Optically Controlled Quantum Dot Nanomagnets

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We report on several spectacular experimental observations obtained for self-assembled CdTe quantum dots doped with magnetic impuritie.

First of all, we find that for such structures resonant excitation of spin polarized excitons leads to robust ferromagnetic alignment of magnetic impurities within CdMnTe quantum dots. Due to strong spatial confinement this optically induced zero-field magnetization is very stable and persists up to 150K. This remarkable effect has been observed on both ensemble and single quantum dot levels.

Secondly, subwavelength optical microscopy imaging of CdMnTe quantum dots reveals that at B = 0T for continuous laser illumination each dot exhibits strong and unique circular polarization despite completely unpolarized ensemble emission. This implies that after an exciton recombines, the spontaneous ferromagnetic alignment of magnetic impurities persists for over 100 microseconds, which is a million times longer than in CdMnTe quantum wells. The spin memory effect points toward a qualitatively different picture of magnetization dynamics in the zero-dimensional limit.

We also propose and demonstrate a way to directly probe the magnetization of magnetic quantum dots by measuring the exciton Zeeman splitting of nonmagnetic CdTe quantum dots placed in the vicinity of ferromagnetically aligned CdMnTe quantum dots. From the dependence of the Zeeman splitting on the polarization of the excitation we estimate the internal magnetic field of spin polarized Mn ions to be of the order of 0.2T. Possible mechanisms responsible for the observed effects will be discussed. Importantly, as the exciton spin relaxation in nonmagnetic CdTe quantum dots depends on the energy level degeneracy (which can be lifted by external magnetic field), this approach can be successfully used to tune the spin dynamics of the excitons confined in semiconductor quantum dots.

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