Record High Power Single-Mode Operations of Surface Grating VCSELs

Tokyo Tech. P&I Lab., ○Ahmed M. A. Hassan, X. Gu, M. Nakahama, M. Ahmed, and F. Koyama
E-mail: hassan.a.ab@m.titech.ac.jp

Introduction: Due to diverse applications such as LiDAR and 3D sensing, the global market for VCSELs has exploded in recent years. High beam quality, ease of fabrication in two-dimensional arrays, and low-cost mass-production are advantages of VCSEL for these novel applications. Single-mode VCSELs, on the other hand, are limited by their low output power, which can be typically as low as a few mW. The amplification of slow light mode (SLM) is an efficient way to scale up the power to watt-level in a mm-long of conventional VCSEL structures [1]. However, nearly-diffraction-limited narrow beam divergence with high power was obtained, external seed laser is needed to excite SLM [1]. Recently, we proposed and demonstrated a single SLM operation using shallow surface grating VCSEL (SG-VCSEL) [2-4]. Using a high-order grating, we recorded a high power of single mode more than 3W limited by high order diffractions [3]. In this paper, we present a first-order SG-VCSEL with period length of Λ=0.52 µm. A single fan-shape beam is obtained for a 6 mm long device, exhibiting an output power of over 6W under pulse operation and a nearly-diffraction-limited narrow divergence of 0.038° under CW operation.

Structure: Figure 1(a) displays the top view of real device SG-VCSEL. The vertical layer structure is the same as that of conventional oxide confined 850 nm GaAs VCSELs [1-3]. The oxide aperture width is 4µm to obtain a single transverse mode. The output is taken through a top DBRs; thus no facet damages is seen for high-power operations. The radiated output is tilted from vertical by angle (θ) depend on the lasing wavelength as shown in Fig.1(b). The output power can be proportional to the device length which can be extended to several millimeters or even to centimeters. Also, the beam divergence is inversely proportional to the device length which leads to obtain high-power and narrow divergence at the same time.

Results: The L/I characteristics under both CW and 50 ns pulse operations are shown in Fig.1 (c). The maximum output power of 6W limited by self-heating where there is no heatsinking used in experiments. Stable single mode without mode-hoping is confirmed by lasing spectra as shown in insets Fig.1(c) at high currents as 6A and 10A. Far filed pattern is measured as in Fig.1(d). A single diffraction limited fan-beam with divergence of 0.038° was obtained, at low current as 0.35A. Increasing of current to 10A causes broadening of FFP to 0.23° as results of non-uniformity of current and self-heating effect. By wire bonding and using cooler or heatsink to avoid a heat effect at high currents, we predict more power with better beam quality.

Conclusion: We demonstrated the record high power and single-mode operation of the SG-VCSEL, exhibiting 6W with high beam quality. The result shows a potential of the proposed SG-VCSEL for applications such as LiDAR and 3D sensing. We expect higher powers more than 10 W for longer devices with improving the current uniformity. The proposed device offers various unique features such as no facet damages, easiness of grating fabrications, the availability of well-establish VCSEL fabrication processes, and so on.

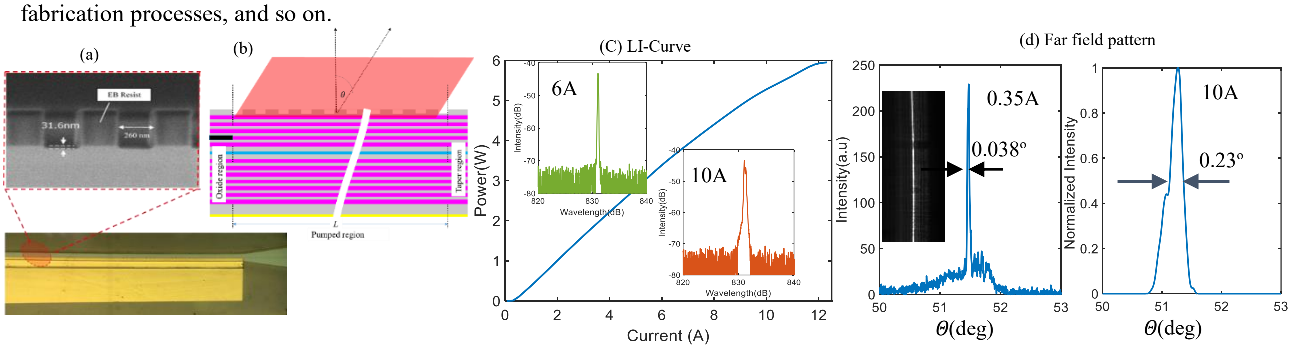

Figure 1: (a) shows the top view of real device with surface grating. (b) is schematic diagram for radiation direction. (c) is L-I curve where the insets figure show wavelength spectrum at 6A and 10A respectively. (d) is FFP at currents 0.35A and 10A respectively.

Acknowledgement: This work was supported by NEDO.

References

[1] F. Koyama, "High Power VCSEL Amplifier for 3D Sensing", Conference on Lasers and Electro-Optics (CLEO), 2020.

[2] A. Hassan, M. Ahmed, M. Nakahama and F.o Koyama, "High-power, quasi-single-mode vertical-cavity surface-emitting laser with near-diffraction-limited and low-divergence beam'', 2020 Jpn. J. Appl. Phys..

[3] A. Hassan, X. Gu, M. Nakahama, S. Shinada, M. Ahmed and F. Koyama, "High power and high beam quality surface grating VCSELs," Conference on Lasers and Electro-Optics (CLEO), 2021.

[4] A. Hassan, X. Gu, M. Nakahama, S. Shinada, M. Ahmed and F. Koyama, "4 W Single-Mode Operation of Surface Grating VCSELs," submitted to 2021 IEEE Photonics Conference (IPC).