Compensation of exciton-ion exchange interaction in quantum dot by application of magnetic field

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Single semiconductor quantum dots (QDs) with individual magnetic manganese ions are of great interest because their photoluminescence spectrum carries information on exchange interaction between electrons from outer shell of ion and band carriers confined in QD. Although much effort was put into such research [1,2] there are still features that were not discussed in detail. One of such features, that were noticed but not investigated comprehensively [2], is energetic degeneration of exciton-ion states at finite magnetic field applied along the growth axis.

This phenomenon is a result of interplay between Zeeman splitting of manganese states and exciton-ion exchange interaction that acts like additional magnetic field (hole spin is constrained along growth axis due to heavy-hole – light-hole splitting). In our work we propose a simple method for identification of magnetic field at which degeneration occurs and apply it to investigate CdTe/ZnTe QD with single Mn^{2+} ion. What is additionally interesting we can achieve either compensation or enhancement of external magnetic field by introducing exciton with particular spin.

In addition to magnetic field that compensates exciton-ion exchange interaction, we apply a in-plane component. Then for σ_- polarization (which is equivalent to observation of exciton with -1 spin projection on growth axis) exchange interaction is compensated by Zeeman effect and all six states undergo mixing. This manifests as splitting of all emission lines (figure 1). Meanwhile for σ_+ polarization ($+1$ exciton spin) in-plane component is only small addition to total magnetic field and do not cause observable mixing.

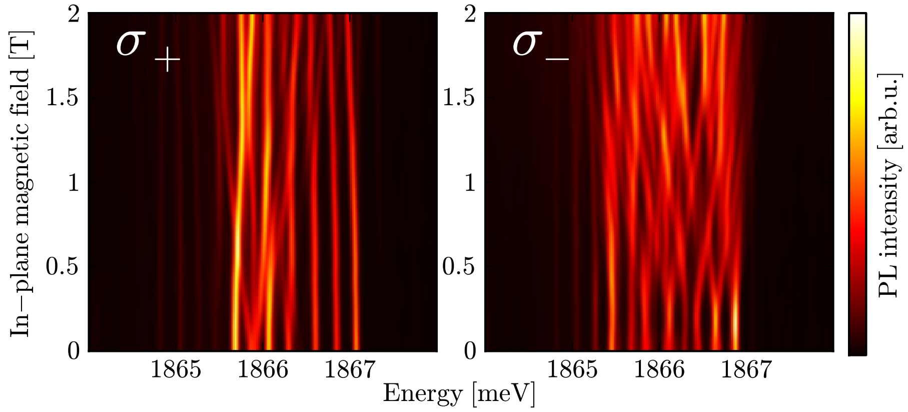

Figure 1: Exciton spectra in magnetic field. The in-plane component of magnetic field varies from 0 to 2 T, while component perpendicular to the sample was constant and equal 2 T. Maps present evolution of spectra in σ_- and σ_+ polarizations, which are equivalent to probing $|-1\rangle$ and $|+1\rangle$ exciton states. In σ_- polarization all lines undergo splitting, while in σ_+ splitting appears only for mixed bright and dark exciton states.

[1] M. Goryca, Phys. Rev. B **82**, 165323 (2010).

[2] L. Besombes, Phys. Rev. Lett. **93**, 207403 (2004).