Joint Winter School on Ultrafast Spin Systems and Correlated Matter (November 12-14, 2025)

Venue

Max Planck Institute of Microstructure Physics, Weinberg 2, 06120 Halle (Saale)
Leopoldina, Jägerberg 1, 06108 Halle (Saale)
Löwengebäude Martin Luther University Halle-Wittenberg, Universitätsplatz 11, 06108 Halle (Saale)
Hallesches Brauhaus, Große Nikolaistraße 2, 06108 Halle (Saale)

Wednesday, November 12

Time	Topic	Room
10.00	**Stuart Parkin** (IMPRS) & **Wolf Widdra** (TRR227) Welcome note	Lecture hall (B.1.11)
10.15	**Kin Fai Mak** (MPI for the Structure and Dynamics of Matter, Hamburg) *Semiconductor moiré materials*	
11.45	Lunch	Lounge
13.00	**Matias Bargeehr** (University of Potsdam) *Picosecond ultrasonics with x-rays - applications to energy transport and magnetisation dynamics*	Lecture hall (B.1.11)
14.30	Coffee break	
15.00	Poster session	Lounge + lobby
18.00	Guided tour Leopoldina (German National Academy of Sciences) / Löwengebäude (Martin Luther University Halle-Wittenberg)	
19.00	Dinner at Hallesches Brauhaus	

Thursday, November 13

Time	Topic	Room
9.00	Walk-in & Coffee	Lounge
9.30	**Maxim Mostovoy** (University of Groningen)	Lecture hall (B.1.11)
11.00	Coffee break	
11.30	**Annika Johansson** (MPI Halle) *Orbital magnetism in solids*	
12.30	Lunch	Lounge
13.30	**Tobias Kampfrath (FU Berlin)** *Ultrafast control of magnetic order by terahertz spin-orbit torques*	Lecture hall (B.1.11)
14.30	Career talk	
15.30	Poster session	Lobby & lounge
17.30	Dinner	Lounge
18.30	Discussions	
20.00	Social evening featuring karaoke	

Friday, November 14

Time	Topic	Room
9.00	Walk-in & Coffee	Lounge
9.30	**Niels Schröter** (MLU Halle)	Lecture hall (B.1.11)
10.30	Lab tours	Labs at MPI and MLU Halle
12.30	Lunch	
13.30	**Melanie Müller** (Fritz Haber Institute Berlin) *Ultrafast scanning tunneling microscopy: Principles and prospects for quantum materials*	Lecture hall (B.1.11)
14.30	Closing remarks & farewell	

Matias Bargheer - Picosecond ultrasonics with x-rays - applications to energy transport and magnetisation dynamics

Picosecond ultrasonics with x-ray probe pulses (PUX) [1] provide unique access to coherent longitudinal acoustic phonons (coherent strain wave packets) and heat transport at the nanoscale (flow of incoherent excitations). Bragg-peak shifts are especially useful experimental observables in nano-layered systems, where all layers can be simultaneously probed and identified by their Bragg angle.

We will highlight fascinating phenomena such as the counterintuitive localization of heat via dissipation [2], dominant phonon heat transport in metals [3], stress on the lattice induced by demagnetization [4] and transduction of THz strain waves by electronic pressure in metallic heterostructures [5] that can be analyzed by PUX.

Additionally, we shall focus on the analysis of magnetoelastic excitations, and how tailoring strain waves can help to actuate spin precession [6-8].

[1] M. Mattern, A. von Reppert, S.P. Zeuschner, M. Herzog, J.-E. Pudell, and M. Bargheer, Concepts and use cases for picosecond ultrasonics with x-rays, Photoacoustics 31, 100503 (2023).
[2] F. Stete, S. Kesarwani, C. Ruhmlieb, F. Schulz, M. Bargheer, H. Lange, Inverted Temperature Gradients in Gold-Palladium Antenna-Reactor Nanoparticles, https://doi.org/10.48550/arXiv.2501.02566
[3] Herzog M., von Reppert A., Pudell J.-E., Henkel C., Kronseder M., Back C. H., Maznev A., and Bargheer M., Phonon-dominated energy transport in purely metallic heterostructures, Advanced Functional Materials 32, 2206179 (2022).
[4] M. Mattern, J.-E. Pudell, K. Dumesnil, A. von Reppert, and M. Bargheer, Towards shaping picosecond strain pulses via magnetostrictive transducers, Photoacoustics 30, 100463 (2023).
[5] M. Bargheer, et al., Electron pressure drives THz phonons in metal-metal superlattices, Research Square 2025, https://doi.org/10.21203/rs.3.rs-6597328/v1
[6] J. Jarecki, M. Mattern, F.-C. Weber, J.-E. Pudell, X.-G. Wang, J.-C. Rojas-Sánchez, M. Hehn, A. von Reppert, and M. Bargheer, Controlling effective field contributions to laser-induced magnetization precession by heterostructure design, Communications Physics 7, 12 (2024).
[7] Mattern M., Weber F.-C., Engel D., von Korff Schmising C., and Bargheer M. Coherent control of magnetization precession by double-pulse activation of effective fields from magnetoacoustics and demagnetization, Applied Physics Letters 124, 102402 (2024).
[8] C. Walz, F.-C. Weber, S.-P. Zeuschner, K. Dumesnil, A. von Reppert, M. Bargheer, Large strain contribution to the laser-driven magnetization response of magnetostrictive $TbFe_2$, Appl. Phys. Lett. 127, 052406 (2025).

Annika Johansson - Orbital magnetism in solids

In addition to their spin, electrons in a crystal carry an orbital angular momentum. In recent years, the field of „orbitronics“ emerged, focusing on the transport and dynamics of orbital magnetization in solids. This field aims to exploit the orbital degree of freedom, alongside with spin and charge, in electronic devices. Although equilibrium orbital magnetization is often quenched by crystal symmetries, nonequilibrium orbital transport phenomena usually exceed their spin counterparts [1-4]. Unlike spintronic phenomena, orbital transport effects do not rely on spin-orbit coupling and can even occur in materials composed of light elements [1]. However, despite some analogies between spin and orbital magnetization, the definition of orbital angular momentum in solids is highly non-trivial, and some established spin transport concepts do not directly apply to orbital transport. In particular the definition and interpretation of „orbital currents“ is under debate, since orbital angular momentum in a crystal is not conserved [5].

In this lecture, I will give an introduction into the definition, calculation, and interpretation of orbital magnetism in solids. This will include small exercises employing the „atom-centered approximation“ as well as the „modern theory of orbital magnetization“ [6]. I will present materials hosting unique orbital textures, such as chiral topological semimetals and orbital Rashba systems. Finally, I will introduce orbital transport phenomena, including the orbital Hall effect and the orbital Edelstein effect, and showcase examples from our recent research projects on orbital magnetization in solids [2,7].

1] Y.-G. Choi, D. Jo, K.-H. Ko, D. Go, K.-H. Kim, H. G. Park, C. Kim, B.-C. Min, G.-M. Choi, and H.-W. Lee. Nature 619, 52 (2023).

[2] A. Johansson, B. Göbel, J. Henk, M. Bibes, and I. Mertig, Phys. Rev. Res. 3, 013275 (2021).

[3] O. Busch, F. Ziolkowski, I. Mertig, and J. Henk, Phys. Rev. B 108, 104408 (2023).

[4] A. Johansson, T J. Phys.: Condens. Matter 36 423002 (2024).

[5] N. H. Aase, E. W. Hodt, J. Linder, and A. Sudbø. Phys. Rev. B 110, 104423 (2024).

[6] T. Thonhauser. International Journal of Modern Physics B 25, 1429 (2011).

[7] S. Leiva-Montecinos, L. Vojáček, J. Li, M.Chshiev, L. Vila, I. Mertig, and A. Johansson, ArXiv:2505.21340 (2025).

Melanie Müller - Ultrafast scanning tunneling microscopy: Principles and prospects for quantum materials

Ultrafast scanning tunneling microscopy (USTM) combines the atomic spatial resolution of conventional STM with femtosecond time resolution. Thanks to recent advances in coupling single-cycle THz and ultrafast laser pulses to low-temperature STM, it has become within reach to directly visualize dynamical processes in quantum materials at their natural length and time scales. These powerful but still young approaches bridge the long-standing gap between ultrafast spectroscopy and static STM, with new opportunities for future quantum materials research.

In this lecture, I will introduce the basic principles of USTM, explain how femtosecond time resolution can be reliably implemented in tunneling measurements, and discuss the associated challenges and capabilities. I will then present recent experimental results, including our studies on charge order dynamics in 1T-TaS_2 and selected pioneering results from the community. Finally, I will outline potential applications of USTM to light-driven phenomena in topological materials, serving as a starting point for discussing its potential application to other classes of quantum materials.

The goal of this lecture is to provide graduate students and researchers in ultrafast spectroscopy with both a conceptual understanding of ultrafast STM and a forward-looking perspective on its potential impact in quantum materials research.