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Dynamic characteristics of GaN-based vertical-cavity surface-emitting laser with an AlInN/GaN semiconductor distributed Bragg reflector

Toshihide Ide[1,2], Ryousuke Iida[3], Tetsuya Takeuchi[3], Xuelun Wang[2], Noriyuki Takada[1] and Mitsuaki Shimizu[2]

[1] National Institute of Advanced Industrial Science and Technology (AIST)
Tsukuba Center 2, 1-1-1 Umezono, Tsukuba, 305-8568, Japan
Phone: +81-29-861-3465 E-mail: t-ide@aist.go.jp
[2] AIST-NU GaN Advanced Device Open Innovation Laboratory (GaN-OIL),
National Institute of Advanced Industrial Science and Technology (AIST)
Furo-cho, Chikusa-ku, Nagoya 464-8601, Japan
Phone: +81-52-736-7611
[3] Meijo University
1-501, Shiogamaguchi, Tempaku-ku, Nagoya 468-8502, Japan
Phone: +81-52-838-2293

Abstract

GaN-based vertical cavity surface emitting laser with an AlInN/GaN semiconductor distributed Bragg reflector has been demonstrated at a wavelength of 415 nm, a threshold current of 7 mA, and a rf input of 1.1GHz. Moreover, the switched light output waveform with steep peaks is observed by the pulsed voltage operation.

1. Introduction

The blue light surface emitting lasers are expected as micro light sources such as a head mount display. Recently, GaN-based blue vertical cavity surface emitting lasers (VCSELs) are demonstrated at the room temperature continuous wave (RT cw) operation [1]. Mainly, their GaN-based VCSELs have a pair of dielectric distributed Bragg reflectors (DBRs) because the epitaxial growth of a semiconductor DBR is difficult due to the large lattice mismatch between GaN-based materials. On the other hand, the fabrication process of VCSELs with a semiconductor DBR is simpler than those with a pair dielectric DBRs. Nowadays, the RT cw operation of GaN-based VCSELs with a semiconductor DBR have been reported [2].

Until now, the dynamic characteristics of GaN-based VCSELs have been reported only in the case of the pair of DBRs [3]. In that report, the dynamic characteristics at the rf frequency of 1GHz has been reported at the cw RT operation. Its device diameter, threshold current, and the parasitic capacitance are 10 μm, 18 mA, and 0.85 pF, respectively. Since its *RC* delay is over 10 GHz, it is predicted that the dynamic characteristics are restricted not by the parasitic elements such as resistances and capacitances.

In this study, we evaluate the dynamic characteristics of the GaN-based blue VCSELs with a semiconductor AlInN/GaN DBR.

2. Experiments

Figure 1 shows the cross-sectional schematic diagram of the fabricated VCSEL. The 40 pairs of undoped-AlInN/GaN semiconductor DBR was grown on (0001) GaN substrate. The active region consists of 5 pairs of InGaN/GaN multi quantum well layers on the n-type GaN layer. On the active region, the p-type GaN layer and the SiO_2 layer with an aperture for the insulating and the current confinement is fabricated. As the p-type electrode, the thin ITO film was deposited. Details of the device structure is described in Ref. 3. The aperture diameter is 5 μm and, this is almost the effective beam spot diameter.

As the device characteristics, the current – voltage *V-I* characteristics, the light output – current *I-L* characteristics, and the spectral characteristics were measured. For the dynamic characteristic measurement, the network analyzer E5061B was employed, and the spectra are measured by the ANDO AQ6315A. At the pulse measurement, the photodetector THORLAB DET025A/M was used. All these measurements were performed at the RT cw operation.

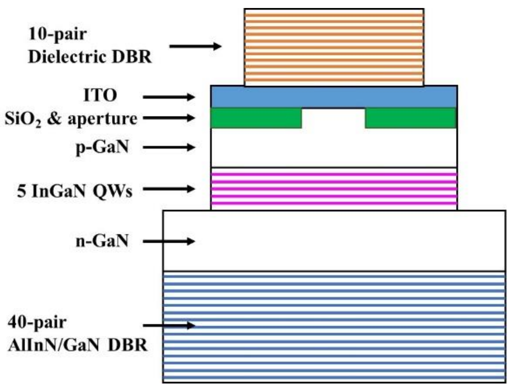

Fig. 1 cross-sectional schematic diagram of the fabricated VCSEL with a AlInN/GaN semiconductor DBR.

3. Results and discussion

Figure 2 shows the *V-I* and the *I-L* characteristics of the fabricated VCSEL. The threshold current is 8 mA. From the spectral measurements, the lasing wavelength and the full width at half maximum (FWHM) are 415 nm and 0.5 nm at the resolution of 0.2 nm, respectively.

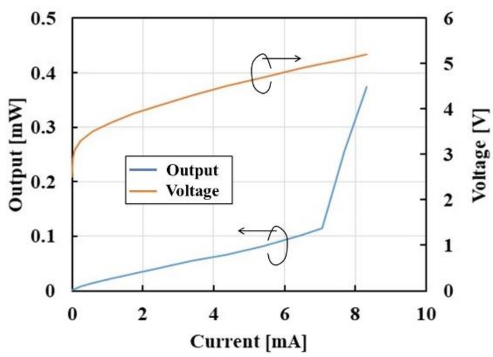

Fig. 2 *V-I* and the *I-L* characteristics of the fabricated VCSEL.

Figure 3 shows the lasing spectra of the dynamic operation varying the applied dc voltage. The rf input power provided by the network analyzer was fixed at the 10 dB, which corresponds to the sinewave voltage with an amplitude of 0.7 V. By increasing the dc voltage, the peak intensity is enhanced. In this voltage change, there is no change of the lasing wavelength and the FWHM of the peak.

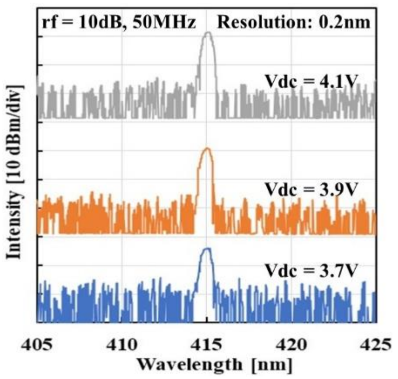

Fig. 3 lasing spectra of the dynamic operation varying the dc voltage.

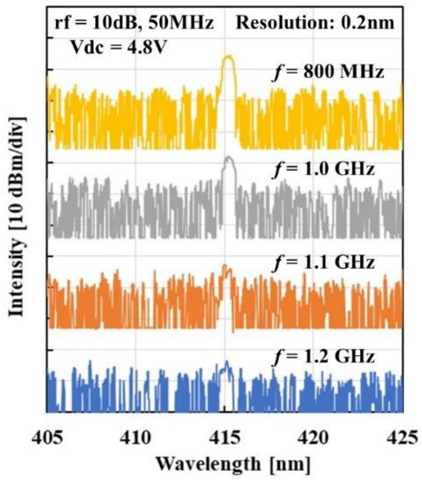

Fig. 4 lasing spectra at a frequency of around 1 GHz. For enhancing the lasing frequency.

Figure 4 shows the lasing spectra at a frequency of around 1 GHz. For enhancing the lasing frequency, the dc voltage is increased. The injection current in these conditions is assumed to be around 15 mA. At the frequency of the 1.1 GHz, the lasing peak can be observed. Since in our measurement, the spontaneous emission peak could be measured at the resolution of above 1.0 nm, the spectral peak at the 1.1 GHz is obviously due to the lasing operation.

Figure 5 shows the light output waveform driven by the square pulse voltage. The amplitude of the pulse voltage is 1.4 V, and the dc voltage of 4 V is applied. The repetition frequency and the duty are 20 MHz and 20%, respectively. In Fig. 5, the switched light output waveform with steep peaks is observed by the pulsed voltage operation. The time of this steep peak is considered to correspond to the maximum lasing frequency.

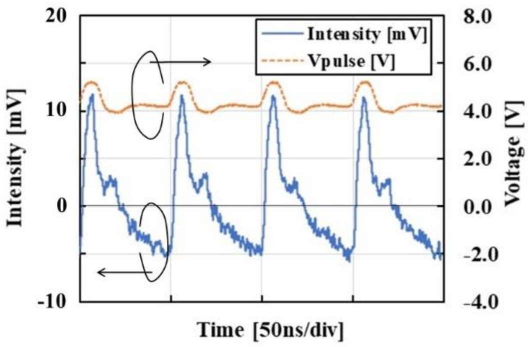

Fig. 5 light output waveform driven by the square pulse voltage.

From the impedance measurement, the resistance and capacitance in our device are 85 Ω and 1 pF, respectively. The *RC* delay estimated by these values is about 10 GHz. Therefore, in our VCSEL, the maximum frequency is considered to be not affected by the *RC* delay. Moreover, our maximum frequency is similar to those of the VCSEL with a pair of dielectric DBRs and the stripe-type GaN-based lasers. In these results, the bottle neck of the maximum frequency may be the hole injection due to its low mobility.

4. Summary

In summary, we demonstrated the dynamic characteristics of GaN-based VCSEL with a semiconductor DBR by driven the rf sine wave and pulse wave voltage. The maximum lasing frequency of 1.1 GHz can be obtained. This value may be dependent on the behavior of the hole injection.

Acknowledgements

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