O 79: Plasmonics and nanooptics: Light-matter interaction, spectroscopy III

Time: Thursday 10:30–12:15 Location: HSZ/0403

O 79.1 Thu 10:30 HSZ/0403

Cavity control of multiferroic order in the single-layer NiI_2 — •Chongxiao Fan[1,2], Emil Viñas Boström[1], Xinle Cheng[1], Lukas Grunwald[1], Dante Kennes[2], and Angel Rubio[1,3] — [1]Max Planck Institute for the Structure and Dynamics of Matter — [2]Institute for Theory of Statistical Physics, RWTH Aachen University — [3]Initiative for Computational Catalysis, Flatiron Institute

Controlling materials in thermal equilibrium, through their interactions with quantum fluctuations of the electromagnetic field, is a promising new frontier in material engineering. Although recent experiments have demonstrated cavity effects in charge density wave, quantum Hall systems and superconducting systems, a smoking gun experiment is lacking for magnetic systems. To a large extent this comes from the focus on discontinuous phase transitions (e.g. from antiferro- to ferromagnetic), where a large light-matter coupling is required for cavity modifications to be observable. Here, we instead propose spiral magnets as a promising platform to explore cavity effects, where even a small cavity-mediated change in magnetic interactions is directly reflected in a change of the spiral wavelength. For concreteness we focus on the single-layer multiferroics NiI_2 and $NiBr_2$, with the surface phonon polaritons of the paraelectric substrate $SrTiO_3$ acting as the cavity. We show that the surface cavity suppresses the ratio J_3/J_1 of the third nearest and next nearest neighbor exchange interactions, leading to a increase of the spiral wavelength and the eventual transition into a ferromagnetic state. Our work proposes a realistic platform to observe cavity renormalization effects in magnetic systems.

O 79.2 Thu 10:45 HSZ/0403

Compressing few-cycle optical near fields in the tip-sample junction of a scanning probe microscope — •Sam S. Nochowitz, Tom Jehle, Juanmei Duan, and Christoph Lienau — Institute of Physics, University of Oldenburg, 26129 Germany

Plasmonic nanogaps confine light to dimensions in the nanometer or even sub-nanometer range while simultaneously enhancing the local electromagnetic field strength. This spatial confinement of light led to dramatic advances in nanosensing (1) and tip-enhanced Raman Spectroscopy. So far, the time dynamics of the fields emitted from such nanocavities have achieved little attention. Here, we introduce a broadband interferometric scattering-type SNOM technique to reconstruct amplitude and phase of light scattered from a sharp gold taper acting as a near-field probe. We isolate the near-field that is scattered from the apex and quantitatively measure its time structure (2). The apex field decays within 6 fs, a decay time mainly given by the radiative damping of the apex mode. Upon approaching the tip to a gold surface, the coupling of the apex field to its image dipole results in 2-fold reduction in the decay time to less than 2.7 fs, caused by phase shifts in the apex response, predicted in FDTD simulations (3). Our results pave the way towards linear and nonlinear ultrafast oscilloscopy with nm/fs resolution. (1) R. J. Chikkardy et al., Nature 535, 127 (2016); (2) T. Jehle, submitted (2025). (3) S. Thomas et al. New J. Phys. 17 (2015).

O 79.3 Thu 11:00 HSZ/0403

Symmetry Guidelines of Vacuum Cavity Material Engineering — •Jingkai Quan[1], Chongxiao Fan[1], Benshu Fan[1], I-Te Lu[1], and Angel Rubio[1,2] — [1]Max Planck Institute for the Structure and Dynamics of Matter, Luruper Chaussee 149, 22761, Hamburg, Germany — [2]Center for Computational Quantum Physics, Flatiron Institute, Simons Foundation, New York City, New York, 10010, USA

Cavity material engineering, which manipulates material properties by exploiting vacuum-fluctuating photon modes in dark cavities, is a rapidly advancing field. Despite significant progress, most studies focus on isolated combinations of materials and cavity modes. In this study, based on a comprehensive group theory analysis, we develop a general framework for cavity material engineering with linearly polarized vacuum photon modes. We analyze the symmetry of the effective photon-free Hamiltonian inside dark cavities and establish a complete symmetry-breaking characterization induced by cavity photon modes across all 32 crystalline point groups. Building on this analysis, we predict phenomena such as the degeneracy lifting and emergence of new infrared and Raman spectral features induced by cavity modes. More intriguingly, we reveal a previously overlooked effect: cavity-induced polarization in non-polar crystals, and derive the corresponding tensor forms. These predictions are validated through advanced quantum-electrodynamical density-functional theory (QEDFT) calculations. Our work uncovers the fundamental symmetry principles governing light-matter interactions in the dark cavity and provides a systematic roadmap for future researches in cavity material engineering.

O 79.4 Thu 11:15 HSZ/0403

Low temperature near-field fingerprint spectroscopy of 2D electron systems in oxide heterostructures and beyond — Julian Barnett[1], Konstantin Wirth[1], Richard Hentrich[2], Yasin C. Durmaz[2], Felix Gunkel[3], Marc-Andre Rose[3], and •Thomas Taubner[1] — [1]I. Institute of Physics (IA), RWTH Aachen University — [2]Attocube Systems AG, Munich — [3]PGI-7, Forschungszentrum Jülich

Scattering-type scanning near-field optical microscopy (s-SNOM) is a useful tool for the non-destructive investigation of buried confined electron systems with nanoscale resolution, however, a clear separation of carrier concentration and mobility was often not possible. Here, we predict a characteristic fingerprint response of the LaAlO3/SrTiO3 2DEG in the mid-infrared spectral range, which was not experimentally accessible in the past, and verify this using a state-of-the-art tunable narrow-band laser in cryo-s-SNOM at 8 K [1]. Our modeling allows us to separate the influence of carrier concentration and mobility on fingerprint spectra and to characterize 2DEG inhomogeneities on the nanoscale. We show that our fingerprint spectra are a universal feature and generally applicable to confined electron systems, like topological insulators or stacked van-der-Waals materials.

[1] J. Barnett et al., Nat. Comm. 16, 4417 (2025).

O 79.5 Thu 11:30 HSZ/0403

Tunable skyrmion, meron, and skyrmion bag topologies in surface phonon polariton lattices — •Julian Schwab[1], Florian Mangold[1], Bettina Frank[1], Timothy J. Davis[1,2], and Harald Giessen[1] — [1]4th Physics Institute, Research Center SCoPE, and Integrated Quantum Science and Technology Center, University of Stuttgart, Germany — [2]School of Physics, University of Melbourne; Parkville Victoria 3010, Australia

Surface phonon polaritons (SPhPs) enable nanoscale manipulation of mid-infrared light via deeply subwavelength topological vector textures, such as skyrmions. Achieving dynamic, real-time control over these topological features remains challenging. Here, we theoretically propose and numerically demonstrate an actively tunable platform on a silicon carbide membrane that creates diverse topological lattices, including skyrmions, merons, and skyrmion bags. By exploiting the sublinear SPhP dispersion, we dynamically adjust the excitation wavelength to tune the topological character of the lattices. This allows for the tunability between bubble-type and Néel-type configurations in the electric field and the spin angular momentum. Furthermore, we identify a novel singularity-type meron arising from the interplay of electric and magnetic spin components. This texture exhibits topological charge conservation in moiré superlattices and a spatially confined spin reversal with tunable lateral sizes as low as $\lambda_{\mathrm{SPhP}}/29$. These findings provide a versatile framework for on-chip, reconfigurable topological photonic devices with potential applications in high-resolution imaging and precision metrology.

O 79.6 Thu 11:45 HSZ/0403

Raman Studies of Proximity Effects in Epitaxial Graphene: Emphasis on Strong Light-Matter Coupling — •Zamin Mamiyev, Narmina O.Balayeva, Dietrich R.T. Zahn, and Christoph Tegenkamp — Institut für Physik, Technische Universität Chemnitz

Proximity engineering provides a route to tailor the electronic and vibrational properties of epitaxial graphene without introducing structural disorder. Because phonons and electronic states in graphene are strongly coupled, Raman spectroscopy provides a reliable approach to studying the quasiparticle dynamics and their modification in graphene.

In this work, we investigate how Sn and In intercalation, their nanoscale distributions, and the resulting interfacial reconstructions modify the phonon dynamics of quasi-free monolayer graphene on

SiC(0001), particularly focusing on the plasmonically enhanced light-matter interaction regimes, such as in surface- (SERS) and tip- (TERS) enhanced Raman spectroscopies. Using resonance μ-Raman and TERS, we map the charge doping, electron-phonon coupling, and anharmonicities with high spectral and spatial resolution. Combined with electron diffraction, scanning tunneling microscopy (STM), and atomic force microscopy (AFM), our measurements allow us to study the optical fingerprints of strain, charge transfer, and symmetry-breaking that originate from distinct metal-intercalated interfaces and confined 2D metallic layers [1-2]. [1] Z. Mamiyev et.al., Adv. Optical. Mat. e00979 (2025); [2] Z. Mamiyev et.al., Carbon 234, 120002 (2025)

O 79.7 Thu 12:00 HSZ/0403

Inelastic electron-light interaction probed by holographic scanning transmission electron microscopy — •Tim Dauwe[1,2], Nora Bach[1,2], Murat Sivis[1,2], and Claus Ropers[1,2] — [1]Max Planck Institute for Multidisciplinary Sciences, Göttingen, Germany — [2]4th Physical Institute, University of Göttingen, Germany

Ultrafast Transmission Electron Microscopy (UTEM) is a unique tool to study inelastic electron-light scattering (IELS). Photon-Induced Near-Field Electron Microscopy (PINEM) can now routinely image optical fields at laser-excited nanostructures in magnitude. Phase-resolved imaging is enabled by sequential interactions [1,2]. However, this requires an elaborate geometry with multiple optical interaction stages and offers only limited variability in tailoring the interaction. In this work, we combine IELS with a STEM holography approach, using two spatially separated, coherent electron probes [3]. By recording the interference pattern in the far field behind an electron spectrometer, we get simultaneous access to the energy of the electrons and the phase imprinted during the inelastic interaction. Our results from two interfering quantum walks reveal exotic electron states governed by interaction strengths and relative phase differences. Our approach further enhances the UTEM near field imaging capabilites and enables tailoring of electron states by multiple parallel electron-light interactions.

[1] D. Nabben et al., Nature 619 (2023)
[2] J.H. Gaida et al., Nat. Photon. 18 (2024)
[3] F.S. Yasin et al., J. Phys. D: Appl. Phys. 51 205104 (2018)