Photoreflectance spectroscopy of coupled quantum wells and quantum dots

G. Sęk, K. Ryczko, J. Misiewicz
Insitute of Physics, Wrocław University of Technology
Wybrzeże Wyspiańskiego 27, 50-370 Wrocław, Poland
M. Bayer, A. Forchel
Institute of Physics, University of Würzburg
Am Hubland, D-97074 Würzburg, Germany

Photoreflectance spectroscopy has been used to study optical transitions in coupled quantum wells and quantum dots. The derivative nature of this contactless electromodulation technique allows observing excited state transitions in the low-dimensional structures like transitions between split states in coupled systems, including the symmetry-forbidden ones.

We investigated the dependence of the transition and splitting energies on the thickness of barrier for $Al_{0.3}Ga_{0.7}As$/GaAs double quantum wells with thin AlAs separating layer and for $In_{0.045}Ga_{0.955}As$/GaAs structures with three or four coupled wells. In the case of the latter material system the influence of number of interacting wells has been also analysed. For $In_{0.045}Ga_{0.955}As$/GaAs double quantum well the dependence of the intensity of parity-forbidden transitions on the built in electric field has been investigated. Excitonic symmetry-forbidden transitions can be observed due to the effect of mixing of heavy and light hole excitons and/or due to some asymmetry in the structure. We have shown that the built-in electric field in the region of our double quantum well is weak enough to do not cause any significant energetic shift of features due to quantum confined Stark effect, on one hand. On the other hand, it is sufficient to change strongly the oscillator strength of forbidden transitions. To change the internal electric field, we have used photoreflectance in the three-beam mode with a third beam continuously illuminating the sample and causing changes of the built-in electric fields due to the photovoltage effect. This method works as a contactless forward bias and allows changing the field down to the flat band conditions.

We have also investigated the coupling effects in self-assembled vertically aligned $In_{0.6}Ga_{0.4}As$/GaAs double quantum dots. Transitions between split states in double quantum dots as well as in wetting layer double quantum wells have been observed. The splitting energy between two lowest double dot- and double well-related transitions as a function of the width of the GaAs separating barrier has been derived.

All the experimental results have been supported by simple calculations in the effective mass approximation.