Control of hole spin dephasing in a coupled quantum dot system

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In this contribution, we analyze hole spin coherence during spin-preserving tunneling between self-assembled coupled quantum dots (CQDs) subject to external magnetic field and coupled to the acoustic phonon bath. We find that spin pure dephasing is caused by difference of Zeeman splittings in the QDs and is present despite of the absence of direct coupling between the spin and the phonon bath. It is a "which-way" type of decoherence [1], where the bath effectively "measures" the spin of the tunnelling hole via the energies of emitted phonons.

In our previous work [2], we predicted this mechanism and studied the case of electron spin. We proposed a model quantifying spin dephasing as a function of the morphological parameters of the quantum dots, as well as external fields. The latter allowed us to come up with possible ways of controlling said dephasing with use of external electric and magnetic fields.

In the case of hole spin, we propose an additional mechanism of the decoherence control via tilting the magnetic field. The idea is based on the strong anisotropy of the hole g-factor in quantum dots resulting from the p-type character of valence band states. Depending on the out-of-plane angle at which the magnetic field is applied, effective g-factors change and their difference between QDs may cancel out thanks to the geometry typical for real self-assembled structures. For planarly misaligned QDs in-plane rotation of magnetic field may also be beneficial due to the breaking of g-tensor axial symmetry. In this way dephasing via the "which-way" channel may be eliminated or significantly diminished in a feasible manner.

Here, we present preliminary results, based on realistic calculations using the 8-band $\boldsymbol{k}\cdot\boldsymbol{p}$ model in the envelope function approximation, where we also include coupling with the phonon-induced deformation potential and piezoelectric field. Calculations are conducted for simulated InGaAs CQDs with realistic geometry based on cross-sections of real samples and a trumpet-shaped indium concentration inside QDs. Hole dynamics is described in the density matrix formalism via a non-secular Markovian master equation in the Redfield form. We analyze the hole g-factor anisotropy and spin dephasing as a function of the angle of applied magnetic field and evaluate the degree of decoherence both analytically and numerically.

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