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High-Power Distributed Feedback Laser Diodes Emitting at 820nm*

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Abstract: By etching a second-order grating directly into the Al-free optical waveguide region of a ridge-waveguide (RW) AlGaInAs/AlGaAs distributed feedback (DFB) laser diode, a front facet output power of 30mW is obtained at about 820nm with a single longitudinal mode. The Al-free grating surface permits the re-growth of a high-quality cladding layer that yields excellent device performance. The threshold current of these laser diodes is 57mA, and the slope efficiency is about 0.32mW/mA.

Key words: distributed feedback laser diodes; Al-free gratings; ridge-waveguide
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1 Introduction

High-power AlGaAs/GaAs distributed-feedback (DFB) laser diodes are attractive light sources for many applications, including optical disc recording systems, fiber-optic distribution networks, and fiber-optic sensors.

Although AlGaAs/GaAs DFB laser diodes have been researched for over 20 years[1~5], the high reactivity of Al to oxygen is still a problem[6], resulting in large performance degradation that occurs during the fabrication of AlGaAs gratings. To alleviate this problem, Al-free gratings have been introduced into AlGaAs/GaAs DFB laser diodes[7~9]. In this work, experimental results of 820nm DFB laser diodes with Al-free gratings are shown. Particularly, we choose AlGaInAs instead of GaAs as the material for the active layer to make sure that the TE mode is favored.

2 Device structure and fabrication procedure

The DFB laser wafer was grown by metal-organic chemical vapor deposition (MOCVD) in two steps. The first step consisted of an n-GaAs buffer, an n-$Al_{0.42}Ga_{0.58}As$ cladding, a 70nm $Al_xGa_{1-x}As$ (x: 0.42~0.2) waveguide, a 7nm 0.65% compressively strained AlGaInAs active quantum well (QW) sandwiched by 15nm $Al_{0.2}Ga_{0.8}As$ barriers, a 70nm $Al_xGa_{1-x}As$ (x: 0.2~0.42) waveguide, and an InGaP layer in which the second-order grating (period 244nm) was formed by holographic photolithography and dry etching followed by wet etching. Cross-sectional scanning electron micrographs (SEM) of the gratings before and after the second epitaxial growth are shown in Fig. 1. The gratings became smoother and flatter after the second epitaxial growth due to the mass transport. After surface cleaning, a 100nm $Al_{0.2}Ga_{0.8}As$ layer, a p-$Al_{0.42}Ga_{0.58}As$ cladding, and a p-GaAs contact layer were grown in the second step. The ridge waveguide (RW) was fabricated by wet etching in combination with an etch-stop layer in our case. Following device fabrication, the wafers were thinned, polished, and metallized. The cavity length L was 400μm. The front and rear facets were anti- (5%) and high- (95%) reflection coated, respectively. The devices were mounted p side-down on heat sinks. All measurements were performed under continuous-wave (CW) operation.

3 Results

Figure 2 shows the optical power versus drive current (L-I) and voltage versus drive current (V-I) for a typical DFB laser with L = 400μm. The threshold current of the device was about 57mA, with a slope efficiency of 0.32mW/mA. The laser

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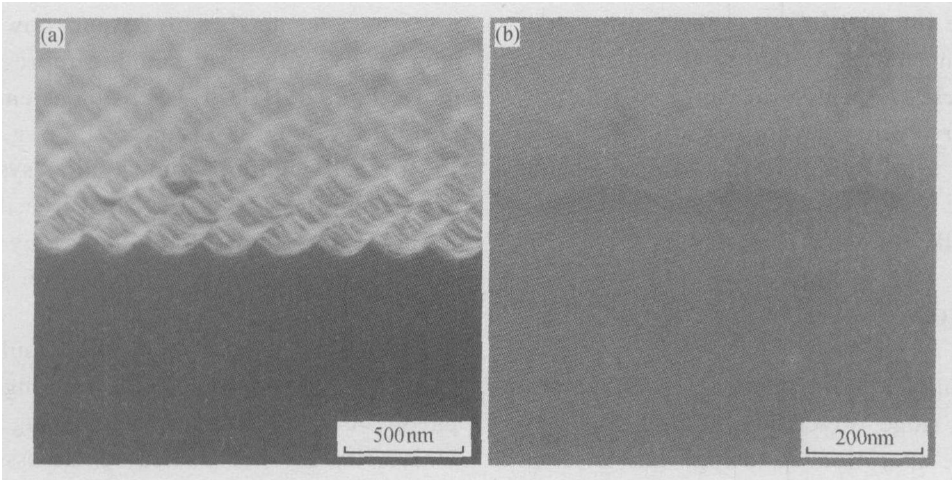

Fig. 1　Scanning electron micrographs of cross sections of gratings before (a) and after (b) the second growth

achieves a maximum kink-free power of 30mW from the front facet. The optical spectra of the laser are depicted in Fig. 3 at a current of 130mA. The side mode suppression ratio between the lasing mode and other cavity modes was larger than 30dB. The vertical and lateral far-field profiles are shown in Fig. 4. The vertical and lateral far-field had full widths at half-maximum (FWHM) of 34.8° and 13.5°, respectively, at a current of 130mA which were in agreement with the calculations.

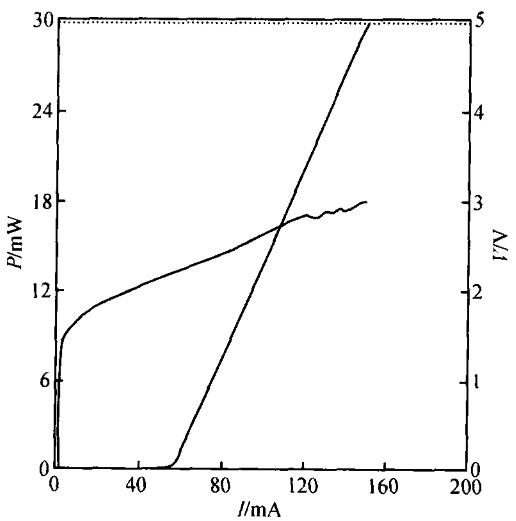

Fig. 2　Light-current and voltage-current characteristics of coated DFB laser (CW, $L = 400\mu m$, T = 25 ℃)

The spectral linewidth was measured using an interferometer. A linewidth of 80MHz was obtained at a 5mW output power. To achieve a higher output power, temperature controlling is needed, which will be further studied. The spectral line-

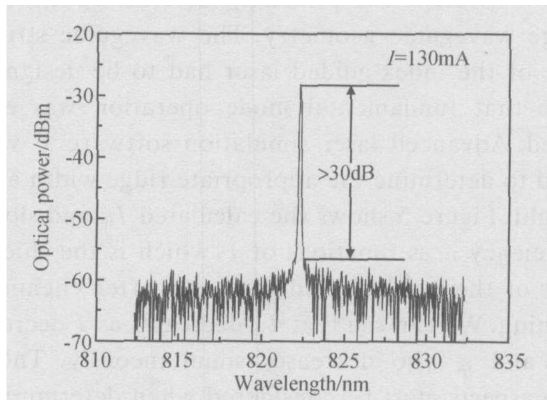

Fig. 3　Optical spectrum at 130mA　Device is the same as in Fig. 2.

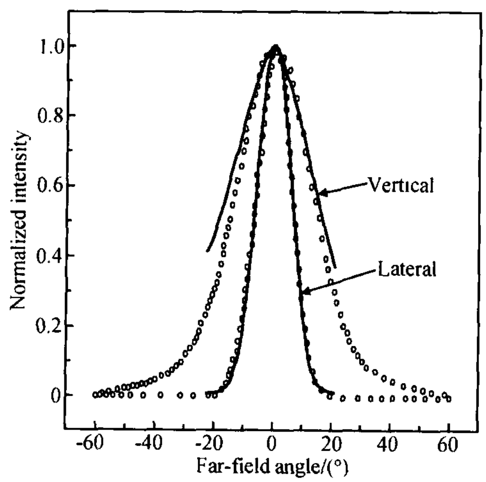

Fig. 4　Vertical and lateral far-field profiles at 130mA　Device is the same as in Fig. 2. The lines give the experimental results and the dots give the calculated ones.

width of a DFB laser diode is given by[10]

$$\Delta \nu \propto \frac{\alpha_0}{\kappa^2 L^3} \tag{1}$$

where α_0 is the internal loss, κ is the grating coupling coefficient, and L is the cavity length. The linewidth is relatively high in our experiments. However, a narrower spectral linewidth can be expected as the fabrication of the grating is improved and the laser cavity is lengthened as shown above. This will also be further studied.

4 Discussion

Lateral optical confinement was accomplished with a ridge waveguide. Maintaining fundamental mode operation up to high power levels required a careful analysis of the mode stability[11,12], which was primarily determined by the ridge waveguide geometry. The waveguide structure of the index-guided laser had to be designed such that fundamental mode operation was ensured. Advanced laser simulation software[13] was used to determine the appropriate ridge width and height. Figure 5 shows the calculated I_{th} and slope efficiency η_s as functions of t, which is the thickness of the residual cladding layer after chemical etching. We can see that I_{th} decreases as t decreases, and η_s also decreases simultaneously. These two aspects must be considered when determining the ridge depth. Our analysis showed that a ridge width of 3μm and height of 1.4μm were appropriate to satisfy the conditions mentioned above. The calculated vertical and lateral far-field profiles are shown in Fig. 4 for comparison with the experimental ones.

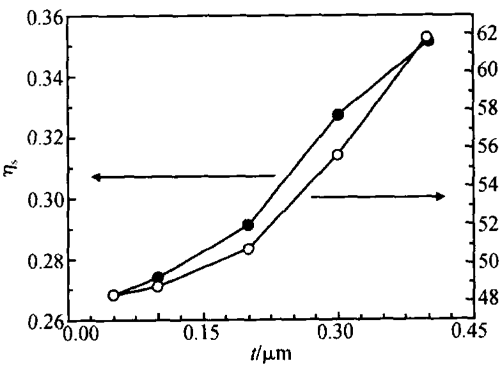

Fig. 5 Calculated I_{th} and η_s as functions of t

5 Conclusion

In summary, we have fabricated AlGaInAs/AlGaAs RW-DFB laser diodes emitting at about 820nm with Al-free gratings by two-step MOCVD growth. The maximum output power is up to 30mW CW with a side mode suppression ratio of more than 30dB. DFB laser diodes emitting at adjacent wavelengths of interest (e. g. ,852nm for the optical pumping and cooling systems of the most accurate Cs clocks) can be easily fabricated by slight variations of the active layer width and composition and the grating period.

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激射波长为 820nm 的大功率分布反馈激光器*

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摘要: 通过将二级光栅直接刻在脊形波导 AlGaInAs/AlGaAs DFB 激光器的无铝光波导层上,实现了波长约为 820nm,单面功率为 30mW 的单纵模激光器. 由于采用无铝光栅,保证了二次外延质量,从而得到较好的器件性能. 激光器的阈值电流为 57mA,斜率效率约为 0.32mW/mA.

关键词: 分布反馈激光器; 无铝光栅; 脊形波导

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