TT 92: Transport – Poster

Time: Thursday 18:00–20:00 Location: P4

TT 92.1 Thu 18:00 P4

Development of a scanning NV magnetometer for quantum senisng experiments at room-temperature — •Yue Yu, Ricardo Javier Peña Román, and Aparajita Singha — IFMP, TU Dresden, Dresden, Germany

Nitrogen-Vacancy (NV) center based sensors are widely used because they are versatile, precise, and suitable for exploring a broad range of systems. We have previously designed NV setups capable of operating in ultra high vacuum (UHV) and cryogenic environments, which, however, are only meaningful to use with samples that mandate such extreme measurement conditions. In order to expand our measurement capabilities to room temperature (RT) systems (such as exploration of nanomagnetism in RT-stable 2D materials, antiferromagnetic / ferromagnetic spin textures, stable molecular systems) as well as to enable rapid pre-screening of both samples and NV probes prior to transferring them into the UHV cryogenic setups, we are now setting up a room-temperature-scanning-NV magnetometer. This system integrates atomic force microscopy (AFM) with optical readout of single NV centers and will feature microwave delivery directly on the AFM tip to achieve highly localized and efficient spin control. This setup will also feature piezo-controlled permanent magnets, thus enabling quantitative magnetic-field mapping with nanometer-scale spatial resolution. Together with our UHV low-temperature scanning NV magnetometer and UHV confocal microscopes, it will form a unified platform for a complete workflow across ambient, cryogenic, and UHV environments.

TT 92.2 Thu 18:00 P4

Development of an Ultra High Vacuum and Low Temperature Scanning NV Magnetometer — •Sandip Maity[1], Ricardo Javier Peña Román[2,1], Dinesh Pinto[1,3], Isabel Pfander[1], Klaus Kern[1,3], and Aparajita Singha[2,4] — [1]Max Planck Institute for Solid State Research, Stuttgart — [2]IFMP, TU Dresden, Germany — [3]Institut de Physique, École Polytechnique Fédérale de Lausanne, Lausanne — [4]Wurzburg-Dresden Cluster of Excellence (ct.qmat)

The nanoscale spatial resolution and calibration-free quantifiable magnetic field measurement capabilities of nitrogen-vacancy (NV) centers have enabled us to investigate the properties of magnetic spin textures with high magnetic sensitivity through scanning probe microscopy across a wide range of temperatures and pressure. In the poster I will be presenting the development of a scanning probe magnetometer capable of imaging magnetic textures under ultra-high vacuum and low temperature. Moreover, we have integrated commercial NV tips with a home-built tip holder equipped with an AFM amplifier and microwave excitation on the tip (not on the sample). This compact and modular probe holder allows us to have a magnetic image of any sample region without restriction. To exploit the quantifying nature of NV magnetometry using Optically Detected Magnetic Resonance, a coherent microwave (MW) delivery to the probe is mandatory. I will also present different means of delivering MW to the NV probes through different designs of the tip holders in a practical and versatile manner and how effective they are in coherently manipulating the NV spin states.

TT 92.3 Thu 18:00 P4

Advances in building a cryogenic scanning NV magnetometer — •Kilian Srowik[1,2], Lotte Boer[1], Hayden Binger[1], Young-Gwan Choi[1], Ahmet Ünal[1], Luminita Harnagea[2,4], Sabine Wurmehl[2], Bernd Büchner[2,3], and Uri Vool[1] — [1]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany — [2]Leibniz Institute for Solid State and Materials Research, IFW Dresden, Dresden, Germany — [3]Institute for Solid State and Materials Physics, TU Dresden, Dresden, Germany — [4]Indian Institute of Science Education and Research, Pune, India

In the last decade, the Nitrogen-Vacancy (NV) defect in diamond has emerged as an ideal quantum sensor to probe magnetic stray fields. By using a diamond nanopillar, containing a single NV center, as the tip of an atomic force microscope (AFM), it becomes possible to perform Scanning NV magnetometry (SNVM). This configuration not only enables us to measure with high spatial resolution and sensitivity, it also makes a broad temperature range accessible. While room temperature NV systems are widely used already, cryogenic NV setups still remain sparse. At the MPI CPfS, we are in the final stages of building a cryogenic SNVM setup, capable of measuring at variable temperatures down to 1.8K. This paves the way to study a multitude of interesting phenomena, like magnetic phase transitions and superconductivity. In particular, we want to focus on investigating the magnetic structure of unconventional superconductors, like the recently emerged Weyl semimetal γ-$PtBi_2$, reported to have superconducting surface states with a nodal superconducting gap structure.

TT 92.4 Thu 18:00 P4

On-surface spin characterisation of isolated molecules using room temperature NV magnetometry — •Olga Shevtsova[1,2], Bernhard Putz[3], Ulrich Ziener[3], and Aparajita Singha[1,2] — [1]IFMP, TU Dresden, Germany — [2]Würzburg-Dresden Cluster of Excellence (ct.qmat) — [3]Universität Ulm, Ulm, Germany

Molecular spins have been receiving significant attention as promising candidates for quantum technologies, offering unique advantages in stability, tunability, and scalability. In particular, our work focuses on carbon-based open-shell molecular systems - stable chlorinated trityl radicals that host an unpaired electron spin. Understanding the coherent properties of these molecular spins is a crucial step toward their integration in practical quantum applications. However, probing such properties remains challenging due to limitations in sensitivity, environmental constraints, and the invasiveness of existing techniques.

Nitrogen-Vacancy (NV) centers in diamonds can operate over a wide temperature range and provide non-invasive optical readout, making them versatile and highly suitable tools for deepening existing knowledge. In this study, we leverage NV-center-based quantum sensors to investigate both the coherent properties of molecular spins and the limits of detecting extremely low spin concentrations, potentially down to a single spin. By combining the precision of NV magnetometry with the inherent stability of open-shell systems, our work aims to provide deeper insight into their viability as stable and controllable components for future quantum technologies.

TT 92.5 Thu 18:00 P4

Probing Vortices in Superconductors with Scanning Quantum Microscope — •Sreehari Jayaram[1], Malik Lenger[1], Lucas Pipim[3], Ruoming Peng[1], Rainer Stoehr[1], Mathias S. Scheurer[3], Jurgen Smet[2], and Joerg Wrachtrup[1,2] — [1]3rd Institute of Physics, University of Stuttgart, Allmandring 13, Stuttgart 70569, Germany — [2]Max Planck Institute for Solid State Research, Heisenbergstrasse 1, Stuttgart 70569, Germany — [3]Institute for Theoretical Physics III, University of Stuttgart, Pfaffenwaldring 57, Stuttgart 70569, Germany

Magnetic dynamics at the nanoscale provide crucial insight into the behavior of superconductors. Using single-spin scanning quantum microscopy, we probe vortex dynamics in superconductors. Our measurements reveal a disordered vortex glass phase that melts near the critical temperature. Magnetic noise persists well below **, with a strength that increases at lower temperatures*contrary to expectations. This behavior, detected via spin decoherence, points to an intrinsic origin driven by competition between supercurrent density and thermal fluctuations. Our results establish single-spin microscopy as a powerful platform for investigating fluctuations in 2D superconductors.

TT 92.6 Thu 18:00 P4

Double galvanic access to a microwave cavity for flux-mediated optomechanics with carbon nanotubes SQUIDs — •Julian Sehr, Tim Althuon, Philipp Wiedemann, Sophie Klingel, Philipp Bennett, Tino Cubaynes, and Wolfgang Wernsdorfer — Karlsruher Institut für Technologie (KIT), 76131 Karlsruhe

Carbon nanotubes (CNTs) are attractive as Josephson junction weak links, offering ballistic, one-dimensional transport and the ability to electrostatically tune their carrier density and transmission. By employing two parallel Josephson junctions formed from a single carbon nanotube mechanically transferred onto the circuit after growth, we realised a superconducting quantum interference device (DC-SQUID). The device supports an induced supercurrent of up to 4 nA through a single CNT-based junction. We expect to increase the critical current by changing the superconductor of the electronic circuits from molybdenum-rhenium to niobium. Embedding such a SQUID into a non-linear microwave cavity opens up the possibility to couple the phonon modes of the CNT to cavity photons via flux-mediated optomechanical coupling. This will be realised by making the cavity galvanically accessible from both sides, while the boundaries of the resonator are defined by a filtering stage using an on-chip planar capacitance.

TT 92.7 Thu 18:00 P4

Nonlinear Nanomechanics in Suspended Carbon Nanotubes — •Philipp Bennett, Sophie Klingel, Julian Sehr, Tim Althuon, Tino Cubaynes und Wolfgang Wernsdorfer — Karlsruher Institut für Technologie, Karlsruhe, Germany

Suspended carbon nanotubes (CNTs) serve as a unique platform for the implementation of nanomechanical systems (NEMS), owing to their electrical, mechanical, and quantum properties in a single nanoscale object. Because of their well-defined quantum dot states and mechanical degree of freedom, suspended CNTs are attractive for studying the coupling between electronic transport and nanomechanics and as candidates for mechanical qubits.

Building a two-level phononic system at the quantum level requires a certain degree of nonlinearity. In contrast to other hybrid approaches, we rely on purely intrinsic nonlinearities, which minimizes the additional decoherence arising from external sources. The degree of intrinsic nonlinearity can be quantified via the ratio K/κ, with K being the Kerr nonlinearity and κ the decoherence rate of the resonator. Our group has recently measured the Kerr-constant for a purely mechanical system. The next step is to further reduce the decoherence rate κ. To this end, we follow two complementary strategies: enhancing CNT quality by introducing water during growth, and improving the readout by implementing an MHz-range RLC tank circuit in the dilution cryostat. These improvements are meant to boost the degree of intrinsic nonlinearity in our system, paving the way to various applications, like magnetometers for single-molecule magnets or mechanical qubits.

TT 92.8 Thu 18:00 P4

Transmission resonances for periodically driven local potentials — •Daniel Weber — RPTU University Kaiserslautern-Landau, D-67663 Kaiserslautern, Germany

We model tunneling trough a quantum dot using a locally driven 1D tight-binding Hamiltonian. Using Floquet theory, we produce exact numerical results before we derive an analytic prediction of position and amplitude of transmission resonance in dependence of driving frequency, coupling strength and local energy levels. Starting with a suitable transformation of the Hamiltonian, we use a high frequency approximation to derive a valid analytical approximation for frequencies in the systems energy scales. The results can be used for the design of efficient nano-electronic devices, in photonic waveguides or can be useful for ultra-cold gages in optical lattices.

TT 92.9 Thu 18:00 P4

STM-Break Junction Measurements of Organic Dyes — •Yannic Altmann[1,2], René Matzdorf[1], and Rüdiger Faust[2] — [1]Institute of Physics, University of Kassel, Heinrich-Plett-Straße 40, 34132 Kassel, Germany — [2]Institute of Chemistry, University of Kassel, Heinrich-Plett-Straße 40, 34132 Kassel, Germany

Current research in molecular electronics explores multiple ways to manipulate the conductivity of molecules inside of single-molecule junctions using external stimuli. Examples are magnetic fields [1], external forces [2], as well as electromagnetic radiation [3].

We use a LT-STM to measure the conductance of single oligo(phenylene ethynylene) molecules in STM break junction inspired experiments in two different ways: $I(z)$-spectroscopy as well as $I(t)$-spectroscopy. The goal of the project is to do similar measurements on organic dye molecules to study the effects of molecule excitation with visible light on the molecular conductance.

[1] G. Mitra *et al.*, Nano Letters 22, 5773 (2022)
[2] P. Zhou, *et al.*, Jo. American Chem. Soc. 145, 18800 (2023)
[3] E-D. Fung *et al.*, Nano Letters 17, 1255 (2017)

TT 92.10 Thu 18:00 P4

Vorticity as an Origin-Independent Measure of Electronic Circulation in Crystals — •Aristo Ardyaneira, Leonard Prokisch, Moritz Rübling, and Ferdinand Evers — Institute of Theoretical Physics, University of Regensburg, D-93053 Regensburg, Germany

Orbital angular momentum (OAM) plays a central role in the emerging field of orbitronics, but its definition in real space is problematic because it depends on the choice of origin. Common approaches - such as the atomic-centered approximation or unit-cell integration - either neglect interstitial contributions or are not uniquely defined. We propose vorticity as an alternative, origin-independent measure of the local electronic circulation. Although closely related to the experimentally accessible magnetic field, vorticity has received little attention in solid-state contexts. Using the Mandelung formulation of quantum mechanics, we derive an equation of motion for the electronic vorticity and demonstrate its direct connection to the magnetic field in a crystal. This framework provides a natural and physically transparent description of electronic spinning motion relevant for orbitronic phenomena.

TT 92.11 Thu 18:00 P4

Photogalvanic Effect as a Probe for Distinguishing type-I and type-II Semi-Dirac Systems — •Bristi Ghosh[1], Malay Bandyopadhyay[1], and Snehasish Nandy[2] — [1]Indian Institute of Technology Bhubaneswar, Bhubaneswar, Odisha 752050, India — [2]National Institute of Technology Silchar, Assam, 788010, India

The photogalvanic effect (PGE) generates a direct photocurrent under polarized light in non-centrosymmetric systems, manifesting as the linear photogalvanic effect (LPGE) or circular photogalvanic effect (CPGE) depending on light polarization. Using quantum kinetic theory within the relaxation-time approximation, we theoretically explore the PGE as a probe of quantum geometry in anisotropic type-I and type-II semi-Dirac (SD) systems. The PGE conductivity, comprising injection, shift, resonant, higher-order pole, and anomalous contributions, exhibits a pronounced enhancement in type-II systems compared to type-I. For the CPGE, both anomalous and resonant terms, arising from Fermi surface contributions, decrease with increasing chemical potential in type-I but increase in type-II systems. For the LPGE, the xxx-component of the shift conductivity in type-II SD reverses sign upon tuning the gap tuning parameter δ, while other components remain invariant, similar to type-I behavior. These contrasting CPGE and LPGE responses provide clear optical signatures distinguishing the two SD phases. The predicted effects, potentially realizable in TiO_2/VO_2 heterostructures, establish the PGE as a sensitive probe of quantum geometry and a promising route toward next-generation optoelectronic applications.

TT 92.12 Thu 18:00 P4

Intrinsic Nonlinear Magneto-Electric Hall Effect — •Sunit Das and Amit Agarwal — Department of Physics, Indian Institute of Technology, Kanpur 208016, India

We propose a new mechanism for an intrinsic nonlinear magnetoelectric Hall (MEH) response in multilayer van der Waals materials. The predicted Hall conductivity is bilinear in an out-of-plane gate electric field and the magnetic field, independent of scattering time, and can arise even in nonmagnetic systems with weak spin-orbit coupling. This response originates from an emergent layer-orbital quantum geometry whose sign reverses with the gate field, faithfully tracking the underlying layer polarization. Our comprehensive symmetry analysis reveals that a large class of polar and chiral nonmagnetic materials can permit this magnetotransport. Using the gated bilayer as a representative platform, we demonstrate sizable MEH signals. We further show that the same layer-orbital polarizability drives a longitudinal nonlinear response in chiral materials, providing a robust probe of structural chirality. These results reveal an intrinsic nonlinear transport channel that broadens the landscape of magnetoelectric phenomena and establishes layer-orbital quantum geometry as a key tool for novel transport-based material characterization.

TT 92.13 Thu 18:00 P4

QMC study of heat transport in 2D Dirac materials — •Luis Thremer[1], Adrien Reingruber[1], Maksim Ulybyshev[1], and Fakher F. Assaad[1,2] — [1]Institut für Theoretische Physik und Astrophysik, Universität Würzburg, 97074 Würzburg, Germany — [2]Würzburg-Dresden Cluster of Excellence ct.qmat, Am Hubland, Würzburg, Germany

Strongly correlated systems can host varying (and often competing) scattering mechanisms, making them an ideal playground for studying their influence on various transport properties. In particular, Dirac systems can undergo a Gross-Neveu phase transition, switching from a semi-metallic to a Mott-insulating phase. Experimental evidence of this transition was long-sought and recently tentatively realised in experiments on twisted WSe_2 tetralayers. We investigate the heat transport and the behaviour of the heat conductivity across the Gross-Neveu phase transition in strongly correlated 2D Dirac materials. In particular, we focus on their dependence on the change in the nature of the low-lying excitations from electrons to antiferromagnetic spin waves, which occurs across the phase transition. For this study, we use unbiased quantum Monte Carlo and Kubo linear response theory to extract the transport coefficients from the Euclidean time correlators. We also investigate the effects of long-range Coulomb interaction on the heat transport. Since long range interaction leads to the appearance of non-local terms in the heat current, long range Coulomb interaction can potentially significantly alter the thermal-transport behaviour.

TT 92.14 Thu 18:00 P4

Curvature, Torsion, and Non-Metricity in the Continuum Theory of Lattice Defects — •Marvin Henke and Nikodem Szpak — Fakultät für Physik, Universität Duisburg- Essen, Duisburg, Germany

The continuum theory of lattice defects provides a tractable mesoscale framework for electron transport, circumventing microscopic complexity. It maps dislocations and disclinations onto curvature and torsion within an effective Riemann-Cartan geometry. The equivalence of the two latter concepts is an ongoing debate in General Relativity. Motivated by two-dimensional systems, like graphene, we investigate the mapping of metric-induced curvature onto torsion while preserving physical aspects of the dynamics. Among them, a crucial problem with the (eigen)time scaling along the trajectories of (quasi)particles appears. Our approach to solve this problem lies in the relaxation on the standard metric compatibility condition, which introduces the non-metricity tensor as an additional geometrical object, thus opening a new opportunity to discuss deep problems of differential geometry in the context of real physical systems.

TT 92.15 Thu 18:00 P4

Magnetotransport measurements of magic angle twisted bilayer graphene — •Monica Kolek Martinez de Azagra, Sirri Batuhan Kalkan, and R. Thomas Weitz — Georg August Universität Göttingen

Magic angle twisted bilayer graphene (MATBG) has in recent years been established as a powerful platform for exploring strongly correlated electron phenomena in two-dimensional materials [1]. The rich phase diagram of two graphene layers stacked on top of each other with a precise twist angle of 1.1° has been widely studied with a special emphasis on investigating the robust superconducting state, whose exact nature and origin have yet to be determined [2,3]. Here, we present our recent progress in the fabrication and electric characterization of high-quality, encapsulated MATBG devices, highlighting key experimental observations.

[1] Bistritzer & MacDonald, PNAS 108, 12233 (2011).
[2] Cao et al., Nature 556, 80 (2018).
[3] Cao et al., Nature 556, 43 (2018).

TT 92.16 Thu 18:00 P4

Competition of FCI and CDW in a Two-Band Model — •Marco Schönleber and Maria Daghofer — Institut für Funktionelle Materie und Quantentechnologien, Stuttgart, Deutschland

Fractional quantum hall physics with vanishing magnetic fields has become an increasingly important research topic in recent years due to new findings in the field of moiré materials. Experimental signatures of these phases are often observed in combination with signatures of charge ordered or other symmetry broken phases. This indicates that band mixing might play an elementary role in the complete description of this phase of matter. For this purpose, an extended Hubbard model on a triangular lattice with $\nu = 2/3$ is considered. This allows the formation of bands of non-trivial topology as well as the formation of commensurate charge density waves. The analysis is carried out by exact diagonalisation and DMRG. By varying band gap and interaction strength the topologically non-trivial FCI competes with the symmetry-broken CDW phase.

TT 92.17 Thu 18:00 P4

Chiral Kondo Lattice Emergence in Moiré Heterostructure — •Benjamin Heinrich and Maria Daghofer — Institute for Functional Matter and Quantum Technologies (FMQ), University of Stuttgart

Moiré systems composed of van der Waals heterostructures provide an experimentally accessible platform to realize a wide range of strongly correlated electron phenomena. Using transition metal dichalcogenide materials, such as an AB-stacked $MoTe_2/WSe_2$ bilayer, gives rise to an effective multi-orbital Hubbard model on the honeycomb lattice, which can be tuned via doping and the introduction of charge transfer energy through external voltages. Including strong Ising spin-orbit coupling leads to chiral Kondo exchange between localized and itinerant electrons in different layers near half-filling [1], To gain a better understanding of experimentally observed phenomena, including magnetic ordering, numerical modeling is performed using exact diagonalization, and finite-size effects are further reduced using the variational cluster approach.

[1] Guerci et al., Sci. Adv. 9, eade7701 (2023)

TT 92.18 Thu 18:00 P4

Simulation of charge density wave effects in the layered van der Waals material $GdTe_3$ — •Shen van Hassel[1], Sergii Grytsiuk[1], and Malte Rösner[1,2] — [1]Radboud University, Nijmegen, Netherlands — [2]Bielefeld University, Bielefeld, Germany

In this study, we use *ab initio* downfolding techniques to demonstrate that the Fermi surface (FS) of the undistorted rare-earth tritelluride $GdTe_3$ can be accurately represented by a minimal tight-binding model derived from the in-plane *p*-orbitals of the Te bilayer. To examine the effect of the charge density wave (CDW) in $GdTe_3$, we expand our Hamiltonian to effectively model electron-phonon interactions by assuming and testing self-energy models within the Nambu-Gor'kov space. We calculate the spectral function, which agrees well with experimental ARPES data. Our results provide a simple and effective model for simulating CDW effects in $GdTe_3$, paving the way for a fully *ab initio* approach applicable to a broader class of materials.

TT 92.19 Thu 18:00 P4

Ultra-Low Temperature Fast QPI on Quantum Materials — •Alexander LaFleur, Rian A.M. Lighthart, Kevin Hauser, Gleb Neplyak, and Fabian D. Natterer — Department of Physics, Univeristy of Zurich, Winterthurerstrasse 190, CH-8057, Switzerland

Scanning tunneling microscopy/spectroscopy (STM/S) is a powerful experimental technique capable of elucidating the hidden nature of many quantum materials and phases. The characterization of unconventional superconductors, topological insulators, heavy-fermion systems, Kagome superconductors, and Weyl semimetals, have been broadly pushed forward by atomic resolution STM/S imaging. Yet, for many candidate quantum materials, current techniques for acquiring STM data, such as energy-dependent local density of state (LDOS) maps, fall short of the energy resolution necessary to show definitive band structure characteristics of these phases. We propose to combine ultra-low temperature STM (330 mK) with Fast Quasi-Particle Interference (Fast QPI) techniques to increase the effective hold time and energy resolutions of LDOS Maps taken on quantum materials. The Fourier transform of Fast QPI, which uses parallel spectroscopy to simultaneously measure LDOS across many channels in frequency space, allows the energy dependent LDOS to be measured in a fraction of the time of conventional dI/dV lock-in techniques. This increase in energy resolution given the time constraints of ultra-low temperature measurements holds the potential to demonstrate new and novel observable phenomena in quantum materials and the elusive states they harbor.