Dominating Mechanisms of Hole Spin-flip Relaxation in a Self-assembled Quantum Dot

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In this paper, we study various hole spin-flip mechanisms in a self-assembled quantum dot (QD). We compare the contributions from various spin-flip channels, depending on the strain present in the system as well as external axial magnetic field. We expand our previous work [1] and investigate two distinct classes of mechanisms of spin-flip relaxation. The first one is *spin admixture*, where relaxation is due to mixing of the bands and is propagated by piezoelectric effect as well as diagonal part of the deformation potential Hamiltonian. The second one is *direct spin-phonon coupling* propagated by off-diagonal part of the deformation potential Hamiltonian. We show that the spin-flip process is dominated by admixture mechanisms due to different couplings, depending on the magnitude of the strain.

To this end we calculate hole wave functions using 8-band $\boldsymbol{k}\cdot\boldsymbol{p}$ method in the envelope function approximation [2, 3]. Calculations were conducted for realistic InGaAs QD structures of high and low indium concentration, resulting in high and low strain regimes, respectively. Hole-phonon couplings were calculated taking into account both piezoelectric and deformation potential couplings as well as both longitudinal and transversal polarizations of the acoustic phonons.

Our results show characteristic $\propto B^5$ and $\propto B^7$ behaviour of the spin flip rate in the studied structures. Moreover we observe saturation of the rate for high magnetic fields ($B \gtrsim 3$ T), to the exact value depending of the strain in the system. We also studied leading contributions to the admixture mechanisms and we found that for the low strain QD structure Rashba effect dominates, while for the high strain QD structure Dresselhaus effect and d_v strain contributions dominate. Finally, we propose an effective model which is in good agreement with the results obtained using the $\boldsymbol{k}\cdot\boldsymbol{p}$ framework.

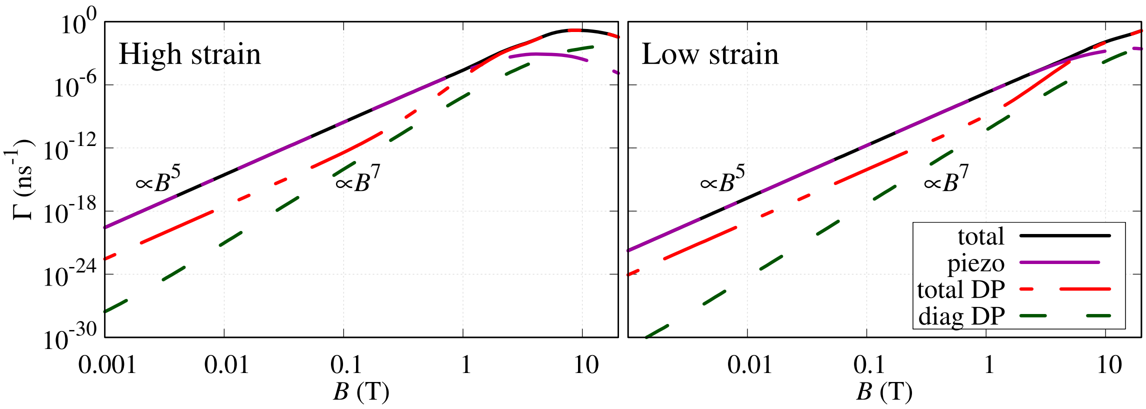

Figure 1: Magnetic field dependence of the spin-flip relaxation rate Γ.

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[1] K. Gawarecki, M. Krzykowski, *Phys. Rev. B* **99**, 125401 (2019).

[2] R. Winkler, *Spin-Orbit Coupling Effects in Two-Dimensional Electron and Hole Systems*, Vol. 191 of *Springer Tracts in Modern Physics* (Springer, Berlin, 2003)

[3] K. Gawarecki, *Phys. Rev. B* **97**, 235408 (2018).