Electro-absorption Modulator Integrated with Transverse Coupled Cavity VCSELs

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INTRODUCTION

Semiconductor lasers, especially VCSELs, have been widely used as data transmitters to construct cost-effective high-speed infrastructure [1]. A key challenge currently is to achieve higher modulation bandwidth of VCSELs to meet the demand for rapidly growing data traffics. Earlier works from our lab have shown that transverse coupled cavity VCSELs (TCC-VCSELs) can achieve a bandwidth enhancement through direct modulation [2,3]. On the other hand, the integration of an electro-absorption modulator is also a good candidate to realize high-speed operation beyond the limit of direct modulation. So far, there have been reports on vertical integrations of a VCSEL and an electro-absorption modulator [4]. In our group, we proposed and demonstrated the lateral integration of VCSEL and slow-light modulator [5]. However, there still remains a difficulty in increasing the coupled power. In this paper, we propose an electro-absorption modulator laterally integrated with TCC-VCSELs for increasing the output power.

SCHEMATIC STRUCTURE

A schematic structure of the coupled cavity VCSEL integrated with an electro-absorption modulator is illustrated in Fig. 1(a). The laser is connected with a wider external cavity on the right side and a mode selector on the left side. Electrical isolation is achieved through ION implantation. The connection between the laser cavity and external modulator leads to a leaky travelling wave in the lateral direction which can be absorbed when reversed voltage is applied at the modulator. The external cavity is much longer than the external modulator to avoid light reflection from the end surface of the cavity into the modulator. The mode selector is used for increasing the coupling strength between the laser and modulator. The near filed pattern of a fabricated device with 5mA current injection at the laser side is shown in Fig.1 (b). A very strong light leakage from the laser side into the modulator side can be clearly observed in the figure.

EXPERIMENTAL MEASUREMENTS

Output power of the device with different current injection at the laser side and no voltage at the modulator side is measured through a power meter and shown in Fig.2. Our device shows a strong output power of over 1mW under current injection beyond 5.5mA at the laser side, which should be enough for modulation operation. With reversed voltage at the modulator side, we expect large extinction ratio of the external modulator based on the NFP above.

In Fig.3, output power of the device under 5.5mA at the laser side and different bias voltage at the modulator side is shown. The effect of electro-absorption is clearly observed. With increased revrsed bias voltage at the external cavity, output power from the device decreases quickly. A extinction ratio of nearly 7dB is achieved with -3v bias voltage at the modulator. The experimental measurments agree with our expectations. It should be noted that some kinks can be seen on the curves in Fig.2 and Fig.3. These kinks are due to the optical feedback from the end face of the external cavity. We plan to applied reversed voltage at the end of the external cavity to avoid optical feedback in the future before the small and large signal modulation.

CONCLUSIONS

Based on the experimental results, we demonstrate that our electro-absorption modulator integrated with TCC-VCSELs can achieve a rather high output power, large coupling strength and extinction ratio. This kind of device is expected to be used as a high-speed, super-compact and cost-effective external modulator in the future.

REFERENCES

[1] F. Koyama, J. Lightwave Technol. **24**, 4502 - 4513 (2006).
[2] H. Dalir and F. Koyama, Appl. Phys. Lett.**103**, 091109 (2013).
[3] X. Gu, M. Nakahama, A. Matsutani, F. Koyama, ECOC 2015, 7341735 (2015).
[4] D. M. Grasso, D. K. Serkland, G. M. Peake, K. M, Geib, and K. D. Choquette, IEEE J. Quantum Electron., 42, no. 12, pp1248-1254 (2006),
[5] H. Dalir, Y. Takahashi and F. Koyama, OPTICS EXPRESS, vol. 22, no. 21, pp. 25746-25755, (2014).

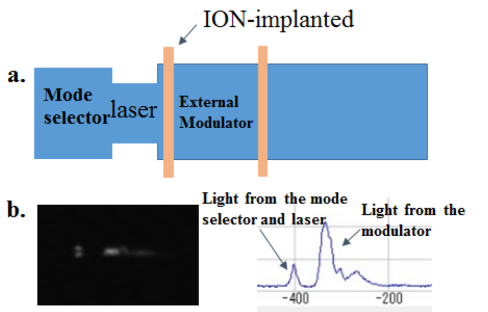

Fig. 1 (a) Schematic structure of the integrated external modulator based on TCC-VCSELs (b) Near field pattern of one device.

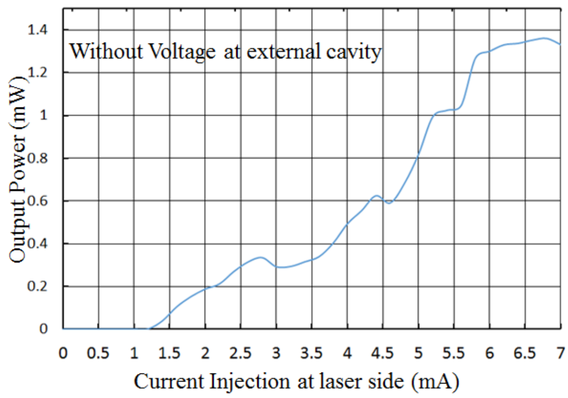

Fig. 2 Output power of the integrated external modulator with different current injection at the laser side.

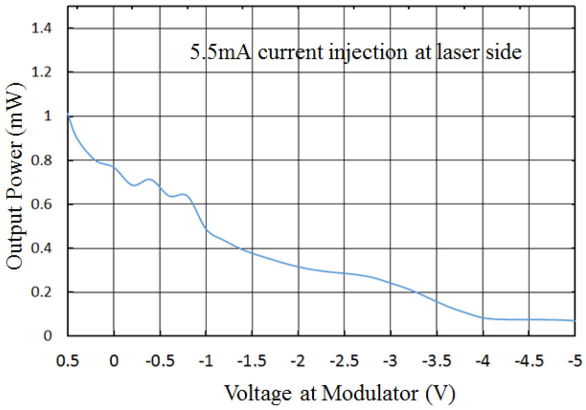

Fig. 3 Output power of the integrated external modulator with 5.5mA current injection at laser side and different voltage at the external modulator.

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