MA 44: Focus Session: Curvilinear magnetism: Magnetics with nanoscale curved geometries (joint session MA/TT)

The behaviour of any physical system is determined by the order parameter whose distribution is governed by the geometry and topology of the physical space of the object, in particular its dimensionality and curvature. Specifically, spin textures, static and dynamic magnetic responses become sensitive to bends and twists in physical space. In this respect, curvature effects emerged as a novel tool to tailor magnetic properties and responses relying on geometric deformations. In magnetism, coupling between geometry of a magnet and magnetic order parameter brings about novel responses of curved thin films, nanowires and nanoparticles and enforces topological constraints on the number and type of magnetic solitons living in a curved space. Curvatures can force a geometry-driven local interactions like Dzyaloshinskii-Moriya interaction (DMI) and anisotropy as well as novel non-local chiral symmetry breaking effects, which were confirmed experimentally using electron holography studies of magnetic cap-shaped structures. Advances in experimental techniques (fabrication and tomographic characterization) allow validating theoretically predicted effects and apply them for functional devices as was demonstrated with geometrically twisted 3D racetracks. Recent highlights of the community include experimental proof of curvature stabilised skyrmions, explorations of curvilinear altermagnets, tailoring magnetic solitons in curvilinear 2D magnets, curvilinear magnetoelectrics, use of curvilinear magnetic architectures to tune superconducting transport, and magnetoionic manipulation of magnetic states in nanostructures to name just a few representative topics, which will be covered at the focused symposium.

Organizers: Denys Makarov, d.makarov@hzdr.de; Paola Gentile, paola.gentile@spin.cnr.it

Time: Thursday 9:30–13:00 Location: POT/0151

Invited Talk MA 44.1 Thu 9:30 POT/0151

2D and 3D racetracks: Interplay of geometric and magnetic chiralities — •Stuart Parkin — Max Planck Institute for Microstructure Physics, Halle (Saale), Germany — Martin Luther University Halle-Wittenberg

Magnetic Racetrack Memory (RTM) is a unique memory-storage device that relies on the current driven motion of multiple domain walls along magnetic conduits that can be arranged either horizontally (2D) or vertically (3D). It has great potential as a high performance, non-volatile memory that has enormous data storage capacity compared to today*s memory technologies. Atomically engineered 2D magnetic racetracks in the form of synthetic antiferromagnets allow for very high current induced motion of nanoscopic chiral domain walls[1]. Recently we have shown that 2D RTM can be scaled to dimensions that are technologically relevant with widths of just ~50 nm[2]. 3D racetracks would allow for the highest density memories. Using a state-of-the-art multi-photon super-resolution lithography system we form 3D scaffolds of arbitrary shapes on which the racetracks can be subsequently deposited. We discuss 3D racetracks that are formed with clockwise and anticlockwise chiral twists and curved cross-sections. The interplay between the geometrical chirality and the spin chirality of the individual domain walls allows for domain wall diode devices [3]. [1] S. S. P. Parkin, S.-H. Yang, Nat. Nanotechnol. 2015, 10, 195. [2] J.-C. Jeon, A. Migliorini, J. Yoon, J. Jeong, S. S. P. Parkin, Science 2024, 386, 315. [3] A. M. A. Farinha, S.-H. Yang, J. Yoon, B. Pal, S. S. P. Parkin, Nature 2025, 639, 67.

Invited Talk MA 44.2 Thu 10:00 POT/0151

Combined MFM/KPFM at the Ultimate Sensitivity Limit for Probing Curvature-Engineered Micromagnetic States — •Emily Darwin[1], Reshma Peremadathil Pradeep[1,2], Luca Berchialla[3], Daniel Rotthardt[1,2], Ales Hrabec[3], and Hans Hug[1,2] — [1]Empa, Swiss Federal Laboratories for Materials Science and Technology, 8600 Dübendorf, Switzerland — [2]Department of Physics, University of Basel, 4056 Basel, Switzerland — [3]aul Scherrer Institut PSI, 5232 Villigen, Switzerland

Curved substrates offer a promising route for tailoring the magnetic properties of multilayer systems, potentially stabilizing topologically non-trivial spin textures such as skyrmions. However, local variations in surface inclination can significantly affect growth conditions, altering crystallographic orientation or even disrupting the multilayer architecture.

In this study, we investigate a Pt/Co/Ru multilayer deposited on a polymer substrate patterned with nanoscale semispherical bumps using a combined single-pass Magnetic Force Microscopy (MFM) and Frequency-Modulated Kelvin Probe Force Microscopy (FM-KPFM) technique. Our system achieves unprecedented sensitivity to both magnetic and electrostatic interactions. We find that steep, near-vertical walls at the perimeter of hemispherical features locally disorder the multilayer stack, resulting in distinct changes in the contact potential difference. This disruption facilitates magnetic flux return and enables the formation of circular magnetic domains aligned with the external magnetic field on the dome tops.

Invited Talk MA 44.3 Thu 10:30 POT/0151

Curvilinear magnetism in superconducting spintronics — •Sol Jacobsen — Center for Quantum Spintronics, Norwegian University of Science and Technology NTNU, Trondheim, Norway

Replacing semiconductor-based computational components with superconducting elements can give an energy saving of two orders of magnitude. To harness this, we need precise control of the interaction between superconducting and magnetic components. Geometric curvature controls the superconducting transition by affecting spin relaxation and precession in superconductor-magnet heterostructures [1]. To functionalize this in devices, we can dynamically alter the curvature by inducing bending-strain. This can for example lead to electrically controlled superconducting spin-valves, current-reversal, and chirality-dependent ground states in triplet-SQUIDs [1-3]. In this presentation, I will discuss how real-space geometric curvature provides new pathways for manufacturing and controlling the interaction between superconductivity and magnetism in wires and thin films, and anticipate future developments in the field.

[1] Salamone et al, Phys. Rev. B 104 (2021) L060505; 105, (2022) 134511. [2] Salamone et al, Appl. Phys. Lett. 125 (2024) 062602. [3] Skarpeid et al, J.Phys.:Condens.Matter, 36 (2024) 235302.

15 min break

Invited Talk MA 44.4 Thu 11:15 POT/0151

Advanced Control of Magnetic Nanostructures via Metasurface Engineering and Voltage-Driven Functionalities — •Anna Palau — Institut de Ciència de Materials de Barcelona (ICMAB-CSIC)

Understanding and manipulating magnetic micro- and nanostructures are fundamental to advancing technologies in data storage, spintronics, and magnetic sensing. Magnetic metasurfaces have recently attracted significant interest for their ability to locally configure magnetic field distributions and overcome limitations of traditional magnetic imaging techniques. In this work, we demonstrate how metasurfaces enable precise control of vortex motion, coercive fields, and saturation behaviour in magnetic nanostructures without altering their intrinsic anisotropy [1]. We show that metasurfaces can overcome magnetic field constraints in X-ray Photoemission Electron Microscopy (XPEEM), enabling high-resolution imaging of magnetisation states under conditions previously inaccessible. Additionally, we explore electric-field-driven ionic migration as a complementary route for voltage-controlled, non-volatile modulation of magnetic and superconducting properties [2], highlighting new opportunities for energy-efficient control and advanced characterisation. [1] Barrera et al. ACS Nano 19, 10461 (2025), [2] Günkel et al. Small 2411908 (2025), Spasojević et al. Nat. Commun. 16, 1990 (2025)

Invited Talk MA 44.5 Thu 11:45 POT/0151

Magnetic tomography of noncollinear spin textures in curvilinear geometries — •Sandra Ruiz-Gomez — ALBA Synchrotron, Barcelona, Spain

Three-dimensional nanomagnetic systems offer a unique platform for discovering and controlling complex spin textures. Recent advances in 3D nanofabrication, magnetic characterization techniques, and micromagnetic modeling are now enabling precise control of curvature, torsion, and geometry at the nanoscale, opening new routes for engineering spin textures in three-dimensional architectures.

In this talk, I will present our latest results on how geometrical design and 3D architecture can be exploited to tailor the energy landscape of domain walls, manipulate their topological properties, and guide their motion from straight nanowires to more complex curved cylindrical and tubular geometries. By combining state-of-the-art fabrication techniques with high-resolution imaging and theoretical analysis, we identify how curvature can be harnessed to stabilize complex spin textures, enabling deterministic control over their dynamics.

Overall, this work highlights how 3D nanomagnetism can be leveraged to access new regimes of topological control, with implications for next-generation spintronic devices, robust information carriers, and reconfigurable magnetic architectures.

MA 44.6 Thu 12:15 POT/0151

Transferred magnetic nanomembranes for curvilinear magnetism and spintronics — •Olha Bezsmertna[1], Oleksandr Pylypovskyi[1], Rui Xu[1], Mykola Vinnichenko[2], Andrea Sorrentino[3], Daniel Wolf[4], Axel Lubk[4], Peter Fischer[5,6], and Denys Makarov[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden, Germany — [2]Institute for Ceramic Technologies and Systems IKTS, 01277 Dresden, Germany — [3]Alba Light Source, MISTRAL beamline, Cerdanyola del Vallès 08290, Spain — [4]Leibniz Institute for Solid State and Materials Research, 01069 Dresden, Germany — [5]University of California, Santa Cruz, United States — [6]Lawrence Berkeley National Laboratory, Berkeley, United States

The functionality of the magnetic nanomembranes can be extended through controlled transfer processes and geometric design. We show that advanced giant magnetoresistive thin films can be reliably transferred onto various substrates using green chemistry, preserving their structural integrity and magnetic performance, thus enabling mechanically conformal devices for applications where low weight, flexibility, and durability are essential [1]. With the developed technique, we demonstrate fabrication of curvilinear hierarchical magnetic nanotemplates and their subsequent transfer to an appropriate handling support enabling high-resolution transmission microscopy investigations (electron- and x-ray-based) of the impact of geometric curvature on complex magnetic states [2].

References: [1] Bezsmertna et al. Adv. Funct. Mater. 35, 2502947 (2025). [2] Bezsmertna et al. Nano Lett. 24, 15774 (2024).

MA 44.7 Thu 12:30 POT/0151

Magnetic solitons in spherical maghemite nanoshells — •Oleksandr V. Pylypovskyi[1], Gaspare Varvaro[2], Davide Peddis[2,3], Priyanka Mishra[4], Carmine Autieri[4], Filipp N. Rybakov[5], Denis D. Sheka[6], and Denys Makarov[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf e.V., 01328 Dresden, Germany — [2]CNR-Istituto di Struttura della Materia, 00015 Roma, Italy — [3]Universitá degli Studi di Genova, 1-16146 Genova, Italy — [4]International Research Centre Magtop, Institute of Physics, Polish Academy of Sciences, 02668 Warsaw, Poland — [5]Uppsala University, Uppsala SE-751 20, Sweden — [6]Taras Shevchenko National University of Kyiv, 01601 Kyiv, Ukraine

Topology of the shape of magnetic nanoarchitecture makes a major impact on global properties of its magnetic textures [1,2]. Here, we present a fabrication of maghemite spherical shells and a theoretical analysis of magnetic solitons they host in equilibrium. The ferrimagnetic shells with a radius and shell thickness of about 4 nm and 1.4 nm have a radial easy axis that favors skyrmionic textures. Their ground state corresponds to a 3D onion state with the change of the radial component of magnetization at the equator. In this presentation, we will also report on the localization of magnetic solitons on spherical shells.

[1] V. P. Kravchuk et al., PRB **94**, 144402 (2016); [2] O. M. Volkov, O. V. Pylypovskyi et al., Nat. Commun., **15**, 2193 (2024).

MA 44.8 Thu 12:45 POT/0151

Coherent Spin Waves in Curved Ferromagnetic Nanocaps of a 3D-printed Magnonic Crystal — •Kilian Lenz[1], Huixin Guo[2], Mateusz Golebiewski[3], Ryszard Narkowicz[1], Jürgen Lindner[1], Maciej Krawczyk[3], and Dirk Grundler[2] — [1]Inst. of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, Germany — [2]School of Engineering, Institute of Materials,Laboratory of Nanoscale Magnetic Materials and Magnonics, École Polytechnique Fédérale de Lausanne, Switzerland — [3]Institute of Spintronics and Quantum Information, Adam Mickiewicz University, Poznań, Poland

In this work we present ferromagnetic resonance measurements and simulations of a 3D magnonic crystals embedded in an on-chip microresonator. It was realized by two-photon lithography of a 3D woodpile structure and atomic layer deposition of a 30-nm-thin Ni film. Operated near 14 and 24 GHz, the microresonator output revealed numerous coherent magnons with distinct angular dependencies reflecting the underlying face-centered cubic lattice. The micromagnetic simulations show that some of the edge modes are localized at the curved nanocaps and that they remain robust against changes of the field orientation. These cap modes exhibit an unexpected phase evolution. The findings advance the development of functional microwave circuits with 3D magnonic crystals and strengthen their visionary prospects for edge-dominated magnon modes.