MA 40: Focus: Terahertz radiation and magnetism

Organized by M. Kläui (U. Mainz) and P. M. Oppeneer (Uppsala University)

Magnetization dynamics has been studied intensively with pump-probe magneto-optical spectroscopy, in which an ultrashort infrared laser pulse is used to excite the electrons in a material and subsequently trace the magnetization dynamics using the probe pulse. Ultrashort pulses in the terahertz regime (frequencies of 1 - 20 THz) have only recently become available. Since THz radiation has typical energies that match those of the fundamental low-energy excitations in solids, such as phonons and magnons, it can ideally be employed to excite these directly, without exciting the electron system first. Consequently, THz radiation experiments have recently begun to unlock new insight in ultrafast magnetic processes, either by using THz radiation as a pump or as a tool to analyze the spin and charge dynamics. This Focused Session is dedicated to highlighting the emerging opportunities to employ THz radiation in magnetism research and to underline the novel fundamental insight that THz experiments have recently provided.

Time: Thursday 9:30–11:45 Location: H32

Invited Talk MA 40.1 Thu 9:30 H32

Sub-cycle terahertz electronics and magnonics: control and nanoscopy — •Rupert Huber — Department of Physics, University of Regensburg, 93053 Regensburg, Germany

High-intensity terahertz (THz) sources have become a unique tool to explore condensed matter under atomically strong electric and magnetic biasing. We show that terahertz fields of up to 11 GV/m can accelerate electrons in bulk semiconductors to perform complete Bloch oscillation cycles within half an oscillation period of the drive field. The concomitant magnetic field component allows us to control spins in magnetically ordered solids. Intense THz pulses drive the spin degree of freedom into a massively nonlinear response regime. By combining scanning probe microscopy with phase-locked high-field THz waveforms and field-sensitive electro-optic sampling, we unite sub-cycle time resolution with nanometer and even atomic-scale spatial resolution. Our results shed fundamentally new light onto the structure and dynamics of the elementary building blocks of condensed matter and spark hope for electronics and magnetic storage at optical clock rates.

Invited Talk MA 40.2 Thu 10:00 H32

Probing and controlling ultrafast magnetism with terahertz electromagnetic pulses — •Tobias Kampfrath — Fritz Haber Institute, Berlin, Germany

Sub-picosecond terahertz (THz) electromagnetic pulses are not only capable of probing and even controlling numerous low-energy excitations such as phonons, excitons and Cooper pairs but they also provide novel access to ultrafast magnetism.

As a first example, we optically launch ultrafast spin transport and study its conversion into charge currents by means of the inverse spin Hall effect [Nature Nanotech. 8, 256 (2013)]. Our approach allows us to monitor ultrafast spin currents, provides a quick and easy estimate of the strength of the spin Hall effect and leads to new and efficient emitters of THz pulses that fully cover the range from 1 to 30 THz without gap [http://arxiv.org/abs/1510.03729]. Second, we probe spin-lattice coupling by selective excitation of optical phonons in the model ferrimagnetic insulator yttrium iron garnet. A magnetization quenching on a time scale as short as 1 ps is found, attesting to a highly efficient equilibration of lattice and spins. We present a new microscopic mechanism of phonon-to-magnon conversion that provides a quantitative explanation of our experimental findings.

The results shown here were obtained in close collaborations with the research groups of L.M. Hayden, M. Kläui, Y. Mokrousov, M. Münzenberg, P.M. Oppeneer, A. Paarmann, I. Radu and D. Turchinovich.

15 min. break

Invited Talk MA 40.3 Thu 10:45 H32

THz Spintronics: Magnetotransport and Magnonics — •Zuanming Jin[1,2], Mathias Kläui[3], Tobias Kampfrath[4], Guohong Ma[2], Mischa Bonn[1], and Dmitry Turchinovich[1] — [1]Max Planck Institute for Polymer Research,Mainz,Germany — [2]Department of Physics,Shanghai University,Shanghai,China — [3]Institut für Physik, Johannes Gutenberg-Universität Mainz,Mainz,Germany — [4]Fritz Haber Institute of the Max Planck Society,Berlin,Germany

Spin-dependent conduction in metals underlies all modern magnetic memory technologies, such as giant magnetoresistance (GMR). According to the fundamental Mott model, the charge current in ferromagnetic transition metals is carried by non-mixing populations of sp-band Fermi-level majority- and minority-spin electrons, experiencing spin-dependent momentum scattering with localized electrons originating from the spin-split d-band. The direct observation of magneto transport under such fundamental conditions, however, requires the conductivity measurements on the ultrafast, sub-100 fs timescale, at which the electron momentum scattering occurs. Here, using ultrafast terahertz spectroscopy on a GMR spin-valve, we directly observe the magneto transport in a metallic system under the fundamental conditions of Mott model. As a result, we are able to directly determine the fundamental parameters of magneto-transport - spin-dependent densities and momentum scattering times of conduction electrons in a ferromagnetic metal. Further, we will discuss the direct excitation, observation, and coherent control of THz-frequency magnons in rare-earth orthoferrites.

Invited Talk MA 40.4 Thu 11:15 H32

Precessional spin motion and magnetization quenching induced by intense Terahertz pulses — •Christoph Hauri — SwissFEL, Paul Scherrer Institute, 5232 Villigen-PSI, Switzerland

Laser pulses in the low-frequency Terahertz range (1 – 15 THz) with field strength up to several GV/m and several Tesla have become available only very recently. Such pulses offer novel opportunities to explore ultrafast magnetization dynamics and magnetic domain switching in a regime differing from the commonly used optical lasers where the magnetization control is mediated by heat deposition. We show that strong THz fields allow coherent spin excitation even without exciting a magnetic mode (e.g., magnon). Our investigations on cobalt, nickel and iron thin films unravel the onset of a co-existence of precessional motion and ultrafast magnetization quenching as function of the THz field strength. While the coherent precessional motion is induced by the magnetic field the concomitant electric field component gives rise to fast demagnetization. Our findings illustrate the fundamental limits of metallic ferromagnetic thin films in view of magnetic switching by THz fields.