Kondo Correlations in Optical Spectrum of Electrons Confined in Quantum Dots Doped with Single Mn Spin

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Kondo effect is one of the non-perturbative effects in condensed matter physics. Most theory of Kondo effect describes non-interacting electrons occupying states directly interacting with a magnetic impurity (MI) while those electrons of the Fermi sea that do not interact with the MI are neglected. Recent fabrication of quantum dots (QDs) doped with single magnetic Mn impurity and with controlled number of electrons opens the opportunity to investigate analogs of Kondo effect in finite interacting electron system.

In parabolic quantum dots doped with a single Mn ion in its centre only electrons that occupy zero angular momentum orbitals are directly coupled with Mn spin and those electrons in orbitals with finite angular momentum are not coupled with Mn spin. Therefore, these QDs are perfect candidates to investigate both the role of electron-electron interactions (e-e) and the role of electrons in angular momentum channels that are not directly coupled with Mn spin on the Kondo-like physics.

We present here a microscopic model of N-interacting electrons confined in a CdTe QD doped with a single Mn impurity. The Hamiltonian is composed of a kinetic energy, e-e Coulomb interactions, and electron-Mn exchange interaction (e-Mn). The e-Mn contact exchange interaction is described by a Heisenberg Hamiltonian [1]. The QD electron single particle states are treated in the effective-mass approximation as states of a two-dimensional harmonic oscillator. The Hamiltonian matrix is constructed in the space of N electron configurations and M states of the MI. Using exact diagonalization techniques we calculate the eigenvalues and eigenvectors of our many-body Hamiltonian.

Here we show our results for a QD containing up to six electrons and Mn in the QD centre as function of a number of confined shells and e-e interaction. We observe that by changing the number of shells one can tune exchange interaction between electrons and Mn, from ferromagnetic to antiferromagnetic or zero. More importantly, we find an effective e-e mediated interaction between spins of electrons in finite angular momentum orbitals with spins of Mn ions. This indirect exchange interaction modifies Kondo interactions in the interacting electrons system.

To extract Kondo correlations in interacting electron system, we add an exciton to N electrons plus Mn, and calculate its photoluminescence spectrum (PL) as described in Ref. [2]. Here we present the PL spectrum for the X^{3-} +Mn complex, i.e, four electrons and a hole in the initial state of the emission, for a QD containing three shells. We show how indirect exchange interaction between electrons and Mn can be detected in PL spectrum.

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