Coexistence of nearly free and strongly bound trions from magneto-photoluminescence of two-dimensional quantum structures with tunable electron or hole concentration

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A dilute two-dimensional (2D) gas of charge carriers in a quantizing perpendicular magnetic field hosts spectacular emergent phenomena exemplified by fractional quantum Hall effect, well-known to depend on both many-body interaction effects and single-particle localization.

We studied coexistence and competition of nearly free and laterally localized radiative excitonic complexes in quantum Hall systems, as revealed in satellite recombination channels activated by their coupling with surrounding nearly free carriers. In contrast to most previous experiments involving 2D electrons we used valence holes whose higher mass appears critical in contrasting the emission signatures from the free and localized charged excitons (trions).

The experiments involve low temperature (T=2–30K), high magnetic field (B=0–23T), polarization resolved (σ^-/σ^+) photoluminescence (PL) on high-quality quantum wells. The key feature was two-beam illumination (photon energies below and above band-gap in the barrier) enabling dynamical tuning of carrier concentration in the acceptor-doped structures – beyond the point of *p*- to *n*-type conversion.

In comparative PL studies of symmetric and asymmetric structures with different widths (w=15–22 nm) and concentrations (tunable, electrons or holes – in the same sample) we were able to identify and understand multiple optical transitions, including nearly free excitons and trions, excitonic complexes bound to charged impurities placed in the well and in the barriers, and their (positive and negative) cyclotron replicas. In particular, we studied the effect of *p*- to *n*-type conversion on those transitions and on the stability of the corresponding complexes.

The most insightful results concern emission from positive trions moving almost freely in the quantum well (X^+) or bound to nearby ionized acceptors in the barrier (AX). We show distinction between X^+ and AX transitions and coexistence of both complexes. As expected, the X^+ shows in the spectra about 1 meV below the exciton X, split into three lines (family of bound states distinguished by spin and angular momentum). The AX is observed far below the X^+, in form of multiple parallel, equidistant, weak lines, corresponding to the acceptors placed on different crystallographic planes in the barrier, characterized by discrete distance from the well. Striking contrast between X^+ and AX lines in their (strong vs nearly absent) dependence of the energy position on the well width. Crucial for the identification of both complexes was also dramatic difference in their binding energy (in contrast to X^- vs DX in previously studied *n*-type wells). Alternative interpretation in terms of AX^- instead of AX will also be discussed.

Samples: GaAs/GaAlAs single quantum wells grown by MBE on (001)-oriented semi-insulating GaAs substrate, Carbon δ-doped in one or both barriers; hole mobility (at T=4.2 K): μ=(1.2-7.4)×10^5 cm^2/Vs; hole concentration (in the dark): p=(1.51–2.4)×10^{11} cm^{-2}.