2026 Swiss Workshop on Materials with Novel Electronic Properties

Basic research and applications

Les Diablerets

Switzerland

MaNEP SWITZERLAND NETWORK

August 25th - 27th, 2026

Program & Abstracts

2026 Swiss Workshop on Materials with Novel Electronic Properties

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PROGRAM OVERVIEW

Tue, Aug 25, 2026	
11:15	Registration & Drinks at the Glacier Hotel
12:00	Lunch
13:30	Welcome
Quantum magnetism *Thierry Giamarchi*	
13:45	**Stephen Blundel**
14:15	Karina Kazarian
14:30	Alexander Ferguson
14:45	Aishwarya Vishwakarma
15:00	Maria Herz
15:15	Coffee break
Out of equilibrium & cavities *Markus Müller*	
15:45	**Jérôme Faist**
16:15	Honey Boban
16:30	Nelson Hua
16:45	Aymen Mahmoudi
17:00	**Stefan Mathias**
17:30	**1' Poster session**
18:00	**Poster session 1 & commercial exhibit**
20:30	Dinner

Wed, Aug 26, 2026	
Applications *Carmine Senatore*	
08:30	**Bernard Auchmann**
09:00	Enrico Della Valle
09:15	Francesco Lonardo
09:30	Ryan Thompson
09:45	Rok Venturini
10:00	Coffee break
Oxide interfaces *Jean-Marc Triscone*	
10:30	**Jacobo Santamaria**
11:00	**Marta Gibert**
11:30	Ludovica Tovaglieri
11:45	Patrycja Paruch
12:00	Karen Sobnath
12:15	Lunch
2D Materials *Titus Neupert*	
13:45	**Ajit Srivastava**
14:15	Zekang Zhou
14:30	Dominik Juraschek
14:45	Johannes Motruk
15:00	Caroline Tornow
15:15	Coffee break
Superconductivity I *Manfred Sigrist*	
15:45	Mark H. Fischer
16:00	Ilia Moghayer
16:15	Kiryl Pakrouski
16:30	Giulia Venditti
16:45	**Mark Janoschek**
17:15	**1' Poster session**
17:45	**Poster session 2 & commercial exhibit**
20:30	Conference Dinner

Thu, Aug 27, 2026	
Out of equilibrium/theory *Vadim Geshkenbein*	
08:30	**Elsa Abreu**
09:00	Joël Morf
09:15	Davide Bertolusso
09:30	**Jan von Delft**
10:00	Coffee break
Superconductivity II *Fabian von Rohr*	
10:30	Tejas Singar
10:45	Toni Shiroka
11:00	Gediminas Simutis
11:15	Daruisz J. Gawryluk
11:30	**Philip Moll**
12:00	Poster prize & closing ceremony
12:30	Lunch bag

DETAILED PROGRAM

August 25 (Tue)

Registration & Drinks at the Glacier Hotel 11:15 – 12:00

Lunch 12:00 – 13:30

Welcome address 13:30 – 13:45

August 25 (Tue) 13:45 – 15:15

Session 1: **Quantum magnetism**

Chair: Thierry Giamarchi (University of Geneva, Switzerland)

13:45 – 14:15 **Hyperfine-enhancement as a route to persistent spin dynamics in singlet-state systems**
Stephen Blundell (University of Oxford, England)

14:15 – 14:30 **Structural Origin of the Magnetic Field-Induced Electric Polarization of $GdMn_2O_5$**
Karina Kazarian (Paul Scherrer Institut, Switzerland)

14:30 – 14:45 **Phonon Angular Momentum and Effective Fields in CeF3**
Alexander Ferguson (University of Fribourg, Switzerland)

14:45 – 15:00 **Current-driven resonant spin dynamics in a single organic molecule**
Aishwarya Vishwakarma (ETH Zürich, Switzerland)

15:00 – 15:15 **Controlling the Magnetic Properties of the Layered van der Waals Crystals $V_{1-x}Cr_xI_3$**
Maria Herz (University of Geneva, Switzerland)

Coffee 15:15 – 15:45

August 25 (Tue) 15:45 – 17:30

Session 2: **Out of equilibrium & cavities**

Chair: Markus Müller (Paul Scherrer Institut, Switzerland)

15:45 – 16:15 **Controling solid state phases through vacuum fields**
Jérôme Faist (ETH Zürich, Switzerland)

16:15 – 16:30 **Correlation induced quantum spin Hall insulating state in monolayer $TaIrTe_4$**
Honey Boban (University of Geneva, Switzerland)

16:30 – 16:45 **Phonon-Driven Pathway to the 1T-TaS_2 Hidden State**
Nelson Hua (Paul Scherrer Institut/ETH Zürich, Switzerland)

16:45 – 17:00 **Revealing Polaronic Effects and Their Impact on Transport in Titanium Trisulfide through UV-ARPES**
Aymen Mahmoudi (University of Fribourg, Switzerland)

17:00 – 17:30 **Unraveling exciton dynamics in 2D quantum materials on ultrashort time- and lengthscales using time-resolved momentum microscopy**
Stefan Mathias (University of Göttingen, Germany)

1' poster presentations 17:30 – 18:00

Chair: Andrea Caviglia (University of Geneva, Switzerland)

Poster session 1 & commercial exhibit 18:00 – 20:30

Dinner 20:30

August 26 (Wed)

August 26 (Wed) 8:30 – 10:00

Session 3: **Applications**

Chair: Carmine Senatore (University of Geneva, Switzerland)

8:30 – 9:00 **High Fields, High Stakes: REBCO Technology for High-Energy Physics**
Bernard Auchmannn (Paul Scherrer Institut, Switzerland)

9:00 – 9:15 **Quantum confinement and strain effects in Ge/SiGe quantum wells**
Enrico Della Valle (ETH Zürich/Paul Scherrer Institut, Switzerland)

9:15 – 9:30 **Industrializing Internal Oxidation for High-Jc Nb_3Sn in Future Collider Magnets**
Francesco Lonardo (University of Geneva, Switzerland)

9:30 – 9:45 **Emergent magnetism in $NbSe_2$ thin films**
Ryan Thompson (University of Fribourg, Switzerland)

9:45 – 10:00 **Room-temperature memristive switching between charge density wave states**
Rok Venturini (Jozef Stefan Institute, Slovenia/Paul Scherrer Institut, Switzerland)

Coffee 10:00 – 10:30

August 26 (Wed) 10:30 – 12:15

Session 4: **Oxide interfaces**

Chair: Jean-Marc Triscone (University of Geneva, Switzerland)

10:30 – 11:00 **Twist-Programmable transport in $BaTiO_3$ Moiré membranes**
Jacobo Santamaria (Universidad Complutense, Spain)

11:00 – 11:30 **Tailoring magnetism in double-perovskite RE_2NiMnO_6 heterostructures**
Marta Gibert (TU Wien, Austria)

11:30 – 11:45 **Domains and superdomains in ferroelectric lead titanate heterostructures and membranes**
Ludovica Tovaglieri (University of Geneva, Switzerland)

11:45 – 12:00 **There's the rub - exploring the unusual nanotribology and surface electrochemistry of ferroelectrics**
Patrycja Paruch (University of Geneva, Switzerland)

12:00 – 12:15 **Current-induced extrinsic contributions in nonlinear transport measurements at the LAO/STO interface**
Karen Sobnath (University of Geneva, Switzerland)

Lunch 12:15 – 13:45

August 26 (Wed) 13:45 – 15:15

Session 5: **2D Materials**

Chair: Titus Neupert (University of Zürich, Switzerland)

13:45 – 14:15 **Signatures of Collective photon emission and ferroelectric exciton ordering in moiré crystals**
Ajit Srivastava (University of Geneva, Switzerland)

14:15 – 14:30 **Competing Orders Driven by Wigner Crystal Phase in Rhombohedral Graphene**
Zekang Zhou (EPF Lausanne, Switzerland)

14:30 – 14:45 **Lattice Hall effects**
Dominik Juraschek (Eindhoven University of Technology, Netherland)

14:45 – 15:00 **Fractional Chern insulator edges: crystalline effects and optical measurement**
Johannes Motruk (University of Geneva, Switzerland)

15:00 – 15:15 **Observation of ring states in a delicate topological insulator**
Caroline Tornow (ETH Zürich, Switzerland)

Coffee 15:15 – 15:45

August 26 (Wed) 15:45 – 17:15

Session 6: **Superconductivity I**

Chair: Manfred Sigrist (ETH Zürich, Switzerland)

15:45 – 16:00 **Superconductivity in a Chern band: effects of time-reversal-symmetry breaking and topology**
Mark H. Fischer (University of Zürich, Switzerland)

16:00 – 16:15 **Pinning landscape of moiré superconductors**
Ilia Moghayer (ETH Zürich, Switzerland)

16:15 – 16:30 **Unconventional superconducting correlations in fermionic many-body scars**
Kiryl Pakrouski (ETH Zürich, Switzerland)

16:30 – 16:45 **Angular-momentum-flavored Majorana zero modes**
Giulia Venditti (University of Geneva, Switzerland)

16:45 – 17:15 **Introducing the new NCCR Muoniverse**
Mark Janoschek (University of Zürich/Paul Scherrer Institut, Switzerland)

1' poster presentation 17:15 – 17:45

Chair: Andrea Caviglia (University of Geneva, Switzerland)

Poster session 2 & commercial exhibit 17:45 – 20:30

Conference dinner 20:30

August 27 (Thu)

August 27 (Thu) 8:30 – 10:00

Session 7: **Out of equilibrium/theory**

Chair: Vadim Geshkenbein (ETH Zürich, Switzerland)

8:30 – 9:00 **THz dynamics and ground state control of quantum materials**
Elsa Abreu (ETH Zürich, Switzerland)

9:00 – 9:15 **From bright to dark: Mapping exciton dynamics in Black Phosphorus with trARPES**
Joël Morf (University of Fribourg, Switzerland)

9:15 – 9:30 **Entropy transport through a superfluid quantum point contact: A Keldysh field-theory approach**
Davide Bertolusso (University of Geneva, Switzerland)

9:30 – 10:0 **Quantum criticality in the two-dimensional Hubbard model**
Jan von Delft (Ludwig-Maximilians-Universität München, Germany)

Coffee 10:00 – 10:30

August 27 (Thu) 10:30 – 12:00

Session 8: **Superconductivity II**

Chair: Fabian von Rohr (University of Geneva, Switzerland)

10:30 – 11:45 **Doping evolution of intertwined electronic orders in cuprates**
Tejas Singar (University of Geneva, Switzerland)

10:45 – 11:00 **Nodal-line superconductivity in chiral crystals**
Toni Shiroka (Paul Scherrer Institut/ETH Zürich, Switzerland)

11:00 – 11:15 **Uniaxial Control of Cuprate Superconductors**
Gediminas Simutis (Paul Scherrer Institut, Switzerland)

11:15 – 11:30 **Insights into low pressure region density waves in bulk Ruddlesden-Popper nickelates**
Daruisz J. Gawryluk (Paul Scherrer Institut, Switzerland)

11:30 – 12:00 **Shape-tuning quantum materials**
Philip Moll (Max-Planck-Institute for the Structure and Dynamics of Matter, Germany)

Poster prize & closing ceremony 12:00 – 12:30

Lunch bag 12:30

POSTER SESSIONS

August 25 (Tue) 18:00 – 20:30

Poster session 1

Joep Van den Eijnden	**Multi-scale modelling of Nb3Sn cable for accelerator magnets**	1-1
Gleb Neplyakh	**Multifrequency Tunneling Spectroscopy**	1-2
Anna Efimova	**Universal relation between residual resistivity and A coefficient in correlated metals**	1-3
Tina Arh	**Spin and lattice dynamics in the two-ladder quantum magnet Cu-CPA**	1-4
Kai Roeseler	**Molten-Metal Flux Synthesis as a Tool Towards New Quantum Materials**	1-5
Elodie Iglesis	**Carrier dynamics in semiconductor InSb and topological material $ZrTe_5$, studied with ultrafast terahertz time-domain spectroscopy**	1-6
Yanis Wenger	**Connecting the 2D Ising, Heisenberg and XY magnets**	1-7
Subhrangsu Sarkar	**Magneto-dielectric coupling in a magnetic high entropy oxide**	1-8
Samudra Sur	**Interplay of Noise and Reservoir-induced Decoherence in Persistent Currents**	1-9
Baptiste Demazure	**Two-dimensional coherent spectroscopy for magnetophononic dynamics**	1-10
Ivo Gabrovski	**From Landau levels to Hofstadter physics**	1-11
Sofie Castro Holbæk	**Altermagnetic spin splitting of the quasiparticle spectrum in multiband superconductors**	1-12
Janek Tangermann	**Competing 6R- and $4H_b$-polytype formation in post-annealed TaS_2**	1-13
Stáňa Tázlarů	**Theoretical framework for polarization dependent magneto-absorption in (anti)ferromagnetic materials**	1-14
Nicolas Brunner	**DFT Analysis of Raman-Active Modes in $NbSe_2$ Polymorphs and Strained $NbSe_2$**	1-15
Bernhard Lüscher	**Tensor-Train Approaches to Superconductivity**	1-16
Bruce Normand	**Two-dimensional coherent spectroscopy of composite collective excitations**	1-17
Jeppe Cederholm	**Spin Excitations Near the Pressure-Induced Antiferromagnetic Transition in SrCu2(BO3)2**	1-18
Malo Hervé	**Ultrafast Magnetic Fields from THz-Driven Chiral Phonons**	1-19
Anshuman Verma	**Tunable Space-Charge Doped Two-Dimensional Materials for Scanning Probe Microscopy Investigations**	1-20
Claude Monney	**Ultrafast recovery dynamics of dimer stripes in $IrTe_2$**	1-21
Ilaria Maccari	**Theory of switchable half-quantum flux rings of the kagome superconductor CVS**	1-22

Poster session 2

Romain Babouche	**Critical Current Anisotropy and Electromechanical Limits of REBCO Coated Conductors for Ultra-High-Field Magnets**	2-1
Jessica Ruffiner	**Strain dependent multiferroicity in TbMnO3 thin films observed by infrared ellipsometry**	2-2
Monica Ciomaga Hatnean	**Disorder and Magnetism in Rare Earth Silicate Compounds**	2-3
Konrad Puzniak	**Magnetic excitation of the near-ideal molecule-based Haldane spin chain Ni2(3,5-lut)4 in a magnetic field**	2-4
Christophe Berthod	**Benchmark solution of the continuum model for metallic hydrogen, using the full energy- and momentum-dependent Eliashberg formalism**	2-5
Maksim Plekhanov	**Probing intertwined electronic instabilities in superconducting Ruddlesden-Popper nickelates through chemical and structural tailoring**	2-6
Daniel Bustamante	**Ferron Hall Effect**	2-7
Levi Oudejans	**Superconductivity and the pseudogap phase in LSCO under uniaxial strain**	2-8
Dario Marchiani	**Electronic structure of the correlated van der Waals metal MoOCl2**	2-9
Salony Mandloi	**Probing the intrinsic field in few-layer Janus RhSeCl using ARPES**	2-10
Ishita Pushkarna	**Interface controlled electronic phases in two-dimensional materials on gold**	2-11
Tanguy Prongué	**Micro-ARPES study of mono- and few-layers TaIrTe4**	2-12
Andrés Felipe Bareno Prieto	**Itinerant large polarons in hexagonal boron nitride**	2-13
Tiangang Zhou	**Solvable Random Unitary Dynamics in a Disordered Tomonaga-Luttinger Liquid**	2-14
Mykhailo Pavliuk	**Equivalence of Different Limiting Bulk Spectra in Non-Hermitian Lattice Systems**	2-16
Stefano Gariglio	**Lattice coupling across epitaxial oxide heterostructures**	2-17
Céline Lichtensteiger	**Domains, superdomains and ripples in epitaxially strained and free-standing PbTiO3**	2-18
Tancredi Thai Angeloni	**All-oxide hybrid phonon-plasmon resonators based on a strongly correlated metal**	2-19
Bosai Lyu	**Superresolution Localization and Control of 2D Quantum Emitters**	2-22
Yaxian Wang	**Coherent Spin-Lattice Dynamics for Ultrafast Magnetic Switching in 2D Magnets**	2-23

ABSTRACTS

of the

oral presentations

Hyperfine-enhancement as a route to persistent spin dynamics in singlet-state systems

Stephen Blundell

University of Oxford

Many magnetically frustrated systems exhibit what is known as persistent spin dynamics (PSD) in μSR experiments, the origin of which has remained mysterious since their discovery in the 1990s. As the temperature is lowered, the muon-spin relaxation rate rises (as would be expected for the slowing-down of spin fluctuations) but this rate then saturates at low temperature, the low-temperature fluctuations being interpreted as PSD. To explain this phenomenon, we describe how muons can couple to singlet states and illustrate this with experimental data taken on Tm2Ti2O7. The key idea is that the hyperfine interaction, usually neglected in treatments of electronic magnetism, provides a route in which excited states can be mixed into the ground state, and this new state can couple to the "quantum muon" [1]. This mechanism lies behind the effect found in some quantum spin ice compounds [2], but here it is not based on the distortion effects surrounding the muon [3,4]. We will show how this idea can be extended to understand the way muons couple to a variety of systems exhibiting highly frustrated magnetism [5], as well as to dynamical problems more generally [3].

[1] S. J. Blundell, J. Phys.: Conf. Ser. 2462, 012001 (2023).

[2] F. R. Foronda, F. Lang, J. S. Möller, T. Lancaster, A. T. Boothroyd, F. L. Pratt, S. R. Giblin, D. Prabhakaran and S. J. Blundell, Phys. Rev. Lett. 114, 017602 (2015).

[3] J. M. Wilkinson and S. J. Blundell, Phys. Rev. Lett. 125, 087201 (2020).

[4] S. J. Blundell and T. Lancaster, Appl. Phys. Rev. 10, 021316 (2023).

[5] Hank C.H. Wu, Francis L. Pratt, Benjamin M. Huddart, Dipranjan Chatterjee, Paul A. Goddard, John Singleton, D. Prabhakaran, and Stephen J. Blundell, Phys. Rev. Lett. 135, 046704 (2025).

Structural Origin of the Magnetic Field-Induced Electric Polarization of $GdMn_2O_5$

Karina Kazarian,[1] Jakub Vonka,[1] Bill Pedrini,[1] Adrian Rutschmann,[1,2] Nicola Colonna,[3] Victor Balédent,[4] Simon Gerber,[1] and Alexander Steppke[5]

[1] *PSI Center for Photon Science, Paul Scherrer Institute, Switzerland*
[2] *Laboratory for Solid State Physics and Quantum Center, ETH Zürich, Switzerland*
[3] *PSI Center for Scientific Computing, Theory and Data, Paul Scherrer Institute, Switzerland*
[4] *Laboratoire de Physique des Solides, Université Paris-Saclay, France*
[5] *PSI Center for Neutron and Muon Sciences, Paul Scherrer Institute, Switzerland*

We investigate the magnetoelectric coupling of $GdMn_2O_5$, a multiferroic where the electric polarization and magnetic order are strongly coupled [1]. The compound exhibits a magnetic field-induced electric polarization, where the component along the crystallographic *a* axis persists and even increasing after removal of the magnetic field, suggesting access to a novel, path-dependent ground state [2]. The microscopic mechanism behind this persistent polarization remains unclear and resolving it requires a direct structural probe to track the lattice response in the presence of high magnetic fields.
The emergence of an electric polarization is believed to result from atomic displacements caused by changes in magnetic ordering through magnetoelastic coupling. Our experiments using the new pulsed magnet setup at the SwissFEL Cristallina-Quantum experimental station are guided by density functional theory simulations covering scenarios, ranging from simple atomic displacements of the magnetic Gd ions to lattice relaxation driven by changes of the magnetic order. These models predict intensity variations of specific lattice Bragg peaks, providing a direct experimental benchmark for the structural origin of the magnetic field-induced electric polarization.

[1] G. Yahia *et al*. Recognition of exchange striction as the origin of magnetoelectric coupling in multiferroics. Phys. Rev. B **95**, 184112 (2017).
[2] V. Balédent *et al*. Electronic ground-state hysteresis under magnetic field in $GdMn_2O_5$. Phys. Rev. B **108**, 104419 (2023).

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Phonon Angular Momentum and Effective Fields in CeF3

Alexander Ferguson,[1] Ivan Mohelsky,[1] Florian Le Mardelé,[2] David Santos-Cottin,[1] Vladimir Martinez,[3] Lucile Chassat,[1] Yuriy Pashkevych,[1,4] Andrei Sirenko,[3] Milan Orlita,[2,5] Premysl Marsik,[1] and Christian Bernhard[1]

[1] *Department of Physics, University of Fribourg, Fribourg, Switzerland*
[2] *LNCMI, CNRS-UGA-UPS-INSA, Grenoble, France*
[3] *Department of Physics, New Jersey Institute of Technology, Newark, USA*
[4] *O. Galkin Donetsk Institute for Physics and Engineering NAS of Ukraine, Kyiv, Ukraine*
[5] *Institute of Physics, Charles University, Prague, Czech Republic*

The 4f-paramagnetic rare-earth trihalides have received renewed attention due to the growing interest in chiral and axial phonons, which are lattice vibrations that carry angular momentum. The coherent control of these phonons in rare-earth trihalides has been proposed to generate effective magnetic fields far above those expected from the ion motion [1], with this being demonstrated by measurements of ultrafast magnetism in CeF3 for a single 10.5 THz phonon [2].
We make use of the generalised magneto-ellipsometry technique to measure the phonon Zeeman effect. We observe an asymmetric splitting between upper and lower phonon branches, suggesting that further theoretical work is needed. Our measured phonon magnetic moments are some of the largest observed and closely agree with those implied by the ultrafast magnetism experiments [2], proving equivalence between the phonon inverse Faraday effect and the phonon Zeeman effect.

[1] Juraschek, D. M., Neuman, T., & Narang, P, Phys. Rev. Research 4(1), 013129 (2022).
[2] Luo, J., Lin, T., Zhang, J., Chen, X., Blackert, E. R., Xu, R., Yakobson, B. I., & Zhu, H, Science 382(6671), 698-702 (2023).

Current-driven resonant spin dynamics in a single organic molecule

Stepan Kovarik, Richard Schlitz, Aishwarya Vishwakarma, Dominic Ruckert, Pietro Gambardella, and Sebastian Stepanow

Department of Materials, ETH Zurich, CH-8093 Zürich, Switzerland

Resonant driving of localized spins by electric current provides an alternative route to magnetic resonance at the atomic scale. Whereas conventional electron paramagnetic resonance (EPR) relies on an oscillating magnetic field to drive spin transitions, here the excitation is mediated by spin-polarized transport through a tunnelling junction. Using EPR-STM to probe an organic molecule with well-defined, delocalized electronic states, we show that a radio-frequency spin-polarized tunnelling current can drive electron paramagnetic resonance via spin-transfer torque acting on a localized magnetic moment. Because both excitation and readout are mediated by the transport channel, this approach directly couples spin dynamics to charge flow and provides access to coherent control, relaxation, decoherence, and transport-induced linewidth broadening within a single local-probe experiment. These results establish organic molecular systems as a promising platform for out-of-equilibrium spin dynamics and quantum magnetism at the single-spin level. The same mechanism extends naturally to larger molecular architectures, where electronic delocalization, exchange coupling, and local addressability can be tuned by chemical design.

[1] S. Kovarik, R. Schlitz, A. Vishwakarma, D. Ruckert, P. Gambardella, and S. Stepanow, Science 384, 1368–1373 (2024).

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Controlling the Magnetic Properties of the Layered van der Waals Crystals $V_{1-x}Cr_xI_3$

Maria Herz,[1] Felix Eder,[1] Anastasiia Lukovkina,[1] Sara López-Paz,[2] Enrico Giannini,[1] and Fabian von Rohr[1]

[1] *Department of Quantum Matter Physics, University of Geneva, CH-1205 Geneva, Switzerland*
[2] *Department of Chemistry, University of Copenhagen, 2100 København, Denmark*

Layered van der Waals materials have gained an ever-increasing interest due to their ability to provide a versatile playground to explore the emergence of new quantum phenomena. Among these, the trihalides CrI_3 and VI_3 stand out due to their unique magnetic properties and the interplay with their structural transitions,[1,2] with recent studies focussing on elucidating the effect of layer control in CrI_3,[3] and on the importance of the spin and orbital moments in VI_3.[4] To date, only one experimental study exists on their elemental doping,[5] and none on the solid solution due to its significant synthetic challenge.
Our work showcases the successful growth of single crystals across the entire range of the solid solution of $V_{1-x}Cr_xI_3$, *i.e.*, $x = 0 - 1$, by employing the self-selecting vapour-growth (SSVG) technique.[6] In the resulting magnetic measurements, we identified three regimes. In the $0.1 \leq x \leq 0.3$ regime, we observed complex ferri- and ferromagnetic behaviour parallel and perpendicular to the crystallographic *c*-axis, and spin-glass-like behaviour. For $0.4 \leq x \leq 0.6$, we observed a transition from one to two ferri- and ferromagnetic transitions in both orientations, while for $0.7 \leq x \leq 0.9$, we observed two ferri- and ferromagnetic transitions parallel to the crystallographic *c*-axis.

[1] M. A. McGuire et al., Chemistry of Materials, 27, 612-620 (2015).
[2] T. Marchandier et al., Physical Review B, 104, 014105 (2021).
[3] B. Huang et al., Nature, 546, 270-273 (2017).
[4] A. De Vita et al., Nano Letters, 24, 1487-1493 (2024).
[5] S. Pan et al., Journal of Alloys and Compounds, 908, 164573 (2022).
[6] A. Lukovkina et al., Chemistry of Materials, 36, 6237-6245 (2024).

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Controling solid state phases through vacuum fields

Jerome Faist

ETH Zurich

While the effect of vacuum fields on atomic system (such as through the Lamb shift) is well known, there is a recent interest in controlling the many-body phases of solid-state systems using vacuum fluctuations strongly coupled to such a system inside a microcavity. In such a system, the strength of the electric field caused by the vacuum fluctuations, which can be maximized in circuit-based resonators with a scaled down volume to deep subwavelength values. We have used transport to probe the ultra-strong light-matter coupling and shown that the latter can induce a breakdown of the integer quantum Hall effect. We have also explored the effect of a cavity on the fractional quantum Hall effect using a hovering cavity experiments[1] and recently demonstrated the orientation of a stripe phase using an analog to a Casimir torque[2].

[1] Enkner, J. et al. Tunable vacuum-field control of fractional and integer quantum Hall phases. Nature 1–6 (2025) doi:10.1038/s41586-025-08894-3.

[2] Graziotto, L. et al. Cavity QED Control of Quantum Hall Stripes. arXiv.org https://arxiv.org/abs/2502.15490v1 (2025).

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Correlation induced quantum spin Hall insulating state in monolayer $TaIrTe_4$

Honey Boban,[1] Tanguy Prongue,[1] Felix Eder,[1] Amarjyoti Choudhury,[2] Fabian von Rohr,[1] Marco Gibertini,[2,3] Anna Tamai,[1] and Felix Baumberger[1,4]

[1] *Department of Quantum Matter Physics, University of Geneva, Geneva, Switzerland*
[2] *Dipartimento di Scienze Fisiche, Informatiche e Matematiche, Universita di Modena e Reggio Emilia, I-41125 Modena, Italy*
[3] *Centro S3, CNR - Istituto Nanoscienze, I-41125 Modena, Italy*
[4] *Swiss Light Source, Paul Scherrer Institute, Villigen, Switzerland*

Monolayer $TaIrTe_4$ is theoretically predicted to be a quantum spin Hall insulator [1]. A recent transport study on monolayer $TaIrTe_4$ has confirmed the insulating state at zero doping and reported edge conduction, consistent with a topological insulating state [2]. Intriguingly, a second insulating state with comparable edge conduction was found in gated samples where the chemical potential lies inside the non-interacting conduction band. This second insulating state was attributed to an electronic instability driven by saddle points van Hove singularities in the band structure.
We will present the first micro-focused ARPES results from monolayer $TaIrTe_4$. Our ARPES results confirm the insulating state of monolayer $TaIrTe_4$ and directly reveals the presence of van Hove singularities in the band structure.
In addition, we will also present preliminary results from bulk $TaIrTe_4$ and discuss their consistency with the putative type-II Weyl semimetal state predicted theoretically.

[1] P. J. Guo et al., Phys. Rev. B 102, 2020.
[2] J. Tang et al., Nature 628, 2024.

Phonon-Driven Pathway to the 1*T*-TaS_2 Hidden State

Nelson Hua,[1,2] Xun Jia,[3] Corinna Burri,[1,4] H.G. Bell,[1,4] Swan Htun,[3] Faris Dizdarević,[1,4] Maël Clémence,[1,4] Aidan G. McConnell,[1,4] Wenxiang Hu,[1,4] Adrian Rutschmann,[1,4] Travis Frazer,[3] Jan Ravnik,[1] Vincent Esposito,[5] Matthias Hoffmann,[5] Takahiro Sato,[5] Diling Zhu,[5] Hasan Yavas,[5] Serhane Zerdane,[1] Shih-Wen Huang,[1] Roman Mankowsky,[1] Mathias Sander,[1] Ian K. Robinson,[6,7] Dragan Mihailović,[8] Yue Cao,[3] and Simon Gerber[1]

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Among the layered transition-metal dichalcogenides, 1*T*-TaS_2 uniquely exhibits a hidden, metallic charge density wave phase. A myriad of experiments have demonstrated the ability to use an optical or electrical excitation to access this metastable state [2,3], but ultimately the nonthermal mechanism that unlocks this hidden phase has eluded observations. Here we used time-resolved X-ray diffraction with three-dimensional reciprocal space resolution to reveal the coherently driven dynamics tied to both the commensurate and hidden charge density wave states. Supported by dynamic structure factor simulations [3] and unsupervised machine learning, our results show that an out-of-plane A_g phonon mode in the commensurate state facilitates a dismantling of dimers and a subsequent interlayer restacking to the hidden state. Furthermore, progressive bulk switching and a transient interlayer melting of the hidden phase underscores the significance that stacking dynamics play in an otherwise strongly correlated two-dimensional material.

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Revealing Polaronic Effects and Their Impact on Transport in Titanium Trisulfide through UV-ARPES

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The quasi-one-dimensional semiconductor titanium trisulfide (TiS_3) exhibits a metal–insulator transition accompanied by pronounced transport anomalies, whose microscopic origin remains under debate [1,2,3]. In this work, I present a detailed ARPES investigation of its electronic structure, focusing on the role of electron–phonon interaction. High-resolution UV-ARPES measurements reveal clear signatures of strong coupling, including replica bands and spectral weight redistribution characteristic of Holstein polarons formed via interaction with an infrared-active A_u phonon mode.
By systematically varying temperature and carrier concentration, we track the evolution of these polaronic features and observe a pronounced renormalization of the quasiparticle dispersion and linewidth. These spectral changes correlate directly with anomalies in the resistivity, providing evidence for a crossover between distinct charge transport regimes governed by many-body interactions.
Our results establish a direct link between microscopic many-body interactions and macroscopic transport properties in TiS_3, highlighting the power of ARPES as a tool for understanding complex quantum materials.

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[2] E. Gorlova *et al.*, Nonlinear transport and anisotropy in quasi-one-dimensional TiS_3, *Physica B* **460**, 11–15 (2015).
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Unraveling exciton dynamics in 2D quantum materials on ultrashort time- and lengthscales using time-resolved momentum microscopy

Stefan Mathias

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Two-dimensional semiconducting quantum materials and organic semiconductors have emerged as promising materials for next-generation optoelectronics and energy harvesting. At their heart lies the process of exciton formation: when light is absorbed, Coulomb-bound electron-hole pairs, termed excitons, carry and convert energy on nanometer spatial and femtosecond temporal scales. Understanding the very first moments of light–matter interaction, along with subsequent exciton relaxation and energy conversion, is vital for designing devices with new functionality and high efficiency.
To study light-matter interaction and exciton dynamics in such 2D quantum material heterostructures, we have developed a state-of-the-art, photoemission-based experiment [1] that enables us to observe exciton dynamics in space and time, spanning nanometers and femtoseconds. This approach uncovers the characteristic fingerprints of exciton generation, tracks their dynamics of energy transfer and thermalization, and lets us map the elusive dark exciton landscape in 2D semiconductors.
In my talk, I will show how we probe ultrafast light-matter interactions [2] and resolve the formation dynamics of dark interlayer excitons across a variety of 2D quantum materials [3-7]. I will discuss the identification of distinctive photoemission signatures linked to these processes, show how the dark exciton landscape can be mapped, and introduce “photoemission exciton tomography” [6], a new technique that enables tracing ultrafast charge transfer from transition metal dichalcogenides (TMDs) to organic layers in real time [7].

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[2] Merboldt et al., Nature Physics 21, 1093-1099 (2025).
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[4] Bange et al., Science Adv. 10, eadi1323 (2024).
[5] Schmitt et al., Nature Photonics 19, 187-194 (2025).
[6] Bennecke et al., Nature Communications 15, 1804 (2024).
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High Fields, High Stakes: REBCO Technology for High-Energy Physics

Bernhard Auchmann

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In this contribution, we approach superconductivity from the perspective of a magnet engineer in the field of high-energy physics, where field strength, field quality, robustness, and cost are of the essence. For decades throughout the Nb-Ti era, the conductor was regarded as a tightly specified commodity. To a degree, this attitude prevails today for Nb3Sn and MgB2. Over recent years, however, fusion applications have catapulted the community into the era of REBCO technology. Due to their microscopic properties and manufacturing processes, commercially available tapes pose a host of new and highly relevant challenges to magnet engineering and accelerator design. Meeting these challenges has the potential to enable new applications well beyond accelerators, while rendering existing ones more sustainable and economical. In this early stage of REBCO technology, we discuss how managing screening currents, quench protection, and mechanical strain may accommodate today's tapes, and how advances in conductor technology can make a difference in the prospects for large-scale adoption.

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Quantum confinement and strain effects in Ge/SiGe quantum wells

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Germanium-silicon-germanium (Ge/Si_xGe_{1-x}) heterostructures are an emerging group-IV platform for quantum devices, high-mobility electronics, and hybrid superconductor-semiconductor architectures. In these systems, strain, quantum confinement, and spin-orbit coupling strongly reshape the valence-band structure of Ge quantum wells, thereby defining the electronic properties of low-energy hole states. However, the momentum-resolved electronic structure of buried strained Ge quantum wells has so far only been inferred indirectly. Here we use soft X-ray angle-resolved photoemission spectroscopy (SX-ARPES) to directly probe strained Ge quantum wells embedded in SiGe barriers [1]. We resolve strain-split and size-quantized valence subbands, identify their heavy-hole, light-hole, and split-off character, and determine the valence-band offset at the Ge/SiGe heterojunction. Comparison with *ab initio* calculations shows that quantitative agreement requires explicit inclusion of the confinement potential imposed by the SiGe barriers, which strongly affects the dispersion, ordering, and mixing of the hole states. Our results provide a direct experimental picture of the hole subband structure in Ge/SiGe quantum wells, establishing a basis for predictive design of group-IV quantum and electronic devices.

[1] Della Valle, E., et al. (2026). "Direct observation of strain and confinement shaping the hole subbands of Ge quantum wells". https://doi.org/10.48550/arXiv.2603.18753.

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Industrializing Internal Oxidation for High-Jc Nb_3Sn in Future Collider Magnets

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The proposed Future Circular Collider (FCC) requires compact 14 T class dipole magnets, with more than 5000 units distributed along a 91 km ring, for enabling proton-proton collisions at 85 TeV. Nb_3Sn is currently the only technology with sufficient industrial maturity for this application but further increases in critical current density (Jc) at high magnetic fields are essential for achieving the target field in an economically viable manner. Enhancing Jc relies on improving flux pinning via microstructural control. Internal oxidation is a promising approach, using Nb-based alloys with electropositive elements (e.g., Hf) and an oxygen source (SnO_2). During Nb_3Sn synthesis, nanoscale HfO_2 precipitates form, refining grain size thus increasing grain boundary pinning while also acting directly as pinning centers. Our previous material studies have demonstrated substantial grain refinement (from 120 nm to <50 nm) and Jc values up to 3700 A/mm^2 at 15 T and 4.2 K. In this work, we focus on translating these advances into practical conductor technology. We develop strategies to implement internal oxidation in Nb_3Sn wires within industrially scalable routes, targeting nanoscale control over kilometer-length conductors. This contribution addresses the key challenge of bridging optimized material properties with manufacturable high-performance wires for future accelerator magnets.

Emergent magnetism in $NbSe_2$ thin films

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$NbSe_2$ is a transition metal dichalcogenide (TMDC) well known for having the highest superconducting transition temperature among all pristine TMDCs. While bulk $NbSe_2$ is only found in its 2H superconducting phase, it has been shown that 1T-$NbSe_2$ can be stabilized on a substrate through molecular beam epitaxy growth[1], with extremely different properties from the 2H phase. 1T-$NbSe_2$ is not superconducting, but a Mott insulator that exhibits localized magnetic moments as seen through Kondo resonances[2], and has recently been characterized as a spin liquid[3]. However, no evidence of long-range magnetic order has been shown to date. In this work, we grown mixed phase 2H/1T-$NbSe_2$ thin films on $YAlO_3$ substrates using molecular beam epitaxy. New Raman modes are found to be present, particularly at the edge of the films, distinguishing it from the pure 2H phase. We observe the onset of a sizeable magnetoresistance around 75 K, and a pronounced magnetic hysteresis at low temperatures, implying the existence of a long-range magnetic order. However, muon spin rotation experiments showed no presence of a strong magnetic transition, limiting the possible magnetic volume fraction of the film to be less than 5%.

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Room-temperature memristive switching between charge density wave states

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Control over the novel quantum states that emerge under non-equilibrium conditions is of both fundamental and technological importance. Metastable charge density wave (CDW) states are particularly interesting as their electrical manipulation could lead to ultra-efficient memory devices. However, using electrical pulses for non-volatile resistance switching involving CDW states has been limited to cryogenic temperatures [1]. We investigate a recently discovered layered semiconductor $EuTe_4$, which exhibits the coexistence of distinct CDW orders [2,3]. We report that electrical pulses can be used for excitation to non-equilibrium, yet stable electronic states across a broad temperature range from 6 K to 400 K [4]. We find that switching occurs through a non-thermal pathway and is reversible via a thermal erase procedure. The resistance of the new electronic state is tunable by the pulse voltage, so the device acts as a memristor. Our calculations suggest that switching leverages a bistability in the stacking of CDW order in Te layers, which are separated by the weak Eu-Te link. Low-voltage, fast, and energy-efficient CDW switching holds great promise for memristor applications.

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Twist-Programmable transport in $BaTiO_3$ Moiré membranes

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Twisted 2D van der Waals stacks have revealed emergent electronic phases driven by moiré superlattice potentials. Recent progress in releasing and transferring single-crystalline transition-metal-oxide membranes has now brought complex oxides into the moiré arena. As correlated 3d-electron systems, oxides host intertwined charge, lattice and spin degrees of freedom, often featuring ferroic order persisting to room temperature, raising the prospect of chiral polar and magnetic textures shaped by twist-controlled interlayer couplings. Yet oxide moiré platforms depart fundamentally from the vdW paradigm because their strong bonding: registry-dependent ionic–covalent bonding, surface terminations and oxygen defect chemistry can drive interfacial reconstruction, disordered layers or even gap-like separations. While substantial effort is directed toward sharpening and reconstructing these interfaces, such defect-enabled interlayers may themselves be functional, providing reconfigurable barriers in which transport is mediated by vacancy-related traps and thermally assisted emission.
In this talk, I will focus on twisted BaTiO3 membrane junctions with symmetric Au electrodes, where the moiré interface acts as a geometrically programmable barrier for oxygen-vacancy motion. Vacancy blocking establishes a non-uniform defect profile and an interfacial dipole that re-partition the electric field and render transport strongly temperature- and sweep-history dependent: at high temperature we observe pronounced irreversibility consistent with a bias-conditioned, trap- and space-charge–modified barrier, whereas cooling suppresses this history dependence and drives a crossover toward field-emission–dominated transport. Increasing twist angle systematically attenuates the irreversibility, consistent with enhanced vacancy confinement and faster relaxation of bias-induced space charge. These results position twist as a single geometric knob to engineer defect electrostatics, enabling reconfigurable memristive elements and suggesting a route to volatile neuromorphic primitives in freestanding oxide membranes.

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Work in collaboration with V. Zamora[1], V. Rouco[1], H. Aramberri[2], M. Cabero[3], G. Sánchez-Santolino[1], A. Rivera[1], F. Mompean[4], M. Garcia Hernandez[4], J. Íñiguez[2], C. Leon[1]

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Tailoring magnetism in double-perovskite RE_2NiMnO_6 heterostructures

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Atomically engineered transition-metal-oxide heterostructures provide a versatile platform for probing and tailoring magnetic properties at the ultrathin limit and across interfaces. We focus on the double-perovskite family RE_2NiMnO_6 (RE = rare earth), a class of insulating ferromagnets —an unusual combination of properties. La_2NiMnO_6 exhibits a Curie temperature (T_c) of 280 K, while T_c decreases linearly across the series with decreasing RE-radius.

In RE_2NiMnO_6 thin films, ferromagnetic order persists down to at least 3 unit cells in epitaxial layers, and we further show that this behavior is retained in free-standing membranes.

To engineer the magnetic phase diagram and probe interfacial coupling, we fabricated atomic-scale-controlled superlattices comprising La_2NiMnO_6 and RE_2NiMnO_6 (RE = Nd, Sm) layers, which have distinct Curie temperatures. Large-period superlattices display two separate magnetic transitions characteristic of the parent compounds. In contrast, reducing the period yields a single transition, indicating that low-period heterostructures behave as a unique material. Interfaces also enhance the Nd-Ni-Mn exchange interaction.

Moroever, in these superlattices, scanning transmission electron microscopy and first-principles calculations reveal unequal antipolar displacements consistent with electric polarization, suggesting hybrid improper ferroelectricity. Together with robust ferromagnetism, these results highlight double-perovskite heterostructures as a promising platform for multiferroic devices.

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Domains and superdomains in ferroelectric lead titanate heterostructures and membranes

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$PbTiO_3$ exhibits a bulk paraelectric-ferroelectric phase transition at a critical temperature T_c of 765 K, developing a switchable polarization along the c-axis mostly driven by ionic displacements. Theoretical studies in $PbTiO_3$ thin films have revealed complex phase diagrams with different configurations of domains - regions with uniform polarization - that can be controlled in terms of size and shape by tailoring the electrostatic boundary conditions, film thickness, deposition temperature, and epitaxial strain [1]. Domains are separated by interfaces termed domain walls. At larger length scales, domains can self-organize into superdomains - periodic or hierarchical structures with characteristic sizes ranging from hundreds of nanometers to several micrometers. This implies the existence of superdomain walls, which may exhibit properties distinct from conventional domain walls.
We investigate domain and superdomain structures in $PbTiO_3$ heterostructures. We demonstrate that both domain and superdomain periodicities scale with the thickness of the ferroelectric layer, enabling precise control of their densities through thickness engineering [2,3]. We further show that ferroelastic domains can propagate structural distortions into adjacent layers [4]. Beyond epitaxial thin films, we explore domains and superdomains in membranes, where the constraints imposed by the substrate are removed [5].

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There's the rub - exploring the unusual nanotribology and surface electrochemistry of ferroelectrics

Seongwoo Cho, Iaroslav Gaponenko, Loïc Musy, and Patrycja Paruch

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Ferroelectric materials host a wide range of unusual structural features, often linked to emergent functional properties. At domain walls or in regions with high strain gradients, in particular, the complex interaction between polarisation, electrostatics, and strain can lead to chiral polarisation textures, electrical conductivity, mechanical responses, and charge or chemical segregation, which we access primarily with scanning probe microscopy, coupled with machine learning analysis. For example, we have observed the switchable, polarisation-dependent friction and wear behaviour of ferroelectrics — down domains have lower friction coefficients and show slower wear rates than up domains. This asymmetry is enabled by flexoelectrically coupled polarisation in the up and down domains under a sufficiently high contact force. This polarisation-dependent tribological asymmetry is a general feature across different ferroelectric families with varying chemical compositions and crystalline symmetry. Such switchable tribological properties of ferroelectrics offer an alternative route to visualise and control ferroelectric domains and can be combined with multi-pass patterning as domain-based dynamic smart masks, with which we demonstrate three-dimensional nanostructuring exploiting the asymmetric wear rates of up and down domains. Such patterning can, furthermore, be scaled up to technologically relevant (mm–cm) size.

Current-induced extrinsic contributions in nonlinear transport measurements at the LAO/STO interface

Karen Sobnath, Stefano Gariglio, Giacomo Sala, and Andrea Caviglia

University of Geneva

Electron motion in a solid can arise from the local distribution of the wavefunctions, as encoded in the quantum geometric tensor [1]. This tensor consists of a real part, the quantum metric and an imaginary part, the Berry curvature. Under an oscillating current, transport experiments are an excellent probe to disentangle linear from higher-order nonlinear responses originating from distinct geometrical contributions [2]. However, commonly used control parameters such as electrostatic gating and temperature can themselves be modulated by the applied current, leading to undesired extrinsic nonlinear effects [3].

Here we report a systematic and general procedure one could use to identify and possibly rule out spurious contributions to transport generated by current-induced modulation of gate voltage and temperature. We implement this approach with magneto-transport measurements in the two-dimensional electron gas at $LaAlO_3/SrTiO_3$ interface. This system exhibits Rashba spin-orbit coupling at the origin of nontrivial geometrical features in momentum space and has been shown to host intriguing linear and nonlinear transport phenomena [4,5].

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Signatures of Collective photon emission and ferroelectric exciton ordering in moiré crystals

Ajit Srivastava

University of Geneva

In this talk, I will present our recent observation of many-body interaction-induced ferroelectric ordering of moiré excitons in H-stacked WSe2/WS2 heterobilayer. Strong exciton-exciton repulsion leads to an excitonic Mott state with a large on-site energy Uxx 35 meV. Due to the interplay of anisotropic nature of dipolar interactions, large Uxx, and spatially indirect in-plane excitons in H- stacking, we observe signatures of ferroelectric ordering of moiré excitons in time-resolved photoluminescence spectra. In particular, we find a reduction in emission lifetime consistent with this ordering, which can be thought of as a novel cooperative phenomenon [1]. Our observations open new avenues to explore a system of correlated moiré electrons and excitons as a rich platform to study and create quantum matter in a driven-dissipative setting and also a many-body quantum open system simulator to uncover novel cooperative phenomena.

[1] Luka Matej Devenica, Zach Hadjri, Jan Kumlin, Daniel Suárez-Forero, Runtong Li, Klevis Domi, Bosai Lyu, Weijie Li, Ludivine Fausten, Valeria Vento, Nicolas Ubrig, Song Liu, James Hone, Kenji Watanabe, Takashi Taniguchi, Thomas Pohl and Ajit Srivastava, Nature Materials (2026).

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Competing Orders Driven by Wigner Crystal Phase in Rhombohedral Graphene

Zekang Zhou

EPFL

Rhombohedral graphene systems provide a unique platform where strong electronic interactions and nontrivial band topology coexist at low carrier densities and high displacement fields, giving rise to a rich landscape of emergent electronic phases. Here, we report that the highly insulating state on the low-density side of chiral superconductivity in rhombohedral pentalayer graphene (R5G) corresponds to a Wigner crystal (WC) phase. Under an out-of-plane magnetic field, the system hosts competing magnetic-field-stabilized superconductivity (fSC) and unconventional reentrant quantum Hall (RIQH) states. These emergent phases are closely connected to the underlying WC. Our results establish that WC phase plays an important role in the phase diagram of rhombohedral multilayer graphene and highlight its connection to a rich landscape of emergent phases.

Lattice Hall effects

Dominik Juraschek

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The thermal Hall effect describes the generation of a transverse heat current arising from a longitudinal thermal gradient, which in semiconductors and insulators is primarily carried by collective excitations, such as phonons and magnons. In recent years, the phonon Hall effect has been shown to be ubiquitous in crystalline solids, including materials ranging from simple semiconductors to ferroelectrics and high-temperature superconductors. Here, we generalize the phonon Hall effect to different types of lattice excitations, including chiral phonons and ferrons. Specifically, I will present three recent predictions of novel Hall responses of the crystal lattice: First, the phonon angular momentum Hall effect, in which a transverse angular momentum current is generated similar to the conventional spin Hall effect [1]. Second, the ferron Hall effect, in which a transverse polarization current is generated by a magnetic field [2]. Third, the phonon polariton Hall effect, in which light is deflected by a magnetic field when traveling through a dielectric material [3].

[1] Bustamante Lopez, Brehm, and Juraschek, arXiv:2604.01899.

[2] Bustamante Lopez and Juraschek, in preparation.

[3] Yaniv and Juraschek, arXiv:2509.16100.

Fractional Chern insulator edges: crystalline effects and optical measurement

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Edge states of chiral topologically ordered phases are commonly described by chiral Luttinger liquids, effective theories that are exact only in the hydrodynamic limit. In crystalline systems, however, deviations from simple power-law scalings of correlators generally emerge. Motivated by recent bulk observations of fractional Chern insulators in two-dimensional materials, we revisit this framework and systematically quantify deviations from the hydrodynamic limit due to lattice effects. Using a combination of analytical arguments and numerical simulations, we extract the anomalous boundary exponent from correlation functions—showing that it robustly tracks the bulk filling factor—while independently determining non-universal edge velocities and associated energy scales from short-time dynamics. Applied across integer and fractional Chern insulators in bands with realistic Berry-curvature inhomogeneity, our procedure provides stable estimators that connect edge responses to bulk topology beyond the flat-band limit. Finally, we propose experimental probes of excitonic fractional Chern insulators, whose charge-neutral nature hinders conventional detection. In particular, time-resolved edge spectroscopy provides direct access to the predicted exponents and velocities, offering a viable route to identifying these phases.

[1] https://arxiv.org/abs/2511.17494.

Observation of ring states in a delicate topological insulator

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Topological insulators are typically characterized by particularly stable properties, such as global invariants, and can be identified by probing their robust surface states. A recently discovered novel form of band topology, delicate topology, challenges this paradigm: its defining property, multicellularity, can be removed by introducing a coupling to local orbitals anywhere in the spectrum, even far above the relevant band gap. This makes it hard to diagnose delicate topology with conventional probes that access only low-energy degrees of freedom. Here, we introduce strong local impurities as a spectroscopic probe of a delicate topological insulator which we realize in a phononic metamaterial. By tuning the impurity strength and performing orbital-resolved readout, we observe recently proposed indicators of topology: ring states, in-gap bound states whose frequencies remain pinned in the strong-impurity limit while their real-space profiles form a pronounced ring around the impurity site. We find that these ring states persist even when the multicellularity in our system is removed by a weakly hybridizing additional orbital. Our results establish impurity-induced ring states as probes of complex multiband physics, including delicate topological phases.

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Superconductivity in a Chern band: effects of time-reversal-symmetry breaking and topology

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Time-reversal-symmetry breaking is generally detrimental for superconductivity. However, recent experiments found superconductivity emerging in materials showing an anomalous Hall effect, indicative of time-reversal-symmetry breaking. We study the stability of superconducting orders and the mechanisms that suppress superconductivity in the prototypical anomalous Hall system, the Haldane model, where complex hopping parameters result in loop currents with a compensated flux pattern and topologically non-trivial bands. We find that neither singlet nor triplet states are generically suppressed, but the real-space structure plays a crucial role in the stability of the orders. Interestingly, the nearest-neighbor chiral states of $d \pm id$ or $p \pm ip$ symmetry couple linearly to the flux, leading to critical temperatures depending on the chirality. We further study the anomalous thermal Hall effect, κ_{xy}/T, which vanishes at zero temperature for trivial superconducting states, but reaches a finite value corresponding to the Chern number in a topological superconducting state. Our results illustrate that broken time-reversal symmetry through a finite flux is neither generically destructive for superconductivity, nor does it imply non-trivial topologically of the emerging superconductor. However, for multiple competing pairing channels the flux order favors a chiral superconducting state.

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Pinning landscape of moiré superconductors

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Moiré materials are 2D layers stacked on top of each other with a slight twist angle or lattice mismatch. We develop a Ginzburg–Landau framework to describe the vortex pinning landscape of moiré superconductors, in which spatial inhomogeneity enters through spatially varying superconducting parameters.
We show that intrinsic periodic modulation inherited from the moiré lattice creates a periodic pinning potential for vortices. This contribution scales as $\sim \exp\left(-\frac{4\pi}{\sqrt{3}}\frac{\xi}{L_m}\right)$, where ξ is the coherence length and L_m is the moiré length. As a result, the pinning channel can vanish even when the coherence length and moiré period are comparable. Depending on the magnitude of ξ/L_m, intrinsic periodic pinning can be relevant, such as in supermoiré and twisted $NbSe_2$ structures, or strongly suppressed such that this pinning channel becomes negligible, as in magic-angle graphene systems. We further show that local twist angle variations can partially lift this suppression. Applying our framework to magic-angle graphene, we find that bulk pinning is dominated by disorder-induced inhomogeneity rather than intrinsic moiré periodicity.

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Unconventional superconducting correlations in fermionic many-body scars

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Weak ergodicity breaking in interacting quantum systems may occur due to the existence of a subspace dynamically decoupled from the rest of the Hilbert space. In two-orbital spinful lattice systems, we construct such subspaces that are in addition distinguished by strongest inter-orbital and spin-singlet or spin-triplet, long-range superconducting pairing correlations. All unconventional pairing types we consider are local in space and unitary. Alternatively to orbitals, the additional degree of freedom could originate from the presence of two layers or through any other mechanism. Required Hamiltonians are rather non-exotic and include chemical potential, Hubbard, and spin-orbit interactions typically used for two-orbital superconducting materials. Each subspace is spanned by a family of group-invariant quantum many-body scars combining both 2e and 4e pairing/clustering contributions. One of the basis states has the form of a BCS wavefunction and can always be made the ground state by adding a mean-field pairing potential. Analytical results in this work are lattice-, dimension- and (mostly) system size-independent. We confirm them by exact numerical diagonalization in small systems.

[1] Phys. Rev. B 113, 085135 (2026); https://doi.org/10.1103/gjvn-lf4r.

Angular-momentum-flavored Majorana zero modes

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The search for Majorana particles [1] is important both for fundamental understanding and possible topological quantum computation [2]. Since Majorana particles are an equal superposition of particle and antiparticle, they are naturally sought in superconductors, in the form of Majorana zero modes (MZMs). From Kitaev's seminal paper [3], the quest to engineer devices capable of hosting MZMs is still ongoing. The search for new compounds hosting robust MZMs, however, requires a deeper understanding of these states. Fu and Kane [4] showed that a MZM can emerge in the vortex-core states of an s-wave superconductor on top of a three-dimensional strong topological insulator (TI). We study a d+id superconductor placed on a TI (d+id + Dirac model) [5] and show that the vortex-core MZMs can carry a nontrivial angular momentum. This establishes new *flavors* of Majorana modes, independent of the Chern number and classified with respect to the windings of the order parameter and underlying normal state. Contextually, we assess the stability and topological protection of these MZMs, as well as possible experimental signatures. The possibility of having different flavors of MZMs opens new directions for advancing the study of Majorana modes.

[1] A. Yazdani, F. von Oppen, B. I. Halperin, and A. Yacoby, Science 380, eade0850 (2023).

[2] D. Aasen, M. Aghaee, Z. Alam, M. Andrzejczuk, A. Antipov, M. Astafev, L. Avilovas, A. Barzegar, B. Bauer, J. Becker, et al., Phys. Rev. Res. 7, 041002 (2025).

[3] A. Kitaev, Usp. Fiz. Nauk 17, 131 (2001).

[4] Liang Fu, and C. L. Kane, Phys. Rev. Lett. 100, 096407 (2008).

[5] G. Venditti, C. Berthod, L. Rademaker, Phys. Rev. B 113 014502 (2026).

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Introducing the new NCCR Muoniverse

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Muon science is a vibrant field that explores and exploits the unique properties of muons, the "heavy siblings" of electrons. Muoniverse is a newly funded National Center for Competence in Research (NCCR) that, building on the world-leading muon facility at the Paul Scherrer Institute PSI, unites universities, industry, artists and museums in their endeavor to use muons to enable advances in fields ranging from quantum technologies and renewable energy to archaeology and cultural heritage. Here we will focus on presenting the goals of Muoniverse in the fields of condensed matter and material science.

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THz dynamics and ground state control of quantum materials

Elsa Abreu

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Quantum materials exhibit rich phase diagrams, strongly sensitive to external parameters, which include intriguing properties such as electronic correlations, superconductivity, and spin and charge order. These macroscopic properties arise from complex interactions between electronic, structural, spin and orbital degrees of freedom. The complexity of these interactions poses a tremendous challenge for the understanding, modeling and technological applications of quantum materials.
One approach that has proven successful in decoupling the effect of different degrees of freedom is to perform time-resolved measurements. Photoexcitation by a low photon energy terahertz pulse, in particular, ensures that the out-of-equilibrium sample remains close to its electronic ground state. I will discuss two examples in our work, where we explore the THz response of Mott insulators and of spin-ladder compounds.
Another approach to address the complexity of quantum materials is to reduce the available parameter space by choosing one external parameter, such as pressure, which can be continuously controlled while preserving thermal equilibrium. Pressure has been used extensively in equilibrium but only to some extent with ultrafast measurements. I will discuss our ongoing work to combine ultrafast THz, high pressure and low temperature capabilities.

From bright to dark: Mapping exciton dynamics in Black Phosphorus with trARPES

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Excitons, bound electron-hole pairs, determine key optical properties of semiconductors. While conventional optical probes are sensitive only to bright, zero-momentum excitons, time-resolved ARPES (trARPES) maps the full energy landscape and gives direct access to optically forbidden dark excitons. [1] Beyond their role in radiative processes, the possibility of engineering electronic properties of solids through coherent excitons has gotten a lot of attention, making their relaxation and decoherence dynamics an important open question. [2] In this study, we resonantly pump excitons in the small-gap semiconductor black phosphorus to directly measure their binding energy and dynamics. Comparing resonant with different above-gap pump schemes, we identify fundamental differences in the relaxation pathways of excitons and free carriers in the conduction band. Interactions with phonons scatter the excitons into states with higher energy, leading to a cooling of the lattice. Using a quantum-kinetic theoretical framework, we further show that exciton-phonon scattering in this single-valley semiconductor leads to ultrashort decoherence times, limiting the possibility of long-lived coherence-driven phenomena.

[1] M. Reutzel et al., Probing excitons with time-resolved momentum microscopy, London: Advances in Physics: X, 2024.
[2] V. Pareek et al., Driving floquet physics with excitonic fields, London: Nature Physics, 2026.

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Entropy transport through a superfluid quantum point contact: A Keldysh field-theory approach

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We study the matter and entropy transport between two ultra-cold neutral Fermi-gas reservoirs linked by a quantum point contact under a chemical-potential gradient. We describe the two leads with a BCS mean-field model and derive the current-bias characteristics for both particle and entropy transport. We compute the out of equilibrium steady-state currents by using the Keldysh formalism. In accordance with previous works in the literature, we confirm the well-known behavior for the particle current and extend the computation to the entropy current in the BCS regime. The entropy current shows an oscillatory behavior at low voltage in the ballistic junction limit. We analyze the results for a wide range of values of the junction's transparency. We also compare our findings with experimental results in cold atomic gases in the unitary regime.

Quantum criticality in the two-dimensional Hubbard model

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We study the normal-state, doping-driven phase diagram of the square-lattice Hubbard model using a four-patch dynamical cluster approximation combined with the numerical renormalization group as a cluster solver, which gives direct access to real-frequency dynamics at essentially zero temperature. In a parameter regime relevant for cuprates, $U = 7t$ and $t' = -0.3t$, we find a critical doping $p^\star$ that marks a continuous quantum phase transition between a pseudogap metal and a normal Fermi liquid. The transition is identified by a continuous collapse, from both sides, of the Fermi-liquid scale extracted from charge, spin, and d-wave pairing susceptibilities. This collapse produces a non-Fermi-liquid regime at intermediate energy scales, which appears to extend to arbitrarily low scales at $p^\star$. As $p^\star$ is crossed from the normal Fermi liquid at $p > p^\star$ into the pseudogap metal at $p < p^\star$, the coherent low-energy spectral weight in the antinodal region is lost and replaced by a narrow, metallic pseudogap, while the nodal region evolves smoothly and remains comparatively coherent. This gives rise to Fermi arcs in the pseudogap metal at $p < p^\star$, since the zero-frequency spectral weight remains large in the nodal region but is strongly suppressed in the antinodal region.
Furthermore, we study dynamical scaling in the quantum-critical fan of the pseudogap-metal to Fermi-liquid transition of the $t - t'$ Hubbard model, accessing real-frequency dynamics over several decades at arbitrary temperatures. Close to the critical doping, the local spin and cluster-current susceptibility spectra exhibit $x = \omega/T$ scaling of the form $\chi''(\omega, T) \sim \tanh(x/2)$, and the cluster contribution to the optical conductivity obeys $T\sigma'(\omega, T) \sim \tanh(x/2)/x$, implying a $1/T$ cluster dc-conductivity. In the scaling regime, the vertex contribution to the cluster optical response is much larger than the bubble contribution. We further find evidence for a marginal- Fermi-liquid nodal self-energy. This, together with the $1/T$ vertex contribution to the conductivity, implies strange-metal optical transport in the quantum critical region. Our results describe several qualitative aspects of several experimental observations.

[1] https://arxiv.org/abs/2605.15059.
[2] https://arxiv.org/abs/2605.15060.

Doping evolution of intertwined electronic orders in cuprates

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Hole-doped cuprates exhibit a complex phase diagram characterized by the coexistence of multiple electronic orders, including superconductivity, magnetism, the pseudogap and charge order. Hole doping of the CuO_2 planes via interstitial oxygen atoms modifies the electronic structure, leading to pronounced changes in both the superconducting gap and the pseudogap.

Here, we investigate the doping evolution of the local density of states (LDOS) modulations in the $Bi_2Sr_2CaCu_2O_{8+\delta}$ (Bi-2212) superconductor using scanning tunneling microscopy (STM). We focus on the evolution of the vortex core electronic structure, where superconductivity is locally suppressed, providing access to the underlying non-superconducting ground state across the phase diagram [1-3].

We further examine the doping dependence of zero-field periodic charge modulations and their relationship with superconducting and pseudogap orders through spectroscopic imaging of local electronic variations. Our results provide insight into how intertwined electronic orders evolve with carrier concentration in the Bi-2212 high temperature superconductor.

[1] T. P. Singar et al., arXiv:2512.13588 (2025).

[2] I. Maggio-Aprile et al., Physica C: Superconductivity and its Applications 615 (2023) 1354386.

[3] T. Gazdić et al., Physical Review X 11, 031040 (2021).

Nodal-line superconductivity in chiral crystals

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Structural handedness is a defining characteristic of *chiral crystals*, which are known to exhibit exotic quantum phenomena resulting from the interaction of band topology, spin-orbit coupling (SOC) and electronic correlations. Due to the limited availability of suitable chiral-crystal materials, their unconventional superconductivity (SC) has remained largely unexplored.

Here, we report the discovery of *unconventional superconductivity* in the La(Rh,Ir)Si family of materials by combining muon-spin spectroscopy, band-structure calculations and perturbation theory. This family, characterized by a double-helix chiral structure, hosts exotic multifold fermions, which are absent in other topological chiral crystals. While LaRhSi behaves as a fully gapped superconductor, substituting $4d$-Rh with $5d$-Ir significantly enhances the SOC, leading to topological nodal-line SC in LaIrSi. Our newly developed model shows that the nodal-line SC arises from an isotropic SOC with a specific strength. This exotic mechanism extends our conventional understanding of materials that can exhibit unconventional SC, as these typically rely on significantly anisotropic SOC to promote triplet pairing. Our work establishes a new type of phase diagram that provides a *comprehensive roadmap* for identifying and engineering unconventional superconductivity in chiral crystals.

[1] P. Narang, C. A. C. Garcia, and C. Felser, *Nat. Mater.* **20**, 293 (2021).
[2] T. Shang et al., *Adv. Matter* **37**, e11385 (2025).
[3] T. Shang, T. Shiroka, *Front. Phys.* **9**, 270 (2021).

Uniaxial Control of Cuprate Superconductors

Gediminas Simutis

Paul Scherrer Institute

I will present our recent advances in using uniaxial pressure as a clean “surgical” tool to tune quantum phases while simultaneously obtaining microscopic insights via scattering experiments. The realizations of the experiments are enabled through technical developments by minimizing the background and enabling the tuning in-situ [1].
To achieve the fine-tuning, we have designed a uniaxial device based on an actuator-motor mechanism, efficient feedback loops, and a sample-holder design enabling rapid exchange of the samples [2]. I will demonstrate the capabilities of this device by reporting the control of charge and structural degrees of freedom as studied by X-rays in an archetypal cuprate [3,4].
We extend the in-situ experiments to neutron scattering of magnetism in cuprates characterized by small moments, which remains challenging for pressure studies. We overcome these difficulties by designing a low-background uniaxial strain cell, performing neutron-tracing simulations and using aggressive focusing and energy analysis. Such a setup allowed us to track the spin order parameter [5] and the superconducting transition temperature as a function of uniaxial pressure applied in different directions [6]. I will finish by discussing our ongoing work on studying the interplay of magnetism and superconductivity in uniaxially pressurized systems.

[1] 1. Simutis et al., Swiss Neutron News 62, 14 (2023).
[2] 2. Simutis et al., Review of Scientific Instruments 94, 013906 (2023).
[3] 3. Guguchia et al., PNAS 121 (1) e2303423120 (2023).
[4] 4. Thomarat et al., Communications Physics 7, 271 (2024).
[5] 5. Simutis et al., Communications Physics 5, 296 (2022).
[6] 6. Philippe et al., In preparation.

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Insights into low pressure region density waves in bulk Ruddlesden-Popper nickelates

Dariusz Jakub Gawryluk

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Ruddlesden-Popper phases of rare earth nickelates represent a class of compounds that lie close to intrinsic instabilities, where their atomic, magnetic, and electronic structures are highly sensitive to subtle changes in chemical composition, topology, dimensionality, and external stimuli. As a result, they exhibit complex and highly tunable physical phenomena. Recent experimental discoveries of high-pressure induced superconductivity [1,2], as well as the presence of coexisting spin density waves in the low-pressure regime [3] and charge density waves across a very broad pressure range [3,4], have expanded efforts toward understanding their mutual correlations with the underlying structure and chemistry and, ultimately, the mechanism of superconductivity in this family. I will present an overview of selected structural and chemical variants within this perovskite related subgroup, with an emphasis on recent progress in studying their magnetic structures and their correlations to the lattice.

[1] H. Sun et al., Nature 621, 493 (2023).
[2] Y. Zhang et al., Nat. Phys. 20, 1269 (2024).
[3] R. Khasanov et al., Nat. Phys. 21, 430 (2025).
[4] Y. Meng et al., Nat Commun 15, 10408 (2024).

Shape-tuning quantum materials

Philip Moll

Max-Planck-Institute for the Structure and Dynamics of Matter

Materials with novel electronic properties are commonly studied in bulk crystal form, an ideal platform to uncover their thermodynamic ground state properties. Recent advances in crystal micromachining using Focused Ion Beams have demonstrated how reducing the size of 3D systems below relevant length scales of their physics can induce qualitatively new phenomena absent in bulk form. Key mechanisms are microscopic surface design, geometric frustration and dimensional reduction - phenomena well studied in 2D systems like thin-films or exfoliated vdW systems yet largely unexplored in 3D materials. I will review recent cases of shape tuning of quantum systems in Kagome superconductors[1], semi-metals at the quantum limit [2] and related quantum materials.

[1] C. Guo et al., Nature 647, 68-73 (2025).
[2] J. Seo et al., Nature Physics 22, 232-238 (2026).

ABSTRACTS

of the

poster presentations

Multi-scale modelling of Nb3Sn cable for accelerator magnets

Joep Van den Eijnden,[1,2] Juerg Leuthold,[1] Jasmin Smajic,[1] Xiang Kong,[1] Theo Tervoort,[1] Douglas Araujo,[2] Bernhard Auchmann,[2] and André Brem[2]

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As part of the Swiss Accelerator Research and Technology (CHART) initiative, we have developed and validated a multiscale modeling framework for Nb3Sn Rutherford cables. This routine bridges the gap between micrometer-scale filament strain and cable-scale performance, providing a design tool for superconducting accelerator magnets in the 14 T range.
The workflow integrates explicit dynamics (LS-DYNA) to simulate plastic deformation during cabling with a Python-based automation tool that generates finite element models in ANSYS APDL from the resulting geometries. By incorporating measured, non-linear material properties and a homogenization strategy for the interfilamentary region, the model accurately predicts critical current reduction under transverse stress we get from experiments, and can predict the mechanical behaviour of superconducting cable stacks.
In this work, we present the deployment of this framework to support the PSI subscale superconducting magnet campaign. The modeling tool is used to evaluate stress-managed magnet designs and assess their mechanical impact on Nb3Sn cable performance. The routine is currently being integrated into the PyMBSE framework, enabling both PSI magnet development projects and the broader superconducting accelerator magnet community to leverage this technique.

Multifrequency Tunneling Spectroscopy

Gleb Neplyakh, Rian Ligthart, Ajla Karić, Alexander LaFleur, Kevin Hauser, Berk Zengin, Philipp E.J. Maier, Carolina A. Marques, and Fabian D. Natterer

University of Zurich

Scanning tunnelling spectroscopy (STS) probes the local density of states (LDOS) via differential conductance measurements. Conventional STS acquires spectra through sequential bias sweeps with a small modulation, making large-area spectroscopic mapping slow.
We introduce Parallel Spectroscopy (PS), previously applied to quasiparticle interference (QPI) measurements [1,2]. PS exploits the nonlinearity of the $I(V)$ characteristic: a larger modulation drive generates higher harmonics that encode the full spectrum. Simultaneous demodulation of multiple harmonics enables reconstruction of the energy dependence in a single measurement. We further extend this approach to multi-tone waveform drives.
In synergy with compressed sensing [3], PS dramatically reduces acquisition time while preserving spectral fidelity.

[1] Berk Zengin et al., Fast spectroscopic mapping of two-dimensional quantum materials, Phys. Rev. Research 3, L042025 (2021).
[2] Ajla Karić et al., High dynamic range scanning tunneling microscopy, MethodsX Vol. 13, 102857 (2024).
[3] Jens Oppliger et al., Adaptive sparse sampling for quasiparticle interference imaging, MethodsX Vol. 9, 101784 (2022).

Universal relation between residual resistivity and A coefficient in correlated metals

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Understanding how electronic correlations and disorder jointly influence charge transport remains a central challenge in quantum materials. In this work, we disentangle these intertwined effects by independently tuning the degree of randomness (via chemical substitution) and the strength of electronic correlations (via physical pressure) in metallic phases proximate to a Mott–insulating state. Focusing on the low-temperature Fermi-liquid regime, where the resistivity follows

$$\rho(T) = \rho 0 + A * T^2$$

, we systematically extract both the residual resistivity $\rho 0$ and the coefficient A, which scales with the square of the quasiparticle mass enhancement. Contrary to conventional expectations that $\rho 0$ is independent of correlation strength, our experiments reveal a robust linear scaling between $\rho 0$ and A at fixed disorder level. We interpret this finding through a phenomenological framework in which spatial fluctuations of the chemical potential enhance the residual scattering rate, leading to

$$\rho 0 \propto A * \sigma\mu^2$$

, where $\sigma\mu^2$ quantifies the variance of chemical-potential disorder. Crucially, when comparing our results with transport data from a wide range of correlated metals-organic Mott systems, oxides, heavy-fermion compounds, and moiré heterostructures-we find this linear relation to be universal across diverse material classes. This discovery establishes a new scaling law linking disorder and correlation effects in strongly interacting electron systems and provides a unified perspective on charge transport in correlated metals.

[1] arXiv:2508.21759.

Spin and lattice dynamics in the two-ladder quantum magnet Cu-CPA

Tina Arh,[1] Jonas Philippe,[1,2] Frank Elson,[3] Stanisław Gałęski,[13] Kirill Povarov,[14] Sergio Sanz,[4] Marvin Metzelaars,[4,5] David W. Tam,[3] Ola K. Forslund,[2,6] Oksana Shliakhtun,[1,2] Chengyu Jiang,[3] Jakob Lass,[1] Duc Le,[7] Jacques Ollivier,[8] Pierre Bouillot,[9] Thierry Giamarchi,[9] Marek Bartkowiak,[1] Daniel G. Mazzone,[1] Paul Kögerler,[5] Martin Månsson,[3] Andreas M. Läuchli,[10,11] Yasmine Sassa,[3,12] Marc Janoschek,[1,2] Bruce Normand,[10] and Gediminas Simutis[1,12]

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Quantum spin ladders are materials that bridge the gap between spin dimer and spin chain systems. They can often be realized in metal-organic compounds in which large organic groups between the magnetic ions decrease the interaction strengths, so that the magnetization can be saturated with experimentally accessible magnetic fields. On the other hand, large organic groups can host low-lying phonons that make materials soft and susceptible to magnetoelastic effects as well as structural transitions at fairly low temperatures. Metal-organic $(C_5H_9NH_3)_2CuBr_4$ (Cu-CPA) was recently found to contain two inequivalent spin ladders at temperatures below such a structural transition [1]. A recent success in synthesis of large single crystals has allowed us to perform high-resolution neutron spectroscopy [2] and high-field magnetization measurements. In the former, we observe the two branches of the triplon dispersion that confirm the coexistence of two inequivalent spin ladders and help us estimate the relative strengths of their leg and rung exchange interactions, which are inherently difficult to determine from the thermodynamic measurements alone. Additionally, we show that the low-energy local phonons are sensitive to the spin correlations, making the material a great candidate to study the interplay of spin and lattice dynamics.

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Molten-Metal Flux Synthesis as a Tool Towards New Quantum Materials

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Molten-metal flux synthesis is a well-established synthetic approach, in which single-crystal growth is facilitated by dissolving high-melting metals in low-melting ones.[1,2] It has been proven as a fruitful method for the formation of metastable or kinetically stabilized phases, which would otherwise be unattainable by conventional solid-state methods.[3] Layered chromium-chalcogenide-based quantum materials are of particular interest due to their rich magnetism and strong electronic correlations.[4] In this presentation, we systematically explore the engineering of alkali-chromium-telluride flux reactions to obtain large single-crystals of delafossite-type $A\mathrm{CrTe_2}$ (A = alkali cation) phases as well as previously unreported $A_{2.4}\mathrm{Cr_8Te_{14}}$ compounds, which combine the structural architecture of layered $A\mathrm{CrTe_2}$ phases [4] and tunneled $A\mathrm{Cr_5Te_8}$ hollandite-likes [5]. Beyond the synthetic work, we determine their magnetic properties and their spin structure. Their diverse magnetism in combination with their layered structure makes them ideal candidates for future spintronic devices.

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Carrier dynamics in semiconductor InSb and topological material $ZrTe_5$, studied with ultrafast terahertz time-domain spectroscopy

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Topological materials gather a lot of interest for their remarkable properties [1], [2], [3]. Due to the strong intertwinement between their electronic, structural, and topological degrees of freedom, a light-induced control of their structure would open the possibility to tune their properties and topological phase. A first step towards this exciting possibility is to understand carrier and phonon dynamics in such systems.
The development of the Terahertz Time-Domain Spectroscopy (THz-TDS) technique has opened many possibilities to characterize modes in matter that were until then inaccessible [4], [5]. By integrating this time-resolved technique into a pump-probe configuration, one can investigate the ultrafast transient photoconductive response and carrier dynamics of a broad range of materials. We developed such set-up to conduct optical pump - THz probe measurements on several samples.
I will first present a study of photo-induced carrier dynamics in a low bandgap semiconductor Indium Antimonide (InSb) and I will discuss and model the influence of pump fluence on these dynamics. In a second part, I will report similar pump-probe measurements on the topological semi-metal zirconium pentatelluride ($ZrTe_5$), that allowed the study of its ultrafast carrier dynamics. If time, I will complement these results with a study of its structure's dynamics conducted by time-resolved Raman spectroscopy.

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Connecting the 2D Ising, Heisenberg and XY magnets

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We study the classical ferromagnetic Heisenberg model with single spin anisotropy in two dimensions. While the 2d Heisenberg model does not order at any finite temperature, it is known that for strong easy-axis anisotropy we recover the Ising model with a second-order phase transition. The other limit, strong easy-plane anisotropy, yields an XY model with a topological BKT transition. Using Monte Carlo simulations we interpolate between these limits, showing how the Ising, Heisenberg and XY cases are connected: in particular, we focus on how the critical behavior fundamentally changes as we tune the anisotropy.

Magneto-dielectric coupling in a magnetic high entropy oxide

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We report the dielectric and magnetic properties of epitaxial thin films of a magnetic high entropy oxide (HEO) perovskite Nd(Cr0.2Mn0.2Fe0.2Co0.2Ni0.2)O3 having magnetic orderting temperature, Tmag≈190 K. At T ≫ Tmag, the dielectric response has a significantly large zero-frequency dielectric constant of ≈230-250. The reversible dc bias voltage loops exhibit three distinct peaks centred at zero and finite positive and negative voltage. The zero-bias peak is governed by the oxygen sublattice while the finite bias peaks originate from cationic dipoles. The maximal response of the latter appears to be shifted to finite bias by a static uncompensated electric field due to a vertical gradient of the oxygen content. Below Tmag, this anomalous dielectric response is strongly suppressed. We also find that the zero freq. dielectric constant follows the non-magnetic volume fraction measured from low energy muSR. These findings indicate a unique correlation between configurational entropy, dielectric response, and magnetic properties. In combination with a large dielectric strength, it enables a non-hysteretic tuning of the dielectric response with multiple parameters like temperature, electric, and magnetic field, which can find application in perovskite electronics.

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Interplay of Noise and Reservoir-induced Decoherence in Persistent Currents

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Persistent current is a hallmark of quantum phase coherence. We study the fate of the persistent current in a non-equilibrium setting, where a tight-binding ring is subjected to stochastic disorder as well as a fermionic reservoir attached to each site. We evaluate the current using Keldysh technique and find that it exhibits non-monotonic behavior, suggesting two distinct mechanisms of decoherence. While coupling to the reservoirs introduces a coherence length scale given by the inverse of the coupling strength, the other mechanism is more subtle and driven by the ratio of noise strength to reservoir coupling. The interplay of noise and reservoir constitutes a purely non-equilibrium steady state with a flatter distribution function that we effectively describe using classical rate equations. We discuss possibilities of realizing our findings in ultracold-atom experiments.

Two-dimensional coherent spectroscopy for magnetophononic dynamics

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Two-dimensional coherent spectroscopy (2DCS) uses the time delay in a pump-pump-probe protocol to perform a systematic analysis of the nonlinear response of an out-of-equilibrium system. One route to the ultrafast control of collective phenomena in quantum magnetic materials is magnetophononics, which combines coherent driving of the lattice by ultrashort THz laser pulses with the intrinsic spin-lattice coupling to create a nonequilibrium magnetic response. The hybridization of phononic and magnetic modes leads to mutually repelling composite excitations whose splitting dominates the 2DCS spectrum, creating 2-, 4- and 6-peak clusters at the characteristic second-order (sum and difference frequencies) and third-order (two-quantum, non-rephasing, pump-probe and rephasing) response features. In addition, the 2DCS spectrum contains elongated peaks and antidiagonal streak features that we show reflect the presence of a continuum of magnetic excitation energies, and hence enable a decomposition of the nonlinear excitations into their elementary constituents. Finally, we compute the 2DCS spectrum of a simplified model for the quantum magnet $CuGeO_3$, where the saddle point in the density of states enhances the visibility of further horizontal, vertical and diagonal streaks.

From Landau levels to Hofstadter physics

Ivo Gabrovski and Louk Rademaker

DQMP, UniGe

We study spinless electrons in a magnetic field subject to a square periodic potential and present a method to derive a Hofstadter-like tight-binding model starting from Landau levels. We demonstrate how the Hofstadter regime emerges from a continuum Hamiltonian as the strength of the periodic potential is increased, identifying the associated topological phase transitions. Based on this, we introduce a dimensionless parameter that characterizes the Hofstadter regime. In addition, we show that the Hofstadter model requires corrections when the magnetic field is large enough that the magnetic length becomes comparable to or smaller than the lattice constant.

Altermagnetic spin splitting of the quasiparticle spectrum in multiband superconductors

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Multiband superconductors contain internal orbital or sublattice degrees of freedom, which can qualitatively alter the properties of the superconducting state. In particular, the internal structure of the superconducting order parameter, rather than its momentum dependence, can have nontrivial transformation properties, leading to so-called internally anisotropic pairing states. These states can exhibit phenomena absent in single-band superconductors, such as Bogoliubov Fermi surfaces.
Here, we investigate superconductivity in a two-orbital model with spin-orbit coupling, but spin-degenerate bands due to time-reversal- and inversion symmetry. Focusing on even-parity, time-reversal-symmetry-breaking superconducting states, we investigate pairing states with a non-unitary orbital structure, which generate spin splitting of the Bogoliubov quasiparticle bands. Interestingly, these bands exhibit either altermagnetic- or ferromagnetic-like spin structures, depending on the symmetry of the pairing state. These spin splittings are unique to multi-orbital systems and are related to the time-reversal-odd bilinear formed by the order parameter components.
Finally, we discuss possible experimental manifestations of the altermagnetic-like Bogoliubov quasiparticles, thereby providing experimental fingerprints of time-reversal symmetry-breaking superconductivity with nontrivial internal structure.

Competing 6R- and $4H_b$-polytype formation in post-annealed TaS_2

Janek Tangermann, Felix Eder, and Fabian von Rohr

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Transition metal dichalcogenides (TMDs), with their layered van der Waals structures, offer a rich playground for studying how differences in local coordination (polymorphism) and stacking sequence (polytypism) influence emergent quantum phenomena. Both polytypes, $4H_b$-TaS_2 as well as 6R-TaS_2, display the coexistence of competing quantum states, i.e., superconductivity and charge density waves (CDWs) [1]. Despite the subtle structural difference, only $4H_b$-TaS_2, however, has been found to display signatures of time-reversal symmetry breaking, suggesting chiral superconductivity [2]. Consequently, crystal defects and stacking disorder suspected in naturally grown bulk crystals can have considerable influence on the electronic structure of these phases.

In this work, we investigate the formation of $4H_b$-TaS_2 and 6R-TaS_2 by post-annealing of 1T-TaS_2 crystals. In the narrow temperature range where 1T transforms into 2H-TaS_2, both $4H_b$-and 6R-TaS_2 can form, revealing a competition of the two polytypes and causing inherent structural disorder. Here, we evaluate the synthesis control by means of heating-rates, annealing temperatures and durations by following the phase transitions in (powder) X-ray diffraction experiments. Furthermore, modelling diffraction profiles to match the observed diffuse scattering provides a crucial tool to quantify disorder in crystal structure elucidation.

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Theoretical framework for polarization dependent magneto-absorption in (anti)ferromagnetic materials

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Microscopic structure of (anti)ferromagnets (A)FMs can be described using Heisenberg spin Hamiltonians, with corresponding parameters such as spin-spin exchange couplings or anisotropies. Experimental determination of these parameters typically involves measurement of magnetic excitation spectra either via inelastic neutron scattering(INS) or (THz)GHz magneto-absorption.
While the absorption experiments provide greater accuracy than INS, they are limited to the Γ-point ($k = 0$) only, making the inclusion of external magnetic field H vital to extend the available dataset. Another avenue, which remains largely unexplored in the present literature, is the polarization control of the applied (THz)GHz field. This, together with recent measurements as in [1] (Fig. 6), motivate our theoretical study of the phenomena.

We utilize both numerical spin dynamics model and analytical description of the linear response regime in the linear spin wave theory(LSWT) framework to determine the circularly polarization(CP) dependent absorption coefficient and derive expressions connecting microscopic parameters of simple FMs and AFMs to features of resulting measurable magneto-absorption curves.

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DFT Analysis of Raman-Active Modes in $NbSe_2$ Polymorphs and Strained $NbSe_2$

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Although the 2H phase of $NbSe_2$ has been well characterized by Raman spectroscopy [1,2], there is currently no experimental data available for the Raman active modes of other polymorphs of $NbSe_2$ such as the 1T and 3R phases. Furthermore, Raman studies of related structural variants, including self-intercalated $NbSe_2$,as well as investigations of strain effects in MBE-grown $NbSe_2$, remain scarce [2,3]. To address this gap, we performed density functional theory (DFT) calculations to determine the phonon frequencies and irreducible representations of the vibrational modes in these systems. The calculations were carried out using Quantum ESPRESSO and Phonopy workflows implemented within AiiDA. These theoretical results are compared to experimental data obtained on $NbSe_2$ grown via MBE on various oxide substrates. This provides a preliminary reference framework for identifying different polymorphs and strain-induced modifications in $NbSe_2$ via Raman spectroscopy.

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Tensor-Train Approaches to Superconductivity

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Superconductors are notoriously difficult to simulate realistically, both regarding their instabilities and their properties, as the electronic bandwidth of a generic material is often of the order of eV, while the features we are interested in translates to an energy scale of about 0.01 - 1 meV. For a faithful simulation of instabilities or material properties starting from a microscopic description, a calculation, thus, needs to cover multiple energy scales and resolve even low-energy features, which is often numerically prohibitive in both time and memory. Here, we discuss a workflow for such calculations based on a tensor-train approach to make use of the typical scale separation of Greens functions. We explore the potential of such an approach and point out bottlenecks on the example of calculating quasiparticle interference patterns, where a high resolution is crucial to accurately model the features of different gap functions. While tensor trains offer a numerically cheap hold of the superconducting Greens function, the challenge lies in the subsequent operations, in particular element-wise multiplications, that need to be performed on them. We analyze the performance of tensor-train based methods and propose avenues to push these methods even further.

Two-dimensional coherent spectroscopy of composite collective excitations

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A universal approach to the ultrafast control of collective excitations in quantum materials is by coherent THz driving of lattice modes (phonons), whose intrinsic coupling to the electronic and magnetic degrees of freedom can create a wealth of nonequilibrium phenomena. The origins of these phenomena lie in nonlinear processes, meaning those involving hybridised states and resonances composed of multiple elementary constituents, which are reflected in the higher-order response functions of the system. Two-dimensional coherent spectroscopy (2DCS) offers a uniquely powerful means of unlocking this nonlinear response, and we apply it to investigate the composite collective excitations of a phonon-driven quantum magnet. The composite "magnetophononic" excitations are mutually repelling phonon-bitriplon hybrids and the nonlinear excitations are higher multiplets of these hybrids [1]. Beyond the peak clusters characterising the second- and third-order 2DCS response, we find a wide selection of streak patterns. These arise not from disorder but from the energetic continuum of the bitriplon dispersion, and they allow the composite nonlinear excitations to be "fractionalised" into their underlying constituents. We illustrate this concept by discovering extensive streak features throughout THz 2DCS spectra computed for the spin-Peierls chain compound $CuGeO_3$ and discuss the broader applications of 2DCS in nonequilibrium quantum matter.

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Spin Excitations Near the Pressure-Induced Antiferromagnetic Transition in SrCu2(BO3)2

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SrCu2(BO3)2 (SCBO) is a frustrated quantum magnet well described by the Shastry-Sutherland model [1-3], where hydrostatic pressure tunes the hierarchy of exchange interactions and drives a sequence of quantum phases including a long-range antiferromagnetically ordered state [4-7]. We performed inelastic neutron scattering on a single crystal at 4.2(2) GPa at the Institut Laue-Langevin (ILL) using the IN8 triple-axis spectrometer with a Paris-Edinburgh press, probing spin dynamics within the pressure-induced ordered phase.

The measured magnetic excitation spectrum exhibits clear dispersive modes and is well described by linear spin-wave theory, enabling extraction of effective exchange parameters from inelastic neutron scattering data measured under high pressure conditions. The refined parameters are consistent with values reported at higher pressures [8] and provide direct evidence for a Goldstone mode in the ordered state. A quantitative description requires a finite interlayer coupling, highlighting its importance for the magnetic Hamiltonian under pressure.

These results complement previous high-pressure studies and provide further input for theoretical models of SCBO under extreme conditions.

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Ultrafast Magnetic Fields from THz-Driven Chiral Phonons

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Coherent optical control of the solid state is paving the way for applications based on out-of-equilibrium materials. Here, we study how dynamical magnetization can emerge in materials where chiral phonons are driven by resonant ultrashort laser pulses.
Dynamically chiral phonons have been predicted to be able to produce artificial magnetic fields on the order of tens of Tesla, but the existence of an induced magnetic field extending outside the solid sample has yet to be characterized. Such a study requires strong narrowband THz pulses with adjustable frequency and polarization. A tunable THz source in the 1-15THz domain is used with complete pulse-to-pulse control of the ellipticity. This way we were able to observe ellipticity dependent rotation inside CeF3.
Ultrafast proximate magnetometry (UPOM) gives access to the magnetic field outside a sample on sub picosecond time scale. UPOM hence allows us to distinguish effects arising from purely artificial gauge fields and from the creation of real magnetic fields inside a driven sample. This will eventually lead to the possibility to individually control phonon, electron and spin degrees of freedom, with notable use in phononics or spintronic applications.

Tunable Space-Charge Doped Two-Dimensional Materials for Scanning Probe Microscopy Investigations

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Doping effects in 2D materials have been known to induce a variety of emergent quantum phenomena, like insulator-metal/superconductor transitions, changes in the charge density wave phases, and other interesting phase transitions [1, 2, 3, 4]. Among the different techniques available to tune the chemical potential, the anodic bonding, derived from a commercial process traditionally used to electrostatically bond a semiconductor to an ionic glass under an applied electric field, has the advantages of inducing high carrier doping ($\sim 10^{13} - 10^{14}$ cm^{-2}) and to produce pristine surfaces suitable for scanning probe microscopy investigations at the atomic scale. Here, we illustrate the progress in the fabrication and characterization of hole-doped few layers flakes via anodic bonding.

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Ultrafast recovery dynamics of dimer stripes in $IrTe_2$

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The transition metal dichalcogenide $IrTe_2$ displays a remarkable series of first-order phase transitions below room temperature, involving lattice displacements as large as 20% of the initial bond length [1]. This is understood as the result of strong electron-phonon coupling leading to the formation of local multicenter dimers arranged into one-dimensional stripes [2]. In this work, we study the out-of-equilibrium dynamics of these dimers and track the time evolution of their population following an infrared photoexcitation using free-electron laser-based x-ray photoemission spectroscopy [3]. First, we observe that the dissolution of dimers is driven by the transfer of energy from the electronic subsystem to the lattice subsystem, in agreement with previous studies. Second, we observe a surprisingly fast relaxation of the dimer population on the timescale of a few picoseconds. By comparing our results to published ultrafast electron diffraction and angle-resolved photoemission spectroscopy data, we reveal that long-range order needs tens of picoseconds to recover, while the local dimer distortion recovers on a short timescale of a few picoseconds.

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[3] M. Rumo et al., Phys. Rev. 113, 024117 (2026).

Theory of switchable half-quantum flux rings of the kagome superconductor CVS

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The fundamental nature of the superconducting state in CsV_3Sb_5 remains highly debated. Recent Little-Parks measurements on CsV_3Sb_5 single-crystal rings highlight robust anomalous behavior, revealing half-quantum flux oscillations in nearly all tested samples. Strikingly, a finite bias current can reversibly tune these rings back to a standard zero-flux state. These observations are incompatible with a conventional superconducting framework. We examine the mechanisms underlying these half-quantum-flux oscillations and their current-driven switching. Our findings suggest the presence of a multi-component order parameter. Specifically, we propose that two competing superconducting states couple differently to the applied bias current, fundamentally altering their energetic balance. In this model, the applied current acts as a tuning parameter that controls the dominant instability, successfully explaining the crossover from half-quantum to zero-flux behavior.

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Critical Current Anisotropy and Electromechanical Limits of REBCO Coated Conductors for Ultra-High-Field Magnets

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REBCO (Rare-Earth Barium Copper Oxide) coated conductors (CCs), consisting of textured REBCO thin films deposited on flexible metallic tapes, are key enabling materials for next-generation ultra-high-field magnets, promising transformative applications in fusion energy, particle accelerators, and healthcare applications. At the University of Geneva, an experimental campaign was conducted to address the intrinsic and structural anisotropies of REBCO CCs that currently limit their performance. Mechanical anisotropy, arising from the layered architecture, increases susceptibility to delamination under stress, while superconducting anisotropy causes strong variations of the critical current (I_c) with temperature, magnetic field magnitude, and orientation. To optimize magnet design, three commercial REBCO CCs were characterized in collaboration with Tohoku University over 5-55 K and 1-24 T, linking the differences in their performance to nanostructure and flux pinning. Scaling laws were derived from the datasets to aid practical design. Additionally, in partnership with CERN, a novel approach assessed delamination strength under electromagnetic loading, simulating magnet operating conditions. Transverse stresses as low as 5 MPa were found to cause irreversible I_c degradation, with SEM/EDX analyses identifying the failure initiation site. These findings provide essential insights for the reliable design of REBCO-based ultra-high-field magnets, supporting their role in advancing future technological developments.

Strain dependent multiferroicity in TbMnO3 thin films observed by infrared ellipsometry

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We investigated three $TbMnO_3$ thin films (200 nm, 91 nm, and 44 nm) on *b*-cut $YAlO_3$ substrates using infrared ellipsometry at temperatures between 7 K to 300 K. Shimamoto *et al.* grew the films by PLD and reported that strain modifies the multiferroic order in the films and their ferroelectric polarization reaches 2 μC cm^{-2} along the *a*-axis. This is significantly larger than the bulk polarization of 0.06 μC cm^{-2} oriented along the *c*-axis.
Eight of nine *a*-axis and seven of eight *c*-axis phonon modes were resolved by infrared ellipsometry in all films, along with two longitudinal optical phonons along the out-of-plane (*b*) direction. The 200 nm film exhibits bulk-like phonon behavior. As thickness decreases, most modes systematically blue shift, indicating increased strain. Since $YAlO_3$ has smaller lattice constants than bulk $TbMnO_3$, theoretical in-plane compressive strains of −2.1% along the *a*-axis (5.180 Å vs. 5.293 Å) and −0.4% along the *c*-axis (7.371 Å vs. 7.403 Å) are expected, increasing interatomic restoring forces and explaning therefore the observed phonon hardening.
The $Mn\breve{}O$ stretching/bending mode near 340 cm^{-1} splits in the two thinnest films, but remains unsplit in the thickest. The splitting occurs at higher temperatures and is more pronounced in the thinnest sample. In the orthorhombic structure of $TbMnO_3$, no degenerate phonons are expected; however, a Raman-active mode exists near 340 cm^{-1}. The activation of the Raman mode in the infrared spectra arises from symmetry breaking due to the induced polarization or zone folding effects related to the magnetic supercell.

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Disorder and Magnetism in Rare Earth Silicate Compounds

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Rare earth silicates are an interesting class of materials owing to their potential for applications. The magnetic properties of these materials have not been investigated in detail until recently due to the complexity of the phase diagrams. Rare earth silicates systems form in a large number of chemical, e.g. R_2SiO_5, $R_2Si_2O_7$ and $R_{4.67}(SiO_4)_3O$, and structural phases. At ambient pressure, depending on the nature of the rare earth ion and temperature, R_2SiO_5 crystallizes in 2 crystal-types, whereas $R_2Si_2O_7$ has 7 polymorphs. The arrangement of the magnetic rare earth ions varies greatly for each chemical phase and structural type, leading thus to a wide array of possible magnetic properties across the entire rare earth series of silicates. New studies show that C-type $Yb_2Si_2O_7$ is a strongly spin-orbit coupled quantum dimer magnet [1], whereas C and D-polytypes of $Er_2Si_2O_7$ are Ising-like antiferromagnets below $T_N = 2.3$ and 1.9 K, respectively [2-5]. Here, I will discuss the challenges associated with the synthesis of crystals of the R_2SiO_5, $R_2Si_2O_7$ and $R_{4.67}(SiO_4)_3O$ chemical composition [4,6], and I will present our recent results on the structural and magnetic properties of these materials [4,5, unpublished results].

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Magnetic excitation of the near-ideal molecule-based Haldane spin chain Ni2(3,5-lut)4 in a magnetic field

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Quantum magnets are a special class of magnetic materials in which long-range magnetic order is suppressed or destroyed by strong quantum spin fluctuations, which become increasingly relevant towards zero temperature. Study of such systems is at the forefront of condensed matter physics. Among these materials, spin-1 Heisenberg antiferromagnetic (AFM) chains, known as Haldane chains, are of special interest due to their novel magnetic properties [1,2,3]. Recently, interest in predicting and controlling the magnetic ground state of $S = 1$ quantum magnets has been fueled by the realization of multiple magnetic phases in a series of organic compounds. One dimensional spin-1 AFM chain NiI_2(3,5-lut)$_4$, where 3,5-lutidine (C_7H_9N), has emerged as a significant molecular system for studying low-dimensional quantum magnetism, due to its near-ideal realization of isotropic Haldane spin chain [4]. Among Haldane systems with comparable degrees of anisotropy, including Y_2BaNiO_5, $PbNi_2V_2O_8$, and $SrNi_2V_2O_8$, NiI_2(3,5-lut)$_4$ has the lowest energy scale and is therefore a uniquely ideal Haldane system that provides easy access to the entire Haldane phase for field-tuning through the quantum critical region associated with the closure of their Haldane gaps using dc magnetic fields.

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Benchmark solution of the continuum model for metallic hydrogen, using the full energy- and momentum-dependent Eliashberg formalism

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The superconductivity of highly pressurized metallic hydrogen was predicted long ago [1, 2]. The model underlying these predictions is a continuum description featuring homogeneous gases of electrons and protons—the electron or proton density being the model unique parameter. The Coulomb interaction between charges is screened using an approximate dielectric function, yielding a retarded interaction between the electrons. It turns out that the superconducting critical temperature T_c derived from that model at a given density depends dramatically on the approximation used, ranging from thousands of Kelvin to tens of milliKelvin [3]. We have solved the full energy- and momentum-dependent Eliashberg equations, both for the normal and pairing self-energies, and obtained a maximum T_c of ~ 0.13 K at a density $\sim 1.3 \times 10^{21}$ cm^{-3}. The computation is surprisingly heavy given the simplicity of the model and reveals that insufficient numerical convergence can also lead to wide variations in the calculated T_c. Our results question the standard method for calculating T_c of real materials, where the momentum dependence of the Eliashberg theory and the normal self-energy are ignored.

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Probing intertwined electronic instabilities in superconducting Ruddlesden-Popper nickelates through chemical and structural tailoring

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Ruddlesden-Popper nickelates have recently emerged as a compelling system for exploring unconventional superconductivity and intertwined electronic and magnetic orders. Ongoing studies aim to map out spin density wave (SDW), charge density wave (CDW), and superconducting phases across different compositions and structural motifs. By tailoring the chemical composition and tuning structural features through external parameters such as temperature and pressure, it becomes possible to influence the balance between these competing ordering phenomena. We present an overview of the current state of research on these systems, with particular emphasis on the role of chemical substitution influence over the structural transformations and the evolution of SDW, CDW, and superconducting phases. We address future directions that may help uncover the mechanisms driving superconductivity in these complex oxide systems. The exploration of novel chemical variants and their associated magnetic structures is outlined together with current limitations in synthesis and characterization, with the goal of clarifying the superconductivity mechanisms and their interplay with competing orders.

Ferron Hall Effect

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Hall physics in solids has expanded far beyond its charge-transport setting and now includes transverse responses of neutral excitations such as magnons and phonons. An example is the phonon Hall effect, in which broken time-reversal symmetry causes lattice vibrations to deflect, generating a transverse heat current. More recently, nonequilibrium lattice dynamics have been extended to Hall-type responses, including transverse currents of phonon angular momentum [1,2]. Motivated by these developments, we ask whether the lattice can carry and deflect not only heat or angular momentum, but also structural order parameters. Ferroelectrics provide a natural platform to explore this possibility because their soft polar modes encode the ferroelectric distortion and carry electric polarization, giving rise to the ferron quasiparticle [3].
In this presentation, I introduce the ferron Hall effect as a Hall-type response of the polarization-carrying soft-mode sector in a ferroelectric. Under a longitudinal thermal gradient and broken time-reversal symmetry, the driven soft-mode dynamics acquires a transverse component that is odd in the magnetic field, producing a transverse ferron current and an edge accumulation of polarization [4]. I present microscopic results for ferroelectric $BaTiO_3$, where the effect appears as a transverse nonequilibrium polarization signal, suggesting a route toward thermal and magnetic control of ferroelectric order.

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Superconductivity and the pseudogap phase in LSCO under uniaxial strain

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A prominent open question in understanding the cuprate phase diagram is whether the pseudogap represents a competing phase or is a precursor to superconductivity. Strain is an effective tuning parameter, modifying the crystal structure and thereby hopping amplitudes, the position of the van Hove singularity, and the Fermi surface topology independent of doping.

In $La_{1.6-x}Nd_{0.4}Sr_xCuO_4$ under hydrostatic pressure, transport measurements indicate that the critical doping p^* at which the pseudogap closes shifts with strain [1]. Accompanying calculations suggest that this shift tracks the doping p_{FS} at which the Fermi level crosses the van Hove singularity (a Lifshitz transition). The relation between p^* and p_{FS} point to a close link between the pseudogap and the Fermi surface topology.

We investigate the connection between the pseudogap and the Lifshitz transition by performing ARPES on uniaxially strained, microstructured $La_{2-x}Sr_xCuO_4$ (LSCO). Our initial measurements show that the superconducting gap is suppressed by uniaxial strain, while the pseudogap increases. The contrasting behaviour of the gaps suggests a distinct microscopic origin, consistent with a competition between the pseudogap and superconductivity.

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Electronic structure of the correlated van der Waals metal MoOCl2

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MoOCl2 is a van der Waals material characterized by a pronounced in-plane anisotropy in its electronic and optical properties. Recent transport studies reported a high room-temperature resistivity deep in the bad-metal regime and a Kadowaki-Woods ratio exceeding that of heavy fermions, typical signatures of strongly correlated metals [1]. At the same time, MoOCl2 was recently shown to sustain long-lived collective excitations, including hyperbolic plasmon polaritons, modes typically associated with coherent charge dynamics in metals [2]. In this talk, I will present a detailed investigation of the electronic structure of MoOCl2 using micro-focused ARPES. Our measurements confirm the pronounced electronic anisotropy. However, a comparison with DFT shows compelling evidence for weak to moderate electronic correlations, in direct contrast to the interpretation of transport measurements. Interestingly though, the renormalization of the quasiparticle dispersion varies strongly along the Fermi surface. Our analysis shows that this implies non-local interactions, which we attribute predominantly to the strong dimerization of Mo.

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Probing the intrinsic field in few-layer Janus RhSeCl using ARPES

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Two-dimensional (2D) Janus transition metal dichalcogenides (JTMDs) are a distinctive class of materials characterized by a transition metal layer sandwiched between two different chalcogen layers, breaking the out-of-plane mirror symmetry. In few-layer form, Janus materials are expected to show an intrinsic out-of-plane electric field, driven by the electronegativity difference between the two chalcogen layers. This internal field has been proposed to enable a range of novel phenomena, including atomic-scale p–n junctions, passive electrostatic gating, large Berry curvature, and Rashba spin splitting [1-3]. While this effect is robust in density functional theory calculations, its direct experimental observation has remained elusive.

Here, we report the first direct detection and quantification of the intrinsic electric field in few-layer RhSeCl, a newly synthesized Janus semiconductor with exceptionally low chalcogen mixing. We study 2D heterostructures in which exfoliated few-layer RhSeCl is encapsulated between two monolayer graphene sheets. Using angle-resolved photoemission spectroscopy (ARPES), we directly probe the charge transfer from the two surfaces of RhSeCl to graphene, demonstrating an atomic-scale p–n junction, where electron- and hole-doped graphene sheets are separated by only $\sim 2\,\mathrm{nm}$.

In addition, we present ARPES results from termination-dependent studies of bulk RhSeCl, revealing differences between Cl- and Se-terminated surfaces.

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Interface controlled electronic phases in two-dimensional materials on gold

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Interfaces strongly influence the electronic properties of atomically thin materials. Here, we present how coupling between two-dimensional transition-metal dichalcogenides and a metallic substrate can tune their electronic behavior at the nanoscale. Using low-temperature scanning tunneling microscopy and spectroscopy, we investigate exfoliated monolayers of molybdenum disulfide (MoS_2) and vanadium diselenide (VSe_2) on Au(111). In MoS_2, hybridization with the substrate produces moiré-periodic electronic modulations whose amplitude depends on the twist angle between the two lattices, becoming weaker at larger angles [1]. VSe_2 instead highlights the role of interface coupling in stabilizing different charge-ordered phases: bilayers preserve a bulk-like charge density wave, monolayers directly coupled to Au(111) show suppressed ordering, and locally decoupled regions recover a distinct charge-ordered state [2]. These results demonstrate how twist angle, hybridization, and local decoupling provide routes to engineer electronic phases in two-dimensional materials.

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Micro-ARPES study of mono- and few-layers TaIrTe4

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Two-dimensional materials continue to attract significant interest due to their unique physical properties and potential applications in future electronic devices. Here, we present micro-focus angle resolved photoemission (ARPES) measurements from mono- and few-layer $TaIrTe_4$. Density functional theory calculations predict that $TaIrTe_4$ is a type-II Weyl semimetal in the bulk and a quantum spin Hall insulator in mono- and bilayer forms. Intriguingly though, a recent transport study by Tang *et al.* [1] reported two insulating phases in monolayer $TaIrTe_4$, both with edge conductance approaching $\frac{e^2}{h}$ in short channels. The second insulating phase, observed in gated samples where the chemical potential lies a few 10 meV in the conduction band, cannot be explained in a non-interacting picture and thus provides strong evidence for a correlated quantum spin Hall insulator phase. Raman experiments on few-layer $TaIrTe_4$ further provide evidence for a charge density wave regime below 60 K [2]. Our micro-ARPES data on monolayer $TaIrTe_4$ show a quasi-one-dimensional dispersion susceptible to a density wave instability at a wave vector consistent with the filling of the experimentally observed quantum spin Hall insulator phase. Our data further reveal a van Hove singularity close to the Fermi level but suggest that it is not a major driver of the many-body instability.
We further present first data from few-layers $TaIrTe_4$, taken below and above the critical temperature. The measurements reveal the expected Rashba spin-splitting arising from broken inversion symmetry, and the splitting between bonding and antibonding states. However, the experimental band structures differ quantitatively from DFT calculations, challenging the reliability of interpretations of Raman and transport data based on DFT band structures.

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Itinerant large polarons in hexagonal boron nitride

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Hexagonal boron nitride (hBN), an apparently simple band insulator, underpins research in diverse fields. It emerged as the default gate dielectric for the entire field of 2D materials. In parallel, hBN attracts attention in quantum science. Defects in hBN show potential as single photon emitters and quantum sensors. Moreover, hyperbolic phonon polaritons in hBN have been used to study strong light matter interaction and to demonstrate highly sub-wavelength confinement of light with potential applications in quantum technology. Here, we study the propagation of a single photo hole at the top of the valence band of hBN using high-resolution angle-resolved photoemission (ARPES). Our spectral function data reveal replica bands with increased effective mass, a fingerprint of Fröhlich polarons caused by long-range electron–phonon coupling. We support this interpretation with spectral function calculations using a self-consistent diagrammatic approach assuming a forward coupling peaked at $q = 0$.

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Solvable Random Unitary Dynamics in a Disordered Tomonaga-Luttinger Liquid

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Disordered one-dimensional interacting systems have long been characterized through conventional correlation-function observables. A complementary perspective from quantum information theory uses the frame potential to quantify the randomness of the unitary ensemble generated by a quantum system, yet no analytical treatment has so far been achieved for interacting one-dimensional systems. In this Letter, we derive a closed-form, nonperturbative expression for the frame potential of a Tomonaga-Luttinger liquid with quenched Gaussian forward-scattering disorder. Exploiting the exactly quadratic structure of the disorder-averaged Keldysh action, we show that the frame potential ratio decays as a power law at early times and saturates to a late-time plateau controlled by a single coupling parameter. Strongest randomness is achieved near the Heisenberg ferromagnetic point and can be exponentially enhanced through a multiple-quench protocol. We validate our results against the microscopic random field XXZ spin chain across the entire gapless phase, with direct implications for algorithm design in analog quantum simulation platforms.

Equivalence of Different Limiting Bulk Spectra in Non-Hermitian Lattice Systems

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We address a long-standing problem in non-Hermitian materials: why spectral functions obtained under different boundary conditions, such as periodic and open boundaries, can appear drastically different even though they describe the same bulk system. We show that this apparent contradiction is only superficial. For a broad class of lattice models, all bulk spectral descriptions derived from large finite samples are physically equivalent in the bulk: they encode the same local response, the same propagation dynamics, and the same experimentally relevant bulk information. Thus, the bulk density of states is universal, even in the presence of strong boundary sensitivity and the non-Hermitian skin effect. We also show that the remaining differences between spectral descriptions are closely tied to the topology of an associated Hermitian doubled system, providing a simple physical perspective on when boundary-related spectral anomalies can arise. Using the Hatano-Nelson model as an illustrative example, we clarify how markedly different open- and periodic-boundary spectra can nevertheless represent the same bulk physics. These results resolve the old ambiguity of boundary-condition-dependent spectral functions in non-Hermitian systems and provide a clearer foundation for interpreting experiments and designing non-Hermitian materials.

Lattice coupling across epitaxial oxide heterostructures

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The most common crystal system of the perovskite structure is the orthorhombic one, accommodating different cation sizes via rotations of the octahedra. In thin-film heterostructures, these rotations can propagate from the substrate through the layers, thereby altering the materials' physical properties. However, coupling this degree of freedom within the unit cell may conflict with the elastic strain imposed by the mismatch between the lattice of the film and that of the substrate.
We have studied this phenomenon in $LaVO_3$ thin films grown on [1 1 0]-oriented $DyScO_3$ substrates. Misfit strain favours the [0 0 1] orientation of the film. However, this orientation results in a mismatch in oxygen octahedral connectivity at the interface. Modifying the growth temperature alters the lattice volume of $LaVO_3$, thereby changing the effective misfit strain applied to the thin film. Through X-ray diffraction, scanning transmission microscopy and Raman spectroscopy investigations, we probe the film structural properties as the strain evolves from compressive to tensile strain.

Domains, superdomains and ripples in epitaxially strained and freestanding PbTiO3

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In ferroelectric thin films, the complex interplay between mechanical and electrostatic boundary conditions allows for the formation of a large variety of domain structures with fascinating properties. These domain structures not only change the properties of the ferroelectric itself, but can also be used, in heteroepitaxial structures, to change the properties of other materials through electrostatic and structural coupling.
In this work, we study the complex ferroelastic/ferroelectric domain structure in the prototypical ferroelectric PbTiO3. We investigate epitaxially strained structures grown on (110)o-oriented DyScO3 substrates, using a combination of atomic force microscopy (AFM), laboratory and synchrotron x-ray diffraction and high-resolution scanning transmission electron microscopy. We observe that the anisotropic strain imposed by the orthorhombic substrate creates a large asymmetry in the domain configuration, with domain walls macroscopically aligned along one of the two in-plane directions. We show that the film thickness dependence of the domains periodicity deviates from the Kittel law. As the ferroelectric film thickness increases, we find that the domain configuration evolves from flux-closure to a/c-phase, with a larger scale arrangement of domains into superdomains.
In SrRuO3/PbTiO3 heterostructures, we find, above a certain critical thickness, that the large structural distortions associated with the ferroelastic domains in PbTiO3 propagate to the top layer, leading to nanoscale domain engineering in SrRuO3 thin films.
Finally, we remove the epitaxial strain imposed by the substrate and study the new domain configuration in a freestanding PbTiO3 membrane that exhibits well-organized ripples. Using piezo-response force microscopy, second-harmonic generation and contact resonance-AFM, we show that both the ferroelectric domain configuration and mechanical properties of the ripples are different from the rest of the membrane.

[1] Lichtensteiger etal., APL Materials, 11(061126), 2023.
[2] Lichtensteiger etal., APL Materials, 11(101110), 2023.
[3] Tovaglieri etal., APL Materials, 13 (021118) 2025.
[4] Segantini etal., Small, e06338 (2025).
[5] Tovaglieri etal. JAP, 139 150701 (2026).

All-oxide hybrid phonon-plasmon resonators based on a strongly correlated metal

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We investigate all-oxide hybrid phonon-plasmon resonators based on the strongly correlated metal $SrVO_3$. By coupling plasmonic excitations in $SrVO_3$ to surface phonon polaritons in the oxide environment, we engineer infrared resonances that are both tunable and sensitive to correlation effects. Beyond their potential as low-loss IR resonators, these hybrid modes provide a platform to probe electron-electron and electron-phonon interactions in $SrVO_3$.

Superresolution Localization and Control of 2D Quantum Emitters

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In transition-metal dichalcogenide (TMD) heterobilayers, lattice mismatch and reconstruction create localized traps for interlayer excitons, forming quantum emitters with potential as nanoscale sensors of correlated phases of matter [1]. These emitters are electrically tunable and inherit spin-valley selection rules and strong light-matter coupling, yet deterministic spatial control remains challenging due to subwavelength confinement and disorder. In this talk, I will present a platform that combines cryogenic optical spectroscopy with scanning probe microscopy to investigate trapped interlayer excitons in WSe2/MoSe2 bilayers [2]. By exploiting AFM-based local Stark shift, we achieve super-resolution localization of emitters separated by only a few tens of nanometers and demonstrate deterministic control of individual charge states, including trion formation. Time-resolved measurements further allow us to resolve radiative and non-radiative decay channels, revealing controlled manipulation of individual exciton dynamics and opening a path toward coherent inter-dot coupling. These results establish a platform for sensing and trapping anyons in semiconducting FCIs [3].

[1] W. Li, et al., arXiv:2111.09440 (2024).
[2] B. Lyu*, V. Vento*, et al., in preparation (2026).
[3] W. Li, et al., Nature 651, 48 (2026).

Coherent Spin-Lattice Dynamics for Ultrafast Magnetic Switching in 2D Magnets

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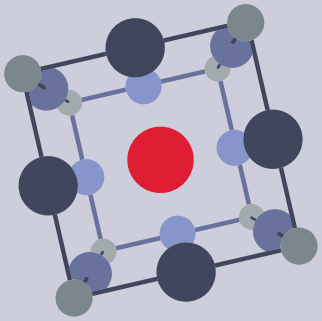
Two-dimensional magnetic materials provide a promising platform for ultrafast and energy-efficient spin control. In this talk, I will discuss how coherent lattice motion can be used to manipulate magnetic order on femtosecond to picosecond timescales under optical and terahertz excitation. Using first-principles real-time simulations, we reveal the coupled dynamics of spins, electrons, and phonons in nonequilibrium 2D magnets. In monolayer Fe3GeTe2, we identify coherent phonons as a key ingredient for ultrafast demagnetization and demonstrate a phonon-assisted spin-flip process occurring within a few hundred femtoseconds. The magnetic switching is accompanied by transient changes in the electronic topology. Extending these ideas to antiferromagnets, we further show that tailored terahertz pulses can drive switching between distinct antiferromagnetic orders in monolayer MnPSe3 through nonlinear phononic effects.
These results highlight coherent spin–lattice dynamics as a general route toward ultrafast magnetic switching and provide theoretical guidance for future optospintronic devices based on low-dimensional materials.



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