Phonon-assisted hyperfine spin flip during carrier tunneling in a quantum dot molecule

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We consider a quantum dot molecule (QDM), i.e. two coupled single quantum dots (QDs) with carriers coupled to nuclear spins via hyperfine interactions. We show that below certain value of magnetic field (much higher for an electron than for a hole), the hyperfine process dominates over the spin-orbit-induced spin relaxation.

In general, the hyperfine interaction with the nuclear spins is inefficient due to large mismatch between electronic and nuclear Zeeman energies. Moreover, holes interact with nuclei only via relatively weak dipole interactions, which supresses the hyperfine process even more. Hence, hyperfine spin relaxation in self-assembled QDs is ineffective. In QDM, spin relaxation takes place not only within one Zeeman doublet, but can also be accompanied by a charge relaxation tunneling between the QDs (the two branches of s shell).

In this presentation, we present the rates of phonon-assisted hyperfine spin flip during electron and hole tunneling [1]. We use the 8-band $\boldsymbol{k}\cdot\boldsymbol{p}$ theory in the envelope function approximation. In combination with the multi-band hyperfine Hamiltonian [2] it provides a reasonably accurate description of the hyperfine interaction. We show, that the hyperfine phonon-assisted spin-flip tunneling for electrons dominates over the spin-orbit-induced process at magnetic fields below ≈ 1 T. For holes the hyperfine mechanism becomes important only for fields below 10^{-2} T.

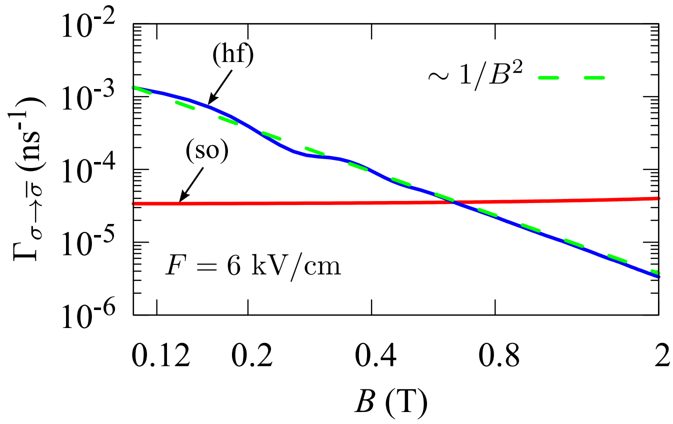

Figure 1: Spin-flip transition rates of electron as a function of the magnetic field, for fixed electric field $F = 6$ kV/cm.

[1] P. Karwat, K. Gawarecki, and P. Machnikowski, arXiv:1902.09515.
[2] P. Machnikowski, K. Gawarecki, and Ł. Cywiński, arXiv:1902.09153.