

# Spin-Orbit-Induced Hole Spin Relaxation in a Quantum Dot Molecule: the Effect of $s$ - $p$ Coupling

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We study the effect of the coupling between the hole  $s$ -shell of one quantum dot and the  $p$ -shell in the other dot forming a quantum dot molecule on the spin relaxation between the sublevels of the hole  $s$ -state. Using an effective model that captures the spin-orbit effects in the  $p$ -shell irrespective of their origin, we show that the strong spin mixing in the  $p$ -shell can be transferred to the  $s$ -shell of other dot, leading to enhanced phonon-assisted spin relaxation in a certain energy range around the  $s$ - $p$  resonance if the dots are misaligned and the magnetic field is tilted from the sample plane (Fig. 1). We calculate the relaxation rate using Fermi's golden rule as a function of the magnitude of axial electric field and the magnitude and orientation of magnetic field. We find spin-relaxation rates in the nanosecond range (Fig. 2) known in literature. While the rate peaks at the exact  $s$ - $p$  resonance, where the wave functions are delocalized and spin mixing is large, it remains high also in a certain energy interval around the resonance, where both the spin polarization and hole localization are nearly perfect (Fig. 2b,c). In addition, for the specific spectrum of band energies in function of electric field the relaxation abruptly slows down.

Fig. 1: Schematic representation of the system: two QDs stacked along the  $z$  axis (growth direction) and misaligned with respect to the vertical axis.

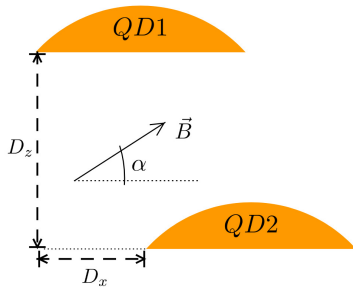
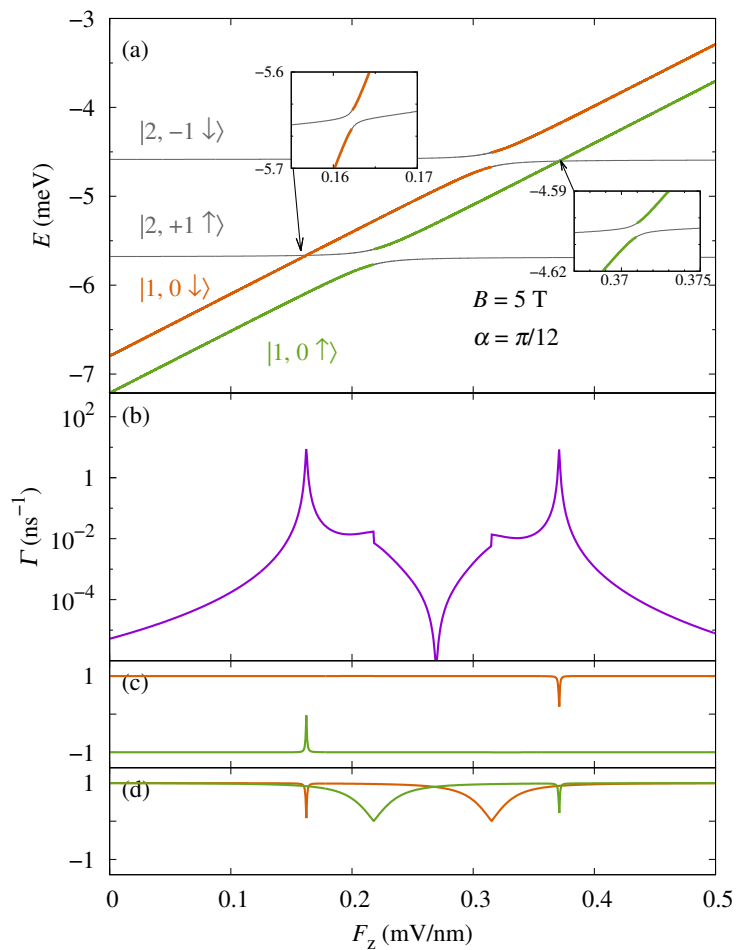


Fig. 2: (a) The eigenstates of the system in the energy range around the  $s$ - $p$  resonance; bold lines mark the states localized in QD1. (b) Hole spin relaxation rate between the Zeeman sublevels in the  $s$ -shell of QD1. (c) Spin polarization of the two states. (d) Localization of the two states.



[1] K. Kawa, P. Machnikowski, arXiv:1902.09161 [cond-mat.mes-hall].