MA 6: Magnetic Instrumentation and Characterization

Time: Monday 9:30–11:45 Location: HSZ 403

MA 6.1 Mon 9:30 HSZ 403

What is the longitudinal magneto-optical Kerr effect? — Jon Ander Arregi, Patricia Riego, and •Andreas Berger — CIC nanoGUNE, San Sebastian (Spain)

We explore the commonly used classification scheme for the magneto-optical Kerr effect (MOKE), which essentially utilizes a dual definition based simultaneously on: (i) the components of the magnetization vector with respect to the plane of incidence and (ii) specific elements of the reflection matrix, which describe light reflection from a ferromagnetic surface. We find that an unambiguous correspondence in between both definitions is valid only in special cases, while in more general cases, it leads to inconsistencies due to an intermixing of the presumed separate MOKE effects of longitudinal, transverse and polar magnetization components. As an example, we investigate in this work both theoretically and experimentally a material that possesses anisotropic magneto-optical properties in accordance with its crystal symmetry. The derived equations predict a so-far unknown polarization effect for the transverse magnetization component and at the same time, explain inconsistencies in between Kerr rotation and ellipticity measurements in the longitudinal geometry. Experimental results on epitaxial hcp Co films confirm our findings and demonstrate that magneto-optical anisotropy causes significant deviations from the commonly employed MOKE data interpretation scheme.

MA 6.2 Mon 9:45 HSZ 403

Investigation of the domain sizes in Co/Pd multilayers via soft x-ray resonant magnetic scattering — Kai Bagschik[1,2], •Ralph Buss[1,2], Robert Frömter[1,2], Judith Bach[1], Björn Beyersdorff[1], Leonard Müller[3], Stefan Schleitzer[3], Magnus Hårdensson Berntsen[3,4], Christian Weier[5], Roman Adam[5], Jens Viefhaus[3], Claus Michael Schneider[5], Gerhard Grübel[2,3], and Hans Peter Oepen[1,2] — [1]Institut für Nanostruktur- und Festkörperphysik, Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Hamburg, Germany — [3]DESY, Hamburg, Germany — [4]KTH Royal Institute of Technology, Kista, Sweden — [5]Peter Grünberg Institut, Jülich, Germany

We present results of a magnetic SAXS experiment on a wedge-shaped $(Co_{0-10Å}/Pd_{10Å})_8$ multilayer film in the multidomain state. The diffraction patterns show isotropic rings which result from strongly disordered magnetic domain patterns. To describe the scattering pattern, a model has been developed based on a one-dimensional domain pattern with gamma-distributed domain sizes [1].

Structure factors generated from the model are fitted to the experimental data with very good agreement. The analysis reveals average domain sizes (depending on Co-thickness) that significantly deviate from the value commonly extracted from the peak position of the structure factor. The structure factor is described by the same shape parameter of the gamma distribution independent on the mean domain size.

[1] K. Bagschik, et al., Phys. Rev. B **94**, 134413 (2016).

MA 6.3 Mon 10:00 HSZ 403

Nuclear Magnetic Resonance Force Microscopy at milliKelvin Temperatures — •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 combines Atomic Force Microscopy with Nuclear Magnetic Resonance and aims to obtain a 3D-image with nm-resolution. In the last decade, progress has been made in improving the resolution of this technique, enabling this technique to image a Tobacco Virus with 5 nm resolution [1]. In conventional setups, a laser is used as detection method, giving significant heating of the resonator at temperatures below 1 Kelvin. Our MRFM makes use of superconducting NbTiN detector chips in combination with a Superconducting Quantum Interference Device (SQUID), to generate the necessary RF magnetic fields and to detect the motion of the force sensor. These modifications have allowed us to operate our MRFM at temperatures as low as 20 mK [2], improving the sensitivity towards single spin and opening possibilities to use this technique for interesting condensed matter systems, such as topological insulators, iron-doped palladium, and nitrogen-vacancy centers in diamond.

[1] C. L. Degen et al., Proc. Natl. Acad. Sci. U. S. A. 106, 1313 (2009).
[2] J. J. T. Wagenaar et al., Phys. Rev. Applied 6, 014007 (2016).

MA 6.4 Mon 10:15 HSZ 403

User-selected electron vortex beams for atomic scale magnetic measurements — •Darius Pohl[1], Sebastian Schneider[1,2], Paul Zeiger[3], Jakob Spiegelberg[3], Jan Rusz[3], Peter Tiemeijer[4], Sorin Lazar[4], Xiaoyan Zhong[5], Kornelius Nielsch[1,2], and Bernd Rellinghaus[1] — [1]IFW Dresden, P.O. Box 270116, D-01171 Dresden, Germany — [2]TU Dresden, D-01062 Dresden, Germany — [3]Uppsala University, Department of Physics and Astronomy, SE-752 37 Uppsala, Sweden — [4]FEI Company, PO Box 80066, 5600 KA Eindhoven, The Netherlands — [5]NCEM Beijing, Tsinghua University, Beijing 100084, P.R. China

Electron vortex beams (EVBs) carry a discrete orbital angular momentum (OAM), L, and are predicted to reveal magnetic dichroism in electron energy loss spectroscopy upon interacting with magnetic samples. Focusing the probe down to sub-nanometer diameters is, however, a necessary condition to be fulfilled. The generation of atom-size EVBs in the double aberration-corrected FEI Titan^{3}3 80-300 transmission electron microscope (TEM) is achieved by the implementation of a dislocation-type apertures into the condenser lens system. A new optical setup allows for scanning TEM investigations (STEM) with vortex beams, whose OAM is selected by means of an additional discriminator aperture. Performance of this new optical setup is shown by atomic resolution imaging as well as spectroscopy on $SrTiO_3$. First measurements on magnetic samples will be presented.

MA 6.5 Mon 10:30 HSZ 403

Spectroscopy of the quadratic magnetooptic tensor of materials with the cubic structure — •Robin Silber[1,2], Ondřej Stejskal[1], Jan Dušek[3], Lukáš Beran[3], Jaromír Pištora[1], Günter Reiss[2], Martin Veis[3], Timo Kuschel[2,4], and Jaroslav Hamrle[3] — [1]VSB - Technical University of Ostrava, Czech Republic — [2]CSMD, Physics Department, Bielefeld University, Germany — [3]Charles University, Prague, Czech Republic — [4]University of Groningen, The Netherlands

The magnetooptic Kerr effect (MOKE) is a well known and very useful tool in the field of ferromagnetic material characterization [1]. Most of the MOKE techniques rely solely on effects linear in magnetization (**M**). Nevertheless, there is also its part being even in **M**, the quadratic MOKE (QMOKE). Handling and understanding the underlying origin of QMOKE could be key to utilize this method for research of antiferromagnetic materials in the future. Here, we present a technique of QMOKE spectroscopy based on the 8-directional method [2] applied on the Fe thin films grown on MgO substrate. From measured QMOKE spectra, further two complex spectra of quadratic magnetooptic (MO) tensor [3] are yielded, using standard Yeh's 4×4 matrix formalism. Those quadratic MO parameters are further discussed and compared with ab-initio calculations.

[1] T. Kuschel et al., J. Phys. D: Appl. Phys. 44, 265003 (2011)
[2] K. Postava et al., J. Appl. Phys. 91, 7293 (2002)
[3] Š. Višňovský, Czech. J. Phys. B 36, 1424 (1986)

MA 6.6 Mon 10:45 HSZ 403

XAS and XMCD of size-selected lanthanoid clusters and complexes in the gas phase — •Martin Timm[1], Christine Bülow[1], Rebecka Lindblad[1,2], Vicente Zamudio-Bayer[1,3], Bernd von Issendorff[3], and Tobias Lau[1] — [1]Institut für Methoden und Instrumentierung der Forschung mit Synchrotronstrahlung, Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Albert-Einstein-Straße 15, 12489 Berlin, Germany — [2]Synkrotronljusfysik, Lunds Universitet, Box 118, 22100 Lund, Sweden — [3]Fakultät für Physik, Universität Freiburg, Stefan-Meier-Straße 21, 79104 Freiburg, Germany

Lanthanoid-based materials are currently of great interest in molecular magnetism because of their unquenched $4f$ orbital magnetic moments. Our cryogenic ion-trap end station at BESSY II allows us to perform x-ray absorption and x-ray magnetic circular dichroism spectroscopy of cold, size-selected, free cluster and organometallic complex ions in the presence of a magnetic field, and to investigate the effect of com-

plexation by ligands on their magnetic properties. We will outline this unique approach to magnetic properties of molecular materials and present first spectroscopic data of free gadolinium and terbium cluster ions and complexes.

MA 6.7 Mon 11:00 HSZ 403

Combining time-resolved Electron Microscopy with in-situ radio-frequency excitation — •Marcel Möller, Nara Rubiano da Silva, Armin Feist, Sascha Schäfer, and Claus Ropers — 4th Physical Institute, Georg-August-University, Göttingen, Germany

Ultrafast Transmission Electron Microscopy (UTEM) is an emerging technique providing simultaneous nanometer spatial and femtosecond temporal resolution. Typically, the structural or electronic processes studied in this approach are triggered by intense optical excitation.

Here, we present our implementation of radio-frequency electrical stimulation in UTEM, synchronized to the train of electron probe pulses. In a first experiment, we quantitatively map the amplitude and phase of localized electrical field distributions at the end of electrical waveguides by the spatial streaking of femtosecond electron pulses. Secondly, we probe the resonant excitation of magnetic vortices by spin-polarized radio-frequency currents using Lorentz-Microscopy with continuous and synchronously-pulsed electron beams. Our work will allow for the time-resolved investigation of numerous resonant and non-resonant phenomena driven in nanostructures with megahertz to terahertz fields and currents.

MA 6.8 Mon 11:15 HSZ 403

High sensitivity quantum limited electron spin resonance spectroscopy — •Sebastian Probst[1], Philippe Campagne-Ibarcq[1], Audrey Bienfait[1], Jarryd J. Pla[2], Denis Vion[1], Daniel Esteve[1], Klaus Moelmer[3], John J. L. Morton[4], and Patrice Bertet[1] — [1]Quantronics group, CEA Saclay, France — [2]School of Electrical Engineering and Telecommunications, University of New South Wales, Australia — [3]Department of Physics and Astronomy, Aarhus University, Denmark — [4]London Centre for Nanotechnology, University College London, United Kingdom

Electron spin resonance (ESR) spectroscopy is widely employed for the detection and characterization of paramagnetic species and their magnetic and chemical environment. In a classical ESR spectrometer, the spins precess in an external magnetic field and emit small microwave signals into a cavity, which are amplified and measured. In this work, we make use of the toolbox of circuit quantum electrodynamics to boost the sensitivity of such a spectrometer by many orders of magnitude to the level of $10^2\,\mathrm{spins}/\sqrt{\mathrm{Hz}}$ with a signal-to-noise ratio of 1. This is achieved by using a low impedance, high quality factor superconducting micro-resonator in conjunction with a Josephson parametric amplifier operated below 20 mK. The energy relaxation time T_1 of the spins (Bi donors in ^{28}Si) is limited by the Purcell effect to 21 ms allowing fast repetitive measurements while the coherence time T_2 is approximately 1.7 ms. This work is a step towards inductive detection of individual spins, which would be beneficial for quantum information processing and chemical analysis of materials at the single spin level.

MA 6.9 Mon 11:30 HSZ 403

An element-selective probe of atomic polarization reminiscent of the linear Stark-effect — •Katharina Ollefs[1,3], Verena Ney[2], Fabrice Wilhelm[3], Andrei Rogalev[3], and Andreas Ney[2] — [1]Universität Duisburg-Essen and CENIDE, Germany — [2]Johannes Kepler Universität, Austria — [3]European Synchrotron Radiation Facility (ESRF), France

We have studied Co doped ZnO and range of other polar and non-polar materials using x-ray absorption near-edge spec-troscopy (XANES) in external electric fields [1]. A rigid band shift by a few meV/kV is found which scales linear with the applied field thus being reminiscent of the linear Stark-effect. This is corroborated by the consistent presence of this effect in polar thin films and bulk crystals and its absencein non-polar materials as well as in conducting films. The observed rigid band shift is isotropic andscales linear with the atomic number of the studied element. Therefore, XANES in electrical fields opens the perspective to study atomic polarization with element specificity in a range of functional materials.

[1] V. Ney, F. Wilhelm, K. Ollefs, A. Rogalev, and A. Ney, Phys. Rev. B 93, 035136 (2016)