PAUL SCHERRER INSTITUT

3rd PSI Condensed Matter Retreat

13 - 14 November, 2018

EMPA Akademie
Dübendorf

Program Overview

Tuesday, 13 November 2018

Time	Title	Speaker/Chair
08:30-09:00	Welcome Coffee & Registration	
09:00-09:30	Welcome to EMPA	*P. Gröning*
09:30-10:30	Facilities: Overview & Highlights	*S. Gerber*
09:30	*SLS facility update*	F. Nolting
09:45	*SwissFEL facility update*	H.T. Lemke
10:00	*SINQ facility update*	M. Kenzelmann
10:15	*SμS facility update*	A. Amato
10:30-11:00	Coffee Break	
11:00-12:00	Ultrafast x-ray science	*M. Altarelli*
12:00-13:00	Buffet Lunch	
13:00-13:30	Flash Talks (even #'s)	*A. Turrini*
13:30-14:30	Contributed Talks: Session 1	*H. Sigg*
13:30	*Ultrafast charge localization in a valence fluctuating Eu-based material*	J.R. Linares Mardegan
13:50	*Ultrafast Mott transition in V_2O_3 by terahertz electric-field driven tunneling*	F. Giorgianni
14:10	*Orbital dynamics during the laser induced insulator to metal transition*	S. Parchenko
14:30-15:30	Poster Session & Coffee (even #'s)	
15:30-16:30	Contributed Talks: Session 2	*L.J. Heyderman*
15:30	*Time-resolved imaging of magnetic skyrmion and domain wall dynamics*	S. Finizio
15:50	*Damping modulation in magnetic thin films*	S. Saha
16:10	*Using POLDI as a tool for the development of advanced materials*	J. Capek

Tuesday, 13 November 2018

Time	*Title*	*Speaker/Chair*
16:30-17:00	What's next - future perspectives	*Ch. Rüegg*
17:00-17:30	Flash Talks (odd #’s)	*D. Tartarotti Maimone*
17:30-18:30	Poster Session (odd #’s)	
18:30-20:00	Poster Session (all #’s) & Apéro Riche	

Wednesday, 14 November 2018

Time	*Title*	*Speaker/Chair*
08:30-09:00	Welcome Coffee	
09:00-10:00	Contributed Talks: Session 3	*M. Kenzelmann*
09:00	*Temperature vs pressure phase diagram of $FeSe_{1-x}S_x$ investigated by µSR*	S.P. Holenstein
09:20	*Electron-phonon coupling and polaronic effects in the bismuthate high-T_c superconductors*	M. Naamneh
09:40	*Signatures of the topological s^{+-} superconducting order parameter in the type-II Weyl semimetal T_d-$MoTe_2$*	Z. Guguchia
10:00-10:30	Coffee Break	
10:30-11:30	Facilities: Upgrade Flash Talks	*H. Lemke*
10:30	*Using nuclear spins to probe and tune quantum magnets*	M. Müller
10:37	*CAMEA - A novel neutron spectrometer for extreme environment investigations*	J. Lass
10:44	*New perspectives in materials discovery with recently purchased high temperature, high pressure floating zone crystal growth setup*	E. Pomjakushina
10:51	*Complex sample environment at SINQ*	M. Bartkowiak
10:58	*The new SµS instrument FLAME*	H. Luetkens
11:05	*Recent and future RIXS upgrades at the Swiss Light Source*	T. Schmitt
11:12	*Furka, the future experimental station for condensed matter and quantum materials at Athos SwissFEL*	C. Svetina
11:19	*The ATHOS endstation for atomic, molecular and optical sciences*	K.A. Schnorr
11:30-12:30	Contributed Talks: Session 4	*L. Patthey*
11:30	*Ultrafast reversal of the ferroelectric polarization*	R. Mankowsky
11:50	*Element specific XUV transient grating spectroscopy*	R. Bohinc
12:10	*Ultrafast demagnetization of an iron-nickel composite probed with a single 2-color XFEL shot*	B. Rösner
12:30-13:30	Buffet Lunch	
13:30-14:30	Contributed Talks: Session 5	*C. Niedermayer*
13:30	*Lasing in highly strained Ge microbridges*	F.T. Armand Pilon
13:50	*Switching properties of photomagnetic molecular cubes: from thick films towards adsorbed monolayers*	N. Daffé
14:10	*Coherent quantum degrees of freedom in rare earth fluorides*	M. Grimm
14:30-15:00	Coffee Break	

Wednesday, 14 November 2018

Time	*Title*	*Speaker/Chair*
15:00-16:00	Contributed Talks: Session 6	*F. Nolting*
15:00	*Dimensional reduction in $BaCuSi_2O_6$ investigated by neutron scattering*	S. Allenspach
15:20	*Multiferroicity in $CoFe_2O_4$-$SrTiO_3$ self-assembled thin films*	L. Maurel Velàzquez
15:40	*Exploring the electron transfer at cuprate/manganite interfaces with X-ray Linear Dichroism (XLD)*	R. Gaina
16:00-16:10	Flowers & Poster Prize	*D.T. Maimone, S. Gerber, H. Lemke*

Plenary Talks

Advanced Materials and Surface Science at EMPA

Pierangelo Groening[1, *]
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For a long time, material science was a heuristic, empirically shaped approach to synthesizing and characterizing novel materials. The micrometer was the relevant scale for describing the physical properties of the materials. The situation has changed completely with the advent of nanoscience. Modern material science today is applied nanoscience or a field of nanotechnology. The scientific and technological development of the nanoscale opens up completely new possibilities for material science to explore and develop novel materials, moving away from empirical to rational approaches.

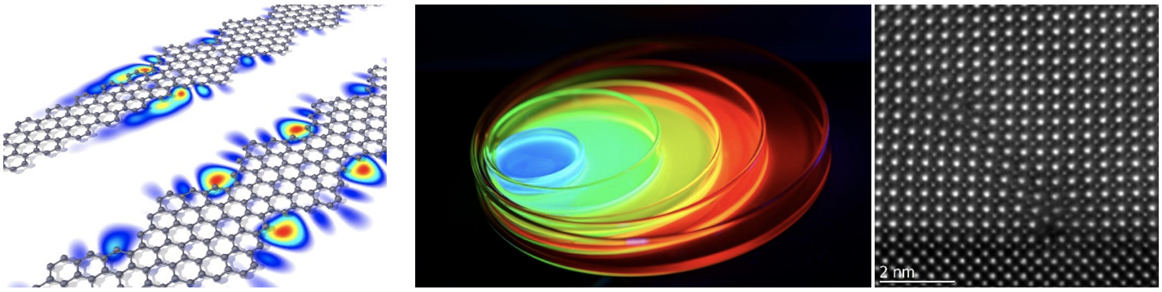

FIG. 1: Left: Tight binding calculation of robust quantum states created in the transition zone of graphene nanoribbons with alternating widths. Middle: Ultra high brilliant fluorescent perovskite nanocrystals. Right: STEM picture showing dislocations and cation positions in BiFeO3

Most new high performance materials owe their excellent, sometimes even novel, properties to their components and their structural arrangement - their nanoscale architecture. Only if components and architecture are coordinated, do the desired properties unfold - much like in a building. For its optimization, conventional, purely experimental scientific approaches are increasingly insufficient. ”Computational modelling and simulation” as well as ”machine learning” approaches are becoming more and more important in materials research. In the Research Focus Area ”Nanostructured Materials & Coatings” we consistently pursue nano-scientific approaches in the development of new materials.

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Ultrafast x-ray science

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The investigation of time-resolved properties of matter on a sub-ps time scale started with the development of fs lasers, going back to the 1970's, and has been recently extended towards shorter length scales by several techniques: High Harmonic Generation (HHG) from table-top lasers, UED (Ultrafast Electron Diffraction) and the Free-Electron Lasers (FEL's), producing x- ray pulses with peak brilliance exceeding that of synchrotron beams by up to 9 orders of magnitude, with ultra-short duration, in the region of $\sim$10 fs (10-14 s), and with a high (laser- like) degree of transverse coherence. The promise and early successes of the x-ray FEL?s has stimulated the construction of a number of facilities in Europe, in the US and in Japan, South Korea and China, and more are still under construction. We shall briefly review the existing facilities and their salient features: wavelength range, repetition rate, and the mode of generation of x-rays (Self-Amplified Spontaneous Emission or "Seeded"). Special attention shall be given to one of the recent additions to the handful of operating X-ray Free-Electron Lasers (XFEL?s), the European XFEL, resulting from the collaboration of 12 countries and now operating in the Hamburg region in Germany. Applications of these new sources include unprecedented insights into phase transformations in condensed matter, including the physics of liquids and nucleation processes; technologically relevant solid-state processes such as the fundamental time limits of erasing and writing magnetic memory elements; the study of matter under extreme high-energy density conditions; time-resolved studies in the sub-ps range ("molecular movies") of chemical reactions, and biochemical processes such as photosynthesis.

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Contributed Talks: Session 1

Ultrafast charge localization in a valence fluctuating Eu-based material

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Pressure, magnetic field and temperature are important driving forces to manipulate the 4*f* electrons and therefore the valence.[1] The time scales of these charge fluctuations and how these affect the crystal structure is poorly understood. In order to elucidate the dynamics of the 4*f* electrons, we selected the $EuNi_2(Si_{1-x}Ge_x)_2$ system with x = 0.79 as an ideal playground to study the charge localization and the lattice dynamic using X-ray absorption and diffraction techniques. $EuNi_2(Si_{0.21}Ge_{0.79})_2$ compound exhibits an abrupt valence instability around 90 K[2,3] in which in the high-temperature phase, Eu ions are approximately divalent (Eu^{2+}), while in the low-temperature regime its drastically increases to 2.83 (towards Eu^{3+}). Pump and probe experiments with a pump laser of 50 fs and 800 nm wavelength and X-ray probe with energy tuned to the Eu L_3 absorption edge (6977 eV) were carried out at the Bernina station of the SwissFEL facility. After a short optical excitation, we report a charge delocalization happening up to approximately 150 fs (Fig. 1a) in which the electrons are being removed from the 4*f* shells (Fig. 1b). Surprisingly after this charge delocalization, around 200 fs the system shows the same charge state as the equilibrium state, however, it continues to increase. It suggests the electrons that before were itinerants now are returning to the 4*f* shells in time scales of hundreds femtoseconds. Simultaneously, the crystal lattice has also been affected by this fast charge alteration in which it shows as an expansion of the lattice.

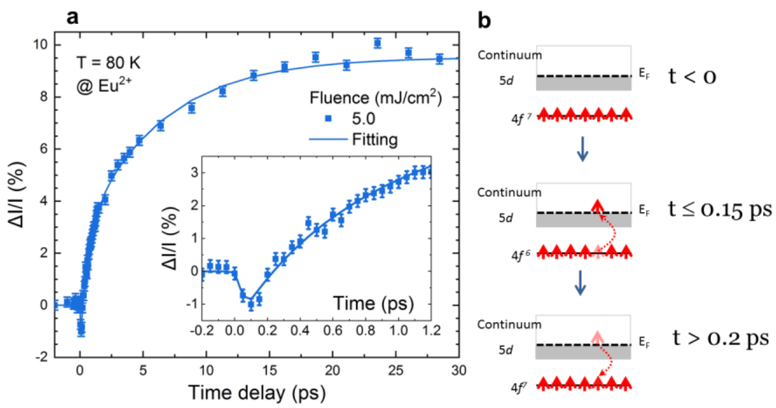

FIG. 1. **a** Time delay of the fluorescence signal collected at the Eu^{2+} peak at 80 K with an optical excitation of 5 mJ/cm^2. Negative values of the intensity indicate charge delocalization (towards Eu^{3+} valence), while positive represent localized charges (towards Eu^{2+} valence). **b** Schematics of the Eu 4*f* electrons as a function of time.

[1] V. Guritanu et al., *Phys. Rev. Lett*. **109**, 247207 (2012); and references therein.
[2] T. Hotta, *J. Phys. Soc. Jpn*. **84**, 114707 (2015).
[3] K. Ichiki et al., *Phys. Rev. B* **96**, 045106 (2017); and references therein.

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Ultrafast Mott transition in V_2O_3 by terahertz electric-field driven tunneling

Flavio Giorgianni,[1,*] Joe Sakai[2], Stefano Lupi[3]

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Vanadium sesquioxide (V_2O_3) is a canonical Mott-Hubbard material which has attracted broad attention in fundamental and applied physics because it undergoes insulator-to-metal transition (IMT) driven by electronic correlation in concomitance with a lattice transformation. The electronic and the lattice contributions could not be disentangled when IMT is driven by conventional stimuli such as temperature, pressure, fast voltage and deposition of optical energy with near infrared lasers [1].
Using intense THz pulses, we reveal the emergence of an ultrafast insulator-to-metal transition in V_2O_3. The strong electric field stimulus, non-resonant with the phonon modes, induces a sub-ps collapse of the Mott gap faster than one THz cycle by impulsive dielectric breakdown.
Following intense sub-ps electric-field excitation of the THz pulse, using ultrafast THz pump-near Infrared (NIR) probe spectroscopy, a pure electronic metallization is observed as indicated by the decrease of transmission at probe wavelengths due to the increase of the Drude-like spectral weight.
Additionally, the temperature evolution of the dynamics shows a so far unexplored crossover between ultrafast quantum tunneling regime to a ps-timescale lattice-assisted thermal transition.
Intense THz pulse is an effective approach to achieve a purely electronic Mott transition opening promising pathways towards faster and more efficient electronic switches [2] and for laser high-harmonic generation in condensed matter [3].

[1] Limelette, P., *et al*. "Universality and critical behavior at the Mott transition." Science 302, 89-92 (2003). https://doi.org/10.1126/science.1088386

[2] Hwang, H. Y., *et al*. "Emergent phenomena at oxide interfaces." Nature materials 11.2, 103 (2012). https://doi.org/10.1038/nmat3223

[3] Silva, R. F. *et al* "High-harmonic spectroscopy of ultrafast many-body dynamics in strongly correlated systems." Nature Photonics 12, 266-270 (2018). https://doi.org/10.1038/s41566-018-0129-0

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Orbital dynamics during the laser induced insulator to metal transition.

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Laser induced phase transition is in great interest at the present moment. Number of "probe" techniques was implemented to track ultrafast changes in materials. We aimed to study laser induced insulator to metal transition (IMT) with Resonant Inelastic X-ray Scattering (RIXS) in soft X-ray regime to track directly the changes in the band structure on the ultrafast time scale. The investigating material was thin film of V_2O_3 – prototypical Mott Hubbard material which have insulator to metal transition at T=160K. It was pumped with 800nm p-polarized fs laser pulse to induce the transition. The experiment was carried at LCLS free electron laser. During the experiment we was able to induce ultrafast insulator to metal transition and collect RIXS spectra for different delay times to follow the changes in band structure during the transition. Obtained spectra are in good agreement with data, collected in static regime using synchrotrons radiation in static regime. With this study we want not only to prove possibility of making ultrafast RIXS experiments in solids but also to clarify electron band structure dynamics. With obtained results we show that electronic band structure changes strongly depends on laser fluence at first several picoseconds after the excitation and be tracked with ultrafast RISX techniques.

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Contributed Talks: Session 2

Time-resolved imaging of magnetic skyrmion and domain wall dynamics

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The quest for faster and more efficient magnetic data storage devices has recently ignited a considerable attention in the study of magnetic domain walls and exotic spin configurations such as the magnetic skyrmion. To understand the applicability of those spin configurations for novel data-storage devices, their dynamical behaviors need to be investigated. In the work presented here, we report on first time-resolved scanning-transmission x-ray microscopy (STXM) measurements of the domain wall and skyrmion dynamics in nanostructured devices combining a sub-25 nm spatial resolution with a sub-200 ps temporal resolution. In particular, the current- and magnetic field-induced domain wall motion and of the current-induced skyrmion nucleation and field-induced skyrmion annihilation processes were investigated in detail. These measurements allowed us to observe the absence of incubation times for the dynamical processes (i.e. that the investigated spin configurations do not exhibit an inertial mass), and that the current-induced and magnetic field-induced processes exhibit substantially different timescales, underlining the different physical mechanisms driving the dynamical processes. An in-depth unraveling of all the contributions to the observed dynamical behaviors, including the influences of non-uniform currents and magnetic fields, Joule-heating, spin-transfer and spin-orbit torques is now necessary. The achievement of such an understanding will allow for the fabrication and improvement of magnetic domain wall and skyrmion-based data storage concepts.

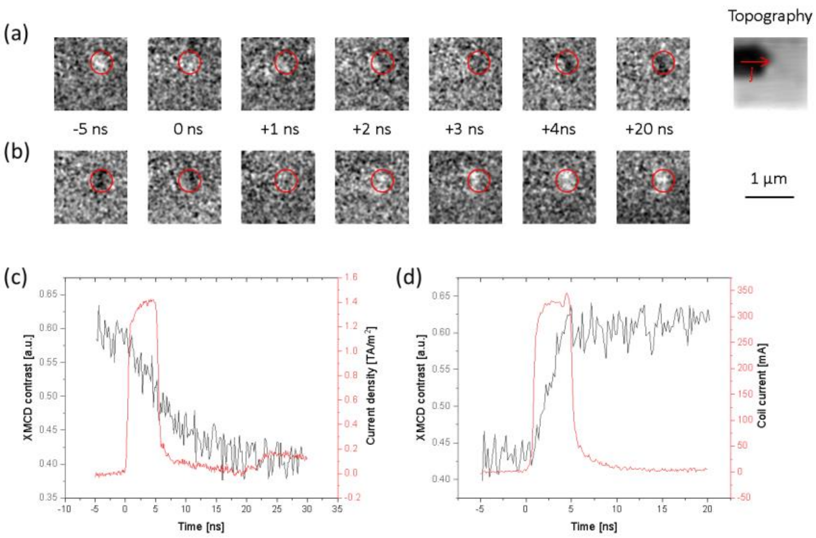

FIG. 1: Time-resolved imaging of the current-induced skyrmion nucleation and field-induced skyrmion annihilation processes. (a-b) Snapshots of a time-resolved STXM image depicting the nucleation (a) and annihilation (b) processes. The red circle marks the position of the magnetic skyrmion in the images. (c-d) Time-resolved variation of the magnetic contrast upon the nucleation (c) and annihilation (d) of the magnetic skyrmion. A clear difference in the timescales of the nucleation and annihilation processes can be observed.

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Damping Modulation in Magnetic Thin Films

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Understanding and controlling the damping in ferromagnetic thin films is very important for emerging technologies including magnonics and spintronics. One of the possible ways to manipulate magnetic damping is injection of spin current generated due to spin Hall effect [1] which is an emerging phenomenon where the properties of electrical charge current can be transferred to the electron's intrinsic angular momentum (spin current), and vice versa. This enables a mutual data transfer between spin and charge, and the generated spin currents can be used to manipulate magnetic moments as well as the intrinsic damping of the ferromagnetic material. These phenomena have a high potential for the development of future low-power electronics based on the spin-orbit interaction. To measure the modulation of damping, we use a time-resolved magneto-optical Kerr effect microscope (TR-MOKE), which has the best spatial and temporal resolution to measure the damping of the ferromagnetic film. In this project, we have demonstrated that the damping of Pt/Co/Ta film with high perpendicular anisotropy varies linearly with the electrical current density. The observations will have a strong impact on the development of spintronics devices, such as spin transfer torque nano-oscillators or domain wall racetrack memories.

[1] L. Liu et. Al., *Science*, 336, 555-558 (2012)

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Using POLDI as a tool for the development of advanced materials.

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The worldwide demand for reducing the greenhouse gas emissions, achieve better fuel efficiency and safety in automobiles has led to the development of new classes of modern materials and alloys. Typical structural materials for light-weight automotive applications are advanced-high strength steels which exhibit exceptional strength and ductility and new class of Mg-alloys with high strength, good corrosion performance and high formability. During the development process of automotive structures, the performance of the structural components is tested by simulation tools. To improve the accuracy of the virtual models, the irreversible effects of the forming processes and advanced manufacturing processes (e.g. additive manufacturing) must be integrated by means of coupling the successive operations in a virtual process chain. Experimental result on the deformation processes that these materials undergo during thermomechanical treatment and cold-forming processes is important input in micromechanical models that the simulation tools are constituted by. The engineering materials diffractometer, POLDI, offers unique experimental capabilities to study these materials in situ under complex deformation processes, similar to real-life applications, see Fig. 1 [1]. The experimental studies unveiled the deformation mechanisms in TRIP steels and Mg-alloys, under multiaxial and strain-path change deformations, exhibiting an interplay between dislocation glide, mechanical twinning and phase transformations) [2–4]. The results are discussed with respect to the loading state and evolution of microstructure during deformation.

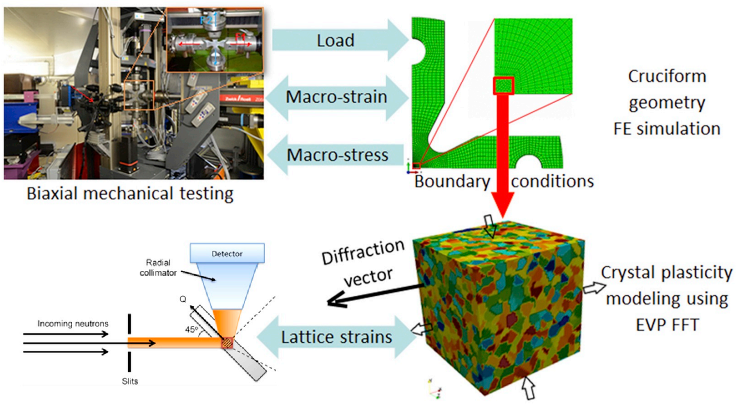

FIG. 1: Synergy of experiments and simulations: experimental results obtained from multiaxial loading at POLDI can be used to formulate crystal plasticity frameworks to be applied in macroscopic finite element models capable to capture the mechanical behavior of whole parts under service loading conditions [1].

[1] M.V. Upadhyay, S. Van Petegem, T. Panzner, R.A. Lebensohn, H. Van Swygenhoven, Acta Materialia 118 (2016) 28–43.
[2] S. Van Petegem, J. Wagner, T. Panzner, M.V. Upadhyay, T.T.T. Trang, H. Van Swygenhoven, Acta Materialia 105 (2016) 404–416.
[3] J. Čapek, K. Máthis, B. Clausen, M. Barnett, Acta Materialia 130 (2017) 319–328.
[4] E. Polatidis, W.-N. Hsu, M. Šmíd, T. Panzner, S. Chakrabarty, P. Pant, H. Van Swygenhoven, Scripta Materialia 147 (2018) 27–32.

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Contributed Talks: Session 3

Temperature vs pressure phase diagram of $FeSe_{1-x}S_x$ investigated using μSR

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The interplay of nematic, superconducting and magnetic orders is an actively discussed area of topical condensed matter physics [1]. Iron based superconductors are highly suitable to investigate this issue and muon spin rotation (μSR) is a prime technique due to its sensitivity to both superconductivity and magnetism. In the project presented here we use hydrostatic pressure and sulfur substitution to manipulate the competition, coexistence and coupling between the different orders in the iron based superconductor FeSe. Application of hydrostatic pressure to FeSe suppresses the nematic order and leads to the appearance of static magnetic order for pressures above 0.8 GPa [2]. At the same time, the superconducting T_c increases from 8 K at ambient pressure up to 37 K at approx. 7 GPa [3]. In contrast to earlier reports using electrical resistivity [4, 5] we find that sulfur substitution shifts the magnetic dome to lower pressures and does not lead to a splitting into two distinct domes (Fig.1). Our results indicate that it is rather the magnetic than the nematic fluctuations that support superconductivity in FeSe.

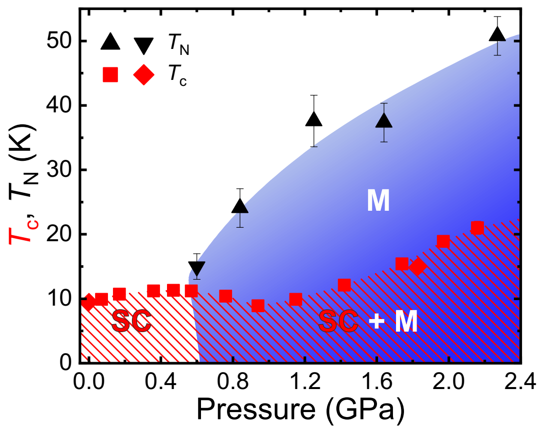

FIG. 1: Temperature vs pressure phase diagram of $FeSe_{1-x}S_x$ with x≈0.095. SC and M denote the superconducting and magnetic phase respectively. The onset of magnetic order is shifted to lower pressures compared to stoichiometric FeSe. [this work]

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[1] Q. Si et al., Nat. Rev. Mater. **1** 160117 (2016)
[2] M. Bendele et al., Phys. Rev. Lett. **104**, 87003 (2010).
[3] S. Margadonna et al., Phys. Rev. B **80**, 64506 (2009).
[4] K. Matsuura et al., Nat. Commun. **8**, 1143 (2017)
[5] L. Xiang et al., PRB **96**, 024511 (2017)

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Electron-phonon coupling and polaronic effects in the bismuthate high-T_c superconductors

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[2]*Laboratory for Scientific Developments and Novel Materials, Paul Scherrer Institut*

[3] *Physics and astronomy, University of Tennessee*

Coupling between electrons and phonons can play a major role in defining novel phases in condensed matter physics. In the weak coupling regime, it is well understood that these interactions are essential for the formation of electron pairs that enable conventional superconductivity. However, beyond the weak coupling regime, the consequences of electron-phonon interactions in the many body theory remain ambiguous. Here we investigate strong electron-phonon coupling in the bismuthate superconductor compound $Ba_{1-x}K_xBiO_3$. In the insulating parent compound, phonons dress the charges to form a lattice of frozen polarons. By doping with holes, the long-range ordering of the polarons becomes disrupted, and eventually superconductivity emerges. We have tracked the electron-phonon coupling as a function of doping using resonant inelastic X-ray scattering. The experimentally determined size of the coupling parameter cannot be fully accounted for under any single established polaron theory. Even more surprisingly, the coupling strength is virtually constant with doping, even as the sample begins to show metallicity and superconductivity. The results present a challenge to existing theories and give a new perspective in the role of the parent compound interaction in defining the superconductor state.

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Signatures of the topological s^{+-} superconducting order parameter in the type-II Weyl semimetal T_d-$MoTe_2$

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In its orthorhombic T_d polymorph, $MoTe_2$ is a type-II Weyl semimetal, where the Weyl fermions emerge at the boundary between electron and hole pockets. Non-saturating magnetoresistance and superconductivity were also observed in T_d-$MoTe_2$. Understanding the superconductivity in T_d-$MoTe_2$, which was proposed to be topologically non-trivial, is of eminent interest. We provide the first microscopic investigation of the superconductivity in T_d-$MoTe_2$ [1]. Specifically, the zero temperature magnetic penetration depth $\lambda_{eff}(0)$ and the temperature dependence of λ^{-2}_{eff} were studied in the type-II Weyl semimetal T_d-$MoTe_2$ by means of μSR experiments as a function of pressure up to $p \simeq 1.3$ GPa. Remarkably, the temperature dependence of $1/\lambda^2_{eff}(T)$ is inconsistent with a simple isotropic s-wave pairing symmetry and with presence of nodes in the gap. However, it is well described by a 2-gap s-wave scenario, indicating multigap superconductivity in $MoTe_2$. We also excluded time-reversal symmetry breaking in the high-pressure SC state with sensitive zero-field μSR experiments, classifying $MoTe_2$ as time-reversal-invariant superconductor with broken inversion symmetry. In this type of superconductor, a 2-gap s-wave model is consistent with a topologically non-trivial superconducting state if the gaps Δ_1 and Δ_2 existing on different Fermi surfaces have opposite signs. μSR experiments alone cannot distinguish between sign changing s^{+-} (topological) and s^{++} (trivial) pairing states. However, considering the strong suppression of T_c in $MoTe_2$ by disorder, we suggest that s^{+-} state is more likely to be realized in $MoTe_2$ than the s^{++} state. Should s^{+-} be the SC gap symmetry, the high-pressure state of $MoTe_2$ is, to our knowledge, the first known example of a Weyl superconductor, as well as the first example of a time-reversal invariant topological (Weyl) superconductor. Finally, we observed a linear correlation between T_c and the zero-temperature superfluid density $\lambda^{-2}_{eff}(0)$ in $MoTe_2$, which together with the observed two gap behavior, points to the unconventional nature of superconductivity in T_d-$MoTe_2$. We hope the present results will stimulate theoretical investigations to obtain a microscopic understanding of the relation between superconductivity and the topologically non-trivial electronic structure of T_d-$MoTe_2$.

[1] Z. Guguchia et. al., Nature Communications 8, 1082 (2017).

Upgrade Talks

Using nuclear spins to probe and tune quantum magnets

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We will explore new ways to use nuclear spins in order to probe, tune and control entangled phases of quantum magnets, in particular quantum spin liquids - both in and out of equilibrium. Rare earth atoms that carry both electronic and nuclear spin lead to complex magnetism, since electronic and nuclear spins are often entangled, an aspect that has so far often been disregarded in the research on quantum spin liquids. Nuclear spins tend to quench quantum fluctuations of the electronic spins and thus tend to suppress spin liquid states, at least if all rare earth atoms in the material carry a nuclear spin. We will turn this apparent drawback into an advantage: We will manipulate nuclear spins, e.g. by controlling the isotope content of atoms with nuclear spin, or by exciting hyperfine levels with microwaves, so as to tune the quantum fluctuations of rare earth magnets. Furthermore, we observe single atoms with nuclear spin embedded in a matrix of isotopes without nuclear spin can act as defects that can be read out optically and are expected to lead to new insight regarding the correlations in entangled quantum magnets.

This project is a cross-divisional collaboration between CMT, NUM and PSD, combining expertise in sample growth, neutron and x-ray scattering, optical spectroscopy, pump-probe techniques, as well as theory. It aims at establishing an open PSI-platform fordevelopingcutting edge quantum technology based on rare earth magnets. Discussions and exchange of ideas from NMR and other areas that are related to this research direction are highly welcome.

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CAMEA - A novel neutron spectrometer for extreme environment investigations

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The novel triple axis spectrometer is a work horse of neutron scattering used to map both the static correlations and elemental excitations in condensed matter materials. Neutron measurements are in general flux limited, and there are continuous efforts to improve the sensitivity: Increase the number of neutrons created at the source, increase the number of neutrons reaching the sample by better neutron transport, utilize as many of the neutrons at the detector as possible. In this talk we report on one such approach: the upgrade of the RITA2 instrument at SINQ with the multiplexing secondary spectrometer, CAMEA[1]. With 104 detectors and more than 600 analyser crystal a large part of reciprocal space will be covered within the scattering plane making CAMEA ideal for experiments with extreme environments, such as magnets and pressure cells. Being the first instrument to utilize the prismatic analyser concept[2] and due to the similarities with the upcoming BIFROST spectrometer at ESS[3], CAMEA will pave the way for the next generation of secondary triple axis spectrometers.

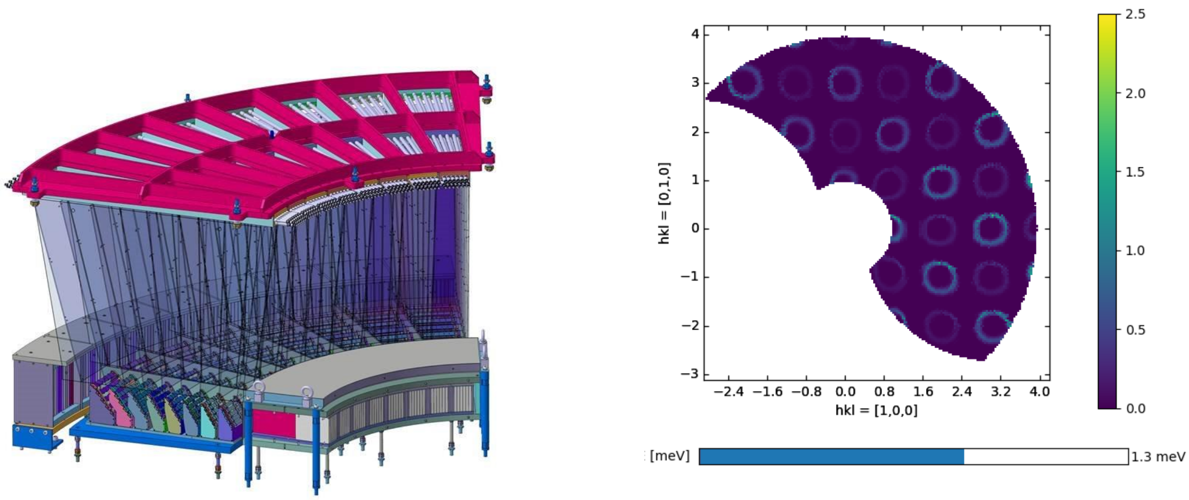

FIG. 1: **Left**: Concept drawings of secondary spectrometer[1]. **Right**: Constant energy plot for two sample rotation scans for McStas[4] simulated data of a simple magnon.

[1] Review of Scientific Instruments, Groitl, F et al. ; CAMEA - A novel multiplexing analyzer for neutron spectroscopy; 2016

[2] Birk, J. O., Mark, M., Freeman, P. G., Jacobsen, J., Hansen, R. L., Christensen, N. B., Lefmann, K. (2014). Prismatic analyser concept for neutron spectrometers. Review of Scientific Instruments, 85(11). https://doi.org/10.1063/1.4901160

[3] Ronnow, H., Lefmann, K., Chrsitensen, N. B., Jurnyi, F., Mark, M., Birk, J. O., Freeman, P. G. (2014). CAMEA Continuous Angle MultiEnergy Analysis Spectrometer Concept Phase Report.

[4] Lefmann L. and Nielsen; McStas; Neutron News 10, 20;1999.

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New perspectives in materials discovery with recently purchased high temperature, high pressure floating zone crystal growth setup

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Solid State Chemistry Group (LMX/NUM) is working on synthesis and crystal growth of materials with novel electronic and magnetic properties. A first single crystal floating zone optical mirror furnace was approved at PSI in 2003 with a support of the R'EQUIP program. Since it was installed, a numerous of single crystals interesting for their electrical and/or magnetic properties have been grown and investigated with large scale facilities of PSI. However, the existing furnace has serious limitations concerning the maximum available temperature of the floating zone (2200^{o}C) and maximum gas pressure during growth (10 bar). In the meantime, thanks to a technological development, optical mirror furnaces appear on the market which were capable to overcome these limits. Using such instrumentation crystallization of materials with very high melting points or/and decomposing at low pressures of the growing atmosphere becomes possible. In our recent R'EQUIP proposal we have demanded the single crystal floating zone optical mirror furnace of a new generation with following specification:

- Working (crystal growth) temperature up to 3000^{o}C
- Possibility of an application of a pressure of inert or active gas up to 150-200 bar
- Possibility to use the system for crystallization of intermetallic compounds at high vacuum/purified inert gas

For crystallization of intermetallic compounds melting and molding facility, which is necessary to prepare starting rods needed for crystallization processes, was also requested.

Both instruments, namely high temperature high pressure floating zone crystal growth and levitating melting facility manufactured by SciDre company (Dresden, Germany) were brought into operation this year and successfully tested.

In my "upgrade flash talk" I will show first results of successful crystal growth using this new setup.

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Complex Sample Environment at SINQ

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Neutron scattering techniques are developed tools serving a number of scientific communities to answer ever more complex scientific questions. The ability to control the sample condition during the experiment is an important part for science success. Progress in the field of sample environment is made by expanding the achievable parameter space, acquiring additional sample properties via in-situ measurements or by enabling time dependent studies. At SINQ, the sample environment group focuses on temperature and magnetic fields by providing access to a temperature range from 1800K down to 50mK and magnetic fields up to 14.9T. In addition, the group is involved in the realisation of new capabilities under these extreme conditions in order to close the gap to lab based techniques. With the implementation of the currently running SINQ upgrade program experiments on smaller samples will be possible. Subsequently, this will open opportunities for new sample environment equipment. Smaller samples allow to sacrifice sample space to enable experiments at higher pressures, magnetic and electric fields. I will present the current and future capabilities for multi-parameter experiments under extreme conditions at SINQ.

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The new SμS instrument FLAME

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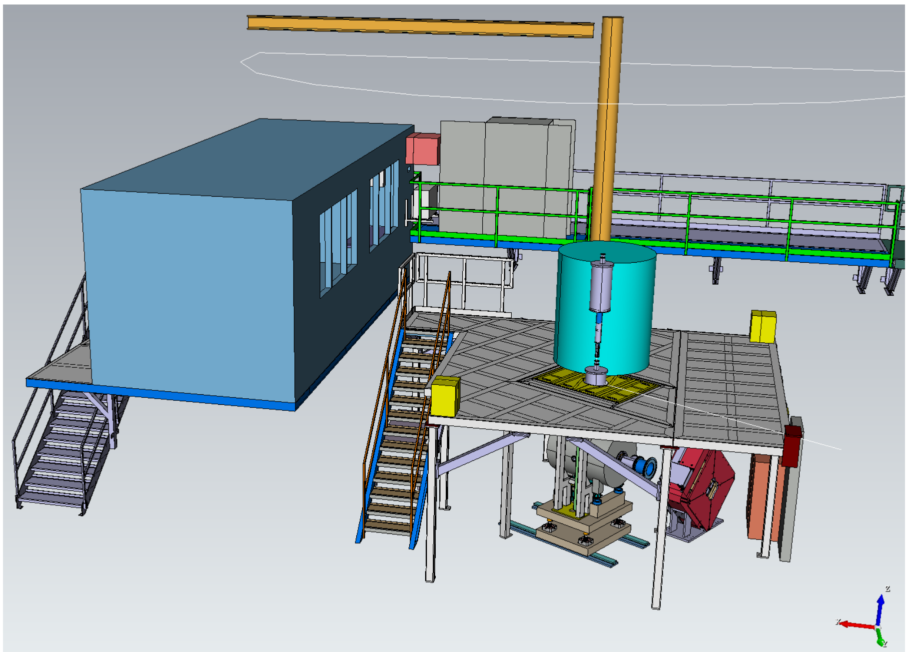
To be at the high end of international research, the μSR instruments of the SμS need to be kept at the state-of-the-art. This requires a permanent development of new experimental capabilities to be able to address topical research questions. Therefore, LMU took the strategic decision, at the beginning of 2017, to start the planning of a new instrument called FLAME (FLexible and Advanced MuSR Environment). It is foreseen that FLAME will go into user operation in the second half of 2020.

The design objectives for the FLAME instrument have been determined by the needs of the diverse and growing Swiss and international user community of the SμS facility and the compatibility and complementarity with the existing μSR instrumentation. FLAME will allow addressing a broad range of novel scientific fields that could not be studied up to now due to its partially unique features:

1) broad temperature range of 20 mK up to 310 K with magnetic fields of up to 3.5 T
2) ideal ZF, LF and TF measurements in high spatial homogeneity and temporal stability
3) small samples with practically no background
4) improved time resolution of <150 ps
5) in-situ modification of the sample by external stimuli like uniaxial pressure
6) multi samples cold finger for fast turnover times and reference samples
7) flexibility for future upgrades and compatibility with equipment of the μSR facility



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Recent and future RIXS upgrades at the Swiss Light Source

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The experimental development of the Resonant Inelastic X-ray Scattering (RIXS) technique in the soft X-ray energy range has been tremendous during the last 15-20 years, in particular after the installation of the ADRESS beamline of the SLS and its RIXS spectrometer. The combined RIXS resolving power of beamline and spectrometer have recently been improved to above 14'000. This improvement has been achieved by upgrading the RIXS spectrometer with the Electron Multiplying (EM) CCD camera RIXSCam. This custom EM-CCD camera allows adjusting the signal to readout noise ratios thereby enabling a read-out speed of 3 MHz for reading a complete chip below 1 sec. This is a prerequisite for the employment of event centroiding algorithms with reasonable duty cycles. We have recently demonstrated that an effective spatial resolution of 2-4 μm depending on photon energies can be achieved in photon counting mode for such a CCD camera based on a commercially available chip. The camera at the ADRESS beamline comprises of 3 horizontally clustered chips in order to increase the signal strength correspondingly. In addition to these recent upgrades, we will also summarize suggested upgrading scenarios for beamline and spectrometer for the future RIXS facility at SLS 2.0. These envisioned upgrades will allow accessing a lower excitation energy scale of quantum materials that are currently inaccessible for RIXS investigations. Submicron probing capabilities will enable to investigate the devices components of future electronic devices as well as to address problems of intrinsic heterogeneous materials and electronic phase separation.

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C. Svetina

Title

Furka, the future experimental station for condensed matter and quantum materials at Athos SwissFEL

Abstract

Furka, the end-station for condensed matter and quantum materials at Athos beamline, will be dedicated to time resolved Resonant Inelastic and Elastic X-ray Scattering (tr-RIXS and tr-REXS) as well as time-resolved soft X-ray diffraction (tr-SXD) for studying ultrafast dynamics in correlated materials and, more in general, quantum matter. The intriguing properties of quantum materials originate from the strong coupling between charge, orbital, spin, and lattice degrees of freedom. Ultrafast spectroscopy and tr-SXR are unique tools to disentangle different degrees of freedom with unprecedented control and precision.

After a brief overview of the Athos project describing its unique features, we will present the Furka's scientific case giving a general concept of the instrument. The experimental station is currently in the design phase and will be able to provide a versatile environment for future users with the possibility to host solid samples at cryogenic temperatures. One the most interesting features will be the possibility to perform tr-RIXS scanning the momentum transfer. In the future it will be investigated the option to perform time-resolved X-ray Magnetic Circular Dychroism (tr-XMCD), taking advantage of the circular polarized light provided by Athos combined with an external magnetic field applied to the sample, and nonlinear optics too.

The commissioning phase is foreseen from January until September 2021 followed by the pilot experiments.

The ATHOS endstation for atomic, molecular and optical sciences

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The new instrument for atomic, molecular and optical (AMO) sciences, to be setup at the soft X-ray (250 to 1800 eV) branch ATHOS of SwissFEL, will enable new research on the dynamics of gas-phase atoms and molecules, clusters, liquids and nanoparticles. Our goal is to trace electronic structure changes and nuclear rearrangement on timescales down to a few femtoseconds or even faster and exploiting the state-selectivity of X-rays for spatial resolution. The special operation modes of ATHOS are of particular relevance: ultrashort pulses down to hundreds of attoseconds, high-power operation with several mJ pulse energy and two-color X-ray pump-probe. Given the diverse sample environments, a high degree of flexibility for the instrumentation, specifically a broad portfolio of sample injectors and detection techniques, such as electron and ion spectroscopy, diffractive imaging and absorption spectroscopy, are crucial. The endstation is currently in the design phase. Thus, this is the perfect time to discuss ideas going beyond the planned capabilities of the instrument. In particular, collaborations on sample preparation and detection techniques are very welcome.

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Contributed Talks: Session 4

Ultrafast reversal of the ferroelectric polarization

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The macroscopic electric polarization of ferroelectric materials is formed by the shifts of oppositely charged ions at a structural phase transition. Information can be stored in the direction of this polarization, and switching between the two states is typically induced by pulsed electric fields on sub-nanosecond time scales [i]. Reversing the polarization with ultrashort laser pulses would be an important step toward the design of high-speed ferroelectric data storage. Here, we follow an approach, which was recently proposed in the framework of density functional theory calculations [ii]. Rather than driving the ferroelectric mode directly, we couple to it indirectly by resonant excitation of an auxiliary higher-frequency phonon mode with femtosecond mid-infrared pulses. Large-amplitude excitation of a high-frequency infrared-active lattice mode induces transient reversal of the ferroelectric polarization in $LiNbO_3$, forced by the anharmonic coupling between the driven and the lower-frequency ferroelectric mode. [iii]

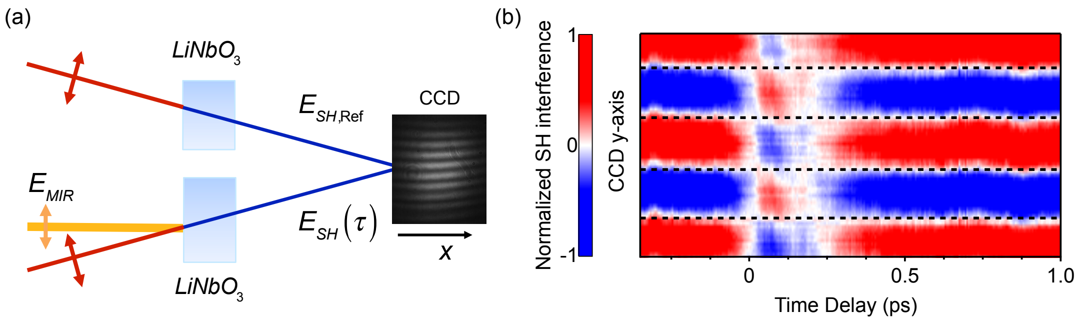

Fig. 1: (a) Experimental geometry for phase sensitive measurements of the second harmonic electric field, generated in the $LiNbO_3$ sample. The time dependent second harmonic signal from the excited $LiNbO_3$ crystal was interfered with a reference second harmonic field from an unexcited sample and measured with a CCD camera. The resulting interference pattern consisted of fringes on top of a Gaussian background, which was subtracted. (b) Time resolved measurement of the interference fringes, integrated along the x axis of the camera and normalized. The data shows a transient phase change by 180° (sign reversal) in the delay range between 0 fs and 200 fs.

[i] J. Li et al., *Appl. Phys. Let.* **84** 1174 (2004)
[ii] A. Subedi, *Phys. Rev. B* **92**, 214303 (2015)
[iii] R. Mankowsky et al., *Phys. Rev. Lett.* **118**, 197601 (2017)

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Element specific XUV transient grating spectroscopy

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Extending the methodologies of nonlinear optics to the X-ray regime is a promising and exciting avenue in the light of the recent development of X-ray free electron lasers. With the advent of fully coherent fs X-ray pulses, time-resolved X-ray four wave mixing (X-FWM) experiments became feasible. For the first time, space, time, and energy resolved XUV-transient grating experiments on S_3N_4 recorded around the Si $L_{2,3}$-edge have been realized. The observed signal decays have been assigned to ultrafast charge carrier dynamics driven by Auger recombination and electron diffusion. The increase of the XUV energy above the absorption edge resulted in a shortening of the signal decay, which could be connected to an increase in the initial charge carrier density. The possibility to combine the X-FWM approach with the atomic selectivity provided by XUV/X-ray photons may open up the way for a manifold of studies on ultrafast processes and correlations with chemical sensitivity.

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Ultrafast Demagnetization of an Iron-Nickel Composite Probed with a Single 2-Color XFEL Shot

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Dynamics on a femtosecond timescale can be accessed with pump-probe experiments using ultrashort light pulses, which have to be repeated for a series of discrete time delays. Recently, significant advances have been made in streaking the arrival time of an X-ray probe pulse in order to record the full time trace of a pump-probe experiment with a single X-ray free-electron laser (XFEL) shot [1,2]. However, a pump-probe experiment of a multi-component sample at different absorption edges suffers from a loss of the absolute timing when switching between photon energies.

We report on an experiment at the FERMI XFEL based on dedicated novel diffractive x-ray optical element, which allows for probing the demagnetization of a permalloy composite at both the iron and nickel M-edge using the same pump pulse. The optics was illuminated by two different harmonics of FERMI, resulting in a pulse with two photon energies [3]. As the time delay is defined by the experimental geometry only, both energies arrive simultaneously at the sample in the focal plane. Behind the sample, the time response of the X-ray absorption at both absorption energies is recorded on a CCD detector. This scheme offers a unique possibility to conduct parallel pump-probe experiments of complex material systems at several absorption edges with femtosecond relative timing. The method can be used to answer the fundamental mechanistic questions in magnetic materials that consist of different elements, whether the observed pumping effects in the electronic and spin system originate from one particular element or proceed independently as a function of time. The concept can be extended to broad-band XFEL pulses, as offered by Athos, taking a step forward to jitter-free transient X-ray spectroscopy.

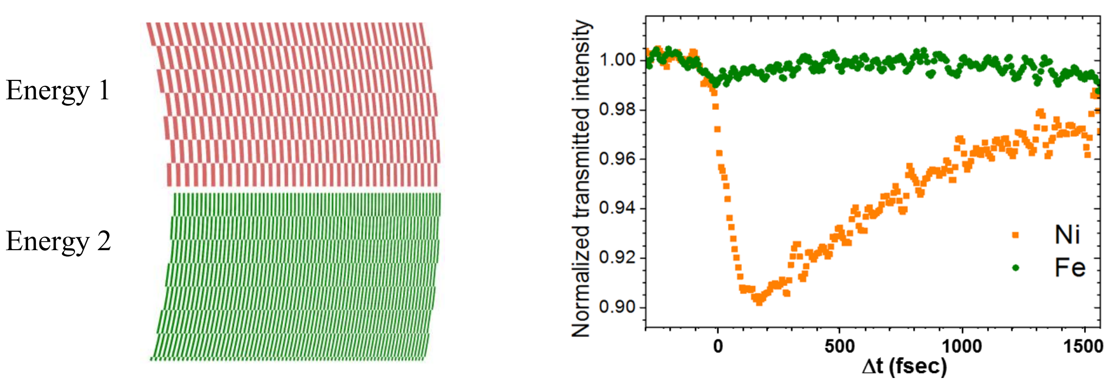

FIG. 1: Left: Schematic view of a twin focus off-axis zone plate for two colors. Right: b) Absorption changes caused by ultrafast demagnetization of a Ni-Fe film. Both curves were probed simultaneously in a single-shot pump-probe experiment at the iron and nickel M-edges.

[1] Buzzi M, M Makita, L Howald *et al*, Sci Rep **7** (2017), p. 7253. https://dx.doi.org/10.1038/s41598-017-07069-z

[2] David C, P Karvinen, M Sikorski *et al*, Sci Rep **5** (2015), p. 7644. http://dx.doi.org/10.1038/srep07644

[3] Willems F, C von Korff Schmising, D Weder *et al*, Struct Dynam **4** (2017), p. 014301. https://doi.org/10.1063/1.4976004

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Contributed Talks: Session 5

Lasing in highly strained Ge microbridges

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Recently, Germanium (Ge) has been addressed as a promising candidate for the development of a fully Si-compatible light source, thanks to its CMOS compatibility and "near" direct bandgap configuration of a - 140 meV offset between the conduction band states at Γ and L. The application of tensile strain or the alloying of Ge with Sn represent two possible ways to induce a realignment of the bands and thus increase the radiative recombination efficiency. Despite lasing in GeSn alloy system with a direct band gap configuration has been recently achieved and further developed, no analogous results in strained Ge have been proved, until our recent development at PSI. Here, we report clear lasing operation in Ge micro bridges with uniaxial tensile strained above 5 %, integrated into an optical cavity composed by two parabolically shaped corner cube mirrors. Lasing is achieved under optical pumping at an energy below the band gap of the unstrained region of the cavity, namely 2.25 µm, with a pulse length of 100 ps, which represents a time at least two orders of magnitude longer than any carrier dynamics lifetime. Under these conditions, we report unambiguous evidences of lasing: low threshold at carrier concentration of order 10^{17} cm^{-3}, linewidth narrowing down to 30 GHz, an increase of the emission efficiency of many order of magnitude and single mode operation, as a result of the archetypal mode competition behaviour.

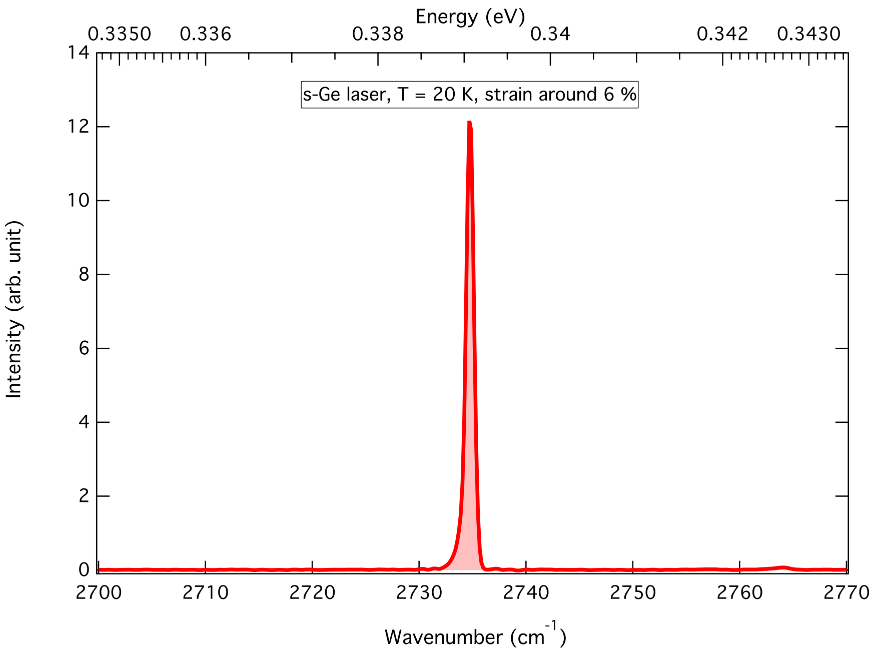

Figure.1 *High resolution spectrum of single mode emitting at 3.65 µm of the strained Germanium laser, excited at 20 K under pulsed excitation at 2.25 µm wavelength.*

Switching Properties of Photomagnetic Molecular Cubes: From Thick Films Towards Adsorbed Monolayers

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Switchable molecules exhibiting tunable physical properties as a function of external stimuli (electric or magnetic fields, temperature, light, pressure) find an increasing interest for their potential use in molecule-based electronic devices such as molecular switches, sensors or qubits. An encouraging group of compounds has emerged from Fe/Co molecular complexes exhibiting concomitant changes in their optical and magnetic properties induced by a metal-to-metal electron transfer coupled to a spin transition (see Fig.1). By means of X-ray Absorption Spectroscopy (XAS) and X-ray Magnetic Circular Dichroism (XMCD), we observe at low temperature the formation of a light-induced excited metastable state in photomagnetic heterocubane Fe_4Co_4 molecular clusters [1,2]. Upon application of stimuli of laser light and temperature, we follow the oxidation state changes of the Fe and Co ions, while XMCD measurements yield the element specific magnetic moments delivering insight into their spin states. The calculations of the X-ray spectra allow us to quantify the distribution of diamagnetic Fe^{II}_{LS}-CN-Co^{III}_{LS} pairs and of the paramagnetic Fe^{III}_{LS}-CN-Co^{II}_{HS} ones in the ground and light-induced excited state, respectively. Following up this promising study on the molecular bulk phase, we are currently investigating whether the molecules keep their charge-transfer properties when adsorbed on a suitable surface. First recent results suggest the presence of photoswitching of the photo-functional molecules in the monolayer regime, albeit in a modified form presumably due to the effect of the perturbation by the surface.

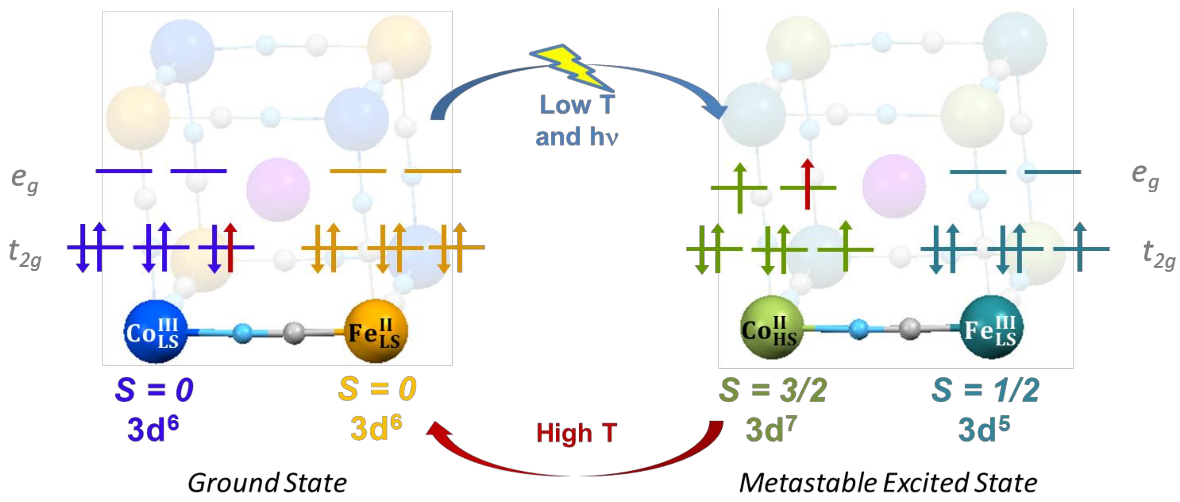

Fig. 1: Scheme of the Co and Fe electronic and spin states of the heterocubane Fe_4Co_4 molecules in the ground state and in the light-induced photoexcited state.

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[1] D. Garnier, J.-R. Jiménez, Y. Li, J. von Bardeleben, Y. Journaux, T. Augenstein, E. M. B. Moos, M. T. Gamer, F. Breher, and R. Lescouëzec, Chem. Sci. **7**, 4825 (2016).
[2] J.-R. Jiménez, M. Tricoire, D. Garnier, L.-M. Chamoreau, J. von Bardeleben, Y. Journaux, Y. Li, and R. Lescouëzec, Dalton Trans. **46**, 15549 (2017).

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Coherent quantum degrees of freedom in rare earth fluorides

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Very long-lived coherent quantum degrees of freedom are experimentally observed in the diluted rare earth fluoride $LiHo_xY_{1-x}F_4$, whose nature has remained a mystery [1]. At low temperatures, the randomly distributed Ho ions can be treated as effective spin-1/2 systems that interact with each other via the magnetic dipolar interaction. I will discuss the possible origin of the coherent degrees of freedom, based on the interplay between nuclear and electronic spins and their hyperfine and dipolar interactions, as well as crystal field distortions. Our analysis has inspired new ideas of how to realize quantum memories in solid state systems or molecular magnets. We plan to test these ideas in other rare earth magnets, such as GGG, where similar long-lived quantum objects have been found [2]. Collaborations with experimentalists working with GGG would be most welcome.

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[1] Ghosh, S., Parthasarathy, R., Rosenbaum, T. F., & Aeppli, G. ; Coherent Spin Oscillations in a Disordered Magnet. Science, 296(5576) (2002)
https://doi.org/10.1126/science.1070731
[2] Ghosh, S., Rosenbaum, T. F., & Aeppli, G. ; Macroscopic Signature of Protected Spins in a Dense Frustrated Magnet. PRL, 101(15) (2008)
https://doi.org/10.1103/PhysRevLett.101.157205

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Contributed Talks: Session 6

Dimensional Reduction in $BaCuSi_2O_6$ Investigated by Neutron Scattering

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Quasi low-dimensional systems normally display a dimensional crossover into 3D behavior either because of the divergence of the correlation length close to a critical point or due to vanishing thermal fluctuations when approaching zero temperature. Contrary to this, the quantum magnet $BaCuSi_2O_6$, which consists of stacked 2D layers hosting spin dimers, undergoes a *dimensional reduction* from 3D to 2D in close vicinity to the quantum critical point inside its Bose Einstein Condensate phase [1, 2]. Mechanisms for this *dimensional reduction* were proposed based on frustration of the interlayer exchange resulting from an assumed antiferromagnetic intralayer exchange [3, 4]. However, more recent density functional theory calculations suggest ferromagnetic intralayer exchange [5] which would render frustration of the interlayer exchange impossible. We have performed high-resolution neutron spectroscopy and high magnetic-field neutron diffraction experiments to answer the crucial question of the sign of the intralayer exchange. Calculating the spectrum of this system for various dimer models, we were able to determine the spin Hamiltonian and exchanges of this compound. Our results suggest that the intralayer exchange are effectively ferromagnetic, while there exist at least three types of different dimers in $BaCuSi_2O_6$ [6]. We conclude that the existence of different dimer types might lead to 2D behavior in close vicinity to the quantum critical point in this exciting material.

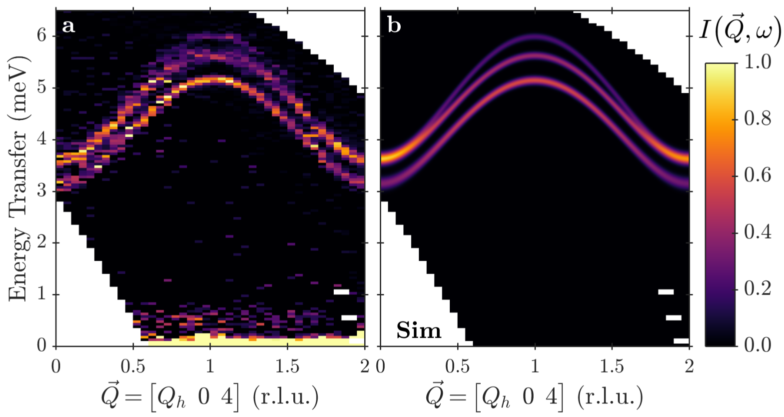

FIG. 1: **a)** Experimental and **b)** simulated spectrum of $BaCuSi_2O_6$ along $[Q_h\ 0\ 4]$ (r.l.u.). The experimental spectrum was measured using inelastic neutron scattering.

[1] C.E. Sebastian *et al.*, Nature **441**, 617 (2006).
[2] S. Krämer *et al.*, Phys. Rev. B. **76**, 100406(R) (2007).
[3] C.D. Batista *et al.*, Phys. Rev. Lett. **98**, 257201 (2007).
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[6] Ch. Rüegg *et al.*, Phys. Rev. Lett. **98**, 017202 (2007).

Multiferroicity in $CoFe_2O_4$-$SrTiO_3$ self-assembled thin films

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The lack of suitable materials with strong magnetoelectric coupling at room temperature is hindering the use of voltage-controlled magnetic memories, which will enable a drastic reduction in energy consumption for data storage application. Therefore, researchers are pursuing the development of efficient room-temperature multiferroic two-phase systems with an effective coupling of the ferromagnetic and ferroelectric responses [1]. Our approach is to create a self-assembled morphology of $CoFe_2O_4$ magnetic nanopillars in a $SrTiO_3$ matrix, to promote an efficient elastic coupling between the two phases. The magnetostrictive $CoFe_2O_4$ nanopillars induce local strain in the $SrTiO_3$ when the sample is subjected to an external magnetic field. The induced strain is not only capable of creating a ferroelectric order in $SrTiO_3$, which is known to be a quantum paraelectric in the bulk [2], but it can also select a specific direction of the spontaneous polarization in the material, thus forming a multiferroic material. By using X-ray absorption spectroscopy, we established how an applied magnetic field induces variation of the symmetry in the *d*-orbitals of Ti^{4+} along different directions of the film, enabling the direction of the spontaneous polarization to be determined. Furthermore, we have correlated these results with those obtained by macroscopic magnetization and ferroelectricity measurements to establish beyond any doubt the presence of a strong magnetoelectric coupling in our system.

[1] A. Chen *et al., Acta Materialia* **61**, 2783 (2013)
[2] U. Aschauer and N. Spaldin, *J. Phys. Condens. Matter.* **26**, 112203 (2014)

Exploring the electron transfer at cuprate/manganite interfaces with X-ray Linear Dichroism (XLD)

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The interface effects in cuprate/manganite multilayers are the subject of many extensive studies, which are focused not only on superconducting properties of antagonistic $YBa_2Cu_3O_7$ (YBCO), but also on its magnetic and electronic properties.

Our last investigations proved that in $Nd_{1-x}(Ca_{1-y}Sr_y)_xMnO_3$/YBCO /NCSMO (NYN) trilayers, the interfacial electron transfer and the orbital reconstruction of the interfacial Cu ions depend significantly on hole doping x and tolerance factor t, and the subsequent charge/orbital order of the manganite.

X-ray Linear Dichroism (XLD) is the suitable technique for probing orbital occupancy, by measuring the variation of the x-rays absorption spectra (XAS) as a function of polarization direction of the linearly polarized x-rays. For a series of NYN samples, XLD studies showed that the charge transfer (red shift of the Cu-resonance ions from interface, compared with those from bulk-side) and the orbital reconstruction are more pronounced at lower hole doping, x. In this sense, these aspects are strongly related with the emergence of different charge/orbital and magnetic orders of the manganite which affect the adjacent YBCO layer. They are connected phenomena that are driven by the chemical potential difference between NCSMO and YBCO.

The interface phenomena can potentially lead to combined superconducting/charge-ordered quantum states in YBCO that can be adjusted via manganite layers and external control parameters, like magnetic field or photons.

Posters

Poster Session Overview

Tuesday, 13 November 2018

14:30-15:30 Poster Session (even #’s)

17:30-18:30 Poster Session (odd #’s)

18:30-20:00 Poster Session (all #’s) & Apéro Riche

Wednesday, 14 November 2018

16:00-16:10 Poster Prize and Flowers

Posters selected for flash talks are printed in bold

Board	*Title*	*Author*
1	The polar distortion and its relation to magnetic order in multiferroic $HoMnO_3$	N. Ortiz
2	STM study of endohedral fullerenes	N. Bachellier
3	X-ray linear dichroism for probing magnetic dynamics in the low-damping ferrimagnetic insulator yttrium iron garnet	J. Bailey
4	Reversible magnetoelectric switching by electrochemical lithium intercalation	G. Bimashofer
5	Ultrafast demagnetisation dynamics in multiferroic $CoCr_2O_4$	M. Decker
6	Towards highly efficient off-axis Fresnel zone plate analyzers for increasing resolution and throughput in spectroscopy (RIXS, XAS)	F. Döring
7	Electric field control of magnetism in PMA multilayer structures	C.A.F. Vaz
8	Lattice distortions analysis of $RNiO_3$ across the R - applying the symmetry-adapted distortion modes analysis	D. Gawryluk
9	Ultrafast melting of antiferromagnetic order in Slater insulator, $NaOsO_3$	N. Gurung
10	Reducing the superparamagnetic blocking temperature of permalloy nanomagnets in artificial square spin ice	K. Hofhuis

11	Controlling of ferromagnetic and antiferromagnetic thin films by current-generated spin-orbit torques	A. Hrabec
12	Tuning the electronic structure of $LaNiO_3$ heterostructures	J. Jandke
13	Mixed ground state in a S=1 kagome antiferromagnet, a MuSR and heat capacity study	J.C. Orain
14	**Three-dimensional imaging of ferroic materials using coherent x-rays**	D. Karpov
15	Quest for quantum Heisenberg AFM in spinel chalcogenides $CdYb_2Se_4$	K. Guratinder
16	**Beyond conventional magnetic order in the Shastry-Sutherland frustrated magnet TmB_4**	D. Lançon
17	**Development of a new soft x-ray ptychography spectro-microscope at the Swiss Light Source (SLS)**	M. Langer
18	Revisiting the magnetic structure of $La_{1/3}Sr_{2/3}FeO_3$ by neutron powder diffraction	F. Li
19	Chiral coupling between in-plane and out-of-plane nanomagnetic patterns induced by interfacial Dzyaloshinskii-Moriya interaction	Z. Luo
20	Spin wave emission from vortex cores	S. Mayr
21	FEL based XUV coherent FWM experiments	G. Pamfilidis
22	**Magnetic coupling of $SrRuO_3/La_{0.7}Ba_{0.3}MnO_3/SrRuO_3$ trilayers**	C. Piamonteze
23	Variance monitoring and kernel density estimation for 2D experimental data as an attempt for efficient use of beamtime	K. Saito
24	A combined investigation of single cobalt nanoparticles by means of X-PEEM and HAADF-STEM and structural simulations.	T. Savchenko
25	Restabilization of the Q-phase and two quantum critical point in the Nd-doped $CeCoIn_5$	J. Shen
26	Complex interplay between superconductivity and magnetism in $Nd_{1-x}Ce_xCoIn_5$	D.T. Maimone
27	Investigations of scaling and dynamics in the kagome ice phase of $Ho_2Ti_2O_7$	A. Turrini
28	Neutron grating interferometry from micro-structures to magnetic induced phase shift and beyond	J. Valsecchi
29	Low temperature platform for THz pump – x-ray probe experiments at SwissFEL	J. Vonka

30	Spin dynamics in the one-dimensional spin system $NaCuF_3$	F. Xiao
31	Thermal neutron single-crystal diffractometer Zebra at SINQ	O. Zaharko
32	Probing the origin of ferromagnetic stability of LSMO/SRO	A. Zakharova
33	**Ultrafast magnetic and orbital phase transitions in a 4d correlated system**	S. Zerdane
34	Spin wave dynamics in antiferromagnetically coupled magnetic trilayers	J. Zhou
35	Floating zone growth of RAlGe, a magnetic Weyl semimetal	P. Puphal
36	Resonant soft x-ray magnetic scattering and imaging of spin textures in skyrmion-hosting materials	V. Ukleev
37	**Unconventional order-disorder phase transition in improper ferroelectric hexagonal manganites**	S. Skjaervoe
38	Magnetism in semiconducting molybdenum dichalcogenides	Z. Guguchia
39	'Neutron Microscope' - experience from the users' experiments and future prospects	P. Trtik
40	**Spin and lattice correlations in $SrCu_2(BO_3)_2$**	B. Wehinger
41	Dependency of the 2 dimensional electronic state of $CaTiO_3$ with film thickness and underlayer	E.B. Guedes
42	$LiY_{1-x}Ho_xF_4$ – a candidate material for the implementation of solid state qubits	A. Beckert
43	Manipulating the ground state in nickelates using proximity with magnetic layers	M. Caputo
44	Anomalous electronic and magnetic behavior of Weyl semimetal Fe_3Sn_2	K. Neeraj
45	Structural details of the surface relaxation of multiferroic GeTe(111)	D. Sostina
46	Ground-state and excitations in the dipolar magnets on a honeycomb lattice $ErBr_3$, $YbBr_3$	C. Wessler
47	**Hidden correlations of a quantum liquid of octupoles**	R. Sibille

The polar distortion and its relation to magnetic order in multiferroic $HoMnO_3$

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Multiferroic materials have attracted significant attention, primarily because the coupling between the electric and magnetic order parameters presents the possibility of controlling magnetic properties by applying electric fields (and vice versa) [1].
The orthorhombic (Pbnm) $HoMnO_3$ is of particular interest due to its high magnetically-induced polarization values (P) and magnetoelectric coupling strength. The mechanism behind this involves high magnetic frustration, which results in a magnetic order that creates a distortion in the crystal lattice. This distortion breaks inversion symmetry and creates a macroscopic electric polarization P along the a-axis [2].
This distortion does not exclusively affect the atomic positions along the polar axis, it also moves atoms along other directions. For instance, the distortion enables intensities of reflections such as (050), which is forbidden in Pbnm and just probes motions solely along the b axis (see fig.1.(a)). This does not represent the polar distortion (see fig.1.(c)) neither does correspondingly to the polarity of the domain. In comparison, the (362) reflection showed in fig.1.(b) is an allowed reflection and due to have component along the polar axis we observe the polar distortion (d), visualized by the difference caused by opposite domains. We investigated the atomic distortion to identify the broken symmetry of Pbnm in thin films of $HoMnO_3$ with 17nm thickness at low temperature and the relation between the magnetic order of Ho and the structural distortion.

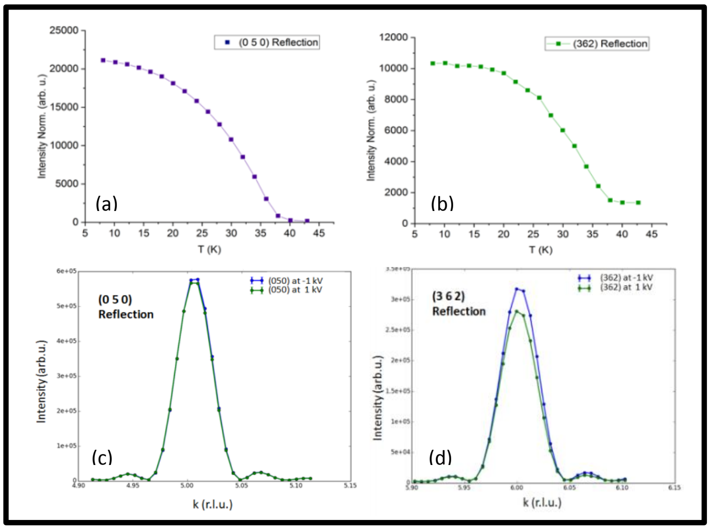

Figure 1. Temperature dependence: (a) a forbidden reflection (050) and (b) an allowed reflection (362). (c) and (d) show k-scans along the (050) and (362) direction respectively for 2 opposite E-fields (+1 kV and -1 kV).

[1] N. A. Spaldin et al., vol. 309, 391-392 (2005)
[2] N. Lee et at, Phys. Rev. B **84**, 020101 (2011)

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STM study of endohedral fullerenes

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A promising route to create always smaller electronic and magnetic devices is the use of single molecular magnets (SMM). Interesting candidates for SMM are endohedral fullerenes, consisting of a carbon cage encapsulating a magnetic core. Such molecules have already shown interesting properties : XMCD and SQUID measurements on $Dy_nSc_{3-n}N@C_{80}$ revealed a long remanence relaxation time at low temperature (2 K) [1-3].

The system under study here is the $Tb_2@C_{79}N$ molecule, where two terbium atoms are encapsulated in a carbon and nitrogen shell. They have been deposited on Cu(111) and Au(111) crystals and investigated by Scanning Tunneling Microscope (STM). This study was initially meant to complement XMCD measurements but opens new possibilites to investigate endohedral fullerenes at the single molecule scale.

The first results of the study shows a weak influence of the chemical species used as host surface and spectroscopic differences between neighbouring molecules within the same network. Further ideas include depositing those molecules on magnetic surfaces (Co/Cu(111)), the use of XPD, and STM in contact.

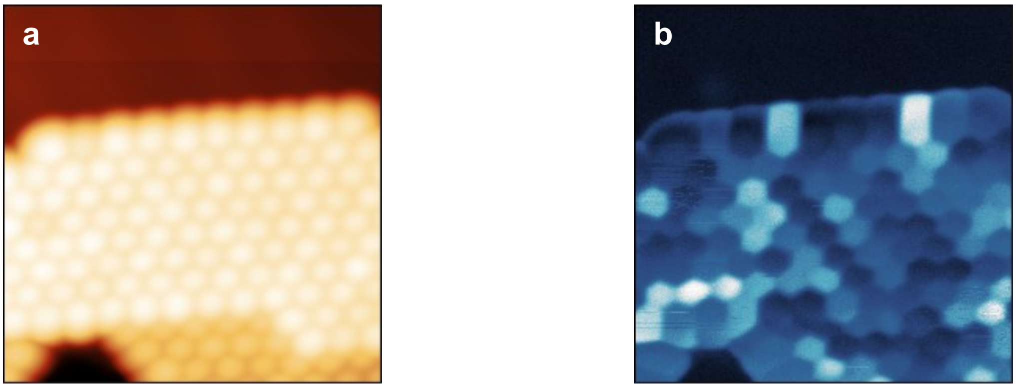

Fig. 1: (a) STM picture of a island, -0.632V, 50 pA.
(b) corresponding dI/dV map with same settings.

[1] M. Treier et al, Phys. Rev. B, 081403R, (2009)
[2] R. Westerstrom et al., J. Am. Chem. Soc. 134, 24, 9840-9843 (2012)
[3] R. Westerstrom et al., PRL 114, 087201 (2015)

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X-ray linear dichroism for probing magnetic dynamics in the low-damping ferrimagnetic insulator yttrium iron garnet

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Imaging magnetic dynamics in a range of materials on the nm length scale and GHz time scales is important for the development of spintronic and magnonic devices. Time resolved scanning transmission x-ray microscopy (TR-STXM) is one of the few techniques that is capable of simultaneously meeting these criteria. Up to now TR-STXM measurements have exclusively made use of x-ray magnetic circular dichroism (XMCD) to achieve magnetic contrast. XMCD suffers the limitation however that it is sensitive to net magnetisation, consequentially for some samples (such as antiferromagnets) it cannot be used. In contrast x-ray magnetic linear dichroism (XMLD) is sensitive to the axis of magnetisation, and as such can be used in different systems. Here we present the first use of XMLD for imaging magnetic dynamics with TR-STXM. We use this technique to characterise vortex, domain wall and spin wave dynamics in the ferrimagnetic insulator and magnonic material of choice yttrium iron garnet (*see Figure*). Our findings demonstrate a novel and important advance in time resolved magnetic x-ray microscopy opening the door to the study of ultrafast magnonics based on antiferromagnets.

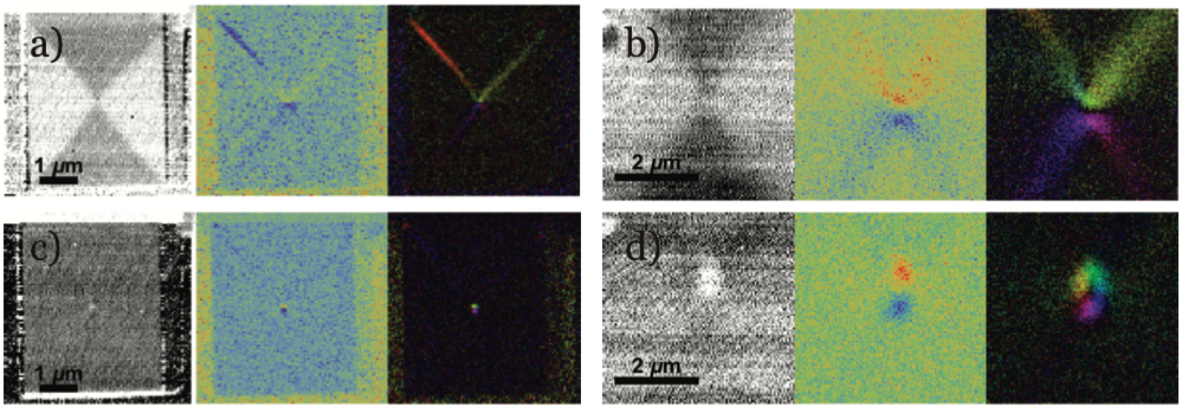

FIG. 1: Snapshots of time resolved measurements of domain wall and vortex core motion
RF (71 MHz) excitations create oscillations in the vortex core and domain wall structure, as imaged using XMLD and XMCD. The geometry of our sample leads (when no external filed is applied) to a domain structure and vortex core. a) and c) are overviews, while b) and d) show a close up of the vortex core. Using a combination of XMLD (a and b) and XMCD (c and d) we are able to observe both the in-plane and out of plane dynamics. For each figure the left column shows absorption, centre row shows dynamics contrast and right-hand column shows a phase/amplitude image extracted with Fourier analysis.

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Reversible magnetoelectric switching by electrochemical lithium intercalation

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We are working on a method to observe the relation between charge ordering and magnetism in manganites ($A^{3+}_{1-x}B^{2+}_{x}\mathrm{MnO_3}$). These have complex phase diagrams as a function of composition x and temperature T with a variety of magnetic and electronic phases. $\mathrm{La_{1-x}Sr_xMnO_3}$ (LSMO) shows transitions between ferromagnetism (FM) and paramagnetism at room temperature and between antiferromagnetism (AFM) and FM at lower T for $x \approx 0.5$. It is believed that the driving force is the ordering of Mn^{3+} and Mn^{4+}, which sets in at $x \approx 0.5$.[1] Our approach is to reversibly[2] change the Mn^{3+} / Mn^{4+} ratio by de-/lithiating the material electrochemically, using a Li-ion battery-like half-cell (see figure 1) and to monitor the process in-situ. In addition to LSMO we use the already lithiated material $\mathrm{La_xSr_yLi_zMnO_3}$ (LSLMO) starting on the FM-side of the phase boundary. Polarized Neutron Reflectometry (PNR) gives insight to the lithium distribution and the magnetic induction profile within the manganite layers. The reversibility[2] of the process allows us to investigate the same sample in various states around the phase transitions and thus will help to resolve the contributions to the phase formation and to quantify their mutual connection.

Samples of various compositions were grown by Pulsed Laser Deposition and characterized structurally and electrochemically. To determine the magnetic states of the virgin samples, PNR measurements were carried out at room T as well as down to 100 K on Amor. For the in-situ PNR measurements an electrochemical cell was designed and built. The first measurements qualitatively showed that magnetic switching is possible for LSLMO and gave hints that also LSMO undergoes the phase transition.

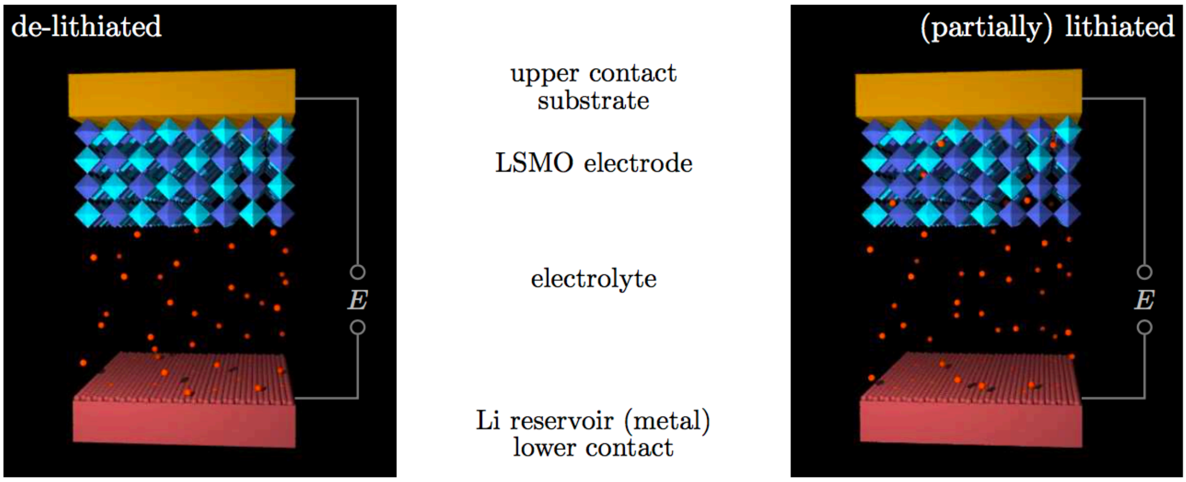

FIG. 1: Schematic of the li-ion battery-like half-cell

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[1] E. Dagotto et al., Physics Reports 344, 1 (2001)
[2] S. Dasgupta et al., Advanced Materials 26, 4639 (2014)

Ultrafast demagnetisation dynamics in multiferroic $CoCr_2O_4$

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The study of ultrafast processes in solid states aims to better understand the underlying interactions on sub-nanosecond timescales, giving us insight into possible technological applications and their physical limits, as for example in magnetic recording devices. Recent studies on antiferromagnetic systems showed demagnetization dynamics in a range between 200 fs and 23 ps [1,2]. In our work we present the demagnetization dynamics of $CoCr_2\,O_4$ (CCO), an insulating ferrimagnet with spinel structure, which shows multiferroic properties below T_S=27 K [3]. Femtosecond LASER pump, X-ray probe measurements in reflectivity geometry on the Co L3 edge were performed at the Femtospex beamline at Bessy II (HZB) in Berlin for four different temperatures. The Data show demagnetization dynamics in the order of 2 ps, which lies in between the results found for these two oxide systems. A better understanding of the observed points to a limitation of the demagnetization timescales by the energy transfer from the electronic system to the lattice. To test such a scenario, theoretical calculations to determine the strength of the electron phonon couplings might be helpful.

[1] S.L Johnson et al., PRL 108, 037203 (2012)
[2] J. A. Johnson et al., PHYSICAL REVIEW B 92, 184429 (2015)
[3] Y. J. Choi et al., *PRL* **102**, 067601 (2009)

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Towards highly efficient off-axis Fresnel zone plate analyzers for increasing resolution and throughput in spectroscopy (RIXS, XAS)

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X-ray spectroscopic techniques such as Resonant Inelastic X-ray Scattering (RIXS) and fluorescence yield X-ray Absorption Spectroscopy (XAS) are very photon hungry and can benefit strongly from more efficient optics. We have implemented and successfully tested transmission off-axis Fresnel zone plates for use as analyzer optics for spectroscopy at synchrotrons and X-ray free electron lasers (See Fig. 1). This project aims at increasing throughput and resolution in advanced spectroscopic experiments by making use of imaging capabilities of zone plates for two dimensional mapping approaches. By exploiting volume diffraction effects inside the zone structures, the efficiency of off-axis zone plates can be boosted significantly. We have performed several proof-of-concept experiments showing the current and future potential of zone plate analyzers for spectroscopy [1,2]. Our latest results indicate that using higher diffraction orders may be useful in the future for increasing the energy resolution, while maintaining a sufficiently high efficiency due to volume diffraction effects. This project could benefit strongly from a collaboration partner, who adds an interesting material system, where soft X-ray RIXS or XAS measurements could be performed. The novel analyzer scheme opens up a variety of new measurement possibilities including RIXS-imaging, energy mapping and ultra-fast time resolved investigations at X-ray free electron laser sources.

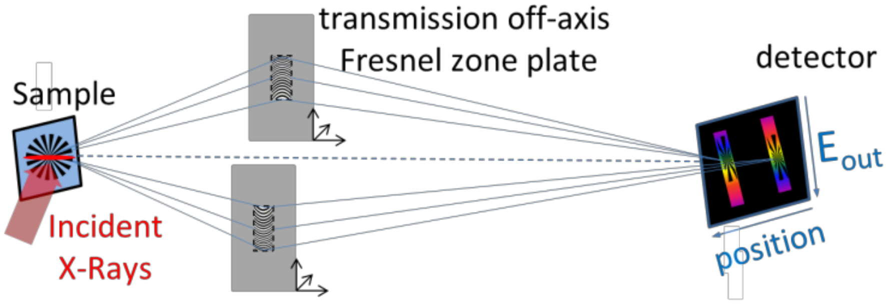

FIG. 1: Sketch of the new two-color imaging spectroscopy setup: Two independent transmission off-axis Fresnel zone plates are used to collect and disperse the emitted light from the sample to two different lines at the detector. Two separate spatially and spectrally resolved images of different emission energies can be obtained at the same time.

[1] Marschall, F., et al., Transmission zone plates as analyzers for efficient parallel 2D RIXS-mapping. Scientific Reports, 2017. 7(1): p. 8849. https://doi.org/10.1038/s41598-017-09052-0

[2] Döring, F., et al., ID-Full Field Microscopy of Elastic and Inelastic Scattering with Transmission off-axis Fresnel Zone Plates. Microscopy and Microanalysis, 2018. 24(S2): p. 184-185. https://doi.org/10.1017/S1431927618013260

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Electric field control of magnetism in PMA multilayer structures

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In this work we present our recent results on the electrostatic control of the magnetic properties of Pt,Ta/Co/Pt perpendicularly magnetised structures using Si_3N_4 membranes as the gate dielectric. We find that the domain configuration and magnetic anisotropy are modulated by the applied electric field, demonstrating the presence of a magnetoelectric coupling in the system. In the case of the asymmetric trilayer structures we observed the coexistence of in-plane and out of plane magnetic regions, which we attribute to the combined effect of DMI and film roughness. Micromagnetic simulations are being presently carried out to gain further insights into the mechanisms underlying the stabilisation of the perpendicular magnetic state for the asymmetric structures. From electrical characterisation of the device structure, we find that the presence of charge traps in the Si_3N_4 membrane hinders the reversible control of the magnetic properties via electric fields, and may require either the use of stoichiometric Si_3N_4 or, alternatively, other oxide materials as gate dielectric.

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Lattice distortions analysis of *R*NiO_3 across the *R* - applying the symmetry-adapted distortion modes analysis

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All members of the rare earth nickelates (*R*NiO_3) family, with the exception of metallic $LaNiO_3$, display a Metal to Insulator Transition (MIT) at temperatures T_{MIT} which increase by decreasing the *R* ionic radius. The electronic localization is associated to a charge disproportionation of the type $2Ni^{3+} \leftrightarrow Ni^{3+\delta} + Ni^{3-\delta}$ and with subtle structural distortions related to the $Ni^{3+\delta}/Ni^{3-\delta}$ charge order. Taking advantage of our high oxygen pressure system (Pmax = 2 kbar), a series of the *R*NiO_3 was synthetized. Using neutron X-Ray diffraction the lattice anomalies of *R*NiO_3 across *R* have been re-investigated and interpreted in terms of "frozen" normal distortion modes [1]. We identify a breathing mode with non-zero amplitude below T_{MIT} and associate it to the charge order responsible for the MIT [2]. Based on our new experimental results two models for the Ni magnetic structure will be also discussed.

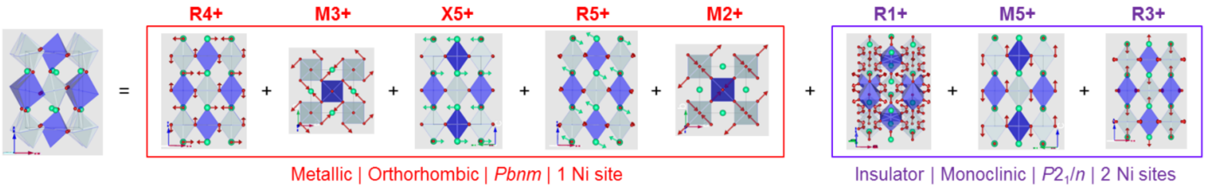

FIG. 1: Schematic view of distorted perovskite structure of the *R*NiO_3 as a sum of the global atomic displacements.

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[1] Perez-Mato, JM, *et al.;* Acta Cryst A**66**, 558 (2010); https://doi.org/10.1107/S0108767310016247
[2] Gawryluk, DJ, *et al.;* arXiv:1809.10914; https://arxiv.org/abs/1809.10914

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Ultrafast melting of antiferromagnetic order in Slater insulator, $NaOsO_3$

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The metal-insulator transition in 5*d* transition metal oxide $NaOsO_3$ which occurs concomitantly with antiferromagnetic ($T_{MIT} = T_N$) has been proposed to be of Slater mechanism [1, 2, 3, 4, 5]. However, there is no consensus and other mechanisms such as a Lifshitz transition have also been proposed. Having observed ultrafast change in reflectivity (see FIG. 1) upon photo-excitation, we sought to study the time-evolution of long-range ordering arising separately from structural, magnetic and electronic ordering upon ultrashort laser pulse excitation using time-resolved resonant x-ray diffraction. From our preliminary data analysis, we observe a significant drop of the antiferromagnetic peak intensity within 60 fs (see FIG. 2) after photo-excitation, while the timescale associated with the drop of intensity of a structural reflection is in the order of 9 ps. Our next step is to develop a model to quantitatively describe the time and fluence dependence of the magnetic and lattice reflections. A comparison with the ultrafast dynamics of long range ordering in other transition metal oxides will ultimately enable us to gain more insight about the nature of the MIT.

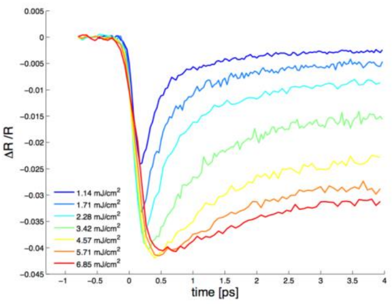

FIG. 1: Ultrafast change in reflectivity upon photo-excitation with λ = 800 nm laser pulse.

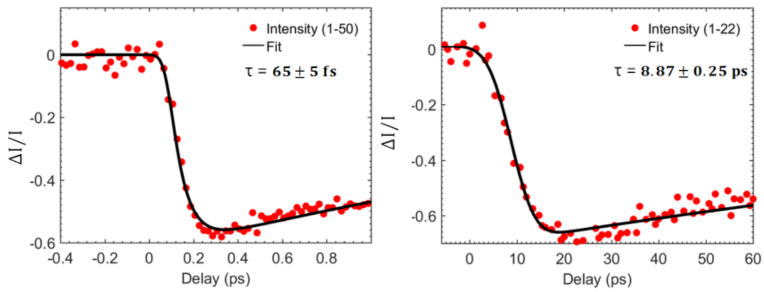

FIG. 2: Ultrafast drop (≈ 60 fs) of the antiferromagnetic peak (1-50) intensity upon photo-excitation versus timescale associated with the drop of intensity of a structural reflection (1-22) which is ≈ 9 ps.

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Reducing the superparamagnetic blocking temperature of Permalloy nanomagnets in artificial square spin ice

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Geometrical frustration arises when not all interactions are simultaneously satisfied, and artificial spin systems offer an ideal platform to study this with the use of microscopy techniques. Using spatially-resolved X-PEEM, we compare the thermal relaxation in artificial square spin ice where the Permalloy is grown on a heavy-metal interface and a silicon substrate. The interfacial interaction between the Permalloy nanomagnets and the heavy-metal layer is hypothesized to give rise to an interfacial Dzyaloshinskii-Moriya interaction (iDMI), which lowers the magnetization switching barrier. Thus, the superparamagnetic blocking temperature of the nanomagnets reduces, while the strength of their magnetostatic coupling remains unaffected. Initial hysteresis loops measured with MOKE show a significant decrease of the coercivity as a function of thickness, and micromagnetic simulations qualitatively show the same trend when including iDMI. However, a direct measurement of iDMI strength is necessary to confirm the hypothesis. Our next aim is to observe and verify the long-range magnetic order in artificial kagome spin ice using X-PEEM.

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Controlling of ferromagnetic and antiferromagnetic thin films by current-generated spin-orbit torques

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Over the past ten years, research into ferromagnetic spintronics has made significant steps in terms of the discovery of new mechanisms driving the speed of magnetization switching. The discovery of spin-orbit torques allowed efficient manipulation of magnetic domain walls [1] or skyrmions [2]. However, the fundamental limits associated with ferromagnets mean that new concepts beyond conventional spintronics are required. Antiferromagnets, thanks to exchange coupling, offer significantly faster dynamics which, together with other appealing properties, makes them extremely promising for spintronics applications. There has been great interest in antiferromagnets for spintronics recently, since they bring the promise of a low power alternative to ferromagnetic devices. In this project, the goal is to determine the microscopic mechanisms governing magnetization reversal in antiferromagnetic thin films by characterising the films with high spatial and time resolution. We focus on the Mn_2Au system [3], a room temperature metallic antiferromagnet, which is one of the two promising candidates for spin-orbit torque-driven staggered magnetization control. In order to reach this goal, the role of antiferromagnetic domains, crystal grains, device boundaries and heat will be elucidated.

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[2] A. Hrabec, V. Křižáková, S. Pizzini, J. Sampaio, A. Thiaville, S. Rohart, and J. Vogel, Phys. Rev. Lett. **120**, 227204 (2018).
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Tuning the electronic structure of LaNiO$_3$ heterostructures

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Since many, years rare earth nickelates (RNiO3) attract the researchers interest due to their huge variety of fascinating physical properties which are tunable by the interplay of electron correlations and crystal structure [1]. It was suggested that electron correlations tuned by heterostructuring could even induce a cupratelike Fermi surface. We investigate the evolution of the electronic structure of LaNiO3 (LNO) thin films in proximity to manganite layers (strontium and calcium doped lanthanum manganite – LSMO and LCMO) grown on STO and NGO substrates. The films were grown by pulsed laser deposition (PLD). The combined study of Angle resolved photoemission spectroscopy (ARPES), transport properties and X-ray magnetic circular dichroism (XMCD) reveal anomalies around T=50K and T=150K as well as a strong dependence on the substrate. Understanding these properties could be crucial for tuning the nickelates towards superconductivity.

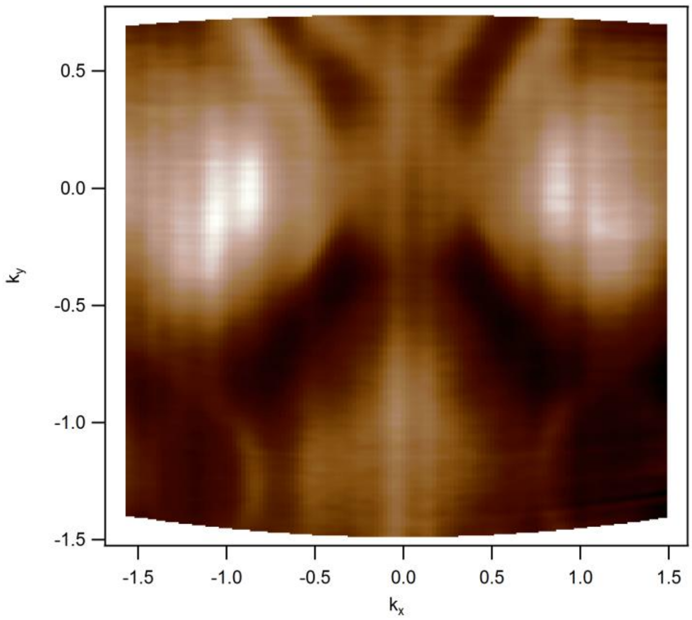

FIG. 1: Fermi surface map measured with ARPES at a photon energy of 90eV.

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* Electronic address: jasmin.jandke@psi.ch

Mixed ground state in a $S = 1$ Kagome antiferromagnet, a μSR and heat capacity study

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The study of the highly frustrated kagome model is an intense topic of condensed matter research focusing on the quantum ($S = 1/2$)[1] and classical ($S > 1$)[2] cases while the intermediate case ($S = 1$) has been poorly studied. However, few theoretical studies and experimental realization of $S = 1$ kagome compounds pointed out an exotic valence bond crystal ground state and, in real material, a preponderant influence of the deviations to the model in the stabilization of a defined ground state, as for the $S = 1/2$ case. To analyze the influence of anisotropies in the destabilization of the valence bond crystal ground state we studied by μSR and heat capacity the $S = 1$ kagome compound $(NH_4)_2[C_2H_8N][V_3F_{12}]$ which presents Dzyaloshinskii-Moriya interactions, onsite magnetic anisotropy of V^{3+} and a buckled magnetic lattice. Previous susceptibility measurements revealed antiferromagnetic interactions with a Curie Weiss temperature of -28(2) K and two transitions in this compound : one at 10 K to a weak ferromagnetic state and the other at 6 K to either an antiferromagnetic long range order or a spin glass like state[4]. Our μSR and heat capacity measurements pointed out persistence of spin fluctuations between 10 K and 6 K in combination to low value of magnetic entropy below 10 K, which could be the signature of a ferromagnetic transition of the spin part perpendicular to the kagome lattice with persisting dynamics magnetism within the kagome planes. Below 6 K, our μSR measurement lightened up a transition to a mix ground state with probable incommensurate antiferromagnetically long range ordered phase and a spin glass like one. From different calculations and considerations about other experiments, it is likely that the anisotropy of the lattice is the main mechanism at the origin of the 10 K transition and of the incommensurability of the ordered phase. However, more experiments, for instance neutron scattering or electronic spin resonance, in addition to DFT calculations could be performed to have more insights in the influence of the lattice anisotropy in the destabilization of the valence bond crystal state theoretically expected.

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[4] F. H. Aidoudi *et al*, Dalton Transaction **43**, 6304 (2014).

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Three-dimensional imaging of ferroic materials using coherent X-rays

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Topological approach in studies of ferroic materials suggests new ways for enhancing their properties. Studies of three-dimensional polarization/domain dynamics in model systems such as Barium Titanate (BTO) is necessary for understanding of topologies and their relations to the properties of systems at the nanoscale. We show here how Bragg coherent diffractive imaging (BCDI) technique was used in imaging of topological vortices in individual nanoparticles of BTO under external electric field [1]. Current approach was applied to samples composed of nanoparticles in a matrix. Availability of dedicated structured thin-filmed and nano-ferroelectric devices could be beneficial for exploring the potential of the technique and for collecting data on three-dimensional behavior of topological phases in-operando.

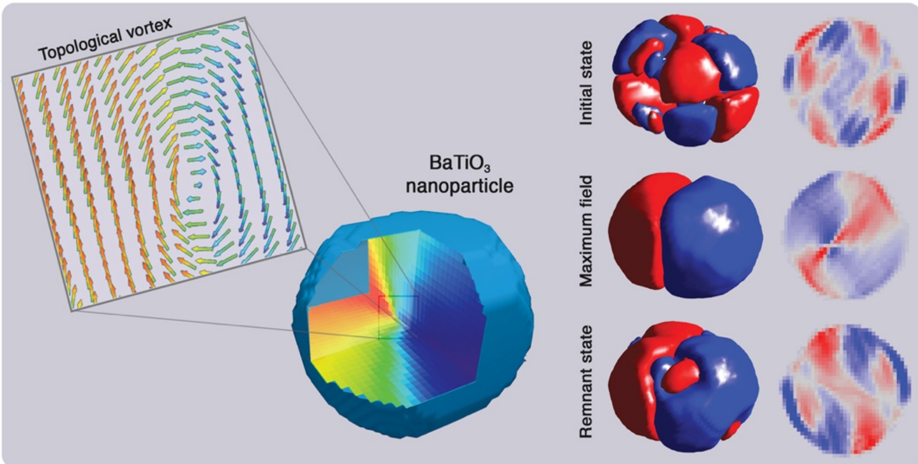

FIG. 1: Three-dimensional visualization of the ferroelectric vortex.

[1] Karpov D., *et al.*; *Three-dimensional imaging of vortex structure in a ferroelectric nanoparticle driven by an electric field*. Nature Communications 8, 280 (2017); https://doi.org/10.1038/s41467-017-00318-9

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Quest for quantum Heisenberg antiferromagnet in spinel chalcogenide $CdYb_2Se_4$

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The geometrically frustrated magnetic pyrochlore lattice with exotic magnetic behaviour is well established in titanates $R_2Ti_2O_7$ (R= rare earth) [1]. Spinel compounds AR_2X_4 with R-ions also residing on the pyrochlore lattice similarly exhibit unconventional magnetism [2, 3]. The basic distinction between the two families is the local environment of the rare earth ions [4, 5]. Here, we present a neutron scattering study of the crystal electric field (CEF), magnetic ground state, and spin dynamics of $CdYb_2Se_4$. Extending recent studies on $CdYb_2Se_4$ [2, 4], our results illustrate and discuss both the ground state CEF level and magnetic ground state specified by k=0 propagation vector. Additionally, we observed low energy spin excitations evolving with temperature and magnetic field. This grants a possibility to identify the exchange Hamiltonian of this frustrated antiferromagent with strong quantum character.

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Beyond conventional magnetic order in the Shastry-Sutherland frustrated magnet TmB_4

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Geometrically frustrated lattices such as the 2D Shasty-Sutherland lattice are known to induce emergent quantum phenomena such as spin liquids, topologically protected states, and complex magnetic order. The spin liquid $SrCu_2(BO_3)_2$ is a famous example of the physical realisation of the Shasty-Sutherland lattice lattice in an insulator [1], yet there exists a family of rare-earth metal tetraborides that exhibit both lattice-induced geometrical frustration and itinerant behavior [2]. In this context, the magnetic order in the frustrated magnet TmB_4 is of particular interest. The arrangement of the Tm rare-earth moments in each layer are indeed topologically equivalent to the 2D Shasty-Sutherland lattice while the crystal field effects lead to a strong Ising anisotropy. Unlike $SrCu_2(BO_3)_2$, antiferromagnetic order has been shown to exist in TmB_4 below 10 K. Nevertheless, competing interactions lead to a complex magnetic-temperature phase diagram [3], with unusual evolution of the magnetic order. Additional interest in TmB_4 is driven by the emergence of fractionalized magnetization plateaus as seen in $SrCu_2(BO_3)_2$ [4].

Through measurements of neutron diffuse magnetic scattering and resonant soft X-ray scattering, we have demonstrated the co-existence of magnetic order with short-ranged correlations induced by the frustrated exchange interactions in TmB_4. In addition, I will discuss the commensurate antiferromagnetic and three incommensurate magnetic phases with strong history-dependent interconversion hosted by the temperature-field magnetic phase diagram. Using a reproducible protocol for single crystal neutron scattering experiments in such a history-dependent system, we have established the evolution of the unconventional magnetic ordering in TmB_4 as a function of temperature and applied field.

[1] S. Michimura et al. J. Phys. Soc. Jpn., Vol. 78 2009
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Development of a New Soft X-ray Ptychography Spectro-Microscope at the Swiss Light Source (SLS)

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Ptychography is a diffractive imaging technique offering the advantages of phase- and amplitude sensitive imaging as well as the overcoming of the resolution of conventional X-ray microscopes towards the limit given by the wavelength of the X-ray light. For the investigation of nanoscaled magnetic systems, the soft X-ray energy range (500 – 2000 eV) is highly relevant, due to the presence of the L2 and L3 edges of 3d transition metals in this energy range and their characteristic high-contrast X-ray magnetic circular dichroism (XMCD). We are currently developing a new soft X-ray microscope [1] based on ptychography at the SIM beamline at the Swiss Light Source with the goal to provide wavelength-limited spatially-resolved maps of the spectroscopic and magnetic response of a broad variety of materials. For a successful image reconstruction, this technique relies on the acquisition of high-quality diffraction patterns, which are detected in transmission under overlapping illumination. Here, we benefit from the collaboration with the PSI detectors group providing us the *Mönch* detector [2], a low-noise charge integrating hybrid pixel detector, which is incorporated into our setup, offering a high dynamic range with single-photon counting capability in the soft X-ray energy range. We demonstrate the imaging and spectroscopy capabilities of this new ptychography setup on a ferrimagnetic FeGd sample with out-of-plane magnetic domains (Fig. 1) using the Fe L2 (720 eV) and L3 (707 eV) absorption edges as well as the Gd M5 (1190 eV) edge. In addition, reconstructions of other interesting magnetic structures will be discussed, such as a 50 nm small magnetic vortex core—a magnetic singularity. This setup will be the basis for a dedicated user-friendly end-station that will take full advantage of the upcoming upgrade of the SLS to a diffraction-limited light source. [3]

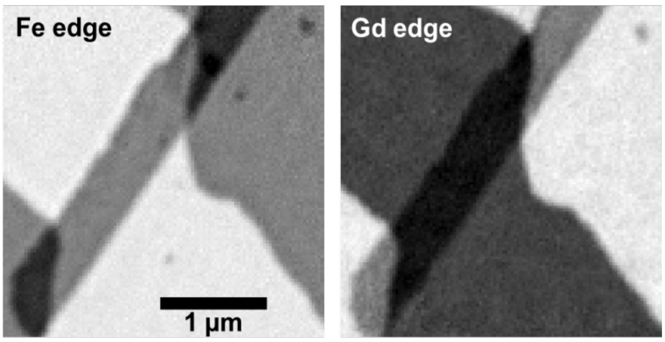

FIG. 1: Magnetic domains of a FeGd sample with inverted XMCD contrast due to ferrimagnetism.

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[3] M. L. acknowledges funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No. 701647.

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Revisiting the Magnetic Structure of $La_{1/3}Sr_{2/3}FeO_3$ by Neutron Powder Diffraction

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Magnetic structure is closely related to the novel electronic properties of a strongly correlated electron system, however for many systems it is a still unresolved issue. $La_{1/3}Sr_{2/3}FeO_3$ is such a system - although the magnetic structure was reported to be $P\bar{3}m1$ or $P1$ from the neutron diffraction studies performed at 50 K and 15 K, respectively [2, 3], both solutions seem problematic: the former seems not to be a correct solution since the presence of rotoinversion $\bar{3}$ is incompatible with the claimed collinear magnetic structure; and the latter has no any symmetry restrictions in space group $P1$. In this study, the magnetic ordering of this compound has been revisited by neutron powder diffraction down to 2 K. From full symmetry analysis, a canted helical model and a collinear model are proposed [4]. The neutron diffraction pattern is equally well fitted by either model (see FIG. 1). It is believed that the other rare earth doped (for instance Pr or Nd) system shows a similar magnetic structure.

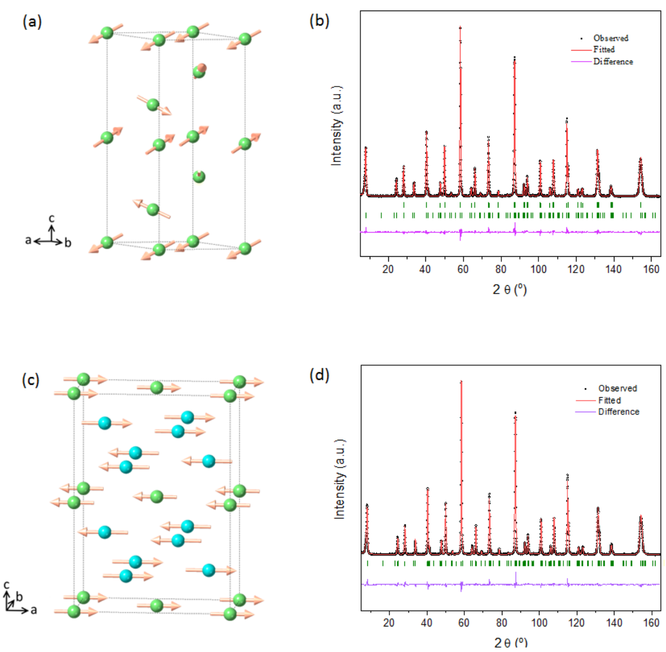

FIG. 1: The canted helical model (a), the collinear model (c), and corresponding fitting pattern (b) and (d).

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Chiral coupling between in-plane and out-of-plane nanomagnetic patterns induced by interfacial Dzyaloshinskii-Moriya interaction

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The emerging interfacial Dzyaloshinskii-Moriya interaction (iDMI) can lead to fast current-driven domain wall motion and the formation of topological magnetic skyrmions, which is promising for the design of high-performance spintronic devices. Here, a nanometric island of Pt/Co/AlO_x (Al) was fabricated with patterned regions of varying out-of-plane and in-plane magnetic anisotropies. We observed that, due to iDMI, the magnetization orientation of adjacent out-of-plane and in-plane regions satisfy the chirality. This chiral coupling between out-of-plane and in-plane magnetization might offer a platform to design novel lateral coupled nanomagnetic system.

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Spin Wave Emission from Vortex Cores

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Spin waves, as spatially propagating oscillations of the magnetisation, could be potentially used as signal carriers in future spintronic logic and memory devices, due to their lower power consumption and possible miniaturisation when compared to current charge-based technology [1]. In the context of miniaturisation it was shown recently that the generation of spin waves with ultra-short wavelengths can be achieved by using the gyration of a magnetic vortex core [2,3]. For technological applications a separation between the generator and transport structure is indispensable, therefore we investigate the feasibility to inject spin waves from a generator structure into a continuous film. For this micromagnetic simulations and first experimental results using time-resolved scanning transmission X-ray microscopy are presented.

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XUV FWM signals have been measured in forward and back scattering configuration. X-ray scattering typically shows a resonant behavior when the energy is tuned near an atomic absorption edge of an element in the material. The resonant effect results mostly from tightly bound inner electrons, with strong variation of the atomic scattering factor near the edges. FEL based XUV-transient gratings (TG) experiments on diamond and around the Si L-absorption edge have been realized. From delay time-dependent TG - measurements, information about ultrafast charge carrier dynamics and the subsequent energy dissipation into lattice vibrations can be extracted. Differences in the signal decays related to detuning from the absorption edge have been observed.

Magnetic coupling of $SrRuO_3/La_{0.7}Ba_{0.3}MnO_3/SrRuO_3$ trilayers

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Thin films of transition metal oxides often present distinct properties below a certain critical thickness. In this work we have studied heterostructures composed of ferromagnetic oxides $SrRuO_3$ (SRO) and $La_{0.7}Ba_{0.3}MnO_3$ (LBMO) which present a strong antiferromagnetic coupling through their common interface[1, 2]. LBMO layer thicknesses were varied between 1 u.c. (unit cell) and 5 u.c and enclosed between two layers of SRO with constant 3 u.c. thickness each. X-ray magnetic circular dichroism measurements were carried out at the Mn $L_{3,2}$-edges and Ru $M_{3,2}$-edges. Hysteresis curves for the individual elements were measured to disentangle the individual contributions to the total magnetization. For 3|1|3 trilayers SRO shows a clear hysteresis curve. This result is surprising given that thin films of SRO do not show ferromagnetism below 4 u.c [3]. Moreover, 1 u.c. of LBMO shows a strong antiferromagnetic coupling to SRO evidenced by an inverted hysteresis loop. On the other extreme 3|5|3 trilayers show an almost normal hysteresis curve for LBMO and a linear magnetization curve with no remanence for SRO. We will give a few possible scenarios that could explain the different magnetic behavior of 3 u.c. SRO for a chaging thickness of LBMO.

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Variance monitoring and kernel density estimation for 2D experimental data as an attempt for efficient use of beamtime

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Beamtime at large experimental facilities is precious and should be used efficiently. However, measurement time is rarely statistically optimized and is often based on a rule of thumb. In this presentation, we propose variance monitoring for measurement time optimization and data smoothing with kernel density estimation for measurement time reduction. Variance improvement rate per unit measureument time can be a simple measure for on-site statistical qualitiy monitoring. Kernel density estimation with Gaussian kernel can reduce measurement time for anisotropic intensity distribution. Both ideas can be applied to a wide range of experiments using 2D detector without any instrumental investiment. There may be other ideas in modern statistics that can help make beamtime more efficient.

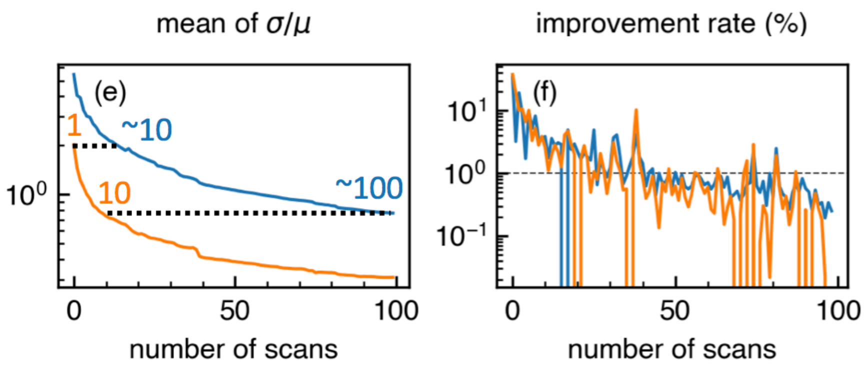

FIG. 1 Variance variation of normal averaged data and smoothed data (right) and the improvement rate of variance (left), both as a function of measurement time.

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A combined investigation of single cobalt nanoparticles by means of X-PEEM and HAADF-STEM and structural simulations.

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Anomalous values of magnetic moments and magnetic anisotropies are often observed in *3d* transition nanoparticles but origin of the variation of these properties within a narrow particle size range is still poorly understood. Our approach combines single nanoparticle X-ray magnetic circular dichroism (XMCD) contrast detection by means of X-ray photo-emission electron microscope (X-PEEM) and structural characterization on atomic level with high-angle annular dark-field scanning transmission electron microscopy (HAADF-STEM) of exactly the same nanoparticle. The acquired data is compared with simulated STEM images and atomistic spin dynamic simulations. Besides single crystalline fcc cobalt nanoparticles, we consider nanoparticles containing structural defects such as stacking faults being observed experimentally and evaluate magnetic energy barriers and spontaneous magnetization axes. Experiment and simulation suggest that the magnetic properties of cobalt nanoparticles are determined by a complex competition of shape, surface, and structural contributions. In this contribution we will discuss simulated results with respect to the experimental data.

Restabilization of the Q-phase and two quantum critical points in the Nd-doped CeCoIn5

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In heavy fermion superconductors, the interplay of superconducting and magnetic fluctuations can result in unconventional superconductivity and create quantum phases with critical transitions. A representative case for the coexistence of superconducting and magnetic order is the well-known Qphase in CeCoIn5 where the antiferromagnetism exists at low-temperature (T < 250 mK) and highfield (μ0H > 9.5 T for H||ab) area within the superconducting phase. It was firstly reported by specific heat and resistivity studies while neutron scattering studies [1] evidenced the magnetic order to be an incommensurate spin density wave which led to the name Q-phase [2]. Our recent studies on 2% and 3.5% Nd-doped CeCoIn5 show the Q-phase magnetic order at high-field region along (0.554,0.554,0.5) as well as a low-field SDW phase with the same order, see FIG. 1. Furthermore, a phase separation was observed in the 3.5% Nd-dope case, suggesting that some additional mechanism may need to be introduced to restabilize the Q-phase in this series.

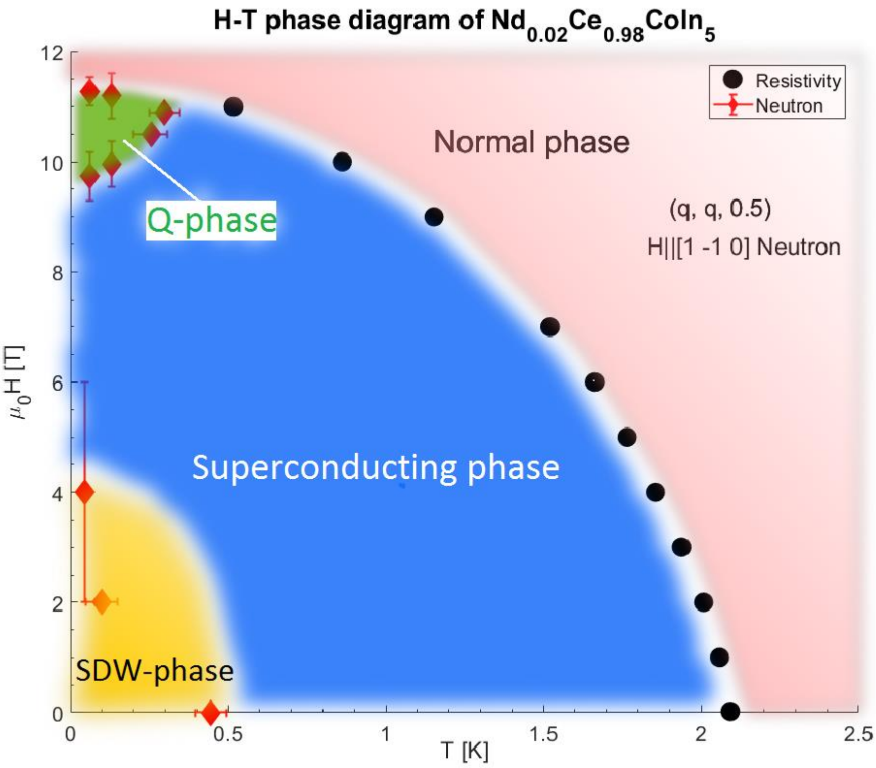

FIG. 1: The H-T phase diagram of $Nd_{0.02}Ce_{0.05}CoIn_5$.

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Complex interplay between superconductivity and magnetism in $Nd_{1-x}Ce_xCoIn_5$

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Unconventional superconductivity frequently develops near quantum critical points (QCP) separating magnetically ordered from paramagnetic ground states at zero temperature [1]. Examples in which superconductivity and magnetism compete are commonly found in nature. However, in some heavy fermion compounds, the interplay between magnetism and superconductivity can be more complex. In $CeCoIn_5$, an antiferromagnetic (AFM) spin-density wave (SDW) that cooperates with the superconducting state orders is observed at low temperatures and high magnetic fields [2]. Chemical substitution of Nd at the Ce site stabilizes novel electronic ground states enabling the study of these complex interdependences. In $Nd_{0.05}Ce_{0.95}CoIn_5$, a QCP inside the superconducting state separates magnetic order at low magnetic fields from the high field phase. Both SDWs reveal an identical symmetry [3], but a distinct coupling between magnetism and superconductivity is found [4]. In this investigation, we employ neutron scattering and ultrasound spectroscopy to follow the evolution of these two AFM phases in selected Nd chemically substituted $CeCoIn_5$. When increasing the Nd doping, the ground state is modified giving strength to the low field SDW phase, providing an ideal platform for the investigation of the nature of this state as well as its relation with superconductivity.

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Investigations of scaling and dynamics in the kagomé ice phase of $Ho_2Ti_2O_7$

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Frustration of the exchange and dipolar interactions between Ising-like rare earth magnetic moments oriented along the pyrochlore easy axes produces a quasi-degenerate manifold of 2-in/2-out (ice rule) ground states in the spin ices $Dy_2Ti_2O_7$ and $Ho_2Ti_2O_7$ [1]. Applying a medium strength field along the [111] direction of a spin ice results in a magnetization plateau known as kagomé ice [2], where the pyrochlore lattice can be separated into stacked triangular and kagomé planes, with spins in the triangular planes being parallel to the field, while those in the kagomé planes are not. In kagomé ice, the ice rules compete with the applied field, favoring 2 in/1 out orientations on each triangle of the kagomé lattice, reducing both the degeneracy and the entropy of the system [3]. Kagomé ice is a two dimensional analog of spin ice with its own distinct set of spin correlations [4, 5].

Kagomé ice hosts a variety of interesting phase transitions and crossovers with varying field and temperature, including a Kasteleyn transition as the field direction is tilted from the [111] towards the $[11\bar{2}]$, the scaling for which can be observed in the structure factor of neutron scattering measurements [4–8]. The concentration of spin flip excitations in spin ice (recontextualized as magnetic monopole quasiparticles [9]) experiences various crossovers with increased field and temperature, including Kibble-Zurek scaling below the critical point [10] and peaks in the magnetization, specific heat [3] and susceptibility [11]. As the energy of spin flip excitations in the kagomé plane changes with the applied field, the mobility of monopole quasiparticles is constrained further from their spin ice counterparts. Using diffuse neutron scattering and high frequency susceptibility measurements on a single crystal sample of $Ho_2Ti_2O_7$, alongside Monte Carlo simulations, we have observed and characterized signals of the scaling near the Kasteleyn transition and crossovers attributed to changing monopole density above the critical point.

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Neutron grating interferometry from micro-structures to magnetic induced phase shift and beyond

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Neutron grating interferometry (nGI) is an established neutron imaging method that has found successful application in a wide range of scientific fields such as soft matter, magnetism and superconductors [1–3]. Compared to conventional small-angle scattering techniques, which can reach structure size in the range between 1 nm to multiple hundreds of nm, nGI provides information about the microstructures of few µm, through the dark-field image (DFI), and the induced phase shift, differential phase contrast image (DPCI), with spatial resolution capabilities. One of the main goals of the new developments in nGI is to bridge this gap between imaging and small-angle scattering. Here we present the latest results achieved with new dedicated nGI setups which can extend the probed range down to tens of nm and enable directional sensitivity without loosing the chance of spatially resolve the scattering function. A selection of polystyrene micro-spheres of different sizes, cohesive SiO_2 powder and oriented carbon fibers were chosen as model systems to study and characterize the scattering function at different length scales. Furthermore, we established a novel approach combining nGI with polarized neutrons which enables us to retrieve quantitative information about the phase shift induced by strong magnetic field gradients. With a view to the ODIN imaging beam-line at the European spallation source (ESS) we developed and tested an optimized nGI setup with a higher mean visibility for a wide range of wavelengths suited for time-of-flight (TOF) applications. The extended accessible range unlocks several applications in fields that were not covered yet by conventional neutron imaging techniques from the behaviour of biological systems, such as bacteria, to cutting edge technology, like fuel cell and additive manufacturing.

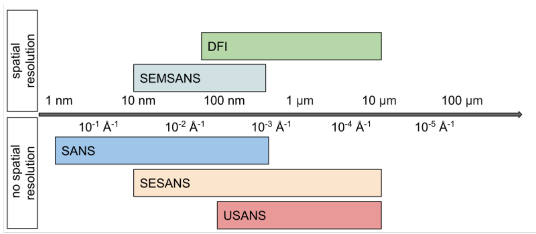

FIG. 1: Size range comparison for scattering techniques in reciprocal space without spatial resolution: SANS, SESANS and USANS. SEMSANS and DFI combine scattering and imaging approach covering structure sizes between 15 nm to 13 µm.

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LOW-TEMPERATURE PLATFORM FOR THZ PUMP – X-RAY PROBE EXPERIMENTS AT SWISSFEL

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The energy scale of quantum phenomena, such as charge or spin order and superconductivity is in the order of meV, corresponding to THz frequencies. Consequently, non-ionizing, single-cycle THz excitation can be used to induce and control transient quantum states, while the subsequent ultrafast X-ray free-electron laser (FEL) probe pulses allow to directly observe the alternations of the ground states and their femtosecond temporal evolution. Such approach has already been successfully implemented with the study of electromagnon dynamics [1]. We report on the first steps towards cryogenic sample environment at SwissFEL by developing a sub-5 Kelvin flow cryostat for THz-driven X-ray diffraction with in-situ sample positioning. Extending the experimental capabilities towards lower temperatures will allow the application of the pump-probe method to dynamics studies of phenomena such as quantum magnetism.

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Spinon dynamics in the one-dimensional spin system $NaCuF_3$

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Progress in the investigation of emergent ground states and novel excitations in condensed matter systems relies on the existence of materials described by simple theoretical models. One of the fields where most progress has been made in identifying and characterizing emergent phenomena in real systems is quantum magnetism. Here we report the synthesis, bulk properties and spin dynamics probed by inelastic neutron scattering of the quasi-one-dimensional $S = 1/2$ chain compounds $NaCuF_3$. Contrary to what's been observed in other 1D materials where a gap emerges at the zone center below the ordering temperature, the dynamic structure factor $S(q,\omega)$ of $NaCuF_3$ shows characteristic of both spinon continuum at high energy and dispersion well described by linear spin wave model at low energy. Similar behavior was also recently reported for CuO spin systems. [1]

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Thermal Neutron Single-Crystal Diffractometer Zebra at SINQ

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Neutron crystallography plays an important role in physics thanks to its complementarity with X-ray techniques for chemical structures and its unique ability to probe microscopic arrangements of magnetic moments. Here we present the new single-crystal thermal neutron diffractometer Zebra, which is now fully operational and enables experiments that tackle current challenges in condensed matter physics. Zebra is optimized for small samples and extreme sample environments, which enables to study challenging systems where exotic properties emerge at extreme magnetic fields, high pressures and/or very low temperatures. The neutron delivery system, the shielding of the entire instrument and the non-magnetic sample-positioning system are new. Moreover, three detection units are now available: a conventional point detector with collimation capabilities, an area detector with 14×14 degrees angular coverage and a graphite analyser with a point detector, all mounted on lifting arms. We have already realized a number of experiments in both four-circle and tilt geometry, using any of the three detectors. The success of these various experiments highlight the excellent capabilities of the instrument, for instance measuring crystals down to 0.1 mm^3 or probing ordered moments down to 0.1 μ_B at extreme conditions.

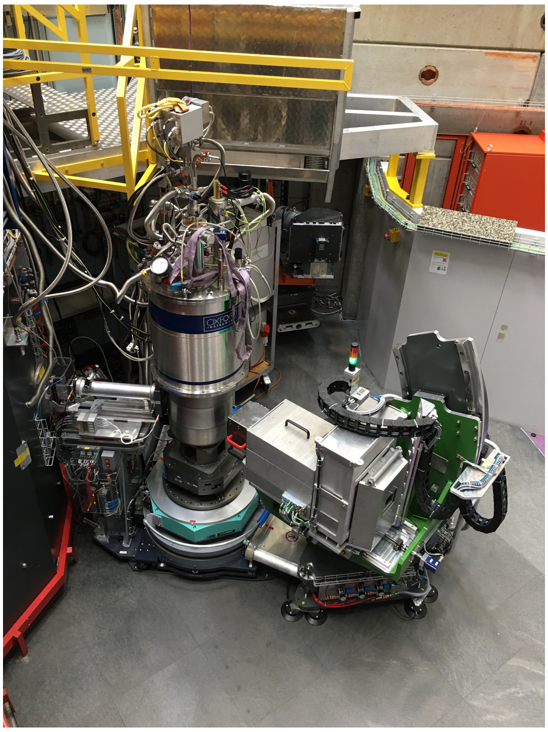

FIG. 1. Photograph of the Zebra instrument at SINQ, PSI.

Probing the origin of ferromagnetic stability of LSMO/SRO

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Magnetic switching and spin canting in bilayers of oxides heterosctructures has a particular significance for quantum electronics [1]. Therefore probing magnetic properties at the oxides interface is required. In this project we used XAS, XLD and XMCD at the Mn $L_{3,2}$-edges and Ru $M_{2,3}$-edges to understand the ferromagnetic stability of $La_{0.7}S_{0.3}MnO_3$ when interfaced with $SrRuO_3$ compared with $LSMO/SrTiO_3$. It has been proposed that charge transfer at the interface between LSMO and SRO allow the $dx^2 - y^2$ orbital to mediate the in-plane double exchange and therefore stabilize the ferromagnetic ordering of LSMO down to a 1-2 unit cells [2]. We have probed the orbital anisotropy and magnetism of LSMO on bilayers of SRO/LSMO deposited on TiO2 terminated STO and compared to STO/LSMO, with varying thickness of LSMO (2/4/8 u.c.)/SRO (3/20 u.c.)/STO. Antiferromagnetic coupling of 2 and 4 u.c. LSMO with SRO was observed even below critical thickness of LSMO. Moreover, 4 u.c. of LSMO shows remanence above SRO T_c.

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Ultrafast magnetic and orbital phase transitions in a 4d correlated system

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In the 4d correlated material Ca_2RuO_4, the interactions between lattice, charge, orbital and magnetic degrees of freedom (DOF) form stable states differing in magnetization or conductivity, with different magnetic and electronic phase transitions that can be triggered by temperature pressure and light. To understand the elementary mechanisms associated with the magnetic and orbital changes, it is necessary to study this process on the time scale of atomic motions. In this work, we investigated the ultrafast magnetic and orbital dynamics by time resolved resonant diffraction at the Ruthenium L-edge [1]. With SwissFEL Bernina, this tender energy regime becomes accessible at an FEL diffraction instrument for the first time. In order to study the ultrafast magnetic and orbital dynamics, we followed the intensity change of (100) reflection [1] after excitation by an ultrashort IR pulse (cf. Fig.1) at 80 K. Our results show a decrease of integrated Bragg intensity (100) which is due to the Antiferromagnetic (AF) transition.

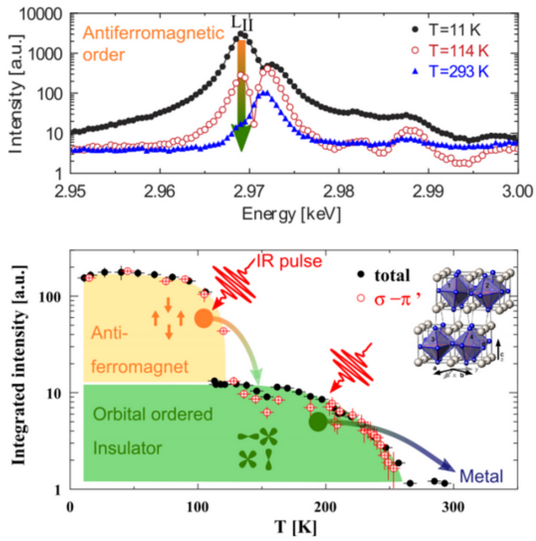

FIG. 1: Top left: Temperature series of (100) reflection intensity as function of energy in the vicinity of the Ru L_{II} edge (adapted from [1]). Bottom left: The L_{II} edge feature (Q-integrated intensities) indicates magnetic and orbital order through decrease by one order of magnitude at the AF and insulator-metal phase transitions. Both can be investigated and their transitions caused by impulsive excitation by IR light.

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Spin wave dynamics in antiferromagnetically coupled magnetic trilayers

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Magnetic trilayer films in which two ferromagnetic layers couple antiferromagnetically via a nonmagnetic spacer layer lead to the discovery of giant magnetoresistance effect [1]. In addition to this, the spin wave dynamics in these films can be also modified by the interlayer coupling, which can form a nonreciprocal dispersion relation [2]. In this work, we have measured the spin wave dynamics of antiferromagnetically coupled magnetic trilayer films using a time-resolved magneto-optical Kerr microscope. We observed a decrease in precession frequency of the spin waves in these films, compared with normal ferromagnetic films. We attribute this frequency decrease to the antiferromagnetic coupling. In future, we will investigate the spin wave nonreciprocity in these trilayers.

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[2] K Di, et al. Sci. Rep. 5 10153 (2015)

Floating zone growth of *R*AlGe (*R* =Pr, Ce), a magnetic Weyl semimetal

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Weyl semimetals are a new class of materials revealing two linear Weyl points in the electron bands generating novel features in transport such as the anomalous Hall effect and negative longitudinal magnetoresistance. The poster will introduce the system *R*AlGe (R = Ce, Pr), which was theoretically proposed as a type-II Weyl semimetal [1] that also shows ferromagnetic order at low temperatures. Using the travelling solvent floating zone technique stoichiometric *R*AlGe crystals were grown (see FIG. 1). X-ray and neutron diffraction, magnetization, specific heat and resistivity measurements are used to study the structure and magnetic groundstates. Both systems prove to crystallize in the anticipated polar $I4_1$ md (#109) space group with the necessary noncentrosymmetry required by theory. While PrAlGe displays the expected easy-axis ferromagnetic order along the c-axis below 16 K, CeAlGe surprisingly displays an easy plane antiferromagnetic order below 5 K. The synthesized samples provide an ideal platform for microscopic explorations of the correlation physics between the magnetism and topologically non-trivial properties in the electronic structure, especially considering the tunability in the substitution series $Pr_xCe_{1-x}AlGe$.

FIG. 1: Photos of a) the cast CeAlGe rod, and the oating zone grown crystals of b) CeAlGe and c) PrAlGe.

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Resonant soft X-ray magnetic scattering and imaging of spin textures in skyrmion-hosting materials

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Magnetic properties of transition metals (TM) are generally determined by the 3*d* valence electrons. Resonant soft X-ray scattering (RSXS) at $L_{2,3}$ absorption edges of TM involves 2*p*-to-3*d* transitions, thus being an element-selective probe with possibility to distinguish magnetic signal from different elements in multicomponent magnets [1]. Moreover, the spatial coherence of the X-ray beams provided by modern synchrotron radiation sources and free-electron lasers give vast opportunities for the lensless imaging using coherent diffraction imaging, ptychography, and holography [2]. High brilliance, element selectivity and coherence of the synchrotron radiation beams allowed us to successfully exploit RSXS and imaging to study the local magnetization distribution in various skyrmion-hosting compounds under flexible sample environment. For example, complicated combinations of the low-temperature magnetic states, such as helical, conical, chiral soliton and skyrmion lattices (Fig. 1) have been found in a strained FeGe lamella [3]. We plan to further investigate more exotic spin textures, such as skyrmions and anti-skyrmions in non-centrosymmetric materials by RSXS. Collaboration with advanced nanofabrication and X-ray scattering groups would be helpful to establish the realization of RSXS and imaging techniques at PSI.

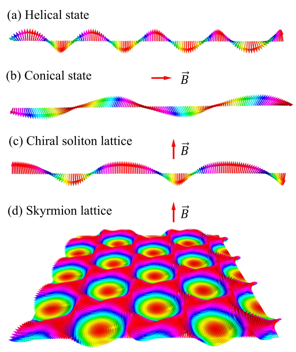

FIG. 1: Schematic illustration of spin configurations in helical state (a), conical state (b), chiral soliton lattice (c), and skyrmion lattice (d).

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Unconventional order-disorder phase transition in improper ferroelectric hexagonal manganites

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The improper ferroelectricity in $YMnO_3$ and other related multiferroic hexagonal manganites are known to cause topologically protected ferroelectric domains that give rise to rich and diverse physical phenomena. The local structure and structural coherence across the ferroelectric transition, however, are not well understood [1] . Here we reveal the evolution of the local structure in $YMnO_3$ using a combination of neutron total scattering and first-principles calculations [2] . The results show that, at room temperature, the local and average structures are consistent with the established ferroelectric ground state structure. On heating, both local and average structural analyses show striking anomalies consistent with increasing fluctuations of the order parameter angle from $\sim$ 800 K up to the Curie temperature. These fluctuations result in an unusual local symmetry lowering into a continuum of structures on heating which coincides well with reported temperatures for which the observable polarization vanishes. This local symmetry breaking persists into the high-symmetry non-polar phase, constituting an unconventional type of order-disorder transition.

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Magnetism in Semiconducting Molybdenum Dichalcogenides

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Transition metal dichalcogenides (TMDs) are interesting for understanding fundamental physics of two-dimensional materials (2D) as well as for many emerging technologies, including spin electronics. Here, we report the discovery of long-range magnetic order below T_M = 40 K and 100 K in bulk semiconducting TMDs 2H-$MoTe_2$ and 2H-$MoSe_2$, respectively, by means of muon spin-rotation (μSR), scanning tunneling microscopy (STM), as well as density functional theory (DFT) calculations. The muon spin rotation measurements show the presence of a large and homogeneous internal magnetic fields at low temperatures in both compounds indicative of long-range magnetic order. DFT calculations show that this magnetism is promoted by the presence of defects in the crystal. The STM measurements show that the vast majority of defects in these materials are metal vacancies and chalcogen-metal antisites which are randomly distributed in the lattice at the subpercent level. DFT indicates that the antisite defects are magnetic. Further, we find that the magnetic order stabilized in 2H-$MoTe_2$ and 2H-$MoSe_2$ is highly sensitive to hydrostatic pressure. These observations establish 2H-$MoTe_2$ and 2H-$MoSe_2$ as a new class of magnetic semiconductors (MS) and opens a path to studying the interplay of 2D physics and magnetism in these interesting semiconductors. Our present system offers unique advantages to synthesize magnetic semiconducting materials. First, the defects contributing to magnetism are intrinsic in the crystal, and are uniformly distributed. This can alleviate some of the materials challenges commonly faced in MS synthesis. Second, the materials are cleavable and readily grown in large area form down to a monolayer thickness. As is well known in these materials, the bandgap is a strong function of thickness, giving us tunability over the semiconductor properties. Third, the chemical potential and electric field in thin films is easily tuned by electrostatic gates, allowing for the possibility of tunable magnetism as has been seen for GaAs. Finally, these materials can be easily layered by van der Waals heteroepitaxy allowing for the creation of unique new device concepts in the future.

‘Neutron Microscope’ – experience from the users’ experiments and future prospects

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High-resolution neutron imaging has been flagged up as one of the key requirements by the neutron imaging user community. PSI ‘Neutron Microscope’ project led to a considerable advancement in the available spatial resolution of neutron imaging at PSI and currently allows for imaging with down to about 5 micrometres spatial resolution. The transferrable nature of the ‘Neutron Microscope’ allows for its use at different beamlines of SINQ (namely at ICON, POLDI and BOA) and also at other neutron sources (such as ILL). Since 2017, ‘Neutron Microscope’ is included in the user programme as an instrument available at ICON and POLDI beamlines. This option attracted high number of users. Several highlights are shortly summarized. Likewise, the future prospects are concisely discussed.

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Spin and lattice correlations in $SrCu_2(BO_3)_2$

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$SrCu_2(BO_3)_2$ is an excellent realisation of the Shasty–Sutherland model, which consists of a set of spin 1/2 dimers on a 2D square lattice. The spin correlations in this system capture a central theme of condensed matter physics by sitting precariously on the quantum edge between isolated, gapped excitations and collective, ordered ground states. Upon application of external magnetic field the system undergoes a series of quantum phase transitions at fractional values of the saturation field. The phases correspond to Mott insulator phases of dimer states and possible superfluid and supersolid phases.
The ratio between inter- and intra-dimer coupling determines the phase diagram and this ratio can be directly controlled by application of external pressure. Upon increasing pressure $SrCu_2(BO_3)_2$ undergoes a quantum phase transition from a spin dimer to spin plaquette state, as directly shown by high-pressure neutron spectroscopy [1], see Figure 1.

Interestingly, the magnetic phase transitions leave clear fingerprints not only in the magnetic but also in the lattice response [2,3]. I will present recent results of high-pressure ultrasound studies that allow to probe the spin-lattice correlation and thus provide an important step towards a complete picture of the quantum dynamics in $SrCu_2(BO_3)_2$. Furthermore, I will discuss ultrafast THz pump-and-probe experiments which show how spin-lattice coupling can be used to drive electro-magnetic interactions.

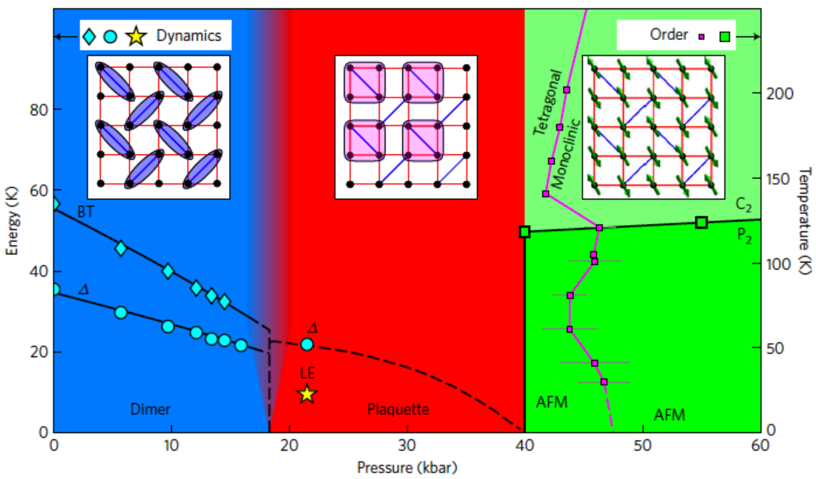

Figure 1. Pressure-temperature phase diagram of $SrCu_2(BO_3)_2$ including magnetic exchange energies. Dimer phase (blue), plaquette phase (red) and antiferromagnetic phase (green) are sketched in the inserts. Above 45 kbar a structural phase transition brakes the tetragonal symmetry implying non-orthogonal dimers.

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Dependency of the 2 Dimensional Electronic State of CaTiO3 with Film Thickness and Underlayer

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The perovskite $CaTiO_3$ was recently added to the group of oxides hosting a metallic surface state [1,2], along with $SrTiO_3$ and other transition metal oxides. In particular, films with 20 unit cells (u.c.) grown by Pulsed Laser Deposition have shown a 2 dimensional electronic state (2DES) composed of only band with d_{xy} character [1]. We have extended this study by growing 5 u.c. $CaTiO_3$ films grown on $SrTiO_3$ with and without a 20.u.c underlayer of $SrRuO_3$ and investigating them with angle-resolved photoelectron spectroscopy. The results revealed distinct surface reconstructions and a 2DES with different characteristics, which include the reappearance of d_{xz}- d_{yz}-derived bands and kinks in the band dispersion due to electron-phonon interactions. Also, not only the 2DES found on these films are different from each other, but they also present a striking difference from the 2DES found on $SrTiO_3$, namely, the absence of a second Rashba-split d_{xz}-derived band. These results show that it is possible to manipulate the properties of these metallic surface states and the strength of many-body interactions by controlling the film thickness and underlayer.

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$LiY_{1-x}Ho_xF_4$ - a candidate material for the implementation of solid state qubits

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The model magnet $LiY_{1-x}Ho_xF_4$ has been shown to exhibit a variety of quantum many-body phenomena, such as quantum phase transitions [1], quantum annealing [2], long- lived coherent oscillations [3] and long-range entanglement [4]. Earlier work [5] probed crystal field level transitions optically in a Fourier transform infrared (FTIR) spectrometer with a lab infrared source and 1.2 m optical path difference (OPD). We present data using high-brilliance synchrotron radiation light in the far infrared regime from the Swiss Light Source (SLS) taken with a high-resolution FTIR spectrometer. This unique system features 11 m OPD allowing us to probe state transitions with unprecedented precision of 0.00077 cm^{-1} (23 MHz) and to extract the full width half maximum (FWHM) of a single hyperfine line as function of temperature and various dopings down to $x = 0.01\%$. We model the behavior of the linewidths as a function of temperature and concentration. Estimations based on our results of the zero-temperature, zero-concentration limit lead to a minimum FWHM of $\sim$0.01 cm^{-1}, corresponding to a lifetime of $\sim$0.5 ns. In addition, we resolve a further splitting of the hyperfine structure which we attribute to an isotopic effect of ^{6}Li and ^{7}Li. Further investigation in combination with a drive source, might allow us to demonstrate coherent manipulation of crystal field states.

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Manipulating the ground state in nickelates using proximity with magnetic layers

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Transition metal oxides (TMO) are a class of materials where the charge, orbital, magnetic, and spin degrees of freedom are mutually connected. Interfacing different TMOs offers the possibility to act on each of these degrees of freedom, tailoring new materials with desired properties. In this work, we investigate the effect of the presence of a magnetic proximity layer on the ground state of neodymium nickelate (NNO), interfacing thin NNO films with manganite layers (strontium and calcium doped lanthanum manganite – LSMO and LCMO) grown *via* pulsed laser deposition (PLD). Angle resolved photoemission spectroscopy (ARPES) and X-ray magnetic circular dichroism (XMCD), supported by momentum-resolved density fluctuation (MRDF) theory, revealed the suppression of the PM metal – AFM insulator transition in NNO thin films, and the emergence of a new FM metal ground state. This work paves the way for tailoring magnetic properties in different oxides, where already existing magnetic ordering can be tuned using proximity effects.

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Anomalous electronic and magnetic behavior of Weyl semimetal Fe_3Sn_2

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Ferromagnets with anomalous magnetic behavior based on topology are recently being considered for spintronics or for next generation of memory devices. Ferromagnetic Weyl semimetals could be potentially useful for spintronics since their electronic structure can be manipulated using external magnetic field. Fe_3Sn_2, predicted to be a Weyl semimetal, is a room temperature ferromagnet and undergoes a spin reorientation transition (SRT) between 300 K and 100 K, where the easy axis of magnetization rotates from c-axis at high temperature to the ab Kagome plane at low temperatures. Understanding this SRT on a microscopic level is the focus of our study in addition to exploitation of its electrical properties. We have studied the bulk magnetic properties of single crystal Fe_3Sn_2 using DC and AC magnetization and the magnetic domain structure using photoemission electron microscopy (PEEM). SRT is clearly seen using PEEM with the magnetic domains being much larger when the moments are in the ab plane than when they are out of plane. In addition, anomalous magnetoresistivity behavior and anomalous Hall Effect are being explored with the goal to ultimately produce high quality thin films of Fe_3Sn_2 for nanoelectronic devices.

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Structural details of the surface relaxation of multiferroic GeTe (111)

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Mn-doped GeTe has recently gained attention because of coupled ferroelectric and ferromagnetic ordering, i.e., multiferroicity, and the possibility to switch the magnetic polarization by applying an electrical field [1, 2]. The host material, germanium telluride, is a narrow gap semiconductor featuring ferroelectric ordering below 625 K. In the ferroelectric phase, the lattice has a rhombohedral structure where the Ge and Te sublattices are displaced along the distortion direction. For device applications, it is essential to understand possible relaxation at the surface of the material and its influence on polarization.

In this contribution, we present measurements of the detailed atomic structure of the GeTe (111) surface using photoelectron diffraction. Atomic layer positions are determined from angle and energy scans of the Ge 3s and Te 4s core level photoelectron peaks to a depth of six atomic layers below the surface. We find that the surface deviates significantly from the truncated bulk structure. While the top bilayer stays intact with a shortened bonding distance, the second layer breaks up and resembles the paraelectric rock salt structure. This could mean that a ferroelectric domain wall is present just below the surface.

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https://doi.org/10.1103/PhysRevX.8.021067

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Abstract: **Ground-state and excitations in two-dimensional dipolar magnets RBr_3 (R = Er,Yb)**

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Some exciting phenomena are only observable in two-dimensional systems. Dipolar magnets on a honeycomb lattice are expected to show fascinating phase transitions [1,2,3]. Neutron scattering is used to investigate the ground state and excitations of dipolar magnets $ErBr_3$ and $YbBr_3$. Currently, the neutron studies are on-going for both compounds. We obtained evidence for a Kosterlitz-Thouless transition in $ErBr_3$ and we observed only short-range correlations in $YbBr_3$, in contrast to theoretical predictions. We plan to do calculations of the dynamical susceptibility to understand the experimental results of both materials.

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Hidden Correlations of a Quantum Liquid of Octupoles

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In a quantum spin liquid (QSL), the magnetic moments of the constituent electron spins evade classical long-range order to form an exotic state that is quantum entangled and coherent over macroscopic length scales [1]. In rare-earth pyrochlore oxides, one such state called quantum spin ice (QSI) can be realised and lead to emergent electrodynamics [2]. Here, we present new results on the Ce^{3+} pyrochlore stannate, $Ce_2Sn_2O_7$ [3], in which measurements of the crystal-electric field transitions using inelastic neutron scattering indicate the dipole-octupole nature of the single-ion ground state doublet. Moreover, thermal neutron diffraction experiments conducted at PSI (HRPT at SINQ) reveal a liquid-like signal originating from correlated magnetic octupoles, and fits of the magnetic susceptibility at very low temperature are consistent with the formation of an octupolar QSI state. These results strongly suggest that $Ce_2Sn_2O_7$ is a (quantum) liquid of octupoles – thus one of very few cases, perhaps together with NpO_2, where octupoles appear to be the driving force (or primary order parameter) of a correlated state.

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