MA 30: Ultrafast Magnetization III

Time: Wednesday 9:30–12:45 Location: HSZ 101

MA 30.1 Wed 9:30 HSZ 101

Conical Mirror XUV Polarimeter for complete ultrafast magnetic sampling at M- edges of Fe, Co & Ni — •Christian Strüber[1,2], Bertram Friedrich[1], Felix Willems[1], Piet Hessing[1], Kelvin Yao[1], Wolfgang Dietrich Engel[1], Daniel Schick[1], Bastian Pfau[1], Clemens von Korff Schmising[1], and Stefan Eisebitt[1,3] — [1]Max-Born-Institut, Berlin — [2]Freie Universität Berlin — [3]Technische Universität Berlin

Transient XUV absorption spectroscopy at 3p to 3d transitions (M-edges) probes changes to the magnetic dichroism initiated by a visible/NIR pump pulse. In a complementary technique the Faraday rotation of linear XUV pulses transmitted through thin magnetic layers is observed with an XUV polarization analyzer. In current setups the polarization detector needs to be rotated slowing down acquisition. We present a conical mirror XUV (COMIX) polarimeter for ultrafast magnetic investigations that access the full complex dichroic index of refraction. Due to the rotational symmetry of the device the COMIX polarimeter samples all rotation angles simultaneously. By observing the magnetically dependent changes in ellipticity $\Delta\epsilon$ and orientation $\Delta\theta$ of the polarization state after transmitting through thin magnetic samples the full complex magneto-optical functions are measured. In a first demonstration of the COMIX polarimeter's capabilities, we compare Faraday measurements at FeGd samples performed at synchrotron and HHG sources.

MA 30.2 Wed 9:45 HSZ 101

A novel high flux XUV light source for the study of ultrafast element-specific magnetization dynamics — •Christina Möller, Johannes Otto, Henrike Probst, Mariana Brede, Matthijs Jansen, Sabine Steil, Daniel Steil, and Stefan Mathias — 1. Physikalisches Institut, Göttingen, Germany

In recent years, it has been shown that the combination of a femtosecond extreme ultraviolet (XUV) light source with magneto-optical Kerr measurements (MOKE) provides a powerful tool for the study of element-specific magnetization dynamics. Using a high-harmonic based XUV MOKE setup, it was for instance found that femtosecond spin currents drive ultrafast magnetic processes [1], how magnetic sublattices interact on femtosecond timescales [2], and that spin dynamics can be induced coherently and directly on the timescale of the optical excitation itself [3,4].

Here, we present our new element-specific HHG based MOKE experiment, which makes use of a high-repetition rate fiber-based laser amplifier system, and adds high magnetic fields and cooling capabilities to the control of the magnetic sample, thereby overcoming limitations of the first harmonic generation (HHG) based MOKE setups. We show first element-specific data of a Fe/Ni alloy and manganite films highlighting the improved signal quality of the setup.

[1] Rudolf et al., Nature Comm. 3, 1037 (2012).
[2] Mathias et al., PNAS 108, 4792 (2012).
[3] Hofherr et al., Science Advances, in press (2019).
[4] Siegrist et al., Nature 571, 240 (2019).

MA 30.3 Wed 10:00 HSZ 101

Separating spin and orbital magnetic dynamics via time-resolved x-ray absorption — •N. Thielemann-Kühn[1], T. Amrhein[1], W. Bronsch[1], S. Jana[2], N. Pontius[2], C. Schüssler-Langeheine[2], R. Engel[3], P. Miedema[3], M. Beye[3], B. van Kuiken[4], A. Scherz[4], R. Carley[4], L. Le Guyader[4], N. Agarwal[4], L. Mercadier[4], G. Mercurio[4], M. Teichmann[4], A. Yaroslavtsev[4], and M. Weinelt[1] — [1]Freie Universität Berlin, Arnimallee 14, 14195 Berlin — [2]Helmholtz-Zentrum Berlin für Materialien und Energie, Alberteinsteinstr. 15, 12489 Berlin — [3]Deutsches Elektronen Synchrotron DESY, Notkestraße 85, 22607 Hamburg — [4]European XFEL GmbH, Holzkoppel 4, 22869 Schenefeld

We study ultrafast spin and orbital momenta dynamics by recording highly energy-resolved 3d-4f absorption spectra. After optical excitation we identify changes in L and S via the multiplet structure. Due to the strong localization of the 4f states the absorption spectra of rare earth metals can be described by atomic calculation of their trivalent ions. At the European XFEL we preformed pump-probe X-ray absorption spectroscopy for the RE-metals Tb and Gd, at the 3d-4f absorption edge. We find that only for Tb we excite multiplet components with the pump laser. This implies transient decoupling of L and S, for which we observe a time-dependence that follows the 5d6s hot electron distribution. We conclude that scattering with the optically excited 5d6s valence electrons leads to excitation of the 4f multiplet components.

MA 30.4 Wed 10:15 HSZ 101

Characterization of high harmonics spectra generated by the 1.3TW /1 kHz JuSPARC laser system in different gas targets — •Christian Greb[1], Roman Adam[1], Sarah Heidtfeld[1], Fangzhou Wang[1], Derang Cao[1,2], Markus Büscher[1], and Claus M. Schneider[1] — [1]Forschungszentrum Jülich, Peter Grünberg Institute, 52425 Jülich, Germany — [2]College of Physics, Qingdao University, 266071 Qingdao, China

High harmonic generation (HHG) is a well-established technique for generation of spatially and temporal coherent light pulses from the EUV to soft x-ray region (20 eV - 300 eV). The maximum achievable photon energy (HHG cut-off) can be increased by employing higher intensity and longer wavelength of the fundamental laser light [1]. For our experiments, intended to elucitdate spin and charge dynamics in complex materials, we recently commissioned a new Ti:Sapphire based laser system ($\lambda \sim 800$nm) capable of generating pulse energies up to 38 mJ at a pulse duration of 30 fs (peak power 1.3 TW) and a repetition rate of 1 kHz. In our first experiments, we demonstrate that we can control the HHG process by varying laser intensity, gas pressure and elemental composition, pulse duration, laser focus and and by tuning the gas-target position. In the next step we enhance the maximum HHG energy by tuning the wavelength of the fundamental driving light by employing optical parametric amplification. Our experimental studies provide further insight into the process of high harmonic generation at high peak intensities.

[1] T. Popmintchev et al., Science 336, 6086 (2012)

MA 30.5 Wed 10:30 HSZ 101

Probing strain as a proxy for magnetic ordering in a rare earth metal — •Alexander von Reppert[1], Maximilian Mattern[1], Jan-Etienne Pudell[1], Steffen Zeuschner[1,2], Karine Dumesnil[3], and Matias Bargheer[1,2] — [1]Institut für Physik und Astronomie, Universität Potsdam, Potsdam, Germany — [2]Helmholtz-Zentrum Berlin, Berlin, Germany — [3]Institut Jean Lamour (UMR CNRS 7198), Université Lorraine, Nancy, France

Optical excitation of spin-ordered rare earths triggers a complex response of the crystal lattice, since expansive stresses from electron and phonon excitations compete with a sizable contractive stress induced by spin disorder. Using ultrafast X-ray diffraction experiments we study the layer specific strain response of a Dysprosium film adjacent to a non-magnetic detection layer upon fs laser-excitation. Both the picosecond strain pulse and the thermal transport show signatures of a sizable energy transfer to magnetic excitations in the rare earth. The modeled rise times of the magnetic stress are in close agreement with the recently reported demagnetization timescales, which shows that the strain response can serve as a proxy for the time-dependent magnetic ordering in both antiferromagnetic and ferromagnetic rare earths. We experimentally corroborate this finding using a two-pulse excitation scheme, wherein the first laser pulse changes the magnetic state, while the second pump pulse triggers a lattice response that strongly depends on the degree of disorder of the spin system.

MA 30.6 Wed 10:45 HSZ 101

Ultrafast Control of Charge Density and Spin Density waves in Chromium — •Louis Ponet[1,2], Oleg Gorobtsov[3], Andrej Singer[3], and Sergey Artyukhin[1] — [1]Istituto Italiano di Tecnologia — [2]Scuola Normale Superiore di Pisa — [3]Cornell University, Ithaca

Experimental advances in ultrafast physics have allowed to monitor structural and electronic processes and even phase transitions on their natural timescales. Here we model recent experiments on ultrafast control of spin density wave phase in elemental Chromium with a sequence of optical pulses. The strain wave and CDW, induced by the spin density modulation via exchange striction, are monitored using x-ray diffraction. Results show order parameter oscillations and a partial melting of the SDW in response to optical pulses. Interestingly, depending on the exact delay between two sequential optical pulses,

one can increase or decrease the oscillation amplitude, allowing for optimal control. We use Landau theory and heat transfer equations to describe the dynamics of the interacting charge and spin density waves. All details of the experiment are replicated to a high degree by the model.

15 min. break.

MA 30.7 Wed 11:15 HSZ 101

Mutual influence of relaxation processes in exchange coupled magnetic alloys — •Sebastian T. Weber and Baerbel Rethfeld — Department of Physics and Research Center OPTIMAS, TU Kaiserslautern,

Irradiating ferromagnetic films with an ultrashort laser pulse leads to a quenching of the magnetization on a subpicosecond timescale. The laser-pulse drives the electrons out of equilibrium, which starts a chain reaction of different relaxation processes.
We reveal the different mechanism responsible for the magnetization dynamics and their interplay. We have set up a model [1] to trace the spin-resolved electron dynamics in dependence on different states of the magnetization process. So far, the model needed multiple phenomenological parameters. In this talk, we present our approach to reduce the amount of those parameters.

[1] B. Y. Mueller und B. Rethfeld, Phys. Rev. B 90, 144420 (2014)

MA 30.8 Wed 11:30 HSZ 101

Microscopic theory for the real-time magnetization dynamics in bilayers driven by ultrafast laser pulses — •Hanan Hamamera, Filipe Souza Mendes Guimaraes, Manuel dos Santos Dias, and Samir Lounis — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich & JARA, 52425 Jülich, Germany

Spintronic, magnetic and optical properties of different materials can be manipulated by ultrashort laser pulses [1,2]. Here we present our recently-developed method to investigate ultrafast spin dynamics: Employing a realistic tight-binding Hamiltonian parametrized from first-principles electronic structure calculations, we directly solve for the real-time evolution of the electronic state of a chosen system. We apply this method to different metallic bilayers, such as Fe/W(110) and Co/Pt(001), focusing on how the magnetization dynamics is influenced by its initial orientation and how it relates to the polarization of the driving laser pulse. We also investigate whether a pumping protocol involving a second laser pulse may lead to improved switching, inspired by the experiments of Ref. [3].
This work was supported by the Palestinian-German Science Bridge BMBF program and the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (ERC-consolidator Grant No. 681405-DYNASORE).
[1] T. Seifert *et al.*, Nature Photon. **10**, 483-488 (2016)
[2] J. Chen *et al.*, Phys. Rev. Lett. **122**, 067202 (2019)
[3] K. T. Yamada *et al.*, arXiv:1903.01941 (2019)

MA 30.9 Wed 11:45 HSZ 101

A real-space tight-binding approach to model ultrafast spin dynamics in heterostructures — •Franziska Töpler[1], Jürgen Henk[1], and Ingrid Mertig[1,2] — [1]Martin Luther University Halle-Wittenberg, Halle, Germany — [2]Max Planck Institute of Microstructure Physics, Halle, Germany

In the process of laser-induced ultrafast demagnetization hot spin-polarized electrons are excited. In a system with a magnetic/nonmagnetic interface they generate a spin current crossing this interface. Various origins of this spin current generation are discussed in literature, for example the spin-dependent Seebeck effect [1] or energy- and spin-dependent electron transmittance of the interface [2].

To obtain a better understanding of the underlying microscopic processes and the role of the interface we implemented a real-space tight-binding model. We follow the temporal evolution of occupation numbers, including perturbation by laser excitation, by solving the corresponding equations of motion. Interaction with the phonon system is incorporated as the coupling to a bath in form of Lindblad operators. In addition link currents are defined as intersite occupation flow in analogy to conventional charge and spin currents. We investigate these in model systems composed of magnetic and nonmagnetic sites and compare our results to experimental findings.

[1] Seifert *et al.*, J. Phys. D: Appl. Phys. **51** (2018) 364003
[2] Alekhin *et al.*, J. Phys.: Condens. Matter **31** (2019) 124002

MA 30.10 Wed 12:00 HSZ 101

Macroscopic effects due to atomistic colored noise in magnetization dynamics — •Unai Atxitia[1] and Oksana Chubykalo-Fesenko[2] — [1]Fachbereich Physik, Freie Universitaet Berlin, 14195 Berlin, Germany — [2]Instituto de Ciencia de Materiales de Madrid, CSIC, Cantoblanco, 28049 Madrid, Spain

The atomistic spin dynamics has recommended itself as a tool for modeling magnetization dynamics in the ultrafast timescale. This approach is based on the Langevin dynamics within the white noise approximation [1]. Here we investigate the macroscopic effects arising from the assumption that at the atomic level the noise is colored [2]. We derive analytically an equation of motion for the macrospin dynamics. We show that the colored noise assumption (i) introduces a red shift in the precession frequency which is temperature and correlation time dependent and (ii) slows down both transverse and longitudinal relaxation times. The increase of the transverse relaxation time effectively means the decrease of the so-called Gilbert damping. We compare the results with direct atomistic Langevin dynamics simulations using the colored noise approach [1]. For the transverse dynamics the effect of the colored noise becomes significant for the correlation times larger than 1 ps while for the longitudinal relaxation the effects are already visible for correlation times of the order of several femtoseconds (timescale of the precession in the exchange field). References: [1] R.F.L. Evans et al. J.Phys.:Cond.Matt 26, 103202 (2014) [2] U.Atxitia et al. Phys Rev.Lett. 102 057203 (2009).

MA 30.11 Wed 12:15 HSZ 101

Nonlocal Gilbert damping and magnetic interactions in noncollinear magnetic nanostructures from first principles — Sascha Brinker, •Manuel dos Santos Dias, and Samir Lounis — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich & JARA, 52425 Jülich, Germany

Damping is essential to the magnetization dynamics underpinning the performance of any type of magnetic device. Utilizing a first-principles description of the spin dynamics of noncollinear magnetic nanostructures based on linear-response time-dependent density functional theory [1], we demonstrate that the Gilbert damping and gyromagnetic tensors can be expressed in terms of couplings, chiral or not, of the magnetic moments. We illustrate the theory considering magnetic adatoms, dimers and trimers, both within a generalized Alexander-Anderson model and using real magnetic atoms on Au(111) together with magnetic constraints [2]. These properties are related to the filling of the magnetic orbitals of the clusters, to their hybridization with the surface electrons, and to the role played by spin-orbit coupling. We put forward a generalized Landau-Lifshitz-Gilbert equation accounting for the dependence of damping on the underlying magnetic structure and address the case of different magnetic ground states and their dynamics. — Work funded by the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (ERC-consolidator Grant No. 681405-DYNASORE).
[1] M. dos Santos Dias *et al.*, Phys. Rev. B **91**, 075405 (2015)
[2] S. Brinker *et al.*, New J. Phys. **21**, 083015 (2019)

MA 30.12 Wed 12:30 HSZ 101

Ultrafast electrical signals generation using fs-laser pulses — •Bikash Das Mohapatra[1], Wolfgang Hoppe[1], Georg Woltersdorf[1], and Georg Schmidt[1,2] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Von-Danckelmann-Platz 3, D-06120 Halle, Germany — [2]Interdisziplinäres Zentrum für Meterialwissenschaften, Martin-Luther-Universität Halle-Wittenberg, Heinrich-Damerow-Straße 4, D-06120 Halle, Germany

Electronics are getting faster and it would be relevant to get signals from electronic devices in THz regime. Several methods to generate THz electromagnetic pulses[1] have been researched where ultrafast transverse charge current is generated from spin current by the ISHE. We investigate the ultrafast electrical response from waveguide structures with thermocouples illuminated by fs laser pulses. This can give new insight into the study of thermopower in electronic structures to convert temperature differences into electrical signals in the THz regime. Waveguide structures are used with Au/Pt thermocouples which are fabricated using Sputter deposition and e-beam lithography. When fs-laser is pumped into one of two thermocouples, it leads to a difference in temperature resulting in ultrafast thermovoltage due to the Seebeck Coefficient S=-ΔV/ΔT. The voltages are measured using a 50 GHz sampling oscilloscope. An alternative route is pursued by de-

magnetizing DC biased GMR structures by fs pulses to use the breakdown in resistance for electrical pulse generation.

[1] T. Kampfrath et al. ,"Femtosecond formation dynamics of the spin Seebeck effect revealed by terahertz spectroscopy", Nat. Comm. 9, 2899 (2018).