MA 12: Multiferroics (joint session KFM/MA)

Time: Monday 15:00–17:40 Location: HSZ 105

MA 12.1 Mon 15:00 HSZ 105

Magnetoelectric crystals as model systems of quantum optics — •Janek Wettstein[1], Andrei Pimenov[1], Alexander A. Mukhin[2], Artem Kuzmenko[2], Kirill Amelin[3], Toomas Rõõm[3], Urmas Nagel[3], and David Szaller[1] — [1]Institute of Solid State Physics, Vienna University of Technology, 1040 Vienna, Austria — [2]A. M. Prokhorov General Physics Institute, Russian Academy of Sciences, 119991 Moscow, Russia — [3]National Institute of Chemical Physics and Biophysics, Akadeemia tee 23, 12618 Tallinn, Estonia

The interaction between an ensemble of non-interacting two-level quantum systems and a bosonic field is theoretically described by the Dicke-model which predicts a quantum phase transition in the thermodynamic limit when the strength of the interaction reaches a sufficiently large critical value [1,2]. Here, based on the idea of Ref. [3] we present a method to study the superradiant phase transition in $SmFe_3(BO_3)_4$, where isolated rare-earth quasi-spins (Sm) play the role of the two-level system and the bosonic field is provided by the spin-waves (i.e. magnons) of the antiferromagnetically ordered Fe ions. At low temperatures ($T = 3\,\mathrm{K}$) we observe an avoided crossing of the optically active low-frequency iron magnon and the Sm quasispin excitations with a coupling of about 70% of the critical value needed for the superradiant transition. The strength of the coupling was tuned by varying density and population of the Sm two-level systems.

[1] K. Hepp and E. H. Lieb, Phys. Rev. A 8, 2517 (1973).
[2] Y. K. Wang and F. T. Hioe, Phys. Rev. A 7, 831 (1973).
[3] X. Li et al., Science 361, 794 (2018).

MA 12.2 Mon 15:20 HSZ 105

Strain-Driven Metal-to-Insulator Transition and Charge Ordering in LiV2O4 — Yu-Mi Wu, Ulrike Niemann, Yi Wang, Y. Eren Suyolcu, Minu Kim, Hidenori Takagi, and •Peter A. van Aken — Max Planck Institute for Solid State Research, Stuttgart, Germany

The coupling of local atomic configurations and electronic degrees of freedom plays a fundamental role in understanding metal-insulator transitions and the formation of charge ordering. In particular, such competing interactions become more pronounced in the geometrically frustrated pyrochlore lattice in the spinel structure, due to fluctuations in the charge, spin and orbital channels. By STEM imaging and electron energy-loss spectroscopy, we have investigated mixed-valence spinel LiV2O4 thin films grown on SrTiO3 and MgO (001) substrates. The epitaxial strain strongly affects the spatial configurations of valence states in LiV2O4, and the local valence distributions are resolved at atomic-scale resolution. Two competing phases are detected in the thin films, a metallic charge-disordered heavy-fermion state on SrTiO3 and an insulating charge-ordered state on MgO. Importantly, our result shows that the out-of-plane lattice compression relieves the charge frustration and induces a Verwey-type-like charge-ordering pattern in LiV2O4. This observation provides atomic-scale insight into the strong charge-order correlation and tuneable electronic-phase transitions in related frustrated systems. This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 823717 - ESTEEM3.

MA 12.3 Mon 15:40 HSZ 105

Investigation of multiferroic coupling in $Ca_3Mn_{1.9}Ti_{0.1}O_7$ by optical second harmonic generation — •Yannik Zemp[1], Mads Weber[1], Thomas Lottermoser[1], Morgan Trassin[1], Bin Gao[2], Sang-Wook Cheong[2], and Manfred Fiebig[1] — [1]Department of Materials, ETH Zurich — [2]Rutgers University, New Jersey

Layered perovskite materials, such as $A_3B_2O_7$ Ruddlesden-Popper compounds, are under scrutiny in the search for multiferroics with a strong magnetoelectric coupling and large polarisations at high temperatures. Their crystal structure allows for the implementation of a wide range of magnetic ions and it can be host to geometrically induced ferroelectricity. For $Ca_3Mn_2O_7$, theory predicts a robust magnetoelectric coupling between the improper ferroelectricity and the Mn^{3+} magnetism, mediated by the MnO_6-octahedra tilts. However, experimental evidence is still pending. Here, we investigate such a possible coupling in $Ca_3Mn_{1.9}Ti_{0.1}O_7$. We probe the influence of the magnetic ordering on the ferroelectricity using second harmonic generation (SHG) - a non-invasive, highly symmetry-sensitive laseroptical technique ideal for the study of ferroic order. We observe a strong increase in the SHG signal upon entering the magnetic phase, which indicates a strong influence of the magnetism on the ferroelectricity. Measurements of the SHG spectrum and images of the domain pattern suggest a coupling of the magnetic order to the polarisation mechanism via the octahedral tilts. Our results demonstrate that layered perovskites are promising candidates in search for multiferroics with pronounced magnetoelectric coupling.

MA 12.4 Mon 16:00 HSZ 105

Magnetic Structure and Magnetoelectricity in Holmium-Doped Langasite — •Lukas Weymann[1], Thomas Kain[1], Lorenz Bergen[1], Alexey Shuvaev[1], Evan Constable[1], David Szaller[1], Artem M. Kuzmenko[2], Alexander A. Mukhin[2], Vsevolod Yu. Ivanov[2], Nadezhda V. Kostyuchenko[1,3], Maxim Mostovoy[4], and Andrei Pimenov[1] — [1]Institute of Solid State Physics, Vienna University of Technology, Vienna, Austria — [2]Prokhorov General Physics Institute of Russian Academy of Sciences, Moscow, Russia — [3]Moscow Institute of Physics and Technology, Dolgoprudny, Moscow region, Russia — [4]Theory of Condensed Matter, Zernike Institute for Advanced Materials, Groningen, The Netherlands

The compounds of the rare-earth langasite family R3Ga5SiO14 were investigated for their striking electromechanical properties in the early 1980s and attracted new scientific attention due to their intriguing magnetic and magnetoelectric properties in the past decade. In this work we present the results of a magnetoelectric effect, i.e. electric polarization induced by an external magnetic field, in the diluted holmium langasite.

This effect has an unusual angular dependence, which can be explained by taking into account the three-fold symmetry of the crystal and its rather complex magnetic structure. The latter was investigated by measurements in a Vibrating Sample Magnetometer and a torque magnetometer. Magnetic and magnetoelectric results can be understood taking into account the interplay between crystal symmetry and the local symmetry of the Holmium ions.

20 min. break

MA 12.5 Mon 16:40 HSZ 105

Non-invasive study of buried domain patterns in multiferroic bismuth ferrite — •Marvin Müller[1], Yen-Lin Huang[2], Ramamoorthy Ramesh[2], Morgan Trassin[1], and Manfred Fiebig[1] — [1]ETH Zurich, Switzerland — [2]University of California, Berkeley, USA

Magnetoelectric (ME) multiferroic materials hosting coexisting and coupled electric and magnetic orders allow for low-energy control of magnetism and thus hold great promise for energy-efficient random-access memories and logic devices. In $BiFeO_3/Co_{0.9}Fe_{0.1}$ heterostructures, room-temperature electric-field-induced reversal of the ferromagnetic magnetization has been recently achieved. Despite extensive studies on the ME coupling in $BiFeO_3$, the switching dynamics remain elusive. The lack of direct experimental access to the ferroic properties of the buried material renders *operando* investigations challenging. Here, we probe the ferroelectric switching in the model system $BiFeO_3/Co_{0.9}Fe_{0.1}$. We use spatially-resolved non-invasive optical second harmonic generation (SHG) to map the net polarization of the buried $BiFeO_3$ layer after voltage application. Our results suggest the emergence of a strong net polarization with the first voltage pulse. Additional scanning probe microscopy is used to correlate this observation with the emergence of stripe-domain patterns with 71° domain walls. This work introduces SHG as an effective tool to non-invasively study buried ferroelectric domain states and thus opens novel pathways towards *operando* electro-optic studies on the dynamics in these coupled systems.

MA 12.6 Mon 17:00 HSZ 105

B-site doping effects in multiferroic rare-earth hexagonal manganites — •Marcela Giraldo[1], Martin Lilienblum[1], Hasung Sim[2], Lea Forster[1], Je-Geun Park[2], Thomas Lottermoser[1], and Manfred Fiebig[1] — [1]ETH Zurich, Switzerland. — [2]Seoul National University, Korea.

Chemical doping is an alternative to tailor the properties of complex

oxides. A–site doping in hexagonal $R\mathrm{MnO_3}$ with Ca or Zr leads to a conductivity enhancement at the domain walls while preserving the characteristic topological ferroelectric state of the system. Stronger effects on the magnetism in this multiferroic family are expected by doping at the B–site. This is due to the direct perturbation of the magnetic sublattices formed by Mn^{3+} moments. We investigate Al-doping (0-25%) at the B–site in h-$\mathrm{YMnO_3}$. We use a combination of second-harmonic generation (SHG) and piezoresponse force microscopy to disclose the effects on antiferromagnetic and ferroelectric domain formation. The later ones, for example, reveal a size decrease with increasing degree of doping. Furthermore, a combination of SHG and X-ray diffraction (XRD) unveils a decreasing trend for magnetic/electric ordering temperatures as a function of doping. This is due to the chemical pressure induced by the distinct ionic sizes of Al and Mn and the progressive decomposition of the long-range order. By tracing the changes in the inherent properties of these ferroic systems, we aim to broaden the understanding for new routes in the manipulation of this important class of multiferroics.

MA 12.7 Mon 17:20 HSZ 105

Excitations and switching dynamics in RMn2O5 — Louis Ponet[1,2], •Sergey Artyukhin[1], Maxim Mostovoy[3], and Andrei Pimenov[4] — [1]Italian Institute of Technology, Genova, Italy — [2]Scuola Normale, Pisa, Italy — [3]University of Groningen — [4]TU Wien

RMn2O5 manganites have attracted significant attention due to the complex interplay between Mn and rare earth orders, resulting in multiferroic phases and peculiar excitations. Here we perform model and first-principles simulations to analyze excitations and peculiar switching dynamics in these compounds.