Magnetic anisotropy of a few Mn^{2+} ions in a quantum dot.

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Optical studies of quantum dots doped with magnetic ions are an effective tool for the investigation of spin physics in solid state. In the case of a single Mn^{2+} ion in a CdTe/ZnTe quantum dot a deep understanding of the optical properties of the system has been achieved [1,2]. More advanced investigations showed the possibility of the optical manipulation of the Mn^{2+} spin, providing a way to utilize it as a single spin memory [3,4]. On the other hand the studies of highly-doped dots revealed the formation of the magnetic polaron [5]. The intermediate case of a few magnetic ions in the dot has not been studied so far. Here we present the magneto-optical studies of such a system. Qualitatively new phenomena are revealed and analyzed considering the interactions between the spins of magnetic ions.

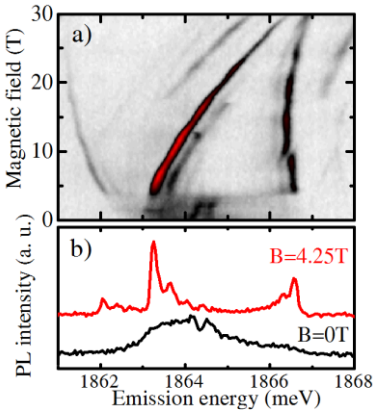

Fig.1 (a) The evolution of the neutral exciton PL line with magnetic field. (b) At about 4T the rapid transition from non-polarized to fully polarized spin state of the Mn^{2+} ions occurs.

The photoluminescence (PL) measurements of weakly-doped single CdTe quantum dots in high magnetic field demonstrate a rapid transformation (Fig. 1a) of the PL feature at a certain value of a magnetic field (ranging from about 3 T up to 10 T for various dots). In the low field regime, the PL spectrum consists of broad lines reflecting the thermal fluctuations of the spin state of the Mn^{2+} ions. At higher fields (above the threshold) only two narrow lines dominate. They correspond to the full polarization of the Mn^{2+} spin system (Fig. 1b). A similar transition was observed before for highly-doped quantum dots [6]. It resulted from the heating of the Mn^{2+} system by the carriers in the low field regime. We show that in our case the origin of the transition is different. We interpret our findings in terms of magnetic anisotropy of the magnetic system in the quantum dot. The axis of the anisotropy is along the growth direction. There are two main contributions to this anisotropy: the biaxial strain and the interaction with the anisotropic heavy hole. If the ratio of the effective exchange interaction between the Mn^{2+} spins and the anisotropy parameter is sufficiently small the Heisenberg type spin interaction between the magnetic dopants becomes the Ising type. In such regime, when the in-plane spin components vanish, the typically expected magnetization steps disappear in favor of a single transition from nonmagnetic to a fully polarized state.

A route from the physics of a single exciton coupled to a single magnetic ion towards the properties of excitons coupled to many magnetic ions will be discussed.

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