Optical manipulation of a single Mn spin in a CdTe-based quantum dot

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The ultimate limit of the magnetic memory miniaturization is a single spin. From this point of view the reading and controlling of a single spin state appears as a very desired possibility. One possible implementation of this idea is the use of a single magnetic ion incorporated in a semiconductor quantum dot. The optical read-out of the electronic spin state has been demonstrated for a single Mn^{2+} ion in a CdTe/ZnTe QD [1]. Recent experiments on this unique quantum system have also shown the possibility to optically manipulate the single Mn spin by injection of spin-polarized excitons into the quantum dot. It was accomplished either by direct quasi-resonant exitation of the dot with circularly polarized light [2] or by using a spin-conserving transfer of the excitons between two coupled quantum dots [3].

The talk summarizes results of our recent studies of the optical orientation and spin-lattice relaxation of the single Mn^{2+} ion in a single quantum dot. First, I will recall properties of self assembled system of CdTe/ZnTe quantum dots. The asymmetrical in-plane inter-dot coupling will be discussed [4]. The studies involve several experimental techniques, in particular photoluminescence excitation (PLE), second-order single photon correlation, and optical orientation. Identification of individual coupled QD pairs will be described. Each pair contains an absorbing dot, identified by a sharp PLE resonance assigned to a neutral exciton transition, and a second, emitting dot, characterized by several PL lines related to its different charge states. Energy and exciton spin transfer dynamics will be discussed. Then, the characteristic times related to the single Mn^{2+} ion spin orientation and relaxation will be discussed and possible mechanisms will be proposed. Particular attention will be paid to the role of dark excitons in the radiative recombination and optical orientation processes. It will be shown that the dark exciton optical transitions are accompanied by simultaneous spin flip of the Mn^{2+} ion present in the same QD. The radiative recombination of dark excitons is efficient only when the exchange interaction with the magnetic ion is combined with the heavy-light hole mixing, related to an in-plane anisotropy of the quantum dot [5]. The use of high magnetic field spectroscopy allowed us to determine all relevant parameters of the studied system, such as the dark exciton oscillator strength, the quantum dot in-plane anisotropy, and the exchange interaction.

[1] L. Besombes *et al.*, Phys. Rev. Lett. **93**, 207403 (2004).
[2] C. Le Gall , Phys. Rev. Lett. **102**, 127402 (2009).
[3] M. Goryca *et al.*, Phys. Rev. Lett. **103**, 087401 (2009).
[4]. T. Kazimierczuk *et al.*, Phys. Rev. B **79**, 153301 (2009).
[5] M. Goryca *et al.*, Phys. Rev. B **82**, 165323 (2010).