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Objekttyp: **Article**

Zeitschrift: **Helvetica Physica Acta**

Band (Jahr): **65 (1992)**

Heft 2-3

PDF erstellt am: **03.05.2024**

Persistenter Link: https://doi.org/10.5169/seals-116418

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Excitonic Recombination of Donor Bound Excitons in Selectively Doped MQW under High Magnetic Fields

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Abstract. The luminescence related to the excitonic transition of selectively doped GaAs/GaAlAs multi-quantum-wells (MQW) has been investigated under high magnetic fields up to 27 T in the temperature-range from 0.4 to 19 K. In all samples a 2D-like free exciton is observed as well as additional structures of excitonic character assigned to excitons bound to neutral (D^0,X) and ionized donors (D^+,X), with binding-energies depending on the doping location. Whereas these binding-energies do not vary with magnetic field, their relative intensities show very interesting dependences, which are analysed.

In the last years various optical methods have been used to investigate the optical properties of selectively doped MQW with different doping locations and well-sizes [1, 2, 3], and gave rise to the identification of (D^0,X) and (D^+,X) excitons. The properties of 2D-like free excitons in a magnetic field were studied theoretically [4] and experimentally [2, 5] by several groups. The investigation of donor-states in magnetic field (B) by far-infrared spectroscopy measurements showed the existence of negatively charged donor (D^-) for co-doping at the center of the well and the barrier [3]. The present work was done to investigate the behaviour of bound excitons in such special circumstances. The samples were mounted in a ^{3}He-cryostat with optical access via a fiber-optic system placed in the hybrid-magnet. Photoluminescence was excited using an Ar^+-Laser (excitation line: 514 nm) and detected by a cooled GaAs-photomultiplier at the exit of a triple-raman-spectrometer, with 0.06 meV resolution. Experiments, where the polarization of the recombination light was investigated, were done in a ^{4}He-cryostat with optical access via a window, mounted in a 10 T superconductiong coil.

The samples (GaAs-$Ga_{0.75}Al_{0.25}$As MQW of 150 periods) were grown by MBE with a well-width of 10 nm and barrier-widths of 5–20 nm depending on the sample. Selective Si-doping, with growth interruption, achieves a concentration ranging from 1×10^{10} cm^{-2} (δ-doping) to 9.9×10^{15} cm^{-3} (uniform doping). A test-sample without any doping was also investigated.

The spectra of the undoped sample only show the recombination-line of the heavy-hole free exciton (HHFE), (Fig. 1), and the spin-split component in magnetic field. The intensity of the σ^+-component remains approximatively constant with B. In all samples this HHFE-line is observed, and shows the same diamagnetic shift. Its intensity does not significantly change with B. In the doped samples, additional structures appear on the low energy side of the HHFE-line, and are attributed to (D^0,X) excitons, either located near the center of the barrier (b) or near the center of the well (w). The measured binding-energies ($E_B(D^0, X(b)) = 1.5 \pm 0.05$ meV and $E_B(D^0, X(w)) = 2.3 \pm 0.05$ meV) do not change with B up to 27 T and are in good agreement with published results [1]. These lines exhibit also the same spin-splitting properties as the HHFE. In samples, with a co-doping, an excitonic recombination line ($E_B \approx 3.3$ meV) appears and grows with B. In samples, with a high compensation rate, δ-doped at the center of the well, this line is always present and has an intensity independent on B. In comparison with other experiments [6] one can assign this line to the recombination of excitons trapped on ionized (D^+)-centers in

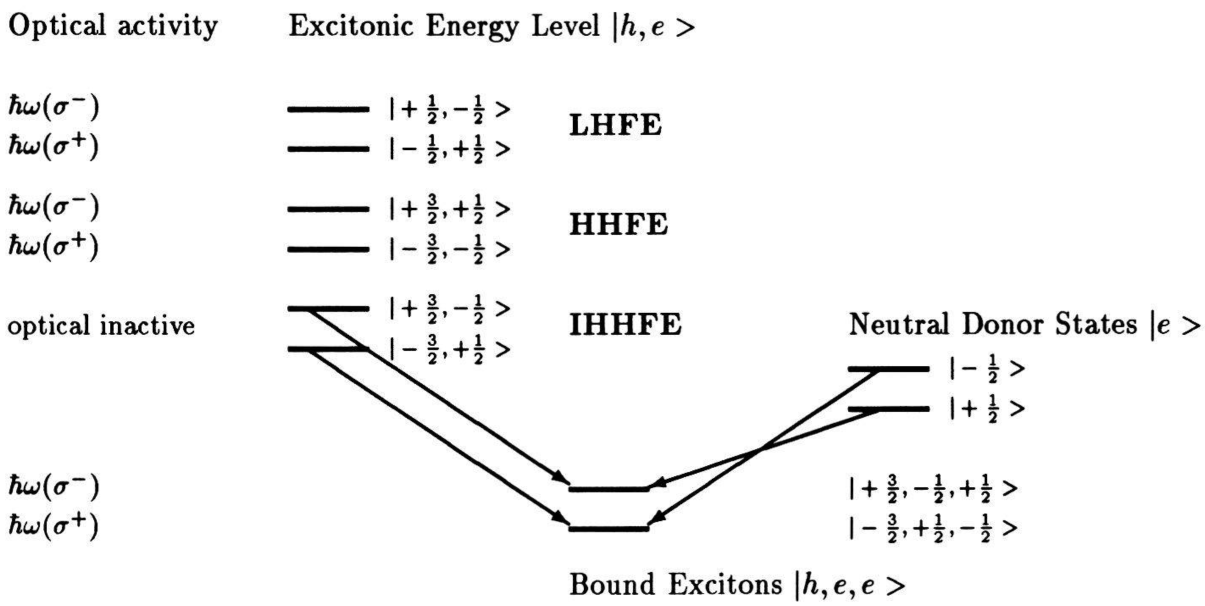

Figure 1: Excitonic Energy Levels and related spin configurations

the barrier. That this line appears and grows with B in those samples where the (D^-)-states are stabilized by the magnetic field [3, 7], can be taken as an indirect evidence of their appearence since they obey the "reaction": $D^0(w) + D^0(b) \Longrightarrow D^-(w) + D^+(b)$. This process should induce an intensity decrease of the (D^0,X) excitons, which is observed. However this decrease is present in all doped samples and then it has to be explained, at least in part, by some other fundamental process involving the creation of these excitons (Fig. 1).

We think that the (D^0,X) excitons are mainly formed by the capture of optical inactive heavy-hole free excitons (IHHFE). The capture is progressively inhibited by the field induced shrinkage of the corresponding wavefunctions, which results in the intensity decrease of the (D^0,X) exciton without effecting that of the HHFE. This happens despite the fact, that high magnetic field favours the creation of IHHFE. This is confirmed by the non linear increase of the (D^0,X) intensity with respect to that of the HHFE upon increasing the excitation power at very high fields.

Our experiments show that in selectively samples the appearance of (D^-)-centers is accompanied, as expected, by the appearance of (D^+)-centers in the barrier. The anomalous intensity variation of (D^0,X) excitons is well explained by the assumption, that they are formed upon the capture of IHHFE by a neutral donor.

This research was partly supported by G.I.F. for Scientific Research and Development, Grant No. G-112-279.7/88.

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