Heating efficiency of the Mn spin system by photoexcited holes in type-II (Zn,Mn)Se/(Be,Mn)Te quantum wells

J. Debus[1], A. A. Maksimov[2], D. Dunker[1], I. I. Tartakovskii[2], E. V. Filatov[2], D. R. Yakovlev[1,3], A. Waag[4], and M. Bayer[1]

[1] *Experimentelle Physik 2, Technische Universität Dortmund, 44227 Dortmund, Germany*
[2] *Institute of Solid State Physics, RAS, 142432 Chernogolovka, Russia*
[3] *Ioffe Physical-Technical Institute, RAS, 194021 St. Petersburg, Russia*
[4] *Institute of Semiconductor Technology, Braunschweig Technical University, 38106 Braunschweig, Germany*

Diluted magnetic semiconductors (DMS) are regarded as model structures for applications in spin electronics, as they combine electronic semiconductor properties with a strong enhancement of spin-dependent phenomena. In this respect, the magnetic ions, incorporated into II-VI host material, play a key role, since their presence leads to a strong exchange interaction of their localized magnetic moments with the conduction-band electrons and/or valence-band holes giving rise to giant magneto-optical effects. A particular example is the excitonic giant Zeeman shift which can be used by optical techniques to obtain information about the spin system of magnetic Mn^{2+} ions and its coupling to free carriers and the phonon bath [1].

Spin-lattice relaxation of the excited Mn^{2+} ion system into its equilibrium with the phonon bath strongly depends on the Mn ion concentration. Its increase leads to the formation of Mn ion clusters providing fast spin relaxation, and spin diffusion from excited single Mn ions to such clusters, in turn, considerably accelerates the spin-lattice relaxation process of DMS on the whole [2]. While the spin-lattice relaxation dynamics have extensively been studied, an open question is the optical heating efficiency of the Mn spin system in DMS structures. The free carriers with excess kinetic energy (photoexcited or electrically injected) can heat (depolarize) the Mn spin system. There are two different ways for transferring energy and spin from hot carriers to the Mn spin system in DMS heterostructures. An indirect transfer arises from phonons emitted by the free carriers and absorbed by Mn ions. A direct way is due to fast carrier exchange scattering on the localized Mn spins and is characterized by very short transfer times in the picosecond range.

We trace the relationship between the lifetime of photoexcited holes and heating efficiency of the Mn spin system in the (Zn,Mn)Se layer of differently thick $Zn_{0.99}Mn_{0.01}Se$/ $Be_{0.93}Mn_{0.07}Te$ heterostructures under different levels of optical excitation power. The giant Zeeman shift of the exciton providing information about the temporal and spatial distribution of the Mn spin temperature is monitored by use of a time-resolved pump-probe reflectivity measurement. The spin and energy transfer efficiency from the photoexcited holes to the Mn system considerably depends on the thickness of the (Zn,Mn)Se layer. Hereby, the importance of multiple hole spin-flip processes for the Mn heating is demonstrated. The photoexcited hole lifetime in the (Zn,Mn)Se layer is very sensitive to the optical excitation power. This allows us to determine the characteristic time of spin and energy transfer from photoexcited holes to the Mn system to about 20 ps.

[1] J. Debus, A. A. Maksimov, D. Dunker, et al., Phys. Rev. B **82**, 085448 (2010).
[2] A. A. Maksimov, D. R. Yakovlev, J. Debus, et al., Phys. Rev. B **82**, 035211 (2010).