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Catastrophic Optical Damage Generation Mechanism in (AlGa)As DH Lasers

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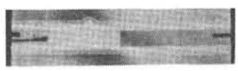
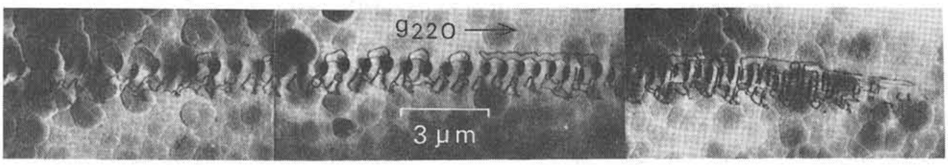
Maximum available optical power in (AlGa)As DH lasers has been limited by the catastrophic optical damage (COD) at a high optical power density operation (several MW/cm^2). Specific dark line defects have been observed in the bulk crystal, as well as mirror surface damage after the COD generation.[1)]However, the mechanism of the COD generation has not been well understood. In this report, the COD generation mechanism is clarified by TEM observation of the defects associated with the COD and by investigating dynamical behaviors of laser light excited by one-shot pulse.

Figure 1 shows an SEM-EBIC image and a TEM micrograph of the dark line defect observed in an (AlGa)As DH laser catastrophically degraded under repetitive 100 nsec pulse operation. In the EBIC image, it is observed that dark lines start from the mirror damage and propagate into the bulk crystal along the stripe direction. The TEM image shows that the lattice defects are composed of periodically positioned dark knots and surrounding dislocation networks. Detailed observation revealed that the dark knots are the multiple dislocation loops having the strong strain field. It was demonstrated that the dark line was introduced by applying one-shot-pulse and the number of produced dark knots was equal to the number of applied one-shot-pulse.



SEM-EBIC

Fig.1 TEM



The characteristic features of the dark knots suggest that these dislocations are formed during quenching of a locally molten region in the active layer and that the dark line growth is due to the repetition of melting and quenching associated with each pulse. The similar mechanism might occured at the mirror surface. Temperature rising mechanism can be estimated as follows. In the laser diode, the injected carriers are depleted near the mirror surface due to the fast non-radiative recombination at the crystal surface. This fact brings about the decrease of the effective band gap of the crystal, being followed by the localized temperature rise due to the strong absorption of laser light power. The temperature rise in the local region, again, causes further band gap decrease. Such a positive feed back gives rise to the heating of a small surface region. Recently, Henry et al.[2)]proposed a model of local heating up to the melting point from the observations of the photo-induced COD. We carried out another experiments which strongly support the above mentioned model.

The transient behaviors of optical power intensity detected from a mirror where COD has occured are shown in Fig. 2. The optical output suddenly fell down to about 40-50% of the initial intensity I_0 when the applied current exceeded a value corresponding to the COD level. When the amplitude of applied one-shot-pulse was increased, the delay time T_d became shorter. Optical output decay may be due to a high reflectivity or absorption at the molten zone. The delay time T_d in Fig. 2 can be understood as a time interval which is necessary for the local region in the active layer to be heated up to the melting point of GaAs. The pulse width dependence of the COD level, as shown in Fig. 3, is explained qualitatively by the above interpretation.

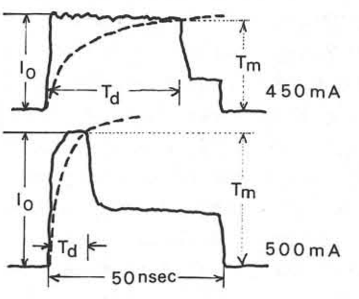


Fig.2 Dotted line represents temperature rise. Tm is melting point of GaAs.

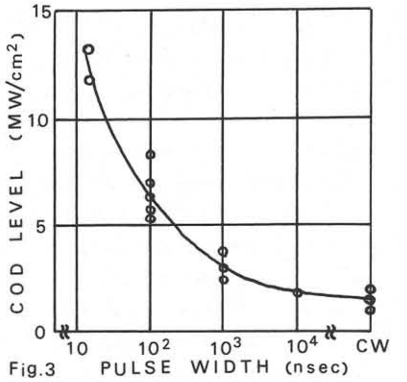


Fig.3

Based on the mechanism described, the increase of COD level has been demonstrated by a new structure laser. A "Window Structure Laser", in which carrier injected region is separated from the mirror surface and the optical absorption at the surface is reduced by a selective doping, showed extremely high COD level (60MW/cm^2) at 100 nsec pulse operation.[3]

It has been shown in this study that COD in (AlGa)As DH lasers occurs in the depleted region near the mirror surface at first and the periodic dark line defects are produced by following repetitive excitation.

References

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3) H. Yonezu, M. Ueno, T. Kamejima and I. Hayashi, IEEE J. Quantum Electron., to be published.