The study of thermal dissociation of acceptor-bound positively charged excitons in GaAs/$Ga_{1-x}Al_xAs$ quantum wells

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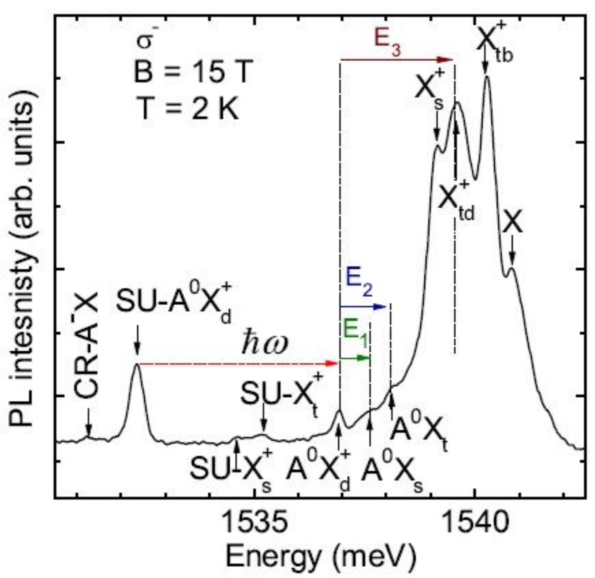

Fig. 1. Comparison of activation energies of dissociation processes with PL spectra.

The three-particle system of fermions, bound by Coulomb interaction are fundamental problem in nuclear, atomic and solid-state physics. Negative and positive trions (X^-=2e+h or X^+=2h+e), analogs of the negative hydrogen ion (H^-) and the positive hydrogen molecule (H^+_2), have been successfully detected in the two dimensional (2D) structures. All investigations of 2D trions were performed at low temperatures, mainly due to their small binding energy. However, temperature dependent emission investigations of trions, free or bound on impurities, may provide valuable information on trion physical properties.

Here, we study the thermal dissociation of free and acceptor-bound positive trions by measurements of temperature dependence of the integrated emission in high magnetic fields up to 17 T in superior quality GaAs quantum wells with 2D hole gas. Three dissociation processes are observed for the well-resolved hole cyclotron replicas ("shake-up") of positive trions bound to neutral acceptors in the hole spin-doublet state (SU-$A^0X^+_d$). To proof that the hole involved in the shake-up process is not bound by the Coulomb interaction to the charged A^0X^+ complex, we have performed numerical calculations of the valence band Landau levels in the Luttinger model beyond the axial approximation. The calculated value of the hole cyclotron energy agrees well with the experimental value of the energy separation of the AX^+ and SU-AX^+ lines determined from the PL spectra. At low temperatures, below 6 K, the dominant dissociation results in a free hole and the exciton bound to the neutral acceptor in the hole spin-singlet or -triplet state ($A^0X^+_d \rightarrow A^0X_s$+h or A^0X_t+h). At higher temperatures, above 9 K, the dissociation into the free positive trion and the neutral acceptor ($A^0X^+_d \rightarrow A^0+X^+$) predominates. From the temperature evolution of the integrated emission of free trion lines (X^+) we evaluated transition energy between two triplet trion states: dark (X^+_{td}) and bright (X^+_{tb}). The ionization energies of all detected dissociation processes are compared with the spectral positions of relevant radiative recombination lines and an excellent quantitative agreement was achieved.