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GaInNAs Distributed Feedback (DFB) Laser Diode with High Resistive Semiconductor Current-blocking Layer

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Abstract

GaInNAs-DFB laser with a high resistive semiconductor current-blocking layer was developed. CW oscillation could be possible up to 110 °C with SMSR > 42dB. 10-Gbps-modulation with a clear eye-opening could be possible between 25 °C and 80 °C.

1. Introduction

Distributed feedback (DFB) lasers with excellent single-mode lasing characteristics are now commonly used in optical networks. However, for the wider use of them, especially in access networks, uncooled operation is essential to reduce the cost and power-consumption drastically. DFB lasers using GaInNAs [1] seem to be most promising for this purpose because carriers (especially electrons) can be confined in the active layer strongly in this material system, leading to much better temperature characteristics than the conventional GaInAsP/InP DFB lasers.

Recently we developed a buried-ridge GaInNAs-DFB laser [2], in which a GaAs grating was formed just above a GaInNAs active region in a current injection region, and was overgrown by an upper cladding layer. In this structure, the center part of a propagating light with high-intensity can be coupled to the grating, so that large coupling coefficients can be obtained easily. Although this structure is common in conventional DFB lasers, we introduced it into the GaInNAs-DFB laser for the first time. Under CW condition, it could oscillate up to 120 °C with SMSR more than 40 dB.

However, this laser had a large parasitic capacitance due to the pn junction in the current-blocking region, and therefore it was not suitable for a high-speed operation. To address this issue, we newly introduced a high resistive semiconductor layer into the current-blocking region to reduce the parasitic capacitance significantly.

In this paper, we report on the first successful operation of a buried-ridge-stripe GaInNAs DFB laser with a high resistive semiconductor current-blocking layer. Good CW single-mode oscillations with SMSR > 42dB were obtained up to 110 °C, and I-L characteristics with good linearity were obtained up to 100 °C. In addition, 10-Gbps-modulation with a clear eye-opening could be possible between 25 °C and 80 °C.

2. Device Structure and Fabrication

A cross-sectional view of the laser is shown in Fig. 1. The epitaxial growth was done by low-pressure OMVPE.

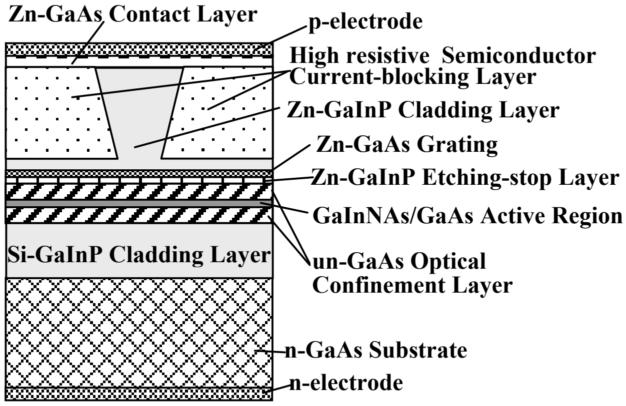

Fig. 1. Cross-sectional view of a GaInNAs DFB laser.

In the first growth, an Si-GaInP cladding layer, an active region sandwiched between undoped GaAs optical confinement layers, a Zn-GaInP etching-stop layer, and a Zn-GaAs grating layer were grown. The active region consists of two $Ga_{0.65}In_{0.35}N_{0.006}As_{0.994}$ quantum well layers (7 nm) separated by a GaAs barrier layer (8 nm).

After the first growth, a first-order Bragg-grating which had a period of 186.8 nm corresponding to a Bragg wavelength of 1237.7 nm and a duty ratio of 50 % was formed in the GaAs grating layer using electron beam lithography and wet-etching.

Next a Zn-GaInP cladding layer and a Zn-GaAs contact layer were overgrown on the GaAs-grating, and a ridge-stripe structure was formed by wet-etching of these layers. Then both sides of the ridge-stripe were buried by high resistive (>10^{10} Ωcm) current-blocking layers to form a buried-ridge structure. Finally, p- and n-electrodes were formed, and thus the laser structure was completed. Laser chips were made by cleavage, and AR/HR facet coatings were performed.

Our structure has the following merits. First, the GaInP layer under the GaAs grating layer can act as an etching-stop layer, so that the etching of the GaAs grating layer can be stopped automatically when the etched surface reaches the GaInP etching-stop layer. Second, since the refractive index difference between the GaAs grating layer and the GaInP cladding layer is large (about 0.2), a small etching depth of the grating is enough to obtain a sufficient coupling coefficient, which makes the flat overgrowth on the grating easy. Finally, by using Al-free materials for the grating and the adjacent layers, oxidization of these layers can be suppressed effectively. This contributes to excellent overgrowth on the grating. In fact, we confirmed in the TEM observation that the

Zn-GaInP cladding layer was successfully overgrown on the GaAs-grating without defects or anomalous growth at the regrowth interface of the GaAs grating region. These merits contribute to a good uniformity and a good reproducibility of the device fabrication.

3. Results and Discussions

The AR(<0.1%)/HR(>90%) coated laser chip having a 300 μm-long cavity and a 2 μm-wide stripe was bonded on a heatsink in a p-side-up configuration. Measurements were performed under CW condition. Fig.2 shows the I-L characteristics. The threshold current and the slope efficiency (SE) at 25 °C were 19.9 mA, and 0.28 W/A, respectively. Oscillation could be possible up to 110 °C, and I-L characteristics with good linearity and small SE change were obtained up to 100 °C. This temperature characteristic seems to be good, considering that no structural optimization was performed. Strong carrier confinement in the GaInNAs active region would contribute to this preferable result.

Fig. 3(a) shows lasing spectra at 2mW. The lasing wavelength of 1237.76 nm at 25 °C was nearly equal to the designed value (1237.7 nm), and it shifted towards the longer wavelength region with the rate of about 0.1 nm/K as shown in Fig. 3(b), which is almost equal to those of the conventional DFB lasers. As also shown in Fig. 3(b), high SMSR values above 42 dB were obtained in all temperatures between 25 °C and 110 °C. This result clearly shows that an excellent single-mode operation was maintained up to high temperature range.

In addition, we performed a direct-modulation experiment using 10-Gbps 2^{31}-1 NRZ signals. Fig. 4 shows eye-diagrams at 25 °C and 80 °C with extinction ratios (E.R.) around 5 dB. In both temperatures, clear eye-openings were obtained, although relatively large pattern jitters were observed at 80 °C, demonstrating that this laser can be operated at 10Gbps up to high temperature region.

The capacitance reduction due to the high resistive current-blocking layer contributed to this improvement in high-speed operation.

4. Conclusions

First successful operation of the buried-ridge-stripe GaInNAs-DFB laser with a high resistive semiconductor current-blocking layer were realized. Excellent CW single-mode oscillations with SMSR > 42dB were obtained up to 110 °C, and oscillation could be possible up to 110 °C. In addition, 10Gbps-modulations with clear eye-openings were obtained between 25 °C and 85 °C. These are the promising results for the uncooled use of the GaInNAs-DFB laser. Further improvements can be expected by optimizing the laser structure.

5. Acknowledgement

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References

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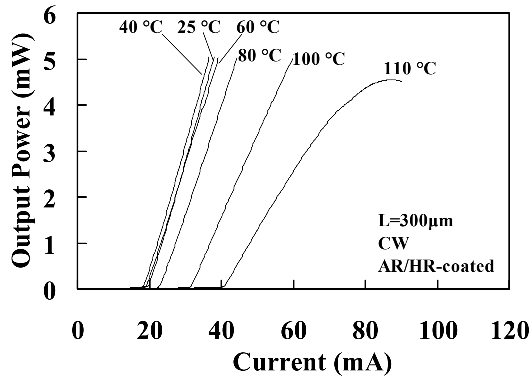
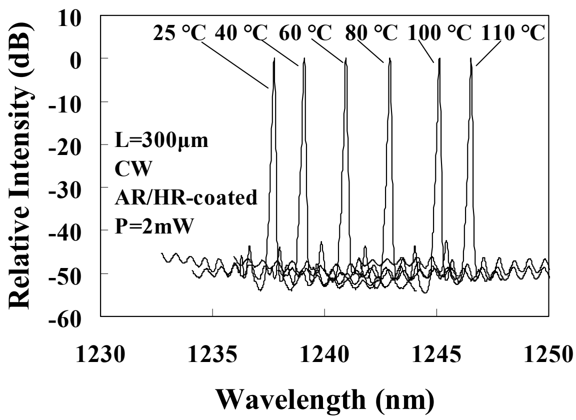
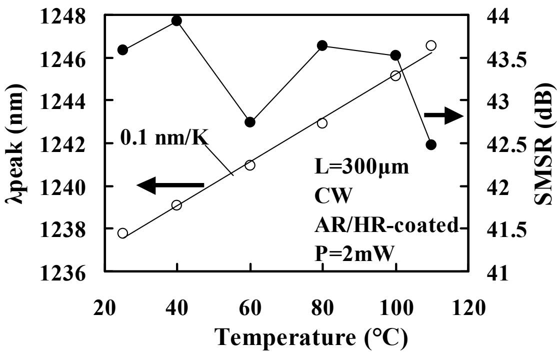


Fig. 2. I-L Characteristics of a GaInNAs DFB laser.

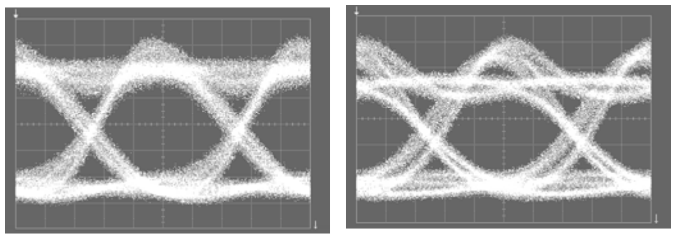


(a) Lasing spectra.



(b) Peak-wavelength and SMSR

Fig. 3. Dependence of oscillation wavelength on temperature.



(a) 25 °C
(I_b : 70mA, E.R. : 4.74 dB)

(b) 80 °C
(I_b : 90mA, E.R. : 5.27 dB)

Fig. 4. Eye-diagrams at 10 Gbps-modulation (V_{pp} : 2V constant)