Carrier spin dynamics in undoped double quantum dots

Michał Gawełczyk and Paweł Machnikowski

Department of Theoretical Physics, Faculty of Fundamental Problems of Technology, Wrocław University of Technology, Wybrzeże Wyspiańskiego 27, 50-370 Wrocław, Poland

In this contribution, we provide a model of the electron and hole spin dynamics in a double quantum dot structure [1], considering the carrier tunneling between quantum dots, which is enhanced by an electric field. Taking into account also the presence of an in-plane or tilted magnetic field, we provide the simulation of magneto-optical experiments which are performed currently on such structures to probe the temporal spin dynamics.

Probing exciton spin dynamics in neutral structures is limited by recombination much faster than the actual spin dynamics. In doped structures, in turn, the initialization of resident spins is subject to the intrinsic dephasing [2] affecting the results of experiments sensitive to spin coherence [3]. The search for undoped systems with long-living spins brought a proposal and first realizations of double quantum wells and dots, in which exciton is spatially separated due to the carrier tunneling.

In our model of such system, spin precession in the magnetic field is treated exactly, while the dissipative dynamics of the system (spin relaxation, dephasing, carrier tunneling between quantum dots, and recombination) is described in the Markov limit by the universal Lindblad superoperator in the master equation for the density matrix evolution. Moreover, we include the spin-orbit coupling effects, which give rise to the mixing of states with different angular momenta and in cosequence to the probability of spin-flip tunneling of carriers. To obtain the direct correspondence with experimentally measured quantities we employ the numerical solution for the density matrix and construct substantial dynamical variables such as spin polarization and coherences for each of QDs.

We reproduce the experimentally observed effect of the extension of the spin polarization life time caused by the charge separation, which occurs in structures of this type. Moreover, we provide a number of qualitative predictions concerning the necessary conditions for observation of this effect as well as about possible channels of its suppression. We consider also the impact of the magnetic field tilting, which results in an interesting spin polarization dynamics. Finally, we discuss the relevance of the spin-flip tunneling caused by the spin-orbit interaction for typical systems.

We find that the effect of spin polarization life time extension depends essentially on the ratio of tunneling time to direct exciton recombination time. The spin-orbit interactions and spin-flip tunneling caused by it lead to the loss of spin coherence which occurs once during the tunneling process at low temperature and accumulates in time at higher temperature. The strength of this effect scales with the localization length, which makes it negligible for small QDs.

[1] M. Gawełczyk, P. Machnikowski, arXiv:1407.4529.

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

[3] M. Syperek, D. R. Yakovlev, A. Greilich, J. Misiewicz, M. Bayer, D. Reuter, and A. D. Wieck, *Phys. Rev. Lett.* **99**, 187401 (2007).