MA 15: Magnetic measurement methods

Time: Tuesday 9:30–12:15 Location: H 1012

MA 15.1 Tue 9:30 H 1012

Magnetic SANS correlation functions of bulk ferromagnets — •Denis Mettus and Andreas Michels — Physics and Materials Science Research Unit, University of Luxembourg

Small-angle neutron scattering (SANS) is a very powerful method for structure determination which can be utilized in a wide range of scientific disciplines such as material science, physics, or chemistry. For bulk ferromagnets, the magnetic neutron scattering cross section is usually dominated by the so-called spin-misalignment scattering, which is related to the transversal magnetization Fourier coefficients. In this talk, we discuss model computations (based on the continuum theory of micromagnetics) for the magnetic correlation function of bulk ferromagnets. Specifically, we provide results for the magnetic correlation function of bulk ferromagnets as a function of applied magnetic field, particle volume fraction, and magnetic-interaction parameters (exchange constant, magnetic anisotropy field, magnetostatic field due to magnetization jumps at internal interfaces).

MA 15.2 Tue 9:45 H 1012

Ab initio calculation of Spin Polarized Low-Energy Electron Diffraction for the systems Fe(001) and Fe(001)-p(1x1)-O — •Stephan Borek[1], Jürgen Braun[1], Ján Minár[1,3], Christian Langenkämper[2], Christian Thiede[2], Anke B. Schmidt[2], Markus Donath[2], and Hubert Ebert[1] — [1]Ludwig-Maximilians-Universität München — [2]Westfälische-Wilhelms Universität Münster — [3]University of West Bohemia, Pilsen

For the implementation of a new type of spin detector at Bessy II a spin filter using the principle of exchange and spin-orbit scattering has to be designed. Among the suitable materials a promising candidate is Fe(001)-p(1x1)-O. The passivated surface has a long lifetime in vacuum and shows a high figure of merit. We will demonstrate the impact of the passivation of a Fe(001) surface on the diffraction patterns by calculating the Spin Polarized Very Low Energy Electron Diffraction (VSPLEED). We investigated two different types of scattering geometries where according to symmetry relations the first one has only exchange scattering whereas for the second both exchange and spin-orbit scattering occurs. Beside we investigated the effect of strong correlations on the basis of the dynamical mean field theory (DMFT). Complementary is the calculation of the so-called target current which also gives insight into the electronic structure. We calculated the target current for the system Fe(001)-p(1x1)-O for a large range of polar angle and kinetic energy. For both the spin polarized diffraction of electrons at the Fe(001)-p(1x1)-O surface as well as for the target current a comparison between theory and experiment will be made.

MA 15.3 Tue 10:00 H 1012

Generation of circularly polarized radiation from a compact plasma-based extreme ultraviolet light source for tabletop X-ray magnetic circular dichroism studies — •Daniel Wilson[1,2,4], Denis Rudolf[1,2,4], Christian Weier[3,4], Roman Adam[4,5], Gerrit Winkler[4,5], Robert Frömter[4,5], Serhiy Danylyuk[4,5], Klaus Bergmann[4,5], Detlev Grützmacher[2,4], Claus M. Schneider[3,4], and Larissa Juschkin[1,2,4] — [1]Experimental Physics of EUV, RWTH Aachen University — [2]Peter Grünberg Institut (PGI-9), Research Centre Jülich GmbH — [3]Peter Grünberg Institut (PGI-6), Research Centre Jülich GmbH — [4]Institut für Angewandte Physik, Universität Hamburg — [5]Chair for Technology of Optical Systems, RWTH Aachen University

We present a compact apparatus for generation of linearly and circularly polarized EUV radiation from a gas-discharge plasma light source between 50 eV and 70 eV photon energy. In this spectral range, the 3p absorption edges of Fe (54 eV), Co (60 eV), and Ni (67 eV) offer a high magnetic contrast often employed for magneto-optical and electron spectroscopy as well as for magnetic imaging. We simulated and designed an instrument for generation of linearly and circularly polarized EUV radiation and performed polarimetric measurements of the degree of linear and circular polarization. Furthermore, we demonstrate first measurements of the X-ray magnetic circular dichroism at the Co 3p absorption edge with a plasma-based EUV light source. Our approach opens the door for laboratory-based, element-selective spectroscopy of magnetic materials and microscopy of ferromagnetic domains.

MA 15.4 Tue 10:15 H 1012

***Ab initio* calculation of *d*-metal L-edge RIXS spectra using many-body quantum chemistry methods** — •Nikolay A. Bogdanov[1], Valentina Bisogni[2], Jochen Geck[3], Liviu Hozoi[1], and Jeroen van den Brink[1,4] — [1]Brookhaven National Laboratory, USA — [2]Institute for Solid State Research, IFW Dresden, Germany — [3]Institute for Theoretical Solid State Physics, IFW Dresden, Germany — [4]Department of Physics, TU Dresden, Germany

We designed a fully *ab initio* quantum chemistry scheme for the computation of both *d*-*d* excitation energies and intensities as measured by resonant inelastic x-ray scattering (RIXS) in *d*-electron systems. RIXS has recently emerged as a powerful tool to reliably probe the charge, spin, and orbital degrees of freedom of correlated electrons in solids [1,2]. As a first application we picked up Li_2CuO_2, a quasi-1D Cu $3d^9$ oxide with a simple valence configuration in the intermediate state. We use embedded-cluster MCSCF and MRCI techniques [3], including scalar relativistic effects, spin-orbit coupling, and the valence orbital relaxation in the presence of the core hole. The transition matrix elements of the dipole operator are obtained by non-orthogonal configuration interaction. A careful analysis of the RIXS spectra is important for understanding the interplay between local distortions and longer-range lattice anisotropy and its effect on the *d*-level electronic structure [3,4] and magnetic interactions [4]. [1] L. Ament *et al.* Rev. Mod. Phys. **83**, 705 (2011); [2] J. Schlappa *et al.* Nature **485**, 82 (2012); [3] H.-Y. Huang *et al.* Phys. Rev. B **84**, 235125 (2011); [4] N. A. Bogdanov *et al.* Phys. Rev. Lett. **110**, 127206 (2013).

MA 15.5 Tue 10:30 H 1012

A hybrid sensor based on nitrogen-vacancy center in diamond and piezomagnetic film for nanoscale probing of stress — •Phani Peddibhotla[1], Benjamin Riedmueller[2], Liam McGuinness[1], Farzaneh Vaghefikia[1], Alexander Gerstmayr[1], Jianming Cai[3], Martin Plenio[3], Berndt Koslowski[4], Ulrich Herr[2], and Fedor Jelezko[1] — [1]Institute for Quantum Optics, University of Ulm, 89081 Ulm, Germany — [2]Institute for Micro- and Nanomaterials, University of Ulm, 89081 Ulm, Germany — [3]Institute for Theoretical Physics, University of Ulm, 89081 Ulm, Germany — [4]Institute for Solid State Physics, University of Ulm, 89081 Ulm, Germany

We report on the development of a hybrid diamond-piezomagnetic system for the measurement of stress (force) [1]. Our experimental setup comprises of an atomic force microscope (AFM) integrated into a confocal microscope. A thin magnetostrictive film is deposited onto the diamond sample containing nitrogen-vacancy (NV) centers. An AFM cantilever tip is used to apply a local force or stress on the thin film, thereby resulting in a change in the stray magnetic field outside the magnetostrictive material. Optical readout of the spin quantum state of the NV center encodes information about the change in the magnetic field thereby resulting in a transduction of force.

[1] J. Cai et al., Nat. Commun. 5:4065 (2014).

MA 15.6 Tue 10:45 H 1012

Temperature dependence of the ferromagnetic resonance in magnetic films — •Kristof M. Lebecki — Nanotechnology Centre, VSB-TU Ostrava, Czech Republic

Ferromagnetic resonance (FMR) is an important experimental tool. The well-known FMR line width equation can be extended *e.g.* by including the Bloch-Bloembergen relaxation. Thus, two-magnon scattering is included. We present here a different approach. Recently proposed Landau-Lifshitz-Bloch approach (LLB) is namely an extension of the Landau-Lifshitz-Gilbert equation (LLG). Contrary to LLG, LLB is valid in the whole temperature range, up to the Curie temperature. We have theoretically analyzed the LLB equation and derived the resonance conditions for the case of a thin film and an in-plane DC field. As a result we got a complex equation for the resonance field that must be solved numerically. However, we propose a handy approximation working well in the whole temperature range. Basing on the resonance field, the FMR line width can be calculated analytically. We show the results of our calculations considering a permalloy film. The resonance field grows remarkably with the temperature. The line width dependence on the microwave frequency is no more linear, a fact that has been observed experimentally in the past. Also, the line width grows with the temperature.

MA 15.7 Tue 11:00 H 1012

All electrical coherent control of the magnetization in a thin Yttrium Iron Garnet film — •Olga Wid[1], Martin Wahler[1], Nico Homonnay[1], Tim Richter[1], and Georg Schmidt[1,2] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, 06099 Halle (Saale), Germany — [2]Interdisziplinäres Zentrum für Materialwissenschaften, Martin-Luther-Universität Halle-Wittenberg, 06099 Halle (Saale) , Germany

We have investigated the magnetic properties of Yttrium Iron Garnet (YIG) thin films using Time Domain Ferromagnetic Resonance (FMR). The sample is placed on a coplanar waveguide and a voltage step is used to induce a precession of the magnetization in the sample which is then detected by the induced voltage. A second voltage step which can be applied with variable time delay allows us to coherently control the precession. With suitable delay times the amplitude of the precession can either be maximized or the precession can be completely stopped. This method allows for a very precise investigation of the precession dynamics. The high quality of the YIG films (best FMR linewidth 2 Oe @ 9.6 GHz) permits us to observe the precession over a time of more than 50 ns (for comparison: Permalloy shows a precession over 5 ns). Our experiments are supported by micromagnetic dynamic simulations using OOMMF and MuMax2 which nicely confirm our experimental results.

MA 15.8 Tue 11:15 H 1012

A Ferromagnetic Resonance scanner with 20 μm resolution — •Carola Lottis, Ralf Meckenstock, Christian Schöppner, and Michael Farle — Faculty of Physics and CENIDE, University Duisburg-Essen, Germany

The enlarged surface-to-volume ratio of nano structures, inhomogeneous demagnetizing fields due to confined geometries, roughness and morphology have considerable influence on magnetic properties and lead to complex magnetic excitations. Here, we present a micro resonator technique used in combination with a submicrometer positioning system to determine magnetic properties of single nano magnets, that do not have to be prepared specially for- or in the micro resonator, but stay in their natural environment.

To reach a sensitivity of 10^6 spins for FMR detection, a micro resonator is evaporated on a silicon-nitrite membrane (250 μm x 250 μm and 200 nm thick). The FMR sensitive area is 20 μm ∅ and at a distance of <10 μm above the sample. An optical microscope is mounted above the FMR scanner to facilitate the positioning of the sample in the FMR sensitive area. The positioning system has a working range of 6.1 mm in all three directions with a resolution of 1 nm. First results on an iron silicon ferromagnetic stripe with a "zig-zag" form (65 μm long, 1.5 μm wide and 18 nm thick) will be shown. Small deviations of the FMR due to the zig-zag structure's dipole field can be resolved.

The authors thank the DFG for financial support within the program LI1567/3-1.

MA 15.9 Tue 11:30 H 1012

Sensitivity enhancement in microscale cantilever magnetometry — •Julia Körner[1], Christopher F. Reiche[1], Bernd Büchner[1,2], and Thomas Mühl[1] — [1]Leibniz-Institut für Festkörper- und Werkstoffforschung IFW Dresden — [2]Institut für Festkörperphysik, Technische Universität Dresden

The study of magnetic properties of increasingly smaller single particles poses great challenges to researchers. As the probe's size shrinks according to the particle size, an increasing effort has to be taken to gain reliable data from measurements. In case of cantilever magnetometry very low stiffness cantilevers are usually employed. [1]

We have developed a sensor concept which combines a nanowire, e.g. a multi walled carbon nanotube (MWCNT) oscillator, with state-of-the-art cantilever deflection measurement techniques. Due to the small size and low stiffness of the nanowire, it offers high sensitivity for measuring small magnetic particles positioned at its tip when the system is mechanically excited to oscillate. The oscillation states are detected by using conventional laser-deflection.

[1] B. C. Stipe, H. J. Mamin, T. D. Stowe, T. W. Kenny, D. Rugar, Phys. Rev. Lett. 86 (13), 2001

MA 15.10 Tue 11:45 H 1012

Cross-correlation spin noise spectroscopy of heterogeneous interacting spin systems — •Dibyendu Roy[1,2,3], Luyi Yang[4], Scott A. Crooker[4], and Nikolai A. Sinitsyn[2] — [1]Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Str. 38, 01187 Dresden, Germany — [2]Theoretical Division, Los Alamos National Laboratory, Los Alamos, NM 87545, USA — [3]Center for Nonlinear Studies, Los Alamos National Laboratory, Los Alamos, NM 87545, USA — [4]National High Magnetic Field Laboratory, Los Alamos National Laboratory, Los Alamos, NM 87545, USA

We develop and apply a minimally invasive approach for characterization of inter-species spin interactions by detecting spin fluctuations alone. We consider a heterogeneous two-component spin ensemble in thermal equilibrium that interacts via binary exchange coupling, and we determine cross-correlations between the intrinsic spin fluctuations exhibited by the two species. Our theoretical predictions are experimentally confirmed using two-color optical spin noise spectroscopy on a mixture of interacting Rb and Cs alkali vapors [arXiv:1408.5399]. The results allow us to explore the rates of spin exchange and total spin relaxation under conditions of strict thermodynamic equilibrium.

MA 15.11 Tue 12:00 H 1012

Spin-resolved hard x-ray photoemission from buried magnetic layers. — •X. Kozina[1], E. Ikenaga[2], C.E. Viol Barbosa[3], G.H. Fecher[3], C. Felser[3], K. Kobayashi[4], D. Kutnyakhov[1], K. Medjanik[1], and G. Schönhense[1] — [1]Institut für Physik, Johannes Gutenberg-Universität, Mainz, Germany — [2]Japan Synchrotron Radiation Research Institute, SPring-8, Hyogo, Japan — [3]Max Planck Institut for Chemical Physics of Solids, Dresden, Germany — [4]Japan Atomic Energy Agency, SPring-8, Hyogo, Japan

We discuss the present status and future potential of spin-resolved hard X-ray photoemission (HAXPES). Recently, deeply buried CoFe layers have been studied at the BL09XU end station of SPring-8, Japan, using a large hemispherical analyzer (Scienta R-4000) and a single-channel SPLEED-type polarimeter [1]. The excitation energy of 6 keV assures significantly enhanced probing depth to access buried layers. A spin polarization of about 20% is retained during transmission of the photoelectrons emitted from the Fe 2p3/2 state through a 3-nm-thick oxide capping layer. Single-channel spin detection suffers from the low figure of merit, thus for future measurements in the valence region a multichannel spin detector is indispensable.

Therefore the Mainz group in cooperation with Univ. Wuerzburg (R. Claessen et al.) are developing a novel multichannel spin detector that will be implemented in the HAXPES endstation at PETRA III, Germany (equipped with a Specs Phoibos-225 analyzer). The status of the development is reported.

[1] G. Stryganyuk et al. Jpn. J. Appl. Phys. 51 (2012) 016602