MA 30: Experimental methods and magnetic imaging

Time: Wednesday 15:00–18:00 Location: HSZ 403

MA 30.1 Wed 15:00 HSZ 403

Double-ICEBERG pulses: A next step towards global pulse sequence optimization in NMR — •Simone Köcher and Steffen Glaser — Department of Chemistry, TU München, Garching, Germany

ICEBERG-pulses (Inherent Coherence Evolution optimized Broadband Excitation Resulting in constant phase Gradients) include phase evolution during the radio frequency pulse and create a linear phase dispersion [1]. The ICEBERG concept is extended to consider not only a final phase dispersion but also an initial one, hence called double-ICEBERG-pulses. An optimal control optimization routine for double-ICEBERG-pulses with linear phase slopes is developed which is based on the description by unitary rotations [2]. The effects of phase dispersion, flip angle, and pulse duration on the achievable pulse performance are explored and interpreted by an Euler decomposition scheme. This scheme provides a concept for the design and approximation of ideal pulses. The increased flexibility of double-ICEBERG-pulses offers an additional gain in pulse performance and more adaptability in pulse design.

[1] N. I. Gershenzon, T. E. Skinner, B. Brutscher, N. Khaneja, M. Nimbalkar, B. Luy, S. J. Glaser, *J. Magn. Reson.* **192** (2008), 235-243

[2] N. Khaneja, T. Reiss, C. Kehlet, T. Schulte-Herbrüggen, S. J. Glaser, *J. Magn. Reson.* **172** (2005), 296-305

MA 30.2 Wed 15:15 HSZ 403

Grazing Incidence Nuclear Small-Angle X-ray Scattering: an Advanced Scattering Technique for the Investigation of Ordered Magnetic Nanostructures — •Liudmila Dzemiantsova[1,2,3], Kai Schlage[2], Lars Bocklage[1,2,3], Denise Erb[2], Guido Meier[1,3], and Ralf Röhlsberger[1,2] — [1]The Hamburg Centre of Ultrafast Imaging, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]Deutsches Elektronen Synchrotron DESY, Notkestr. 85, 22607 Hamburg, Germany — [3]University of Hamburg, Institute of Applied Physics, Jungiustr. 11, D-20355 Hamburg, Germany

Grazing incidence nuclear small-angle X-ray scattering (GINSAXS) is a new advanced scattering technique for the magnetic characterization of ordered magnetic nanostructures with sub-nm spatial resolution. While conventional GISAXS is usually employed to investigate lateral structural correlations of the surface morphology, nuclear GISAXS is in addition sensitive to its magnetic state. Here we use GINSAXS to characterize the lateral magnetic configuration in a nanostripe pattern during magnetic reversal and detect a ferro- and an antiferromagnetic state. The origin of this state is a system consisting of different types of nanowires: with and without pads for a domain wall nucleation. Samples were fabricated from 30 nm isotopically enriched permalloy using several steps of electron-beam lithography on silicon substrates. Based on the synchrotron nature of GINSAXS, it will be possible to magnetically characterize complex ordered structures such as spin ice, even under different conditions of pressure and temperature which is hardly accessible for most surface-sensitive magnetic methods.

MA 30.3 Wed 15:30 HSZ 403

Sherman Mapping of Fe(001)-p(1x1)O — •Christian Thiede[1], Christian Langenkämper[1], Kaito Shirai[2], Anke B. Schmidt[1], Taichi Okuda[3], and Markus Donath[1] — [1]Physikalisches Institut, Universität Münster,Germany — [2]Graduate school of Science, Hiroshima University, Japan — [3]Hiroshima Synchrotron Radiation Center, Hiroshima University, Japan

Two major improvements in spin-polarimeter design have been reported recently: (i) Low-energy-electron scattering from oxygen-passivated Fe(001) surfaces, based on exchange interaction, offers long-term stability and a high figure of merit [1,2]. (ii) Specular reflection at high-Z targets, such as W(001), based on spin-orbit interaction, opens the way to multi-channel detection [3,4]. The use of nonmagnetic targets in the latter case complicates the investigation of spin effects in nonmagnetic samples, such as topological insulators.

In our work, we discuss the possibility of using a magnetic target in a display-type spin-polarization detector. We present reflectivity measurements and Sherman maps of a Fe(001)-p(1x1)O target over a wide range of scattering energies and angles. Both quantities contribute to the figure of merit which determines detector performance. Our findings show suitable working points for a new type of exchange-based multi-channel spin-detector with a figure of merit of up to 1.0 x 10^{-2}.

[1] Winkelmann *et al.*, Rev. Sci. Instrum. **79**, 083303 (2008)

[2] Okuda *et al.*, Rev. Sci. Instrum. **79**, 123117 (2008)

[3] Kolbe *et al.*, Phys.Rev. Lett. **107**, 207601 (2011)

[4] Tusche *et al.*, Appl. Phys. Lett. **99**, 032505 (2011)

MA 30.4 Wed 15:45 HSZ 403

Momentum space anisotropy of electronic correlations in Fe and Ni, an analysis of magnetic Compton profiles — •Liviu Chioncel[1,2], Diana Benea[3], Hubert Ebert[4], Igor Di Marco[5], and Jan Minar[4] — [1]Theoretical Physics III, Center for Electronic Correlations and Magnetism, Institute of Physics, University of Augsburg, D-86135 Augsburg, Germany — [2]Augsburg Center for Innovative Technologies, University of Augsburg, D-86135 Augsburg, Germany — [3]Faculty of Physics, Babes-Bolyai University, Kogalniceanustr 1, Ro-400084 Cluj-Napoca, Romania — [4]Chemistry Department, University Munich, Butenandstr. 5-13, D-81377 Munchen, Germany — [5]Department of Physics and Astronomy, Division of Materials Theory, Uppsala University, Box 516, SE-75120 Uppsala, Sweden

The total and magnetic resolved Compton profiles are analyzed within the combined density functional and dynamical mean field theory for the transition metal elements Fe and Ni. A rather good agreement between the measured and computed Magnetic Compton profiles (MCPs) of Fe and Ni is obtained with the standard Local Spin Density Approximation (LSDA). By including local but dynamic many-body correlations captured by Dynamical Mean Field Theory, the Magnetic Compton profile is further improved. The second moment of the difference of the total Compton profile taken along the same momentum direction has been used to discuss the strength of electronic correlations in Fe and Ni.

MA 30.5 Wed 16:00 HSZ 403

Imaging of magnetic domains in TbCo alloys through different capping layers using valence band photoemission magnetic circular dichroism — •Philip Thielen[1,2], Markus Rollinger[1], Pascal Melchior[1], Ute Bierbrauer[1], Sabine Alebrand[1], Christian Schneider[1], Michel Hehn[3], Stéphane Mangin[3], Mirko Cinchetti[1], and Martin Aeschlimann[1] — [1]Physics Department and Research Center OPTIMAS, University of Kaiserslautern, Germany — [2]Graduate School of Excellence Materials Science in Mainz, Kaiserslautern, Germany — [3]Institut Jean Lamour, Université de Lorraine, France

Imaging of magnetic domains of uncapped terbium cobalt (TbCo) alloy thin films is achievable using magnetic circular dichroism in two-photon photoemission electron microscopy (PEEM)[1]. Here we show imaging of magnetic domains of TbCo alloy thin films through a variety of capping layers. The domain patterns appear identical for samples without and with capping layer but have opposite contrast. Using a time-of-flight detector, we record energy distribution spectra of the photoelectrons. While the MCD signal of uncapped samples depends strongly on the photoelectron spectrum and even shows a sign change in a narrow energy range, we find neither a kinetic energy dependence nor a sign change of the MCD signal for capped samples. We discuss the origin of the magnetic asymmetry in case of the capped samples, distinguishing whether the electrons originate from the capping layer or the underlying TbCo layer itself.

[1] P. Melchior et al., Phys. Rev. B 88, 104415 (2013).

15 min. break

MA 30.6 Wed 16:30 HSZ 403

Ultra sensitive magnetic field sensing with single electron spin — •Andrii Lazariev[1], Ganesh Rahane[1], Perunthiruthy Madhu[2], and Gopalakrishnan Balasubramanian[1] — [1]Max Planck Research Group "Nanoscale Spin Imaging", Max Planck Institute for Biophysical Chemistry, Göttingen, Germany — [2]Dept. of Chemical Sciences, TIFR, Mumbai, India

We present an experimental method for the micro- and nanotesla magnetic field measurements using a Nitrogen-Vacancy defect in diamond lattice. The Nitrogen-Vacancy (NV) center in diamond is a lattice defect which appears when a carbon atom is replaced with a nitrogen atom and has a missing lattice node nearby. It can be represented as a pseudo 1/2-spin and sustain its state manipulations under optical or microwave exposure. The NV-center has been proved as a stable nanoscale probe for weak magnetic field. Present work studies a method of Fourier spectroscopy based on modified Phase-Modulated Lee-Goldburg sequence. The study demonstrate the variation of the probe sensitivity to the external magnetic fields and introduces an algorithm based on PMLG sequence allowing to provide the spectra measurements of a multi-frequency (kHz-scale) ultra-weak (uT) magnetic fields.

MA 30.7 Wed 16:45 HSZ 403

A magnetic resonance microscope based on nitrogen-vacancy center in diamond for nanoscale imaging of nuclear spins — Phani Peddibhotla[1], Alexander Gerstmayr[1], Dominik Reitzle[2], Boris Naydenov[1], Berndt Koslowski[2], and •Fedor Jelezko[1] — [1]Institut für Quantenoptik, Universität Ulm, Albert-Einstein-Allee 11, D-89081 Ulm, Germany — [2]Institut für Festkörperphysik, Universität Ulm, Albert-Einstein-Allee 11, D-89069 Ulm, Germany

We report on the development of a scanning probe microscope using nitrogen-vacancy (NV) center in diamond that operates under ambient conditions. Our nuclear magnetic resonance imaging setup comprises of an atomic force microscope (AFM) integrated into an optical confocal microscope . The nanoscale sample under study, containing nuclear spins, is attached onto the tip of an AFM cantilever. The tip is positioned close to a shallow implanted NV center in isotopically purified carbon-12 diamond. Optical readout of the spin quantum state of the NV center encodes information about the magnetic dipolar interaction of sample nuclear spins with the NV electronic spin. Monitoring the fluorescence of the NV center while mechanically scanning the diamond sample with respect to the cantilever tip in three dimensions provides data that could allow the reconstruction of nuclear spin density.

MA 30.8 Wed 17:00 HSZ 403

Imaging of magnetic protein by NV centre in diamond. — •Anna Ermakova[1], Andrea Kurz[1], Goutam Pramanik[2], Jianming Cai[3], Boris Naydenov[1], Tanja Weil[2], Martin Plenio[3], and Fedor Jelezko[1] — [1]Institute of Quantum Optics, University Ulm, Germany — [2]Institute of Organic Chemistry III, University Ulm, Germany — [3]Institute of Theoretical Physics, University Ulm, Germany

To determinate the magnetic structure of a protein it is necessary to use an atomic sited and ultrasensitive magnetic field detector, like the nitrogen-vacancy (NV) centre in diamond. NV centre is a stable optical defect having a spin allowing high sensitive magnetic field detection with nanoscale resolution [1,2]. Nanodiamonds with NV centres can be use for the sensing of the protein ferritin, which keep iron (until 4500 iron atoms per one protein) in the blood to produce haemoglobin in further [3].

In our work we used a bulk diamond with shallow implant NV centres (3-5 nm from the surface). We attached ferritin to a silica particle, which was on the end of AFM tip. In this case one can choose the distance between the NV centre and proteins and measure changes of the relaxation times (T1 and T2) of NV.

Here, we present an image of relaxation times of NV*s spin as a function of the position of ferritin on AFM tip. We compare this with previous result [3] to determine the number of iron ions in the protein.

[1] G.Balasubramanian et al. Nature 455, 648-651 (2008); [2] J.M.Taylor, P.Capellaro et al., Nature Physics 4, 810*816 (2008); [3]A.Ermakova et. al., Nano Letters 13(7), 3305-3309 (2013)

MA 30.9 Wed 17:15 HSZ 403

Magnetic imaging using a scanning single qubit and optimal control — •Thomas Häberle[1], Dominik Schmid-Lorch[1], Khaled Karrai[2], Friedemann Reinhard[1], and Jörg Wrachtrup[1] — [1]3. Physikalisches Institut and Stuttgart Research Center of Photonic Engineering (SCoPE), Universität Stuttgart, Germany — [2]attocube systems AG, Munich, Germany

We present a novel scanning probe technique for magnetic field microscopy that promises a higher spatial resolution than standard MFM [1]. The new scanning probe is the nitrogen-vacancy (NV)-color center in diamond, which can be employed as an atom-sized magnetic field sensor by monitoring the Zeeman-shift of its spin sublevels [2-3].

I will present benchmark measurements on magnetic nanostructures, in particular a quantitative mapping of the field produced by an MFM-tip. These results were used to validate analytical models proposed for quantitative MFM [4]. Furthermore, I will explain the advanced spectroscopy protocol that was applied in the measurements. It is based on optimal control and enables fast acquisition of strongly varying magnetic field gradients with quantum-limited sensitivity [5].

[1] G. Balasubramanian et al., Nature Vol 455, 648-651 (2008)
[2] L. Rondin et al., Appl. Phys. Lett.. Vol. 100, 153118 (2012)
[3] P. Maletinsky et al., Nat. Nanotech. Vol. 7, 320-4 (2012)
[4] T. Häberle et al., New J. Phys. Vol. 14, 043044 (2012)
[5] T. Häberle et al., Phys. Rev. Lett. Vol. 111, 170801 (2013)

MA 30.10 Wed 17:30 HSZ 403

Synchronous precessional motion of multiple domain walls in a ferromagnetic nanowire by perpendicular field pulses — •Mohamad-Assaad Mawass[1,2], June-Seo Kim[1,3], Andre Bisig[1,2], Benjamin Krüger[1], Robert Reeve[1], Tomek Schulz[1], Felix Büttner[1,5], Jungbum Yoon[4], Chun-Yeol You[4], Markus Weigand[2], Hermann Stoll[2], Gisela Schütz[2], Henk J. M. Swagten[3], Bert Koopmans[3], Stefan Eisebitt[5], and Mathias Kläui[1] — [1]Johannes Gutenberg-Universität Mainz, Germany — [2]Max-Planck-Institut für Intelligente Systeme, Stuttgart, Germany — [3]Eindhoven University of Technology, The Netherlands — [4]Inha University, Republic of Korea — [5]Technische Universität Berlin

Magnetic storage and logic devices based on magnetic domain wall (DW) motion rely on the precise and synchronous displacement of multiple domains and DWs. The conventional approach using magnetic fields efficiently drives DWs but does not allow for the necessary synchronous motion of multiple domains. As an alternative method, synchronous current-induced DW motion has been studied, but the required high critical current densities prevent widespread use in devices. Here, we demonstrate a radically different approach: We use out-of-plane magnetic field pulses to move in-plane domains, thus combining the efficiency of field-induced magnetization dynamics with the ability to move neighbouring domains and DWs in the same direction. the displacement can be understood from the acting torques.

MA 30.11 Wed 17:45 HSZ 403

Non-contact bimodal Magnetic Force Microsopy — •Johannes Schwenk[1], Miguel Marioni[1], Niraj Joshi[1], Sara Romer[1], and Hans-Josef Hug[1,2] — [1]Empa, Swiss Federal Laboratories for Materials Science and Technology, CH-8600 Dübendorf, Switzerland. — [2]Department of Physics, University of Basel, CH-4056 Basel, Switzerland

We present a bimodal Magnetic Force Microscopy technique which is capable to reveal the magnetic stray field of a sample as well as the corresponding topography in a single pass scan. Being single pass makes the technique independet from all kinds of instrumental drift and allows to scan with lowest tip sample separation. Therefore it provides high lateral resolution since the tip interacts with low range magnetic stray fields of small magnetic features. The bimodal technique is suitable for vacuum conditions and stable for high Q and soft cantilevers that are necessary for high sensitivity measurements.