Hole spin relaxation in InAs and GaAs quantum dots: the role of Dresselhaus spin-orbit interaction

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Currently, there are ongoing efforts to use the spin of holes confined in quantum dots for quantum information devices.[1] Understanding and controlling the hole spin relaxation is a requisite for further progress, but the underlying mechanism is still under debate. Different theoretical studies have *assumed* different dominating spin-orbit terms,[2-5] but a full comparison is missing.

Here we present a unified description of spin-orbit induced hole spin relaxation in quantum dots. Using k·p theory, we compare the relaxation due to k-linear, k-quadratic (Luttinger Hamiltonian) and k-cubic (Dresselhaus) spin-orbit terms. We show that cubic Dresselhaus spin-orbit interaction dominates over k-quadratic heavy hole-light hole mixing in gated quantum dots, while both mechanisms have comparable contributions in self-assembled dots.

Our systematic study reconciles seemingly contradictory results of previous theoretical works[2,3], sheds light on some experimental open questions, and reveals new effects resulting from the concurrence of different spin-orbit mechanisms. All in all, the dependence of hole spin relaxation on quantum confinement is drastically different from that of electrons.[6]

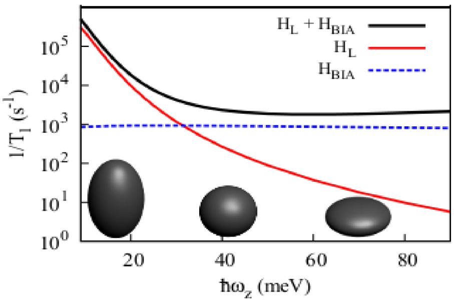

Figure: Hole spin relaxation rate vs vertical confinement for different spin admixture terms. H_L: Luttinger Hamiltonian; H_{BIA}: Bulk inversion asymmetry Hamiltonian.

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