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1060nm Single-mode Transverse Coupled Cavity VCSEL with Surface Relief Engineering for High-speed Modulation

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INTRODUCTION

A vertical-cavity surface-emitting laser (VCSEL) is widely regarded as a key light source in supercomputers, data centers, and access/metro/core networks, in particular for short reach applications [1, 2]. However, the modulation speed of VCSELs is limited by their relaxation oscillation frequency to typically less than 20 GHz [3]. In this paper, we propose and demonstrate 1060nm VCSELs with surface relief engineering, showing single-mode operation and high modulation speed. Thanks to the optical-transverse resonance brought by the shallow etching of a semiconductor surface, clear eye opening was observed up to 54 Gbps NRZ and 80 Gbps PAM4 modulations. Single mode operations with SMSR of more than 30 dB in the entire current pump range were also realized

SCHEMATIC STRUCTURE

The 3D schematic structure of our proposed device is illustrated in Fig. 1(a). The device is fabricated based on a half-VCSEL structure. The process of surface relief is carried at the first step on the wafer. Round regions with a diameter of 6 µm and a 1µm ring outside was formed by shallow wet-etching process on the surface of a wafer. The etching depth is as small as 20 nm. Then round oxidized apertures were formed by mesa dry-etching and followed by wet-oxidation process with the surface relief pattern at center as shown in Fig. 1(a). The diameter of an oxide aperture is 6µm, which fits in the round etched region exactly. 5 pairs of dielectric Ta_2O_5/SiO_2 were deposited above the surface of the mesas to achieve enough top reflectivity as shown in Fig.1 (b). The distance between boundaries of the round region and outside ring is as small as 1 µm to observe the transverse coupled cavity effect [4]. Fig. 1(c) shows the top view of a surface relief of the mesa.

EXPERIMENTAL MEASUREMENTS

Measured spectra of the surface relief VCSEL at different bias currents with the same aperture size are shown in Fig. 2(a). Single mode operation is obtained in the entire current range with SMSR over 30 dB. The transverse mode control due to transverse-resonance is clearly proven by the experimental data. Fig. 2(b) shows the measured L/I of the surface relief VCSEL. As we can see, a single mode power of over 2 mW can be obtained. We measured the small signal modulation response of the surface relief VCSEL and conventional VCSEL fabricated on the same wafer as shown in Fig. 3. The epi-wafer structure is not optimized for high-speed modulation and thus the bandwidth of conventional VCSEL is limited to only 12 GHz as shown in the figure. The small signal bandwidth for the surface relief VCSEL is almost doubled (around 23 GHz at 5mA current) thanks to the transverse coupled cavity resonance. High speed large signal modulations are also carried out as shown in Fig. 4. We observed clear eye opening up to 54 Gbps (NRZ) with an extinction ratio around 4 dB as shown in Figs. 4 (a) and (b). Eye opening are also achieved for 70 Gbps and 80 Gbps PAM4 modulations as shown in Figs. 4 (c) and (d).1060nm Single-mode Transverse Coupled Cavity VCSEL with Surface Relief Engineering for 80Gbps PAM4 Modulation

CONCLUSIONS

We demonstrate the novel concept of high-speed and single-mode 1060nm VCSELs with surface relief engineering. The small signal bandwidth can be doubled thanks to the transverse-resonance brought by the surface relief. We demonstrated large signal modulation of 54 Gbps (NRZ) and 80 Gbps (PAM4). Further optimizations in the fabrication could offer high-speed modulations toward 100Gbps modulations with larger single-mode powers. Our device is promising to be used as high-speed transmitters in the next generation data centers and 6G network

ACKNOWLEDGEMENT

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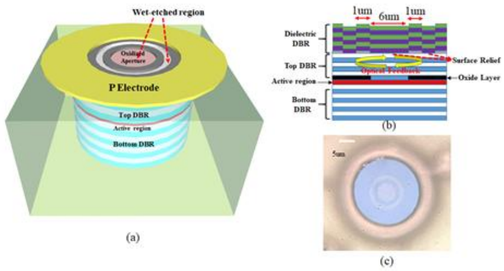

Fig. 1 (a) Schematic structure of the proposed device with surface relief engineering before top dielectric DBR evaporation, (b) Cross-sectional view of the schematic structure after dielectric DBR evaporation, (c) Top view of a surface relief.

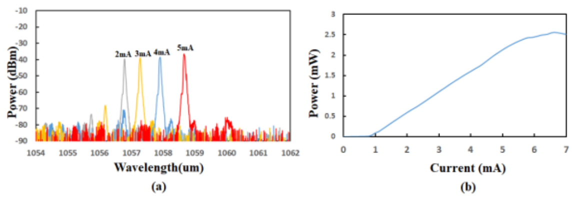

Fig. 2 (a) Measure spectra of a surface relief VCSEL at different currents, (b) Measured L/I of the surface relief VCSEL.

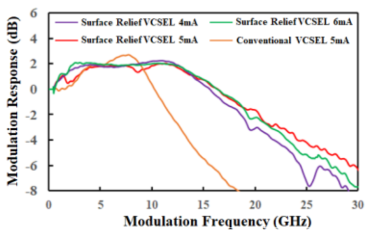

Fig. 3 Small signal response

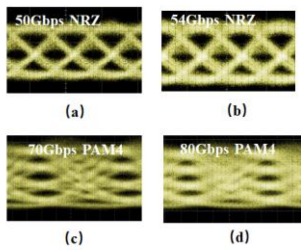

Fig. 4 Large Signal Modulation