MA 16: Magnetic characterization techniques

Time: Tuesday 9:30–12:15 Location: H 0112

MA 16.1 Tue 9:30 H 0112

Nanoscale magneto-optical imaging using a compact extreme-UV source based on high-harmonic generation — •Sergey Zayko[1], Ofer Kfir[1,2], Michael Heigl[3], Christina Nolte[1], Murat Sivis[1], Marcel Möller[1], Birgit Hebler[3], Sri Sai Phani Kanth Arekapudi[3], Daniel Steil[1], Sascha Schäfer[1], Oren Cohen[2], Stefan Mathias[1], Manfred Albrecht[3], and Claus Ropers[1] — [1]University of Göttingen, Germany — [2]Physics Department, Technion, Israel Institute of Technology, Israel — [3]Institute of Physics, University of Augsburg, Germany

Magnetic topological excitations such as domain walls or skyrmions are of great importance for fundamental research and applied science [1,2]. High-harmonic generation offers an exciting possibility to study such physical phenomena at their characteristic nanometre spatial and femtosecond temporal scales using a compact experimental setup [3]. Here, we demonstrate the first results on magnetic imaging with high-harmonic radiation. By using circularly polarized harmonics [4], we access XMCD contrast from nanoscale magnetic domains and obtain quantitative, diffraction-limited absorption and phase images with sub-50 nm spatial resolution. These results open the way towards comprehensive magneto-optical studies with unprecedented spatio-temporal resolution on a table top.

[1] Allwood et al., Science 309, Issue 5741, pp. 1688-1692. (2005)
[2] Mühlbauer et al., Science 323, Issue 5916, pp. 915-919 (2011)
[3] Kfir, Zayko et al., in press.
[4] Fleischer et al.,Nat. Photonics 8, 543-549 (2014)

MA 16.2 Tue 9:45 H 0112

Electron microscopy: magnetic properties in another kind of light — •Daniela Ramermann, Inga Ennen, and Andreas Hütten — Faculty of Physics, University of Bielefeld, Universitätsstraße 25, 33615 Bielefeld, Germany

Modern methods in Transmission Electron Microscopy give deeper insights not only into the structural characterisation but also into magnetic properties of materials. In this talk we want to show the possibilites of Lorentz microscopy, differential phase contrast imaging and EMCD measurements for determining the magnetic properties of cobalt and magnetite nanoparticles and Heusler thin film systems.

MA 16.3 Tue 10:00 H 0112

EMCD measurements with electron vortex beams on ferrimagnetic — •Darius Pohl[1], Sebastian Schneider[1], Jan Rusz[2], Jakob Spiegelberg[2], Peter Tiemeijer[3], Sorin Lazar[3], Xiaoyang Zhong[4], Victor Brabers[5], Kornelius Nielsch[1], and Bernd Rellinghaus[1] — [1]IFW Dresden — [2]U Uppsala — [3]Thermo Fisher Scientific — [4]NCEM Beijing — [5]U Eindhoven

Electron vortex beams (EVBs) carry a discrete orbital angular momentum (OAM), L, and are predicted to reveal electron energy loss magnetic chiral dichroism (EMCD) upon interacting with magnetic samples down to the atomic scale. Our optical setup allows for scanning TEM investigations (STEM) with vortex beams, whose OAM is selected by means of an additional discriminator aperture [1]. As a proof of principle experiment, two samples have been chosen, Sr_2FeMoO_6 and $BaFe_{11}TiO_{19}$. For both samples, an EMCD signal is found by principle component and vector component analysis (PCA and VCA) in the acquired spectra. However, local analysis still suffer from a low signal-to-noise ratio. The status quo of the experiments and simulations of the interaction of the EVB with the ferrimagnetic samples will be presented.

[1] D. Pohl, S. Schneider, P. Zeiger, J. Rusz, P. Tiemeijer, S. Lazar, K. Nielsch, B. Rellinghaus, Sci. Rep. 7 (2017) 934.

MA 16.4 Tue 10:15 H 0112

Detection of ferromagnetic resonance with a proximate organic light emitting diode — •Tobias Grünbaum, Sebastian Bange, Christian H. Back, and John M. Lupton — Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Universitätsstraße 31, 93053 Regensburg, Germany

Several investigations in the newly emerging field of organic spintronics are based on structures of an organic semiconductor in combination with an adjacent ferromagnet. Prominent examples are spin pumping into an organic semiconductor [1] and organic spin valves [2].

We investigated the influence of a magnetic YIG film undergoing ferromagnetic resonance on an organic light emitting diode. Due to a bolometric effect and subsequent heat conduction from the YIG to the organic light emitting diode, the ferromagnetic resonance spectrum of the YIG is reproduced in the voltage drop across the diode. This includes the lineshape, the characteristic frequency dependence of the resonance field, as well as signatures of nonlinear phenomena. Our results show that a bolometric heating effect is the dominant influence of the ferromagnetic resonance on an organic light emitting diode at high excitation power.

[1]: Sun D., et al. Nat. Mater. 15, 863-869 (2016)
[2]: Ehrenfreund E. & Vardeny Z. V., Phys. Chem. Chem. Phys. 15, 7967-7975 (2013)

MA 16.5 Tue 10:30 H 0112

Gold and Graphene Hall Sensors for Scanning Magnetic Field Measurements on Magnetic Microstructures — •Manuela Gerken, André Müller, Davood Momeni Pakdehi, Thomas Weimann, Sibylle Sievers, and Hans Werner Schumacher — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig

Within the overall miniaturization, also magnetic devices are being scaled down into the micro- and nanometer range. This leads to an increasing demand for high resolution quantitative metrology for the resulting spatially varying device stray fields. One promising approach is scanning magnetic field microscopy with Hall sensors. Here, we will present our results on the development of gold and graphene Hall sensors with active areas down to 50 nm x 50 nm. There are some hints that these materials are superior to semiconductor sensors for small active areas and at room temperature (RT). For example, gold sensors are supposed to have a better signal to noise ratio due to the higher applicable current. In contrast, graphene can reveal low carrier density and thus a high RT Hall coefficient. We will address fabrication and design issues of both types of nano-Hall sensors. Furthermore we will discuss the results of the sensor characterization including sensor sensitivity, stability and noise figures as well as an estimation of the uncertainty budget for quantitative magnetic field measurements.

15 minutes break

MA 16.6 Tue 11:00 H 0112

Uniaxial neutron polarization analysis of bulk ferromagnets — •Dirk Honecker — Institut Laue-Langevin, Grenoble, France

Polarized neutron scattering is a powerful technique for investigating the structure and dynamics of condensed matter, in particular magnetic materials and superconductors.

In this contribution, a description of the polarization of scattered neutron of bulk magnetic material will be presented. With respect to small-angle neutron scattering, the model takes into account the relative strength between nuclear and magnetic scattering amplitude as well as interparticle correlations arising from the local magnetic environment in densely packed particle systems.

MA 16.7 Tue 11:15 H 0112

Neutron Depolarization Microscope for Imaging of Ferromagnetic Phase Transitions: Ni_3Al and $HgCr_2Se_4$ under pressure — •Pau Jorba[1], Michael Schulz[2], Daniel Hussey[3], Boris Khaykovich[4], Muhuammad Abir[4], Marc Seifert[1], Vladimir Tsurkan[5], Allois Loidl[5], and Christian Pfleiderer[1] — [1]Physik-Department, Technische Universität München, Germany — [2]Heinz-Maier-Leibnitz Zentrum (MLZ), TUM, Germany — [3]NIST, Gaithersburg, MD, USA — [4]Nuclear Reactor Laboratory, Massachusetts Institute of Technology, USA — [5]Center for Electronic Correlations and Magnetism, University of Augsburg, Germany

We performed neutron depolarization imaging of a large Ni_3Al crystal, and a small $HgCr_2Se_4$ spinel under pressure, to probe bulk magnetic inhomogeneities in the ferromagnetic transition temperature with the spatial resolution about 100 μm. To obtain these spatially resolved depolarization images we employed a neutron microscope equipped with Wolter optic, a neutron image-forming lens, as well as a focusing neutron guide. The depolarization images on Ni_3Al clearly show that the sample doesn't homogeneously go through the ferromagnetic transition. The results on the chromium spinel highlight the advantage of this technique especially for small samples, or sample environments with restricted sample space, as we are able to significantly improve the resolution while decreasing the acquisition time. The novel optical design that enabled acquisition of the high spatial resolution neutron depolarization images is described in detail and image results are compared to a conventional radiography setup without a lens.

MA 16.8 Tue 11:30 H 0112

Magneto-Structural Study of Dihalo-Bridged Copper Dimers: Intra- and Interdimer Interactions as Revealed by Single-Crystal ESR Spectroscopy — •Dijana Žilić[1], Debdeep Maity[1], Mario Cetina[2], Krešimir Molčanov[1], Zoran Džolić[1], and Mirta Herak[3] — [1]R. Bošković Institute, Zagreb, Croatia — [2]Faculty of Textile Technology, Zagreb, Croatia — [3]Institute of Physics, Zagreb, Croatia

Four complexes with two different oxalamide ligands were synthesized: [CuLA(μ-X)]2 and [CuLV(μ-X)]2, X=Cl or Br. The geometry at each Cu(II) ion is ideal or near ideal square pyramidal, whereas two pyramids share one base-to-apex edge with parallel basal planes. The complexes are linked by hydrogen bonds into infinite chains and are further linked into a 3D network. Magn. susc. measurements show that coppers in the dimers are weakly AFM coupled.

Despite very similar structures of these complexes compared with the complexes previously reported and characterized by similar X-ray, magnetization and powder ESR results, single crystal ESR spectra reveal significant differences. Here presented complexes show unusual anisotropic splitting and merging of ESR lines when their crystals rotate in magn. field. The observation of this partially resolved intradimer dipolar splitting enabled estimation of weak interdimer exchange interaction parameter.[1,2]

[1] Žilić D. et al., Dalton Trans. 2014, 43, 11877.
[2] Žilić D. et al., ChemPhysChem 2017, 18, 2397.

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MA 16.9 Tue 11:45 H 0112

Mechanical detection of nanomagnetic phenomena employing coupled nano- and micro-cantilever systems — •Thomas Mühl, Christopher Friedrich Reiche, Julia Körner, and Bernd Büchner — IFW Dresden, Dresden, Germany

Magnetic force microscopy (MFM) and cantilever magnetometry are nanomagnetic measuring techniques that rely on cantilever-based force transducers. Their sensitivity can be improved by reducing the cantilever's dimensions which may lead to difficulties in their read-out. Our recently developed sensor concept [1,2] addresses this issue by a co-resonant coupling of a tiny nanocantilever to a rather conventional microcantilever. The co-resonance is achieved through matching of the eigenfrequencies of the two cantilevers. Thus, if the highly sensitive nanocantilever is subject to an external interaction, the oscillatory state of the coupled system as a whole is changed. This change can be detected at the microcantilever with standard equipment. We present analytical approximations of the resonant behavior, amplitude relations, and effective quantities with respect to damping, mass, and spring constant of the coupled system. Furthermore, we show how the experimental implementation of our approach in MFM enables a huge sensitivity enhancement in case of an in-plane sensitivity imaging mode with the nanocantilever arranged in a pendulum-type geometry.

[1] C. F. Reiche, J. Körner, B. Büchner, and T. Mühl, Nanotechnology 26, 335501 (2015).
[2] J. Körner, C. F. Reiche, R. Ghunaim, R. Fuge, S. Hampel, B. Büchner, and T. Mühl, Sci. Rep. 7, 8881 (2017).

MA 16.10 Tue 12:00 H 0112

Magnetic resonance force microscopy for condensed matter — •Gesa Welker, Martin de Wit, Jelmer Wagenaar, Marc de Voogd, Arthur den Haan, Tom van der Reep, Lucia Bossoni, and Tjerk Oosterkamp — Leiden Institute of Physics, Leiden, The Netherlands

Magnetic resonance force microscopy (MRFM) allows investigation of various kinds of spin-related material properties in small sample volumes. We reduced the operating temperature of this technique by 2 orders of magnitude to 10 mK. As a demonstration, we measured the nuclear spin-lattice relaxation time on copper at temperatures down to 42 mK, verified by the Korringa relation [1] with an interaction volume of $(30nm)^3$. Furthermore, we have conducted a study of the dissipation and frequency shifts of a cantilever interacting with all surrounding spins, allowing us to measure the density and relaxation time of dangling bonds on a SiO_2 surface [2] and impurity spins in bulk diamond. This enables us to understand some problems involving 2LS, one of the bottlenecks in the development of optomechanical-like hybrid quantum devices. Finally, we have developed an innovative method for using the higher modes of the cantilever as radio-frequency (rf) source, removing the need for an on-chip rf source [3]. This is an important step towards an MRFM which can be widely used in condensed matter physics, e.g. to investigate inhomogeneous electron systems.

[1] Wagenaar et al. Phys. Rev. Appl. 6, 014007 (2016). [2] de Voogd et al. Sci. Rep. 7, 42239 (2017). [3] Wagenaar et al. Phys. Rev. Appl. 7, 024019 (2017).