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High power and high temperature operation of 660 nm AlGaInP laser diodes for DVD-R/RW

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1. Introduction

High power 660-nm laser diodes are strongly required for the improvement in the writing speed of DVD-R/RW. Required power is proportional to square root of writing speed experimentally [1]. Output power of 140mW is required for 8x drives now in development, and that of 200mW is supposed to be required for 16x drives in the next generation. High temperature operation is also required since the circumstance temperature around the laser diodes may rise up to 60 – 70 °C in actual drives due to high-density mounting. We have reported the 140mW class 660-nm laser diodes for DVD-R/RW/RAM [2]. In this paper, we demonstrate high-power operation over 200mW at 85 °C by reduction of the absorption loss and the increase of the cavity length.

2. Structure

Laser structure is schematically shown in Fig. 1. This laser is a double-channel type ridge structure and it has the advantage of low absorption loss due to the real refractive index waveguide[2,3]. To avoid catastrophic optical damage at facets, a window-mirror-structure by intermixing the MQW active layer is also adopted. The facets are AR and HRcoated. Chips are mounted in junction down configuration. Cavity length is 1500 um while that of our conventional laser is 1100 um.

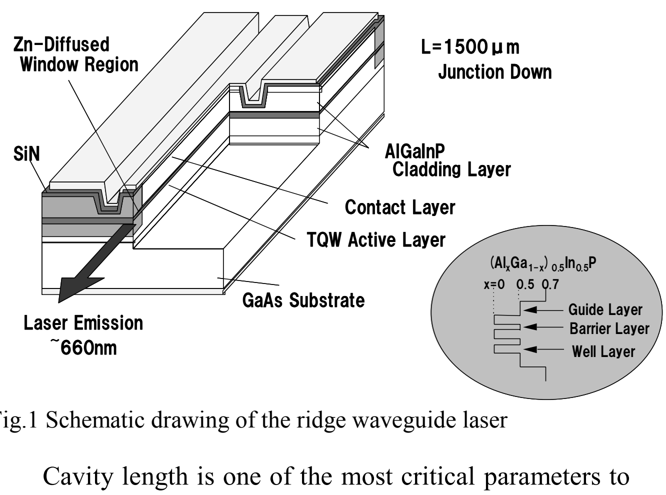

Fig.1 Schematic drawing of the ridge waveguide laser

Cavity length is one of the most critical parameters to realize high power operation at high temperature, since longer cavity length reduces the threshold carrier density and thermal resistance. However, the longer cavity length increases the threshold current, and decreases slope efficiency. The slope efficiency affects maximum output power dramatically in high power laser diodes and, therefore, should be kept as high as possible. The slope efficiency Se is given by the following equation;

$$Se = \frac{1.24}{\lambda_L} * \frac{1}{1+\frac{1-Rr}{1-Rf}\sqrt{\frac{Rf}{Rr}}} * \frac{\ln(\frac{1}{RfRr})}{2\alpha * Lc + \ln(\frac{1}{RfRr})} * \eta_i$$

where λ_L, Rf, Rf, Lc, ηi and α are lasing wavelength, front facet reflectivity, rear facet one, cavity length, internal efficiency, and average internal loss, respectively. Especially for long cavity lasers, reduction of the internal loss α is important to increase the slope efficiency, since the slope efficiency depends on α*Lc.

To reduce α in the p-type cladding layer, low doping density is preferred. However, it increases the resistance of the layer and may cause a carrier leakage over the heterojunction. Therefore, we optimized the doping density of the p-type cladding layer. Next, we adopted an asymmetric cladding layer structure [4]. In this structure, reflective index of n-type cladding layer is higher than that of p-type cladding layer. This makes the optical field shift toward the n-type cladding layer, and α in the p-type cladding layer is reduced.

Slope efficiencies as a function of the cavity lengths are calculated by the equation above and shown in Fig. 2. Since the internal loss α of our laser is reduced as mentioned above, decrease of the slope efficiency is estimated at as small as 10% with the increase of the cavity length from 1100 um of our conventional laser to 1500 um of this work.

Another critical parameter to realize the high power

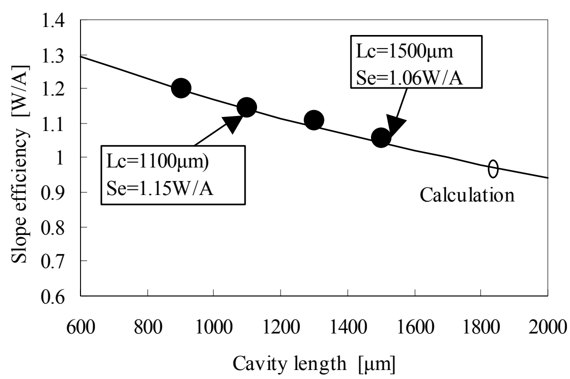

Fig.2 Calculated and measured slope efficiencies.

operation is the stability of the lateral mode. Since a narrow ridge width is required to stabilize the lateral mode, we adopt an ECR dry etching and a wet etching combination technique for the ridge formation.

3. Characteristics

The cavity length dependence of P-I characteristics at 25°C under CW condition is shown in Fig. 3. In spite of decrease of the slope efficiencies at low power and the increase of the threshold currents, maximum output powers and kink powers are improved with the increase of the cavity length. Agreement between the measured and the calculated slope efficiencies are good, as shown Fig. 2. Maximum output power of the 1500 um cavity laser is over 290mW, whereas that of the 1100 um cavity laser is 250mW. This improvement is due to a suppression of the carrier leakage over the heterojunction at high power, since threshold carrier density and thermal resistance are reduced.

Temperature dependence of P-I characteristics under pulse condition is shown in Fig. 4. At room temperature, the kink level is over 250mW for the 1500 um cavity laser, whereas that of the 1100 um cavity laser is 236mW. Even at the high temperature of 85 °C, the kink level is as high as over 200mW for the 1500 um cavity laser. This improvement suggests that a fundamental lateral mode is kept stable up to high power due to a suppression of a temperature rise in the active layer.

Fig. 5 shows far field patterns (FFP's) as a function of the power. The FWHM's of parallel and perpendicular to the junction plane are 10.3 ° and 17.9 ° at 200mW, respectively. Single lobed FFP's up to 250mW means the lateral mode stability.

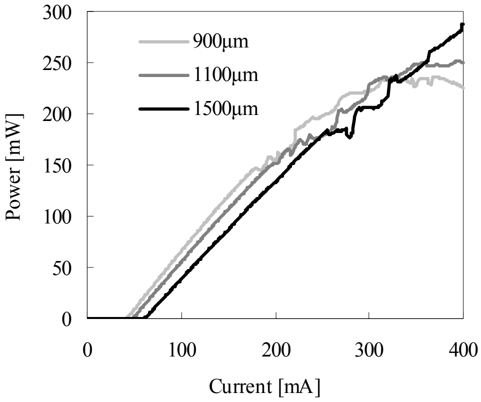

Fig. 3 P-I characteristics at 25°C under CW condition

3. Conclusions

Kink free operation over 250mW at room temperature and over 200mW at 85 °C has been realized by reduction of the absorption loss and the increase of the cavity length. To the best of our knowledge, this is the highest power recorded for narrow stripe laser diodes with a wavelength of 660nm. This laser diode is suitable for the high speed (16x) DVD-R/RW drives in the next generation.

References

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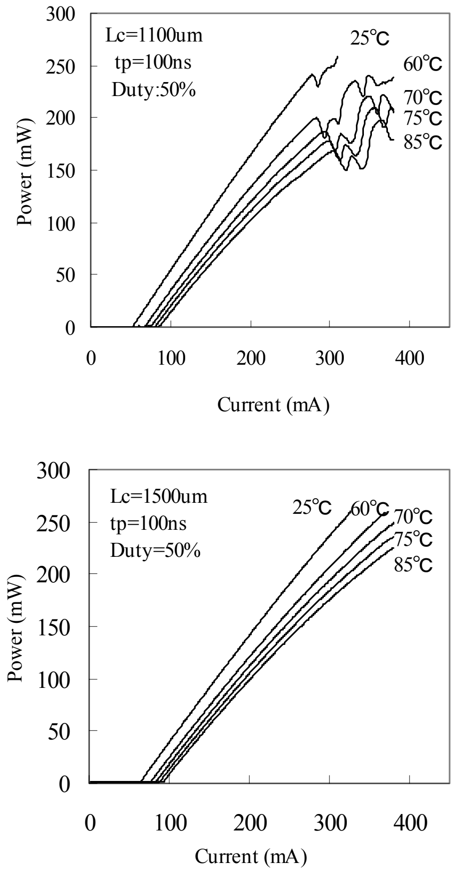

Fig. 4 P-I characteristics under pulse condition for cavity length of 1100 um and 1500 um.

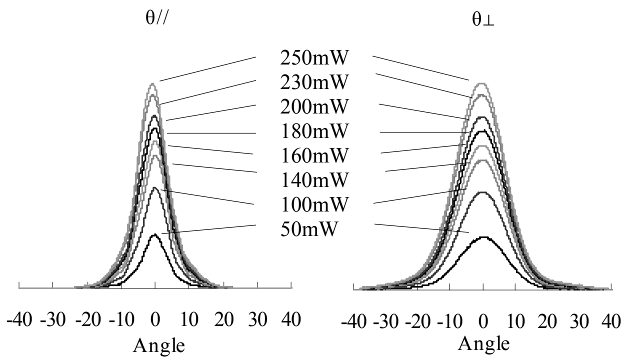

Fig. 5 Far field patterns as a function of power