Dynamics of nuclear spin polarization induced and detected by coherently precessing electron spins in fluorine-doped ZnSe

F. Heisterkamp[1], E. Kirstein[1], A. Greilich[1], E. A. Zhukov[1], T. Kazimierczuk[1,*], D. R. Yakovlev[1,2], A. Pawlis[3], and M. Bayer[1,2]

[1] *Experimentelle Physik 2, Technische Universität Dortmund, 44221 Dortmund, Germany*
[2] *Ioffe Institute, Russian Academy of Sciences, 194021 St. Petersburg, Russia*
[3] *Peter Grünberg Institute (PGI-9), Forschungszentrum Jülich, 52425 Jülich, Germany*

We study the dynamics of optically-induced nuclear spin polarization in a fluorine-doped ZnSe epilayer via time-resolved Kerr rotation (KR) [1]. The nuclear polarization in the vicinity of a fluorine donor is induced by interaction with coherently precessing electron spins in a magnetic field applied in the Voigt geometry. It is detected by nuclei-induced changes in the electron spin coherence signal. This all-optical technique (see Fig. 1) allows us to measure the longitudinal spin relaxation time T_1 of the ^{77}Se isotope in a magnetic field range from 10 to 130 mT under illumination. We combine the optical technique

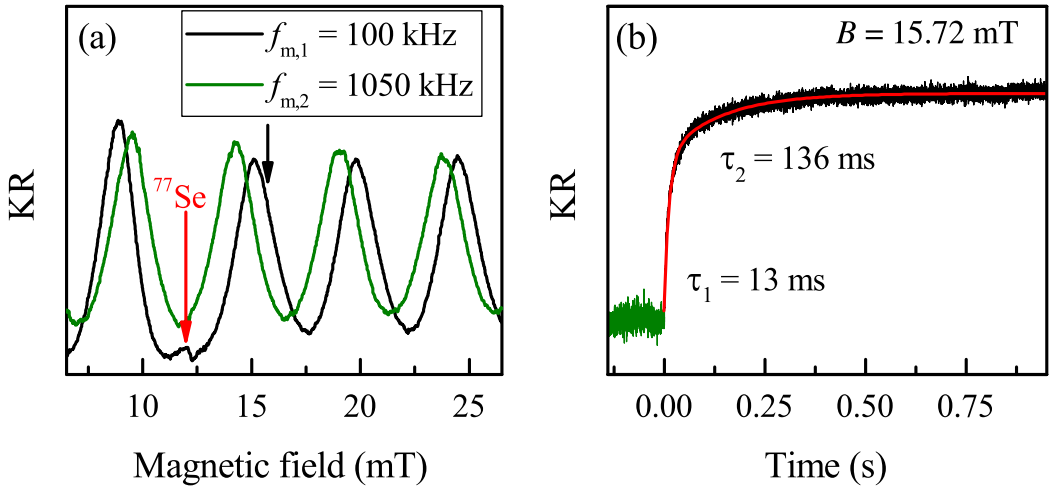

Figure 1: (a) Resonant spin amplification spectra measured at $f_{m,1} = 100\,\text{kHz}$ (black line) and $f_{m,2} = 1050\,\text{kHz}$ (green line). The red arrow marks the optically induced NMR of the ^{77}Se isotope at $f_{m,1} = 100\,\text{kHz}$ and the black arrow marks the magnetic field position ($B = 15.72\,\text{mT}$) for the measurement shown in Fig. 1(b). (b) Change of KR amplitude at fixed magnetic field induced by switching from $f_{m,2}$ (green line) to $f_{m,1}$ (black line). Red line shows a double exponential fit to the data.

with radio frequency methods to address the coherent spin dynamics of the nuclei and measure Rabi oscillations, Ramsey fringes and the nuclear spin echo. The inhomogeneous spin dephasing time T_2^* and the spin coherence time T_2 of the ^{77}Se isotope are measured. While the T_1 time is on the order of several milliseconds, the T_2 time is several hundred microseconds. The experimentally determined condition $T_1 \gg T_2$ verifies the validity of the classical model of nuclear spin cooling for describing the optically-induced nuclear spin polarization.

[1]F. Heisterkamp, E. Kirstein, A. Greilich, E. A. Zhukov, T. Kazimierczuk, D. R. Yakovlev, A. Pawlis, and M. Bayer, *Phys. Rev. B* **93**, 081409(R)(2016).

*Present address: Institute of Experimental Physics, Faculty of Physics, University of Warsaw, 02-093 Warsaw, Poland.