OBSERVATION OF ABSORPTION MODULATION IN A SINGLE QUANTUM WELL EXCITON SCREENING DEVICE

C.Tombling, M.M.Stallard.
Department of Electronic and Electrical Engineering, University College London, Torrington Place, London WC1E 7JE UK

J.S.Roberts.
Department of Electronic and Electrical Engineering, University of Sheffield, Mappin Street, Sheffield S1 3JD, UK.

Introduction

The use of free carriers to control the strength of the exciton resonance in quantum well material has been considered recently [1,2]. The discrete energy levels of the quantum well create subands which can be filled with free carriers, inhibiting the excitonic absorption. The modulation of light by this mechanism has previously been proposed [2,3] and while initial results have been reported [4,5] we present the first direct experimental evidence showing modulation of exciton screening.

Fabrication and Measurements

Single well photodiode structures were grown in a GaAs/AlGaAs material system by atmospheric pressure MOVPE [6] on Si doped substrates (n+). The structure details were as follows: above an intrinsic GaAs well an 800Å undoped $Al_{0.2}GaAs$ barrier region, a p-type $Al_{0.45}GaAs$ layer and a p-type GaAs cap were grown. Below the well was the lower $Al_{0.2}GaAs$ barrier layer which consists of a 100Å undoped spacer region, a 100Å n+ region and a 1.05μm n ($10^{17}cm^3$) region. In addition a 1.5μm $Al_{0.25}GaAs$ layer was grown between the barrier region and the substrate. This structure was grown with well widths of 50Å and 100Å. The heavily doped region, filling the subbands with carriers, ensured that the devices did not exhibit the exciton resonance at zero bias. Mesa etching, for device definition, provided good breakdown voltages and contacting was achieved with Sn/Au and Cr/Au ohmic contacts for the n type substrate and surface p type region respectively. Photocurrent spectra were investigated to probe changes in the carrier density in the quantum well, while capacitance voltage data provided a guide to the exact doping levels in the structure.

Results and Discussion

The photocurrent data illustrated in figure 1a,b depicts the change in the absorption characteristics under conditions of applied reverse bias. The exciton resonance, in the case of the 100 Å well structure, is observed at approximately -6 volts reverse bias, while in the 50 Å well structure it may be discerned at approximately -2 volts. In the case of the 100Å well sample an excitonic edge can be seen, but a clearly defined peak is not observed. This is due to the high fields associated with sweeping the carriers from the well, which reduces the excitonic oscillator strength. The improved definition of the excitonic resonance in the case of the 50Å well is attributed to the increased oscillator stength associated with narrower wells at high fields [7]. Having depleted the carriers from the well, as expected, both samples exhibit the Stark shift with further increase of electric field. Predicted field distributions (fig 2a), combined with a simple model for the charge movement in the well region (fig 2b), support the appearance of the exciton peaks at the observed voltages.

To conclude, we have shown that movement of charge from a quantum well has provided a large change in absorption at the exciton resonance. These results indicate a high contrast modulation, with the advantage of low voltage operation, is possible using this effect.

Acknowledgements

Thanks are due to P.J.Bradley and P.J.Stevens for useful discussions and to Plessey Research for the provision of a case studentship (C.T.).

References

1. S.Schmitt-Rink, D.S.Chemla and D.A.B.Miller. Phys.Rev.B32 (1985) p6601.

2. H.Sakaki, H.Yoshimura and T.Matsusue. JJAP. 26.(7) (1987) pL1104.

3. A.Kastalsky, J.H.Abeles and R.F.Leheny. APL(50) (1987) p708.

4. D.S.Chemla, I.Bar-Joseph, C.Klingshirn, D.A.B.Miller, J.M.Kuo and T.Y.Chang. APL 50(10) (1987) p585.

5. J.H.Leheny, W.K.Chan, A.Kastalsky, J.P.Harbison, L.T.Florez and R.Bhat. EL(23) (1987) p1302.

6. J.S.Roberts, N.J.Mason, M.Robinson. J.Crystal Growth(68) (1984) p442.

7. M.Whitehead, P.Stevens, A.Rivers, G.Parry, J.Roberts, P.Mistry, M.Pate, G.Hill. Submitted to Appl. Phys. Lett. March 1988.

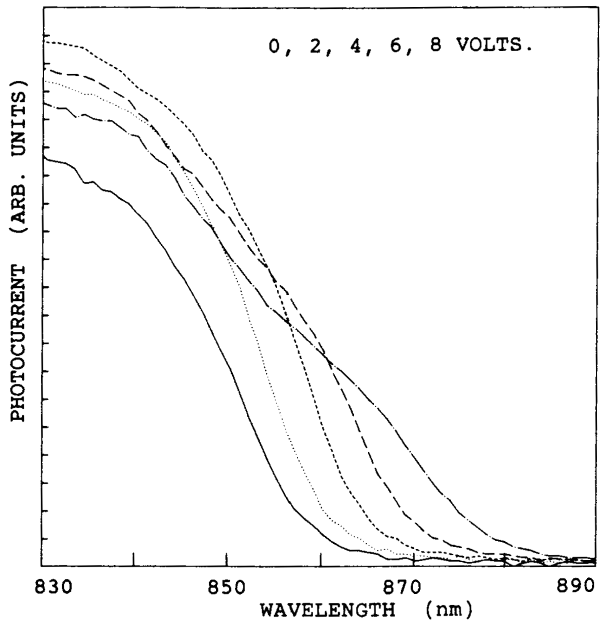

Figure 1a. Photocurrent spectra: 100Å well sample.

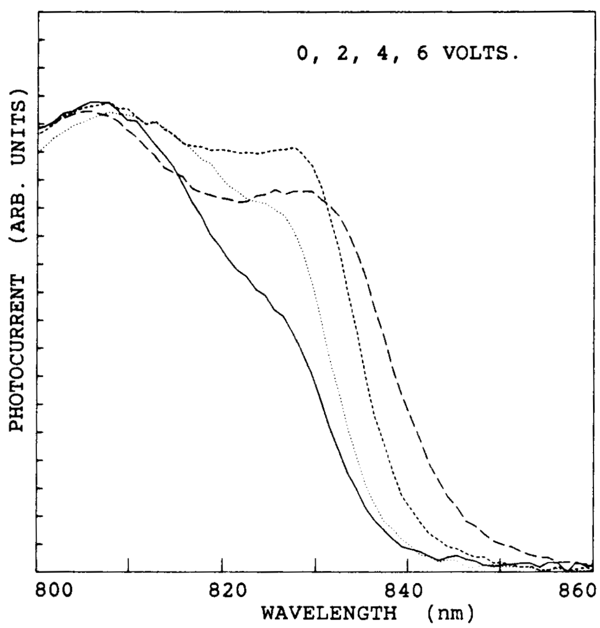

Figure 1b. Photocurrent spectra: 50Å well sample.

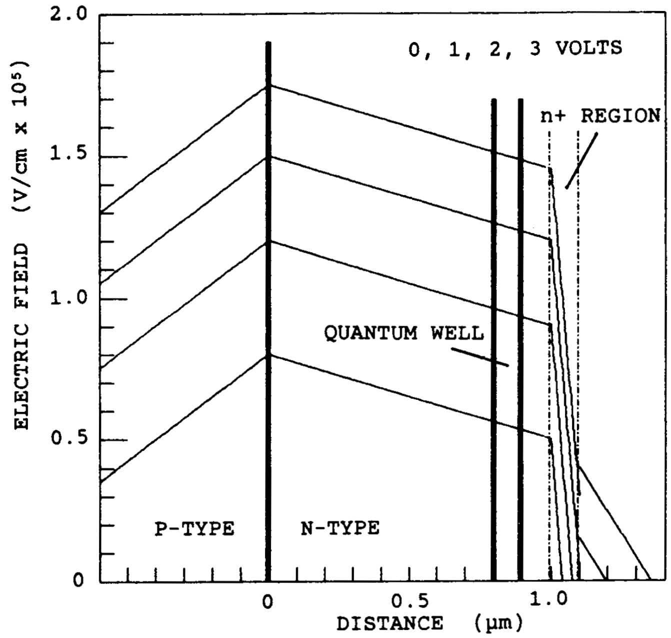

Figure 2a. Predicted electric field distribution in the exciton screening device at bias intervals of 1 volt.

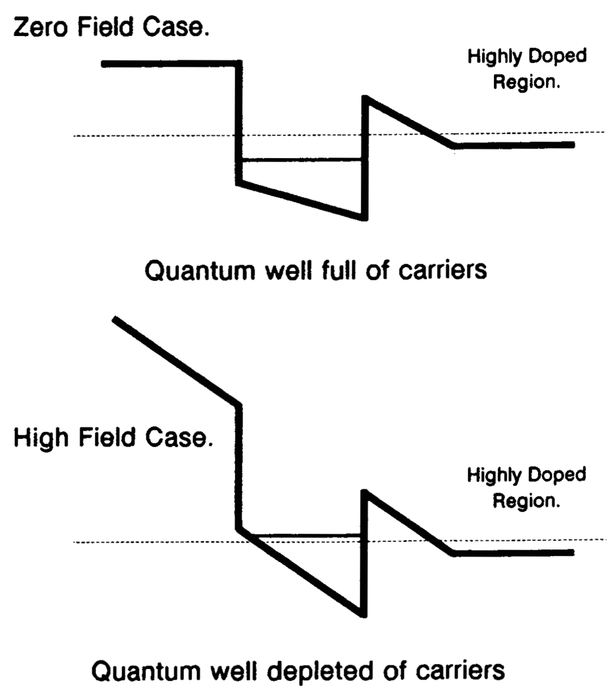

Figure 2b. Simplified electric field curves in the region of the well for the two states of the device.