B—4—3 Internal Loss of InGaAsP/InP Buried Crescent(λ = 1.3 μm) Laser

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The temperature sensitive behaviour of the threshold current I_{th} and the external quantum efficiency η_{ext} in InGaAsP/InP lasers imposes severe limitations on the applications at high ambient temperature. Recently, Adams et al.[1] explained the large temperature dependence of I_{th} and η_{ext} in 1.6 μm lasers by intervalence band absorption model. Similar temperature dependence has been observed also in 1.3 μm InGaAsP/InP lasers.[2] In their model, the internal absorption loss α is remarkably temperature dependent. This implies that the large temperature sensitive behaviour of InGaAsP/InP lasers is determined by those materials of which the lasers are made and there is almost no possibility to improve the temperature sensitive characteristics. However, no measurement of the temperature dependence of internal loss α has actually been done so far both in 1.6 and 1.3 μm lasers. We estimated the temperature dependence of α in 1.3 μm InGaAsP/InP BC(Buried Crescent) laser in the temperature range of 20 ~ 80°C by changing the reflectivity of the mirror facet with reflective coating and examined the possibility of improving the temperature sensitive characteristics.

The reflectivity was increased by coating three or five-layer Si/SiO_2 films on the rear end mirror of the laser. The external differential quantum efficiency η_{ext} is then expressed as

$$\eta_{ext} = \eta_f + \eta_r = \eta_i \cdot \frac{-\frac{1}{2L}\cdot \ln R_f R_r}{\alpha - \frac{1}{2L}\cdot \ln R_f R_r} \qquad (1)$$

where η_f and η_r are the external differential quantum efficiencies of front facet and rear facet, respectively, η_i is the internal quantum efficiency, L is the cavity length of the laser and R_f and R_r are the reflectivities of the front and rear end mirrors, respectively. R_f= 0.31. R_r is nearly equal to 0.61 for three-layer coating and 0.92 for five-layer coating. R_f and R_r have no temperature dependence. When A is defined as $A \equiv \eta_f^{(1)}/\eta_f^{(0)}$, where the superscripts (0) and (1) denote uncoated and coated condition, respectively, α is given as a function of A and the temperature dependence of α is reduced to that of A.

The temperature dependencies of $\eta_f^{(0)}$, $\eta_f^{(1)}$ and A are shown in Fig.1. Though

$\eta_f^{(0)}$ and $\eta_f^{(1)}$ decrease with increasing temperature, $\eta_f^{(1)}/\eta_f^{(0)} (\equiv A)$ has almost no temperature dependence. The average value of A is 1.36 and the standard deviation is 0.05. For three and five-layer reflective coatings, the standard deviations of A's were also very small for five samples in each case and it is understood that the A's are almost independent of temperature.

Calculated temperature dependencies of α are shown in Fig.2. Small scattering of A's leads to a relatively large scattering of calculated α. But in both cases apparent temperature dependencies are not observed in the temperature range of 20~80°C. This implies that the temperature sensitive behaviour of the threshold current in 1.3 μm InGaAsP/InP laser diode is not due to the temperature dependence of internal loss in this temperature range. The average values of α are about 18 cm^{-1} in both cases. This value of α could be explained by free carrier absorption loss and scattering loss.

From equation (1), the observed decrease in η_{ext} can be interpreted as due to the decrease in η_i. Its cause is not well known at this stage, but it might be considered that some leakage current which flows through the InP p-n junctions adjacent to the active region reduces the internal quantum efficiency. In this case there is a possibility to reduce the large temperature dependence of η_{ext} or I_{th} by improving the structure of the lasers.

In conclusion, the internal loss of BC laser is about 18 cm^{-1} and apparent temperature dependence was not observed in the temperature range of 20~80°C. This implies that the temperature sensitive behaviour of the threshold current in 1.3 μm InGaAsP/InP laser diode is not due to the temperature dependence of internal loss. There is a possibility to reduce the large temperature dependent characteristics by improving the structure of the lasers.

References

(1) A. R. Adams et al.; Jpn. J. Appl. Phys., 19, L621(1980).

(2) H. Ishikawa et al.; Electron. Lett., 17, 465(1981).

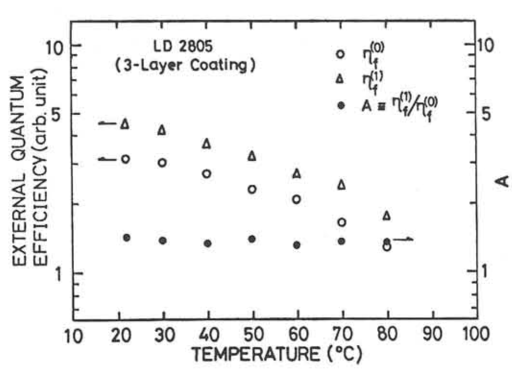

Fig.1 Temperature dependencies $\eta_f^{(0)}$, $\eta_f^{(1)}$ and A.

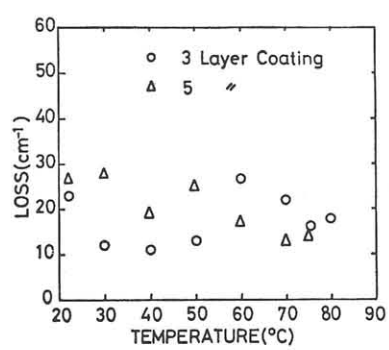

Fig.2 Temperature dependencies of α for 3- and 5-layer reflective coatings. Each point corresponds to an average value of α for five lasers.