Optical control and decoherence of spin qubits in quantum dots

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Single electron spins confined in semiconductor quantum dots (QDs) seem to be promising candidates for implementing quantum information processing schemes. The main advantage of these systems is their relatively long coherence time. Many control protocols for spins in QDs have been developed, mostly based on applying external voltages and exploiting exchange interactions.

It is, however, also possible to control spins by optical means. In quantum dots this can be done by inducing charge dynamics dependent on the spin state of an electron, which is possible due to the optical selection rules and Pauli exclusion principle. Such control methods lead to very short switching times, even on picosecond time scales. A few control protocols of this kind have been proposed [1-3]. Their common feature is optical coupling of both spin states to a trion (charged exciton) state. This opens a quantum pathway between the two spin states via a Raman transition. In this way optical coherent control of a spin in a QD becomes possible.

In this presentation these optical spin control schemes will be reviewed, mostly from a theoretical point of view. Schemes for rotating electron spins will be discussed, as well as methods for optical control of exciton polarization (by coupling to the biexciton state). This review will be followed by an analysis of decoherence processes accompanying the optical spin control schemes. The latter result from the lattice response to the charge evolution necessary to perform the spin rotation [4]. Possible optimization against this decoherence will be discussed.

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