# MA 61: Skyrmion Dynamics

Time: Friday 9:30–11:30 Location: HSZ 401

MA 61.1 Fri 9:30 HSZ 401

**Quantifying the Dzyaloshinskiĭ Moriya Interaction using traveling waves with stationary envelopes** — •Benjamin Zingsem[1], R. E. Camley[2], R. Salikhov[1], R. Meckenstock[1], D. Spoddig[1], R. L. Stamps[3], and M Farle[1] — [1]Faculty of Physics and Center for Nanointegration (CENIDE), University Duisburg-Essen, 47057 Duisburg, Germany — [2]Center for Magnetism and Magnetic Nanostructures, University of Colorado at Colorado Springs, Colorado Springs, Colorado 80918, USA — [3]SUPA, School of Physics and Astronomy, University of Glasgow, Glasgow G12 8QQ, UK

In the presence of Dzyaloshinskii Moriya Interaction (DMI) the magnon dispersion becomes nonreciprocal [1], meaning that counter-propagating waves of the same frequency have different wavevectors. In this combined experimental and theoretical study, we show that this property implies that spinwave eigenmodes of confined systems, such as nanodots, exibit unusual dynamics i.a. they posess aspects of propagating and standing waves. This new type of *standing wave* results in eigenmodes, emerging at microwave excitations (e.g. ferromagnetic resonance (FMR)), which would be undetectable wihtout DMI. Thus the presence of DMI imposes a unique fingerprint on FMR spectra of confined systems which allows for unambigous quantification of the DMI. [2]

[1] J-H Moon, et al. Phys. Rev. B, 88:184404, Nov 2013. [2] Benjamin W. Zingsem, Michael Farle, Robert L. Stamps, and Robert E. Camley. The unusual nature of confined modes in a chiral system. arXiv:1609.03417, 2016.

MA 61.2 Fri 9:45 HSZ 401

**Isolated skyrmion dynamics in confined helimagnetic nanostructures** — •Marijan Beg[1], David I. Cortés-Ortuño[1], Weiwei Wang[1,2], Rebecca Carey[1], Mark Vousden[1], Ondrej Hovorka[1], and Hans Fangohr[1] — [1]Faculty of Engineering and the Environment, University of Southampton, Southampton, SO17 1BJ, United Kingdom — [2]Department of Physics, Ningbo University, Ningbo, 315211, China

Understanding the dynamic response of skyrmionic states is of importance both from the aspect of fundamental physics as well as for their manipulation. We explore the isolated skyrmion ground state dynamics in a 150 nm diameter FeGe disk sample at zero external magnetic field using a full three-dimensional model, which includes the demagnetisation energy and does not make any assumptions about the translational invariance of magnetisation in the out-of-film direction. We compute all existing eigenmodes employing the eigenvalue method, and then, using the ringdown method we determine which eigenmodes can be excited using two different experimentally feasible excitations (in-plane and out-of-plane). Finally, we investigate how the resonant frequencies change when the external magnetic bias field and the disk sample diameter are varied. We observe the existence of only one gyrotropic and one breathing low-frequency eigenmode, and the field-dependent power spectral density maps suggest that the gyrotropic eigenmode is the reversal mode of an isolated skyrmion state. This work was supported by the EPSRC's EP/G03690X/1 and EP/N032128/1 grants and the Horizon 2020 European Research Infrastructure project (676541).

MA 61.3 Fri 10:00 HSZ 401

**Motion of higher-order skyrmions driven by spin-orbit torques** — •Ulrike Ritzmann[1], Stephan von Malottki[2], Joo-Von Kim[3], Karin Everschor-Sitte[1], Jairo Sinova[1], Stefan Heinze[2], and Bertrand Dupé[1] — [1]Johannes Gutenberg Universität Mainz, Mainz, Germany — [2]Christian-Albrechts-Universität zu Kiel, Kiel, Germany — [3]Centre de Nanosciences et de Nanotechnologies, CNRS, Univ. Paris-Sud, Université Paris-Saclay, Orsay, France

Skyrmions are topologically stabilized spin structures on the nanometer scale. They can be manipulated with electric current densities that are orders of magnitude lower than those required for moving domain walls. Especially, isolated magnetic skyrmions can also occur in ultrathin transition metal films at surfaces [1,2] and interfaces [3].

We have shown previously that skyrmions exist in these systems due to a competition between magnetic interactions beyond the first nearest neighbour approximation. We have found that this competition can stabilize higher order skyrmions in Pd(fcc)/Fe/Ir(111) such as antiskyrmions (S=-1) and higher order antiskyrmions (S=-2) [4].

Here, we present a study on the motion of these skyrmions via spin transfer torques. The displacement of skyrmions can be described in a rigid-body approximation [5], whereas the motions of antiskyrmions require to take internal degrees of freedom into account.

[1] Romming et al., Science 341, 636 (2013); [2] B. Dupé et al., Nat. Commun. 5, 4030 (2014); [3] B. Dupé et al., Nat. Commun. 7, 11779 (2016); [4] B. Dupé et al., New J.Phys. 18, 055015 (2016); [5] Thiele, Phys. Rev. Lett. 30, 230 (1973)

MA 61.4 Fri 10:15 HSZ 401

**Towards ferromagnetic resonance in scanning tunnelling microscopy using homodyne detection** — •Marie Hervé, Moritz Peter, Timofey Balashov, and Wulf Wulfhekel — Physikalisches Institut, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

We report on the experimental development of a technique combining ferromagnetic resonance (FMR) and spin-polarized STM. The concept of this technique, inspired by the spin torque diode effect [1], is based on the homodyne detection of the resonance signal. A continuous radio-frequency (rf) voltage is mixed to the bias voltage of the STM. If there is a magnetization precession under the STM tip, the tunneling conductance will be modulated at the resonance frequency. When the rf signal mixed to the tunneling junction hits the resonance frequency of the precession, the tunneling current is rectified. This rectified current can be detected by a conventional transimpedance amplifier. To test this method we investigated the skyrmionic spin structure Fe(0.4ML)/Ir(111) [2]. The experiments allowed to reveal a resonant signal at 615 MHz. This signal is interpreted as a FMR feature.

[2] A. A. Tulapurkar, Y. Suzuki, A. Fukushima, H. Kubota, H. Maehara, K. Tsunekawa, D. D. Djayaprawira, N. Watanabe and S. Yuasa, Nature 438, 339 (2005) [4] S. Heinze, K. von Bergmann, M. Menzel, J. Brede, A. Kubetzka, R. Wiesendanger, G. Bihlmayer and S. Blügel, Nature Physic 7, 713 (2011)

MA 61.5 Fri 10:30 HSZ 401

**Short Wavelength Magnons in Magnetic Vortex Structures** — Georg Dieterle[1], •Johannes Förster[1], Ajay Gangwar[2], Markus Weigand[1], and Sebastian Wintz[3,4] — [1]Max-Planck-Institut für Intelligente Systeme, Stuttgart — [2]Universität Regensburg — [3]Paul Scherrer Institut, Villigen, Schweiz — [4]Helmholtz Zentrum Dresden-Rossendorf

In recent years magnonics has become one of the prime topics in magnetics research. The prospect of possible technological applications has played a major part in this development. The reliable generation of spin waves with short wavelengths is an ongoing challenge in this field, as it is difficult by means of a patterned stripline antenna. Here we report on the imaging of spiral shaped short wavelength spin waves emitted by a magnetic vortex core in a permalloy disc. We take advantage of the magnetic perturbation generated by the small moving core, 10-20nm in diameter, to generate spin waves of sub-100nm wavelength. Imaging of these waves has been done using Time-Resolved Scanning Transmission X-Ray Microscopy at the MAXYMUS endstation of the BESSY II synchrotron facility [1]. The experimentally derived dispersion relations match with analytical expressions for hybridized modes between Damon-Eshbach and exchange dominated magnons in infinite ferromagnetic films. This holds as well for our micromagnetic simulations in these vortex structures.

[1] M. Noske et al., J. Appl. Phys. 119, 173901 (2016)

MA 61.6 Fri 10:45 HSZ 401

**Skyrmion production on demand by homogeneous DC currents** — •Karin Everschor-Sitte[1], Matthias Sitte[1], Thierry Valet[1], Jairo Sinova[1,2], and Artem Abanov[3] — [1]JGU Mainz, Germany — [2]Academy of Sciences of the Czech republic, Czech Republic — [3]Texas A&M University, USA

Topological magnetic textures – skyrmions – have become a major player in the design of next-generation magnetic storage technology due to their stability and the control of their motion by ultra-low current densities. A major challenge to achieve this new skyrmion-

based technology is the controlled and systematic creation of magnetic skyrmions without the need of complex setups. We demonstrate a solution to this challenge by showing how to create skyrmions and other magnetic textures in ferromagnetic thin films by means of a homogeneous DC current and without requiring any standard "twisting" interactions like Dzyaloshinskii-Moriya. This is possible by exploiting a dynamical instability arising by the interplay of current-induced spin-transfer torque and locally engineered anisotropies. The magnetic textures are created controllably, efficiently, and periodically with a period that can be tuned by the applied current strength. We propose specific experimental setups realizable with simple materials, such as cobalt or permalloy, to observe the periodic formation of skyrmions. Thus our findings allows for the production of skyrmions on demand in simple ferromagnets by homogeneous DC currents.

MA 61.7 Fri 11:00 HSZ 401

**Single magnetic skyrmions and skyrmion clusters in the helical phase** — •Jan Müller[1], Rajeswari Jayaraman[2], Fabrizio Carbone[2], and Achim Rosch[1] — [1]Institut für Theoretische Physik, Universität zu Köln, D-50937 Köln, Germany — [2]École Polytechnique Fédérale de Lausanne, CH-1015 Lausanne, Switzerland

Magnetic skyrmions are tiny magnetic whirls which can be stabilized by spin-orbit interactions in magnets lacking inversion symmetry. They are small, extremely stable and can be manipulated by tiny forces. The properties of skyrmions embedded in a ferromagnetic environment have been intensively studied. I will show that within our numerical simulations single skyrmions and clusters of skyrmions can also form in a helical phase and investigate theoretically the energetics and dynamics of such skyrmions. The helical background provides natural one-dimensional channels along which a skyrmion can move rapidly. In contrast to skyrmions in ferromagnets, the skymion-skyrmion interaction has a strong attractive component and thus skyrmions tend to form clusters with characteristic shapes. These clusters are directly observed in transmission electron microscopy measurements in films of the insulating skyrmion material $Cu_2OSeO_3$. Topological quantization, high mobility and the confinement in channels may be useful for future spintronics devices.

MA 61.8 Fri 11:15 HSZ 401

**Magnetic Skyrmions on a Two-Lane Racetrack** — •Jan Müller — Institut für Theoretische Physik, Universität zu Köln, D-50937 Köln, Germany

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. A skyrmion racetrack memory has been suggested where information is encoded in the distance between skyrmions moving in a one-dimensional nanostrip. Here, I propose an alternative design where skyrmions move in two (or more) parallel lanes and the information is stored in the lane number of each skyrmion. Such a multilane track can be constructed by controlling the height profile of the nanostrip. Repulsive skyrmion-skyrmion interactions in narrow nanostrips guarantee that skyrmions on different lanes cannot pass each other. Current pulses can be used to induce a lane change. Combining these elements provides a robust, efficient design of skyrmion-based storage devices.