B-4-5 Characterization of loss mechanism in 1.3 μm InGaAsP/InP laser diodes by acoustical and optical measurements

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Sensitive temperature dependence of threshold currents in InGaAsP/InP double hetero lasers have been intensively investigated, and several models have been proposed.[1)-3)] We report the experimental results of current-injection-induced acoustic (CIA) signals from InGaAsP/InP DH lasers, and show that a large internal optical loss exists and is saturated gradually above the lasing threshold currents. This phenomenon is considered to originate from optical absorption associated with inter-valence-band transitions. The experimental results are explained satisfactorily by our theory, based on the saturable absorption model due to the inter-valence-band transitions.

The I-L characteristics and the CIA signal for a BH InGaAsP/InP (1.3 μm) laser diode are shown in Fig.1(a) and (b), respectively. Saturation of the CIA signal is seen at very low current, the characteristic of which is quite different from that of GaAlAs DH lasers.[4)] Considering the relation between the saturation of the CIA signal and the lasing threshold current for GaAlAs DH lasers, the above results seem to indicate that the gain suppression occurs within the InGaAsP BH lasers well below the "apparent" threshold current, i.e., the lasers are already "lasing" far below the threshold current. This was also verified by the characteristics of the spontaneous emissions.

The CIA signal in Fig.1(b) increases again after the saturation at ∿10 mA. In this current range, the internal losses associated with Auger recombinations[1)] and carrier overflow[2)], will be constant because of the gain suppression. Therefore, the increase of the CIA signal above the saturation level indicates the existence of another internal loss. The CIA signal increment was plotted against the light output in Fig.1(c). A similar graph is shown in Fig.2 for other BH lasers. In all cases, the CIA signal level increases linearly with the light output, and is gradually saturated at about the threshold current in spite of the different I-L characteristics. The results indicate that the internal optical loss coefficient is constant for the low optical intensity but decreases for the high optical intensity. In other words, the apparent threshold current is determined by the optical intensity dependence of the optical loss. A similar result was obtained for an oxide-stripe DH laser.

The most possible mechanism of the saturable optical loss will be absorption associated with transitions of electrons from the split-off valence band into holes in the heavy hole band. The phonons emitted during the relaxation process of the electrons from the excited states in the heavy hole band into the instantaneously unoccupied states in the split-off band induce a local heating in the active layer, i.e., a CIA signal, as shown in Fig.3. We have developed a theory, based on such a saturable absorption model, and the experimental results are explained satisfactorily by the present theory, as shown in Fig.2.

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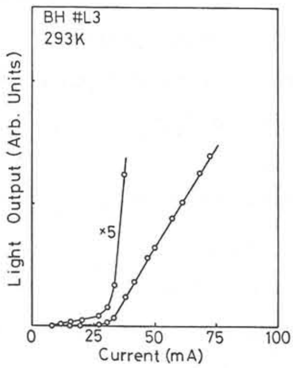

Fig.1(a)

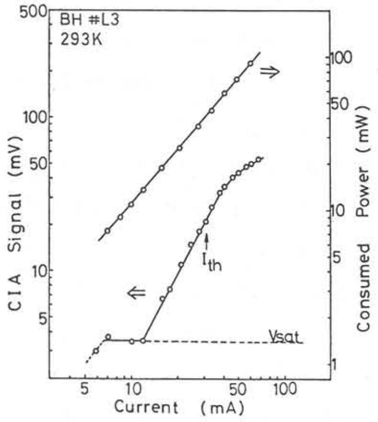

Fig.1(b)

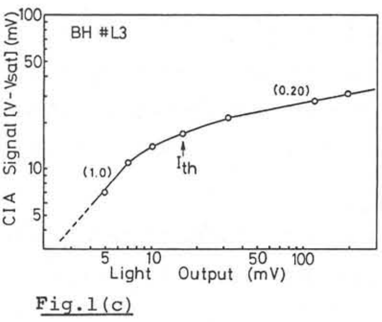

Fig.1(c)

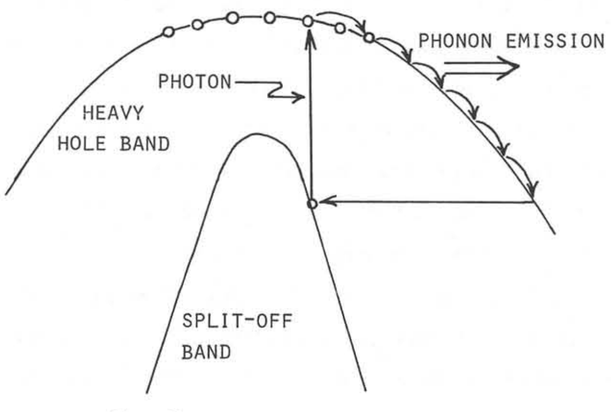

Fig. 3

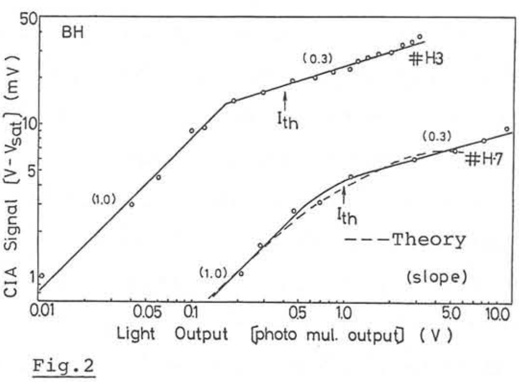

Fig.2