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ZnSe-CdZnSe Multiple Quantum Wells Optical Bistable Device

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We present the first study of room — temperature nanosecond switching property of ZnSe — CdZnSe MQWs F—P—type optical bistable device operation in reflection, in which the switching threshold and contrast ratio in the ZnSe—CdZnSe MQWs optical bistable device are about 47kW/cm^2 and 7:1, respectively. The research results indicate that the major nonlinear mechanism for the optical switching property is due to the change of the refractive index caused by the effect of the excitonic saturating absorption effect in the ZnSe—CdZnSe MQWs.

1. Introduction

Recently room—temperature excitonic optical nonlinearities and optical bistability in wide gap II — VI semiconductors multiple quantum wells (MQWs) have become an interesting research topic. Lee et al. [1] have reported the excitonic saturating absorption in ZnTe—CdZnTe MQWs at room temperature; We have investigated the room — temperature excitonic optical bistabilities in ZnSe — ZnS MQWs with nanosecond switching time[2] and in ZnSe — ZnTe MQWs with picoseeond switching time[3] operation in reflection. In this paper, we report the first study of room tamperature excitonic switching property in ZnSe — CdZnSe MQWs F—P—type optical bistable device with nanosecond switching time operation in reflection.

2. Experimental results and discussion

The material system within the F — P cavity studied here is a ZnSe — $Cd_{0.24}Zn_{0.76}Se$ MQWs of total thickness of 0. 75μm grown by metalorganic chemical vapour deposition (MOCVD) on a n — GaAs substrate which consists of 50 periods of 5nm $Cd_{0.24}Zn_{0.76}Se$ well and 10nm ZnSe barriers. The GaAs substrate was removed by etching to allow making F—P cavity.

The F—P cavity used in our research is made by vacuum deposition with a thermal source under a backgound pressure of 10^{-6} Torr. The reflective layer is made according to the prescription: $(HL)^p (H')$, where p = 5. The notation (HL) implies a quarter — wave of high — index material, H, followed by a quarter—wave of low —index material, L, p times. The region H' is the ZnSe — $Cd_{0.24}Zn_{0.76}Se$ MQWs; here H'=0. 75μm. The high—index material is ZnS with refractive index n_h of 2. 35. The low — index material used is cryolite (Na_3AlF_6) with refractive index n_l of 1. 35. The quarter—wave layers, having ZnS and Na_3AlF_6 alternatively, are deposited on the down—side of the MQWs layer. The reflectivity of the up—side of the MQWs due to the smooth nature face of the MQWs layser is about 0. 35. The reflectivity of down side of the MQWs with the reflective layer is about 0. 9. The excitation source was a tunable dye laser pumped by the 337. 1nm line of a UV—24 N_2 laser producing 6ns pulses at the wavelength of 525nm with repetition rate of 30Hz. The reciver is a 4400 Boxcar average system with minimum gate width of 2ns. The experimental setup is shown in fig. 1.

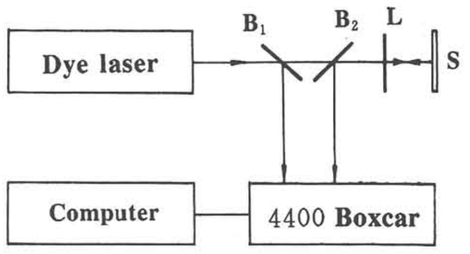

Fig. 1 Schematic diagram for measuring optical switching property in ZnSe-CdZnSe MQWs optical bistable device on reflection at room temperature; (B) beam splitter; (L) lens; (S) sample.

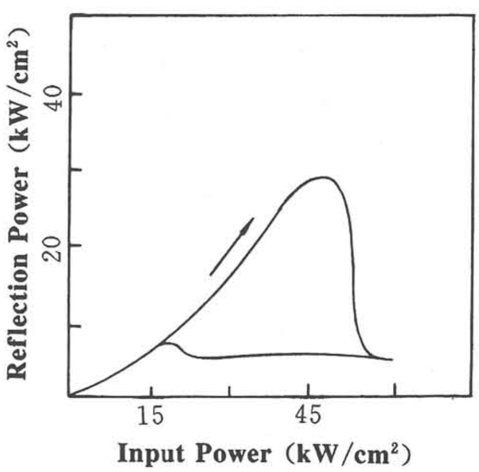

Fig. 2 The optical switching property of ZnSe-CdZnSe MQWs optical bistable device on reflection at room temperature.

Fig. 2 is the room — temperature switching property of the ZnSe—$Cd_{0.24}Zn_{0.76}Se$ MQWs F—P —type optical bistable device operation in reflection . The experimental result shows that the switching threshold and the contrast ratio for the optical bistable device operation in reflection are about 47kW/cm^2 and 7:1, respectively.

For a F—P cavity, the reflectivity is[4]:

$$R=\frac{E+F\sin^2\Phi}{1+F\sin^2\Phi} \qquad (1)$$

where
$$E=\frac{(R_f-R_e)^2}{4R_eR_f}F \qquad (1a)$$

and
$$\Phi=\frac{2\pi}{\lambda}nL \qquad (1b)$$

with
$$R_e=(R_fR_b)^{1/2}e^{-\alpha L} \qquad (1c)$$

Here the R_b and R_f are the exit—face and entrance — face reflectivities, respectively. n and α are the refractive index and absorption coefficient, respectively. λ is the incident light wavelength and L is the cavity length.

In our case, the absorption coefficient α is about 3×10^3/cm, L=0. 75μm, R_f=0. 35 and R_b= 0. 9. From the above parameter, the E and F are about 0. 1 and 6, respectively. we abtain:

$$R=\frac{0.1+6\sin^2\Phi}{1+6\sin^2\Phi} \qquad (2)$$

At high excitation intensity , the refractive index can be changed in the ZnSe-$Cd_{0.24}Zn_{0.76}Se$ MQWs, the change of the refractive index should cause the change of the R. When the excitation intensity in the ZnSe-$Cd_{0.24}Zn_{0.76}Se$ is high enough, the positive feedbeck required for the optical switching property can be achieved by the F-P cavity and the chang of refractive index in the ZnSe-$Cd_{0.24}Zn_{0.76}Se$ MQWs. According to the equation (2), in our case, the idea contrast ratio (CR) for the giving F-P cavity is :

$$CR=\frac{R_{max}}{R_{min}}=\frac{\frac{0.1+6}{1+6}}{0.1}=8.6:1 \qquad (3)$$

The value calculated for the CR is close to the experimental value of 7 : 1. Obvious the CR can is very large by reducing the value of E. The switching threshold can be reduced by optimizing the ZnSe-CdZnSe optical bistable device[4].

In order to study the origin of the optical switching property in the optical bistable device, the absorption spectrum of the ZnSe-$Cd_{0.24}Zn_{0.76}Se$ MQWs is measured at room temperature by using a broad-band continuous wave light source as shown in fig. 3. The excitonic absorption peak in the ZnSe-$Cd_{0.24}Zn_{0.76}Se$ MQWs is about at 520nm, therefore the wavelength of excitation light is just at the excitonic absorption region. On the basis of the excitonic and related nonlinear theories , the intensities in a MQWs required for the excitonic saturating absorption effect is smaller than that in the band gap effeet in the MQWs. It is reasonable to consider that excitonic saturating absorption effect should firstly play a maior role. Now we want to consider whether the band gap nonlinear effect for the optical switching property of the optical bistable device should play a major role too. We change the wavelength of the excitation light to the position of 520nm, in which the excitonic nonlinear refractive index caused by the excitonic saturating absorption effect is very small than that in the wavelength of 525nm. When the intensity of the excitation light is about equal to $50kW/cm^2$, the optical switching property does not be observed in the experiment. The result indicate that the band gap nonlinear effect does not play a major role. Therefore the major nonlinear mechanism for the optical switching property is major due to the excitonic nonlinear refractive index caused by the excitonic saturating absorption effeet in the ZnSe-$Cd_{0.24}Zn_{0.76}Se$ MQWs.

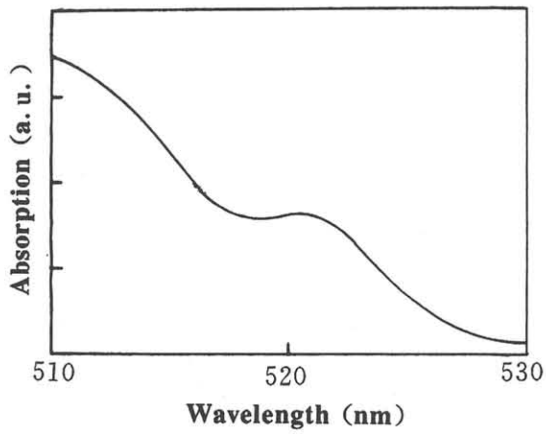

Fig. 3 The absorption spectrum of ZnSe-CdZnSe MQWs at room temperature.

3. Conclusions

In conclusion, we have studied the room-temperature nanosecond switching property of ZnSe-CdZnSe MQWs F-P-type optical bistable device operation in reflection, for the first time. The experimental result indicates that the optical switching threshold and contrast ratio for the optical bistable device are about $47kW/cm^2$ and 7 : 1, respectively. The research results indicate that the major nonlinear mechanism for the optical switching property is due to the change of the refractive index caused by the effect of the excitonic saturating absorption in the ZnSe-CdZnSe MQWs. To further optime the F-P cavity and the material system, the optical switching property in the ZnSe-CdZnSe MQWs optical bistable device can be expected to become a useful switching device with low switching threshold, fast response time and high contrast ratio[3].

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