MON 21: Quantum Materials

Time: Monday 16:30–18:30 Location: ZHG103

MON 21.1 Mon 16:30 ZHG103

Directional Control of Fermi Arcs via Pseudo-Magnetic Fields — Sachin Vaidya[1], •Alaa Bayazeed[2], Adolfo Grushin[3], Marin Soljačić[1], and Christina Jörg[2] — [1]1Department of Physics, Massachusetts Institute of Technology, Cambridge, MA, USA — [2]Physics Department and Research Center OPTIMAS, RPTU Kaiserslautern-Landau, Germany — [3]Univ. Grenoble Alpes, CNRS, Grenoble INP, Institut Néel, France

Weyl materials are three-dimensional topological systems characterized by Weyl points, which are band crossings in momentum space that act as sources or sinks of Berry curvature. These points give rise to surface states known as Fermi arcs, connecting Weyl points of opposite chirality. Under a magnetic field, the bulk band structure reorganizes into quantized Landau levels (LL), with the zeroth LL inheriting the chirality of the associated Weyl point. We investigate how pseudo-magnetic fields, arising from engineered spatial variations, influence such systems. These fields couple differently to Weyl points of opposite chirality, enabling all zeroth LLs to exhibit the same group velocity. Coating the surfaces with photonic bandgap materials, we suppress this radiation and reveal topological surface states that restore the balance of chirality. We experimentally demonstrate this in a photonic multilayer analogue of Weyl semimetals with tailored layer thicknesses and partially reflective Bragg mirrors. Our system maps complex topological physics of strained Weyl semimetals onto an accessible photonic platform.

MON 21.2 Mon 16:45 ZHG103

Emergent quantum phenomena in a two-dimensional magnet — •Ying-Jiun Chen[1], Tzu-Hung Chuang[2], Jan-Philipp Hanke[1], Markus Hoffmann[1], Gustav Bihlmayer[1], Yuriy Mokrousov[1,3], Stefan Blügel[1], Claus Michael Schneider[1,4], and Christian Tusche[1,4] — [1]Forschungszentrum Jülich — [2]National Synchrotron Radiation Research Center, Taiwan — [3]Johannes Gutenberg University Mainz — [4]University of Duisburg-Essen

Quantum phenomena that result from the breaking of time-reversal symmetry offer an innovative platform for nonvolatile switching of physical properties by controlling the direction of the sample magnetization. Magnetic order serves as an ideal means to create on-demand topological phase transitions and significantly alter the topology of the electronic states. In this talk, we present emergent quantum phenomena and magnetic control in a two-dimensional magnet by momentum microscopy. We show that giant open Fermi arcs are created at the surface of an ultrathin hybrid magnet, composed of two iron monolayers, where the Fermi-surface topology is substantially modified by hybridization with the heavy-metal substrate tungsten [1]. The interplay between magnetism and topology allows us to control the shape and the location of the Fermi arcs by tuning the magnetization direction, which dominates spin and charge transport as well as magneto-electric coupling effects [2]. Our findings not only provide a knob to tune the physical properties in a solid, but also offer a platform for prospective quantum devices. [1] Y.-J. Chen et al., Nat. Commun. 13, 5309 (2022). [2] Y.-J. Chen et al., Appl. Phys. Lett. 124, 093105 (2024).

MON 21.3 Mon 17:00 ZHG103

Strong Spin-Magnon coupling between paramagnetic ion GdW10 and VdW antiferromagnet CrSBr — •Jorge Perez-Bailon, David Garcia-Pons, Xavier del Arco-Fargas, David Zueco, and Maria Jose Martinez-Perez — Instituto de Nanociencia y Materiales de Aragón CSIC-Universidad de Zaragoza, Calle Pedro Cerbuna 12, 50009, Zaragoza, España

Cavity Quantum Electrodynamics (QED) has proven to be a highly powerful platform for manipulating and interrogating qubits. In these systems, strong coupling between qubits and quantized fields, typically photons, forms the basis for applications ranging from quantum sensing of individual spins to coherent qubit interactions. However, the reliance on photons in conventional electromagnetic cavities imposes intrinsic limitations on the maximum achievable coupling strengths and the accessible regimes of quantum physics.

Here we study the magnon-spin interaction between the layered van der Waals antiferromagnet CrSBr and the paramagnetic ion crystal GdW10 using microwave absorption spectroscopy at millikelvin temperatures. Analysis of macroscopic samples revealed multiple CrSBr resonances, attributed to phase differences among its layers, while an anticrossing at low power indicates strong coupling, which disappears at higher power as the paramagnet saturates. These findings suggest that CrSBr and similar materials could serve as magnonic platforms in hybrid quantum systems.

MON 21.4 Mon 17:15 ZHG103

Impurity scattering in one-dimensional cavity QED systems — •Lukas I. Krieger[1] and Peter P. Orth[2] — [1]Department of Physics, Saarland University, 66123 Saarbrücken — [2]Department of Physics, Saarland University, 66123 Saarbrücken

We consider the effects of impurity scattering in materials strongly coupled to high-finesse electromagnetic cavities. We focus on the regimes of deep to extremely strong coupling between light and matter degrees of freedom, where perturbative methods to cavity QED break down. We use an unitary transformation introduced by Ashida et al. [PRL 126, 153603 (2021)], the asymptotic decoupling (AD) transformation, which shifts the minimal coupling of the vector potential to the momentum to the potential terms describing the influence of periodic crystal lattice and impurities. We consider one-dimensional models of electrons subject to the AD frame light-matter interaction and we analyze the influence of the light-matter coupling to the scattering of electron waves at an impurity site. The impurity scattering will be tackled by perturbation theory in the impurity potential at low orders and by a Green's function treatment to sum up the relevant diagrams contributing to scattering.

MON 21.5 Mon 17:30 ZHG103

Orbital Topology of Chiral Crystals for Orbitronics — Kenta Hagiwara[1,2], Ying-Jiun Chen[1], Dongwook Go[3], Xin Liang Tan[1,2], Sergii Grytsiuk[1], Kui-Hon Ou Yang[4], Guo-Jiun Shu[5], Jing Chien[4], Yi-Hsin Shen[4], Xiang-Lin Huang[5], Iulia Cojocariu[1], Vitaliy Feyer[1], Minn-Tsong Lin[4,6], Stefan Blügel[1], Claus Michael Schneider[1,2], Yuriy Mokrousov[1,3], and •Christian Tusche[1,2] — [1]Forschungszentrum Jülich — [2]University of Duisburg-Essen — [3]Johannes Gutenberg University Mainz — [4]National Taiwan University, Taiwan — [5]National Taipei University of Technology, Taiwan — [6]Academia Sinica, Taiwan

Chirality is ubiquitous in nature and manifests in a wide range of phenomena including chemical reactions, biological processes, and quantum transport of electrons. In quantum materials, the chirality of fermions, given by the relative directions between the electron spin and momentum, is connected to the electronic band topology. Here, we show that in structurally chiral materials like CoSi, the orbital angular momentum (OAM) serves as the main driver of a nontrivial band topology in this new class of unconventional topological semimetals, even when spin-orbit coupling is negligible. A nontrivial orbital-momentum locking of multifold chiral fermions in the bulk leads to a pronounced OAM texture of helicoid Fermi arcs at the surface [1]. Our findings highlight the pivotal role of the orbital degree of freedom for the chirality and topology of electron states, in general, and pave the way towards the application of topological chiral semimetals in orbitronic devices. [1] Hagiwara et al., Adv. Mater. 2418040 (2025).

MON 21.6 Mon 17:45 ZHG103

Mechanism of the electrochemical hydrogenation of graphene — •YUCHIAN SOONG — Department of Physics and Astronomy, The University of Manchester, Manchester M13 9PL, UK

The electrochemical hydrogenation of graphene has been recently shown to induce a robust and reversible conductor-insulator transition, which is of strong interest in logic and memory applications. However, its mechanism remains unknown. Here we show that it proceeds as a reduction reaction in which proton adsorption competes with a process attributable to the formation of H2 molecules. Graphene*s electrochemical hydrogenation is up to 6 orders of magnitude faster than alternative hydrogenation methods and is fully reversible via the oxidative desorption of protons. We demonstrate that the proton reduction rate in defect-free graphene can be enhanced by an order of magnitude by the introduction of nanoscale corrugations in its lattice and that the substitution of protons for deuterons results both in lower potentials for the hydrogenation process and in a more stable compound. Our results pave the way to investigating the chemisorption of ions in 2D materials at high electric fields, opening a new avenue to control these materials* electronic properties.

MON 21.7 Mon 18:00 ZHG103

Shadow Wall Epitaxy - Towards the all-in-situ fabrication of ZnSe-based Quantum Devices — •Christine Falter[1,2], Yurii Kutovyi[1,2], Nils von den Driesch[1,2], Denny Dütz[2,3], Lars R. Schreiber[2,3], and Alexander Pawlis[1,2] — [1]Peter Grünberg Institute, Forschungszentrum Jülich GmbH, 52428 Jülich, Germany — [2]JARA-FIT, Jülich Aachen Research Alliance, Forschungszentrum Jülich and RWTH Aachen University, Germany — [3]JARA-Institute for Quantum Information, RWTH Aachen University, 52074 Aachen, Germany

Wide band-gap semiconductors such as ZnSe offer a wide range of unique properties making them well-suited for a variety of quantum devices. However, in standard fabrication schemes, surface states and defects introduced during ex-situ applied processing steps can limit the performance of the final device. With this in mind, we have developed a Shadow Wall technique for molecular beam epitaxy (MBE), which allows for all-in-situ device fabrication making all post processing steps obsolete. The technique relies on the pre-patterning of vertical walls on the substrate and the precise alignment of material fluxes during deposition. In our contribution, we focus on the realization of an all-in-situ ZnSe-based field effect transistor (FET). We demonstrate the MBE growth of high quality ZnSe layers on pre-patterned substrates, the in-situ realization of well-defined spatially separated metal contacts and the electrical characterization of the final device. The optimization of the ZnSe FET platform is a first step towards the realization of qubits based on gate defined quantum dots in ZnSe.

MON 21.8 Mon 18:15 ZHG103

Low-density InAs quantum dots grown by local droplet etching for telecom O-band single-photon emission — •Elias Kersting, Nikolai Spitzer, Severin Krüger, Hans Georg Babin, Andreas Wieck, and Arne Ludwig — Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Germany

InAs quantum dots (QDs) grown by molecular beam epitaxy (MBE) are promising candidates for single-photon sources (SPS). Emission in the telecom O-band (1260 - 1360 nm) is particularly desirable due to the low transmission loss in optical fibers. However, conventional Stranski-Krastanov (SK) InAs QDs face challenges in achieving low and well-controlled densities in the suitable range of 0.1-10 QDs/μm^2, as well as in precisely tuning the emission wavelength.

We present an alternative approach based on local droplet etching (LDE), in which nanoholes in a GaAs matrix are filled with InAs to form QDs. The dot density is determined by the nanohole pattern, enabling precise and scalable control. A strain-reducing layer (SRL) enables shifting of the emission wavelength into the telecom O-band. Homogeneous QD growth is achieved through shutter-synchronized deposition, making this approach well-suited for scalable SPS fabrication. We detail the fabrication method and present structural and optical characterization results.