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Picosecond Excitonic Optical Bistability in ZnSe-ZnTe/GaAs MQWs on Reflection at Room Temperature

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The excitonic optical bistability with picosecond switching time in ZnSe—ZnTe/GaAs multiple quantum wells (MQWs) has been studied on reflection at room temperature for the first time . The experimental results indicate that the switching threshold from high to low state and the contrast ratio for the optical bistability are about 1. 1MW/cm^2 and 6 : 1, respectively. The major nonlinear mechanism for the optical bistability is due to the change of refractive index caused by the excitonic saturating absorption.

1. Introduction

Optical bistability of semiconductor superlattices has become an interesting research topic recently. In particular a F—P optimized for operation on reflection, it has many distinct advantages over those used in transmission, such as a reduced effect of loss and infinite contrast ratio [1] ZnSe—ZnTe MQWs can cover a wide spectra range by changing the well and barrier widths in the material system, and can be expected to be used in optical bistable devices. We have reported the picosecond optical bistability of ZnSe—ZnTe/CaF_2 MQWs in transmission at room temperature[2], we attributed the major nonlinear mechanism for the optical bistability to the band shrinkage of the ZnSe—ZnTe MQWs. In this paper, we report the first observation and study of the excitonic optical bistability with picosecond switching time in ZnSe—ZnTe/GaAs MQWs on reflection at room temperature.

2. Experimental results and Discussions

The sample studied here is a ZnSe — ZnTe MQWs of total thickness of 1μm grown by metalorganic chemical vapour deposition (MOCVD) on GaAs substrate, which consists of 100 periods of 2nm ZnTe wells and 8nm ZnSe barriers. The excitation source is a Nd : YAG laser producing 1ns pulses at a wavelength of 532nm with repetition rate of 1Hz. The time dependence of incident and reflection pulses is received at the same time by using a M176 high speed streak camera with 2ps response time. The experimental setup is shown in fig. 1.

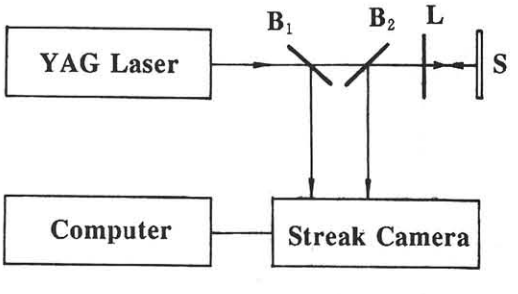

Fig. 1 Schematic diagram for measuring optical bistability in ZnSe — ZnTe MQWs on reflection at room temperature: (B) beam splitter; (L) lens; (S) sample.

Fig. 2 is the normalized temporal shapes of incident I_0 and reflection I_r pulses in the ZnSe — ZnTe/GaAs MQWs at room temperature . The experimental result shows that the 1ns incident I_0 pulse is compressed into 750ps reflection I_r pulse. The fact indicates that the dependence of the reflection intensities I_r on the incident intensities is nonlinear . Based on the changes of incident and reflection intensities, we get the corresponding hysteresis loop by making the reflection intensities as a function of incident intensities as shown in fig. 3.

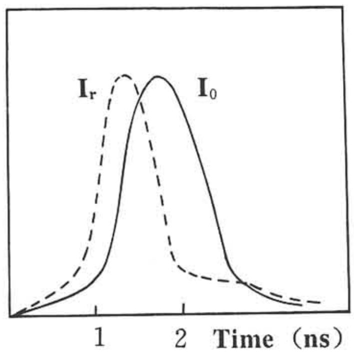

Fig. 2 Time dependence of the normalized temporal shapes of incident (solid curve) I_0 and reflection (dashed curve) I_r pulses in ZnSe—ZnTe/GaAs MQWs at room temperature.

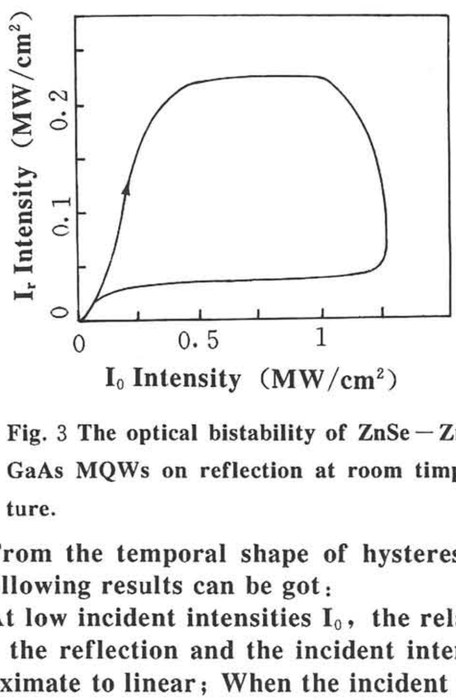

Fig. 3 The optical bistability of ZnSe—ZnTe/GaAs MQWs on reflection at room timperature.

From the temporal shape of hysteresis loop, the following results can be got:

At low incident intensities I_0, the relation between the reflection and the incident intensities is approximate to linear; When the incident intensity changes from 0.4 to $1.1MW/cm^2$, the reflection intensities is close to a constant; With further increasing the incident intensities, the reflection intensities rapidly change from high to low state, the change shows a obvious switching effect. The results indicate that the nonlinear threshold of ZnSe—ZnTe/GaAs MQWs at the wavelength of 532nm is about $0.4MW/cm^2$, and the switching threshold from high to low state and the contrast ratio for the optical bistability obtained in our experiment are about1.1 MW/cm^2 and 6 : 1, respectively.

In order to study the origin of the optical bistability, the absorption spectrum of ZnSe—ZnTe/GaAs MQWs is measured at room temperature by using a broad—band continuous wave light source as shown in fig. 4. The excitonic absorption peak is at 531nm, therefore the wavelength of excitation light is just at the excitonic absorption region. On the basis of the excitonic and related nonlinear theories, the major nonlinear mechanisms are as follows:

The nonlinearities due to excitonic effect include phase space filling of excitonic state,[3] excitonic screening of Coulomb and excitonic band broadening[3,4]; The nonlinearities due to band gap effect include band filling and band shrinkage[2,5]. The character of excitonic nonlinear effects is the excitonic saturating absorption and character of band gap nonlinear effects is the shift of the band edge absorption. As a general rule, the intensities in MQWs reguired for the excitonic nonlinear effect is smaller than that in the band gap effect. It is reasonable to consider that the excitonic nonlinear effect for the optical bistability should first play a major role with increasing the incident intensities. Now we want to consider whether the band gap nonlinear effect for the optical bistability play a major role too. In terms of the character of the band gap effect, the band edge absorption spectrum are measured by using a pump and probe technigue[3]. The pump and probe lights are the 337.1nm line of a N_2 laser and the tunble dye laser from 440 to 480nm by using the Coumarin—460 pumped by the 337.lnm line of the N_2 laser, and the pump intensity is about $1.1MW/cm^2$. The shift of band edge absorption is not observed in the experiment. On the other hand, the absorption coefficient of the ZnSe—ZnTe MQWs at the 337.1nm is larger than that at the 532nm. The results indicate that the band gap effect for the optical bistability not

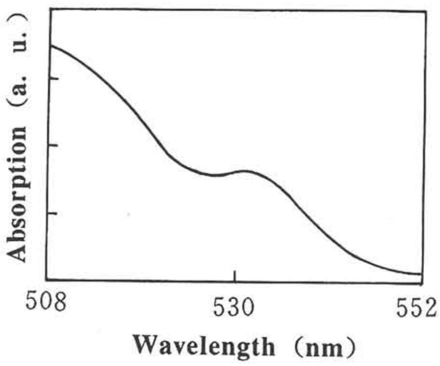

Fig. 4 The absorption spectrum of ZnSe—ZnTe/GaAs MQWs at room temperature.

play a major role. Therefore, the major nonlinear mechanism for the optical bistability is due to the excitonic nonlinear effect. According to the excitonic nonlinear theories in MQWs, the major excitonic nonlinear mechanism in MQWs is due to the phase space filling of excitonic state and excitoic band broadening, and the excitonic screening of Coulomb not play a major role. Based on the above analysis, we attribute the major nonlinear mechanism for the optical bistability to the phase space filling of excitonic state and excitonic band broadening due to the exciton—exciton interaction.

In our experiment, the reflectivities of the both natural faces in the ZnSe—ZnTe MQWs are about 0. 3. Therefore, the both natural faces of the sample can form a simple F—P cavity. On the basis of the theories of optical bistability with a F—P cavity for operation on reflection[1)] and the relation of Kramers—Kronig, the excitonic nonlinear effect due to the phase space filling of excitonic state and excitonic band broadening will cause the change of refactive index, and the positive feedback required for the optical bistability can be achieved by the simple F-P cavity and the change of refractive index due to the excitionic saturating absorption.

The switching intensity of 1. 1MW/cm^2 for the optical bistability considered as a useful device is large, the reason can be considered by the low reflectivities in the simple F—P cavity and the light interference effect in multilayers of the MQWs. Our recent research result indicates that the light interference effect in multilayers of MQWs depend on the widths and the refractive indices of the well and barrier, and it affects the quality of the F—P cavity, it must be considered to be corrected for the general formula of reflection or transmission in a F—P cavity. Therefore, in order to reduce the switching thteshold for the optical bistability, it is very important to optimize the well and barrier widths of the MQWs except the F—P cavity[1)].

3. Conclusions

In conclusion, we have studied the excitonic optical bistability with picosecond switching time in the ZnSe—ZnTe/GaAs MQWs on reflection at room temperature for the first time, the switching threshold and the contrast ratio for the optical bistability are about 1. 1MW/cm^2 and 6 : 1, respectively. Based on the experimental results obtained here、the theories of excitonic nonlinearities and F—P cavity, we attribute the major nonlinear mechanism for the optical bistability to the phase space filling of excitonic state and the excitonic band broadening, and the major positive feedback for the optical bistability to the simple F—P cavity and the change of refractive index due the excitonic saturating absorption. The high switching threshold can be considered by the low reflectivities in the simple F—P cavity and the affection due to the light interference effect of multilayers in the MQWs, to optimize the F—P cavity[1)] and the well and barrier widths in the MQWs, the optical bistability in the ZnSe—ZnTe MQWs can be expected to become a useful switching device with low switching intensity、fast response time and high contrast ratio.

Achnowledgements

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