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FABRICATION OF 980 nm HIGH POWER BROAD AREA LASER DIODES

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Abstract: In this paper, we have reported the design and fabrication of InGaAs/AlGaAs/GaAs strained layer double quantum well 980 nm broad area laser diodes. The 100 µm wide stripe uncoated laser diode chip with 1000 µm cavity length demonstrated 870 mW CW output power at 1.8A at 25^{0}C. The output power was thermally limited due to epi-side mounted. The slope efficiency was ~ 0.7 W/A.

1. INTRODUCTION

The applications of high power broad area semiconductor laser diodes are not only limited to material processing, pumping of solid state lasers, fiber lasers or lasers for space applications, but they find great potential in biomedical medical applications [1]-[2] too like laser assisted surgery, photodynamic therapy etc. Due to some inherent advantages like their light weight, portable size, lower cost, longer operating life and better operating conditions make them ultimate choice for biomedical usage as mentioned above. Recently, high power broad area semiconductor laser diodes emitting wavelength around 980 nm are being widely used in various medical applications e.g. cutting of soft tissue, cleaning of root canal etc.

In this paper, we present the design and fabrication of 980 nm broad area laser diodes.

2. LASER STRUCTURE DESIGN

Strained layer InGaAs/AlGaAs/GaAs GRINSCH DQW (Graded Index Separate Confinement Heterostructure Double Quantum Well) lasers were grown by Metal Organic Chemical Vapor Deposition technique. The composition of Indium in InGaAs QW, thickness of QW as well as doping in cladding and waveguide layers were optimized to ensure low threshold current, high quantum efficiency and emission wavelength around 980 nm at room temperature [3]. The laser material consists of 7 nm thick $In_{0.24}Ga_{0.76}As$ quantum wells surrounded by 10 nm thick GaAs barrier layers and followed by $Al_xGa_{1-x}As$ graded index layers where the Al fraction x is linearly varied from 0% to 50%. Fig.1. shows the schematic of the material composition of 980 nm laser diodes. The grown costumed material was supplied by FBH, Berlin, Germany.

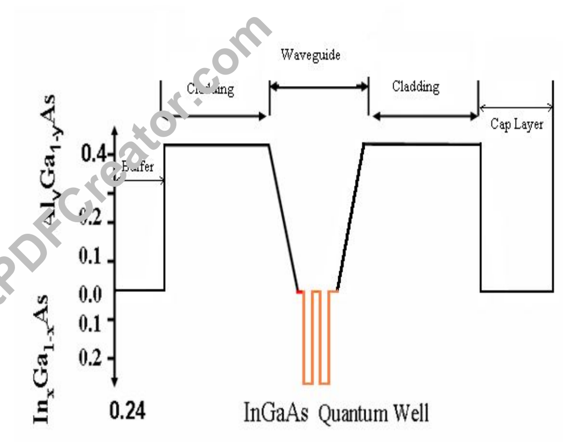

Fig. 1. GRINSCH DQW InGaAs/GaAs Strained Layer Structure

3. FABRICATION

Broad area laser diodes with different stripe widths of 100 µm, 150 µm and 200 µm were fabricated. The 100 µm, 150 µm and 200 µm mesas were formed by wet chemical etching of top p+ GaAs cap and p-AlGaAs cladding layers in H_2O_2:H_2SO_4:H_2O (1:1:20) chemical solution at 20^{0}C and followed by deposition of 1500 A^0 thick Al_2O_3 using RF magnetron sputtering for electrical isolation as well as lateral confinement of longitudinal modes. The e-beam evaporated Ti/Pt/Au p-contact metallization was patterned using lift-off technique. Before loading samples in e-beam system, samples were etched in HCl:H_2O (1:50) solution at room temperature for 15sec to remove native oxide. The 3 µm thick selective electroplating of Au was carried out. After completion of front side processing, the substrate was thinned down to ~120 µm and followed by 1% bromine methanol polishing. AuGeNi/TiPt/Au was deposited by e-beam for n-contact. The laser samples were alloyed at 400^{0}C in nitrogen atmosphere for 40sec to reduce n-contact resistance. Finally, the wafer was cleaved into bars of resonator lengths 1000 µm, 1500 µm & 2000 µm, respectively. The detailed fabrication flow chart of 980 nm laser diodes is shown below. Figure 2. shows the fabricated laser diodes.

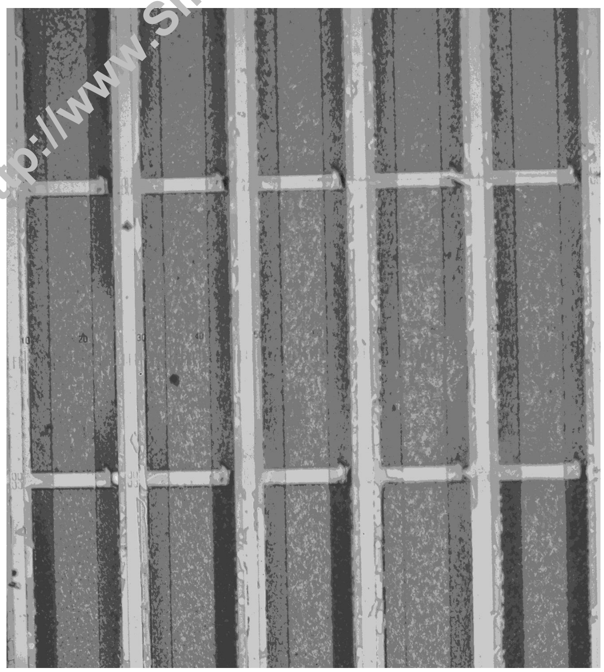

Fig. 2. Photomicrograph of fabricated broad area 980 µm laser diodes

4. DEVICE CHARACTERISTICS

With out AR (antireflection)/HR (high reflection) coated wire bonded laser chip was mounted junction side up on gold plated copper heat sink with In/Ag solder. The continuous wave (CW) L-I-V (light-current-voltage) characteristics of 1mm cavity length and 100 µm ridge width laser diode chip at 25 ^{0}C is shown in figure 3. The threshold current was ~ 330 mA. The CW output power was 870 mW at 1.8 A and when current was further increased, the output power was not increased linearly due to heat dissipation (thermally limited). The laser output power was 1.1 W when it was directly operated at current of 2 A. The L-I-V characteristics of laser diode chip was carried out at facility of the M/s. Optiwave Photonics Limited, Hyderabad, India.

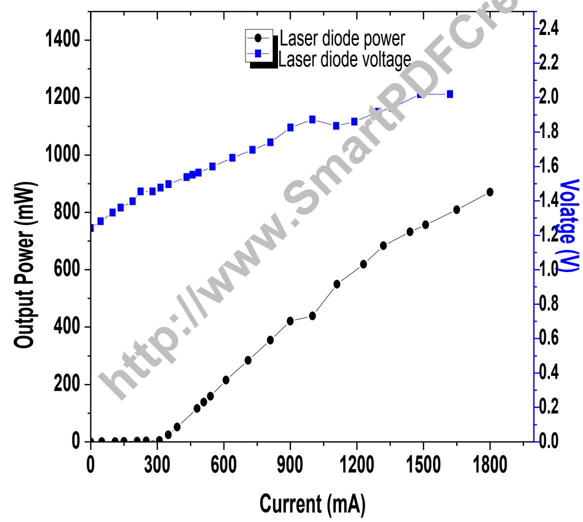

Fig. 3. CW L-I-V characteristics of 980 nm broad area laser diode

5. RESULTS AND DISCUSSION

The design, fabrication and characteristics of strained layer InGaAs/AlGaAs/GaAs GRINSCH double quantum wells 980 nm high power broad area laser diodes are described. The laser diodes have different ridge widths (100, 150 & 200 µm) & different cavity lengths (1 mm, 1.5 mm & 2.0 mm), respectively. We achieved high power levels under CW operation (870 mW) per facet at current of 1.8 A and 1.1 W per facet, when operated directly at 2.0 A. The slope efficiency and threshold current density of laser diode were ~ 0.7 W/A, ~ 330 A/cm^2, respectively. The CW output power was thermally limited. The output power will be increased when laser chips would be mounted epi-side down due to proper heat dissipation.

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