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Development of picosecond time-resolved nuclear resonance scattering and a novel synchrotron Mössbauer source at PETRA III

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Nuclear inelastic scattering (NIS) is not bound by optical selection rules, which restrict the accessible vibrational modes in other techniques such as Raman scattering. It gives the phonon density of states (pDOS) at the instant the x-ray photon gets absorbed. Therefore, it is well suited to study the time evolution of pDOS in optically excited materials containing Mössbauer-active nuclei [1, 2].

We developed a time-resolved optical laser pump-NIS probe experiment at the beamline P01, PETRA III, DESY (Hamburg). 14.4 keV synchrotron radiation (SR) pulses formed the probe. Optical excitation was caused by time-delayed 250 fs laser (LR) pulses from a 1030 nm source, which was synchronized to the synchrotron ring and emits pulses at every 2nd or 4th SR pulse. We measure the dynamics of the excited state with a time-resolution of 100 ps by performing NIS of the SR pulse accompanied by the LR pulses. The ground state was measured in identical conditions using the SR pulse(s) in the absence of the LR pulse.

We show the evolution of pDOS after laser excitation in a 3 µm thick Fe foil and spin crossover complexes: $[Fe(PM\text{-}BiA)_2(NCS)_2]$ and $[Fe(Htrz)_4(trz)_2](BF_4)$. We also report the progress in the development of a novel synchrotron Mössbauer source based on the nuclear Bragg reflection from a $K_4Fe(CN)_6.3H_2O$ crystal.

[1] S. Sakshath et al, Hyperfine Interact. 238, 89 (2017)

[2] R. Rohlsberger, Nuclear condensed matter physics with synchrotron radiation, Springer (2004)

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