled cavity effect.

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5. References

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