SYSD 1: SKM Dissertation Prize

Time: Monday 9:30–11:50 Location: H2

Invited Talk SYSD 1.1 Mon 9:30 H2
Synchronization and Waves in Confined Complex Active Media — •Jan Frederik Totz — Technische Universität Berlin, Berlin, Germany

Self-organization phenomena that lead to pattern formation and synchronization play an important role in biology, chemistry, physics and technological applications. They manifest for example in electrical waves on the heart muscle, fireflies flashing in unison, power-grid blackouts and neurological functions as well as disorders.

I will present a versatile experimental setup based on optically coupled catalytic micro-particles, that allows studying synchronization patterns in very large networks of relaxation oscillators under well-controlled laboratory conditions. In particular I will show our experimental verification of the elusive spiral wave chimera state, whose existence was predicted more than 15 years ago. This pattern features a wave rotating around a spatially extended core that consists of phase-randomized oscillators. The spiral wave chimera is likely to play a role in cortical cell ensembles, arrays of SQUIDS and carpets of cilia.

Furthermore, these experimental capabilities facilitate the free choice of network topology, coupling function as well as its strength, range and time delay, which can even be chosen as time-dependent. This opens the door to a broad range of future experimental inquiries into pattern formation and synchronization on large networks, which were previously out of reach.

Invited Talk SYSD 1.2 Mon 9:50 H2
Spin scattering of topologically protected electrons at defects — •Philipp Rüssmann — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

Topological materials and their transport properties are a field of great interest, as research in this area has produced promising material candidates for future low-power electronics or even quantum information technology. Like in any other material, defects are unavoidable and ubiquitous, which makes the understanding and control of their microscopic physical properties and their interactions one of the major pieces missing in the puzzle around topological-materials-based technology.

In this talk I will present a quantitative picture of the impurity scattering of topologically protected electrons, studied at the examples of strong three-dimensional topological insulators as well as type-II Weyl semimetals. Using *ab initio* calculations, I will highlight the importance of resonances in the scattering potential of defects, which gives a unified view on quasiparticle interference, quantum coherence, and magnetic interactions in topological matter. The very good agreement between our theoretical results and several different experiments such as STM, XMCD, or ARPES sets the foundations for tuning transport properties and controlling the magnetization in the fascinating class of topological materials in the future.

Invited Talk SYSD 1.3 Mon 10:10 H2
Beyond the molecular movie: Revealing the microscopic processes behind photo-induced phase transitions — •Chris W. Nicholson — University of Fribourg, 1700 Fribourg, Switzerland — Fritz-Haber-Institut der Max-Planck-Gesellschaft, 14195 Berlin, Germany

Following a "molecular movie", i.e. the real-time position of atoms during structural changes and chemical reactions is consistently cited as a key scientific challenge, relevant not only for condensed matter physics, but also femto-chemistry and biology. However, it is the dynamics of electronic excitations that ultimately lead to atomic motion across a free energy surface and the formation and breaking of chemical bonds.

In this talk, I will present femtosecond electronic structure measurements employing a recently developed setup for time- and angle-resolved photoemission spectroscopy at 22 eV and 500 kHz. This setup enables the extension of electronic band mapping throughout the full Brillouin zone to excited states above the Fermi level, as well as tracking the evolution of states and their populations during photo-induced phase transitions. Focusing predominantly on the model transition occurring in In nanowires on a Si(111) surface, I will reveal the mechanistic insights gained from measurements in momentum space that allow an understanding of not only the microscopic electronic processes driving a structural phase transition, but also the formation and breaking of chemical bonds on the femtosecond timescale. These considerations therefore extend the molecular movie concept, and may allow for optical control of structural reactions with cross-disciplinary application.

Invited Talk SYSD 1.4 Mon 10:30 H2
Thermodynamic bounds on current fluctuations — •Patrick Pietzonka — Department of Applied Mathematics and Theoretical Physics, University of Cambridge, UK — II. Institut für Theoretische Physik, Universität Stuttgart, Germany

For fluctuating thermodynamic currents in non-equilibrium steady states, the thermodynamic uncertainty relation expresses a fundamental trade-off between precision, i.e. small fluctuations, and dissipation. Using large deviation theory, we show that this relation follows from a universal bound on current fluctuations that is valid beyond the Gaussian regime and in which only the total rate of entropy production enters. Variants and refinements of this bound hold for fluctuations on finite time scales and for Markovian networks with known topology and cycle affinities. Applied to molecular motors and heat engines, the bound on current fluctuations imposes constraints on the efficiency and power.

Invited Talk SYSD 1.5 Mon 10:50 H2
Lightwave-driven quasiparticle acceleration — •Fabian Langer[1], Christoph P. Schmid[1], Stefan Schlauderer[1], Martin Gmitra[1], Jaroslav Fabian[1], Philipp Nagler[1], Christian Schüller[1], Tobias Korn[1], Peter G. Hawkins[2], Johannes T. Steiner[2], Ulrich Huttner[2], Stephan W. Koch[2], Mackillo Kira[3], and Rupert Huber[1] — [1]University of Regensburg, 93040 Regensburg, Germany — [2]University of Marburg, 35032 Marburg, Germany — [3]University of Michigan, Ann Arbor, MI 48109, USA

Strong-field light-matter interaction by the electric field of light elevates electronic transport in solids to its intrinsic timescales. Coherent phenomena like Bloch oscillations and the resulting high-order harmonic emission can be driven and controlled in bulk semiconductors, for the first time. Here, we investigate coherent quasiparticle acceleration in semiconductors. We highlight the ballistic dynamics of electrons and holes driven by a strong multi-THz field after optical carrier generation. This scheme allows us to collide a crystal electron with its hole inside the semiconductor in close analogy to the three-step process in high-harmonic generation in gases. Furthermore, we show how quasiparticle acceleration can be extended from controlling the translational motion to changing quantum attributes of the underlying quasiparticles. Electron-hole acceleration in a monolayer of tungsten diselenide can be used to change the valley pseudospin of the electron-hole pair, effectively switching this quantum degree of freedom. This method brings the concepts of valleytronics and potentially quantum information processing to optical cycle scales.

Invited Talk SYSD 1.6 Mon 11:10 H2
Ultrafast plasmon-driven point-projection electron microscopy — •Jan Vogelsang, Germann Hergert, Andreas Wöste, Petra Gross, and Christoph Lienau — Institut für Physik, Carl von Ossietzky Universität, 26129 Oldenburg, Germany

Ultrafast electron microscopy opens a path towards spatially resolving ultrafast processes as they happen on the femtosecond time and nanometer length scale. It demonstrates its strength when ensemble-averaging methods are not sufficient anymore to unravel nanoscale dynamics like the coherent charge transfer in new types of solar cells or nanoplasmonic processes in ultrafast optical devices. Still, a time resolution of less than 100 fs has not been demonstrated in a spatially resolved experiment so far. Electron pulses disperse as they propagate, which limits the temporal resolution. We circumvent this problem by reducing the electron propagation distance to only a few 100 nm.

As a prerequisite, we demonstrate for the first time an ultrafast electron point source driven by adiabatic nanofocusing of surface plasmon polaritons. It permits 50 times more efficient electron emission from the apex of a gold tip without illuminating the apex directly.

The direct consequence is the demonstration of electron microscopy experiments with an unprecedented temporal resolution of less than 25 fs. We watch the charge separation in the gap of a single nanoresonator with this plasmon-driven electron microscope.

In a last step, the microscope is further developed to perform electron holography with sub-10-nm spatial resolution and electron spectroscopy without sacrificing the temporal resolution.

Invited Talk SYSD 1.7 Mon 11:30 H2

Helimagnets, sand patterns and fingerprints linked by topology — •Peggy Schönherr — ETH Zürich, Zürich, Switzerland

Helimagnets, liquid crystals, sand patterns, and fingerprints are examples of lamellar materials with periodically assembled layers. The lamellar texture imparts a unique combination of order and mobility finding, having profound implications in biology, physics, chemistry, and technology. They also find applications in liquid-crystal displays and electro-optical devices. Order and mobility are strongly affected by the presence of topological defects arising from imperfections in the planar configuration. In my talk, I will demonstrate that helimagnets are a striking analogue to liquid crystals showing similar ordered topological defects that are typical for lamellar materials like sand patterns or fingerprints. Crucially, however, the topological structures exist at the nanoscale with additional functionality arising from the magnetic order. Combining magnetic force microscopy and micromagnetic simulations, I will show three fundamental classes of domain walls to arise in the near-room-temperature helimagnet iron germanium. In contrast to conventional ferroics, the domain walls exhibit a well-defined inner structure, which - analogous to cholesteric liquid crystals - consists of topological disclination and dislocation defects. Similar to the magnetic skyrmions, such domain walls can carry a finite topological charge, permitting an efficient coupling to spin currents and contributions to a topological Hall effect, opening the door to innovative device concepts.