TT 59: 2D Materials V – Magnetic, spintronic, and topological properties (joint session HL/TT)

Time: Wednesday 15:00–17:15 Location: POT/0081

Invited Talk TT 59.1 Wed 15:00 POT/0081

Dual proximity engineering of spin-orbit and magnetic effects in graphene heterostructures — •Christoph Kastl — Walter Schottky Institute, School of Natural Sciences, Technical University of Munich — Munich Center for Quantum and Technology (MCQST)

The coexistence of induced spin-orbit coupling (SOC) and magnetic exchange fields is predicted to drive graphene into topological phases, such as the quantum anomalous Hall state. Here, I will discuss the prospect of using monolayer graphene proximitized by WSe_2 (SOC) and $Cr_2Ge_2Te_6$ (magnetic exchange) for such dual proximity control. To determine the type and strength of the induced SOC, I will compare Landau fan analysis, where level anticrossings can serve as direct signatures of spin-orbit splittings, to optoelectronic measurements on graphene/WSe_2 heterostructures, where the photogalvanic effect can provide an indirect fingerprint of SOC. Low-temperature magneto-transport measurements of the heterostructures with combined magnetic and SOC proximity reveal a large and gate-tunable anomalous Hall effect persisting at zero magnetic field, signaling an intrinsic Berry curvature arising from the interplay of SOC and magnetism. These results highlight the coexistence of spin-orbit and magnetic proximity effects in graphene-based van der Waals heterostructures and establish a route toward topological graphene phases.

TT 59.2 Wed 15:30 POT/0081

Twist angle and pressure tuning of proximity-induced spin-orbit coupling in graphene/WSe_2 heterostructures — Tobias Rockinger[1], Bálint Szentpéteri[2], Szabolcs Csonka[2], Marina Marocko[1], Julia Amann[1], Ziyang Gan[3], Antony George[3], Andrey Turchanin[3], Kenji Watanabe[4], Takashi Taniguchi[4], Dieter Weiss[1], Péter Makk[2], and •Jonathan Eroms[1] — [1]Department of Physics, University of Regensburg, Regensburg, Germany — [2]Department of Physics, Budapest University of Technology and Economics, Budapest, Hungary — [3]Institute of Physical Chemistry, Friedrich Schiller University Jena, Jena, Germany — [4]National Institute for Materials Science, Tsukuba, Japan

Proximity-induced spin-orbit interaction in heterostructures of graphene and transition metal dichalcogenides has been studied intensely in the past few years. However, present experiments still suffer from poor reproducibility, as one key parameter, the twist angle between the crystal axes of both materials, has not been systematically controlled during fabrication. Band structure calculations, on the other hand, have predicted a decisive influence of this parameter. In our experiments, we control the twist angle during fabrication by aligning fractured or CVD grown edges and resolving the ambiguity of zigzag and armchair directions using a crystallographic etching process. We employ weak antilocalization to extract the spin-orbit coupling parameters quantitatively, and report excellent reproducibility and a good match to theoretical predictions. We also confirm the influence of high pressure on the proximity effect.

TT 59.3 Wed 15:45 POT/0081

Nonlinear optical probing of local quantum geometry — •Nele Tornow[1], Paul Herrmann[1], Clemens Schneider[2], Jan Wilhelm[2], and Giancarlo Soavi[1,3] — [1]Institute of Solid State Physics, Friedrich Schiller University Jena, Jena, Germany — [2]Institute of Theoretical Physics and Regensburg Center for Ultrafast Nanoscopy, Regensburg, Germany — [3]Abbe Center of Photonics, Friedrich Schiller University Jena, Jena, Germany

With its direct relation to many phenomena in solid matter, quantum geometry has become a concept of increasing interest in solid state physics. However, measurements of the local quantum geometry, *e.g.,* Berry curvature, has been possible to date only *via* angle-resolved photoemission spectroscopy [1]. On the other hand, in one of our recent theoretical works [2] we have shown that there is a link between linear circular dichroism and derivatives of Berry curvature in 3D crystals with preserved time-reversal symmetry (TRS).

In this presentation I will further demonstrate both, experimentally and with analytical solutions of semiconductor Bloch equations, that in a 2D semiconductor with broken TRS, the emerging second-harmonic circular dichroism can be used as a direct probe of the Berry curvature at the opposite ± K valleys, providing a new all-optical approach to access the local quantum geometry in 2D materials.

[1] Schüler, M. et al., Sci. Adv. 6, eaay2730 (2020)
[2] Soavi, G. and Wilhelm, J., arXiv:2501.03684 (2025)

15 min. break

TT 59.4 Wed 16:15 POT/0081

Proposal for Resolving Quantized Landau Orbits via Elastic XUV Scattering — •Sabrina Meyer[1], Andreas Knorr[1], Stephen Hughes[2], and Lara Greten[1,2] — [1]Institut für Physik und Astronomie, Technische Universität Berlin, Germany — [2]Department of Physics, Queen's University, Kingston, Canada

In a strong perpendicular magnetic field, a two-dimensional electron gas is quantized into discrete Landau levels. We propose a method to extract the spatial structure of Landau orbits via scattering with extreme ultraviolet radiation, whose wavelength naturally matches the Larmor radius. In a microscopic theory, we derive the far-field spectrum emitted by the optically induced current density. Contributions from Landau orbits within this spectrum are suppressed due to scattering effects imposed by the sample geometry. By normalizing against the zero-magnetic-field reference, however, we define a Landau level scattering spectrum that isolates Landau orbit information. This gives access to the probability density distributions of individual Landau level wave functions featuring radial maxima at the quantized Larmor radii.

TT 59.5 Wed 16:30 POT/0081

Berry Phase Shift in Folded Bilayer Graphene — •Hannes Kakuschke, Lina Bockhorn, and Rolf J. Haug — Institut für Festkörperphysik, Leibniz Universität Hannover, 30167 Hannover, Germany

Mono- and bilayer systems of graphene have been extensively researched due to their unique magnetic und electronic transport properties. In more recent works, folded graphene [1-5] has gained interest as a platform for topological phenomena, such as zero-line modes [4]. However, these systems rely on self-assembled folded graphene, found by chance during exfoliation or induced by tearing [1-5]. Our dry-transfer approach allows us to fold graphene around hBN in a controllable manner, decoupling the overlapping graphene regions. In these samples, we observe a Berry phase shift from 2π to π near the edge of folded bilayer graphene, attributed to local strain fields and stacking shifts.

[1] J. C. Rode et al., Ann. Phys. 529, 1700025 (2017).
[2] J. C. Rode et al., 2D Mater. 6, 015021 (2018).
[3] L. Bockhorn et al., Appl. Phys. Lett. 118, 173101 (2021).
[4] S. J. Hong et al., 2D Materials 8, 045009 (2021).
[5] S. J. Hong et al., Phys. Rev. B 105, 205404 (2022).

TT 59.6 Wed 16:45 POT/0081

Probing spin-orbit coupling in graphene/WSe_2 heterostructures by the circular photogalvanic effect — Ernst Knöckl, •Matthias Klein, Alexander Holleitner, and Christoph Kastl — Walter Schottky Institute, School of Natural Sciences, Technical University of Munich

We investigate proximity-induced spin–orbit coupling (SOC) in graphene/WSe_2 heterostructures using the circular photogalvanic effect (CPGE) as a symmetry-selective and experimentally accessible probe of spin–valley-locked band textures [1]. By measuring helicity-dependent photocurrents as a function of gate voltage, excitation energy, and device geometry, we aim to disentangle Rashba and valley-Zeeman SOC contributions and to extract their magnitude and sign as a function of the graphene–WSe_2 twist angle. The observed trends in CPGE sign reversals and scaling behavior provide quantitative indications of interfacial symmetry breaking and moiré-enhanced spin–valley coupling, supported by comparison to microscopic transport models. These results are expected to establish CPGE as a promising metrological probe of proximity SOC in 2D heterostructures and to complement ongoing efforts in twist-angle-dependent spin–orbit engineering in graphene/TMD systems [2,3].

[1] Kiemle, J., et al. ACS nano 16.8, 12338-12344 (2022)

[2] Yang, H., et al. Nat. Mater. 23, 1502-1508 (2024)
[3] Zhang, Y., et al. Natur 641, 625-631 (2025)

TT 59.7 Wed 17:00 POT/0081

Study of the non-trivial spin texture in Tellurium and the consequences in charge-spin interconversion — •Andrés Martínez-García[1], Daniel Gosálvez-Martínez[1], Carlos Sabater[1], and Juan José Palacios[2] — [1]Departamento de Física and Instituto Universitario de Materiales de Alicante (IUMA), Universidad de Alicante, Alicante, Spain. — [2]Departamento de Física de la Materia Condensada and Condensed Matter Physics Center (IFIMAC), Universidad Autónoma de Madrid, Madrid, Spain.

Tellurium is a chiral semiconducting material with a narrow band gap that can be synthesized with well-defined handedness in nanowires and flakes, making it an excellent platform for studying chirality-related charge-spin interconversion in nanodevices. The coupling between charge and spin degrees of freedom is closely connected to the spin texture in momentum space. In this work, we demonstrate that tellurium exhibits a nontrivial radial spin texture at the top of the valence band, where the spin polarization aligns parallel to the HK direction of the Brillouin zone, while spins in the perpendicular ZHL plane display a nontrivial winding. We investigate the electronic transport and resulting spin polarization within the Landauer transport formalism using first-principles calculations. This approach allows us to map the transport properties along each crystallographic direction and to identify correlations between the spin polarization of the induced current and the underlying momentum-space spin texture. Our results provide microscopic insight into chirality-driven spin responses in tellurium and highlight its potential for spintronic applications.