KFM 29: Multiferroics and Magnetoelectric Coupling (joint session MA/KFM)

Time: Thursday 15:00–16:45 Location: H47

KFM 29.1 Thu 15:00 H47

Fast non-volatile electrical switching of the magnetoelectric domain states in the cubic spinel Co_3O_4 — •Maximilian Winkler, Somnath Ghara, Korbinian Geirhos, Lilian Prodan, Vladimir Tsurkan, Stephan Krohns, and Istvan Kezsmarki — Universität Augsburg, Augsburg, Deutschland

Here, we investigate the magnetoelectric effect of Co_3O_4 at temperatures far below the Neel-temperature of T_N = 30K. A large magnetoelectric coefficient of up to 14ps/m is achieved if the system is cooled through TN while magnetic and/or electric fields are applied. According to these poling procedures we provide a systematic analysis of how the magnetoelectric domain state can be controlled and even in situ switched by reversing the direction of either the electric or the magnetic field. The complete switching of the antiferromagnetic state is found to be faster than microseconds. Altogether, the control of the magnetoelectric domains and the fast switching dynamics makes the linear magnetoelectric coupling of Co_3O_4 highly interesting for spintronics.

KFM 29.2 Thu 15:15 H47

Contribution of charge and strain coupling in artificial multiferroic Fe3O4/PMN-PT heterostructures — •Patrick Schöffmann[1,2], Anirban Sarkar[2], Mai H. Hamed[2], Tanvi Bhatnagar-Schöffmann[3], Sabine Pütter[4], Philippe Ohresser[1], Brian J. Kirby[5], Alexander J. Grutter[5], Juri Barthel[6], Emmanuel Kentzinger[2], Annika Stellhorn[2], Martina Müller[7], and Thomas Brückel[2] — [1]Synchrotron SOLEIL, France — [2]Forschungszentrum Jülich GmbH, JCNS-2 and PGI-4, JARA-FIT, Germany — [3]Centre de Nanoscience et de Nanotechnologies, CNRS, Université Paris-Saclay, France — [4]Forschungszentrum Jülich GmbH, JCNS@MLZ, Germany — [5]NIST Center for Neutron Research, USA — [6]Forschungszentrum Jülich GmbH, ER-C-2, Germany — [7]Fachbereich Physik, Universität Konstanz, Germany

To be able to develop denser and faster data storage and computing solutions artificial multiferroic heterostructures are a promising approach, as they enable direct switching of magnetic states with voltage. We grow ferrimagnetic Fe3O4 thin films on ferroelectric PMN-PT substrates to study the effect of strain and polarisation induced by the substrate onto the magnetic properties of the film. We found that the coupling due to strain and charge is strongly dependent on the orientation of the sample in an external magnetic field as well as the substrate cut. We will present a simple model to explain the contribution of strain and charge for different substrate and magentic field orientations.

KFM 29.3 Thu 15:30 H47

Microscopic theory of the THz modes and their nonreciprocal directional dichroism in the antiferromagnet Fe2Mo3O8 — •Kirill Vasin[1,2], Alexey Nurmukhametov[2], Mikhail Eremin[2], Anna Strinic[1], Lilian Prodan[1], Vladimir Tsurkan[1], István Kézsmárki[1], and Joachim Deisenhofer[1] — [1]Augsburg University, Augsburg, Germany — [2]Kazan, Russia

In the present work, the transmission measurements of a polar dielectric Fe2Mo3O8 were performed by THz time-domain spectroscopy. The origin of the low-lying excitations is not clear, but they were assigned to electromagnons and magnons due to their appearance below TN.

Our microscopic model successfully describes the origin of the optical excitation spectrum in a broad frequency range from the THz to the near-infrared frequency range and the observed dichroism of the low-lying optical modes because of the on-site excitations of the Fe2+ ions in this material. We used the technic of the effective Hamiltonian, including the effects of the crystal field, superexchange interaction and spin-orbit coupling, to model the level schemes of Fe ions projected on the ground configuration of 3d6 electrons.

The directional dichroism in Fe2Mo3O8 can be described by the interference of magnetic and electric-dipole matrix elements, which depend on the applied magnetic field. Our modelled results agrees to the acquired experimental data.

KFM 29.4 Thu 15:45 H47

Magnetization reversal through an antiferromagnetic state — •Somnath Ghara[1], Evgenii Barts[2], Kirill Vasin[1], Dmytro Kamenskyi[1], Lilian Prodan[1], Vladimir Tsurkan[1], Maxim Mostovoy[2], Istvan Kezsmarki[1], and Joachim Deisenhofer[1] — [1]Experimentalphysik V, University of Augsburg, Augsburg, Germany — [2]University of Groningen, Groningen, The Netherlands

The polar magnet $Fe_2Mo_3O_8$ has recently attracted tremendous interests due its versatile properties, such as magnetoelectric effect and giant thermal hall effect. This compound has a polar hexagonal (space group $P6_3mc$) structure at room temperature and undergoes a collinear antiferromagnetic ordering of Fe^{2+} moments below T_N = 60 K, accompanied by a large electric polarization besides that of the structural origin. Upon application of (high) magnetic field, a metamagnetic transition from the antiferromagnetic to a ferrimagnetic state takes place. The ferrimagnetic state can also be stabilized by partially substituting Fe^{2+} ions by Zn^{2+} ions. The magnetic symmetry ($6m'm'$) of the ferrimagnetic state is compatible with a linear magnetoelectric effect. In this talk, I will show that at the coercive field of the isothermal reversal of a ferrimagnetic state in $Fe_{1.86}Zn_{0.14}Mo_3O_8$ the pristine antiferromagnetic state re-emerges as a metastable state. The reappearance of the antiferromagnetic state, supported by the theoretical calculations, is reflected in a large change of electric polarization and directly established by the reoccurrence of the characteristic low-energy THz excitation of the AFM state.

KFM 29.5 Thu 16:00 H47

Transfer of a domain pattern between ferroic orders — •Yannik Zemp[1], Ehsan Hassanpour[1], Yusuke Tokunaga[2], Yasujiro Taguchi[3], Yoshinori Tokura[3], Thomas Lottermoser[1], Manfred Fiebig[1], and Mads C. Weber[1,4] — [1]Department of Materials, ETH Zurich — [2]University of Tokyo — [3]Riken CEMS, Japan — [4]IMMM, Université Le Mans

In multiferroic materials with two ferroic orders, the order parameters and their respective domain patterns may be rigidly coupled or completely independent, with both of these cases having their merits. We show that in materials with three ferroic order parameters, unusual combinations of coupling and independence are possible. One such material is $Dy_{0.7}Tb_{0.3}FeO_3$. Here, an antiferromagnetic order of the rare earth ions (L) and a ferromagnetic order of the iron ions (M) induce an electric polarisation (P) and a trilinear coupling term $M \cdot L \cdot P$ contributes to the free energy. This coupling term dictates that a reversal of one order parameter needs to be compensated by the product of the other two order parameters to minimise the free energy. Using this fact, we show that a domain pattern in M can be transferred to P while erasing it in the original order parameter, and vice versa, by the application of magnetic and electric fields. We measure the P and M patterns independently by optical second harmonic generation imaging and Faraday rotation microscopy, respectively. The third order parameter L acts as the "memory buffer" for the transfer. The presented work demonstrates the significance of exploration in multiferroics beyond a bilinear coupling.

KFM 29.6 Thu 16:15 H47

Magnetoelectric domains and topological defects in hexagonal manganites — •M. Giraldo, Q. N. Meier, A. Bortis, D. Nowak, N. A. Spaldin, M. Fiebig, M. C. Weber, and Th. Lottermoser — Department of Materials, ETH Zurich

Domains and domain walls reflect the different interdependence of magnetic and electric order in multiferroics. For example, in type-II multiferroics, magnetic and electric domain patterns are one-to-one linked, whereas in type-I multiferroics, magnetic and electric domain morphologies can be different, and their coupling no longer mandatory. We show – using experiment and theory – that multiferroics with separately emerging magnetic and electric order can have a strong bulk magnetoelectric coupling even though the leading magnetoelectric cross-coupling is symmetry-forbidden. We show, taking ErMnO3 as example, that the structural distortions that lead to the ferroelectric polarization also break the balance of the competing superexchange contributions. The resulting bulk coupling leads to novel types of topological defects, like magnetoelectric domain walls and multifold vortex-like singularities. We argue that the apparent independence of magnetic and electric orders in type-I multiferroics leads to uncommon phenomena, not open to the type-II class, which can open additional degrees of freedom for the future control of their magnetoelectric functionality [1].

[1] M. Giraldo, Q.N. Meier, A. Bortis et al. Magnetoelectric coupling of domains, domain walls and vortices in a multiferroic with independent magnetic and electric order. Nat Commun 12, 3093 (2021).

KFM 29.7 Thu 16:30 H47

Measuring Antiferromagnets with a SQUID Setup in Magnetically Shielded Environments — •Michael Paulsen[1], Jörn Beyer[1], Michael Fechner[2], Ralf Feyerherm[3], Klaus Kiefer[3], Bastian Klemke[3], Julian Lindner[3], and Dennis Meier[4] — [1]Physikalisch-Technische Bundesanstalt, Berlin, Germany — [2]Max Planck Institute for the Structure and Dynamics of Matter, CFEL, Hamburg, Germany — [3]Helmholtz-Zentrum Berlin, Berlin, Germany — [4]Norwegian University of Science and Technology, Trondheim, Norway

Antiferromagnets possess zero net dipole magnetization. While predictions of higher order magnetizations have been made for Cr_2O_3, few confirmed measurements exist. In this contribution, we present low-temperature measurements gained on different systems with antiferromagnetic order in very low magnetic backgrounds using a dedicated SQUID setup. In particular, we discuss our results on exterior quadrupolar magnetic fields and relate the distinct quadrupolar magnetic signals to the microscopic spin arrangement in our model systems.