Non-Markovian spin transfer dynamics in optically excited diluted magnetic semiconductor quantum wells

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Diluted magnetic semiconductors (DMS) combine the versatility of the semiconductor host material with strong magnetic properties of the integrated dopants, making them promising candidates for future spintronic devices. A crucial step towards the realization of such devices is to gain a profound understanding of the exchange interaction between the spins of localized dopants and free carriers. In the literature, the exchange interaction is usually split up into the mean field part, which leads to a coherent precession of dopant and carrier spins around one another, and the spin dependent scattering part, which is responsible for spin transfer dynamics between the two spin subsystems. The latter effect is usually treated on the level of Markovian rate equations.

In this contribution we use a recently developed quantum kinetic approach [1] which explicitly accounts for the finite memory depth of the system to simulate the spin transfer dynamics in a (ZnMn)Se DMS quantum well.

We find pronounced signatures of a coherent exchange of spin between the electronic and the Mn subsystem: while an initially prepared total electron spin simply decays exponentially in the Markovian limit, time-dependent changes of the sign of the total electron spin are predicted by our quantum kinetic model [2]. Such non-Markovian features are usually connected to a large memory depth of the system. However, the spin memory function of the considered system turns out to decay on a sub-femtosecond timescale and, thus, more than three orders of magnitude faster than the electron spin. This seeming contradiction can be resolved by noting that in the Markovian limit not only memory effects are neglected but also the spin dependent electron redistribution over the carrier energies is missing, which in the full quantum kinetic equations occurs due to the energy-time uncertainty. The latter is crucial for the occurrence of sign reversals of the total electron spin, as we can show by artificially suppressing the redistribution of electronic energies while still accounting for the spin memory of the system [2].

Finally, we demonstrate that significant deviations from the Markov limit are most clearly observable if the spin polarized electrons are excited by two laser pulses of different color and opposite circular polarizations such that there is practically no net transfer of angular momentum from the laser field to the electronic system. Under these distinguished excitation conditions, the total electron spin should remain zero according to the standard Markovian rate equations for a DMS quantum well. In contrast, our quantum kinetic simulations predict a sizeable build-up of spin polarization in the conduction band which exhibits oscillations that persist for times much longer than the duration of the exciting laser pulses. These oscillations represent a clear signature of a coherent non-thermal exchange of spin between the electronic and the Mn subsystems.

[1] C. Thurn and V. M. Axt, Phys. Rev. B **85**, 165203 (2012).
[2] C. Thurn, M. Cygorek, V. M. Axt and T. Kuhn, ArXiv:1303.4322 (2013).