MA 31: Multiferroics and Magnetoelectric Coupling (joint session MA/KFM)

Time: Wednesday 15:00–18:00 Location: EB 407

MA 31.1 Wed 15:00 EB 407

Real-time imaging of nonequilibrium domain evolution into a multiferroic phase — •Jan Gerrit Horstmann[1], Yannik Zemp[1], Ehsan Hassanpour Yesaghi[1], Thomas Lottermoser[1], Mads C. Weber[2], and Manfred Fiebig[1] — [1]Dept. of Materials, ETH Zurich, Switzerland — [2]Institut des Molécules et Matériaux du Mans, Le Mans Université, France

We investigate the dynamics of magnetic domain formation across spin-reorientation transitions in multiferroic $Dy_{0.7}Tb_{0.3}FeO_3$. Combining Faraday imaging at kHz frame rates with fast optical excitation we find that thermal quenches of the system can be harnessed to imprint the characteristic bubble domain pattern of the weak ferromagnetic order at elevated temperatures onto the low-temperature multiferroic phase. We identify the quenching rate across the different spin reorientation transitions as the decisive parameter governing the domain memory and the formation of metastable domain states forbidden in thermal equilibrium. Our results highlight the potential of optical stimuli for the switching and control of multiferroic domain structures, enabling the creation of new functional states via nonequilibrium pathways.

MA 31.2 Wed 15:15 EB 407

Asymmetry of the magnetic-field-driven phase transition in h-$ErMnO_3$ — •Lea Forster[1], Ipek Efe[1], Morgan Trassin[1], Manfred Fiebig[1], Thomas Lottermoser[1], and Mads C. Weber[2] — [1]Department of Materials, ETH Zurich, Switzerland — [2]IMMM UMR 6283, University Le Mans, France

We report on the asymmetry of the magnetic-field-induced phase transition of the Mn^{3+} order in hexagonal $ErMnO_3$ under magnetic field application along the six-fold axis. Below the Néel temperature, we observe that with increasing magnetic field the Mn^{3+} and Er^{3+} appear to reorder simultaneously. However, with decreasing magnetic field, the reverse phase transition of the Mn^{3+} shows an intermediate stage where the spins are partially in the zero-field and partially in the applied-field state, while the Er^{3+} reverses almost instantaneously to its zero-field state. This asymmetry of the forward and reverse transition in the Mn^{3+} order becomes more and more pronounced at lower temperatures. We gain access to both the Mn^{3+} and Er^{3+} sublattices using optical second-harmonic generation and SQUID magnetometry. Our investigation of this asymmetric magnetic field-induced phase transition further underlines the complex coupling mechanisms of the Mn^{3+} order to the rare-earth orders in hexagonal manganites.

MA 31.3 Wed 15:30 EB 407

Magnetoelectric Effects in 2D Magnets: A Multiscale Approach Applied to Topological Solitons in CrI_3 — •Alexander Edström[1], Paolo Barone[2], Silvia Picozzi[3], and Massimiliano Stengel[4,5] — [1]Department of Applied Physics, KTH Royal Institute of Technology, 10691 Stockholm, Sweden — [2]CNR-SPIN, Area della Ricerca di Tor Vergata, Via del Fosso del Cavaliere 100, I-00133 Rome, Italy — [3]CNR-SPIN, c/o Università degli Studi 'G. D'Annunzio', 66100, Chieti, Italy — [4]ICMAB-CSIC, Campus UAB, 08193 Bellaterra, Spain — [5]ICREA , 08010 Barcelona, Spain

Topological defects, such as domain walls or Skyrmions, are expected to carry an electrical polarization, opening for the possibility to stabilize, control and detect them with electric fields, even in collinear ferromagnets like CrI_3. Here, we present a multiscale approach, combining atomistic and continuum magnetoelectric models, to accurately describe magnetoelectric coupling at different length scales, with all parameters extracted from first principles. The models are validated for spin spirals, revealing a sizeable magnetoelectric polarization. We describe the relation of the magnetoelectric parameters to electric field-induced Dzyaloshinskii-Moriya interactions. The models are then used to calculate the electric polarization and net dipole moments of magnetic domain walls (DWs) and Skyrmions, revealing e.g. that Skyrmions carry an out-of-plane electric dipole moment, while that of anti-Skyrmions lies in the plane. Finally, we discuss the possibility to stabilize these magnetic textures, none of which are otherwise energetically stable in the monolayer limit of CrI_3, using electric fields.

MA 31.4 Wed 15:45 EB 407

Electric field-driven dynamics of meron domain walls in spin spiral multiferroics — •Luca Maranzana[1,2] and Sergey Artyukhin[1] — [1]Italian Institute of Technology, Genoa, Italy — [2]University of Genoa, Genoa, Italy

Spin spiral multiferroics exhibit strong coupling between magnetic and ferroelectric orders, allowing cross-control. Since their discovery by Kimura et al. in 2003, these materials have attracted great interest galvanized by the prospect of new high-efficiency information storage devices, where the magnetic bits are switched through an external electric field. Nevertheless, the electric field-driven dynamics of domain walls in spin spiral multiferroics (i.e. the mechanism underlying this switching) is still poorly understood. Here, we address this problem for meron domain walls, which arise at low anisotropy and consist of a periodic chain of merons (half-skyrmions). The topological charge lies at the heart of the dynamics and can be controlled by modifying the meron configuration or applying an external magnetic field. Domain walls with zero total topological charge present a low-field dynamics reminiscent of a massive particle in one dimension. In contrast, those with non-zero total topological charge evince a peculiar nonlocal dynamics where all the spins in the system rotate and the mobility is drastically reduced.

MA 31.5 Wed 16:00 EB 407

Antimagnetoelectricy in multiferroic $BiCoO_3$ from first-principles — •Bogdan Guster[1], Maxime Braun[1,2], Houria Kabbour[2], and Eric Bousquet[1] — [1]Physique Théorique des Matériaux, QMAT, CESAM, Université de Liège, B-4000 Sart-Tilman, Belgium — [2]Univ. Lille, CNRS, Centrale Lille, ENSCL, Univ. Artois, UMR 8181-UCCS-Unité de Catalyse et Chimie du Solide, F-59000 Lille, France

The lack of magnetoelectric response in a multiferroics is prompted by the magnetic space group symmetry. This is the case of $BiCoO_3$ where the C-AFM ground state prohibits the promotion of a magnetoelectric coupling. However, at the microscopic level, the local magnetoelectric coupling could exhibit non-zero responses for both spin and orbital components. Here we show from first-principles calculations that the amplitude of dynamical magnetic charges arising from both spin- and orbital-lattice coupling in the C-AFM phase of $BiCoO_3$ are large when compared to the paradigmatic Cr_2O_3. While globally the response is zero, we resolute that the pseudo-tensorial character of the dynamical magnetic charges manifests an alternating sign for atoms yet on the same Wyckoff position. Consequently, unlocking the C-AFM phase, one could potentially allow for a large magnetoelectric response. To prove this, we calculate the full magnetoelectric response in the ferromagnetic phase of $BiCoO_3$ and we find a colossal response of 1000 ps/m, among the largest reponses found so far in a single-crystal. We will discuss several strategies on how this large response could be released in some specific conditions and why the response is large.

MA 31.6 Wed 16:15 EB 407

Electric field induced reversal of spin alignment in graphone/hexagonal boron nitride on Ni(111) — Jaime Oliveira da Silva and •Fernando Nogueira — CFisUC, Department of Physics, University of Coimbra, Rua Larga, 3004-516 Coimbra, Portugal

Spintronic applications require a precise and efficient way of manipulating the material's magnetisation. This work demonstrates that it is possible to revert the surface magnetisation of a graphene sheet covered in half by hydrogen by applying an external electric field. To demonstrate this possibility, we study a prototypical material where this effect occurs: a 2D layer material formed by a Ni(111) substrate, an hBN monolayer and a graphone sheet. Screening of the Coulomb interactions between the ferromagnetic surface and the graphone layer plays a key role int the magnetisation reversal, enabling graphone to partially recover its isolated magnetisation value. The screening is due to the forming of an ionic bond between the N and B atoms in the hBN sheet. As the proposed material has a flat band at the Fermi level, our work also provides prospects for investigating flat-band instabilities.

15 min. break

MA 31.7 Wed 16:45 EB 407

Thermal conductivity in multiferroic CaBaCo4O7 — •Reza

Firouzmandi[1], Matthias Gillig[1], Yusuke Tokunaga[2], Yasujiro Taguchi[2], Yoshinori Tokura[2], Christian Hess[3], Vilmos Kocsis[1], and Bernd Büchner[1] — [1]IFW-Dresden, Dresden, Germany — [2]RIKEN-CEMS, Wako, Japan — [3]University of Wuppertal, Wuppertal, Germany

The coupling between the electronic and magnetic degrees of freedoms can lead to exotic transport phenomena in multiferroic materials. Particularly the propagation of charge neutral heat carriers can reveal interesting features in the thermal transport properties. Here, we report the thermal conductivity measurements in multiferroic CaBaCo4O7 which is built up by alternating Kagome and triangular layers of edge sharing CoO4 tetrahedra in mixed valence state. We find anomalies related to the magnetic ordering as well as huge anisotropy in thermal conductivity. Field dependence of the thermal conductivity resembles to that of the ferroelectric polarization. We attribute the anisotropy to the strong phonon scattering on the orthorhombic twinning.

MA 31.8 Wed 17:00 EB 407

Non-trivial Spin Structures And Multiferroic Properties Of The DMI-Compound Ba2CuGe2O7 — •Korbinian Fellner[1], Sebastian Mühlbauer[1], Peter Wild[1], Michal Dembski-Villalta[1], Tommy Kotte[2], Markus Garst[3], Alexandra Turrini[4], and Bertrand Roessli[4] — [1]Heinz Maier-Leibnitz Zentrum (MLZ), Technische Universität München, Garching, Germany — [2]Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Dresden, Germany — [3]Karlsruhe Institute of Technology (KIT), Karlsruhe. Germany — [4]Paul Scherrer Institut (PSI), Villigen, Switzerland

Incommensurate spiral magnets have raised tremendous interest in recent years, mainly motivated by their wealth of spin structures, such as skyrmions. A second field of interest is multiferroicity: Helical spin structures are in general ferroelectric, enabling the coupling of the electric and magnetic properties. Ba2CuGe2O7, featuring a quasi-2D structure with Dzyaloshinskii-Moriya interactions (DMI), is a material that is interesting in both of these regards and combines them with a third one: a variety of unconventional magnetic phase transitions. Neutron diffraction is used for an examination of the distribution of critical fluctuations in reciprocal space, associated with the paramagnetic to helimagnetic transition of Ba2CuGe2O7. It's reduced dimensionality prompts a transition from incommensurate antiferromagnetic fluctuations to 2D antiferromagnetic Heisenberg fluctuations, showcasing a varied array of magnetic phase transitions in spiral textures. Recently, a new phase with a vortex-antivortex magnetic structure has been theoretically described and experimentally confirmed.

MA 31.9 Wed 17:15 EB 407

Atomic-scale visualization of multiferroicity in monolayer NiI_2 — Mohammad Amini[1], •Adolfo Fumega[1], Hector Gonzalez-Herrero[1,2,3], Viliam Vano[1,4], Shawulienu Kezilebieke[5], Jose Lado[1], and Peter Liljeroth[1] — [1]Department of Applied Physics, Aalto University, FI-00076 Aalto, Finland — [2]Departamento de Fisica de la Materia Condensada, Universidad Autonoma de Madrid, E-28049 Madrid, Spain — [3]Condensed Matter Physics Center (IFIMAC), Universidad Autonoma de Madrid, E-28049 Madrid, Spain — [4]Joseph Henry Laboratories and Department of Physics, Princeton University, Princeton, NJ 08544, USA — [5]Department of Physics, Department of Chemistry and Nanoscience Center, University of Jyvaskyla, FI-40014 University of Jyvaskyla, Finland

Multiferroics have been seen as a disruptive building block for technological applications. Recently, evidence of multiferroicity has been provided in monolayer NiI_2. However, the multiferroic order in monolayer NiI_2 has not been characterized yet. In order to address this issue, here we perform an atomic-scale visualization of monolayer NiI_2. This is achieved by exploiting the atomic-scale magnetoelectric coupling in NiI_2 to image spin-spiral multiferroics via scanning tunneling microscope (STM) experiments. Moreover, we directly show external electric field control of the multiferroic domains. Our result demonstrates a novel methodology to analyze and characterize the magnetic and electric orders in this type of multiferroics materials.

MA 31.10 Wed 17:30 EB 407

Ptychographic imaging of multiferroic domains in freestanding $BiFeO_3$ films — •Tim A. Butcher[1], Nicholas W. Phillips[1], Chia-Chun Wei[2], Carlos A. F. Vaz[1], Armin Kleibert[1], Simone Finizio[1], Jan-Chi Yang[2,3], Shih-Wen Huang[1], and Jörg Raabe[1] — [1]Paul Scherrer Institut, 5232 Villigen PSI, Switzerland — [2]Department of Physics, National Cheng Kung University, Tainan 70101, Taiwan — [3]Center for Quantum Frontiers of Research & Technology (QFort), National Cheng Kung University, Tainan 70101, Taiwan

The multiferroic domains in freestanding bismuth ferrite films were imaged with the synchrotron technique of soft X-ray ptychography, which can achieve a high spatial resolution in the order of 5 nm. The ferroelectric domains show a linear dichroic contrast at the Fe L_3 edge, while the antiferromagnetic spin cycloid was reconstructed from its diffraction peak under resonant scattering conditions. The results directly visualise the strong magnetoelectric coupling and the changes in the multiferroic domain patterns with varying film thickness.

MA 31.11 Wed 17:45 EB 407

Imaging the antiferromagnetic domains in $LiCoPO_4$ via the optical magnetoelectric effect — •Boglárka Tóth[1], Vilmos Kocsis[2,3], and Sándor Bordács[1,4] — [1]Department of Physics, Institute of Physics, Budapest University of Technology and Economics, Hungary — [2]RIKEN Center for Emergent Matter Science (CEMS), Japan — [3]Institut für Festkörperforschung, Leibniz IFW-Dresden, Germany — [4]ELKH-BME Condensed Matter Research Group, Budapest University of Technology and Economics, Hungary

$LiCoPO_4$ is a widely researched compound. Not only it is a very promising candidate as a cathode material for lithium-ion batteries, but also shows strong linear magnetoelectric (ME) effect. Its two sublattice antiferromagnetic (AFM) order emerging below $T_N = 21.7$ K breaks spatial inversion and time-reversal symmetries, and correspondingly gives rise to the ME effect. We investigated the optical ME effect of $LiCoPO_4$, which manifests in the so-called directional dichroism; the light absorption difference for counter propagating beams. The absorption of polarized light in the sample was measured after poling, i.e., field-cooling the sample across T_N in external E and B fields simultaneously, to stabilize one or the other AFM domain. There is a finite absorption difference for the two AFM domains, which, considering they are time-reversal pairs of each other, we interpret as directional dichroism. A simple transmission microscope setup was constructed to image the AFM domains based on their absorption difference.