Journal of Luminescence 45 (1990) 215–217
North-Holland

STIMULATED PHOTO LUMINESCENCE OF ZnSe GROWN BY VAPOR PHASE EPITAXY

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In this paper we report stimulated emission in ZnSe epilayers under a nitrogen laser excitation. The ZnSe epilayers were grown by vapor phase epitaxy on n-GaAs substrates. The optical gain of the ZnSe epilayers was measured according to the method of Shaklee et al. in Phys. Rev. Lett. 26 (1971) 888. The stimulated emission spectra of the ZnSe epilayers at various excitation intensities were measured. The spectrum at high excitation intensity shows a dominant P band. The exciton–exciton (E_x–E_x) inelastic collision process is the dominant gain mechanism in the ZnSe epilayers at 64 K.

1. Introduction

In recent years extensive studies have been made on stimulated emission in II–VI semiconductors at low temperatures under intense optical or electron beam excitation. In these cases, transitions related to the exciton recombination are considered to be important as the optical gain mechanism. Catalano [2] and his coworkers have investigated the stimulated emission of ZnSe single crystals under one photon or two photon excitation in the temperature range between 20 and 100

under these conditions ranged from 1–2 μm/h. The film thickness was about 10 μm. A nitrogen laser (model QJD-9) with a peak power of 3 MW/cm^2 was used as the excitation source. The pulse duration was 10 ns and the repetition frequency was 10 Hz. The spontaneous luminescence spectra were measured by a grating monochromator (model 44W) with a RCA-C31034 cooled photomultiplier. The stimulated emission spectra and optical gain were measured using the gain measurement technique developed by Shaklee et al. [1]. A rectangular beam of light of variable length from the nitrogen laser

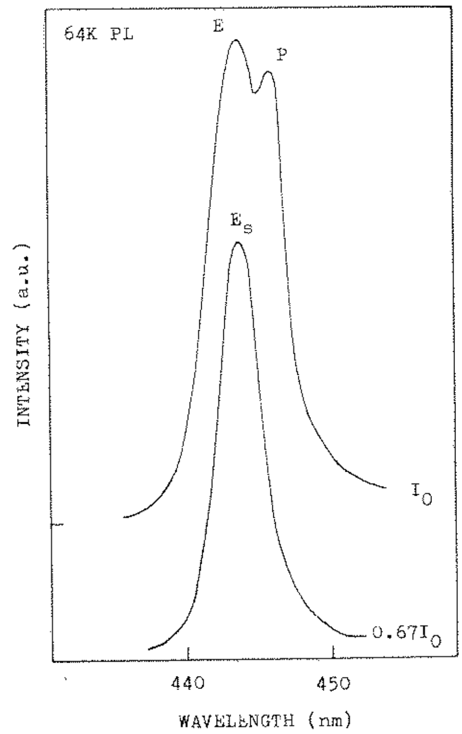

Fig. 1. The spontaneous emission spectra of ZnSe epilayers under various excitation intensities, excited by the 337.1 nm line of a N_2 laser with $I_0 = 2$ MW/cm^2.

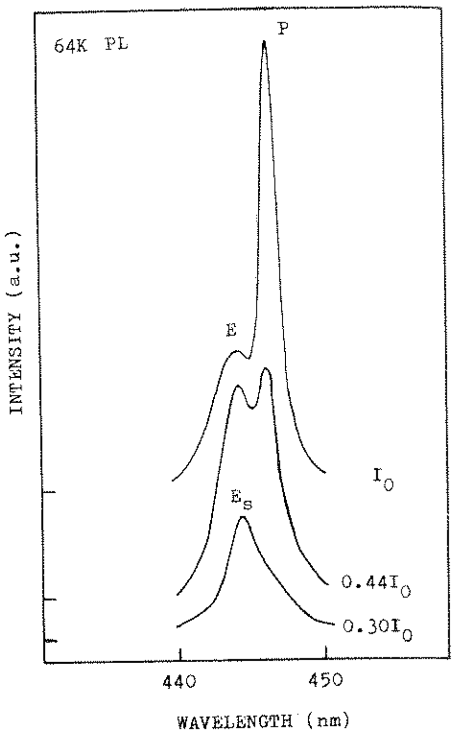

Fig. 2. The stimulated emission spectra of ZnSe epilayers under various excitation intensities, excited by the 337.1 nm line of a N_2 laser with $I_0 = 3$ MW/cm^2.

This suggestion was supported by the following two facts: first, the luminescence profile agrees with a theoretical calculation of the spontaneous emission spectrum for E_x–E_x interaction and exciton–carrier (E_x–e) interaction. Secondly, the luminescence intensities of the P and E bands depend quadratically and linearly on the excitation intensity, respectively [3].

The stimulated emission spectra of ZnSe at 64 K measured for various excitation intensities are given in fig. 2. The spectra show two bands, E and P, which are identified as E_x–e and E_x–E_x recombination radiation, respectively, under high excitation intensity. However, the stimulated emission intensity of the P band increases much faster with increasing excitation intensity than that of the spontaneous emission. This large increase is suggestive of gain in the E_x–E_x scattering recombination. The fact that the half width of the E_s band decreases with increasing excitation intensity, as shown in fig. 3, further demonstrates that there is gain in the P band.

Another positive identification of stimulated emission and gain on the P band is obtained by studying the luminescence intensity as a function of excitation length. The result is shown in fig. 4, which is a plot of emission intensity of the P band versus excitation length (l). Since the luminescence intensity (I) is proportional to $\exp(gl)$, where g is the net optical gain, this experimental result conclusively demonstrates the existence of stimulated E_x–E_x scattering recombination in the ZnSe epilayers. The departure from linearity in the curve of

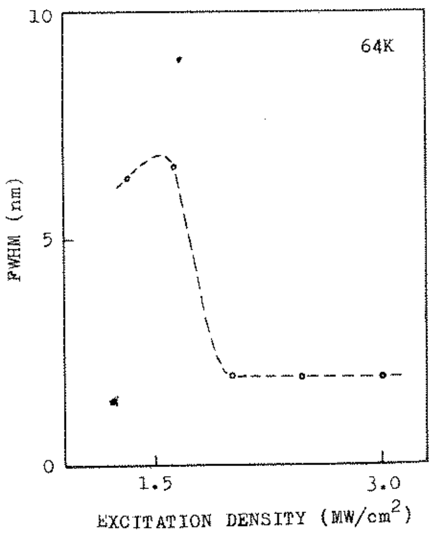

Fig. 3. The dependence of the full width of the E_s band on excitation intensities for ZnSe epilayers.

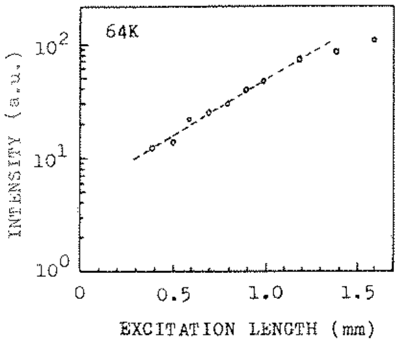

Fig. 4. Photoluminescence intensity of the P band as a function of excitation length for ZnSe epilayers.

fig. 4 at longer excitation length is to be expected because of saturation effect [1]. The magnitude of the optical gain was obtained to be about 15 cm^{-1}, when the excitation intensity is 3 MW/cm^2. In our experiment, only the 337.1 nm line of the nitrogen laser was used as the pumping source. In this case the pumping laser photon energy is much larger than the band gap of ZnSe. Moreover the penetration depth is about an order of magnitude shorter than that for resonant pumping. This is why the optical gain obtained here is rather small. We believe that it is possible to obtain suitable gain, if the ZnSe epilayers used here are excited by a resonant dye laser.

In conclusion, we have reported stimulated emission in ZnSe epilayers grown by VPE, and demonstrated that radiative decay accompanied by E_x–E_x scattering is the dominant gain mechanism in the ZnSe epilayers.

References

[1] K.L. Shaklee et al., Phys. Rev. Lett. 26 (1971) 888.
[2] I.M. Catalano et al., Solid State Commun. 43 (1982) 371.
[3] J.H. Zhang, MSc Thesis, Changchun Institute of Physics (1989).