

Room-Temperature Excitonic Optical Bistability in ZnSe-ZnCdSe/CaF₂ Multiple Quantum Wells.

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The excitonic optical nonlinearity and optical bistability are studied in ZnSe—ZnCdSe multiple quantum wells at room temperature. The increasing absorption and dispersive optical bistabilities with ns switching time are obtained at different excitation wavelengths for the first time. One observes a reduction of the absorption peak strength and a broadening on either side of excitonic absorption peak with increasing the incident intensities. The result indicated that the major contribution to the nonlinearity is the excitonic band broadening.

1. Introduction

Recently excitonic optical nonlinearity and bistability in wide gap II—VI semiconductor have attracted considerable attention due to the large excitonic binding energy.¹⁾ In particular, the corresponding enhancement of exciton binding energy in superlattices and multiple quantum wells (MQWs) make it possible to apply room temperature excitonic effects for optical switch and optical bistability devices.^{2,3)} Shen and Fan et al.²⁾ have studied the room temperature excitonic optical bistability in ZnSe—ZnS MQWs. Yang et al.⁴⁾ also reported the optical bistability with ns response time due to excitonic absorption effect at room temperature in ZnSe—ZnCdSe MQWs. Recently they⁵⁾ have obtained the picosecond optical bistability at room temperature in ZnSe—ZnCdSe bistable device. In this paper we reported the first observation of the room temperature increasing absorption and dispersive optical bistability at different excitation wavelengths in ZnSe—ZnCdSe MQWs.

2. Experiment

ZnSe—Zn_{0.8}Cd_{0.2}Se MQWs are grown on transparent CaF₂(111) substrates by atmospheric pressure metalorganic chemical vapour deposition (MOCVD). Dimethylzinc (DMZn), dimethylcadmium (DMCd) and 10% H₂Se together with H₂ gas are used as the source materials. A ZnSe buffer layer is intentionally inserted to avoid lattice mismatch between substrate and quantum well. The sample is composed of a hundred Zn_{0.8}Cd_{0.2}Se wells of thicknesses 5nm and ZnSe barrier layer of thicknesses 10nm. The MQWs are grown at 320°C and the growth process was automatically controlled. The excitation source is a dye laser pumped by the 337.1nm line of a N₂ pulse laser. The dye laser pulse is 10ns in duration and 25nm in spectral half

—width with a central wavelength of 520nm. It should be noticed that the Fabry—Perot cavity consisted of the two natural faces of the ZnSe—ZnCdSe MQWs. The incident light intensities is changed by a neutral density filter. The transmitted light from ZnSe—ZnCdSe MQWs under different incident intensities is monitored by a photodiode signal recovery is performed with the aid of a 4400 Boxcar averaging system. The experimental set-up is shown in Fig. 1.

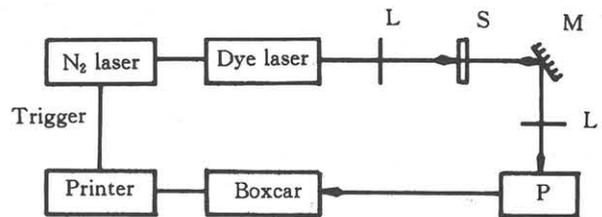


Fig. 1. The experimental set-up for measuring optical nonlinearity and bistability. (S) sample; (M) mirror; (L) lens; (P) photodiode.

3. Results and Discussion

Figures 2 (a), (b) and (c) show the normalized temporal shapes of the transmitted I_t and incident I_i pulses for the ZnSe—ZnCdSe MQWs at room temperature in the condition of three different incident wavelengths, respectively. When the laser pulse with different wavelengths passed the sample, the shapes of transmitted I_t pulse show the deformity compared to the shapes of incident I_i pulse. The insets of Fig. 2. give the corresponding hysteresis loops $I_t = f(I_i)$ at three incident wavelength. We observed the optical bistabilities with different directions of the hysteresis loops. At wavelength of 515nm, the direction of the hysteresis loop is counterclock wise. But the direction is clockwise for the wavelengths of dispersive and increasing absorption optical bistabilities have been obtained.

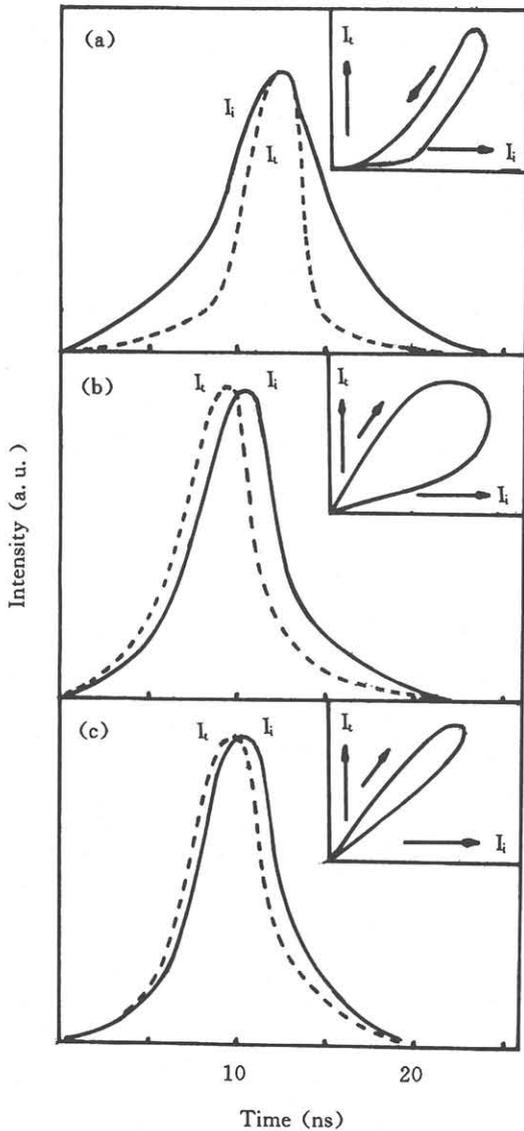


Fig. 2. Time dependence of the temporal shapes of the incident (solid) I_i and transmitted (broken) I_t pulses in ZnSe-ZnCdSe/CaF₂ MQWs at room temperature at different incident wavelengths (a) 515nm, (b) 510nm and (c) 519nm. The inserts show the resulting hysteresis loops (a), (b) and (c).

In order to explain the above experimental result, we measured the emission and absorption spectra of the ZnSe-ZnCdSe MQWs at room temperature, as can be seen in Fig. 3 and Fig. 4. A stronger emission peak is observed in the spectra of Fig. 3 at two excitation densities by the 337.1nm line of an N₂ laser. We noticed that the peak positions of emission band are located at 518.1nm and 520.5nm under the excitation densities of $0.16I_0$ and I_0 , respectively. The band peak shifts to long wavelength side, and the full width at half maxi-

imum (FWHM) of the band becomes broad with increasing excitation densities. In Fig. 3 we also give the emission spectra of the same sample excited by the 365nm line of a 500W Hg lamp at room temperature. One band with narrower linewidth is observed at 516.2nm. In our recent works,⁶⁾ we have reported that the excitonic recombination in ZnSe-ZnCdSe MQWs at 77K, in which free excitonic emission was observed at low excitation density and the excitonic interaction due to exciton-exciton (Ex-Ex) scattering was obtained under high excitation density. The feature in Fig. 3 is similar to the result of Ref. 6. We considered that by Hg lamp excitation the luminescence dominantly come from free excitonic emission Ex, and under N₂ laser excitation Ex and Ex-Ex scattering process exist at same time. With increasing excitation densities Ex-Ex scattering becomes increasingly important. Hence, peak shifting and broadening of the band at two excitation densities in Fig. 3 are explained by above analysis.

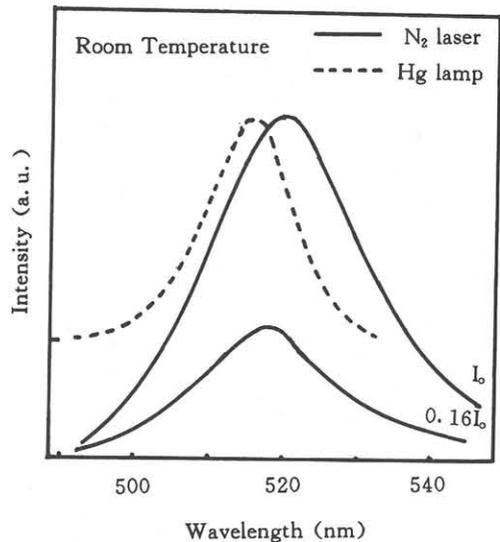


Fig. 3. Emission spectra of ZnSe-ZnCdSe MQWs at room temperature under two excitation I_0 and $0.16I_0$ (337.1nm line of a N₂ laser, $I_0 = 2\text{MW}/\text{cm}^2$). The dashed line gives emission spectrum of the sample at room temperature excited by the 365nm line of a Hg lamp.

Fig. 4 shows the absorption spectra of the ZnSe-ZnCdSe MQWs at room temperature by using broad band continuous wave light source. It is found that the absorption band peaked at 515nm tends to saturating and broadening with increasing incident intensities. It is reasonable to think that the absorption band in Fig. 4 should be attributed

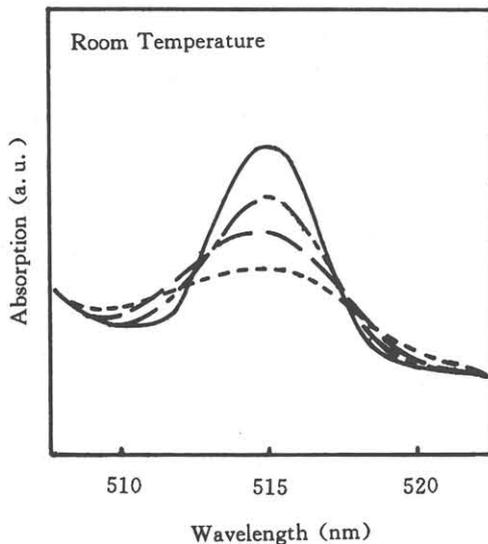


Fig. 4. Spectra of nonlinear absorption for ZnSe—ZnCdSe MQWs on CaF_2 substrates at room temperature at different incident intensities (I).

- $I_1 = 450 \text{ KW/cm}^2$
- - - $I_2 = 180.2 \text{ KW/cm}^2$
- · - $I_3 = 72 \text{ KW/cm}^2$
- $I_4 = 28.8 \text{ KW/cm}^2$

to the exciton absorption. The wavelengths of the incident light in Fig. 2 are just in the excitonic absorption region. The major nonlinear mechanisms related to exciton in semiconductor are as follows: excitonic band broadening,⁷⁾ phase space filling of excitonic states,⁸⁾ excitonic screening of Coulomb,⁹⁾ band filling and band shrinkage^{1,10)} Above nonlinear mechanisms give various contribution at different condition. Accompanied by a shift of band edge absorption with increasing excitation intensities, band filling and band shrinkage usually play major role after the exciton has been ionized at higher intensity. In ZnSe—ZnCdSe MQWs, stronger excitonic effect observed at room temperature due to the much large exciton binding energy should rule out appearing possibilities of band filling and band shrinkage. According to excitonic nonlinear theories, the excitonic screening of Coulomb in superlattice and quantum well structures does not play a major role.⁷⁾ With increasing incident intensities the phase space filling of excitonic states leads to a blue shift of excitonic absorption peak. This phenomenon is not observed in Fig. 4. Moreover, the two excitonic nonlinear effect would cause a reduction of the exciton oscillator strength and could not produce excitonic increasing absorption as shown in Fig. 2. (b), (c). Above analysis shows that the major contribution to the nonlinear-

ity can only be excitonic band broadening. The absorptions decreased in the region of the excitonic absorption peak and increased on either side of excitonic absorption peak are due to excitonic band broadening effect. The result leads to that one observes dispersive optical bistability near wavelength of peak position and increasing absorption optical bistability on either side of absorption band in Fig. 2.

4. Conclusion

We have reported the excitonic optical bistabilities with ns switching time in ZnSe—ZnCdSe MQWs at room temperature. The results indicate that the dispersive and increasing absorption optical bistabilities at different incident wavelengths are observed, for the first time. The analysis of the room temperature emission and absorption spectra shows that the main contribution to the optical nonlinearity is exciton band broadening.

Acknowledgements

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