TRIPLET AND SINGLET STATES IN GaAs/AlGaAs QUANTUM WELLS IN HIGH MAGNETIC FIELDS

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Introduction

The photoluminescence (PL) spectrum of a low-density two-dimensional electron gas exhibits multiple peaks originating from neutral and charged excitons (trions). Without magnetic field only the singlet state of the trion (one hole bound to two electrons with opposite spin) is bound, whereas in finite fields also triplet states (parallel electron spins) appear [1]. Theory predicts that in the limit of high magnetic fields the triplet state becomes the ground state of the trion [2]. We have investigated the magnetic field induced cross-over from the singlet to triplet ground state in a GaAs quantum well (QW).

Results and Discussion

The sample used was a 10 nm GaAs QW containing a low density 2DEG. Polarized PL experiments were performed at a temperature of 1.6 K, in magnetic fields up to 65 T, using pulsed magnets at NHMFL, and HeNe and HeCd laser excitation. Typical spectra are displayed in Figure 1. The obtained PL spectra were compared to those measured at HFML (Nijmegen) up to 30 T, but at lower temperatures (> 0.3 K). We have chosen to use a relatively narrow QW since in that case exciton and trion binding energies are higher and the dispersion of the valence band is more simple, as compared to wider QWs (> 25 nm). The latter fact facilitates the analysis of the effect of Zeeman splittings on the optical spectra. Four excitonic peaks were observed in the σ^- polarized PL spectrum (regularly denoted as neutral exciton (X), singlet trion (T_s) and dark (T_{td}) and bright (T_{tb}) triplet trion), provided the temperature was sufficiently low and the magnetic field above 10 T [1].

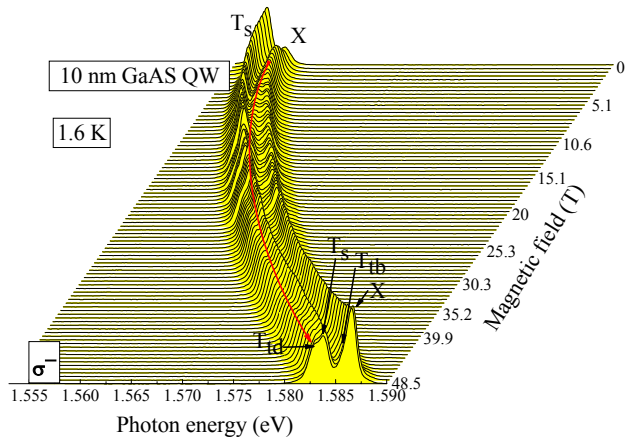

Figure 1. Typical PL spectra of a 10 nm GaAs quantum well (σ^- polarization) in high magnetic fields.

The resulting energy level diagram is shown in Figure 2. Apart from small energetic shifts between the LANL and HFML data, due to differences in the excitation conditions, the two data sets confirm the following picture. We observe a crossing of the T_s emission line with that of the lowest triplet state (T_{td}) around 21 Tesla. We point out that the measured photon energy is not equal to the energy of the trion state, but rather is equal to the difference in energy between the initial (trion) and final state (exciton + free electron) after recombination [3]. Introducing this effect and all relevant Zeeman splittings the actual energy spectrum of all excitonic states is determined. We find that the actual cross-over from the singlet to triplet groundstate occurs at a slightly lower field (20 T) than the crossing of the PL lines, implying that in the high field range (20-65 T) the T_{td} state is the ground state of the 2 electron-1 hole system.

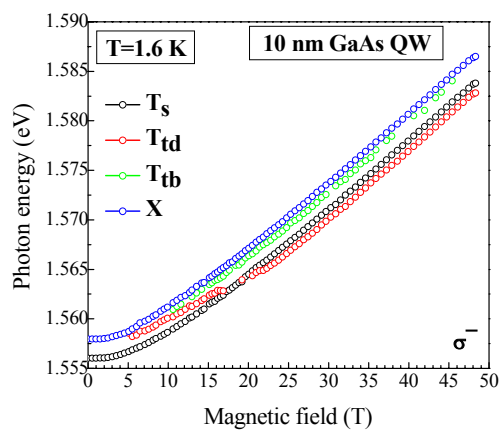

Figure 2. Peak energies of the PL lines of negatively charged and neutral excitons in a GaAs quantum well (σ^- polarization) The cross-over of the T_s and T_{td} lines mark a transition of the trion groundstate from singlet to triplet around 20 T.

References

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[3] G. V. Astakhov, D. R. Yakovlev, S. A. Crooker, W. Ossau, P. C. M. Christianen, V. V. Rudenkov, G. Karczewski, T. Wojtowicz, J. Kossut, *Phys. Stat. Sol. (c)* **1**, 551 (2004).