# MA 27: Ultrafast Magnetization Effects I

Time: Wednesday 9:30–12:45 Location: HSZ/0004

**Invited Talk** MA 27.1 Wed 9:30 HSZ/0004

**Towards sub-10fs magnetization switching** — Reza Rouzegar[1], Oliver Franke[1], Gal Lemut[1], Oliver Gueckstock[1], Junwei Tong[1], Dieter Engel[2], Xianmin Zhang[3], Georg Woltersdorf[4], Piet W. Brouwer[1], Tobias Kampfrath[1], and •Quentin Remy[1] — [1]Department of Physics, Freie Universität Berlin, 14195 Berlin, Germany — [2]Max-Born-Institut für nichtlineare Optik und Kurzzeitspektroskopie, 12489 Berlin, Germany — [3]Key Laboratory for Anisotropy and Texture of Materials (Ministry of Education), School of Material Science and Engineering, Northeastern University, Shenyang 110819, China — [4]Institut für Physik, Martin-Luther-Universität Halle, 06120 Halle, Germany

Femtosecond laser pulses can induce sub-picosecond demagnetization, enabling ultrafast magnetic writing, spin transport, and broadband THz generation. Yet the microscopic processes in the first ~ 10 fs remain poorly understood. Three-temperature models describe energy flow among electrons, spins, and the lattice but neglect angular-momentum transfer, essential for spin dissipation.

Using ultrabroadband THz emission spectroscopy with ~ 10 fs resolution, we find that electron-magnon (em) scattering drives the nonequilibrium spin dynamics, generating both spin flips and magnons in under 10 fs, well before ~ 100 fs demagnetization. Angular momentum is then dissipated primarily through magnon-lattice interactions. Having established em scattering as the dominant sub-10-fs mechanism, we show that THz pulses can harness this coupling to reverse magnetization, pointing to sub-10-fs spin control.

MA 27.2 Wed 10:00 HSZ/0004

**Ultrafast Control of Spin Periodicity in a Helical Heisenberg Antiferromagnet** — •Hyein Jung[1,2], Abeer Arora[2], Deeksha Gupta[3], Franziska Walther[4], Kristin Kliemt[4], Victoria C. A. Taylor[2], Túlio de Castro[2], Hanqian Lu[1,2], Christian Schüssler-Langeheine[3], Niko Pontius[3], Urs Staub[5], Cornelius Krellner[4], Laurenz Rettig[2], Ralph Ernstorfer[1,2], and Yoav W. Windsor[1,2] — [1]Technische Universität Berlin, Berlin, Germany — [2]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin, Germany — [3]Helmholtz-Zentrum Berlin für Materialien und Energie, Berlin, Germany — [4]Goethe-Universität Frankfurt, Frankfurt, Germany — [5]Paul Scherrer Institut, Villigen, Switzerland

The ultrafast manipulation of spin structures is a promising route toward the next generation spintronic devices. In this work, we study the helical Heisenberg antiferromagnet $EuCo_2P_2$ using resonant soft X-ray diffraction (RXD). By probing the magnetic Bragg reflections, we are experimentally sensitive both to the antiferromagnetic (AF) order parameter and to the 4f spin periodicity. We measure their response under three distinct perturbations: (a) femtosecond laser excitation (ultrafast RXD), (b) external magnetic fields, and (c) temperature variation. Employing a Heisenberg model, we directly reveal how the observables respond to each of the perturbations we apply. We further probe the response of the crystal lattice under the same conditions as the spin order and draw a relation between the dynamics of the two. These results offer insight into different routes to control AF spin order and its couplings.

MA 27.3 Wed 10:15 HSZ/0004

**Time-resolved coherent small-angle EUV scattering of magnetic thin film structures** — •Konstanze Korell[1], Sergey Zayko[1], Hung-Tzu Chang[1], Timo Schmidt[2], Murat Sivis[1,3], Manfred Albrecht[2], and Claus Ropers[1,3] — [1]Max Planck Institute for Multidisciplinary Sciences, Göttingen, Germany — [2]Experimental Physics IV, University of Augsburg, Germany — [3]4th Physical Institute - Solids and Nanostructures, University of Göttingen, Germany

Laser excitation yields control over magnetic structures on the femtosecond timescale, yet the corresponding nanoscale response remains difficult to access. Ultrafast coherent diffractive imaging has recently provided real-space insights [1], limited, however, to reversible dynamics. Here, by carrying out coherent speckle diffraction, we combine the strengths of diffraction with the coherence of a source capable of coherent imaging. Through this, we get insights to reversible and irreversible processes. Using a femtosecond high harmonic generation source, we measure pump-probe scattering from magnetic thin films in a laboratory-based setup. We discuss both the opportunities and limitations of this approach providing a basis for the interpretation of nanoscale magnetic dynamics in future ultrafast experiments.

[1] H.-T. Chang et. al, arXiv:2504.17917 (2025)

MA 27.4 Wed 10:30 HSZ/0004

**Exploitation of Spin Wave Resonances in Miniaturized Magnetic Electron Optics for Ultrafast Electron Beam Manipulation** — •Max Herzog[1], Johannes Schultz[1], and Axel Lubk[1,2] — [1]IFF, IFW Dresden, Helmholtzstraße 20, 01069 Dresden — [2]IFMP, TU Dresden, Haeckelstraße 3, 01069 Dresden

Magnetic electron optics that can be switched on sub-nanosecond time scales are useful for the setup of stroboscopic measurements in scanning and transmission electron microscopes. Scaling laws indicate that devices become permeable for alternating magnetic fields with GHz frequency by miniaturizing them to micrometer length scales, therefore decreasing their induction. On these length scales, spin waves can be excited in the magnetic pole pieces which can drastically increase the micro optics effectivity when their resonance condition is met. We fabricate such magnetic multipole optics using lithographic techniques with pole piece sizes in the tens of $\mu$m, a thickness of up to 800 nm, a pole piece distance of 25 $\mu$m as well as variable geometries in order to optimize the resonant behavior. Due to those resonances, the characterized micro optics show an especially strong deflection of the TEMs 300 keV electron beam of more than 100 $\mu$rad at 3 GHz excitation frequency. Conducted electron spin resonance measurements confirm the possibility to excite spin waves in the magnetic pole pieces in the same frequency range. This allows for the application of models of the dispersion relation to determine favorable values for parameters like thickness, exchange interaction, and saturation magnetization in order to achieve the desired resonance frequency.

MA 27.5 Wed 10:45 HSZ/0004

**Terahertz Spectroscopy of non-collinear magnetic state in ferrimagnetic iron garnet** — •Tushar Baruah[1], Andrzej Stupakiewicz[2], Paul H. M. van Loosdrecht[1], and Evgeny A. Mashkovich[1] — [1]II. Physikalisches Institut, Universität zu Köln, 50937 Köln, Germany. — [2]Faculty of Physics, University of Bialystok, Ciolkowskiego 1L, 15-245 Bialystok, Poland.

Data storage technologies and magnetic control research, in general, focuses primarily on magnets with anti-ferromagnetic exchange interactions for their ultrafast picosecond-scale dynamics. Among them, ferrimagnets are particularly appealing, as they combine high Terahertz (THz)-scale eigenfrequencies with the feasibility of ground state control. Non-collinear magnetic states in ferrimagnets exhibit complex spin dynamics, whose ultrafast behaviour remains partly understood. Using a table-top high-power broadband THz pump-optical probe setup integrated with a 10T superconducting magnet, we directly probe the field and temperature dependent spin dynamics in Bi-substituted Gadolinium iron garnet, which is a ferrimagnet with non-collinear magnetic state and a magnetic moment compensation point temperature. Our results show magnetisation dynamics in non-collinear state driven by overlap of exchange modes and THz cavity modes formed by multiple reflections inside the sample.

**15 min break**

MA 27.6 Wed 11:15 HSZ/0004

**Spin-lattice coupling control of ultrafast order melting in antiferromagnetic insulators** — Aleksandr Buzdakov[1], •Ravi Kaushik[1], Nikolai Khokhlov[2], Johan Mentink[2], Sergey Artyukhin[1], and Aleksei Kimel[2] — [1]Istituto Italiano di Tecnologia, Via Morego 30, 16163 Genova, Italy — [2]Radboud University Nijmegen, Institute for Molecules and Materials, 6525 AJ Nijmegen, The Netherlands

Ultrafast order melting in magnetic insulators is governed by two processes: intrinsic intra-spin relaxation and spin-lattice energy transfer. Antiferromagnets, which lack net magnetization, can in principle evade angular-momentum constraints and display markedly faster order-parameter dynamics than ferromagnets, but experimental rates vary widely across materials. Here we combine first-principles magnetostriction calculations, phonon and magnon spectral analysis, atomistic spin-

dynamics simulations and time-resolved second-harmonic generation to disentangle these pathways and explain material-dependent disparities. Focusing on two structurally similar antiferromagnets, $Cr_2O_3$ and $FeBO_3$, we show that the strength of spin-phonon coupling - revealed by magnetostrictive response and phonon-magnon spectral overlap - dictates the dramatic difference in order-melting rates. We also achieved accelerated dynamics in $Cr_2O_3$ and show sub-2-ps order melting in both experiment and simulation. Our results identify spin-phonon coupling as the decisive control parameter for ultrafast antiferromagnetic dynamics and provide a practical framework to design faster switching in antiferromagnetic spintronic devices.

MA 27.7 Wed 11:30 HSZ/0004

**Nonlinear optical probing of a strongly correlated phase transition in epitaxial $NdNiO_3$ thin films** — •Christian Tzschaschel[1,2], Felix Utsch[1], Qi Song[2], Spencer Doyle[3], Grace A. Pan[3], Julia A. Mundy[3], and Stefan Eisebitt[2,4] — [1]Department of Physics, University of Zurich, Switzerland — [2]Max Born Institute for Nonlinear Optics and Short Pulse Spectroscopy, Berlin, Germany — [3]Department of Physics, Harvard University, USA — [4]IOAP, TU Berlin, Germany

The family of rare-earth nickelates is a prime example of strongly correlated oxide materials displaying a wealth of physical phenomena from antiferromagnetism to superconductivity. $NdNiO_3$ specifically exhibits a metal-to-insulator phase transition upon cooling that is concomitant with the emergence of antiferromagnetic order.
Here, we use nonlinear optical second harmonic generation (SHG) in the near-infrared regime to gain insight into the symmetry and ultrafast dynamics of this correlated electronic and magnetic phase transition. In static measurements, we observe a symmetry reduction from orthorhombic in the paramagnetic phase to monoclinic in the antiferromagnetically ordered phase. Upon optical excitation, we observe a quench of the SHG signal and a restoration of the orthorhombic state within 125 fs. Our study highlights the capabilities of nonlinear optics and advances the understanding of strongly correlated quantum materials.

MA 27.8 Wed 11:45 HSZ/0004

**Ultrafast angular momentum transfer in RKKY-coupled 4f antiferromagnets** — S.-E. Lee[1], Y.W. Windsor[1,2], D. Zahn[1], A. Kraiker[3], K. Kummer[3], K. Kliemt[4], C. Krellner[4], C. Schüssler-Langeheine[5], N. Pontius[5], U. Staub[6], D.V. Vyalikh[7], A. Ernst[8], and •L. Rettig[1,9] — [1]Fritz-Haber-Institut der MPG, DE — [2]TU Berlin, DE — [3]ESRF, Grenoble, FR — [4]Goethe-Universität Frankfurt, DE — [5]Helmholtz-Zentrum Berlin, DE — [6]PSI, Villigen, CH — [7]DIPC, San Sebastian, ES — [8]Johannes Kepler University, Linz, AU — [9]RPTU Kaiserslautern-Landau, DE

Antiferromagnets allow for direct angular momentum (AM) transfer between opposing spins, thereby avoiding AM transfer to the lattice, which limits ultrafast magnetization dynamics in ferromagnets. Here, we study the ultrafast magnetization dynamics in 4f antiferromagnetic intermetallics of type $LnRh_2Si_2$ (Ln=Pr, Nd, Sm, Gd, Tb, Dy, Ho) where we modify the magnitude of the on-site RKKY coupling strength via substitution of Ln ions. By combining time-resolved soft X-ray diffraction with ab-initio calculations, we find that the rate of AM transfer between opposing moments is directly determined by this coupling [1]. Moreover, the influence of itinerant conduction electrons has been explored in the Series $GdT_2Si_2$ by varying the transition metal T (T=Co, Rh, Ir). Here, we find a more than twofold increase in ultrafast AM transfer rate between the materials, which we associate with modifications in the conduction electron susceptibility due to differences in their density of states [2].
[1] Nat. Mater. 21, 514 (2022) [2] PRR 6, 043019 (2024)

MA 27.9 Wed 12:00 HSZ/0004

**Time-resolved wide-field SHG imaging of ferroic materials** — •Andrin Caviezel, Jan Gerrit Horstmann, Thomas Lottermoser, and Manfred Fiebig — Department of Materials, ETH Zurich, Zurich, Switzerland

We investigate the ultrafast dynamics of van der Waals ferroics using time-resolved second harmonic generation (SHG) wide-field imaging. Controlling antiferromagnetic order on ultrafast timescales is of central relevance for spintronic applications, and van der Waals ferroics constitute highly promising material platforms. However, achieving such control requires an experimental technique that is simultaneously sensitive to ferroic order and combines micrometer spatial with femtosecond temporal resolution. Here, we present a setup for direct wide-field visualization of ferroic domain structures by exploiting SHG generated from high-energy pulses of an amplified laser system. The adjustable wavelength and polarization of pump and probe pulses, together with tailored pulse sequences for excitation, enable sensitive detection and selective manipulation of magnetic order. Our approach provides access to ultrafast processes in bulk ferroics with microscopic domain patterns as well as in micrometer-sized flakes of van der Waals ferroics under cryogenic conditions, opening new pathways for understanding and steering their nonequilibrium dynamics.

MA 27.10 Wed 12:15 HSZ/0004

**Photoinduced demagnetization and carrier dynamics in $SrRuO_3$ thin films probed by time resolved THz spectroscopy** — •Ankhijur Islam Sekh[1], Harun Mert Iyiisler[1], Phillip Leiprecht[2], Mathias Beck[2], Paul Leiderer[2], Gad Koren[3], Ionela Lindfors-Vrejoiu[4], Paul H.M. van Loosdrecht[4], and Jure Demsar[1] — [1]JGU Mainz — [2]University of Konstanz — [3]Technion, Haifa — [4]University of Cologne

$SrRuO_3$ is an itinerant ferromagnet (Tc $\approx$ 150 K) whose $T^2$ resistivity below 30K signals a ferromagnetic Fermi-liquid ground state. We present the temperature (T) and excitation fluence (F) dependent photoinduced conductivity dynamics of thin films grown by MBE and PLD, following excitation with fs near-infrared pulses. We show that photoinduced changes in THz conductivity are governed by the changes in the scattering rate of the intraband Drude response. The T- and F-dependent photoconductivity dynamics suggest that rapid carrier thermalization is accompanied by magnon generation, consistent with a high spin-flip scattering rate due to strong spin-orbit coupling. Accordingly, over a broad T and F-range, the photoconductivity transients track the evolution of the magnon population. At temperatures below 20K and at lowest F, we observe a delayed rise in photoconductivity, which reflects the reduced e-e thermalization rate with its characteristic Fermi-liquid $T^2$ dependence.

MA 27.11 Wed 12:30 HSZ/0004

**Element-specific magnetization dynamics of epitaxial ultrathin Co/Pt heterostructures** — •Puloma Singh[1], Corentin Aulagnet[2], Thomas Jauk[3], Sangeeta Sharma[1,4], Martin Schultze[3], Stéphane Mangin[2], Clemens von Korff Schmising[1], and Stefan Eisebitt[1,5] — [1]Max Born Institut für Nichtlineare Optik und Kurzzeitspektroskopie, Berlin, Germany — [2]Université de Lorraine, CNRS, Institut Jean Lamour, Nancy, France — [3]Institut für Experimentalphysik, Technische Universität Graz, Graz, EU, Austria — [4]Institute for Theoretical Solid-state Physics, Freie Universität Berlin, Berlin, Germany — [5]Technische Universität Berlin, Institut für Optik und Atomare Physik, Berlin, Germany

Magnetic systems comprising 3d ferromagnetic transition metals and 4d/5d heavy metals are of interest because of their potential application in future energy storage technology. The microscopic process involved after femtosecond laser excitation is complex and is still controversially discussed in the existing literature. We present a systematic and element specific study of epitaxial, ultrathin Co films (0.8 and 1.0 nm) sandwiched by Pt layers. We compare the ultrafast response for the different Co thicknesses as well as for out-of-plane and in-plane magnetic anisotropy by a combination of pump-probe spectroscopy in the optical and extreme ultraviolet spectral range. Exploiting the Pt $O_{2,3}$ and $N_7$ and Co $M_{2,3}$ resonances, we accurately disentangle the intrinsic and proximity induced magnetic moments of Co and Pt. We find consistently larger demagnetization amplitudes of the Pt magnetization compared to Co and a very pronounced thickness dependence.