Extended Abstracts of the 1992 International Conference on Solid State Devices and Materials, Tsukuba, 1992, pp. 237-239

High Temperature (80°C) 100 mW Operation of InGaAlP Visible Laser Diodes

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The high power operation at high temperatures of broad area InGaAlP visible laser diodes has been investigated. The factors limiting the output power were also studied. High temperature (80°C) 100mW operation as well as room temperature watt-class emissions were achieved for broad area lasers containing a strained InGaP active layer. These lasers exhibited stable operation for over 1700 hours for an output power of 100mW at an ambient temperature of 50°C.

1. INTRODUCTION

High power visible laser diodes have been under investigation for a range of applications such as optical disc recording systems[1]. Maximum CW output power exceeding 100mW has already been reported for transverse mode stabilized narrow stripe lasers with a strained thin active layer [2]. Reliable operation was achieved for such lasers emitting output powers up to 30-40mW[3,4]. For other applications, including pumping of solid state laser materials and medical instrumentation, higher output powers have been produced by using broad area structures[5-11]. Recently, a maximum CW output power in excess of 1W, from a single stripe, was reported for such a visible laser[8,9]. However, there has been no report, as of yet, on the high temperature operation of broad area visible lasers, and also, there are only a few reports on their reliability (which was reported at room temperatures[8,11]).

In this paper, we report on high temperature (80°C) 100mW operation as well as room temperature watt-class emissions achieved for broad area InGaAlP visible laser diodes with a strained active layer. The factors limiting the output power will be discussed. Reliable operation for an output power of 100mW, at an ambient temperature of 50°C, are also presented.

2. LASER STRUCTURE

The broad area lasers studied consisted of a double heterostructure, with an undoped $In_{0.59}Ga_{0.41}P$ strained active layer, n-$In_{0.5}(Ga_{0.3}Al_{0.7})_{0.5}P$ and p-$In_{0.5}(Ga_{0.3}Al_{0.7})_{0.5}P$ cladding layers, which were grown on a (100) GaAs substrate by low pressure metal organic chemical vapor deposition (MOCVD). The active layer thickness was 0.02μm to reduce the optical power density at the mirror facets and, thus increase the catastrophic optical damage (COD) power levels[1]. The calculated Γ/d value (Γ:optical confinement factor, d:active layer thickness), which represents the optical power density in the direction perpendicular to the junction plane, was $1.58\mu m^{-1}$.

The use of a strained $In_{0.59}Ga_{0.41}P$ active layer ($\Delta a/a$ = +0.75%), which has a smaller bandgap energy than that of lattice matched $In_{0.5}Ga_{0.5}P$, is effective to increase the electron barrier height at the heterojunction, and thus prevent electron overflow from the active to the p-cladding layers. This results in a remarkable improvement in the temperature characteristics of these devices[2]. Also, the p-type cladding layer was doped as high as $7x10^{17}$ cm^{-3} to increase the confining barrier height for the electrons[2].

An anti-reflection (10%) coating of Al_2O_3 and a high reflection (90%) coating of Al_2O_3/Si multi-layers were deposited on the front and the rear facets, respectively. The cavity length was 600μm. Laser chips were mounted in the p-side down (upside down) configuration on copper heat sinks.

3. RESULTS AND DISCUSSION

3.1 FACTORS LIMITING MAXIMUM POWER

Figure 1 shows the maximum CW output power, Pmax, of the devices at 20°C as a function of stripe width. The Pmax was limited by COD in those lasers with narrow stripe widths, i.e. less than 75μm (closed circles), where Pmax was found to be proportional to the stripe width. This indicates a uniform lasing along the junction plane with a COD power density of 0.15W for a 10μm aperture. In those lasers with stripe widths greater than 75μm (open circles), Pmax was thermally limited.

Figure 2 shows the maximum operation temperature, Tmax, for a CW output power of 100mW, as a function of stripe width. Threshold current densities were constant (1.1-1.2kA/cm^3) for these devices with different stripe widths. The Tmax values were found to decrease as the stripe width was increased, although the lasers with a wider stripe width required a lower operation current density for an output power of 100mW. This deterioration in the thermal characteristics, for the wider stripe lasers, is due to the decrease in the heat diffusion efficiency from the effectively two-dimensional heat flow, for the narrower stripes, to one-dimensional flow, for the wider stripes. These results, shown in Fig.2, thus explain why the maximum output power was thermally limited for lasers with a wider stripe.

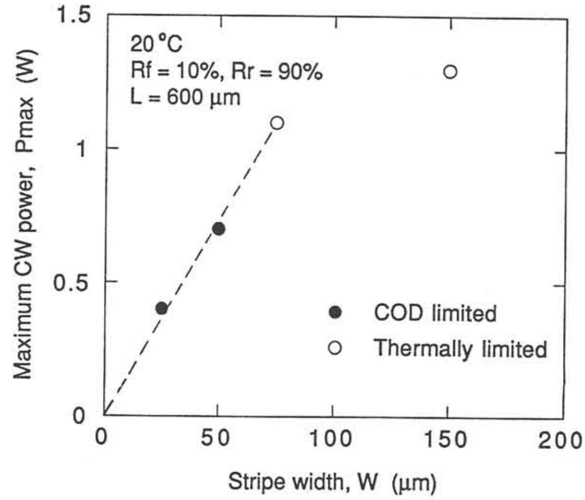

Fig.1 Maximum CW output power at 20°C as a function of stripe width.

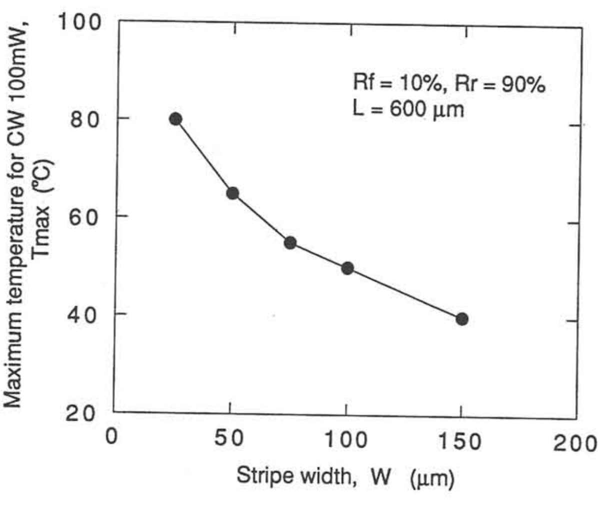

Fig.2 Maximum temperature for 100mW CW operation as a function of stripe width.

As shown in Fig.1, for those lasers with stripe widths wider than 75μm, a maximum CW output power higher than 1W was obtained at room temperature. Figure 3 shows a light-current (L-I) characteristic for a 75μm wide stripe laser. A maximum output power of 1.15W was achieved. The threshold current was 0.5A and the slope efficiency, below 0.5W, was 1.1W/A. The highest output power achieved in this study was 1.3W for a 150μm stripe laser.

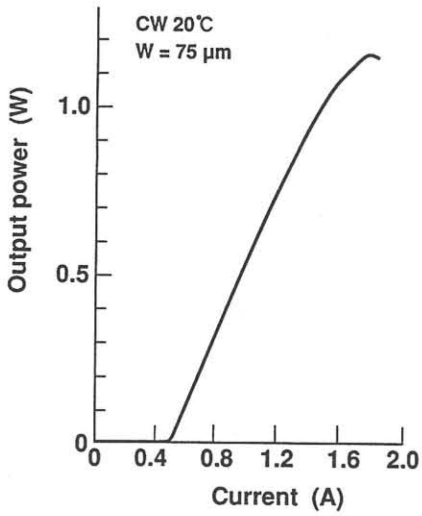

Fig.3 Light-current characteristic for a 75μm stripe laser.

3.2 100mW OPERATION

As a result of using a strained thin active layer, high power oscillation at high temperature has been realized. Figure 4 shows L-I characteristics for a 25μm stripe laser at various temperatures. No kinks are displayed in these L-I curves. 100mW CW operation thus was achieved up to a temperature as high as 80°C, which is the highest value ever reported for this output power. The threshold current was found to be 160mA with a slope efficiency of 1.0W/A at 20°C. The lasing wavelength was

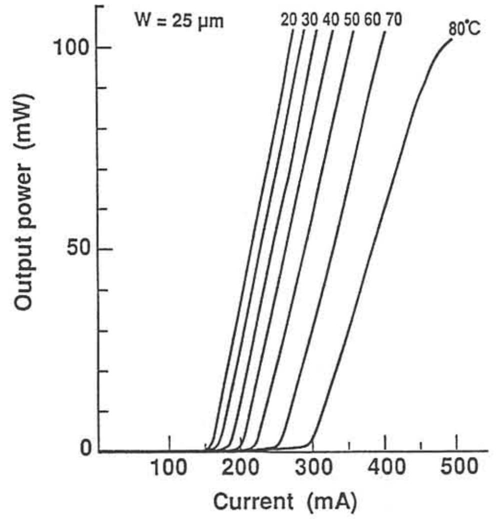

Fig.4 Light-current characteristics for a 25μm stripe laser at various temperatures.

698nm.

Figure 5 shows the far-field profiles, in the direction parallel to the junction plane, for the 25μm stripe laser at 20°C. Full widths at half maximum of the beam divergences are also shown. Stable single lobe shaped patterns were obtained, and the beam divergence was slightly broadened as the output power was increased.

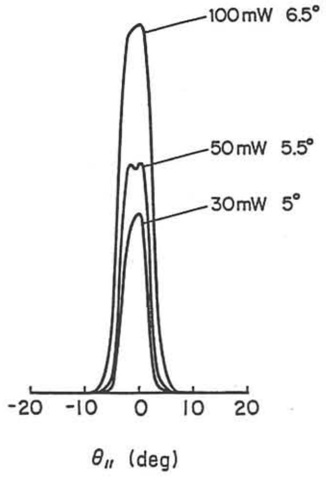

Fig.5 Far field profiles for a 25μm stripe laser.

Figure 6 shows reliability test results at an output power of 100mW for the 25μm stripe lasers. The lasers exhibited stable operation for over 1700 hours for an ambient temperature as high as 50°C. This indicates that the use of a strained active layer causes no serious degradations.

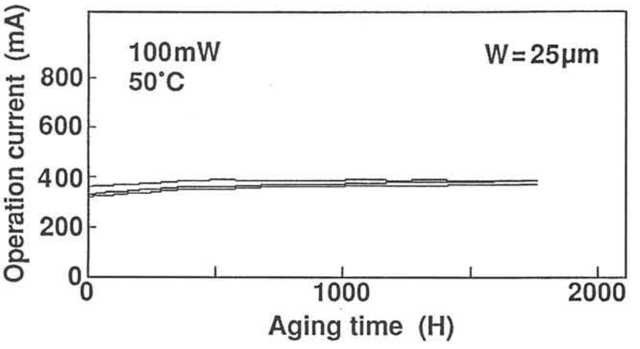

Fig.6 Life test results for 25μm stripe lasers emitting 100mW at 50°C.

4. SUMMARY

High power operation of broad area visible lasers, with a strained active layer, has been investigated. It was found that the maximum output power from the lasers was limited by COD, with a COD power density of 0.15W for a 10μm aperture, for lasers with a stripe width less than 75μm, whilst for lasers with broader stripe widths it was limited by thermal power saturation. Maximum powers exceeding 1W were obtained for lasers having stripe widths broader than 75μm. 100mW operation at a temperature as high as 80°C has been achieved for 25μm stripe lasers. These lasers exhibited stable operation for 1700 hours for an output power of 100mW at an ambient temperature of 50°C. These results assure practical use of such 100mW class visible laser diodes.

ACKNOWLEDGMENTS

The authors would like to thank Dr.A.Hojo and Dr.M.Azuma for their continuous encouragement and N.Shimada for his discussion and support.

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