Nonlinear excitonic Zeeman spin splitting in a single quantum dot

M. R. Molas[1,2], A. A. L. Nicolet[2], M. Potemski[2], and A. Babiński[1]

[1] *Institute of Experimental Physics, Faculty of Physics, University of Warsaw, Hoża 69, 00 681 Warsaw, Poland*

[2] *Laboratoire National des Champs Magnétiques Intenses, CNRS-UJF-UPS-INSA, 25, avenue des Martyrs, 38042 Grenoble, France*

Although the Zeeman splitting of excitons in quantum dots (QDs) usually depends linearly on magnetic field, a non-linear Zeeman splitting has also been reported for neutral excitons (X) in self-assembled InGaAs/GaAs QDs [1]. The non-linear splitting was attributed to a strong field-induced mixing of the lowest-energy heavy-hole (HH) and light-hole (LH) orbital states [1].

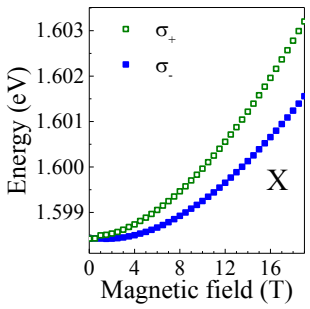
In this communication, we report the magnetospectroscopic study of the neutral exciton and triexciton (3X) confined in single GaAlAs/GaAs QDs using, a micro-photoluminescence (μ-PL) setup at the magnetic field up to 19 T.

The magnetic-field dependent data show a significant difference between the X and 3X lines - Fig. 1. Whereas X undergoes a usual, positive diamagnetic shift, the 3X follows a more complicated pattern as expected of the complex related to the *p*-shell-like single particle state [2]. Moreover the 3X splitting is substantially larger than the X splitting - Fig. 2.

The spin Zeeman splitting ΔE_z of the neutral exciton X is determined by the effective excitonic g^* factor $g^*=g_e+g_h$. The nonlinear dependence of the ΔE_z can be attributed to magnetic-field induced HH-LH mixing.

More complicated is the behaviour of the 3X line. The neutral exciton in a QD is an electron-hole pair related to the ground level - the *s*-shell-like single particle (SP) state. The triexciton is related to the first excited SP level - the *p*-shell. This opens up the possibility of the spin-orbit coupling of the Bloch and envelope functions in the valence band. The angular momentum is no longer a proper quantum number for holes [3]. It is necessary to define a new quantum number - total angular momentum as a sum of former numbers. For the *p*-like hole levels, the dominant contribution of the envelope angular momentum is non-zero, thus additionally increases the orbital Zeeman effect, which is linear as a function of B.

In our communication we discus more details of the model, which takes into account the spin-orbit coupling of holes in QDs and which accounts for the observed non-linear splitting of the 3X in magnetic field. We discuss the effect of magnetic field on the mixing of valence band states and the significance of the orbital Zeeman effect for the description of the Zeeman splitting of the multiexcitonic lines related to the excited levels, such as *p*, *d*,. . .shells.



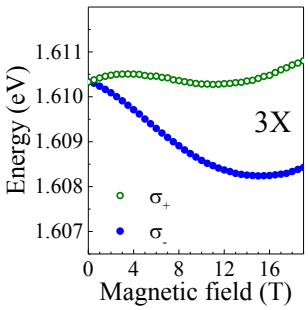


Fig.1 The magnetic field dispersion of the X and 3X lines of the single GaAlAs QD.

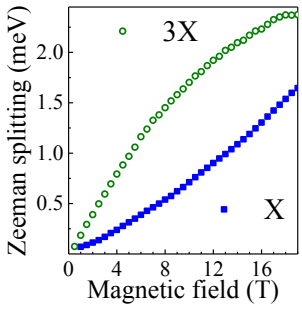


Fig.2 The Zeeman splitting of the X and 3X lines.

[1] A. Babiński, et al, *Phys. Rev. B* **74**, 075310 (2006), V. Jovanov, et al, *Phys. Rev. B* **85**, 165433 (2012).
[2] A. Babiński, et al, *Phys. Rev. B* **74**, 155301 (2006).
[3] J. H. Blokland, et al, *Phys. Rev. B* **75,** 233305 (2007).