Spin dynamics in p-doped semiconductor nanostructures subject to a magnetic field tilted from the Voigt geometry

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Spintronics, with its possible applications like spin memory or semiconductor spin-based quantum computer, is a very promising branch of nanoscience. However, for the control and readout of spin states one has to maximize their life times. Extended life times observed in semiconductor nanostructures, especially for hole spin states (for which reduced hyperfine interaction makes the spin decoherence slower), seem very promising. Thus, the understanding of the properties of spins in confined semiconductor systems is crucial.

We present a description of the time-resolved Kerr rotation and resonant spin amplification (RSA) experiments on an ensemble of independent holes in a semiconductor nanostructure (e.g., confined in a quantum dot or trapped in a quantum well). We extend our former model [1] to describe spin dynamics in a magnetic field tilted from the Voigt geometry. We study the microscopic evolution of spin polarization and obtain an analytical formula for the Kerr signal. We show that the signal consists of two parts: one depending on hole and the other on trion dynamical variables, each containing damped oscillation and decay terms (due to radiative recombination and hole decoherence). This gives us the insight into effective T_1 and T_2 times and their dependence on the magnetic field tilt angle. We also analytically describe the RSA signal in the limit of small tilt angles, when trion spin dynamics does not differ much from the one in the Voigt configuration, but hole spin dynamics is substantially changed due to the strong anisotropy of the hole g-factor. Specifically we show that the RSA signal is nontrivially affected by the equilibrium spin polarization and that the RSA peaks can get inverted in the tilted field.

In our theoretical approach we treat the pump pulse perturbatively (low-power limit) and use a generic Markovian description of the hole and trion dephasing [2]. To obtain the expression for the RSA signal we find the stationary point of the spin polarization transformation corresponding to one repetition of the pulsed laser (pumping, precession and decoherence). We simplify our expressions by assuming that the trion radiative decay rate is much larger then the hole dephasing rates (which is consistent with the experimental conditions). We include also the inhomogenous broadening of the hole g-factors and model it with the normal distribution. The Kerr and RSA response calculated in this way show good agreement with the experimental results.

[1] M. Kugler, K. Korzekwa, P. Machnikowski, C. Gradl, S. Furthmeier, M. Griesbeck, M. Hirmer, D. Schuh, W. Wegscheider, T. Kuhn, C. Schüller, T. Korn, Phys. Rev. B **84**, 085327 (2011).
[2] P. Machnikowski, T. Kuhn, Phys. Rev. B **81**, 115306 (2010).