Electro-Optic Characteristics of GaInP/GaAs/GaInAs Strained Quantum Well Lasers

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Strained-layer GaInAs/GaAs/GaInP single quantum well separate confinement heterostructure lasers emitting at 980nm are reported. Broad area and ridge waveguide uncoated lasers showed threshold current as low as 11mA and external differential quantum eficiency of 65%. Far field patterns exhibited fundamental transverse mode operation with divergence of 10.5° and 2U° for directions parallel and perpendicular to the junction plane, respectively.

I. Introduction

Strained layer GalnAs/GaAs quantum well lasers emitting at 980nm are of considerable interest as pumping sources for Erbium doped optical fiber amplifiers[1]. Very low threshold current densities have been obtained for strained layer GaInAs/GaAs/GaAlAs separate confinement heterostructure single quantum well (SCH-SQW) lasers grown by different techniques. However, it was shown that tlie utilization of GaAlAs cladding layers tends to oxidize the laser faccts and shorten tlie device lifetime. A proposed alternative to minimize this effect is tlie use of GaInP cladding layer due to its lower oxidation rate. low interface recombination rate and higher thermal conductivity[2-4]. In this paper we report the results of GaInAs/GaAs/GaInP SCH-SQW lasers grown by atmospheric pressure metalorganic chemical vapour deposition (MOCVD). Broad area and ridge waveguide (RWG) uncoated Fabry-Perot laser structures have been fabricated with high output power operation, very low threshold currents and low astigmatic beams even at high powers. All the electro-optic characteristics described in this work were obtained under pulsed wave operation mode.

II. Crystal growth, material characterization and laser structure

The laser structures were grown by MOCVD in a one step at 620°C on (100) oriented n^+ GaAs substrates. The RWG structure is shown schematically in Fig.1. Tlie layers consist of (i) an n-type 1.1μm thick $Ga_{0.51}In_{0.49}P$ cladding layer, (ii) a strained ($\Delta a/a \sim$ 2.1%) $Ga_{0.85}In_{0.15}As$ 8 nm tliick layer ernbedded by two undoped GaAs 50 nm thick spacer layers, (iii) a 1.1μm thick p-type $Ga_{0.51}In_{0.49}P$ cladding layer and (iv) a 0.2μm thick p^+-type GaAs contact layer.

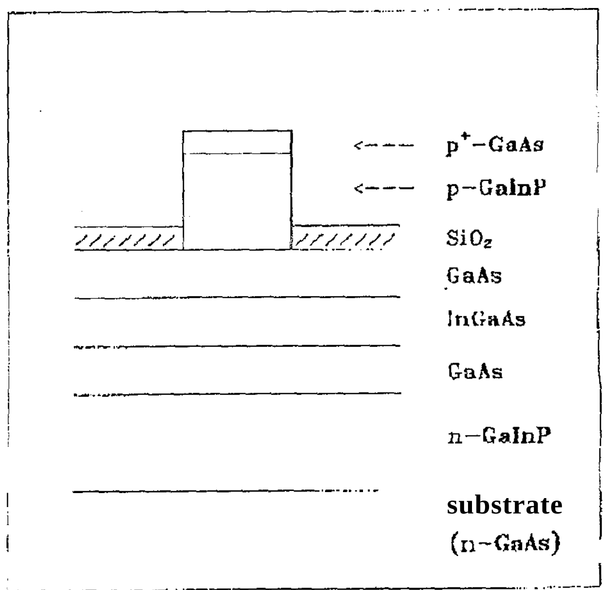

Figure 1: Schematic cross section of the ridge waveguide laser structure.

Before laser processing tlie material, quality evaluation was assessed hy pliotoluminescence (PL) spectroscopy. Figure 2 shows a typical room temperature PL spectrum of a GaInAs/GaAs/GaInP strained layer single quantum well. The transition observed at 650 nm is attributed to tlie GaInP cladding layer. The emis-

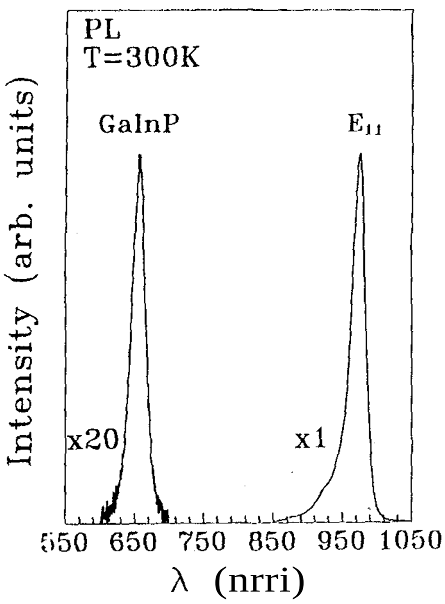

Figure 2: Room temperature PL spectrum of a GaInAs/GaAs/GaInP single quantum well structure.

sion (E_{11}) from the GaInAs well was observed at 978 nm with full width at half maximum (FWHM) of 30 meV, reflecti ıg the goocl quality of the material under investigation.

Broad area and RWG devices were processed by standard methods. TiPtAu aiid AuGeNi/NiAu alloys were evaporated for p and n-ohmic contacts, respectively. The silicon dioxide, used to form the channel guide and foi tlie broad area oxide stripe lasers, was evaporated by plasma enhanced chemical vapor deposition. The mesa stripe with 7μm width was formed by wet chemical etching leaving 1.1μm thick $Ga_{0.5}In_{0.5}P$ cladding layer and 0.2μm thick GaAs contact layer beyond tlie mesa. Outside the mesa, a 0.13μm thick SiO_2 layer was evaporated directly on the GaAs spacer layer. The lasers were cleaved to have differeiit cavity lengths and no antireflection or high-reflectivity coatings were used on the cleaved mirror facets.

RWG quantum well lasers performance is strongly influenced by tlie optical confinement factor (Γ) of the active region[5] and by the lateral effective refractive index step (Δn). High values of Δn ensure strong lateral mode confinement for these devices. In order to evaluate tlie device performance we calculated tlie effective index of tlie slab waveguide in regions inside and outside the mesa. This calculation was carried out using the effective refractive index method approximation[6]. Figure 3 presents Δn and Γ against tlie GaAs spacer layer

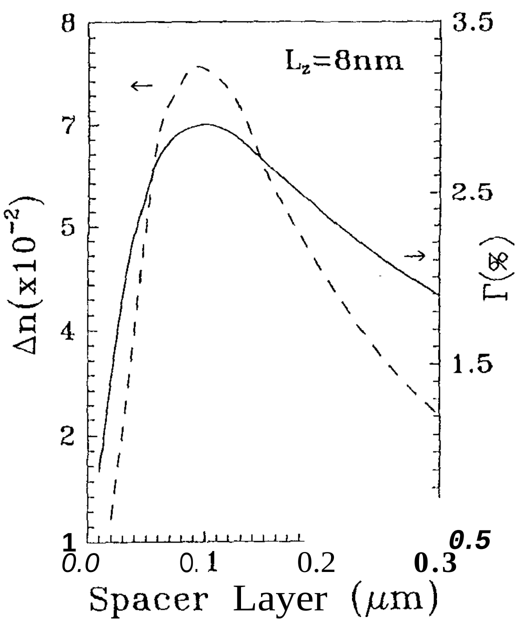

Figure 3: Effective index step (dashed line) and confinement factor (solid line) as a function of the spacer layer thickness calciilated for a ridge waveguide laser with a 8nm thick strained quantum well.

thickness calculated for a 8 nm well width (L,) RWG SQW laser (see Fig.1). Maxima values of Γ = 2.9% and Δn = 0.076 were obtained for the same spacer layer thickness close to 0.1μm. Thus, Δn and Γ can be optimized by adjusting the spacer layer width appropriately. For a 0.05μm spacer layer thickness the model predicts Γ = 25% and Δn = 0.05. These values are somewhat smaller than the maximum of both curves shown in Fig. 3. However, this difference appears to be of no significance as would be confirmed by the good device performance, similar to those reported in the literature, as will be clescribed bellow.

III. Lasing characteristics

The lasers were tested under pulsed operation (pulse width of 800ns and repetition rate of 1kHz) with a duty-cycle of 0.08%. Figure 4 shows the threshold current density (J_{th}) as a function of reciprocal cavity length ($1/L$) for broad area devices[7]. The J_{th} x $1/L$ dependence exhibited a logarithmic behavior, what is expected for strained quantum well lasers[8]. The low transparency current density value of 120 A/cm^2 indicates tlie goocl quality of the laser structure.

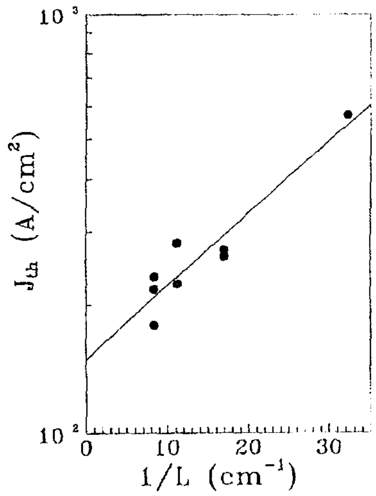

Figure 4: Threshold current density of GaInAs / GaAs / GaInP broad area lasers as a function of reciprocal of cavity length.

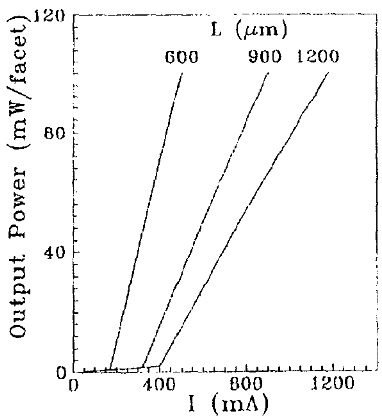

Figure 5: Piilsed wave light/current characteristics for ridge waveguide lasers with different cavity lengths.

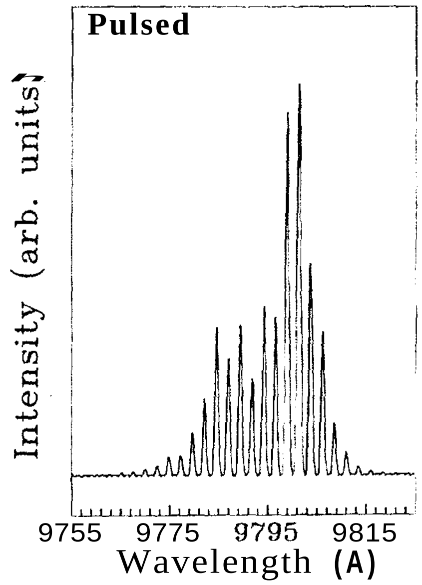

Figure 6: Emission spectrum of the GaInP/GaAs/GaInAs RWG laser.

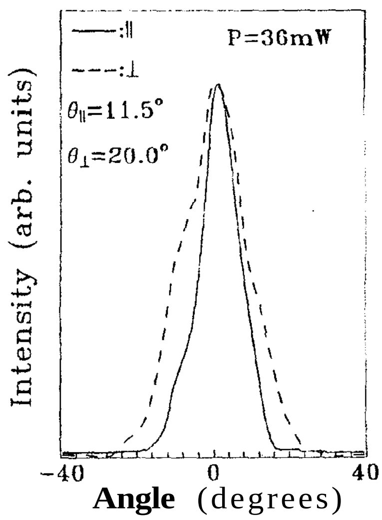

Figure 7: Far-field intensity distributions parallel and perpendicular to the junction plane observed in tlie ridge waveguide lasers.

Pulsed output power of broad area lasers was in excess of 300 mW/facet. Tlie characteristic temperature T_0 of these devices was measured to be in the range of 120-130 K. Tlie L-I curves for RWG devices with different cavity lengths are shown in Fig. 5. The threshold ciirreiit varies from [11] to 37 mA and the external differential quantum efficiency varies from 65% to 30%, for laser cavity lengths ranging from 500 to 1200 μm. Tlie RWG lasers were capable of delivering pulsed optical powers of 90 mW/facet. These characteristics are suitable for optical fiber amplifier pumping sources.

The typical longitudinal mode spectrum of a. RWG laser at 3mW light output power is shown in Fig. 6. Tlie spectrum consists of several modes separated by a ~0.2nm and centered around 980nm.

Another important feature for pumping sourccs is the far-field intensity distributions perpendicular and parallel to the junction plane. The aspect ratio between the FWHM of the two clirections ($\Theta_{\perp}/\Theta_{\|}$) strongly influences the coupling efficiency between the laser and the optical fiber. Typical aspect ratios reported in the literature for strained quantum well RWG lasers are of order of 3:1[2,8-10]. Representative far field intensity distributions parallel and perpendicular to the junction plane recorded at an output power of 36 mW/facet are shown in Fig. 7. The RWG lasers oscillates in the fundamental transversal mode with a FWHM of 11.5°

($\Theta_{\|}$) and 10° ($\Theta_{\perp}$), giving an aspect ratio of 1.74:1. This very low astigmatic divergence suggests that these devices are potential light sources for pumping erbium doped optical fiber amplifiers.

IV. Conclusion

We have fabricated GaInAs/GaAs/GaInP single quantum well broad area and ridge waveguide lasers emitting at 980nm. Ridge waveguide devices with 500μm cavity length exhibited threshold currents as low as 11mA and external differential quantum efficiencies of 65%. The ridge waveguide lasers have been operated to a pulsed output power of 90mW/facet. The far field aspect ratio of 1.74:1 observed suggests that a high laser/optical fiber coupling efficiency could be obtained. These lasers prove to be good candidates as pump sources for erbium doped fiber amplifiers.

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