# MA 14: Magnetization / Demagnetization Dynamics II

Time: Monday 15:00–17:30 Location: HSZ 401

MA 14.1 Mon 15:00 HSZ 401

***Ab initio* theory of laser-induced magnetization in longitudinal and transversal configurations** — •Marco Berritta, Ritwik Mondal, and Peter M. Oppeneer — Department of Physics and Astronomy, Uppsala University, Uppsala, Sweden

All-optical helicity-dependent magnetization switching has recently emerged as a promising way to control a material's magnetization using short optical laser pulses[1]. A precise understanding of the underlying mechanism has not yet emerged, but it is expected that a nonlinear opto-magnetic effect, the inverse Faraday effect (IFE), plays a role to coherently induce magnetization which assists switching. We have recently developed a quantum theory[2] to calculate *ab initio* the laser-induced magnetization in ferromagnetic materials in longitudinal configuration, i.e., when the incoming light is parallel to the magnetization direction. We have extended our theory to treat the transversal configuration where the induced magnetization is normal to the existing magnetization and will thus exert a torque on it. Moreover, we have extended the theory to compute the site- and element-resolved contributions of the IFE in multi-sublattice compounds. Our results provide a roadmap for engineering suitable compounds and manipulating them in optimal configuration to achieve ultrafast magnetization switching.

[1] C.-H. Lambert *et al.*, Science **345**, 1337 (2014); R. John *et al.*, arXiv: 1606.08723 (2016).
[2] M. Berritta, R. Mondal, K. Carva, P.M. Oppeneer, Phys. Rev. Lett. **117**, 137203 (2016).

MA 14.2 Mon 15:15 HSZ 401

**Temperature-dependent Mueller matrix measurements of the optical constants of Ni near the Curie temperature** — Farzin Abadizaman, Jaime M. Moya, and •Stefan Zollner — New Mexico State University, Las Cruces, NM, USA

Previous ellipsometry measurements (S. Zollner *et al.*, Appl. Surf. Sci. in print) of the pseudo-dielectric function of bulk and thin-film Ni at 1.96 eV as a function of temperature reported a discontinuity near the Curie temperature while heating the sample from 80 to 800 K. The discontinuity disappeared when cooling the sample. Our previous experiments were unable to distinguish between the off-diagonal response (magneto-optical Kerr effect) and the on-diagonal response (Drude conductivity and interband transitions). We therefore performed more advanced temperature dependent ellipsometry measurements to determine the Mueller matrix response of bulk and thin-film Ni. We also carried out control measurements on a Ni:V alloy (which is not ferromagnetic for a sufficiently large V content) and other materials to determine the systematic and random errors of the Mueller matrix elements using our J.A. Woollam variable-angle-of-incidence (VASE) ellipsometer.

MA 14.3 Mon 15:30 HSZ 401

**All optical Switching of magnetization on FePt nanoparticle using ultrafast lasers: A rate theory approach for the mechanism** — •Robin John[1], Marco Beritta[2], Denise Hinzke[3], Cai Mueller[4], Tiffany Santos[5], Henning Ulrichs[6], Jakob Walowski[1], Ritwik Mondal[2], Oksana Chubykalo-Fesenko[7], Pablo Nieves[7,8], Jeffrey McCrod[4], Peter M Oppeneer[2], Ulrich Nowak[3], and Markus Muenzenberg[1] — [1]Institut fur Physik, Felix-Hausdorffstrasse-6, Ernst-Moritz-Arndt Universitat Greifswald, Germany — [2]Department of Physics and Astronomy, Uppsala University, P. O. Box 516, SE-75120, Uppsala, Sweden — [3]Department of Physics, University of Konstanz, Konstanz, Germany — [4]Institute for Materials Science, Kiel University, Germany — [5]Western Digital Corporation, San Jose, California, USA — [6]I. Phys. Institut, Georg-August-University Goettingen, Germany — [7]Instituto de Ciencia de Materiales de Madrid, CSIC, Madrid, Spain — [8]ICCRAM, Universidad de Burgos, Burgos, Spain

Ultrafast Magnetization dynamics and all optical switching has been attracting the attention for a few years. Our work emphasizes the fact that the switching of magnetization on FePt granular medium is not merely thermally driven by laser induced heating, but also with a major contribution from helicity dependence in the form of inverse Faraday effect and magnetic circular dichroism. We show both experimentally and theoretically that the magnetization switching is a stochastic process. We have developed a complete multi-scale model to describe helicity dependent AOS in FePt nanoparticle recording medium.

MA 14.4 Mon 15:45 HSZ 401

**Separation of optical and magnetic response in Au films excited by circularly polarized laser pulses** — •D. Schummer[1], S. Sakshath[1], M. Barkowski[1], D. Steil[2], F. Ganss[3], M. Albrecht[3], B. Stadtmüller[1], S. Mathias[2], and M. Aeschlimann[1] — [1]TU Kaiserslautern, Erwin-Schroedinger-Strasse 46, 67663 Kaiserslautern, Germany — [2]University of Göttingen, Friedrich Hund Platz 1, 37077 Göttingen, Germany — [3]University of Augsburg, Universitätsstraße 1 Nord, 86159 Augsburg, Germany

Circularly polarized femtosecond laser pulses have been successfully used to induce intriguing phenomena such as all-optical switching (AOS) of magnetization. In particular, the symmetry breaking effect which dictates the orientation of the magnetization reversal after optical excitation is still heavily debated. One possible explanation is based on the inverse Faraday effect which can induce a transient magnetization in the material by the circularity of the laser light. This phenomena was also predicted for metals with strong spin-orbit coupling such as Au or Pt [1]. In this context, we have studied the subpicosecond magnetic response of Au to a circularly polarized femtosecond laser pulse. As optical probe, we use the time resolved complex magneto-optical Kerr effect. This approach allows us to separate different contributions of the transient magneto-optical response and to identify a transient magnetic state induced by circularly polarized femtosecond laser excitation.

Reference: [1] Berritta et al, Phys. Rev. Lett.117, 137203 (2016)

MA 14.5 Mon 16:00 HSZ 401

**Element-resolved study on the influence of a magnetic dopant on the exchange interaction in FePt on ultrashort timescales** — •Moritz Barkowski[1,2], Daniel Steil[3], Lisa Walter[1], Steffen Eich[1], Jurij Urbancic[1], Benjamin Stadtmüller[1,2], Manfred Albrecht[4], Martin Aeschlimann[1], and Stefan Mathias[3] — [1]TU Kaiserslautern, Erwin-Schroedinger Strasse 46,67663 Kaiserslautern — [2]Graduate School Materials Science in Mainz, Staudinger Weg 9, 55128 Mainz — [3]University of Göttingen, I. Physikalisches Institut, 37077 Göttingen — [4]University of Augsburg, Universitätsstraße 1 Nord, 86159 Augsburg

In this study, we investigate the optically induced ultrafast demagnetization dynamics of a FePt alloy doped with Mn atoms on the characteristic timescale of the exchange interaction of a few femtoseconds. We use high harmonic generation with photon energies in the XUV to gain elemental resolution in a femtosecond magneto-optical Kerr-effect experiment [1] in transversal geometry. Following up on earlier experiments, which showed the importance of the exchange interaction in the demagnetization process in alloys [2,3], we see clear differences in the dynamical responses of the three elements Fe, Pt, and Mn. Our results suggest, that the exchange coupling between the magnetic moments of the FePt alloy and the Mn dopant changes on ultrashort timescales.

**References**

[1] Chan L.-O., Phys.Rev.Letters 103,011005 (2009)
[2] S. Mathias, PNAS 109, 4792-4797 (2012)
[3] A.J. Schellekens, Phys.Rev. B 87, 020407(R) (2015)

**15 min. break**

MA 14.6 Mon 16:30 HSZ 401

**Inhomogeneous laser induced ultrafast magnetization dynamics at Co/Cu(001) films analyzed by interface-sensitive nonlinear magneto-optics** — •Jinghao Chen, Andrea Eschenlohr, Jens Wieczorek, Shunhao Xiao, Alexander Tarasevitch, and Uwe Bovensiepen — Fakultät für Physik, Universität Duisburg-Essen, Lotharstr. 1, 47057 Duisburg, Germany

A femtosecond laser pulse drives metallic ferromagnets into non-equilibrium and causes an ultrafast quenching of the magnetization [1]. The optically excited magnetization dynamics is analyzed via time-resolved optical magnetization-induced second harmonic generation (mSHG). In this work we report a systematic thickness dependent study of Co/Cu(001) in the Co thickness range from 0.4 to 10 nm. We identify two interface contributions and apply a simple model to sep-

arate the contributions from the vacuum/Co und Co/Cu interfaces to the total SHG yield. The transient magnetization dynamics of the Co film in the first 300 fs is dependent on the film thickness. We find that for Co film thickness $d < 3$ nm the vacuum/Co interface is more strongly demagnetized than the Co/Cu interface, for $d > 3$ nm i.e. above the spin dependent inelastic mean free path [2], the Co/Cu interface has a stronger demagnetization than the vacuum/Co interface, which implies that the majority spins at the interface escape into the conducting substrate [3].

[1] E. Beaurepaire et al., Phys. Rev. Lett. **76**, 4250 (1996) [2] V. P. Zhukov et al., Phys. Rev. B **73**, 125105 (2006) [3] J. Chen et al., http://arxiv.org/abs/1608.03842.

MA 14.7 Mon 16:45 HSZ 401

**All-optical switching and ultrafast magnetization dynamics in Pt/Co multilayers** — •Umut Parlak, Roman Adam, Moritz Plötzing, Daniel E. Bürgler, and Claus M. Schneider — Peter Grünberg Institut, PGI-6, Research Centre Jülich, 52425, Jülich, Germany

The observation of all-optical switching (AOS) in ferromagnetic thin films raised many questions concerning the nature of magnetization reversal. Recent studies suggest that the interplay between light-induced sample heating and light helicity plays a crucial role in achieving an efficient switching [1]. We investigate the effect of laser pulse duration, number of pulses, fluence and polarization state of the beam on the AOS efficiency in $[Pt/Co]_N$ multilayers, where N varies from 3 to 9. The response of the samples to the laser light was detected using a magneto-optical Kerr effect (MOKE) microscope combined with the laser system. Our results indicate that AOS probability depends on precise tuning of the above-mentioned laser parameters, and it scales with the number of pulses per illuminated area. Moreover, the dynamics of the AOS and demagnetization processes have been found to depend not only on laser fluence and external magnetic field, but also the multilayer repetition number. [1] Cornelissen, T. D., Córdoba, R., and Koopmans, B. (2016). Microscopic model for all optical switching in ferromagnets. Applied Physics Letters, 108(14), 142405.

MA 14.8 Mon 17:00 HSZ 401

**Effect of spin-orbit coupling on femtosecond spin dynamics in NiPd magnetic alloys** — •Seung-gi Gang[1], Roman Adam[1], Moritz Plötzing[1], Moritz von Witzleben[1], Christian Weier[1], Daniel E. Bürgler[1], Pablo Maldonado[3], Stefan Mathias[4], Martin Aeschlimann[2], Peter M. Oppeneer[3], and Claus M. Schneider[1] — [1]Peter Grünberg Institut PGI-6, Research Centre Jülich, 52425 Jülich, Germany — [2]Department of Physics and Research Center OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany — [3]Department of Physics and Astronomy, Uppsala University, SE-75120 Uppsala, Sweden — [4]Georg-August-Universität Göttingen, I. Physikalisches Institut, 37077 Göttingen, Germany

We studied optically-induced femtosecond spin dynamics in NixPd1-x magnetic alloys with laser pulses (1.55 eV) by recording the time evolution of the transversal magneto optical Kerr effect (T-MOKE) signal at Ni M2,3- and Pd N2,3-absorption edges using extreme ultraviolet (20 to 72 eV) pulses. In static measurements, the Pd subsystem show an magnetic asymmetry with an opposite sign compared to the ferromagnetic Ni. Dynamics of the Ni-subsystem show that increase of the Pd concentration results in a drop of the demagnetization time $\tau$M. The decreased $\tau$M cannot be explained by the simple $\tau$M ~ u/TC scaling, which is typically observed in single-species materials by considering only magnetic moment u and Curie temperature TC. However, the observed behavior can be well understood within a spin-flip scattering framework, if changes of the spin-flip probability due to the enhanced spin-orbit coupling of the heavy Pd atoms is considered.

MA 14.9 Mon 17:15 HSZ 401

**Direct observation of dipolar-exchange magnon and phonon spectra in arbitrary magnetized yttrium-iron-garnet films** — •Dmytro A. Bozhko[1,2], Philipp Pirro[1], Halyna Musiienko-Shmarova[1], Ihor I. Syvorotka[3], Burkard Hillebrands[1], and Alexander A. Serga[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Germany — [3]Department of Crystal Physics and Tehnology, SRC "Carat", Ukraine

We report on results of the experimental investigation of thermal spectra of dipolar-exchange magnons and transversal acoustic phonons in an obliquely magnetized yttrium-iron-garnet (YIG) thin film. Magnons and phonons propagating along the projection of the bias magnetic field $\vec{H}$ ($H = 2500$ Oe) on the film surface were probed by wavevector-resolved Brillouin light scattering spectroscopy. The YIG film of 5.6 $\mu$m thickness was grown in the (111) crystallographic plane on a gadolinium-gallium-garnet substrate by liquid-phase epitaxy. It has been found that in the case of oblique magnetization the spectrum of long-wavelength dipolar magnons splits into forward and backward spin-wave modes with positive and negative group velocities, respectively. With decrease of the magnon wavelength, these modes merge into a single exchange branch. This transition from the dipolar to the exchange regimes, which is still not described by existing theoretical models, is analyzed and discussed. The work is supported by the DFG within the SFB/TR 49.