MA 17: Multiferroics and Magnetoelectric Coupling (joint session MA/FM)

Time: Tuesday 9:30–12:30 Location: POT/0112

MA 17.1 Tue 9:30 POT/0112

Electric polarization driven by non-collinear spin alignment: first principles calculations — •Sergiy Mankovsky[1,3], Svitlana Polesya[1], Jan Minar[2], Hongbin Zhang[3], and Hubert Ebert[1] — [1]Ludwig Maximilian University of Munich, Munich, DE — [2]University of West Bohemia, Pilsen, CZ — [3]TU Darmstadt, Darmstadt, DE

We present an approach for first principles investigations of the spin driven electric polarization in type II multiferroics. We propose a parametrization of the polarization with the parameters calculated using the multiple scattering Green function (KKR-GF) formalism. On this basis, the induced electric polarization of a unit cell can be represented in terms of three-site parameters. Those antisymmetric with respect to a spin permutation can be seen as an ab-initio based counter-part to the phenomenological parameters used in the inverse-DMI model. Beyond to this, our new approach gives direct access to the element- and site-resolved electric polarization. To demonstrate the capability of the approach, we consider several examples, for which the magneto-electric effect is observed either as a consequence of an applied magnetic field (Cr_2O_3), or as a result of a phase transition to a spin-spiral magnetic state (MnI_2 and $AgCrO_2$).

MA 17.2 Tue 9:45 POT/0112

Competition Between Multiferroic and Magnetic Soliton Lattice States in DyFeO3 — •Nikita Andriushin[1], Stanislav Nikitin[2], Oystein Fjellvag[1,3], Ekaterina Pomjakushina[2], Alexandra Turrini[2], Sergey Artyukhin[4], Christof Schneider[2], and Maxim Mostovoy[5] — [1]TU Dresden, Germany — [2]PSI, Switzerland — [3]IFE, Norway — [4]IIT, Italy — [5]University of Groningen, The Netherlands

Simultaneous breaking of time-reversal and inversion symmetries in multiferroics couples ferroelectricity to magnetism and produces unusual phenomena relevant for next-generation electronics. A notable case is $DyFeO_3$, which under magnetic fields shows a giant linear magnetoelectric response and a large spontaneous polarization arising from coexisting Fe and Dy orders. Using high-resolution neutron diffraction, we demonstrate that at zero field $DyFeO_3$ hosts an incommensurate magnetic soliton lattice formed by spatially ordered Dy domain walls with an average size of 231(8) Å. Long-range interactions between these walls are mediated by magnons in the Fe subsystem, analogous to a Yukawa force. An applied magnetic field destroys the incommensurate order, restores the linear magnetoelectric response, and stabilizes the ferroelectric state. The magnetic domain walls carry electric charge, and the soliton array dimerizes when both electric and magnetic fields are applied. Simulations using experimental parameters indicate that competition between ferroelectric and incommensurate states can be effectively tuned by an electric field.

MA 17.3 Tue 10:00 POT/0112

Magnetoelectric coupling in antiferromagnetic $BiCoO_3$ — •Veronica Goian[1], Fedir Borodavka[1], Petr Proschek[2], Maxim Savinov[1], Christelle Kadlec[1], Hong Dong Nguyen[1], Andrei A. Belik[3], and Stanislav Kamba[1] — [1]Institute of Physics of the Czech Academy of Sciences, Prague, Czech Republic — [2]Department of Condensed Matter Physics, Charles University, Prague Czech Republic — [3]National Institute for Materials Science: Tsukuba, Ibaraki, Japan

$BiCoO_3$ is a potential multiferroic material with a C-type antiferromagnetic phase transition at T_N=470 K and a hypothetical ferroelectric phase transition around 1000 K (the sample decomposes at around 470 °C).[1] First-principles calculations predict an unusually strong antimagnetoelectric coupling in $BiCoO_3$.[2] However, no experimental measurements have been reported in the literature to determine the magnetoelectric coupling or related structural properties. This is mainly because $BiCoO_3$ requires high-pressure and high-temperature sintering. We have measured the dielectric permittivity, ferroelectric hysteresis loops, and Raman, THz, and IR spectra to probe the ferroelectric behavior. In addition, we found that $BiCoO_3$ exhibits well-measurable non-linear magnetoelectric coupling.

[1] Oka et al., J. Am. Chem. Soc., 132, 9438-9443 (2010)
[2] Braun et al., Phys. Rev. B, 110, 144442(2024)

MA 17.4 Tue 10:15 POT/0112

Investigation of the piezomagnetic effect in $CaBaCo_4O_7$ — •Jyotiranjan Rout[1], Yusuke Tokunaga[2], Yasujiro Taguchi[2], Yoshinori Tokura[2], Bernd Büchner[1,3], and Vilmos Kocsis[1] — [1]IFW-Dresden — [2]RIKEN, CEMS, Japan — [3]TU-Dresden

In a magnetoelectric material the electric and magnetic responses are intertwined and cross control via the application of external magnetic and electric field are enabled. Ferroelectric polarization implies a special distortion of the lattice where dipolar moment related to the separation of the positive and negative ions are not compensated within the unit cell. Therefore we immediately can imagine the intricate and complicated connection between the magnetoelectric and magnetoelastic properties of a multiferroic.

The Swedenborgite $CaBaCo_4O_7$ exhibits a polar structure, which is accompanied by a ferrimagnetic order at T_C=62 K and a record large change in the ferroelectric polarization. Correspondingly, former magnetoelastic measurements have indeed confirmed the presence of a giant magnetoelastic distortion close to T_C; However, less is known about the magnetoelastic anisotropies.

Here, we report a detailed study of the magnetoelastic anisotropy, completing the connection between magnetoelasticity and magnetoelectricity in this material family. We also report on an unusual feature of the piezomagnetic effect, which suggests the importance of the orbitals in the piezomagnetoelectric effects.

MA 17.5 Tue 10:30 POT/0112

Multiferroic altermagnetism and magneto-orbital excitations in monolayer VCl3 — •Luigi Camerano[1,2], Adolfo Otero Fumega[3], Alessandro Stroppa[2], Jose Lado[3], and Gianni Profeta[1,2] — [1]University of L'aquila, 67100 L'Aquila, Italy — [2]CNR-SPIN L'Aquila, 67100 L'Aquila, Italy — [3]Aalto University, 02150 Espoo, Finland

Van der Waals monolayers featuring magnetic states provide fundamental building blocks for artificial quantum matter. In this contribution I will present the emergence of a symmetry broken multiferroic ground state featuring magneto-orbital excitations and nematic d-wave altermagnetism in monolayer VCl3 [1-4]. All these physics arises from a pure electronic symmetry breaking ultimately stabilizing an antiferro-orbital order ground state showing the emergence of an electronic polarization. Recent experimental evidence report signatures of symmetry breakings and ferroelectricity combined with 2D magnetism, establishing monolayer VCl3 as a novel 2D multiferroic driven by orbital ordering.

References

1. Mastrippolito D., Camerano L. et al. Phys. Rev. B 108,045126 (2023)
2. Camerano, L. et al. 2D Mater. 11, 025027 (2024)
3. Camerano, L. et al. Nano Lett. 25, 4825,4831 (2025)
4. Camerano, L. et al. npj 2D Mater Appl 9, 75 (2025)

MA 17.6 Tue 10:45 POT/0112

Electric control of antiferromagnetic states in an insulator — •Somnath Ghara[1], Maximilian Winkler[1], Sebastian Schmid[1,2], Lilian Prodan[1], Korbinian Geirhos[1], Vladimir Tsurkan[1,3], Wenbo Ge[4], Weida Wu[4], András Halbritter[2], Stephan Krohns[1], and István Kézsmárki[1] — [1]EP5, Institute of Physics, University of Augsburg, Germany — [2]Department of Physics, Budapest University of Technology and Economics, Hungary — [3]Institute of Applied Physics, Moldova State University, Republic of Moldova — [4]Department of Physics and Astronomy, Rutgers University, USA

Electric control of antiferromagnetic (AFM) order is highly desirable for the development of ultrafast and energy-efficient spintronic devices. In this talk, I will show that the strong linear magnetoelectric coupling in the collinear AFM insulator Co_3O_4 enables full isothermal control of AFM order by electric fields deep within its AFM phase, i.e. the Néel vector can be either reversed instantaneously or rotated smoothly. Importantly, we found that even in macroscopic volumes of Co_3O_4, the non-volatile switching between time-reversed AFM states occurs on timescales as short as a few tens of nanoseconds. These observations suggest that the quasi-cubic AFM insulators, such as Co_3O_4, provide an ideal platform for ultrafast manipulation of microscopic AFM domains and may lead to the realization of antiferromagnet-based spintronic devices.

Ref: S. Ghara et al., Phys. Rev. Lett. 135, 126704 (2025).

15 min break

MA 17.7 Tue 11:15 POT/0112

Optical detection of magnetic order in SmFe3(BO3)4 — •Bálint Beke[1], Bence Szász[1], I. A. Gudim[2], L. N. Bezmaternykh[2], Dávid Szaller[1], and Sándor Bordács[1] — [1]Budapest University of Technology and Economics, Budapest, Hungary — [2]Krasnoyarsk, Russia

The chiral crystal structure of $SmFe_3(BO_3)_4$ hosts an easy-plane antiferromagnetic phase below 32 K. Due to the broken inversion, the magnetic order induces electric polarization in this compound, but this polarization averages out to zero when domains are randomly oriented in the ab plane. We studied the 4f-4f excitations of Sm^{3+} ions using polarization resolved magneto-optical spectroscopy. Low magnetic fields, <2 T give rise to linear dichroism that we associate with the rearrangement of antiferromagnetic domains. In finite fields, we could determine the polarization selection rules in a state where the orientation of the antiferromagnetic domains is well defined. Moreover, we detected non-reciprocal absorption of light, which is a finite frequency fingerprint of the optical magnetoelectric effect.

MA 17.8 Tue 11:30 POT/0112

A high-temperature multiferroic $Tb_2(MoO_4)_3$ — •Shimon Tajima, Hidetoshi Masuda, Yoichi Nii, Shojiro Kimura, and Yoshinori Onose — Institute for Materials Research, Tohoku University, Sendai, Japan

We demonstrated magnetic control of ferroelectric polarization at 432 K in ferroelectric and ferroelastic $Tb_2(MoO_4)_3$, in which the polarity of ferroelectric polarization is coupled to the orthorhombic strain below the transition temperature 432 K.

The paramagnetic but strongly magnetoelastic Tb^{3+} magnetic moments enable the magnetic control of ferroelectric and ferroelastic domains; the ferroelectric polarization is controlled depending on whether the magnetic field is applied along [110] or $[1\bar{1}0]$.

MA 17.9 Tue 11:45 POT/0112

Towards topological switching in multiferroics — •Alessandro Granero and Sergey Artyukhin — Italian Institute of Technology (IIT), Genova, Italy

Magnetoelectric switching in GdMn2O5 [1] is the first known example of topological ferroic switching, where magnetic field sweeps across the spin-reorientation transition induce incremental 90° spin rotations described by a topological winding number. While the behavior has been rationalized with a microscopic model, symmetry conditions and minimal model ingredients that enable this behavior are poorly understood. Here we use a symmetry-based Landau theory approach and demonstrate that a toy model with two frustrated antiferromagnetic subsystems and a low-symmetry anisotropy captures the topological switching behavior. The model reveals how sweeps of the driving field move the free-energy minimum continuously in spin-orientation space, in contrast to conventional ferroelectric switching that relies on fixed *P minima and domain-wall nucleation. Multiple switching pathways enabled by the simultaneous presence of E and H fields are summarized by a "switching diagram" [2], linking regions of the H and E field amplitudes to distinct sequences of magnetoelectric transitions. Small parameter variations near diagram boundaries redirect the system along different routes. The results establish a minimal model for topological switching in GdMn2O5 and guide the search for topological switching phenomena in other materials. [1] L. Ponet, et al.: Nature 607, 81-85 (2022) [2] M. Ryzhkov, A. Granero et al.: Communication Materials, in press

MA 17.10 Tue 12:00 POT/0112

Observation of antiferromagnetic domains by low-temperature photoluminescence microscopy — •Bence Szász — Physics Department, Budapest University of Technology and Economics, Budapest, Hungary

The optical oscillator strengths of crystal-field transitions in magnetoelectric antiferromagnets can serve as specific signatures of the underlying magnetic order. In this work, I investigate the feasibility of identifying magnetic domains using a low-temperature optical photoluminescence microscopy system.

MA 17.11 Tue 12:15 POT/0112

Spectroscopy of coupled magnetic and electric resonances — •Dávid Szaller[1,2], Artem M Kuzmenko[3], Alexander A Mukhin[3], Alexey Shuvaev[2], and Andrei Pimenov[2] — [1]HUN-REN-BME Condensed Matter Physics Research Group, and Department of Physics, Institute of Physics, Budapest University of Technology and Economics, Muegyetem rkp. 3., H-1111 Budapest, Hungary — [2]Institute of Solid State Physics, TU Wien, 1040 Vienna, Austria — [3]Moscow, Russia

Controllable non-reciprocal propagation of light is an intensively investigated field of optics, with studies motivated both by fundamental questions and possible telecommunication applications. So far, polarization-independent, switchable one-way transparency has been demonstrated at certain resonances of multiferroic crystals at cryogenic temperatures and in high magnetic fields, limiting the practical implementation. As an alternative approach, we present one-way transparency of an artificial layered structure consisting of split-ring metamaterial and magnetic substrate layers interacting in the dynamic regime [1]. Our quasi-optical experiments in the GHz frequency range show that this unique combination breaks time and space inversion symmetries in external magnetic field. The ease of tuning the dynamic response and the controllable one-way transparency make this approach promising for real-world applications.

[1] A. M. Kuzmenko et al., Phys. Rev. B 112, 134434 (2025).