Modeling of spin dynamics in optically excited electrically gated double quantum wells

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The rapid development of spintronics creates a need for new types of feasible high-fidelity spin manipulation systems. This and the high level of solid-state experimental techniques make the study of spin dynamics in semiconductors reasonable and with a wide area of possible applications.

In this contribution, we present a theoretical study of spin dynamics in a system consisting of two electrically controlled tunneling-coupled quantum wells subjected to a magnetic field. For such a system under optical pumping we simulate the time resolved Kerr rotation (TRKR) as well as resonant spin amplification (RSA) experiments.

Recently, an optical spin initialization scheme based on coupling to the trion state by a pulsed excitation of a p-doped QW was presented [1]. It was shown that the excitation with the subsequent trion recombination as well as coupling to phonons cause partial spin dephasing during the laser pulse [2], which affects the results of current experiments based on the resonant spin amplification effect. This and problems with a proper p-type doping in other materials, led to the proposal of spin initialization in undoped double quantum well systems [3], where the gate-voltage controlled carrier tunneling leads to separation of optically generated electron-hole pairs, which extends the spin lifetime.

In our model of such a system, the additional carrier trapping on local interface fluctuations or nearby defects in quantum wells occurring at low temperatures is considered. Spin precession in the magnetic field (in-plane or slightly tilted) is taken into account exactly, while the dissipative dynamics of the system (including spin relaxation, decoherence, electron and hole tunneling between quantum wells enhanced by the electric field, and radiative recombination) is described in the Markov limit by the universal Lindblad superoperator in the Master equation of motion for the density matrix. The excitation by the circularly polarized laser pulse is accounted for in the second order with respect to the pulse area. To obtain the direct correspondence with experimentally measured quantities we employ the numerical solution for the density matrix from which we find the relevant dynamical variables such as spin polarization and coherences for each QW.

The dependence of the spin dynamics on sample parameters, gate voltage and temperature is analyzed and optimal conditions for preparation of long-living spin polarization are discussed. The comparison of simulated TRKR and RSA curves with experimental data may allow one to extract the dynamical parameters, such as carrier g-factors, spin lifetime and coherence time.

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[2] M. Gawełczyk and P. Machnikowski, *Phys. Rev.* B **87**, 195315 (2013).

[3] C. Gradl, M. Kugler, C. Schönhuber, D. Schuh, D. Bougeard, C. Schüller, T. Korn, conference talk at OPON2013, Bayreuth (2013).