High Power Long Cavity T³ Laser with Extremely Narrow Beam

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A 790nm long cavity T³ laser which has a thin tapered thickness active layer, has been developed. Compared to the 250µm laser, the 350µm long cavity laser has reduced the current density and the thermal resistance which are related with the temperature rise of the active layer. The beam divergence parallel, θp, and perpendicular, θl, to the junction are 11.5° and 15.5°, respectively, and the aspect ratio is 1.35. In spite of such a narrow beam, the laser has emitted over 100mW light output power even at 80 °C, and the fundamental transverse mode has been confirmed at least up to 120mW. Because of T³ structure, threshold current, Ith, has not increased in the range of θl less than 20°. The stable 50mW operation at 50 °C has been confirmed over 1000 hours.

1. Introduction

Short wavelength, narrow beam and high power lasers are expected to better the performance of optical information processing systems, such as disk memories. Especially, a narrow beam is effective for improving the coupling efficiency with optical components. Therefore, a narrow beam laser can supply higher power on the objects (i.e. optical disks) than a wide beam laser of the same light output power. We have reported the high power T³ (Thin Tapered Thickness Active Layer) laser 1-2) which can reduce the optical power density near the mirror and realize the narrow beam divergence by thinning the active layer near the mirror. Furthermore, since the extension of the cavity length is possible to reduce the current density and the thermal resistance 3-4), an extremely narrow beam laser by thinning an active layer, can be realized without degrading the temperature characteristics.

In this paper, we present a high power, short wavelength and extremely narrow beam laser with good temperature characteristics by long cavity T³ structure.

2. Structure and Fabrication

Figure 1 shows the schematic representation of the long cavity T³ laser. The lasers are prepared by MOCVD (Metal Organic Chemical Vapor Deposition)/ LPE (Liquid Phase Epitaxy) hybrid growth technique. Prior to the growth, the narrow ridge (20µm width) near both mirrors, the wide ridge (100µm width) in the inner region and the tapered ridge between the narrow and the wide ridges are formed along the (011) direction on a (100) surface of a p-GaAs substrate. In the first step growth, n-GaAs current blocking layer is grown by MOCVD on the ridged substrate, preserving its ridge

![Fig.1 Schematic structure of a long cavity T³ laser.](image-url)
shape. After the formation of a V-groove which operates as current path and waveguide, p-Al$_{0.47}$Ga$_{0.53}$As lower cladding layer, p-Al$_{0.14}$Ga$_{0.86}$As active layer, n-Al$_{0.47}$Ga$_{0.53}$As upper cladding layer and n-GaAs ohmic contact layer are grown successively by LPE. LPE growth on such a ridged substrate results in an active layer with thin tapered thickness which is thinner near the mirror than in the inner region. The front facet of the laser is AR (anti reflection) coated and the rear facet is HR (high reflection) coated, after the metallization and cleaved processes. The cavity length is 350μm. The laser is mounted in a junction-down configuration.

3. Device Characteristics

It is well known that the external efficiency, $\eta_d$, decreases, and the threshold current, $I_{th}$, increases as the cavity length is extended. The typical slope efficiency from each facet, $\eta_s$, and threshold current, $I_{th}$, of the uncoated long cavity $T^3$ laser are about 0.34 W/A and about 50 mA, respectively, while those of the usual 250μm $T^3$ laser are about 0.39 W/A and about 38mA, respectively. Therefore, the operating current, $I_{op}$, at 30mW output power of the AR-HR coated long cavity laser is about 20% higher than that of the AR-HR coated 250μm laser.

On the other hand, the threshold current density, $J_{th}$, and the operating current density, $J_{op}$, can be reduced as the cavity length, L, is extended. Figure 2 shows the current density, $J_{th}$ and $J_{op}$ at 30mW, of coated long cavity $T^3$ lasers compared to the coated usual 250μm $T^3$ laser. The solid lines are calculated values. $J_{th}$ and $J_{op}$ are lower as L is longer. The major difference is that the operating current density of long cavity lasers are reduced about 1kA/Cm$^2$ compared with the 250μm lasers.

Moreover, the extension of the cavity is possible to reduce the thermal resistance, $R_{th}$ which is a factor of temperature rise of active layer$^{3-4}$. Figure 3 shows the dependence of the thermal resistance on the cavity length. The solid line is calculated value by the model of Joyce and Dixon $^5$. As the L is longer, the $R_{th}$ is lower in inverse proportion to the L. The $R_{th}$ of the long cavity lasers is reduced about 10 K/W compared with the 250μm lasers.

Figure 4 shows the CW light output power versus current characteristics of the long cavity $T^3$ laser (solid lines) compared
with the usual 250μm T³ laser (dashed lines). The full angles at half maximum of the beam divergence perpendicular to junction, θₚ of the long cavity laser and the 250μm laser are 15.5° and 19°, respectively. In spite of the narrower beam, the long cavity laser can emit over 100mW light output power even at 80 °C. The characteristic temperature T₀ of the long cavity laser is 150 K in the range of operating temperature less than 70 °C.

The light output power versus current characteristic for room temperature CW operation is shown in Fig. 5. The threshold current and slope efficiency for the front facet are 58mA and 0.77 W/A, respectively, and the lasing wavelength is about 790nm. The maximum CW light output power over 160mW is achieved without kink.

Figure 6 shows the dependence of the far-field patterns on the power. Stable fundamental transverse mode operation of the laser has been achieved up to 120mW. The

Fig. 4
CW light output power / current characteristics for various temperature, compared with the usual 250μm T³ laser we have reported ².

Fig. 5
Light output power / current characteristic for room temperature CW operation.

Fig. 6
Dependence of far-field pattern on power.
Figure 7 shows the relationship between $\theta_1$ and $I_{th}$ of the uncoated long cavity T$^3$ lasers. The calculated value and the model for calculation are also shown in Fig. 7. The $I_{th}$ of the long cavity laser increases only a little and maintains about 50mA, as $\theta_1$ becomes less than 20°. According to Fig. 7, the difference of the active layer thickness between the inner region and near the mirror, $\Delta d$, is about 0.01-0.02μm, which is similar to the $\Delta d$ of the usual 250μm T$^3$ lasers, as we have reported before 1-2).

The temperature rise of the active layer can be suppressed because of the reduction of the current density, the thermal resistance and the optical power density. Therefore, in a CW aging test under 50 °C, 50mW condition, the long cavity T$^3$ lasers have been operating with little degradation over 1000 hours.

4. Conclusion.

We have demonstrated a long cavity T$^3$ laser by adopting a long cavity in addition to T$^3$ structure. The current density and the thermal resistance have been reduced by this laser. Therefore, the good temperature characteristics up to the high power have been realized. The fundamental transverse mode has been confirmed at least up to 120mW. Moreover, the beam divergence is narrow and nearly circular. Because of T$^3$ structure, $I_{th}$ has not increased, as $\theta_1$ has become extremely narrower. Stable 50mW CW operation at 50 °C has been confirmed over 1000 hours. The long cavity T$^3$ laser is suitable for the obtaining the high power on the objects.

5. References.