Carrier spin dephasing in coupled quantum dots

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Understanding of spin dynamics in a system of coupled quantum dots (QDs) is important due to its potential for future use in spintronic devices. Spin-preserving tunneling in such structures [1] can be exploited to implement a spin-initialization scheme based on exciton dissociation [2].

In this contribution we show that spin coherence is not preserved during carrier tunneling in an external magnetic field if there is a misfit between g-factors in QDs. This decoherence is present even in the absence of direct coupling between the spin and the phonon bath. It is a "welcher-weg" type of decoherence [3], where phonon bath "measures" spin as the carrier tunnels.

Our model consists of a carrier confined in a semiconductor QD coupled to a phonon bath and placed in external magnetic and electric fields. We model spin dynamics using a Markovian master equation in the Redfield form in a broad range of parameters, such as temperature, g-factors and energy levels in QDs, by solving the equation numerically. In further calculations carrier states, g-factors, as well as carrier-phonon couplings were acquired using a multiband $\mathbf{k} \cdot \mathbf{p}$ method [4].

We have found that the decoherence resulting from tunneling of the carrier with the emission of a phonon is strongly correlated to the difference between g-factors in the QDs. Even for a small mismatch of parameters ($\approx 10\%$) effects of decoherence during carrier tunneling become important. We have also studied temperature impact on decoherence. Simulations showed a significant effect in the moderate-temperature regime, with spin decoherence times for a state in thermal equilibrium with respect to the spatial degrees of freedom being 3 orders of magnitude shorter at $T = 30$ K compared to $T = 5$ K. The exponential decay of spin coherence can be attributed to the accumulated coherence loss during repeated thermally activated tunneling between the lowest states in different QDs.

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