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THE STUDY OF THIRD ORDER NONLINEARITIES IN ZnCdSe—ZnSe/GaAs MQWs USING Z—SCAN

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The third order nonlinearities in ZnCdSe — ZnSe multiple quantum wells (MQWs) grown by the metal—organic chemical vapour deposition (MOCVD) on GaAs substrates have been studied at room temperature using Z—scan, for the first time. The research result indicates that the nonlinear refractive index n_2 in the ZnCdSe—ZnSe/GaAs MQWs is about -5.05×10^{-5}esu. Considering the absorption spectra in ZnCdSe—ZnSe/GaAs MQWs under different pump intensities at room temperature obtained here, the major nonlinear mechanism for the third—order optical nonlinearities in ZnCdSe—ZnSe/GaAs MQWs can be due to band shrinkage effect in the ZnCdSe—ZnSe MQWs.
Key words: A. Quantum wells B. Laser processing D. Optical properties
E. Nonlinear optics

1. Introduction

Wide gap II — VI semiconductor MQWs is a kind of nonlinear material with a fine prospect for practice use[1-4]. They have been promising candidates for producing optical bistable switches, semiconductor diode lasers, optical information processing and other nonlinear optical devices with low power, high speed and small size. The nonlinear refractive index is a very important parameter in designing such devices. However, there is not yet a satisfactory method to measure the the nonlinear refractive index for thin film materials. Previous measurements of nonlinearity have used a variety of techniques including nonlinear interferometry [5-6], degenerate four — wave mixing[7], nearly degenerate three—wave mixing[8], ellipse rotation[9], and beam distortion measurements[10-11]. The first three methods, namely, nonlinear interferometry and wave mixing, are potentially sensitive techniques, but all require relatively complex experimental apparatus. Beam distortion measurements, on the other hand, are relatively insensitive and require detailed wave propagation analysis. The Z—scan technique is a sensitive single—beam technique for measuring both the nonlinear refractive index and nonlinear absorption coefficient. It is based on the principles of spatial beam distortion, but offers simplicity as well as very high sensitivity. In this paper we report the first study of cubic nonlinearities in ZnCdSe—ZnSe/GaAs MQWs at room temperature using Z—scan.

2. Experiment

The ZnCdSe — ZnSe MQWs were grown by MOCVD on GaAs substrates and they consisted of 3.8nm wells and 6.2nm barriers repeated for 100 periods. The sample used in this study was prepared by etching a window on GaAs substrates.

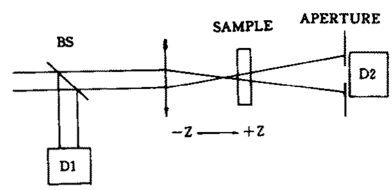

Fig. 1. The Z—scan experimental apparatus

Using a Gaussian laser beam in a tight—focus limiting geometry, as depicted in Fig. 1, we measure the transmittance of the sample through a finite aperture placed in the far field as a function of the sample position (z) measured with respect to the focal plane[12]. 200 picosecond full width at half maximum (FWHM) pulses are focused to a beam waist ω_0 of 33μm from frequency—doubled Nd:YAG laser with the peak irradiance I_0 of 1.63 MW/cm^2.

3. Results and discussion

Fig. 2 shows the Z — scan of the 1μm thick ZnCdSe — ZnSe/GaAs MQWs using 200ps Nd:YAG laser pulses having the peak irradiance of 1.63 MW/cm^2. The peak—valley configuration of this Z—scan is indicative of a negative (self—defocusing) nonlinearity from Fig. 2.

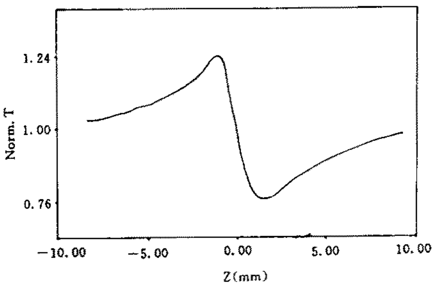

Fig. 2. Measured Z − scan of a 1μm thick ZnCdSe − ZnSe/GaAs MQWs using 200ps pulses at λ=532nm.

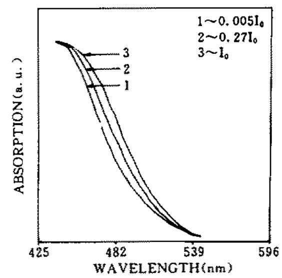

Fig. 3. Change in absorption spectrum under different pump intensities in ZnCdSe−ZnSe MQWs at room temperature (I_0=1.63MW/cm^2)

An easily measurable quantity $\triangle T_{p-v}$ can be defined as the difference between the normalized peak (maximum) and valley (minimum) transmittances, $T_p - T_v$. The variation of this quantity as a function of $|\triangle\Phi_0|$ as calculated for various aperture sizes is found to be almost linearly dependent on $\triangle\Phi_0$ within ±3% accuracy the following relationship holds[12].

$$\Delta T_{p-v} \approx 0.405(1-s)^{0.25}|\Delta\Phi_0| \; for \; |\Delta\Phi_0| \leqslant \pi, \quad (1)$$

where, $\Delta\Phi_0$ is the on−axis phase shift at the focus, $s=1-\exp(-2r_a^2/\omega_a^2)$ is the aperture linear transmittance, with r_a denoting the aperture radius and ω_a denoting the beam radius at the aperture in the linear regime. And

$$\Delta\Phi_0 = k\Delta n_0 L_{eff} \quad (2)$$

where $L_{eff}=(1-e^{-\alpha L})/\alpha$, with L the sample length and α the linear absorption coefficient. Here, the change of refractive index $\Delta n_0=\gamma I_0$ with I_0 being the on − axis irradiance at focus. And nonlinear refractive indexes $n_2(esu)=(cn_0/40\pi)\gamma(m^2/W)$, where c(m/s) is the speed of light in vacuum, n_0 is the linear index of refraction. Thus

$$n_2 = (2.4\times10^6 n_0)\Delta n_0/I_0 \quad (3)$$

In our experiment $n_0=2.45$, $\alpha=5\times10^3cm^{-1}$, $s=0.3$, $\Delta T_{p-v}=0.48$ as shown in Fig. 2. So we can get

$$\Delta\Phi_0 = -1.30,\ \Delta n_0 = -0.14,\ n_2 = -5.05\times10^{-5}esu$$

In order to study the origin of the nonlinear refractive index in the ZnCdSe−ZnSe/GaAs MQWs, the absorption spectra of the ZnCdSe − ZnSe MQWs at room temperature under different intensities of the pump beam (the 532nm line of a Nd:YAG laser) were measured as shown in Fig. 3. Only the absorption edge in ZnCdSe−ZnSe MQWs at room temperature is observed and it shifts to lower energy side with increase in pump intensities in Fig. 3. Therefore, it is reasonable to consider that the major origin for the nonlinear refractive index in the ZnCdSe − ZnSe/GaAs MQWs is due to the band gap effect. On the basis of the nonlinear theories, the nonlinearities due to band gap effect mainly includes band filling and band shrinkage[13−14]. The major characteristics of the band filling and band shrinkage effects are the blue shift and red shift of the band gap absorption, respectively. At high pump intensities, the red shift of band gap absorption is observed at room temperature from Fig. 3. So we can attribute the major nonlinear mechanism for the nonlinear refractive index n_2 obtained here to band shrinkage effect in the ZnCdSe−ZnSe MQWs.

4. Conclusions

In conclusion, the third−order nonlinearities in ZnCdSe−ZnSe multiple quantum wells(MQWs) have been studied using Z−scan at room temperature for the first time. The nonlinear refractive index n_2 in the ZnCdSe−ZnSe/GaAs MQWs is about -5.05×10^{-5}esu. Considering the absorption spectra in ZnCdSe/ZnSe MQWs, the major nonlinear mechanism for the third−order optical nonlinearities in ZnCdSe−ZnSe MQWs is major due to band shrinkage effect in the ZnCdSe − ZnSe MQWs.

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