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Picosecond Optical Bistability of ZnS-ZnTe/GaAs MQWs on Reflection at Room Temperature

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The optical bistability with picosecond switching time in ZnS - ZnTe/GaAs multiple quantum wells(MQWs)has been studied on reflection at room temperature for the first time. The research results indicate that the switching threshold from high to low state and the contrast ratio for the optical bistability are about 1. 2MW/cm2 and 3 : 1, respectively. The major nonlinear mechanism for the optical bistability is due to the change of refractive index caused by the band filling effect.

1. Introduction

Optical bistability of semiconductor superlattices has become an interesting research topic recently. In particular a optical bistability in semiconductor superlattices with F - P cavity 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). We have reported the reflection optical bistabilities in ZnSe - ZnS/GaAs MQWs with nanosecond switching time [2)] and in ZnSe - ZnTe/GaAs with picosecond switching time [3)]. So far, the picosecond optical bistability in ZnS - ZnTe/GaAs MQWs on reflection still has not been reported. ZnS - ZnTe/GaAs MQWs can cover a wide spectra range from red to blue by change of wells and barriers widths in the material system, and can be expected to be used in optical bistable devices. In this paper, we report the first observation and study of the optical bistability with picosecond switching time in ZnS - ZnTe/GaAs MQWs on reflection at room temperature.

2. Experimental Results and Discussion

The sample studied here is a ZnS - ZnTe MQWs of total thickness of 2μm grown by metalorganic chemical vapour deposition(MOCVD)on GaAs substrate which consists of 100 periods of 5nm ZnTe wells and 15nm ZnS barriers. The excitation source is a Nd: YAG laser producing lns pulse at a wavelength of 532nm with repetition rate of 1Hz. The time dependence of incident and reflection pulses is received at the same by using a M176 high speed streak camera with 2ps response time. The experimental setup is shown in fig. 1.

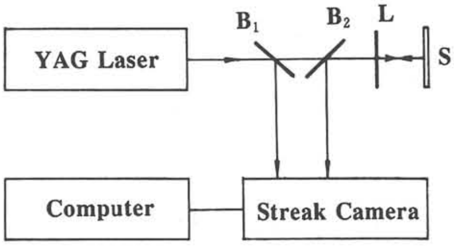

Fig. 1 Schematic diagram for measuring optical bistability in ZnS — ZnTe MQWs on reflection at room temperature; (B) beam splitter; (L) lens; (S) sample.

Fig. 2 is the normalized temporal shapes of incident I_0 and reflection I_r pulses in the ZnS - ZnTe/GaAs MQWs at room temperature. The experimental result shows that the 1ns incident I_0 pulse is compressed into 600ps reflection pulse. The fact indicates that the dependence of the reflection intensities I_r on the incident intensities is nonlinear. Based the change 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.

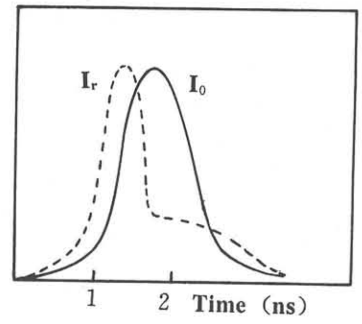

Fig. 2 Time dependence of the normalized temporal shapes of incident (solid curve) I_0 and reflection (dashed curve) I_r pulses in ZnS – ZnTe/GaAs MQWs at room temperature.

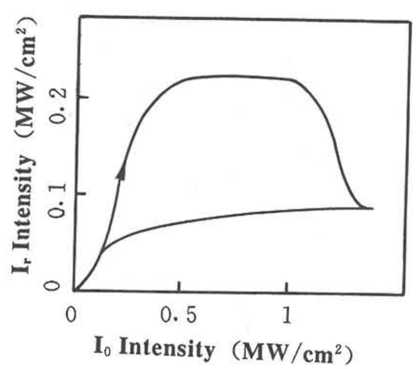

Fig. 3 The optical bistability of ZnS – ZnTe/GaAs MQWs on reflection at room timperature.

In our earier work [4], we had shown that the smooth faces of front and back in ZnSe – ZnS MQWs with high quality can form a simple F – P cavity. Therefore, the major positive feedback mechanism for the optical bistability obtained here can be explained by the effect of a simple F – P cavity from both faces of ZnS – ZnTe MQWs. For a F – P cavity, the optical bistability should be pure absorption or dispersive. The condition for the pure absorption optical bistability is [5]:

$$\frac{\alpha_0 L}{T+\alpha_b L} \geqslant 8 \qquad (1)$$

where $\alpha_0 L$ and $\alpha_b L$ are the linear and unsaturable absorptions, respectively; T is transmission of every face in the F – P cavity. In our case, $\alpha_0 L$ and T are about 0.2 and 0.6, respectively. Obviously, the critical condition for the pure absorption optical bistability is not satisfied in the case for any value of $\alpha_0 L$. Therefore, the optical bistability obtained here in the ZnS – ZnTe/GaAs MQWs is dispersive, that is, the major nonlinear mechanism for the optical bistability in the ZnS – ZnTe/GaAs MQWs is due to the change of refractive index in the ZnS – ZnTe MQWs.

In order to study the origin of the change of the refractive index in the ZnS – ZnTe/GaAs MQWs, the band edge absorption spectrum are measured by using a pump – probe technique. The pump and probe lights are the 337.1nm line of a N_2 laser and the tunable dye laser from 510 to 545 nm by using the Coumarin – 480 pumped by the 337.1nm line of the N_2 laser. When the pump intensity is up to $1MW/cm^2$, the blue shift of band edge absorption is observed in the experiment. On the basis of the nonlinear theories, the major nonlinear mechanisms are the excitonic nonlinear effect and band edge nonlinear effect. In our case, the excitonic absorption in the ZnS – ZnTe/GaAs MQWs is not observed at room temperature, therefore, the excitonic nonilnear effect does not play a major role. The nonlinearities due to band gap effect include band filling and band shrinkage [6,7], in which the band filling and band shrinkage are appeared in the absorption spectrum to the blue and red shifts of absorption edge, respectively. On the basis of the above analytic result, and the experiment results obtained in absorption spectrum under different pump intensities in the ZnS – ZnTe MQWs, we attribute the major nonlinear mechanism for the optical bistability obtained here to the band filling effect. According to the relation of Kramers – Kronig, the band filling effect will cause the change of refractive index. Therefore, 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 band filling effect.

3. Conclusions

In conclusion, we have studied the optical bistability with picosecond switching time in the ZnS – 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 $1.2MW/cm^2$ and 3 : 1, respectively. Based on the experimental results obtained here, the theories of nonlinearities and F – P cavity, we attribute the major nonlinear mechanism for the optical bistability to band filling effect, and the major positive feedback for the optical bistability to the simple F – P cavity and the change of refractive index due to the band filling effect. The high switching threshold can be considered by the low reflectivities in the simple F – P cavity, to optimiz the F – P cavity [8], the optical bistability in the ZnS – ZnTe/GaAs MQWs can be expected to become a useful switching device with low switching intensities, fast response time and high contrast ratio.

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References

1) B. S. Wherrett, IEEE. J. Quantum Electron. 20(1984) 646.
2) D. Z. Shen, X. W. Fan, B. J. Yang, L. C. Chen, J. Q. Yu, J. Lumin. (1994).
3) D. Z. Shen, X. W. Fan, Z. S. Piao and B. J. Yang, Extended Abstracts of the 1992 Internation al Conference on Solid State Devices and Materials, Japan(1992)229.
4) D. Z. Shen, X. W. Fan, G. H. Fan, J. Lumin 48(1991)299.
5) F. Henneberger, Phys. Stat, Sol. (b)137 (1986) 371.
6) D. Z. Shen, X. W. Fan, Z. S Piao and G. H. Fan, J. Cryst. Growth, 117(1992)519.
7) H. Haug and S. Schmitt – Rink, J. Opt. Soc. Am. B2(1985) 1135.
8) D. Z. Shen, X. W. Fan, B. J. Yang, J. Cryst. Growth, 138(1994)625.