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High performance of 1.54 μm InGaAsP high-power tapered laser using high p-doped separate confinement layer and strain compensated multiple quantum wells

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1. Introduction

Semiconductor lasers operating near the 1 W level at eye-safe wavelengths near 1550 nm are needed not only for pumping sources, but also free-space laser communication, laser ladar, and night vision as well. There have been a few reports of narrow stripe diode lasers operating in the 1.48 – 1.55 μm wavelength region with chip power exceeding 300 mW [1-3]. To obtain significantly high brightness and higher output powers, tapered lasers [4], angled-grating distributed feedback lasers [5], master oscillator power amplifiers (MOPAs) [6], and arrays of antiguding lasers [7] have been developed. Among them, tapered lasers consisting of a single mode lasing section and a laterally tapered amplifying section is a promising candidate because of its performance and easy process. Output power of CW 2.35 W and diffraction limited power of CW 1.8 W have been demonstrated on the 1.48 μm tapered lasers [3]. Such performance has been achieved utilizing compressive strained multiple quantum wells (MQWs) InGaAsP material system.

In this study, we report high performance of 1.54 μm InGaAsP tapered lasers utilizing high p-doped separate confinement layer (SCL) and strain compensated InGaAsP MQWs. Maximum output of CW 2.45 W and diffraction limited power of CW 1 W has been demonstrated with the material systems.

2. Laser structure and Fabrication

The 1.54 μm InGaAsP-InP material was grown by metalorganic chemical vapor deposition. The active 6 QW region consists of 6.5 nm thick InGaAsP QWs 10 nm thick InGaAsP barriers. A compressive strain of 0.8 % and a tensile strain of 0.5 % are incorporated in the QW and barrier, respectively. The MQWs is sandwiched in the 20-nm thick inner InGaAsP (1.25 μm-Q) bounding SCL layer. The outer InGaAsP (1.1 μm -Q) confining SCL layers are inserted between the InP cladding layers and the inner SCL layers on both side of upper p-type and lower n-type side. Both of the bounding and confining layers, which is two-step SCL structure, are lattice matched to InP. The thickness of these outer InGaAsP confining SCL layers is 0.7 μm, and is intentionally designed in order to reduce modal gain and thus to prevent filamentation which appear in the broad area lasers [8]. The transversal spot-size of this structure is about 1.6 μm, larger than normal laser structure. Additional thin δ-doped layers are added at the heterointerfaces between p-InP/1.1 μm-Q and 1.1 μm -Q/1.25 μm-Q with Zn ~ $2 \times 10^{18}/cm^3$. The outer 1.1 μm-Q confining SCH layer is moderately doped with Zn ~ $1 \times 10^{17}/cm^3$. These δ-doped layers is intentionlly inserted to suppress the injected carrier overflows into SCL from MQW active layer due to a small conduction band offset in the conventional InGaAsP-InP system [9, 10].

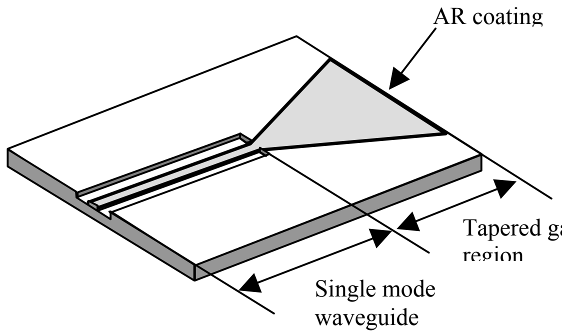

Fig. 1 Schematic diagram of tapered laser

Broad area lasers and tapered lasers are processed using standard fabrication techniques. The p-side metallisation consists of 300 Å of Ti, 600 Å of Pt, 3000 Å of Au. The n-side metallisation consists of 300 Å of AuGe, 600 Å of Ni, 3000 Å of Au. Stripe widths of broad area lasers are 25 μm and 100 μm. Tapered lasers contain a narrow stripe ridge waveguide and a laterally tapered unguided amplifying section. The tapered lasers are coated to obtain anti reflectivity (AR) on the wide side of taper., while broad area lasers are uncoated on the both facets. A schematic diagram of a typical structure is shown in Fig. 1.

The single mode output of the ridge section is amplified in the tapered section, while it is diverging in the lateral direction. Individual devices are mointed p-side down on copper mount using AuSn solder material then attached to a thermo-electric cooler for testing.

3. Experimental result and discussion

The internal loss (α_i) and the internal quantum efficiency (η_i) are calculated from the inverse external quantum efficiency ($1/\eta_{ex}$) versus cavity length (L) for the 25 μm broad area lasers. By fitting the data to the equation $1/\eta_{ex} = 1/\eta_i\,(1- \alpha_i\, L/\ln(R))$, η_i and α_i values of 70% and 9 cm^{-1} are found, respectively. The reflectivity, R, is assumed to be 0.31. Characheristic temperature T_0 is kept as 51 K upto 70 ^{o}C. From the light-current *(L-I)* measurement, it is found that CW output power for the 1500 μm long 100 μm stripe broad area laser is increased 2 times more than that for the broad area laser using the high p-doped SCL and compressively strained InGaAs MQWs, whose device structure is depticed in detail in [9, 10]. Figure 2 shows CW L-I characteristics of the best AR coated tapered laser with 1000 μm long ridge section and 1500 μm long taper section. CW 2.45 W is achieved at 15 ^{o}C. The output power was measured using calibrated Newport thermofile detector (model: 818T-30/CM). Figure 3 shows typical lateral far-field patterns of tapered lasers for the different drive currents from 1.5 A to 6 A. It is clearly shown that the light from tapered lasers is diffraction limited. The maximum diffraction limited output power is measured to be CW 1 W at drive current 5 A. More high diffraction limited power will be obtained with grooves etched down through the active region.

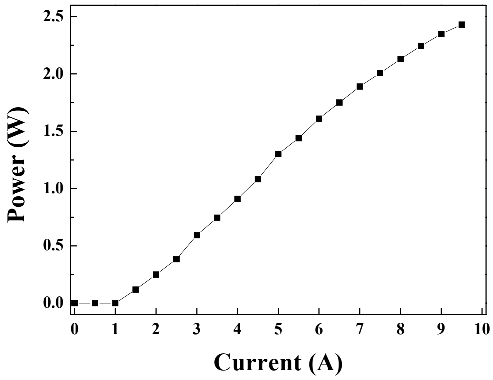

Fig. 2 CW L-I characteristics of 1.54 μm tapered laser tested at 15 ^{o}C.

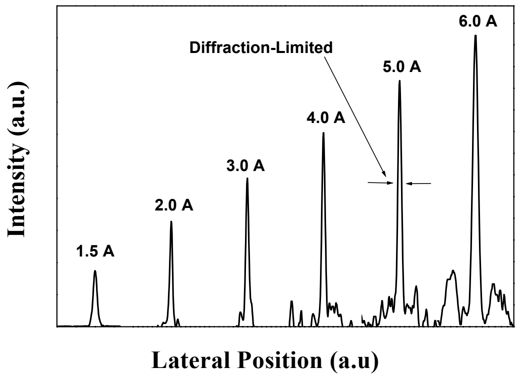

Fig. 3 Lateral far-field patterns at different drive currents from 1.5 A to 6 A for the 1.54 tapered laser

4. Conclusions

We have reported high p-doped SCL and strain compensated InGaAsP MQW taper lasers. The maximum room temperature CW output power of 2.45 W was achieved for the best devices. The diffraction limited power of 1 W was obtained. It is believed that more high diffraction limited power will be obtained with grooves etched down through the active region.

Acknowledgments

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