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Lateral grating DFB AlGaInN laser diodes for optical communications and atomic clocks.

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Abstract. AlGaInN laser diode technology is of considerable interest for telecom applications and next generation atomic optical clocks based on Sr (by using 422nm & 461nm) and Rb at 420.2nm.Very narrow linewidths (<1MHz) are required for such applications. We report lateral gratings on AlGaInN ridge waveguide laser diodes to achieve a single wavelength device with a good side mode suppression ratio (SMSR) that is suitable for atomic clock and telecom applications.

1.Introduction

Laser diodes fabricated from the AlGaInN material system is an emerging technology for next generation telecommunication systems and optical clocksbased on Sr (meeting the 88Sr+ cooling transition [5s2S1/2 -5p2P1/2] by using 422nm & 461nm) and a blue cooling transition for Rubidium (Rb) [4p65s2S1/2 - 4p66p2P3/2] at 420.2nm.A requirement for both of these applications is the need for a single longitudinal optical mode, with a very narrow linewidth (<1MHz), that is stable over a wide range of operating conditions. An AlGaInN laser diode with an etched DFB grating structure to achieve single longitudinal mode performance can be considered. However, there are significant challenges to fabricate a conventional buried DFB grating GaN laser diode.As an alternative, we report preliminary work on lateral grating AlGaInN laser diodes to achieve continuous wave single longitudinal optical mode performance that is suitable for atomic clock and telecom applications.

2.AlGaInN laser diode results

We fabricate AlGaInN ridge waveguide laser diode structures for single transverse mode operation and package the processed laser diode chips into TO5.6mm packages [1].The LIV and the beam profile characteristics for a 2µm ridge waveguide LD structure are shown in figure 1a). The device has an optical power of ~80mW, threshold current of ~65mA, a threshold voltage of ~5 V, a lasing wavelength of 410nm, and a characteristic temperature T_0 of ~120 K. A single transverse mode optical beam profile is observed in both the slow and fast axis (see fig.1 b).

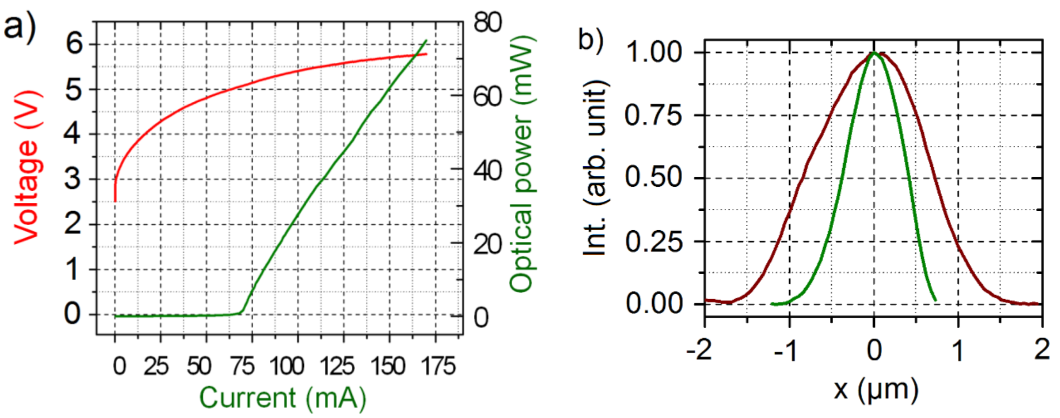

Fig.1 AlGaInN 410nm laser diode characteristics, a) LIV , b) Near-Field (slow axis – red line, fast axis – green line).

High resolution spectral measurements of the AlGaInN LD's reveal the fine mode structure with a characteristic dominant single longitudinal mode in all of these devices more reminiscent of a DFB type of laser device with etched grating, providing optical feedback for mode selection, rather than a more standard 'mode comb' Fabry-Perot device with no etch grating (see fig.3)[1].

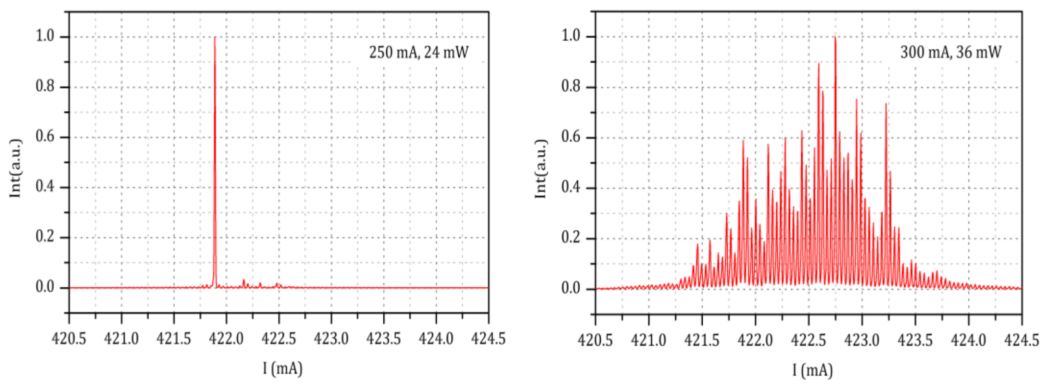

Fig 2 The evolving spectra of a LD's vs increasingcurrent mA/optical power mW (cw) at 20^{0}C

The above results for a Fabry-Perot laser diode (with no etched grating) show that single longitudinal mode operation is achievable; however the mode is unstable and hence is unsuitable for most applications. Therefore we consider sidewall etched as one of the simplest way of manufacturing gratings on ridge waveguide laser devices (figure 3). They have the advantage of simplified fabrication compared to more conventional DFB structures with no need for complex overgrowth steps and have been demonstrated in a range of other material systems and wavelengths [2,3]. However at wavelengths around 400 nm the fabrication of gratings becomes technologically challenging with a first order grating requiring a feature size of around 40 nm, dimensions not practical with our current fabrication technology. In this study we report on preliminary etch and modelling studies of AlGaInN laser diode structures in order to understand the issues of side-wall etching versus laser diode single longitudinal mode performance in order to obtain a practical solution.

3.Fabrication

Device fabrication was carried out on ~410 nm GaN laser grade material. The fabrication for both third order and high order gratings follows the same general process. Grating and ridge patterns were defined in ZEP 520 resist using electron beam lithography (EBL). The EBL tool used was a Vistec VB6 UHR having a write resolution of 1.0nm, enabling the accurate targeting of the emission wavelength. Reactive ion etching was used to transfer the pattern into a 100 nm thick SiO2 hard mask. Inductively coupled plasma (ICP) etching on an STS Multiplex tool was then used to form the grating and ridge. A Cl2/N2 based ICP etch process with 300 W platen and 600 W coil power produced the vertical and smooth etch profile required for good grating performance.

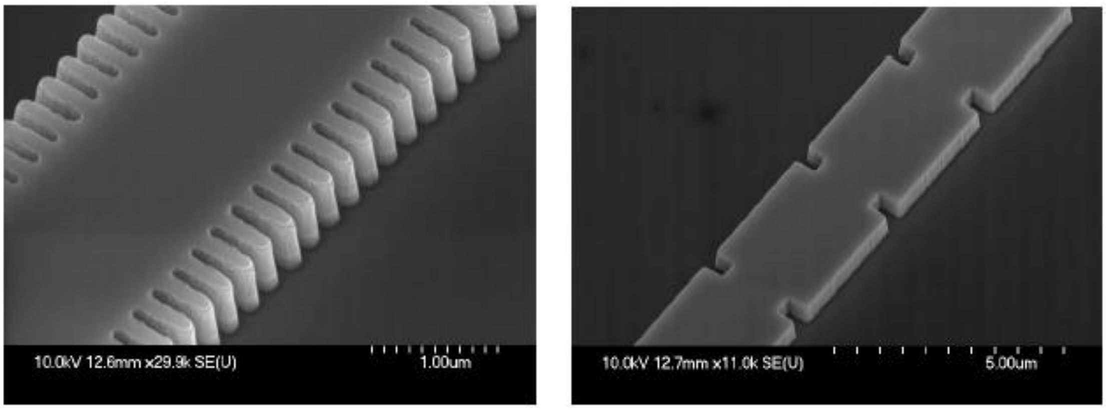

Figure 3 SEM micrographs of the (a) 3rd order grating and (b) the 39th order grating.

4. Conclusions

We observe single longitudinal optical mode performance from a ~420nm AlGaInN laser diode at moderate optical powers (~20mW) and small SMSR. To stabilise the optical mode we investigate side-wall lateral gratings as a way to develop a practical AlGaInN laser diode. We have performed modelling and etch studies of 3^{rd} and 39^{th} order grating to understand the issues with side-wall gratings in AlGaInN ridge waveguide laser structures. Future work will focus on achieving cw operation via an optimised grating design.

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REFERENCES

[1] Najda S P, Perlin P, Suski T, Marona L, Leszczyński M, Wisniewski P, Czernecki R, Kucharski R, Targowski G,Watson M A, White H, Watson Sand Kelly A E.*Opt. Eng.***55**(2), 026112 (2016). doi: 10.1117/1.OE.55.2.026112
[2] Slight T J, Odedina O, Meredith W, Docherty K E, andKelly A E, SPIE OPTO 2016 (pp. 97481A-97481A). International Society for Optics and Photonics.
[3] Zhong Y,Zhu X,Song G,Huang Y,Chen L, Semicond. Sci. Technol. 19(8), 971–974 (2004).