

KFM 4: Multiferroics (joint session KFM/MA)

Time: Monday 15:00–17:40

Location: HSZ 105

KFM 4.1 Mon 15:00 HSZ 105

Magnetoelectric crystals as model systems of quantum optics — ●JANEK WETTSTEIN¹, ANDREI PIMENOV¹, ALEXANDER A. MUKHIN², ARTEM KUZMENKO², KIRILL AMELIN³, TOOMAS RÕÖM³, URMAS NAGEL³, and DAVID SZALLER¹ — ¹Institute of Solid State Physics, Vienna University of Technology, 1040 Vienna, Austria — ²A. M. Prokhorov General Physics Institute, Russian Academy of Sciences, 119991 Moscow, Russia — ³National 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 $\text{SmFe}_3(\text{BO}_3)_4$, 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 ($T = 3\text{ K}$) 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).

KFM 4.2 Mon 15:20 HSZ 105

Strain-Driven Metal-to-Insulator Transition and Charge Ordering in LiV_2O_4 — 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 LiV_2O_4 thin films grown on SrTiO_3 and MgO (001) substrates. The epitaxial strain strongly affects the spatial configurations of valence states in LiV_2O_4 , 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 SrTiO_3 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 LiV_2O_4 . 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.

KFM 4.3 Mon 15:40 HSZ 105

Investigation of multiferroic coupling in $\text{Ca}_3\text{Mn}_{1.9}\text{Ti}_{0.1}\text{O}_7$ by optical second harmonic generation — ●YANNIK ZEMP¹, MADIS WEBER¹, THOMAS LOTTERMOSER¹, MORGAN TRASSIN¹, BIN GAO², SANG-WOOK CHEONG², and MANFRED FIEBIG¹ — ¹Department of Materials, ETH Zurich — ²Rutgers University, New Jersey

Layered perovskite materials, such as $\text{A}_3\text{B}_2\text{O}_7$ 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 $\text{Ca}_3\text{Mn}_2\text{O}_7$, 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 $\text{Ca}_3\text{Mn}_{1.9}\text{Ti}_{0.1}\text{O}_7$. We probe the influence of the magnetic ordering on the ferroelectricity using second harmonic generation (SHG) - a non-invasive, highly symmetry-sensitive laser-optical 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.

KFM 4.4 Mon 16:00 HSZ 105

Magnetic Structure and Magnetoelectricity in Holmium-Doped Langanite — ●LUKAS WEYMANN¹, THOMAS KAIN¹, LORENZ BERGEN¹, ALEXEY SHUVAEV¹, EVAN CONSTABLE¹, DAVID SZALLER¹, ARTEM M. KUZMENKO², ALEXANDER A. MUKHIN², VSELOD YU. IVANOV², NADEZHDA V. KOSTYUCHENKO^{1,3}, MAXIM MOSTOVOY⁴, and ANDREI PIMENOV¹ — ¹Institute of Solid State Physics, Vienna University of Technology, Vienna, Austria — ²Prokhorov General Physics Institute of Russian Academy of Sciences, Moscow, Russia — ³Moscow Institute of Physics and Technology, Dolgoprudny, Moscow region, Russia — ⁴Theory of Condensed Matter, Zernike Institute for Advanced Materials, Groningen, The Netherlands

The compounds of the rare-earth langanite family $\text{R}_3\text{Ga}_5\text{SiO}_{14}$ 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 langanite.

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

KFM 4.5 Mon 16:40 HSZ 105

Non-invasive study of buried domain patterns in multiferroic bismuth ferrite — ●MARVIN MÜLLER¹, YEN-LIN HUANG², RAMAMOORTHY RAMESH², MORGAN TRASSIN¹, and MANFRED FIEBIG¹ — ¹ETH Zurich, Switzerland — ²University 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 $\text{BiFeO}_3/\text{Co}_{0.9}\text{Fe}_{0.1}$ 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 $\text{BiFeO}_3/\text{Co}_{0.9}\text{Fe}_{0.1}$. 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.

KFM 4.6 Mon 17:00 HSZ 105

B-site doping effects in multiferroic rare-earth hexagonal manganites — ●MARCELA GIRALDO¹, MARTIN LILIENBLUM¹, HASUNG SIM², LEA FORSTER¹, JE-GEUN PARK², THOMAS LOTTERMOSER¹, and MANFRED FIEBIG¹ — ¹ETH Zurich, Switzerland. — ²Seoul National University, Korea.

Chemical doping is an alternative to tailor the properties of complex

oxides. A-site doping in hexagonal $RMnO_3$ 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- $YMnO_3$. 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.

KFM 4.7 Mon 17:20 HSZ 105

Excitations and switching dynamics in RMn_2O_5 — LOUIS PONET^{1,2}, ●SERGEY ARTYUKHIN¹, MAXIM MOSTOVOY³, and ANDREI PIMENOV⁴ — ¹Italian Institute of Technology, Genova, Italy — ²Scuola Normale, Pisa, Italy — ³University of Groningen — ⁴TU Wien
 RMn_2O_5 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.