MA 44: Non-Skyrmionic Magnetic Textures

Time: Thursday 15:00–17:45 Location: EB 301

Invited Talk MA 44.1 Thu 15:00 EB 301

Synthetic antiferromagnets with ferromagnetic domains separated by antiferromagnetic domain walls — •Ruslan Salikov[1], Fabian Samad[1,2], Sebastian Schneider[3], Darius Pohl[3], Bernd Rellinghaus[3], Jürgen Lindner[1], Nikolai Kiselev[4], and Olav Hellwig[1,2] — [1]HZDR, Dresden, Germany — [2]TU Chemnitz, Chemnitz, Germany — [3]TU Dresden, Dresden, Germany — [4]Forschungszentrum Jülich, Jülich, Germany

Magnetic nanostructures, such as magnetic domains or magnetic solitons, hold significant potential for advancing data processing, storage, and neuromorphic type of applications. Through the utilization of $[[\text{Co/Pt}]_{X-1}/\text{Co/Ru}]_{N-1}[\text{Co/Pt}]_X$ multilayer metamaterials, we stabilize mixed ferromagnetic/antiferromagnetic (FM/AF) textures. These textures exhibit FM perpendicular stripe and bubble domains, separated by AF Bloch-type domain walls. The acquired bubble domains, characterized by alternating chirality, unveil a promising avenue for three-dimensional memory and logic, combined with the skyrmionic race track memory concept.

MA 44.2 Thu 15:30 EB 301

Tracking the field-induced motion of three-dimensional nanoscale topological magnetisation textures — •Jeffrey Neethi Neethirajan[1], Nicholas William Phillips[2], Marisel Di Pietro Martinez[1], Luke Turnbull[1], Valerio Scagnoli[2,3], Simone Finizio[2], Lars Heller[2], Sandra Ruiz Gomez[1], Klaus Wakonig[2], Mirko Holler[2], Manuel Guizar-Sicairos[2,4], and Claire Donnelly[1,5] — [1]MPI-CPfS, Dresden, Germany — [2]PSI, Villigen, Switzerland — [3]ETH, Zurich, Switzerland — [4]EPFL, Lausanne, Switzerland — [5]WPI-SKCM2, Hiroshima, Japan

Imaging of the nanoscale magnetic configuration of extended systems offers the possibility to study topological magnetic textures in three-dimensional (3D) real space. Indeed, since the development of X-ray magnetic vector tomography and laminography, the static magnetisation configuration of Bloch points, vortex rings and torons has been elucidated. However, it has not yet been possible to directly observe the response of such 3D textures to stimuli such as applied magnetic fields. Here, we image 3D magnetic configuration of a bulk GdCo2 ferrimagnet, which consists of a complex network of topological textures and singularities. By performing field-dependent X-ray magnetic laminography, we track the field-driven response of the 3D magnetic configuration, and observe the propagation of textures in the magnetisation in 3D space. In this way, we are able to gain insights into the creation, propagation and annihilation of topological magnetization textures from quasi-static measurements, important both fundamentally as well as for prospective technologies.

MA 44.3 Thu 15:45 EB 301

Non-coplanar helimagnetism in the layered van-der-Waals metal DyTe_3 — Shun Akatsuka[1], •Sebastian Esser[1], Jonathan White[2], Rinsuke Yamada[1], Seno Aji[3], Shang Gao[4], Yoshichika Onuki[5], Taka-hisa Arima[1,5], Taro Nakajima[3,5], and Max Hirschberger[1,5] — [1]University of Tokyo, Japan — [2]PSI, Switzerland — [3]ISSP, University of Tokyo, Japan — [4]University of Science and Technology of China, China — [5]RIKEN CEMS, Japan

Layered van-der-Waals (vdW) materials are typified by highly anisotropic chemical bonds, enabling exfoliation to realize ultrathin sheets or interfaces. When combined with magnetism, such materials are promising candidates for novel cross-correlation phenomena between electric polarization and the magnetic texture itself. However, the vast majority of these vdW magnets are collinear ferro-, ferri-, or antiferromagnets, with a particular scarcity of lattice-incommensurate helimagnets of well-defined left- or right-handedness. Here we report on the magnetic order of DyTe_3, where insulating double-slabs of Dy-square nets are separated by highly metallic Te-layers.

This cleavable metallic helimagnet hosts a complex magnetic phase diagram, indicative of competing interactions. At high temperatures, above the transition to three-dimensional long-range order, we observe evidence for short-range correlations in individual two-dimensional structural block layers. Our work paves the way for twistronics research, where helimagnetic layers can be combined to form complex spin textures on-demand, using the vast family of rare earth chalcogenides, and beyond.

MA 44.4 Thu 16:00 EB 301

Local control over chiral textures with curvilinear helimagnets — •Luke Turnbull[1], Max Birch[2], Marisel Di Pietro Martinez[1], Rikako Yamamoto[1,3], Jeffrey Neethirajan[1], Marina Raboni Ferreira[1,4], Simone Finizio[5], Sebastian Wintz[6], Rachid Belkhou[7], Claas Abert[8], Dieter Suess[8], and Claire Donnelly[1] — [1]MPI-CPfS, Dresden, Germany — [2]RIKEN CEMS, Saitama, Japan — [3]WPI-SKCM2, Hiroshima, Japan — [4]LNLS, São Paulo, Brazil — [5]PSI, Villigen, Switzerland — [6]HZB, Berlin, Germany — [7]SOLEIL, Saint Aubin, France — [8]University of Vienna, Vienna, Austria

Precise control over the magnetic energy landscape is key for the stabilisation and control of topological magnetisation textures. Until now this has been commonly achieved with the bulk Dzyaloshinskii-Moriya interaction (DMI), a chiral interaction that arises due to broken crystalline inversion symmetry. But recently, there have also been proposals to make use of geometric symmetry breaking with curvature. Here we combine intrinsic and extrinsic interactions in patterned toroidal helimagnets, resulting in a locally varying DMI. Specifically, by patterning nanoscopic tori of single crystal helimagnets and imaging their magnetisation configuration using x-ray ptychographic imaging, we observe the presence of a radial curvature-induced helical texture, that we confirm with finite element micromagnetic simulations. Our work highlights the impact of curvature on chiral helimagnetism, offering opportunities to tailor chiral magnetic textures within curvilinear geometries.

MA 44.5 Thu 16:15 EB 301

Screw dislocations and fractional hopfion rings in chiral magnets — •Maria Azhar — Faculty of Physics and Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg-Essen, 47057 Duisburg, Germany

In chiral magnets, topological defects such as Skyrmions and Hopfions are typically considered in a ferromagnetic background. Recently we predicted that helical phases offer a plethora of novel topological spin textures including screw dislocations where the helical order locally arranges as a spiral staircase [1]. These new topological spin structures, which appear in many facets and look very different locally, have the remarkable property that their far field is universally determined by a topological index ν characterizing the dislocation. Intriguingly, we identify screw dislocations with a smooth magnetic core and a simple screw structure ($\nu = +1$), that can be continuously deformed either to vortices of the XY-order parameter or to vortex strings encircled by fractional Hopfion rings. The latter prediction has recently been experimentally confirmed by means of transmission electron microscopy [2]. Another astonishing spin structure that we predicted arises from a singular core comprising a chain of Bloch points with alternating topological charge. Our findings enrich the portfolio of topological magnetic structures ubiquitously being present in bulk and thin-film helimagnets and will play a crucial role on the way to 3D nanomagnet and spintronics applications.

[1] M. Azhar, V. Kravchuk, and M. Garst, PRL 128, 157204 (2022)
[2] F. Zheng, et al. Nature 623, 718 (2023).

15 min. break

MA 44.6 Thu 16:45 EB 301

Spacetime Magnetic Hopfions from Internal Excitations and Braiding of Skyrmions — •Ross Knapman[1,2], Timon Tausendpfund[2], Sebastián A. Díaz[1,3], and Karin Everschor-Sitte[1] — [1]Faculty of Physics and Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg-Essen, Duisburg 47057, Germany — [2]Institute of Physics, Johannes Gutenberg University Mainz, 55128 Mainz, Germany — [3]Department of Physics, University of Konstanz, 78457 Konstanz, Germany

Magnetic hopfions are three dimensional topological magnetic textures for which the topology is typically defined in terms of space, and time plays only a secondary role in terms of the structures' dynamics. We construct the "spacetime magnetic hopfion", in which the temporal dimension plays an active role in the definition of the structure's topology [1]. We use two approaches: the rotation of a skyrmion's helicity in a frustrated magnet, and the braiding of two skyrmions around one another. The emphasis is placed on the first case, where we use a Ginzburg-Landau description of the system [2] to model the skyrmion's internal modes using micromagnetic and collective coordinate modelling. In tuning the time dependence of the externally applied electric field, we show that it is possible to induce dynamics which realise spacetime magnetic hopfions. We envisage such structures to exist in other areas of physics, outside of magnetic systems.

[1] Knapman, R., Tausendpfund, T., Díaz, S. A., Everschor-Sitte, K., arXiv:2305.07589 (2023).

[2] Lin, S. Z., Hayami, S., Phys. Rev. B **93**, 064430 (2016).

MA 44.7 Thu 17:00 EB 301

From Ferromagnetic Magnetostatics to Antiferromagnetic Topology: Antiferromagnetic Vortex States in NiO-Fe Nanostructures — Michał Ślezak[1], •Tobias Wagner[2], V.K. Bharadwaj[2], Anna Kozioł-Rachwał[1], Tomasz Ślezak[1], and Olena Gomonay[2] — [1]AGH University of Science and Technology, Faculty of Physics and Applied Computer Science, Kraków, Poland — [2]Institut für Physik, JGU Mainz, Germany

Magnetic vortices are topological spin structures commonly found in ferromagnets. However, they are novel for antiferromagnets. In particular, Wu et al. observed the interface-exchange-coupling-dependent transfer of the Fe vortex state to the coupled CoO or NiO layer for patterned microstructures [1]. We experimentally demonstrate that in a nanostructured antiferromagnetic-ferromagnetic hybrid bilayer, a magnetic vortex naturally stabilizes by magnetostatic interactions in the Fe(110) and imprints onto the adjacent NiO(111) via interface exchange coupling. We assume the coupling to be collinear, as recently reported in continuous NiO(111)-Fe(110) bilayers by Ślęzak et al. [2]. Our micromagnetic simulations elucidate the mechanism for the existence of antiferromagnetic vortex states [3]. We find that the interplay between the interface exchange coupling and the antiferromagnetic anisotropy plays a crucial role in locally reorienting the Néel vector out-of-plane in the prototypical in-plane antiferromagnet NiO and thereby stabilizing the vortices in the antiferromagnet. [1] Wu, J. et al. Nat. Phys. 7, 303-306 (2011). [2] Ślęzak, M. et al. Nanoscale 12, 18091-18095 (2020). [3] Ślęzak, M., Wagner, T. et al., in preparation.

MA 44.8 Thu 17:15 EB 301

Three-dimensional reconstruction, magnetization statics and dynamics in innovative curved nanoarchitectures. — •Jose A. Fernandez-Roldan[1], Olha Bezsmertna[1], Rui Xu[1], Oleksii M. Volkov[1], Oleksandr V. Pylypovskyi[1,2], Ondřej Wojewoda[3], Florian Kronast[4], Claas Abert[5], Dieter Suess[5], Michal Urbánek[3], Jürgen Fassbender[1], and Denys Makarov[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Germany — [2]Kyiv Academic University,Ukraine — [3]CEITEC BUT, Brno University of Technology, Czech Republic — [4]Helmholtz-Zentrum Berlin für Materialien und Energie, Germany — [5]University of Vienna, Austria

Recent efforts have focused on exploring three-dimensional (3D) and curved magnetic nanostructures for nanoelectronics, sensorics, and computing, especially emphasizing spin textures and dynamics [1, 2]. However, studies on lattices of nanoarchitectures based on curved 3D elements are limited. Here we explore the properties of innovative, highly regular FeNi lattices of complex geometries [3]. A meticulous 3D reconstruction of the geometry coupled with modelling confirm that this system enables topologically non-trivial magnetic excitations in a high number. Dynamical measurements in combination with modelling confirm a switchable gap and local non-linear excitations. Overall, this system collects unique properties for becoming a captivating platform for advanced technologies in nanoelectronics and computing.

1. D. Makarov et al., Adv.Mater. 34(3), 2101758 (2022).
2. J. A. Fernandez-Roldan et al., APL Materials 10, 111101 (2022).
3. R. Xu, et al., Nat Commun 13, 2435 (2022).

MA 44.9 Thu 17:30 EB 301

Relativistic domain wall motion in ferrimagnets — •Pietro Diona — Scuola Normale Superiore di Pisa, Pisa, Italy — Italian Institute of Technology, Genova, Italy — ETH, Zurich, Switzerland

Domain walls in antiferromagnets are topological sine-Gordon solitons, characterized by relativistic kine- matics with the spin wave velocity setting a crucial limit for the operating speed of a magnetic racetrack memory. The relativistic kinematics of magnetic solitons was experimentally observed for the first time in crystalline ferrimagnets, but open questions on spin dynamics still remain. We aim to maximize the domain wall speed leveraging the tunability of amorphous alloys with rare-earth (RE) and transition-metal (TM) constituting two antiferromagnetic sublattices. By tuning RE concentration, it is possible to calibrate the anisotropy, the magnetization compensation point, and the net angular momentum compensation point, which are the keys to achieve high operating speeds in ferrimagnets. Here we extend the theoretical model describing the domain wall motion assisted by spin orbit torque and in-plane magnetic field [1] to the case of RE-TM systems, taking into account the phenomena of canting, domain wall width broadening and intrinsic pinning. It is proven that a domain wall in a RE-TM system can be described by a modified double sine-Gordon equation. The results are corroborated by magneto-optical Kerr effect (MOKE) measurements of the domain wall motion.

[1]P. Diona et al., IEEE Trans. on Electron Devices, 69(7), 3675 (2022).