SPIN-PHONON DYNAMICS IN DOPED MAGNETIC QUANTUM WELLS

A.V.Akimov[1], A.V.Scherbakov[1], D.R.Yakovlev[1,2], W.Ossau[2], L.W.Molenkamp[2], T.Wojtowicz[3], J.Kossut[3], S.Tatarenko[4] and J.Cibert[4]

[1] *A.F.Ioffe Physical-Technical Institute, Russian Academy of Sciences, 194021 St.Petersburg, Russia*
[2] *Physikalisches Institut der Universität Würzburg, 97074 Würzburg, Germany*
[3] *Institute of Physics, Polish Academy of Sciences, 02-668 Warsaw, Poland*
[4] *Laboratoire de Spectrométrie Physique, Université Joseph Fourier Grenoble 1 - CNRS (UMR 55 88), Boite Postale 87, F-38402 Saint Martin d'Hères Cedex, France*

There is a great present activity aimed at designing spintronic devices using diluted magnetic semiconductors. It was demonstrated recently that a layer of II-VI magnetic semiconductor, included in a GaAs-based *n-i-p* light-emitting diode, can serve as an effective injector of spin-polarized carriers [1]. This result initiated the experimental work reported here where we study the spin-phonon dynamics in doped magnetic semiconductor layers which consist of quantum wells (QWs) with two dimensional either electron (2DEG) or hole (2DHG) gas.

We study three series of magnetic nanostructures: (i) undoped CdMnTe/CdMgTe QWs; (ii) *n*-doped (CdMn)Te/(CdMg)Te QWs with 2DEG; (iii) *p*-doped CdMnTe/CdMgZnTe QWs with 2DHG. The content of Mn ions was x=1% in the undoped and *n*-doped samples and x=0.35% in the *p*-doped sample. The sheet density of the carriers in doped QWs varied from $n_{e(h)}=5\times10^{9}$ to 1.5×10^{11} cm^{-2} and was controlled by a distance of the doping layer to the QW (in the samples with 2DEG) or by optical excitation (in the sample with 2DHG). All structures were grown by MBE with QWs being 8 nm wide.

In the experiments we have measured the spin-lattice relaxation time, τ, using a unique technique which combines an injection of nonequilibrium phonons and an optical detection of the induced changes via the exciton photoluminescence [2]. The phonon generator (a 10 nm constantan film) was evaporated on the substrate and was heated by current pulses. Phonons from the generator propagated through the substrate, reaching the semimagnetic structure with the QW, and there they induced heating of the spin system of Mn ions. The excitons in QWs were created by a laser excitation. The time-resolved detection of the Mn spin temperature was based on monitoring the dynamic shift of the exciton photoluminescence line caused by the giant Zeeman splitting of the excitons characteristic for the diluted magnetic semiconductor material comprising the QW. The sample was mounted inside a superconducting magnet in the Faraday configuration and was immersed in pumped liquid helium (T=1.6 K).

In the undoped QWs we measured a long spin-lattice relaxation time ($\tau\sim10^{-4}$ s) comparable to that measured earlier in bulk magnetic semiconductors. In the doped structures we observe the dramatic acceleration of the relaxation process which is due to the presence of 2DEG or 2DHG. Thus, in the sample with 2DEG ($n_e=1.5\times10^{11}$ cm^{-2}) we observe a reduction of τ by the factor of 5 in comparison with the undoped sample. The 2DHG has an even stronger effect – the reduction of τ measured for $n_h=3\times10^{10}$ cm^{-2} is by the factor of 20. We demonstrated experimentally that it is possible to tune the value of τ by changing the intensity I of the laser excitation in the doped QWs. In the sample with 2DHG, where n_h significantly decreases with an increase of I, we can tune the value of τ from 17 to 44 μs. These experimental results were analysed using a theoretical model which assumed that the acceleration of the spin-lattice relaxation is due to spin-flip transitions between the Mn ions and the carriers present in the QWs.

1. R.Fiederling, M. Keim, G. Reuscher, W. Ossau, G. Schmidt, A. Waag and L.W. Molenkamp, Nature **402**, 787 (1999).
2. A.V. Scherbakov, A.V. Akimov, D.R. Yakovlev, W. Ossau, A. Waag, G. Landwehr, T. Wojtowicz, G. Karczewski, and J. Kossut, Phys. Rev. B **60**, 5609 (1999); Phys. Rev. B **62**, R10641 (2000).