MA 57: Focus Session: Spinorbitronics – from efficient charge/spin conversion based on spin-orbit coupling to chiral magnetic skyrmions III (joint session MA/TT)

Time: Friday 9:30–12:45 Location: H 1012

Invited Talk MA 57.1 Fri 9:30 H 1012

Manipulation of interface-induced Skyrmions studied with STM — •Kirsten von Bergmann — University of Hamburg, Germany

Isolated magnetic skyrmions are envisioned as the basis for future spintronic devices. They can be stabilized by a favorable interplay of magnetic exchange, Dzyaloshinskii-Moriya interaction (DMI), anisotropy and Zeeman energy. The Fe/Ir(111) interface is known to exhibit strong DMI [1] and serves as an ideal basis to build up materials that host single skyrmions on the nanometer length scale. Such small magnetic objects can be imaged, characterized and manipulated using (spin-resolved) scanning tunneling microscopy (STM) [2].

Building upon the Fe/Ir(111)-interface a fine-tuning of the relevant magnetic energies is performed by adding metallic overlayers, by adsorption of hydrogen, or by a variation of the strain within the magnetic film. Magnetic field dependent STM measurements can be used to obtain the specific material parameters [3]. In addition, spectroscopy using a non-magnetic tip electrode reveales the correlation between the local magnetoresistance and the non-collinearity of the spin texture [4]. Such a read-out of the local magnetic state could be combined with the demonstated reversible switching between skyrmion and ferromagnet by local electric fields [5].

[1] Heinze et al., Nature Phys. 7, 718 (2011). [2] von Bergmann et al., J. Phys.: Condens. Matter 26, 394002 (2014). [3] Romming et al., Phys. Rev. Lett. 114, 177203 (2015). [4] Hanneken et al., Nature Nanotech. 10, 1039 (2015). [5] Hsu et al., Nature Nanotech. 12, 123 (2017).

MA 57.2 Fri 10:00 H 1012

anisotropic DMI and micromagnetics of antiskyrmions — •Lorenzo Camosi[1], Olivier Fruchart[2], Stefania Pizzini[1], Stanislas Rohar[3], and Jan Vogel[1] — [1]Institut Néel , CNRS , Grenoble, France — [2]INAC-SPINTEC, CNRS, CEA, Grenoble, France — [3]LPS , CNRS , Orsay , France

A review of our pioneer works for understanding the Antiskyrmions physics in ultrathin magnetic layers is presented. They are topological chiral solitons that may be stabilized when the circular symmetry of the spin configuration is broken due to the inversion of the chirality between perpendicular directions.

In the first part of the talk we explain the relationship between crystal and Dzyaloshinskii-Moriya interaction (DMI)symmetry. Moreover the particular case of anisotropic dmi in ultrathin epitaxial Au/Co/W(110) is presented.

In the second part we show a combined analytical and numerical micromagnetic study of the equilibrium energy, size and shape of anti-skyrmionic magnetic configurations. Anti-skyrmions and skyrmions are compared in systems with the same strength of magnetic interactions. We show that in the presence of dipolar interaction energy of the anti-skyrmion is strongly reduced and its equilibrium size increased with respect to the skyrmion.

MA 57.3 Fri 10:15 H 1012

Skyrmions like it Hot - Temperature Dependence of the Skyrmion Hall Effect — •Kai Litzius[1,2,3], Pedram Bassirian[1], Jonathan Leliaert[4], Sascha Kromin[1], Jakub Zazvorka[1], Ivan Lemesh[5], Nico Kerber[1,2], Alexandra Churikova[5], Daniel Heinze[1], Niklas Keil[1], Markus Weigand[3], Gisela Schütz[3], Geoffrey S. D. Beach[5], and Mathias Klaeui[1,2] — [1]Institute of Physics, Johannes Gutenberg-University Mainz, 55099 Mainz, Germany — [2]Graduate School of Excellence Materials Science in Mainz, 55128 Mainz, Germany — [3]Max Planck Institute for Intelligent Systems, 70569 Stuttgart, Germany — [4]Department of Solid State Sciences, Ghent University, Krijgslaan 281-S1, B-9000 Ghent, Belgium — [5]Department of Materials Science and Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA

Magnetic skyrmions are topologically stabilized nanoscale spin structures that show promise for future spintronic devices. It was found very recently that during their dynamics a sizeable skyrmion Hall angle (SkHA) occurs that surprisingly depends on the skyrmion velocity. [1,2] Different theoretical models have been put forward for the creep [2] and viscous flow [1] regime. By X-ray microscopy, we investigate reproducible skyrmion trajectories at varying temperatures. We find that the angle is independent of the temperature when plotted against the skyrmion velocity and identify two different mechanisms that lead to distinctly different spin Hall angles in the creep and the flow regimes. References: [1] K. Litzius et al., Nat. Phys. 13, 170-175 (2017). [2] W. Jiang et al., Nat. Phys. 13, 162-169 (2017).

MA 57.4 Fri 10:30 H 1012

Bi-stable skyrmion states in Pt/Co/Ir multilayer nanodots as a switchable information memory — •Mateusz Zelent[1], Michał Mruczkiewicza[2], Jaroslav Tóbik[2], Konstantin Guslienko[3,4], and Maciej Krawczyk[1] — [1]Faculty of Physics, Adam Mickiewicz University in Poznan, Poznan, Poland — [2]Institute of Electrical Engineering, Slovak Academy of Sciences, Bratislava, Slovakia — [3]Depto. Fisica de Materiales, Universidad del País Vasco, UPV/EHU, San Sebastian, Spain — [4]IKERBASQUE, the Basque Foundation for Science, Bilbao, Spain

The magnetic skyrmion stability was studied numerically in circular Pt/Co/Ir multilayer stacks with perpendicular magnetic anisotropy and interface Dzyaloshinskii-Moriya interaction (DMI). We have found bi-stable system which can be found in one of the two distinct skyrmion states differing in the skyrmion radius. We demonstrated that two skyrmions can be stabilized due to the different mechanism, primary DMI or primary magnetostatic interaction, leading to small and large size skyrmions, respectively. We developed a technique to compute the total energy of magnetic configurations as a function of the skyrmion diameter, which allows us to estimate the potential barrier between stable states and to explain the influence of dipolar energy contribution on bi-stable skyrmion formation in multilayer dot systems and skyrmion formation in general. Our result can open a new route to develop an efficient skyrmion based memory, with information bit coded as a skyrmion's size. Funded from the EU Horizon 2020, G.A. No. 644348.

MA 57.5 Fri 10:45 H 1012

Skyrmion lifetimes in exchange frustrated ultrathin films — •Stephan von Malottki[1], Pavel Bessarab[2], Anna Delin[3], and Stefan Heinze[1] — [1]Institute of Theoretical Physics and Astrophysics, University of Kiel — [2]School of Engineering and Natural Sciences - Science Institute, University of Iceland — [3]Department of Applied Physics, School of Engineering Sciences, KTH, Kista

The thermal stability of magnetic skyrmions is a key issue for potential applications in spintronic devices. An Arrhenius law can be used to describe the skyrmion lifetime as a function of temperature, which requires knowledge of the energy barrier and the pre-exponential factor. While the energy barrier has already been adressed by several studies [1], the pre-exponential factor for the skyrmion collapse remains unexplored [2,3].

Here, we adress the dependence of the pre-exponential factor on the external magnetic field and demonstrate that it changes qualitatively when exchange frustration is taken into account. We focus on the model system Pd/Fe/Ir(111) [4], described by an atomistic spin model based on parameters from density functional theory [1]. In our approach, the minimum energy paths and thereby the energy barriers are calculated by the geodesic nudged elastic band method, while the pre-exponential factors are determined by harmonic transition state theory [3].

[1] von Malottki *et al.*, Sci. Rep. **7**, 12299 (2017)
[2] J. Wild *et al.*, Sci. Adv. **3.9**, e1701704 (2017)
[3] P. F. Bessarab *et al.*, arXiv:1706.07173v2 (2017)
[4] N. Romming *et al.*, Phys. Rev. Lett. **114**, 177203 (2015)

30 minutes break

Invited Talk MA 57.6 Fri 11:30 H 1012

Magnonics in skyrmion-hosting chiral magnetic materials — •Markus Garst — Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden, Germany

Chiral magnets with a Dzyaloshinskii-Moriya interaction possess spatially modulated phases of the ferromagnetic order parameter like helices and skyrmion lattices. We give an overview of the properties of spinwave excitations in such materials [1]. In the presence of a magnetic field, the magnons are characterized by an inherent non-reciprocity, i.e., their dispersion lack reflection symmetry. We discuss the evolution of non-reciprocity as a function of magnetic field, which has been determined by inelastic neutron scattering on MnSi [2,3]. Moreover, Bragg reflection off the periodicity of the magnetic textures naturally result in magnon band structures. This band structure is topologically non-trivial for the skyrmion lattice due its emergent electrodynamics, which is reflected in non-trivial Chern numbers implying the presence of robust magnon edge states [1]. In addition, we discuss the ferromagnetic resonances of the various phases [4] and their non-reciprocity, which has been experimentally probed by spin-wave spectroscopy and Brillouin light scattering.

[1] M. Garst, J. Waizner, and D. Grundler, J. Phys. D: Appl. Phys. 50, 293002 (2017) [2] M. Kugler, et al. Phys. Rev. Lett. 115, 097203 (2015) [3] T. Weber et al. arXiv:1708.02098 [4] T. Schwarze et al. Nat. Mat. 14, 478 (2015)

MA 57.7 Fri 12:00 H 1012

Field-free deterministic ultrafast creation of magnetic skyrmions by spin–orbit torques — Felix Büttner[1], Ivan Lemesh[1], Michael Schneider[2], •Bastian Pfau[2], Christian M. Günther[2,3], Piet Hessing[2], Jan Geilhufe[2], Lucas Caretta[1], Dieter Engel[2], Benjamin Krüger[4], Jens Viefhaus[5], Stefan Eisebitt[2], and Geoffrey S. D. Beach[1] — [1]Massachusetts Institute of Technology, Cambridge, USA. — [2]Max-Born-Institut, Berlin, Germany. — [3]TU Berlin, Berlin, Germany. — [4]Institut für Lasertechnologien in der Medizin und Messtechnik an der Universität Ulm, Ulm, Germany. — [5]Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany.

Magnetic skyrmions are a very promising option to realize current-driven magnetic shift registers. Generation, transport and annihilation of skyrmions are fundamental operations in this context. We study the generation and intrinsic dynamics of bubble skyrmions via static and time-resolved X-ray holography, combining sub-30 nm spatial resolution with sub-100 ps temporal resolution. It is demonstrated that single skyrmions can be generated deterministically on subnanosecond timescales in magnetic racetracks using spin–orbit torque pulses. Externally applied in-plane magnetic fields are not required in the process. Furthermore, results on the GHz dynamical behavior of bubble skyrmions are presented, where precision observation of the skyrmion trajectory is indicative of the presence of an inertial mass, connected to the skyrmion topology.

MA 57.8 Fri 12:15 H 1012

Speed limits for Skyrmions — •Jan Müller[1], Ben McKeever[2,3], and Karin Everschor-Sitte[3] — [1]Institut für Theoretische Physik, Universität zu Köln, 50937 Köln, Deutschland — [2]Graduate School Materials Science in Mainz, 55128 Mainz, Germany — [3]Institut für Physik, Johannes Gutenberg-Universität Mainz, 55128 Mainz, Deutschland

Magnetic skyrmions are particle-like textures in the magnetization, characterized by a topological winding number. Nanometer-scale skyrmions have been observed at room temperature in magnetic multilayer structures. The combination of small size, topological quantization, and their efficient electric manipulation makes them interesting candidates for information carriers in high-performance memory devices which rely on mobile bits. Skyrmion racetrack memory devices have been suggested where skyrmions move in a one-dimensional nanostrip. The information in the racetracks is encoded either in the distance between skyrmions or in additional attributes of these, e.g. shifts from the center of the track or different winding numbers. In order to drive skyrmions along the racetrack, it is often suggested to apply spin-polarized currents. Besides moving the skyrmions, the applied currents, however, also deform them, which is usually assumed a negligible effect. We study these deformations and show that they trigger an instability which ultimately sets a speed limit in the racetracks.

MA 57.9 Fri 12:30 H 1012

Skyrmion-Antiskyrmion racetrack memory in rank-1 DMI materials — M. Hoffmann[1], B. Zimmermann[1], G. P. Müller[1,2], N. S. Kiselev[1], C. Melcher[3], and •S. Blügel[1] — [1]Peter Grünberg Institut & Institute for Advanced Simulation, Forschungszentrum Jülich & JARA, Jülich, Germany — [2]Science Institute of the University of Iceland, VR-III, Reykjavík, Iceland — [3]Department of Mathematics I & JARA FIT, RWTH Aachen University, Aachen, Germany

Recently, we extended the scope of skyrmions and antiskyrmions and introduced a classification scheme of chiral magnets [1]. Typically investigated Bloch-type skyrmions in B20 alloys and Néel-type skyrmions at (111) oriented interfaces belong to isotropic rank-three DM bulk and rank-two DM film magnets with a DM interaction described by a single spiralization constant. Within this class, antiskyrmions are stable only for bulk crystals with certain point group symmetries. New are the anisotropic rank-two DMI film magnets where skyrmions and antiskyrmions can coexist while the determinant of the spiralization tensor determines which of them has lower energy. Finally, zero determinant indicates a rank-one DMI material in which skyrmions and antiskyrmions have the same energy. Here, we discuss our new classification scheme and discuss the potential of rank-one solids for the design of a racetrack memory based on the coexistence of skyrmions and antiskyrmions where the information is encoded in the object type instead of the presence or absence of a skyrmion [2].

[1] M. Hoffmann et al., Nat. Commun. 8, 308 (2017)
[2] M. Hoffmann et al., to be submitted