KFM 8: Multiferroics and Magnetoelectric Coupling I (joint session MA/KFM)

Time: Wednesday 9:30–12:15 Location: HSZ 401

KFM 8.1 Wed 9:30 HSZ 401

High Temperature THz study of conical phase of BiFeO3 — •Dániel Gergely Farkas[1,2], Boglárka Tóth[1], Kirill Amelin[3], Toomas Rõõm[3], Urmas Nagel[3], Toshimitsu Ito[4], and Sándor Bordács[1] — [1]Department of Physics, Budapest University of Technology and Economics — [2]Condensed Matter Research Group of the Hungarian Academy of Sciences, 1111 Budapest, Hungary — [3]National Institute of Chemical Physics and Biophysics, Tallinn, Estonia — [4]National Institute of Advanced Industrial Science and Technology (AIST), Tokyo, Japan

Multiferroics, materials with coexisting ferroelectric and magnetic order, are one of the most intensively studied systems in modern solid-state physics. BiFeO3 is one of the most studied multiferroic material since its multiferroic phase persists also at room temperature [1].

A recent theoretical model [2] predicted a conical phase between the cycloidal and canted AFM phase in BiFeO3. Magnetization measurements up to 300K have already confirmed the existence of this intermediate phase [3].

We performed THz absorption measurements at temperatures between 5-350K, and observed the magnon spectrum of the conical phase. The phase transitions and their hysteresis were observed at 300 and 350K.

[1] J. Moreau, et al., J. Phys. Chem. Solids 32, 1315 (1971).
[2] Z. V. Greeva, et al., Phys. Rev. B 87, 214413 (2013).
[3] S. Kawachi, et al., Phys. Rev. Mat. 1, 024408 (2017).

KFM 8.2 Wed 9:45 HSZ 401

Metastable transverse conical state in multiferroic BiFeO3 — •Boglarka Toth[1], Daniel Gergely Farkas[1], Jonathan S. White[2], Istvan Kezsmarki[3], Toshimitsu Ito[4], and Sandor Bordacs[1] — [1]Budapest University of Technology and Economics, Physics Department — [2]Paul Scherrer Institute — [3]University of Augsburg — [4]National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, 305-8562 Ibaraki, Japan

Magnetoelectric multiferroic materials with coexisting ferroelectric and magnetic orders have received much attention as they may find applications in low power consumption magnetoelectric memories and data storage devices. Among these materials, $BiFeO_3$ is a unique compound as it is multiferroic even at room temperature, which is essential for future applications. Although $BiFeO_3$ is the most studied multiferroic material, its magnetic phase diagram is not fully understood. Due to the ferroelectric distortion, the so-called Dzyaloshinskii-Moriya interaction is allowed, which, competing with the Heisenberg interaction, results in a cycloidal structure below $T_N = 640$ K in zero field. We investigated the magnetic phases above room temperature using magnetization measurements and small-angle neutron scattering (SANS) and found a transverse conical state between the zero-field cycloidal state and the high field canted antiferromagnetic phase. Furthermore, the conical state with large magnetoelectric effect remains (meta)stable in zero-field after decreasing the magnetic field.

KFM 8.3 Wed 10:00 HSZ 401

Magneto-electric properties and low-energy excitations of multiferroic $FeCr_2S_4$ — •Ana Strinic[1], Stephan Reschke[1], Zhe Wang[1], Michael Schmid[1], Alois Loidl[1], Vladimir Tsurkan[1,2], and Joachim Deisenhofer[1] — [1]Experimental Physics V, Center for Electronic Correlations and Magnetism, University of Augsburg, D-86159 Augsburg, Germany — [2]Institute of Applied Physics, Academy of Sciences of Moldova, MD-2028 Chisinau, Republic of Moldova

$FeCr_2S_4$ is under investigation for over four decades and shows remarkable magnetic as well as electronic properties. While a paramagnetic state is present at room temperature, for low temperatures long-range ferromagnetic order stets in and is followed by an incommensurate magnetic structure. Below $T = 10$ K a multiferroic ground state with orbital ordering is reached and IR phonons indicate a loss of inversion symmetry [1][2][3]. We report on the low-frequency optical excitations measured by THz spectroscopy. We measured the magnetic field dependence within the temperature range of orbital ordering and the temperature dependence of the different phases within the H-T-phase diagram for several polarizations of the THz-radiation in relation to the applied magnetic field. We will discuss the origin of the low-energy excitations and their relation with multiferroic properties of $FeCr_2S_4$.

[1] J. Bertinshaw *et al.*, Scientific Reports, 4, (2014).
[2] L. Lin *et al.*, Scientific Reports, 4, (2014).
[3] J. Deisenhofer *et. al.*, Physical Review B, 100, (2019).

KFM 8.4 Wed 10:15 HSZ 401

Evidence for existence of electromagnon in the multiferroic phase of Cu(II)O: A novel type polarized neutron scattering study at the thermal triple-axis spectrometer PUMA@FRM II — •Avishek Maity[1,2], Steffen Schwesig[1], Fabian Ziegler[1], Oleg Sobolev[1], and Götz Eckold[1] — [1]Institute for Physical Chemistry, Georg-August-University of Göttingen, 37077 Göttingen, Germany — [2]Heinz Maier-Leibnitz Zentrum (FRM II), Technical University of Munich, 85748 Garching, Germany

Since the spontaneous electric polarization was discovered in one of its anti-ferromagnetic (AFM) phases AF2 with $T_n = 230$ K [1], Cu(II)O regained the focus of research as a model compound for high-temperature type-II multiferroics. The ferroelectricity in the AF2 phase is induced by the cycloidal spin arrangement due to an anisotropic super-exchange interaction (DM) leading to an interesting coupling between spinwave and optical phonon namely electromagnon which is the elementary excitations involving in the magnetoelectric coupling [2]. Here we present the results from polarized neutron scattering to characterize low-energy magnetic excitations in the multiferroic phase of CuO using a novel type of polarization analysis available at the thermal triple-axis spectrometer PUMA@FRM II allowing the simultaneous detection of spinflip and non-spinflip scattering. We have determined energy gaps of several magnon modes and evidenced the signature for the existence of electromagnons near 3 and 13 meV [3].

Refs: [1] Kimura *et al.*, Nat. Mat. 7, 291 (2008). [2] Cao *et al.*, Phys. Rev. Lett. 114, 197201 (2015). [3] Maity *et al.* 2019 (submitted).

KFM 8.5 Wed 10:30 HSZ 401

Quantifying multiferroic domain population by nuclear magnetic resonance spectroscopy — •Thomas Gimpel[1], Markus Prinz-Zwick[1], Caroline Steinbrecht[1], Norbert Büttgen[1], Vladimir Tsurkan[1,2], and István Kézsmárki[1] — [1]Experimental Physics V, Center for Electronic Correlations and Magnetism, University of Augsburg, D-86135 Augsburg, Germany — [2]Institute of Applied Physics, Academy of Sciences of Moldova, Academiei strada 5, Chisinau, Republic of Moldova

We demonstrate that nuclear magnetic resonance spectroscopy can be used to measure the volume fraction of multiferroic domains. This new technique is applicable to anisotropic magnets where the different multiferroic domains are characterized either by different orientations of the magnetization or by different forms of the hyperfine coupling or the quadrupole interactions. The latter case is realized, e.g., in type-I mutliferroics where the ferroelectric domains have non-collinear polar axes. We carried out a proof-of-concept study on GaV_4Se_8 which has recently gained interest due to its multiferroic behavior and for hosting Néel-type magnetic skyrmions. This material becomes ferroelectric below 42 K - where four polar domains with polar axes along the cubic <111>-type axes emerge - and orders magnetically below 18 K. Its multiferroic domain population can be controlled either by magnetic or by electric fields. By our new method we can directly quantify the volume fraction of each of the four domains.

15 min. break.

KFM 8.6 Wed 11:00 HSZ 401

Revealing the antiferromagnetic spin density in multiferroic $Ba_2CoGe_2O_7$ — •Henrik Thoma[1], Vladimir Hutanu[2], Manuel Angst[3], Georg Roth[4], and Thomas Brückel[3] — [1]Jülich Centre for Neutron Science JCNS at MLZ, 85747 Garching, Germany — [2]Institute of Crystallography, RWTH Aachen and Jülich Centre for Neutron Science JCNS at MLZ, 85747 Garching, Germany — [3]Jülich Centre for Neutron Science JCNS and Peter Grünberg Institute PGI, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany — [4]Institute of Crystallography, RWTH Aachen, 52056 Aachen, Germany

Polarized neutron diffraction (PND) is a powerful method which provides direct access to the scattering contribution from nuclear-magnetic interference and thus reveals the phase difference between the nuclear and magnetic structure. Generally limited to the case of centrosymmetric structures in the paramagnetic state, this information can be used to construct spin density maps and local susceptibility tensors in order to study the anisotropy between magnetic interactions. Introducing an advanced approach in the maximum-entropy method for a model-free reconstruction of spin densities, these limitations were overcome. PND was applied to study the magnetic anisotropy in the non-centrosymmetric unconventional multiferroic $Ba_2CoGe_2O_7$. Using the new approach, a detailed 3D spin density distribution in the unit cell was obtained for the first time both in the paramagnetic and antiferromagnetic ground state. The obtained results clearly show the 2D character of the magnetic interactions in the title compound and are compared to the results of regular magnetic structure refinement.

KFM 8.7 Wed 11:15 HSZ 401

In situ electric and magnetic control of conductive domain walls in multiferroic GaV_4S_8 — •Somnath Ghara, Korbinian Geirhos, Vladimir Tsurkan, Peter Lunkenheimer, and István Kézsmárki — Experimental Physics V, Center for Electronic Correlations and Magnetism, University of Augsburg, Augsburg, Germany

GaV_4S_8, the lacunar spinel compound, has recently attracted interests due to the presence of different modulated magnetic phases, including Néel-type skyrmions and multiferroic properties. This compound undergoes a transition to the polar rhombohedral ($R3m$) state at T_{JT} = 45 K and a subsequent magnetic transition at T_C = 13 K. In the present work, by polarization and magnetic susceptibility studies, we demonstrate that the population of the four polar domains, with polarization along the four cubic < 111 >-type directions, can be controlled in situ both by electric and magnetic fields. Most interestingly, the dc conductivity of the polar multi-domain state is 10^6 times higher than that of the mono-domain state, indicating the presence of conductive domain walls. Correspondingly, when tuning the domain wall density by magnetic fields, we could achieve a giant magnetoresistance as high as 10^8 %. Furthermore, the conductivity of the domain walls shows a strong non-linearity, in contrast to the bulk.

KFM 8.8 Wed 11:30 HSZ 401

Dielectric loss in spiral magnets — •Francesco Foggetti[1,2], Andrei Pimenov[3], and Sergey Artyukhin[1] — [1]Istituto Italiano di Tecnologia, Genova, Italy — [2]Università di Genova, Genova, Italy — [3]Institut für Festkörperphysik, Wien, Austria

Magnetic frustration often results in non-trivial spin textures. Spiral spin structures are common in magnetic perovskites due to competing exchange interactions and may give rise to ferroelectric polarization via inverse Dzyaloshinskii-Moriya mechanism. Here we model chiral domain walls in the spiral magnetic order and characterize the excitation spectrum using a model Hamiltonian describing spins interacting with polar ionic displacements. Results suggest that high dielectric constant in spiral multiferroics (i.e. $TbMnO_3$, $MnWO_4$) originates from contributions of soft domain wall-localized electromagnons and that spiral order may play a fundamental role in the giant magneto-electric effect, observed in proximity of a phase transition from collinear antiferromagnetic order to a conical spiral in Ni_3TeO_6.

KFM 8.9 Wed 11:45 HSZ 401

Depth-resolved magnetism in La0.67 Sr0.33 MnO3/PMN-PT as a function of applied electric field — •Tanvi Bhatnagar[1,2], Anirban Sarkar[1], Emmanuel Kentzinger[1], Andras Kovács[2], Qianqian Lan[2], Patrick Schöffmann[3], Annika Stellhorn[1], Markus Waschk[1], Brian Kirby[4], Alexander Grutter[4], Rafal Edward Dunin-Borkowski[2], and Thomas Brückel[1] — [1]Forschungszentrum Jülich GmbH, Jülich Centre for Neutron Science (JCNS-2) and Peter Grünberg Institute (PGI-4), JARA-FIT, 52425 Jülich, Germany — [2]Forschungszentrum Jülich GmbH, Ernst Ruska-Centre for Microscopy and Spectroscopy with Electrons and Peter Grünberg Institute (PGI-5), 52425 Jülich, Germany — [3]Forschungszentrum Jülich GmbH, Jülich Centre for Neutron Science (JCNS) at MLZ, 85747 Garching, Germany — [4]NIST Center for Neutron Research, NIST, Gaithersburg, MD

The magnetic depth profile of an epitaxially-grown artificial multiferroic ferromagnetic/ (ferroelectric, piezoelectric) La0.67Sr0.33MnO3/0.7(Pb(Mg1/3Nb2/3)O3)-0.3(PbTiO3)(001) heterostructure is studied using polarized neutron reflectometry, revealing changes in interfacial magnetism when a voltage is applied between the layers. For a better understanding of the results, structural characterization of the interfacial morphology is performed using transmission electron microscopy.

KFM 8.10 Wed 12:00 HSZ 401

Polarized neutron reflectometry of magneto-electric coupling in Fe_3O_4/PMN-PT(011) artificial multiferroic heterostructures — •Patrick Schöffmann[1], Anirban Sarkar[2], Tanvi Bhatnagar[2,3], Mai Hussain Hamed[4], Stephan Geprägs[5], Emmanuel Kentzinger[2], Annika Stellhorn[2], Brian Kirby[6], Alexander Grutter[6], Sabine Pütter[1], Martina Müller[4], and Thomas Brückel[2] — [1]Forschungszentrum Jülich GmbH, JCNS@MLZ, Garching, Germany — [2]Forschungszentrum Jülich GmbH, JCNS-2 and PGI-4, JARA-FIT, Jülich, Germany — [3]Forschungszentrum Jülich GmbH, ER-C-1 and PGI-5, Jülich, Germany — [4]Forschungszentrum Jülich GmbH, PGI-6, Jülich, Germany — [5]Walther-Meißner Institute, BAdW, Garching, Germany — [6]NIST Center for Neutron Research, NIST, Gaithersburg, USA

Magnetoelectric coupling phenomena in artificial thin film heterostructures have attracted attention because of the rich application possibilities in data storage and novel devices. Growing a ferrimagnetic Fe_3O_4 thin film on a ferroelectric $[Pb(Mg_{1/3}Nb_{2/3})O_3]_{0.7}$-$[PbTiO_3]_{0.3}$ (PMN-PT) substrate in (011) orientation constitutes a heterostructure that allows for control of magnetic properties via an applied out-of-plane voltage. Using SQUID magnetometry and polarised neutron reflectometry, a clear change in magnetisation strength and orientation through the sample depth can be observed, upon the application of voltage. The effects are different along the in-plane axes (100) and $(01\bar{1})$.