MA 11: Ultrafast magnetism II

Time: Monday 15:00–17:45 Location: EB 407

MA 11.1 Mon 15:00 EB 407

Ultrafast Dynamics of Spin and Orbital Moments upon Demagnetization in GdFeCo alloys — •Martin Hennecke[1], Ilie Radu[1], Radu Abrudan[2], Torsten Kachel[2], Karsten Holldack[2], Rolf Mitzner[2], Christian Schüssler-Langeheine[2], Arata Tsukamoto[3], and Stefan Eisebitt[1] — [1]Max-Born-Institut, Berlin, Germany — [2]Helmholtz-Zentrum Berlin, Germany — [3]College of Science and Technology, Nihon University, Funabashi, Chiba, Japan

Recent studies of ferrimagnetic GdFeCo alloys have revealed an ultrafast laser-induced magnetization reversal mediated by a transient ferromagnetic-like state [1]; such switching was purely thermally-driven without the need of any other external stimulus [2]. However, the ultrafast angular momentum transfer from and into the spin system during demagnetization and switching events still remains unclear.

Here, we report on time-resolved XMCD measurements performed at the slicing facility of BESSY II that aim at revealing the angular momentum flow during femtosecond laser-induced demagnetization of ferrimagnetic GdFeCo alloy. The magneto-optical sum rules analysis of the fs-XMCD data allowed us to monitor and disentangle the dynamics of elemental spin and orbital moments at Fe and Gd sites. Within the experimental accuracy, we observe a non-equal magnitude change of spin and orbital momenta on Fe sites during the first hundreds of femtoseconds which suggests a direct transfer of angular momentum to the lattice.

[1] I. Radu et al., Nature 472, 205-208 (2011)
[2] T. Ostler et al., Nature Communications 3, 666 (2012)

MA 11.2 Mon 15:15 EB 407

Energy-resolved ultrafast charge, spin and orbital dynamics in [Co/Pd] multilayers — •Loïc Le Guyader[1,2], Daniel Higley[1], Tianmin Liu[1], Zhao Chen[1], Tyler Chase[1], Patrick Granitzka[1], Giacomo Coslovich[1], Alberto Lutman[1], Georgi Dakovski[1], William Schlotter[1], Padraic Shafer[3], Elke Arenholz[3], Olav Hellwig[4], Stefano Bonetti[5], Matteo Pancaldi[5], Mark Lalieu[6], Bert Koopmans[6], Joachim Stöhr[1], Alexander Reid[1], and Hermann Dürr[1] — [1]SLAC, Menlo Park, USA — [2]European XFEL GmbH, Schenefel, Germany — [3]ALS, LBNL, Berkley, USA — [4]TU Chemnitz and HZDR, Germany — [5]Stockholm University, Sweden — [6]TU Eindhoven, The Netherlands

The ultrafast demagnetization is a fundamental problem of modern magnetism, with its microscopic origin remaining intensely debated. Particularly, the role played by the spin-orbit interaction in the moment dissipation to the lattice and that of the exchange interaction in the collapse of long-range order call for measurements capable of resolving the charge, spin and the orbital moment dynamics energy resolved. Here we use soft X-ray Absorption Spectroscopy (XAS) with femtosecond X-ray produced by the Linac Coherent Light Source (LCLS) to probe charge and band structure dynamics around the Fermi energy E_F in a [Co/Pd] magnetic multilayer. Comparing XAS changes at both L_3 and L_2 absorption edges below and above E_F highlights the role played by the $3d_{5/2}$ states. Using X-ray Magnetic Circular Dichroism (XMCD), we further discuss the spin and orbital moment dynamics with respect to the energy resolved charge dynamics.

MA 11.3 Mon 15:30 EB 407

Ultrafast demagnetization in Co/Pt multilayers probed by mSAXS at the Co L-edge — •Matthias Riepp[1], Leonard Müller[1], André Philippi-Kobs[1], Wojciech Roseker[1], Robert Frömter[2], Emanuele Pedersoli[3], Flavio Capotondi[3], Maya Kiskinova[3], Hans Peter Oepen[2], and Gerhard Grübel[1] — [1]Deutsches Elektronen-Synchrotron DESY, Notkestraße 85, 22607 Hamburg, Germany — [2]Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [3]Elettra-Sincrotrone Trieste S.C.p.A. di interesse nazionale, Strada Statale 14 - km 163,5 in AREA Science Park, 34149 Basovizza, Trieste, Italy

Ultrafast demagnetization of thin magnetic films due to an optical pump is a phenomenon which is still discussed highly controversial. Here, to probe the response of magnetization on a nanometer length as well as on a femtosecond time scale, a resonant magnetic small-angle X-ray scattering (mSAXS) experiment was employed at the DiProI beamline at FERMI. Co/Pt multilayers with perpendicular magnetic anisotropy and a maze-domain pattern were investigated. Changes of the magnetic state due to IR-laser irradiation were detected as a function of pump probe delay time. In this experiment we have used soft X-rays tuned to the Co L_3-edge (1.59 nm) by using FERMI's FEL-2. FERMI was tuned to provide linear polarized light at a wavelength of 4.78 nm in the fundamental so that the third harmonic of this radiation was in resonance with the Co L-edge. By comparing the results with the ones obtained using the Co M-edge (20.8 nm), the role of super-diffusive spin currents on the demagnetization is discussed.

MA 11.4 Mon 15:45 EB 407

Magnetization reversal and demagnetization dynamics of Co/Pt multilayers with circularly polarized laser pulses — •Umut Parlak, Roman Adam, Seung-gi Gang, Moritz Plötzing, Daniel E. Bürgler, and Claus M. Schneider — Peter Grünberg Institut, PGI-6, Research Centre Jülich, 52425, Jülich, Germany

All-optical control of magnetization has attracted great interest since it allows magnetization reversal in the absence of applied magnetic fields. Recent studies showed that deterministic magnetization reversal requires accumulation of many pulses in ferromagnetic layers unlike the ferrimagnetic layers which can be switched with single pulses. We present a study of all-optical magnetization reversal of ferromagnetic $[Co/Pt]_N$ multilayers as a function of varying beam parameters. The multilayers were illuminated by a femtosecond laser beam with a wavelength of 800 nm and a repetition rate between 0.01 and 1 kHz. Our results indicate that all-optical magnetization reversal in $[Co/Pt]_N$ multilayers is helicity dependent and the helicity-induced reversal probability scales with the number of pulses per unit area. Single pulses have no effect on magnetism as long as the laser fluence is kept below the demagnetization threshold. For pulses above this threshold, we employed time resolved magneto-optical Kerr effect magnetometry and investigated the ultrafast demagnetization process under exposure of circularly polarized single pulses.

MA 11.5 Mon 16:00 EB 407

Modelling of spin-resolved ARPES experiments on ultra-fast demagnetisation on the basis of the one-step model of photoemission — •Voicu Popescu[1], Jan Minàr[2], Jürgen Braun[1], and Hubert Ebert[1] — [1]Department Chemie, Ludwig Maximilian University, Munich, Germany — [2]University of West Bohemia, New Technologies Research Centre, Plzeň, Czech Republic

The ultra-fast demagnetisation caused by a strong laser pulse was investigated recently by Eich *et al.* [1] by spin and angle-resolved photo emission (ARPES) experiments on the elemental ferromagnet Co [1]. To interpret the dependence of the observed effective exchange splitting on the delay time of this pump-probe experiment two different models were considered: the first one assumes a plain reduction of the exchange splitting in the spirit of the Stoner model, while the second one accounts for a magnon-mediated band-mirroring subsequent to the excitation. The experimental data seem to favour the second model. The present contribution seeks to check this interpretation of the experimental data by performing ARPES calculations for ferromagnetic Fe and Co using the one-step model of photo-emission within the framework of the spin-polarised relativistic Korringa-Kohn-Rostoker method. To allow for a rather direct comparison with experiment both scenarios were modelled as close as possible. The discussion of the resulting ARPES spectra is accompanied by an analysis of the underlying electronic structure.

[1] S. Eich *et al.* Science Advances **3**, e1602094 (2017)

MA 11.6 Mon 16:15 EB 407

Magnetization dynamics during FeRh phase transition investigated with Time-Resolved X-ray Photoemission Spectroscopy — •F. Pressacco[1,2], V. Uhlir[3], M. Gatti[4,5], J. A. Arregi[3], A. Bendounan[6], F. Sirotti[4,6], and W. Wurth[2,7] — [1]CUI, Hamburg — [2]Dep. Physik CFEL Laser Science, Uni. Hamburg — [3]CEITEC BUT, Czech Republic — [4]LPMC, École Polytechnique, France — [5]European Theoretical Spectroscopy Facility (ETSF) — [6]Synchrotron SOLEIL, France — [7]DESY Photon Science, Hamburg

Direct investigation of the electronic structure by time-resolved photoemission is a powerful tool to follow fast modifications of the physical properties of a system. Here we present a Time Resolved X-ray Pho-

toelectron Spectroscopy (TR-XPS) study of the metamagnetic phase transition induced by femtosecond laser excitation in FeRh epitaxial layers. FeRh is a particularly interesting system due to a first-order phase transition taking place at ∼400 K from an antiferromagnetic phase to a ferromagnetic phase (FM), which induces strong modifications of the electronic structure. In particular we observe the formation of a sharp spin-polarized peak close to the Fermi edge. We have measured the appearance of the peak after a 50 fs laser excitation and followed the onset of the FM phase triggered by the optical pulse. Moreover, by comparing the extracted electronic temperature to the intensity of the FM peak, we could show that the FM phase persists at the surface also when the system is expected to be antiferromagnetic. Ab initio density functional theory calculations associate the structure at the Fermi level to Fe 3d empty states.

15 minutes break

MA 11.7 Mon 16:45 EB 407

Influence of the stoichiometry in ferromagnetic alloys on the ultrafast demagnetization — •Simon Häuser[1], Moritz Hofherr[1], Jurij Urbancic[1], Sakshath Sadashivaiah[1], Sebastian Weber[1], Justin Shaw[2], Tom Silva[2], Hans Nembach[3], Daniel Steil[2], Henry Kapteyn[3], Margaret Murnane[3], Mirko Cinchetti[4], Bärbel Rethfeld[1], Benjamin Stadtmüller[1], Stefan Mathias[2], and Martin Aeschlimann[1] — [1]University of Kaiserslautern, Erwin-Schroedinger Strasse 46, 67663 Kaiserslautern, Germany — [2]Georg-August-Universität Göttingen, I. Physikalisches Institut, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany — [3]Department of Physics and JILA, University of Colorado and NIST, Boulder, CO 80309, USA — [4]Experimentelle Physik VI, Technische Universität Dortmund, 44221 Dortmund, Germany

We investigate time- and element-resolved the fs demagnetization dynamics in a ferromagnetic Fe50Ni50 alloy using a transverse magnetooptical Kerr effect experiment at the M-edge. After the optical excitation, we observe an instant response of the Fe subsystem while the onset of the Ni demagnetization is delayed by 90fs. While this result is in qualitatively agreement to previous findings for permalloy (Fe20Ni80), the time different between the onsets of demagnetization of Ni and Fe is clearly larger for Fe50Ni50 compared to Fe20Ni80. Our experimental findings will be compared to theoretical model simulations which allows us to gain insight into the role of the transient Ni-Fe exchange coupling for the ultrafast demagnetization dynamics.

MA 11.8 Mon 17:00 EB 407

All-optical magnetization switching of FePt nanoparticles by fs laser pulses — •D. Hinzke[1], T. Knippenberg[1], M. Berritta[2], R. Mondal[1,2], R. John[3], J. Walowski[3], C. Müller[4], J. McCord[4], P. Oppeneer[2], M. Münzenberg[3], and U. Nowak[1] — [1]Universität Konstanz — [2]Uppsala University — [3]Universität Greifswald — [4]Universität Kiel

Helicity-dependent all-optical switching (HD-AOS) caused solely by the effect of an ultrafast laser pulse was not only demonstrated for ferrimagnets [1] but also for layered, synthetic ferrimagnets [2] and simple ferromagnets [3]. We study HD-AOS in FePt nanograins numerically by using a complete multiscale model [4]. In our simulation it is possible to distinguish thermal and non-thermal contributions to the HD-AOS.

One of our findings is that a principle difference between magnetic circular dichroism (MCD) and inverse Faraday effect (IFE) assisted switching is the helicity-dependent heating. MCD only leads to a stochastic demagnetization process and, therefore, deterministic single-shot magnetization switching is not possible. On the contrary, an additional magnetization contribution is provided by the IFE that supports deterministic magnetization reversal. We investigate the switching probability of single FePt grains as a function of laser power and number of consecutive laser shots.

[1] K. Vahaplar *et al*, Phys. Rev. Lett. **103**, 117201 (2009) [2] S. Mangin *et al*, Nat. Materials **13**, 287 (2014) [3] C.-H. Lambert *et al*, Science **(**345), 1337 (2014) [4] R. John *et al*, Sci. Rep. **7**, 4114 (2017)

MA 11.9 Mon 17:15 EB 407

All optical switching and ultrafast magnetization dynamics in doped FePt thin films — •Martin Stiehl[1], Nataliia Safonova[2], Benjamin Stadtmüller[1,3], Manfred Albrecht[2], and Martin Aeschlimann[1] — [1]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, Erwin-Schroedinger-Strasse 46, 67663 Kaiserslautern, Germany — [2]Institute for Physics, University of Augsburg, Universitätsstraße 1 Nord, 86159 Augsburg, Germany — [3]Graduate School Materials Science in Mainz, Staudinger Weg 9, 55128 Mainz, Germany

The speed of magnetic data storage and information processing is particularly important for device performance but presently limited to a few nanoseconds. In this regard all-optical switching (AOS) is a highly promising effect which allows to switch the magnetization within a few tens of ps.

Here, we focus on the AOS phenomena and the corresponding fs magnetization dynamics in FePt thin films doped with Tb using all optical detection schemes based on the time-resolved magneto-optical Kerr effect. For a Tb concentration of 11% and linear polarization of the optical excitation, we observe a single-shot magnetization reversal within the first ps which lasts over 20ps without indications of remagnetization. We will compare results for different Tb concentrations to gain insight into the role of the dopant for the observed magnetization reversal.

MA 11.10 Mon 17:30 EB 407

All Optical Switching in Ferromagnets: A Dynamical Model Study — •Christiane Scholl — University of Kaiserslautern

We present a microscopic calculation of the spin dynamics due to excitation with off-resonant and close-to-resonance circularly polarized optical fields in a mean-field ferromagnetic model system including spin-orbit-coupling, incoherent nonlinear effects and electronic redistribution processes.

Within the framework of the model, we calculate the evolution of the magnetization and show that, for certain excitation conditions, a polarization dependent switching of the magnetization occurs. In this talk, we clarify the respective contributions of the Inverse Faraday Effect [1,2] and the Spin-selective Optical Stark effect (spin-OSE) as introduced in [3]. We also discuss the effect of electronic heating and the role of off-resonant and nearly-resonant transitions.

[1] A. Kirilyuk, A. V. Kimel and T. Rasing, Rev. Mod. Phys. 82, 2731 (2010)

[2] M. Berritta, R. Mondal, K. Carva, P. M. Oppeneer, Phys. Rev. Lett. 117, 137203 (2016)

[3] A. Qaiumzadeh, G.E.W. Bauer and A. Brataas, Phys. Rev. B 88, 064416 (2013)