TT 37: Skyrmions II (joint session MA/TT/KFM)

Time: Tuesday 9:30–13:15 Location: EB 301

TT 37.1 Tue 9:30 EB 301

Low temperature magnetic field mapping on Néel-skyrmions in GaV4Se8 — •Franziska Seifert[1], Felix L. Kern[1], István Kézsmárki[2], Daniel Wolf[1], Bernd Büchner[1], and Axel Lubk[1] — [1]Leibniz Institute for Solid State and Materials research Dresden, Germany — [2]University of Augsburg, Germany

Skyrmions are promising candidates for magnetic memory devices, because of their small size, thermal stability and high mobility. Here we report on Skyrmion mapping in GaV4Se8 carried out on our dedicated cryo TEM fitted with a continuous-flow liquid He cryostat, facilitating electron holography and Lorentz TEM down to 7K. Bulk GaV4Se8 is predicted to show Neel type skyrmions below 18K under applied magnetic field between 0.10T and 0.45T mT. Using Lorentz TEM, we characterized the cycloidal and skyrmionic phase of thin GaV4Se8 lamellas in dependence of temperature and applied magnetic field. By mapping the magnetic phase diagram of the thin film we identify magnetic textures that are not considered in the bulk phase diagram. We discuss the origins of these in terms of crystal symmetries and strain prevailing in the thin film slab geometry.

TT 37.2 Tue 9:45 EB 301

Probing skyrmion lattice phase by NMR in GaV_4S_8 — •Markus Prinz-Zwick, Norbert Büttgen, Vladimir Tsurkan, Martina Schädler, and István Kézsmárki — Center of electronic correlation and magnetism, University of Augsburg

With the discovery of Néel-Type skyrmions forming in a skyrmion lattice (SkL) in the lacunar spinel GaV_4S_8, the characterization and analysis of such polar axially symmetric skyrmion host materials gained general interest. From a microscopic point of view we want to elucidate the local distribution of internal magnetic fields associated with the SkL and probe spin excitations using Nuclear Magnetic Resonance(NMR) spectroscopy. Since the stability of the SkL phase is limited to the sub-Tesla range, this is a highly challenging issue. Here, we report NMR results within the SkL-phase in the lacunar spinel GaV_4S_8, and the first so called zero-field NMR measurements, where the internal field of the V_4 cubanes was exploited to perform ^{51}V measurements for applied magnetic fields $0 < \mu_0 H < 100\,\mathrm{mT}$.

TT 37.3 Tue 10:00 EB 301

Optically induced demagnetization and coherent spin excitations in GaV4S8 — •Fumiya Sekiguchi[1], Prashant Padmanabhan[1], Rolf B. Versteeg[1], István Kézsmárki[2], and Paul H. M. van Loosdrecht[1] — [1]Institute of Physics 2, University of Cologne, 50937 Cologne, Germany — [2]Experimental Physics V, Center for Electronic Correlations and Magnetism, University of Augsburg, 86135 Augsburg, Germany

Skyrmions are quasiparticle-like topological spin textures stabilized in non-centrosymmetric crystals with Dzyaloshinskii-Moriya interactions. For potential applications and a better understanding of their nature, it is important to understand their creation and annihilation dynamics, as well as their collective excitation spectrum. Here we employ time resolved magneto-optical Kerr experiments to study the magnetization dynamics in the lacunar spinel GaV4S8 which hosts novel cycloid and Néel-type skyrmion magnetic ground states. The experiments show the emergence of a slow demagnetization process in the magnetically ordered states. In addition, we observe coherent collective spin excitations in both the cycloid and skyrmion phases.

TT 37.4 Tue 10:15 EB 301

Temperature dependence of the cubic anisotropy in the room-temperature skyrmion host $Co_9Zn_9Mn_2$ — •Bertalan György Szigeti[1], Dieter Ehlers[2], Kosuke Karube[3], István Kézsmárki[2], Hans-Albrecht Krug von Nidda[2], Markus Preissinger[2], Vladimir Tsurkan[2], Yusuke Tokunaga[3], Yasujiro Taguchi[3], and Yoshinori Tokura[3] — [1]Department of Physics, Budapest University of Technology and Economics,1111 Budapest, Hungary — [2]Experimental Physik V, EKM, Universität Augsburg, 86135 Augsburg — [3]RIKEN Centre for Emergent Matter Science (CEMS), Wako 351-0198, Japan

The β-Mn-type Co-Zn-Mn alloys are cubic chiral room temperature skyrmion hosts already studied by Lorentz transmission electron microscopy, magnetization and small-angle neutron scattering[1]. Spin wave spectroscopy of the Dzyaloshinskii-Moriya interaction has been measured for $Co_8Zn_8Mn_4$ and $Co_9Zn_9Mn_2$[2]. $Co_9Zn_9Mn_2$ can host metastable skyrmions in zero magnetic field below its $T_C \approx$ 400 K Curie-temperature[3]. In this work we present ESR measurements in the field polarized state of $Co_9Zn_9Mn_2$ to investigate the temperature dependence of the cubic magnetocrystalline anisotropy and its influence on the properties of the meta-stable skyrmion lattice state. We found strong correlation between the change in the anisotropy and the trigonal to square lattice transformation of the skyrmion state.

[1] Tokunaga, Y., et al., Nat. Commun. 6, 7638 (2015), [2] Takagi, R., et al., Phys. Rev. B 95, 220406 (2017), [3] Karube, K., et al., arXiv:1709.08047 (2017).

TT 37.5 Tue 10:30 EB 301

Effects of Magnetocrystalline Anisotropy on the Triangular to Square Lattice Transformation of Skyrmions — •Markus Preissinger[1], Dieter Ehlers[1], Kosuke Karube[2], István Kézsmárki[1], Hans-Albrecht Krug von Nidda[1], Bertalan Szigeti[3], Yusuke Tokunaga[2], Yasujiro Taguchi[2], Yoshinori Tokura[2], and Vladimir Tsurkan[1] — [1]Experimentalphysik V, EKM, Universität Augsburg, 86135 Augsburg — [2]RIKEN Centre for Emergent Matter Science (CEMS), Wako 351-0198, Japan — [3]Department of Physics, Budapest University of Technology and Economics, 1111 Budapest, Hungary

The β-manganese-type alloy $Co_8Zn_8Mn_4$ exhibits a helical state below the Curie-temperature $T_c \approx 300\,\mathrm{K}$ [1]. Below the phase transition, between 300 K and 284 K, an equilibrium skyrmion lattice state occurs in weak magnetic fields in the range of 400 Oe. This state can be quenched down to lower temperatures by rapid field cooling. Below 150 K the metastable triangular skyrmion lattice transforms into a square lattice [2]. The magnetocrystalline anisotropy in the ferromagnetic phase was determined by ferromagnetic resonance measurements. We discuss its impact on the phase transition between the two types of skyrmion lattices. On cooling, the increasing cubic anisotropy constant K_1 seems to drive the phase transition of the skyrmion lattice between 150 K and 40 K. The temperature dependence of the corresponding critical fields turns out to be correlated to the anisotropy constant K_1.

[1] T. Hori et al., J. Magn. Magn. Mater. **310**, 1820–1822 (2007).
[2] K. Karube et al., Nature Materials **15**, 1237–1243 (2016).

TT 37.6 Tue 10:45 EB 301

Incommensurate magnetic systems studied with the multi-purpose three-axis spectrometer (TAS) MIRA at FRM II — •Robert Georgii[1], Tobias Weber[1,2], Georg Brandl[1], and Peter Böni[3] — [1]Maier-Leibnitz Zentrum (MLZ), Garching, Germany — [2]Institut Laue Langevin (ILL), Grenoble, France — [3]Physik Department E21, TU München, Garching, Germany

Incommensurate magnetic structures like Helimagnons and Skyrmions are currently intensively studied. Due to their large size and rigid structure they often show very low-lying excitations, where most of the interesting physics is taking place below some meV. The cold-neutron three-axis spectrometer MIRA is an instrument optimized for such low-energy excitations. Its excellent intrinsic resolution makes it ideal for studying incommensurate magnetic systems. Here we will present several examples for the dynamics of such structures which have been measured with MIRA.

TT 37.7 Tue 11:00 EB 301

Induction mapping of the 3D Spin Texture of Skyrmions in Thin Helimagnets — •Sebastian Schneider[1,2], Daniel Wolf[1], Matthew J. Stolt[3], Song Jin[3], Darius Pohl[1], Bernd Rellinghaus[1], Marcus Schmidt[4], Bernd Büchner[1], Sebastian T. B. Goennenwein[2], Kornelius Nielsch[1,2], and Axel Lubk[1] — [1]IFW Dresden, Dresden, Germany — [2]TU Dresden, Dresden, Germany — [3]University of Wisconsin-Madison, Madison, USA — [4]MPI CPfS, Dresden, Germany

Envisaged applications of skyrmions in magnetic memory and logic devices crucially depend on the stability and mobility of these topologically non-trivial magnetic textures in thin films. We present for the first time experimental evidence for a characteristic 3D modulation of the skyrmionic spin texture towards the sample surface. Inherent to this structure is the gradual change of the Bloch nature of the skyrmion in the depth of the film to surface chiral twists. By combining focal series inline electron holography (EH), and off-axis EH to quantitatively reconstruct the projected magnetic field pertaining to both the helical and the skyrmion lattice phase in single crystal nanoplates of the isotropic chiral magnet $Fe_{0.95}Co_{0.05}Ge$ nanoplate with electron tomography and magnetostatic simulations of the fields, we extract quantitative information on the 3D spin texture of skyrmions. Our results highlight the relevance of surfaces for the formation of skyrmions in thin film geometries and pave the way towards a surface-induced tailoring of the skyrmion structure.

15 minutes break

Topical Talk TT 37.8 Tue 11:30 EB 301

Composite topological excitations in ferromagnet-superconductor heterostructures — •Kjetil Hals — Department of Engineering Sciences, University of Agder, 4879 Grimstad, Norway

Heterostructures of conventional superconductors and ferromagnets are currently attracting considerable interest because of their potential use for realizing topological superconductivity. The combination of spin-orbit coupling in the superconductor and the lack of inversion symmetry of these heterostructures leads to a magnetoelectric coupling between the magnetic and superconducting order parameters [1, 2]. In this talk, I demonstrate that the magnetoelectric coupling causes magnetic skyrmions and superconducting vortices to bind, forming skyrmion-vortex pairs (SVPs) which represent topological excitations of the hybrid system [1]. I determine the conditions under which a bound SVP is formed, and characterize the range and depth of the effective binding potential through analytical estimates and numerical simulations. Furthermore, I develop a semiclassical description of the coupled skyrmion-vortex dynamics and discuss how SVPs can be controlled by applied spin currents.

[1] K.M.D. Hals, M. Schecter, M. S. Rudner, Phys. Rev. Lett. 117, 017001 (2016). [2] K. M. D. Hals, Phys. Rev. B 95, 134504 (2017).

TT 37.9 Tue 12:00 EB 301

Magnetoelectric effect and orbital magnetization in skyrmion crystals: new ways for detection and characterization of skyrmions — •Börge Göbel[1], Alexander Mook[2], Jürgen Henk[2], and Ingrid Mertig[1,2] — [1]Max-Planck-Institut für Mikrostrukturphysik, D-06120 Halle — [2]Institut für Physik, Martin-Luther-Universität, D-06120 Halle

Skyrmions are small magnetic quasiparticles, which are uniquely characterized by their topological charge and their helicity. We present theoretically how both properties can be determined without relying on real-space imaging [1].

The topological Hall effect of electrons allows to distinguish skyrmions from antiskyrmions by sign of the topological Hall conductivity [2,3] and the orbital magnetization [1]. Here, we predict a magnetoelectric effect in skyrmion crystals [1], which is the generation of a magnetization (polarization) by application of an electric (magnetic) field. Its dependence on the skyrmion helicity fits that of the classical toroidal moment of the spin texture and allows to differentiate skyrmion helicities: it is largest for Bloch skyrmions and zero for Néel skyrmions. We predict distinct features in the magnetoelectric polarizability that can be used to detect and characterize skyrmions in experiments.

[1] B. Göbel et al., submitted.
[2] B. Göbel et al., Phys. Rev. B **95**, 094413 (2017).
[3] B. Göbel et al., New J. Phys. **19**, 063042 (2017).

TT 37.10 Tue 12:15 EB 301

Antiferromagnetic skyrmion crystals: generation and topological spin Hall effect — •Börge Göbel[1], Alexander Mook[2], Jürgen Henk[2], and Ingrid Mertig[1,2] — [1]Max-Planck-Institut für Mikrostrukturphysik, D-06120 Halle — [2]Institut für Physik, Martin-Luther-Universität, D-06120 Halle

Skyrmions are topologically nontrivial, magnetic quasi-particles, that are characterized by a topological charge. A regular array of skyrmions—a skyrmion crystal (SkX)—features the topological Hall effect (THE) of electrons [1,2], that, in turn, gives rise to the Hall effect of the skyrmions themselves.

We present a generally applicable method to create stable antiferromagnetic skyrmion crystals (AFM-SkXs) by growing a two-sublattice SkX onto a collinear antiferromagnet. As an example we show that both types of skyrmion crystals—conventional and antiferromagnetic—exist in honeycomb lattices. While AFM-SkXs do not show a THE, they exhibit a topological spin Hall effect [3]. The zero skyrmion Hall effect carries over to isolated AFM skyrmions as well. They can move in straight lines, at higher velocities and need lower driving currents compared to conventional skyrmions [4,5].

[1] B. Göbel et al., Phys. Rev. B **95**, 094413 (2017).
[2] B. Göbel et al., New J. Phys. **19**, 063042 (2017).
[3] B. Göbel et al., Phys. Rev. B **96**, 060406(R) (2017).
[4] J. Barker et al., Phys. Rev. Lett. **116**, 147203 (2016).
[5] X. Zhang et al., Sci. Rep. **6**, 24795 (2016).

TT 37.11 Tue 12:30 EB 301

Topological Hall effect in Heusler compound $Mn_{1.4}PtSn$ — •Praveen Vir, Nitesh Kumar, Chandra Shekhar, and Claudia Felser — Max Planck Institute for Chemical Physics of Solids, 01187 Dresden, Germany

Skyrmions are topologically stable vortex-like spin structure which are considered as potential candidate for future high density memory devices. They have been detected in many chiral and polar compounds such as MnSi, FeGe, Co-Mn-Zn, GaV_4S_8 etc. Recently, with the help of Lorentz transmission electron microscopy, one new vortex like spin structure, so called antiskyrmions have been discovered in Mn-based tetragonal Heusler compound $Mn_{1.4}PtSn$ and $Mn_{1.4}Pt_{0.9}Pd_{0.1}Sn$ [1]. Antiskyrmion has been predicted to be anti-particle of Néel or Bloch type skyrmions becuase they annihilate with conventional skyrmions [2]. They are also topologically stable and consist of topological winding number or skyrmion number +1 [3]. Due to this topologically stable spin nature, it can give rise to non-vanishing Berry phase in real space. In other words, there could be nonzero topological Hall effect. Here, we report large topological Hall effect in single crystal of antiskyrmion hosting compounds $Mn_{1.4}PtSn$.

TT 37.12 Tue 12:45 EB 301

Prospecting anti-skyrmions in ultra-thin Co films deposited on W(110) — •Flaviano José dos Santos, Bernd Zimmermann, Stefan Blügel, Manuel dos Santos Dias, and Samir Lounis — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich & JARA, D-52425 Jülich, Germany

Recently, the possibility of anti-skyrmion formation in magnetic films on substrates with low symmetry due to anisotropic Dzyaloshinskii-Moriya interactions (DMI) has been demonstated [1]. Experimentally, such anisotropic DMI has been found for Co-films on W(110) [2]. Motivated by these findings, we investigated from first-principles the tensor of magnetic interactions of films containing up to three layers of Co reconstructed on W(110) surface as a continuation of our previous study [3]. We use the full-potential relativistic Korringa-Kohn-Rostoker Green function method combined with a technique employing infinitesimal rotations to access the different components of the tensor. The anisotropy, magnitude and sign of the interactions are analysed in detail with a focus on the DMI. Using atomistic spin dynamics simulations, we prospect and demonstrate the existence of skyrmions and anti-skyrmions, which depend strongly on the thickness of Co films. Finally, we unveil the spin-wave excitations characterising the topologically distinct skyrmionic objects.

Work supported by the Brazilian agency CAPES (Project No. 13703/13-7) and the European Research Council (ERC-consolidator Grant No. 681405-DYNASORE). [1] Nat. Commun. 8, 308 (2017); [2] Phys. Rev. B 95, 214422 (2017); [3] Phys. Rev. B 95, 134408 (2017).

TT 37.13 Tue 13:00 EB 301

Material systems for skyrmions in Co-based ferro-/antiferromagnetically (FM/AFM) coupled multilayers — •Hongying Jia, Bernd Zimmermann, Gustav Bihlmayer, and Stefan Blügel — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, D-52425 Jülich, Germany

Magnetic skyrmions, in particular AFM skyrmions, are considered as ideal candidates for high storage density information carriers due to the suppressed skyrmion Hall effect and a smaller size by canceling the dipolar fields. So far searching for materials that can host AFM skyrmions is still a challenging task. Magnetic multilayers (MMLs) with composite structures provide a great opportunity to design materials that can host spin-spirals, skyrmions or magnetic domains with optimal properties. Here we will present the qualitative trends of magnetic exchange interactions throughout a wide range of $\{Z|Co|Pt\}$

MMLs (Z=3d: Cu, Zn; 4d: Tc∼Cd; 5d: Au). The AFM coupling in between the Co layers was observed in $\{Z|\mathrm{Co}|\mathrm{Pt}\}$ MMLs (Z=Zn, Ru, Rh, Cd). The effects of 3d-4d-5d hybridization between Co and the nonmagnetic metals, in particular the effects around the Fermi level, on the magnetic interactions will be discussed. The correlation between the electric interface dipole moments and the sign and magnitude of the Dzyaloshinskii-Moriya interaction will be also discussed.

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