Controlling electron spin decoherence in a coupled quantum dot system

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In this contribution we analyze spin decoherence during electron tunneling between coupled quantum dots (CQDs) in an external magnetic field due to a misfit between g-factors. The predicted decoherence is present even without any direct coupling between the spin and the phonon bath. It is an example of "which-way" type of decoherence [1], where phonon bath effectively "measures" the spin during carrier tunneling.

We study this phenomenon in a model describing an electron localized in semiconductor CQDs coupled to phonon bath via deformation potential and piezoelectric couplings as well as placed in external electric and magnetic fields. Carrier states, energies and g-factors are realistically modeled using a multiband $\mathbf{k}\cdot\mathbf{p}$ theory including spin-orbit coupling and piezoelectric field up to second order [2]. Next, phonon spectral densities are calculated and used to model spin dynamics by a Markovian master equation in the Redfield form. Using this model and methodology we are able to study spin dynamics in a broad range of parameters, such as temperature, size and composition of QDs as well as magnetic field, by solving the Master equation numerically.

We have found that our results are consistent with those found earlier, using a simple model [3]. Decoherence observed during spin tunneling depends on the difference in Zeeman splitting between QDs in the system and the tunneling rate. These parameters define the k-space position and width of phonon wave packets and hence their distinguishability, which is inversely proportional to coherence preserved after tunneling. We show that the phonon distinguishability can be controlled not only by structural parameters, like size, shape and composition of the dots, but also by external fields via their impact on the spin splitting and tunneling rate.

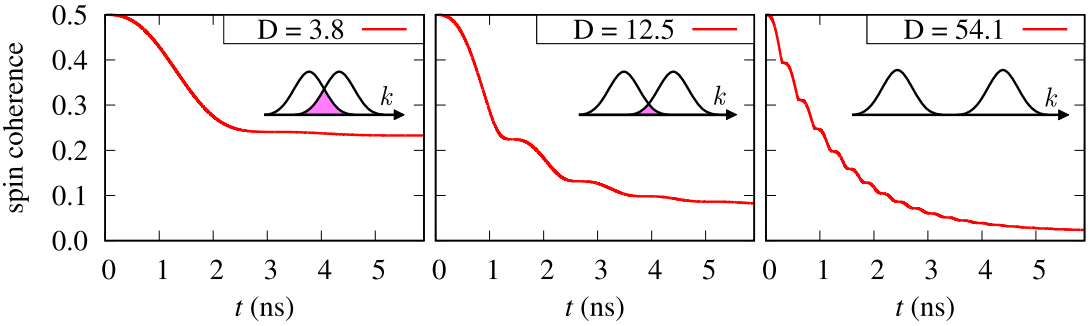

Figure 1: Evolution of total spin coherence during spin tunneling in CQDs with given phonon wave packet distinguishabilities D at $T = 10$ mK. Insets present schematic pictures of phonon wave packet overlaps corresponding to a given value of D.

[1] K. Roszak, P. Machnikowski, Phys. Lett. A **351**, 251 (2006).
[2] K. Gawarecki, P. Machnikowski, Phys. Rev. B **85**, 041305(R) (2012).
[3] M. Krzykowski, M. Gaweczyk, P. Machnikowski, Acta Phys. Pol. A **130**, 1165 (2016).