

High Power 808nm AlGaAs/GaAs Quantum Well Laser Diodes with Broad Waveguide

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Abstract: The 808nm laser diodes with a broad waveguide are designed and fabricated. The thickness of the $\text{Al}_{0.35}\text{Ga}_{0.65}\text{As}$ waveguide is increased to $0.9\mu\text{m}$. In order to suppress the super modes, the thickness of the $\text{Al}_{0.55}\text{Ga}_{0.45}\text{As}$ cladding layers is reduced to only $0.7\mu\text{m}$ while keeping the transverse radiation losses of the fundamental mode below 0.2cm^{-1} . The structures are grown by metal organic chemical vapour deposition. The devices show excellent performances. The maximum output power of 10.2W in the $100\mu\text{m}$ broad-area laser diodes is obtained.

Key words: quantum well; laser diode; waveguide

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1 Introduction

High power 808nm laser diodes are widely used for pumping Nd:YAG solid-state lasers, soldering, material processing, and medical therapy. In order to achieve higher power, one approach is to use a broad waveguide structure that has many advantages over conventional narrow waveguide structure. A broad waveguide structure, which increases the fundamental transverse mode width, results in effectively spreading the intensity over a large area, reducing the intensity at the facets and allowing for higher output power^[1,2]. Additionally, by using the broad waveguide structure, most of the optical intensity concentrates in the undoped waveguide. As a result, the coefficient of internal loss is decreased.

In the wavelength range around 808nm the maximum output power that has been reached so far is 8.8W for a stripe width of $100\mu\text{m}$ ^[3-5]. In this paper AlGaAs/GaAs quantum well laser diodes with a broad waveguide were described. A broad waveguide structure with small vertical farfield divergence was used. The maximum output power of 10.2W in the $100\mu\text{m}$ broad-area laser diodes was obtained. In addition, comparison studies of narrow and broad waveguide laser diodes indicate that using a broad waveguide effectively increases the maximum output power.

2 Design and fabrication

The wafer used to fabricate devices was grown by metal organic chemical vapour deposition (MOCVD). The structure of the wafer is as fol-

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lows: The substrate is a Si doped n^+ -GaAs with Si density of $2 \times 10^{18} \text{ cm}^{-3}$. After growing a $0.2 \mu\text{m}$ GaAs buffer layer, the following layers were grown successively: (1) $0.7 \mu\text{m}$ $\text{N-Al}_{0.55}\text{Ga}_{0.45}\text{As}$ cladding layer, (2) $0.45 \mu\text{m}$ $\text{Al}_{0.35}\text{Ga}_{0.65}\text{As}$ waveguide layer, (3) AlGaAs barriers and double quantum wells, (4) $0.45 \mu\text{m}$ $\text{Al}_{0.35}\text{Ga}_{0.65}\text{As}$ waveguide layer, (5) $0.7 \mu\text{m}$ $\text{P-Al}_{0.55}\text{Ga}_{0.45}\text{As}$ cladding layer, (6) $0.2 \mu\text{m}$ p^+ -GaAs top layer, (7) 20 nm p^+ -GaAs cap layer.

The conduction band diagram of the laser structure is shown in Fig. 1. The waveguide is very broad, $0.9 \mu\text{m}$ thick. Theoretically, such a broad waveguide allows lasing of three transverse modes,

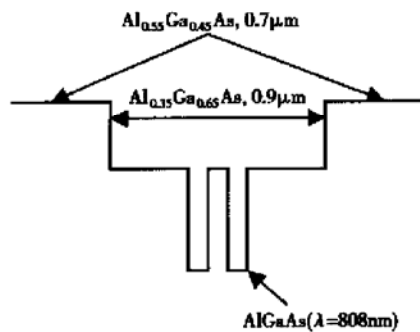


Fig. 1 Schematic diagram of GaAs/AlGaAs broad waveguide laser structure

0th, 1st and 2nd-order mode. Figure 2(a) shows the calculated results of the TE mode field profiles. The optical confinement factor Γ of the 0th, 1st and 2nd-order transverse mode is 2.73%, 0.01% and 1.29%, respectively. In order to suppress the 1st and 2nd modes, the thickness of the cladding layers was decreased to $0.7 \mu\text{m}$, which increases radiation losses to substrate. The transverse radiation losses of the 0th, 1st and 2nd-order mode is 0.18 cm^{-1} , 5.1234 cm^{-1} and 87.24 cm^{-1} , respectively. Since the super modes are suppressed due to small optical confinement factors and large radiation losses to substrate, only the fundamental transverse mode is supported in the broad waveguide. Figure 2(b) shows the calculated results of the vertical far-field pattern. The divergence of the 0th-order transverse mode is 36.7° .

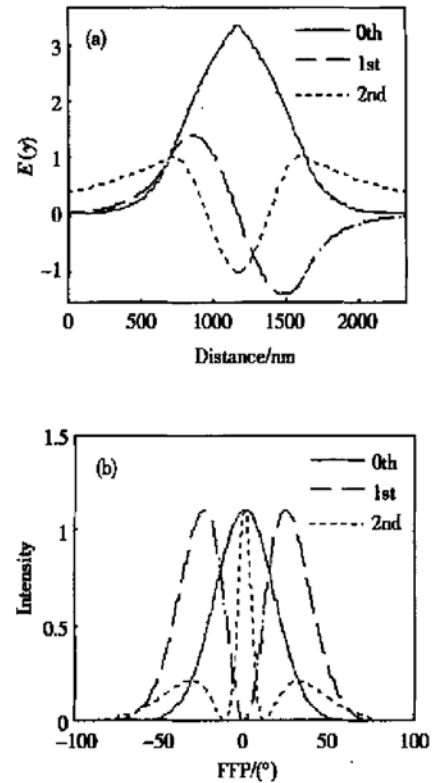


Fig. 2 Calculated results for GaAs/AlGaAs broad waveguide laser structure (a) Optical mode distribution; (b) Vertical far-field pattern

In order to confirm the expected effects from the broad waveguide, laser diodes with a narrow waveguide were fabricated. The structure is a single-quantum-well, with separate confinement heterostructure with aluminum composition $\text{Al}_{0.3}\text{Ga}_{0.7}\text{As}$ confining layers, which form optical waveguide. Even higher aluminum composition $\text{Al}_{0.5}\text{Ga}_{0.5}\text{As}$ cladding layers enclose the narrow waveguide to further confine the optical wave. The waveguide is 100 nm thick.

For the two kinds of laser diodes, the wafer structures are different, but their fabrication processes are almost the same. Broad area laser diodes with stripe widths of $100 \mu\text{m}$ were processed. To reduce the influence of current-spreading the cap layer has been wet-chemically etched beside the contact stripe. Outside of stripe, an insulator layer (SiO_2) was deposited. A Ti/Pt/Au metal contact was evaporated on the p-side. After wafer thin-

ning, n-side was metallized. The wafer was cleaved to obtain cavity lengths of 1.2mm. Low reflection ($R < 5\%$) and high reflection ($R > 95\%$) coatings were formed on the front and rear facets, respectively. Laser diode chips were mounted p-side down on Cu heatsink. The parameters of the devices were described in the following sections.

3 Results

Figure 3 shows the power-current characteristic of a single $100\mu\text{m}$ wide broad-area laser diode at an ambient temperature of 25°C . At a driving current of 1.3A the output power reached 1.0W. The threshold current is 0.38A. The maximum slope efficiency of 1.12W/A was achieved. Due to the low series resistance of 0.195Ω , maximum conversion efficiency reached 42.9% at 1.0W output power.

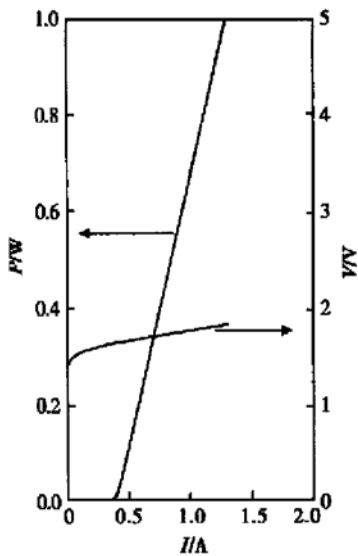


Fig. 3 Light output power versus driving current characteristic for $100\mu\text{m}$ GaAs/AlGaAs laser diodes with a broad waveguide

Figure 4 shows transversal farfield patterns at 1W. The full width at half maximum (FWHM) is 36.6° , closely matching the theoretically calculated results. The farfield profiles indicate that the lasing of all higher order modes is efficiently suppressed and the laser diode is operating in the fundamental

mode.

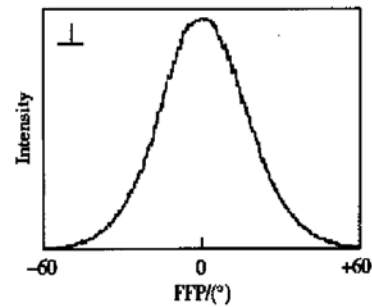


Fig. 4 Measured vertical far-field patterns for $100\mu\text{m}$ GaAs/AlGaAs laser diodes with a broad waveguide

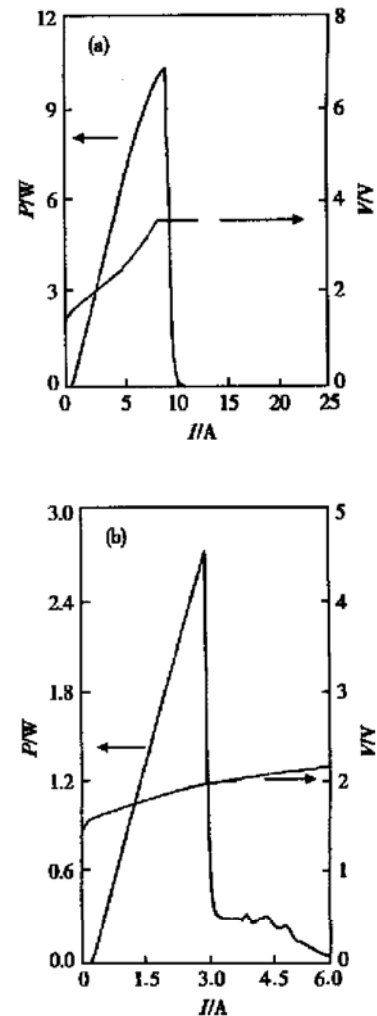


Fig. 5 Maximum output power for $100\mu\text{m}$ GaAs/AlGaAs laser diodes (a) with a broad waveguide and (b) with a narrow waveguide

The maximum output power in the diodes with a broad waveguide was compared with that with a narrow waveguide. Figure 5 shows the output characteristics of the two kinds of laser diodes. Compared to that of narrow waveguide laser diodes, the threshold current is higher because of double wells in broad waveguide laser diodes. The maximum output power of 10.2W is achieved at driving currents 9.8A. In narrow waveguide laser diodes catastrophic optical mirror damage occurred at driving currents 2.9A and the maximum output power are 2.7W. It appears that using a broad waveguide structure increases the maximum output power remarkably.

4 Conclusion

808nm GaAs/AlGaAs laser diodes with a broad waveguide were designed and fabricated.

With optimized waveguide and cladding layer, the devices show excellent performances. The power level of 10.2W from a 100 μ m broad-area laser diode has been measured.

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大功率 808nm AlGaAs/GaAs 宽波导量子阱激光二极管

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摘要: 设计与制作了大功率 808nm AlGaAs/GaAs 宽波导激光二极管. 器件的 $\text{Al}_{0.35}\text{Ga}_{0.65}\text{As}$ 波导厚度提高到 0.9 μm , 宽波导会引起高阶模的激励. 为了抑制高阶模, $\text{Al}_{0.55}\text{Ga}_{0.45}\text{As}$ 限制层厚度降低到 0.7 μm , 同时确保基模的辐射损耗在 0.2cm^{-1} 以下. 采用 MOCVD 进行材料生长, 得到了高性能的器件, 100 μm 条形激光二极管的最大输出达 10.2W.

关键词: 量子阱; 激光二极管; 波导

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