Extended Abstracts of the 2003 International Conference on Solid State Devices and Materials, Tokyo, 2003, pp. 170-171

A-4-1 (Invited)

1300nm-range GaInNAsSb VCSELs

A. Kasukawa, H. Shimizu, C. Setiagung, M. Ariga, Y. Ikenaga, K. Kumada, T. Hama, N. Iwai
The Furukawa Electric Co., Ltd., Yokohama R&D Laboratories
2-4-3 Okano, Nishi-ku, Yokohama 220-0073, Japan
Tel;+81-45-311-1219, Fax;+81-45-314-5190, Email; kasukawa@yokoken.furukawa.co.jp

1. Introduction

GaInNAs [1], GaAsSb, and InAs quantum dots have been attracting much interest as an active media for long wavelength VCSELs on GaAs substrate, because there are advantages that they can be grown monolithically on GaAs/AlGaAs DBR mirror with the high reflectivity and the high thermal conductivity, and one can utilize the matured technologies established for 850-980 nm VCSELs such as AlAs selective oxidation. Since the large conduction band offset can be realized in GaInNAs/GaAs based structure, GaInNAs based material is the leading candidate for temperature-insensitive 1300nm-range VCSELs. Therefore GaInNAs based VCSEL is very promising to be used as high-speed transmission light sources for the SAN/WAN and the metro/access networks.

However, there are rooms to be improved on the crystal quality for practical applications in the 1300 nm wavelength. GaInNAs-VCSELs were reported to have the high Jth of 3.5-12 kA/cm^2 [2-6], which are more than twice as high as those of 850 nm VCSELs. For the solution of this problem, we have proposed GaInNAsSb QW active media [7,8] that includes the small amount of Sb to improve the crystalline quality of GaInNAs by GSMBE growth. We obtained the very low threshold current density of 450 A/cm^2 (150 A/cm^2/well [9]) for in-plane lasers with triple QWs, which is the world record in 1300nm-range GaInNAs-based lasers to our best knowledge. Using this material for the active media, we accomplished the first CW operation of 1300 nm-range VCSELs and VCSEL array with the low threshold current density, the low threshold voltage and the low differential resistance [10]. In this paper, we review the state of the art of long wavelength VCSELs based on GaInNAs(Sb) QWs.

2. Fabrications and Results

Figure 1 shows the schematic diagram of a long wavelength VCSEL. The VCSEL structure with the doped p, n-DBR is grown on an n-GaAs substrate. The active layer is made up of strain-compensated $Ga_{0.63}In_{0.37}N_{0.012}As_{0.972}Sb_{0.016}$ /$GaN_{0.019}$ $As_{0.981}$ triple quantum wells. Mesa-structures buried by polyimide with current flowing aperture by the selectively oxidation of AlAs layer were prepared.

Figure 2 shows the temperature dependence of light output power versus injection current (L-I) curve. The maximum output power increased up to 1.4 mW at 25˚C with the slope efficiency of 0.18 W/A, and the maximum lasing temperature increased up to 95˚C. The maximum single mode output power of 0.73 mW is obtained for a smaller device. Figure 4 shows the lasing spectrum for this device at different bias current. The VCSELs lased at the single mode with an SMSR more than 45 dB up to the injection current of 7 mA. Far-field patterns are shown in Fig.5. A narrow and circular output beam is obtained. A very high coupling efficiency of approximately 70 % into an SMF is obtained without coupling lens, which enables us to realize low cost package. The results of the ACC aging test were shown in Fig.6. The test was carried out at 100˚C under a constant current of 5 mA, corresponding to 11 kA/cm^2. No appreciable change in output power is observed for more than 3500 hours. These results indicate that GaInNAsSb-QW is suitable material for 1300 nm VCSELs.

After the first demonstration of GaInNAs lasers [1], drastic improvements have been accomplished. By the use of GaInNAsSb QW instead of GaInNAs QW, further improvements on lasing characteristics including reliability for long wavelength VCSELs will be expected in near future.

References

[1] M. Kondow et al., Jpn. J. appl. Phys., vol.35, pp.1273-1275, 1996.
[2] S. Sato et al., Electron. Lett., vol. 36, pp. 2018-2019, 2000.
[3] A.W. Jackson et al., Electron. Lett., vol. 37, pp. 355-356, 2001.
[4] T. Takeuchi et al., Conf. Proc. LEOS'01, PD1.2, San Diego, USA, 2001.
[5] A. Ramakrishnan et al., Electron. Lett., vol. 38, pp. 322-324, 2002.
[6] C.S. Murray et al., Proceedings of SPIE, vol. 4649, pp. 31-38, 2002. [7] H. Shimizu et al., IPRM'01, WP-56, Nara, Japan, 2001.
[8] H. Shimizu et al., IEEE J. Select. Topics Quantum Electron., vol.7, pp.355-364, 2001.
[9] C. Setiagung et al., ISLC'02, TuA4, Garmisch, Germany, 2002.
[10] H. Shimizu et al., ISLC'02, ThA2, Garmisch, Germany, 2002.

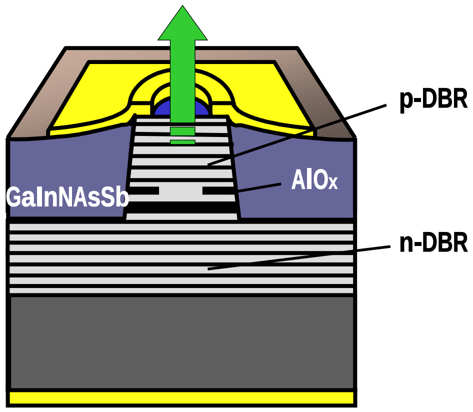

Fig.1. Schematic diagram of a 1300 nm VCSEL.

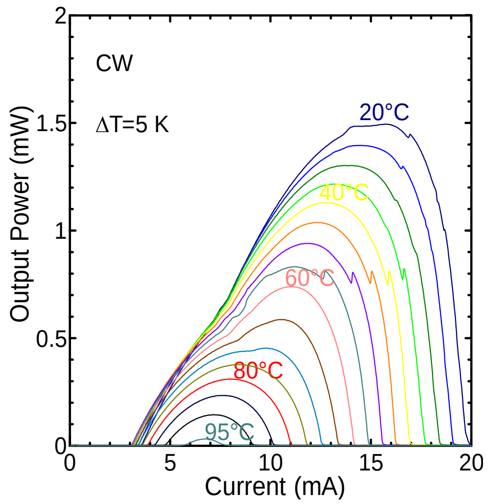

Fig.2. Temperature dependence of the light-current curves under CW operation.

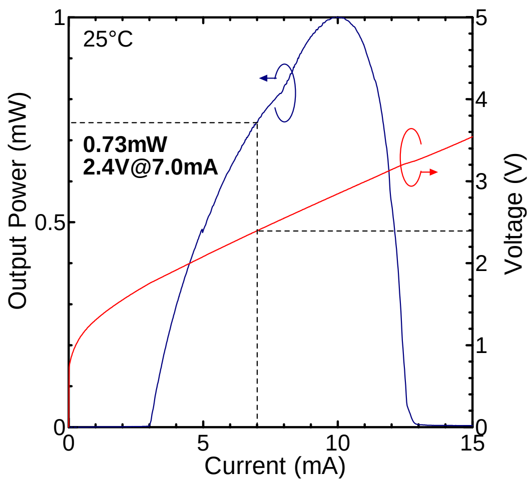

Fig.3. L-I-V curve for a smaller aperture device.

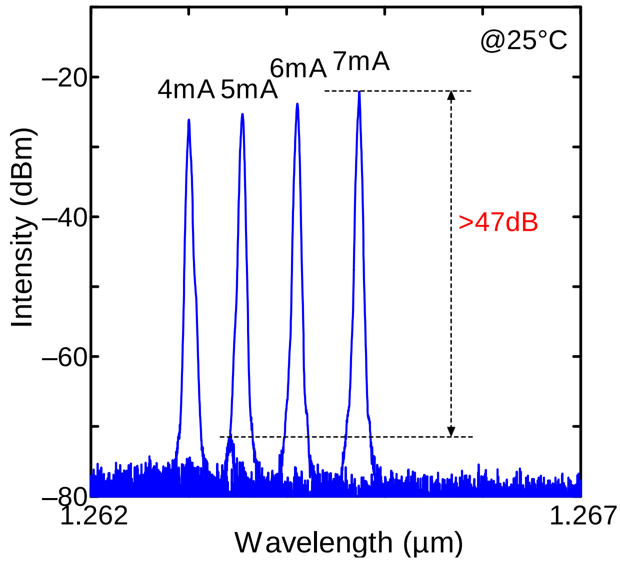

Fig.4. Lasing spectrum for the device at bias current of 4, 5, 6, 7 mA.

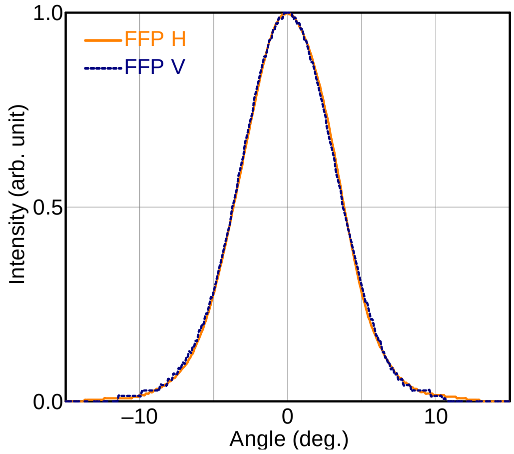

Fig.5. Far-field pattern

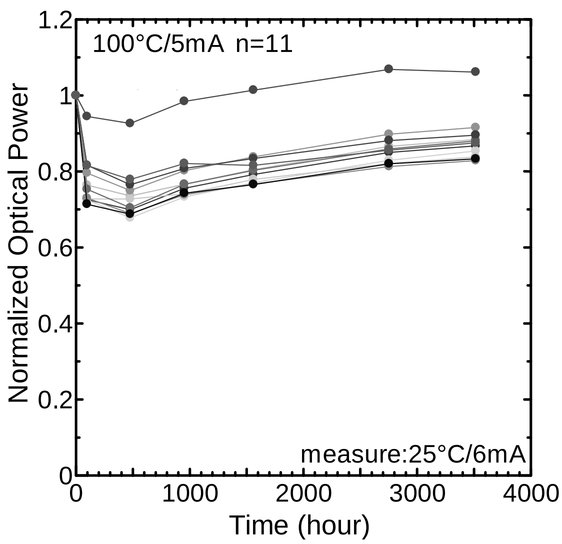

Fig.6. ACC accelerated aging test.