MA 23: Functional Antiferromagnetism

Time: Tuesday 9:30–13:15 Location: HSZ 401

MA 23.1 Tue 9:30 HSZ 401

Bloch lines in antiferromagnetic domain walls — •L. Kuerten[1], M. C. Weber[1], E. Hassanpour[1], M. Trassin[1], Y. Tokunaga[2], Y. Taguchi[3], Y. Tokura[4], Th. Lottermoser[1], and M. Fiebig[1] — [1]Department of Materials, ETH Zurich, Switzerland — [2]Department of Advanced Materials Science, University of Tokyo, Japan — [3]RIKEN Center for Emergent Matter Science, Japan — [4]Department of Applied Physics, University of Tokyo, Japan

Bloch lines are topological defects in magnetic domain walls at which the magnetic chirality of the wall changes. While Bloch lines in ferromagnets have been extensively investigated, they have only been theoretically predicted in antiferromagnets. Here, we use low-temperature magnetic force microscopy to resolve Bloch lines in an antiferromagnetic domain wall for the first time. We perform our experiments in the orthoferrite $DyFeO_3$, which transforms from a ferromagnetic to an antiferromagnetic phase at low temperature. By tracking the magnetic structure across the transition, we show that domains in one phase transform into domain walls of the other phase and vice-versa. We propose that antiferromagnetic Bloch lines emerge from previously existing Bloch lines in domain walls of the ferromagnetic phase – constituting the transfer of a topological defect of the spin structure across a phase transition.

MA 23.2 Tue 9:45 HSZ 401

Current-induced electrical switching of antiferromagnetic MnN — •Mareike Dunz[1], Tristan Matalla-Wagner[1], and Markus Meinert[2] — [1]Center for Spinelectronic Materials and Devices, Department of Physics, Bielefeld University — [2]Department of Electrical Engineering and Information Technology, TU Darmstadt

Electrical switching and readout of antiferromagnets allows to exploit the unique properties of antiferromagnetic materials in nanoscopic electronic devices. Recently, it was shown that switching of magnetic moments via spin-orbit torque is possible in epitaxial films of antiferromagnetic NiO [1]. A spin-polarized current is generated in adjacent Pt layers and exerts a torque on the magnetic moments in the antiferromagnetic film. Here, we report experiments on spin-orbit torque induced switching of a polycrystalline, metallic antiferromagnet with low anisotropy and high Néel temperature [2]. We demonstrate the switching in a Ta / MnN / Pt trilayer system, deposited by (reactive) magnetron sputtering. The dependencies of the switching amplitude, efficiency, and relaxation are studied with respect to the MnN film thickness, sample temperature and current density. Our findings are consistent with a thermal activation model and resemble to a large extent previous measurements on CuMnAs and Mn_2Au, which exhibit similar switching characteristics due to an intrinsic spin-orbit torque.

[1] T. Moriyama et al., Sci Rep. 8, 14167 (2018)
[2] M. Dunz et al., arXiv : 1907.02386v2

MA 23.3 Tue 10:00 HSZ 401

Mechanism of Néel Order Switching in Antiferromagnetic Thin Films — Lorenzo Baldrati[1], Olena Gomonay[1], Andrew Ross[1,2], Mariia Filianina[1,2], Romain Lebrun[1], Rafael Ramos[3], Cyril Leveille[1], •Felix Fuhrmann[1], Thomas Forrest[4], Francesco Maccherozzi[4], Sergio Valencia[5], Florian Kronast[5], Eiji Saitoh[3], Jairo Sinova[1], and Mathias Kläui[1,2] — [1]Johannes Gutenberg-University Mainz, Germany — [2]Graduate School of Excellence Materials Science in Mainz, Germany — [3]WPI-Advanced Institute for Materials-Research, Tohoku University, Japan — [4]Diamond Light Source, Oxfordshire, United Kingdom — [5]Helmholtz-Zentrum Berlin, Germany

Antiferromagnetic insulators (AFMI) are promising candidates for spintronics. They have the potential for ultrafast operation, scalability, due to the lack of stray fields and insensitivity against external magnetic fields. While reading of the Néel order orientation **n** can be achieved electrically via the spin Hall magnetoresistance [1], the electrically writing of **n** is still a challenge. Here we show that one can electrically switch the antiferromagnetic moments with current pulses. The current is applied to a heavy metal (HM) to achieve spin accumulation by the spin hall effect at the AFMI-HM interface, exerting anti-damping like torques on the AFMI [2,3]. The resulting switching was investigated electrically and imaged by x-ray magnetic dichroism [4]. [1] Baldrati et al., PRB 98, 024422 (2018). [2] Moriyama et al., Sci. Rep. 8, 14167 (2018). [3] Chen et al., PRL 120, 207204 (2018). [4] Baldrati et al., PRL 123, 177201 (2019).

MA 23.4 Tue 10:15 HSZ 401

Epitaxial Mn2Au thin films for antiferromagnetic spintronics grown by molecular beam epitaxy — •Satya Prakash Bommanaboyena[1], Stanislav Bodnar[1], Mariia Filianina[1], René Heller[2], Thomas Bergfeldt[3], Mathias Kläui[1], and Martin Jourdan[1] — [1]Institut für Physik, Johannes Gutenberg Universität Mainz, Germany — [2]Institut für Ionenstrahlphysik und Materialforschung, Helmholtz-Zentrum Dresden-Rossendorf, Germany — [3]Institut für Angewandte Materialien, Karlsruher Institut für Technologie, Germany

The recent experimental realization of Néel order switching in antiferromagnetic Mn2Au [1] has sparked a huge interest in the growth of high-quality films of this compound. We report the preparation of high-quality epitaxial Mn2Au(001) thin films using molecular beam epitaxy. Mn and Au were co-evaporated at low deposition rates in ultra-high vacuum onto a heated epitaxial Ta(001) buffer layer deposited on Al2O3 substrates. Structural and morphological characterization of the films was carried out using reflective high energy electron diffraction, x-ray diffraction, x-ray reflectometry and temperature dependent resistance measurements. The films were found to be highly crystalline and smooth with a low defect concentration. Rutherford backscattering spectrometry and inductively coupled plasma optical emission spectroscopy were employed to determine their composition. Additionally, X-ray magnetic linear dichroism-photoemission electron microscopy was used to study their antiferromagnetic domain pattern.
[1] S. Yu. Bodnar et al Nature Communications 9, 2018.

MA 23.5 Tue 10:30 HSZ 401

Spin-flop induced resistance modifications of antiferromagnetic Mn2Au thin films — •Stanislav Bodnar[1], Yurii Sckourski[2], Satya Prakash Bommanaboyena[1], Mathias Kläui[1], and Martin Jourdan[1] — [1]Institut für Physik, Johannes Gutenberg-Universität, Staudinger Weg 7, 55128 Mainz, Germany — [2]Hochfeld-Magnetlabor Dresden (HLD-EMFL), Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden, Germany

Recently it has been shown that the Néel vector in Mn2Au can be switched by the application of current pulses via Néel spin-orbit torques [1]. The process of Néel vector switching was visualized by XMLD-PEEM [2]. In our work we report about the effect of magnetic field induced spin-flop transitions in antiferromagnetic Mn2Au(001) on the resistance of the samples. Two contributions of spin=flop induced resistance changes were observed on different time scales [3]. The first contribution gives rise to resistance reductions of ˜1% and decay on a time scale of seconds. The second contribution is identified as a persistent anisotropic magnetoresistance effect, with a magnitu of ˜0.1%. The results indicate that the origin of current induced large resistance modifications in Mn2Au are associated with domain wall resistance.

[1] S. Yu. Bodnar et al., Nat. Commun. 9, 348 (2018) [2] S. Yu. Bodnar et al., Phys. Rev. B 99, 140409(R) (2019) [3] S. Yu. Bodnar et al., arXiv 1909.12606 (2019).

MA 23.6 Tue 10:45 HSZ 401

Néel vector induced manipulation of valence states in the collinear antiferromagnet Mn2Au — •Hans-Joachim Elmers[1], S. V. Chernov[1], S. P. Bommanaboyena[1], S. Yu. Bodnar[1], K. Medjanik[1], S. Babenkov[1], O. Fedchenko[1], D. Vasilyev[1], S. Y. Agustsson[1], C. Schlueter[2], A. Gloskovskii[2], Y. Matveyev[2], Y. Skourski[3], S. Dsouza[4], J. Minar[4], L. Šmejkal[1], J. Sinova[1], M. Klaeui[1], G. Schoenhense[1], and M. Jourdan[1] — [1]Institut für Physik, Universität Mainz, Germany — [2]DESY, Hamburg, Germany — [3]Helmholtz-Zentrum Dresden-Rossendorf, Germany — [4]University of West Bohemia, Czech Republic

Manipulation of the electronic valence states of the collinear metallic antiferromagnet Mn_2Au was achieved by reorienting the direction of the staggered magnetisation (Néel vector). Pulsed magnetic fields of 50 T were used to direct the sublattice magnetisations of capped epitaxial Mn_2Au (001) thin films perpendicular to the applied field direction by a spin-flop transition. The electronic structure was investigated by hard X-ray angular-resolved photoemission spectroscopy [1]. Our results confirm that the magnetic order parameter in real space provokes considerable changes of electronic states in reciprocal space near the Fermi Level and close to the X points. [1] J. Synchr. Rad. 26, 1996 (2019)

MA 23.7 Tue 11:00 HSZ 401

Tetragonal CuMnAs: Phase stability and finite temperature magnetism — •Karel Carva, Pavel Baláž, David Wagenknecht, and Klára Uhlířová — Charles University, DCMP, Ke Karlovu 5, CZ-12116, Prague, Czechia

The antiferromagnetic semimetal CuMnAs has a high application potential in spintronics. A controlled rotation of magnetic moments' orientation by means of an applied electrical field has been demonstrated in tetragonal CuMnAs, employing spin-orbit torques. However, bulk CuMnAs natively crystallizes in the orthorhombic phase, which has different interesting properties. Tetragonal CuMnAs phase has been achieved in epitaxially deposited samples or by inserting lattice defects linked to non-stoichiometry in CuMnAs [1]. The tendency towards tetragonal phase with an increased Cu content has been confirmed by ab initio calculations [1].

We have estimated the stability of different phases and calculated formation energies of possible defects in the alloy. Mn_{Cu} and Cu_{Mn} antisites and vacancies on Mn or Cu sublattices were identified as most probable defects in CuMnAs. We estimated also the in-plane resistivity of CuMnAs with defects of low formation energies. Finally, we have determined the exchange interactions and estimated the Néel temperature of the ideal and disordered AFM-CuMnAs [2]. A good agreement with the experimental data makes it possible to estimate the structure and composition of real CuMnAs samples.

[1] K. Uhlířová et al., J. Alloys Compd. 771, 680 (2018)
[2] F. Máca et al., Phys. Rev. B 96, 094406 (2017)

15 min. break

MA 23.8 Tue 11:30 HSZ 401

Geometry-induced effects in antiferromagnetic spin chains — Denys Y. Kononenko[1,2], •Oleksandr V. Pylypovskyi[3,2], Ulrich K. Roessler[1], Kostiantyn V. Yershov[1,4], Artem V. Tomilo[2], Jeroen van den Brink[1], Yuri Gaididei[4], Denys Makarov[3], and Denis D. Sheka[2] — [1]Institute for Theoretical Solid State Physics, IFW Dresden, 01069 Dresden, Germany — [2]Taras Shevchenko National University of Kyiv, 01601 Kyiv, Ukraine — [3]Helmholtz-Zentrum Dresden-Rossendorf e.V., Institute of Ion Beam Physics and Materials Research, 01328 Dresden, Germany — [4]Bogolyubov Institute for Theoretical Physics, Kyiv, 03143, Ukraine

Antiferromagnetic nanostructures as objects with ultrahigh eigenfrequencies and low sensitivity to demagnetizing fields are promising candidates for applications in data storage and information processing. Three-dimensional architectures enable new ways for tuning magnetic responses and extend ideas of spintronic devices. Here, we analyze anitferromagnetically ordered curvilinear spin chains and derive a Lagrangian taking into account the exchange interaction and effective anisotropy arising from the dipolar interaction. The static and dynamic properties of the spin system are influenced by emergent geometry-induced anisotropies and Dzyaloshinskii–Moriya interaction, which are illustrated by ring and helix geometries as case studies. Ground states and coupling of spin wave modes due to curvilinear geometry are described.

MA 23.9 Tue 11:45 HSZ 401

Anomalous and topological Hall effects in epitaxial thin films of the noncollinear antiferromagnet Mn_3Sn — •James M. Taylor[1], Anastasios Markou[2], Edouard Lesne[1], Pranava Keerthi Sivakumar[1], Peter Werner[1], Claudia Felser[2], and Stuart S. P. Parkin[1] — [1]Max Planck Institute of Microstructure Physics, Weinberg 2, 06120 Halle (Saale), Germany — [2]Max Planck Institute for Chemical Physics of Solids, Nöthnitzer Str. 40, 01187 Dresden, Germany

Noncollinear antiferromagnets with a $D0_{19}$ hexagonal structure have garnered much attention for their potential applications in topological spintronics. Here, we report the deposition of continuous epitaxial thin films of such a material, Mn_3Sn, with both (0001) c-axis orientation and $(40\bar{4}3)$ texture. In the latter case, the thin films exhibit a small uncompensated Mn moment in the basal plane, quantified via magnetometry. This cannot account for the large anomalous Hall effect simultaneously observed in these films, even at room temperature, with magnitude σ_{xy} $(\mu_0 H = 0\ \mathrm{T}) = 21\ \Omega^{-1}\mathrm{cm}^{-1}$ and coercive field $\mu_0 H_c = 1.3$ T. We attribute the origin of this anomalous Hall effect to momentum-space Berry curvature arising from the symmetry-breaking inverse triangular spin structure of Mn_3Sn. Upon cooling through the transition to a glassy ferromagnetic state at around 50 K, a peak in the Hall resistivity close to the coercive field indicates the onset of a topological contribution to Hall effect. This is due to the emergence of a scalar spin chirality generating a real-space Berry phase, and is controllable using different field cooling conditions.

MA 23.10 Tue 12:00 HSZ 401

Nonlinear photocurrents in antiferromagnets — •Maximilian Merte[1], Frank Freimuth[1], Jan-Philipp Hanke[1,2], Wanxiang Feng[1,3], Stefan Blügel[1], Lukasz Plucinski[1], and Yuriy Mokrousov[1,2] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [2]Institute of Physics, Johannes Gutenberg University Mainz, 55099Mainz, Germany — [3]School of Physics, Beijing Institute of Technology, Beijing 100081, China

In the field of spintronics, the interaction of antiferromagnets with external electromagnetic fields plays a crucial role for future prospects related to fundamental understanding and technological applications. In materials of reduced symmetry a photocurrent which is of second order in the electric field can occur. Recently a response tensor describing these currents was derived based on the non-equilibrium Keldysh formalism [1]. Here we want to report on the implementation of this second order response tensor by means of by means of Wannier interpolation, which can be applied as a postprocessing step to first-principles calculations performed with the Jülich DFT code FLEUR [2]. We apply the developed method to study photocurrents of linear and circular polarized light in antiferromagnets. – We acknowledge funding from DFG through SFB/TRR 173 and computing resources granted by JARA-HPC from RWTH-Aachen University and Forschungszentrum Jülich under projects jara0161, jiff40 and jias1a. [1] Frank Freimuth *et al.*, arXiv: 1710.10480 (2017) [2] www.flapw.de

MA 23.11 Tue 12:15 HSZ 401

Resistivity in Antiferromagnetic System with Domain Wall — •Jun-Hui Zheng, Alireza Quaiumzadeh, and Arne Brataas — Center for Quantum Spintronics, Department of Physics, Norwegian University of Science and Technology, NO-7491 Trondheim, Norway

The ballistic and diffuse transport through a ferromagnetic domain wall (DW) has been well studied for decades. In some cases, the DW serves as an effective barrier potential, increasing the resistance. Antiferromagnetic systems have a more complicated magnetic structure and their DWs have more exotic properties, which has attracted theoretical and experimental attention. Here we theoretically study the resistance due to the antiferromagnetic domain wall scattering by using the adiabatic approximation. Depending on the types of antiferromagnetism, the resistance shows rather different behaviors.

MA 23.12 Tue 12:30 HSZ 401

Propagation length of antiferromagnetic magnons governed by domain configurations — •Andrew Ross[1,2], Romain Lebrun[1], Olena Gomonay[1], Asaf Kay[3], Daniel A. Grave[3], Lorenzo Baldrati[1], Florian Konst[4], Alireza Qaiumzedah[5], Arne Brataas[5], Avner Rothschild[3], Rembert Duine[5,6,7], and Mathias Kläui[1,2,5] — [1]Johannes Gutenberg Universität Mainz, Germany — [2]Graduate School of Excellence Materials Science in Mainz, Germany — [3]Technion-Israel Institute of Technology, Israel — [4]Helmholtz-Zentrum Berlin für Materialien und Energie, Germany — [5]Center for Quantum Spintronics, Trondheim, Norway — [6]Utrecht University, The Netherlands — [7]Eindhoven University of Technology, The Netherlands

Antiferromagnetic (AF) insulators benefit from unparalleled stability in external fields, magnetisation dynamics in the THz range, a lack of stray fields and low Gilbert damping, which should allow for efficient long-range propagation of magnons[1,2]. Here we investigate the underlying mechanisms behind magnon transport in AF thin films. We show efficient spin transport is possible across μm in nm thick thin films, contrary to previous studies reporting nm spin-diffusion lengths [3]. To understand this, we perform XMLD imaging of the AF domains to evidence their role in the propagation of magnons. We achieve efficient control over the AF system and establish the possibility to propagate long-distance spin-waves in AF thin films. [1] Chumak et al., Nature Phys. 11, 6 (2015), [2] Lebrun et al., Nature 561, 222 (2018),

[3] Cramer et al., J. Phys. D: Appl. Phys. 51, 14 (2018)

MA 23.13 Tue 12:45 HSZ 401

Chiral Logic Computing with Twisted Modes in Antiferromagnetic Magnonic Waveguides — •Alexander F. Schäffer[1], Min Chen[2], Chenglong Jia[2], and Jamal Berakdar[1] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, 06120 Halle (Saale), Germany — [2]Key Laboratory for Magnetism and Magnetic Materials of the Ministry of Education & Institute of Theoretical Physics, Lanzhou University, China

Antiferromagnetic (AFM) materials are demonstrated to offer a new exciting platform for ultrafast information processing with low cross talks and good compatibility with existing technology. Particularly interesting for energy-saving computing are low-energy AFM excitations, or magnons. For an AFM waveguide we prove the existence of chiral magnonic eigenmodes that possess a well-defined projection of the angular momentum (AM) along the wave propagation direction. The AM is an unbounded integer determined by the spatial topology of the respective mode and is shown to be exploitable for multiplex AFM magnonic computing. We demonstrate how a variety of symmetry and topology protected logic gates can be realized and operated without Joule heating. A Dzyaloshinskii-Moriya interaction arising at the waveguide boundary allows for a coupling to an external electric field and results in a Faraday effect. Our findings uncover a new aspect of AFM spintronics and point to a novel route to communicating and handling data swiftly, with high fidelity and at low energy cost.

MA 23.14 Tue 13:00 HSZ 401

Antiferromagnetic cavity optomagnonics — •tahereh parvvini[1], victor bittencourt[2], and silvia viola kusminskiy[3] — [1]Max Planck Institute for the Science of Light, Staudtstr. 2, PLZ 91058, Erlangen, Germany — [2]Max Planck Institute for the Science of Light, Staudtstr. 2, PLZ 91058, Erlangen, Germany — [3]Max Planck Institute for the Science of Light, Staudtstr. 2, PLZ 91058, Erlangen, Germany

We propose a cavity optomagnonic system based on antiferromagnetic insulators. We derive the Hamiltonian of the system and obtain the coupling of the antiferromagnetic magnon modes to the optical cavity field as a function of magnetic field and material properties. We show that, in the presence of hard-axis anisotropy, the optomagnonic coupling can be tuned by a magnetic field applied along the easy axis, allowing to bring a selected magnon mode into and out of a dark mode. For easy-axis antiferromagnets the coupling is instead independent of the magnetic field. We study the dynamic features of the driven system including optically induced magnon amplification and cooling, Purcell enhancement of transmission, and induced transparency, and discuss their experimental feasibility.