Controllable electron spin dephasing in coupled quantum dots

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We present a prediction of a spin pure dephasing channel in a spin-preserving electron relaxation in magnetic field between states with unequal g-factors. In particular, we focus on electron tunneling between quantum dots (QDs). The effect, found by us recently in a simple model [2], is present without any spin-environment coupling and is caused by the distinguishability of phonons emitted during tunneling. This results from mismatched Zeeman splittings in QDs and hence different transition energies for the two spin states. In analogy with double-slit experiments, a term *which-way* decoherence is used for such processes appearing if the quantum state of the system affects the reservoir response. Thus, we deal with a fundamental effect of spin measurement effected by the phonon bath via the energy of emitted phonons that leads to the *which-way* dephasing.

We perform accurate modeling of quantum states and realistic dynamical simulations of the pure dephasing accompanying electron tunneling in double QD systems. We focus on the controllability of this effect based on its understanding as a *which-way* decoherence. As such, it depends on the spectral overlap of phonon wave packets, which is determined by tunneling times and difference of Zeeman splittings. We derive this relationship explicitly from the Weisskopf-Wigner spontaneous emission theory and make a quantitative connection between distinguishability of emitted phonons and the amount of information about the spin state leaking to the environment during tunneling. By comparing these calculations with the results of our simulation containing all leading-order phonon-driven and spin-orbit effects, we find the *which-way* channel to be by far the dominant phonon-related spin dephasing mechanism in the system up to room temperature.

Qualitative understanding and quantitative characterization of the dephasing allows us to propose ways of controlling and reducing its magnitude via appropriate sample design and external fields. In the latter case, we propose a protocol of a real-time control over decoherence in real systems, within a range of values extending over many orders of magnitude via feasible tuning of axial electric field.

While we focus mainly on tunneling between QDs, the dephasing mechanism is generic and will affect spin coherence in transitions between states with different Zeeman splittings in any atomic, molecular or solid-state system.

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[1] M. Gawełczyk, M. Krzykowski, K. Gawarecki, P. Machnikowski, arXiv: 1707.06155.

[2] M. Krzykowski, M. Gawełczyk, K. Gawarecki, P. Machnikowski, *Acta Phys. Pol. A* **130**, 1165 (2016).