MA 47: Skyrmions IV (joint session MA/TT)

Time: Thursday 9:30–11:15 Location: POT 6

MA 47.1 Thu 9:30 POT 6

Exploring the tunability of skyrmion lifetimes in 3D materials
— •Markus Hoffmann, Gideon P. Müller, and Stefan Blügel — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

Chiral magnetic skyrmions are of great scientific interests but also of potential relevance in information technology, data storage, processing, and neuromorphic computing. To compete with existing technology, those skyrmions have to fulfill stringent requirements: Long lifetimes at room temperature at small sizes. Therefore, a significant effort of the magnetism community lies on the analysis of the stability of such small skyrmions. One commonly used approach is the calculation of energy barriers by performing LLG and GNEB simulations as well as the determination of the lifetime prefactor by HTST [1]. Up to now, those were mainly performed for skyrmions in 2D systems, *i.e.* atomic layers. For technological applications, however, the third dimension can play a significant role. Particularly magnetic multilayers as well as exchange biased materials are in the focus of interest for technologically relevant materials. Yet, little is known about the stability of skyrmions in such materials. We therefore performed lifetime calculations within our Spirit code [2] and investigated the tunability of skyrmion lifetimes by effects such as exchange bias or interlayer coupling.

We acknowledge funding from the DARPA TEE program through grant MIPR (#HR0011831554) from DOI.

[1] P. F. Bessarab *et al.*, Phys. Rev. B **85** (18), 184409 (2012)
[2] Spirit spin simulation framework, spirit-code.github.io

MA 47.2 Thu 9:45 POT 6

Electrical Transport in FIB microstructures of $Mn_{1.4}$PtSn
— •M. Winter[1,2], S. Hamann[1,3], J. Gayles[3], P. Vir[3], M. Uhlarz[1], M. König[3], C. Felser[3], J. Wosnitza[1,2], and T. Helm[1,3] — [1]Dresden High Magnetic Field Laboratory (HLD-EMFL), HZDR, Dresden, Germany — [2]Institute of Solid State and Materials Physics, TU Dresden, Dresden, Germany — [3]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany

$Mn_{1.4}$PtSn is a half-Heusler compound with tetragonal crystal structure. Only recently, Lorentz transmission electron microscopy measurements have shown that, so-called antiskyrmion phases can be stabilized by applying a magnetic field to the material. Futhermore, it is known that non-trivial magnetic structures such as skyrmions cause a topological contribution to the Hall effect. Therefore, investigations of the electrical transport properties of the material are highly desirable. By using a focused ion beam, we are able to produce samples with submicron feature size, close to the coherence length of the occurring magnetic structures, while maintaining the high quality of a single crystal. This opens the possibility to measure influences of the sample geometry, such as local effects and finite-size effects, on the topological Hall effect caused by the antiskyrmions in $Mn_{1.4}$PtSn.

MA 47.3 Thu 10:00 POT 6

Towards the 3D quantification of Skyrmions in thin helimagnets
— •Sebastian Schneider[1,2], Daniel Wolf[1], Matthew J. Stolt[3], Song Jin[3], Marcus Schmidt[4], Darius Pohl[2,1], Bernd Rellinghaus[2,1], Bernd Büchner[1], Sebastian T. B. Goennenwein[2], Kornelius Nielsch[1], 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

The anticipated application of skyrmions as information carriers in magnetic thin film devices depends crucially on the stability and mobility of these solitons. Within the scope of this work the microscopic magnetic structure of skyrmions, which determines their transport properties, is investigated by means of magnetic measurement methods in transmission electron microscopy. To study the three-dimensional spin texture of Bloch skyrmions in thin helimagnets of FeGe and $Fe_{0.95}Co_{0.05}Ge$ focal series electron holography and off-axis electron holography is employed to determine quantitative maps of the projected in-plane magnetic induction. Although these magnetic induction maps carry the clear signature of Bloch skyrmions, their magnitude is much smaller than the values expected for homogeneous skyrmions extending throughout the thickness of the film. Such a reduction can amongst others be caused by a modulation of the underlying spin textures along the out-of-plane z direction. To further analyse these modulations first electron holographic tomography experiments on Bloch skyrmions in an FeGe needle are performed.

MA 47.4 Thu 10:15 POT 6

Skyrmions for reservoir computing
— •Karin Everschor-Sitte — Institute of Physics, Johannes Gutenberg-University Mainz

The topological properties of magnetic skyrmions, their inherent compact particle-like nature and their complex and nonlinear dynamics make skyrmions interesting for spintronics applications and in particular unconventional computing schemes. [1] In this talk I will address the potential of magnetic skyrmions for reservoir computing, i.e. a computational scheme which allows to drastically simplify spatial-temporal recognition tasks. We have shown that random skyrmion fabrics provide a suitable physical implementation of the reservoir [2,3] and allow to classify patterns via their complex resistance responses either by tracing the signal over time or by a single spatially resolved measurement. [4]

[1] G. Finocchio et al., arXiv:1907.04601 [2] D. Prychynenko et al., Phys. Rev. Appl. **9**, 014034 (2018) [3] G. Bourianoff et al., AIP Adv. **8**, 055602 (2018) [4] D. Pinna et al., arXiv:1811.12623

MA 47.5 Thu 10:30 POT 6

Skyrmion size and shape within continuous magnetization model and atomistic spin model
— •Anastasiia S. Varentsova[1,2] and Pavel F. Bessarab[1,2,3] — [1]ITMO University, St. Petersburg, Russia — [2]University of Iceland, Reykjavík, Iceland — [3]Peter Grünberg Institute and Institute for Advanced Simulation, Forschungszentrum Jülich, Jülich, Germany

We explore the relationship between two approaches to the description of skyrmions in magnetic materials. One of the approaches involves characterization of magnetic states by a continuous magnetization field. Within the other approach, magnetic structures are represented by magnetic moments localized on vertices of a discrete lattice. By tracing contours of constant skyrmion size in the material parameter space, we demonstrate that the continuous magnetization model and the lattice model agree quite well for large skyrmions with smooth profiles, but predict different results for small skyrmions and skyrmions with bubble-like shape. We propose to link the two models by a material parameter transformation that does not rely on the assumption of small spatial variation of the magnetic structure on the scale of the lattice constant. As a result, good agreement between the continuous magnetization theory and the lattice model can be obtained for the whole skyrmion sector of the magnetic phase diagram.

This work was funded by the Russian Science Foundation (Grant No. 19-72-10138), the Icelandic Reseach Fund (Grant No. 184949-052) and Alexander von Humboldt Foundation.

MA 47.6 Thu 10:45 POT 6

Topologically Non-trivial Magnetic and Polar Patterns in Lacunar Spinels
— •Markus Preissinger[1], Hans-albrecht Krug von Nidda[1], Axel Lubk[2], Sándor Bordács[3], Hiroshi Nakamura[4], Vladimir Tsurkan[1], and István Kézsmárki[1] — [1]Experimentalphysik V, Universität Augsburg — [2]Advanced Methods of Electron Microscopy, IFW Dresden — [3]Magneto-Optical Spectroscopy Group, Budapest University of Technology and Economics — [4]Department of Materials Science and Engineering, Kyoto University

The lacunar spinels $Ga(V/Mo)_4(S/Se)_8$ have been the first candidates, where the emergence of Néel-type skyrmions, induced by Dzyaloshinsky-Moriya interaction, has been reported. This group of materials undergo a Jahn-Teller transition at about 40 K losing inversion symmetry in the process. Upon further cooling the system enters a magnetically ordered state. The ground state is a cycloidal phase, while critical fields strongly depend on the direction in which the magnetic field is applied [1][2]. In an attempt to image skyrmions with Lorentz-transmission-electron microscopy (LTEM), we succeeded to find the cycloidal ground state in thin lamellae of $GaV_4(S/Se)_8$ (<100nm) at a hugely increased temperature simultaneously to the Jahn-Teller distortion. In thin lamellae of $GaMo_4S_8$ no magnetic texture but a regular pattern of polarised structural domains has been found, presumably indicating polar skyrmions.

[1] I. Kézsmárki, NMAT 2015, Vol14, pp 1116-1122;

[2] S. Bordács Sci. Rep. 2017, Vol 7, Article number 7548

MA 47.7 Thu 11:00 POT 6

Hopfions in magnetic crystals — Filipp N. Rybakov[1], •Nikolai S. Kiselev[2], Aleksandr B. Borisov[3], Lukas Döring[4], Christof Melcher[4], and Stefan Blügel[2] — [1]Department of Physics, KTH-Royal Institute of Technology, SE-10691 Stockholm, Sweden — [2]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich & JARA, 52425 Jülich, Germany — [3]Institute of Metal Physics of Ural Branch of Russian Academy of Sciences, Ekaterinburg 620990, Russia — [4]Department of Mathematics I & JARA FIT, RWTH Aachen University, 52056 Aachen, Germany

Hopfions are three-dimensional topological solitons, which can be thought of as skyrmion tubes with closed ends. In the pioneering work of Bogolyubsky [1], it was shown that in the micromagnetic model with higher-order derivatives of the order parameter, the hopfions might appear as statically stable solutions. Here we show that the general form of such a micromagnetic functional can be derived from classical spin-lattice Hamiltonians with competing Heisenberg exchange interactions. We present this advanced micromagnetic functional derived for lattices of cubic symmetry and provide a criterion for the existence of hopfions in the systems described by such a functional [2]. Following our approach, similar functionals can be derived for materials of any crystal symmetry. We discuss a variety of hopfion solutions, their static and dynamic properties, and provide concrete guidance for the search of magnetic crystals that allow the existence of hopfions.

[1] I. L. Bogolubsky, Phys. Lett. A **126**, 511 (1988).
[2] F. N. Rybakov, *et al.*, arXiv:1904.00250.