MA 31: Magnetization and Demagnetization Dynamics II

Time: Wednesday 9:30–12:45 Location: H34

MA 31.1 Wed 9:30 H34

Driving spins in magnetic storage FePt by all optical switching — •Robin John[1], Cai Mueller[2], Dagmara Butkovicova[3], Eva Schmoranzerova[3], Pablo Nieves[4], Tiffany Santos[5], Jakob Walowski[1], Oksana Chubykalo-Fesenko[4], Jeffrey McCord[2], and Markus Muenzenberg[1] — [1]Institute for Physics, Ernst-Moritz-Arndt-University, Greifswald, Germany — [2]Institute for Materials Science, Kiel University, Germany — [3]Faculty of Mathematics and Physics, Charles University in Prague, Czech Republic — [4]Instituto de Ciencia de Materiales de Madrid, CSIC, Madrid, Spain — [5]San Jose Research Center, HGST, a Western Digital Company, San Jose, USA

Magnetization manipulation is an indispensable tool for both basic and applied research. Following the work of Lambert et al., we investigate the fluence dependence of all-optical switching. In our work we use a Coherent RegA system to write the patterns with a high repetition rate of 250 kHz with a temporal width of 40 fs. We are able to switch deterministically from the demagnetized ground state back and forth using the two circular polarizations of the laser. We have also tried to find the mechanism of magnetization switching upon the interaction with circular femtosecond laser pulses by comparing the contrast profiles (from Kerr microscopy images) with simulations of spatial profile of the electronic temperature of the system within a range of fluences. We had also conducted ultrafast dynamics experiment using Time-Resolved Magneto Optical Kerr set-up by using the two circular polarizations states of the laser to trace the mechanism.

MA 31.2 Wed 9:45 H34

Ultrafast All-Optical Control of Magnetization on the Nano-Scale — •D. Weder[1], C. von Korff Schmising[1], C. M. Günther[2], M. Schneider[1], B. Pfau[3], B. Vodungbo[4], E. Jal[4], J. Lüning[4], F. Capotondi[5], and S. Eisebitt[1] — [1]Max-Born-Institut, 12489 Berlin — [2]Technische Universität Berlin, 10623 Berlin — [3]Lund University, S-22100 Lund — [4]Sorbonne Universités, 75005 Paris — [5]Elettra-Sincrotrone Trieste, 34149 Basovizza, Trieste

All optical control of magnetization is emerging as a general phenomenon in solid state physics applicable to an ever growing number of magnetic systems [1], including high anisotropy ferromagnetic Co/Pt multilayers [2], technological one of the most important class of materials for ultra-high-density magnetic recording. However, to compete with the bit density of conventional storage devices, all-optical magnetic switching applications rely on sub-wavelength spatial confinement of the optical excitation as well as control of non-local phenomena like super-diffusive spin and electron transport. We engineer sub-wavelength spatial localization of the optical excitation with lithographically fabricated proximity masks and induce tailored transient magnetic gratings and arrays. Extreme ultraviolet radiation from a free electron laser (FERMI, Elettra) is used in a combination of resonant magnetic small angle X-ray scattering and Fourier transform holography imaging experiments [3] giving direct access to the ultrafast evolution of the lateral magnetization on a nanometre length scale. [1]Mangin et al., Nat. Mat., 13, 286 (2014), [2]Lambert et al., Science, 345, 1337 (2014), [3]Korff Schmising et al., PRL, 112, 217203 (2014)

MA 31.3 Wed 10:00 H34

Computer simulations on ultrafast magnetization dynamics in ferrimagnetic $DyCo_5$ — •Andreas Donges[1], Sergii Khmelevskyi[2], Andras Deak[3], Radu-Marius Abrudan[4,5], Florin Radu[4], Ilie Radu[4,6], László Szunyogh[3], and Ulrich Nowak[1] — [1]Universität Konstanz, 78457, Germany — [2]Vienna University of Technology, 1040, Austria — [3]Budapest University of Technology and Economics, 1111, Hungary — [4]Helmholtz-Zentrum Berlin für Materialien und Energie, 12489, Germany — [5]Ruhr-Universität Bochum, 44780 Germany — [6]Technical University Berlin, 10623, Germany

Ferrimagnetic rare earth transition metal alloys have gained a lot of scientific attention, since the seminal work of Radu et al. [1], which showed that the magnetization of such a compound can be switched by a pure thermal excitation. The motivation for our research on $DyCo_5$ is given by a variety of intriguing properties, especially its magnetization compensation point and its spin reorientation transition, where the easy axis changes from the in-plane to the out-of-plane direction [2]. We implemented a multi-scale model, combining ab-initio calculations with an atomistic spin model, to study how this spin reorientation affects magnetization dynamics on the ps and sub-ps time scales. Different dynamics are found, in response to an ultrafast laser excitation, for the in-plane and out-of-plane phases, as well as for the rare earth and transition metal sublattices.

[1] I. Radu, et al., Nature **472**, 205-208 (2011)
[2] T. Tsushima, M. Ohokoshi, JMMM **31-34**, 197-198 (1983)

MA 31.4 Wed 10:15 H34

The role of non-equilibrium hot electrons in ultrafast laser-induced demagnetization — •Ilya Razdolski[1], Alexandr Alekhin[1], Ulrike Martens[2], Markus Münzenberg[2], and Alexey Melnikov[1] — [1]Fritz-Haber-Institut der MPG, Berlin, Germany — [2]Ernst-Moritz-Arndt Universität, Institut für Physik, Greifswald, Germany

Ultrafast demagnetization of thin transition metal films in the absence of the hot carrier transport is studied by time-resolved magneto-optical Kerr effect (MOKE) with 20 fs resolution for various laser fluences. We demonstrate that the key role in the ultrafast magnetization dynamics is played by the non-equilibrium hot electrons, in line with previous theoretical studies. The demagnetization timescale of about 200 fs is determined by their thermalization due to the electron-electron interaction. The subsequent re-magnetization occurs on 1 ps timescale of the electron-lattice interaction. Further, we suggest an approach for the MOKE experiments which allows for the disentanglement of the magnetization dynamics and optical effects by measuring a complete set of the transient optical response data, including reflectivity, MOKE rotation, and ellipticity.

MA 31.5 Wed 10:30 H34

Light-induced magnetization dynamics in a ferromagnetic Rashba-model — •Christiane Scholl, Svenja Vollmar, and Hans Christian Schneider — TU Kaiserslautern, Department of Physics

We numerically investigate magnetization dynamics in a model system of a (mean-field) Rashba-ferromagnet due to non-resonant polarized optical fields. Electron-electron-scattering processes are taken into consideration by means of a modified relaxation-time approximation. Within the framework of this model, we show in microscopic detail how the magnetization dynamics is determined by the polarization direction of the electric field, which can result in a switching of the magnetization. We compare our results with two different models in the literature: inverse-Faraday effect [1] and spin-selective optical Stark effect [2].

[1] D. Popova, A. Bringer, S. Blügel, Phys. Rev. B 85, 094419 (2012)
[2] A. Qaiumzadeh, G. Bauer, A. Brataas, Phys. Rev. B 88,064416 (2013)

MA 31.6 Wed 10:45 H34

Probing ultrafast spin dynamics of interface induced magnetism in platinum with circular polarized light from high harmonics generation — •Felix Willems[1,2], Christopher Smeenk[2], David Weder[1,2], Nick Zhavoronkov[2], Oleg Kornilov[2], Clemens von Korff Schmising[2], Ilie Radu[2], Marc Vrakking[2], and Stefan Eisebitt[1,2] — [1]IOAP, TU Berlin, Straße des 17.Juni 135, 10623 Berlin — [2]Max-Born-Institut, Max-Born-Straße 2 A, 12489 Berlin

All-optical control and manipulation of magnetization in thin magnetic films is a promising route for spintronic and next-generation magnetic data storage devices [1, 2]. However, progress in understanding and, hence, in the successful design of such new multi-component magnetic systems for ultrafast applications has been challenged by the difficulty to experimentally access the underlying complex microscopic processes. We combine a high harmonic generation source with a $\lambda/4$ phase shifter to obtain circularly polarized XUV fs-pulses. The broad spectral bandwidth spanning 40-70 eV makes simultaneous detection of the element-specific spin dynamics via XMCD absorption spectroscopy possible. This allows us to extract information about individual contributions of the different materials and interacting spin systems. We report on first measurements of a Pt/Co/Pt sample showing simulta-

neous ultrafast demagnetization of Co and spin polarized Pt at the Co interface after optical excitation [3]. [1] A. Kirilyuk, A. et al., Rep Prog Phys 76, 026501 (2013). [2] S. Mangin, et al., Nature Materials 13, 286 (2014). [3] F. Willems et al., PRB R (in press)

15 min. break

MA 31.7 Wed 11:15 H34

***Ab initio* theory for ultrafast spin dynamics on the magnetic Ni_3 and Co_3^+ clusters, also with adsorbed MeOH and EtOH molecules** — •Georgios Lefkidis[1], Debapriya Chaudhuri[1], Wei Jin[2], and Wolfgang Hübner[1] — [1]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, Germany — [2]School of Physics and Information Technology, Shaanxi Normal University, Xi'an, China

We present a systematic study of the laser-induced, ultrafast spin dynamics on the magnetic trimers Ni_3 and Co_3^+. We investigate the clusters both bare and with MeOH and EtOH adsorbed, which induce spin-density localization. The quality of our high-level, correlational quantum-chemistry calculations is assessed by comparing with experimental IR and electronic spectra [1,2].

By employing optical Λ processes [3] we achieve coherent manipulation of the well localized spins on the trimers, giving rise to a cyclic-SHIFT-register magnetic-logic element. Analyzing the different contributions to the total angular momentum during the processes we also perform calculations including the rotational normal modes of the trimers. Finally we calculate the Kerr effect and the tolerance of the mechanisms with respect to the laser pulse parameters.

[1] W. Jin, M. Becherer, D. Bellaire, G. Lefkidis, M. Gerhards, and W. Hübner, PRB **89**, 144409 (2014)
[2] D. Chaudhuri, W. Jin, G. Lefkidis, and W. Hübner, JCP **143**, 174303 (2015)
[3] G. Lefkidis, G. P. Zhang, and W. Hübner, PRL **103**, 217401 (2009)

MA 31.8 Wed 11:30 H34

Unified *ab initio* theory of the inverse Faraday effect — •Marco Berritta[1], Ritwik Mondal[1], Karel Carva[2], and Peter M. Oppeneer[1] — [1]Uppsala University, Uppsala, Sweden — [2]Charles University, Prague, Czech Republic

Nowadays, among the rich scenario of magneto-optical phenomena, the inverse Faraday effect (IFE) appears potentially a powerful tool for the control and manipulation of the magnetization of materials. Many studies have been recently performed, however a unifed theoretical interpretation of the IFE is still missing.

On the basis of a general formulation of the second order response to a circularly polarized light pulse [1], which allows to easily include relativistic effects, we perform *ab initio* calculations of the IFE. We present results of calculations for some non-magnetic materials in comparison with results for magnetic materials. We provide a unifed discussion of the relativistic contribution calculated from this theory in comparison to Dirac theory considerations made in [2]. Moreover, although previous theoretical models of the IFE take as an approximation the absence of absorption in materials, we find that absorption can leads to counterintuitive features that can be essential for achieving switching in magnetic materials.

[1] M. Battiato, G. Barbalinardo, and P. M. Oppeneer, Phys. Rev. B **89**, 014413 (2014).
[2] R. Mondal, M. Berritta, C. Paillard, S. Singh, B. Dkhil, P. M. Oppeneer, and L. Bellaiche, Phys. Rev. B **92**, 100402 (2015).

MA 31.9 Wed 11:45 H34

Time- and Spin-resolved Photoemission Study of the Ultrafast Demagnetization Process in thin Co Films using High-order Harmonic Generation — •Moritz Plötzing[1], Markus Rollinger[2], Steffen Eich[2], Sebastian Emmerich[2], Roman Adam[1], Cong Chen[3], Henry Kapteyn[3], Margaret Murnane[3], Lucasz Plucinski[1], Benjamin Stadtmüller[2], Mirko Cinchetti[2], Martin Aeschlimann[2], Claus Schneider[1], and Stefan Mathias[4] — [1]Forschungszentrum Jülich GmbH, Peter Grünberg Insitut 6, 52425 Jülich, Germany — [2]TU Kaiserslautern and Research Center OPTIMAS, 67663 Kaiserslautern, Germany — [3]JILA, University of Colorado and NIST, Boulder, Colorado 80309-0440, USA — [4]Georg-August-Universität Göttingen, I. Physikalisches Institut, 37077 Göttingen, Germany

A powerful experimental technique that promises to provide novel information on the ultrafast demagnetization mechanisms is the direct mapping of the time evolution of the electronic band structure using spin-resolved photoelectron spectroscopy. Our approach combines a bright, femtosecond pulsed extreme ultraviolet (XUV) light source optimized for photoemission with a state-of-the-art spin detector and allows a direct, energy-resolved observation of the electron- and spin-dynamics over the full valence bands of 3d-ferromagnets after optical excitation. We present our experimental setup as well as results of the laser-induced, ultrafast demagnetization in thin Co films. Moreover, we discuss possible underlying mechanisms, e.g. a reduction of the exchange splitting or a spin-mixing, on the basis of our observations.

MA 31.10 Wed 12:00 H34

Magnetic moment of inertia tensor from first principles — •Danny Thonig, Manuel Pereiro, and Olle Eriksson — Department of Material Theory, Uppsala University, Sweden

The evolution of atomic magnetic moments is well described in terms of precession and a damping for the adiabatic limit. Approaching the adiabatic limit, however, turned out to extend the Landau-Lifshitz-Gilbert equation by an inertia contribution [1]. Magnetic inertia ι is the resistance of the magnetic moment to relax, e.g. in ultra fast switching by an external magnetic field [2], that — to the best of our knowledge — have not been characterized on an ab initio basis.

We deduce the moment of inertia tensor from the breathing band model [3] and apply it in the framework of a renormalized Green function tight-binding approach. Slater-Koster parameters were obtained by a genetic-algorithm and Monte Carlo optimization with respect to first-principles results. Our model reveals that the moment of inertia tensor ι_{ij} is non-local and temperature dependent.

Our approach is applied to the bulk Stoner magnets and could be compared to recent experimental measurements [4]. Supported by atomistic magnetization dynamics simulations we reveal the importance of magnetic inertia in ultrafast relaxation processes.

[1] M.-C. Ciornei et al., Phys. Rev. B 83, 020410 (2011).
[2] D. Böttcher et al., Phys. Rev. B 86, 020404(R) (2012)
[3] V. Kamberský, Cz. Journal of Physics B 34, 1111 (1984)
[4] Y. Li et al., Phys. Rev. B 92, 140413(R) (2015)

MA 31.11 Wed 12:15 H34

Ultrafast magnetization dynamics in a spin-orbit coupled ferromagnetic system due to microscopical electron-phonon-scattering — •Kai Leckron[1], Svenja Vollmar[1,2], and Hans Christian Schneider[1] — [1]University of Kaiserslautern — [2]Graduate School of Excellence Materials Science in Mainz

We investigate the (de)magnetization dynamics due to electron-phonon scattering in a ferromagnetic Rashba model. We calculate the electronic spin-density matrix and explicitly show that the incoherent scattering due the electrostatic electron-phonon interaction, which is sometimes called the Elliott contribution to the Elliott-Yafet mechanism, does not lead to spin dynamics. We further analyze the influence of the other contributions to spin dynamics: the spin-dependent electron-phonon interaction and the coherent dynamics of off-diagonal elements of the spin-density matrix.

MA 31.12 Wed 12:30 H34

Nonequilibrium magnetization dynamics beyond the three temperature model — •Karel Carva[1], Pavel Balaz[1], Peter Oppeneer[2], and Pablo Maldonado[2] — [1]Charles University in Prague, DCMP, Ke Karlovu 5, CZ-12116, Prague, Czech Republic — [2]Uppsala University, PO Box 516, 75120 Uppsala, Sweden

Femtosecond magnetization dynamics has been commonly described employing the three temperature model, without verifying its validity. We show when it fails to describe correctly the specific subsystems.

For Gd metal we calculate from first principles exchange interaction between atomic moments, as well as the intra-atomic exchange between Gd 4f and 5d orbitals. Spin dynamics solution of the corresponding effective orbital-resolved Heisenberg Hamiltonian has shown disparate magnetization dynamics of the 4f and 5d moments, in a good agreement with the experiment [1]. The magnetic state here cannot be assigned one temperature for times up to 100 ps.

In order to study lattice behavior we calculate the electron-phonon scattering rates for systems with high electronic temperature [2], and phonon lifetimes due to phonon-phonon scattering. From this we obtain phonon population that differs sharply from the thermal one within picoseconds after the pump. This allows to understand recent experimental observations and disproves the applicability of the model based on one lattice temperature here [3].

1. Frietsch, B. et al. , Nat Commun 6, 8262 (2015).
2. Carva, K. et al., Phys. Rev. B 87, 184425 (2013).
3. Henighan T. et al., arXiv: 1509.03348