O 49: Plasmonics and nanooptics: Light-matter interaction, spectroscopy I

Time: Tuesday 14:30–15:45 Location: HSZ/0403

O 49.1 Tue 14:30 HSZ/0403

Beyond-Dipole Approaches to Generating and Applying Twisted Light — •Esra Ilke Albar[1], Franco Bonafé[1], Valeriia Kosheleva[1], Heiko Appel[1], and Angel Rubio[1,2] — [1]Max-Planck-Institute for the Structure and Dynamics of Matter, Luruper Chaussee 149, 22761 Hamburg, DE — [2]Center for Computational Quantum Physics (CCQ), The Flatiron Institute, 162 Fifth Avenue, New York, New York 10010, USA

We perform numerical electrodynamics simulations where a nanoplasmonic Archimedean spiral is targeted with a circularly polarized, 8-cycle plane wave pulse to probe the generation of twisted pulses, i.e., fields with orbital angular momentum(OAM). We identify mismatches between the generated pulse and the ideal OAM beams, which motivates us to discuss the spatiotemporal optical vortices (STOVs). All realistic electromagnetic fields are finite pulses, while the structural properties of plasmonic OAM generators are often adjusted to the central wavelength. As a next step, we employ a two-particle point charge system to map the local OAM density and confirm the space dependence of the generated pulse. This pushes us to expand beyond the known electric dipole approximation(EDA). We introduce our beyond dipole formalism and present high harmonic generation results computed within this approach.

O 49.2 Tue 14:45 HSZ/0403

Electro-Optic Phonon Polaritons — •Michael S. Spencer[1], Olga Minakova[1], Maximilian Frenzel[1], Joanna M. Urban[1], Martin Wolf[1], and Sebastian F. Maehrlein[1,2,3] — [1]FHI Berlin — [2]HZDR — [3]TU Dresden

Ultrafast control of fundamental excitations and order parameters represents a major driving force for the rising field of terahertz (THz) cavity electrodynamics. However, most efforts to date have not taken full advantage of THz sampling capabilities. By using an electro-optic crystal to fill a cavity, we directly measure intra-cavity electric fields, and polarizations arising from dipole-active excitations, all in the time domain. We identify that under cryogenic conditions, and in high-quality cavities, a polaritonic state is formed from the superposition of cavity photons and optical phonons. We explore the relationship between the light-matter coupling strength and temperature, and between the polariton splitting and cavity quality factor. With our novel electro-optic cavity design, we are able to investigate the detuning-dependence of the strong coupling behavior, obtaining the full picture of light-matter interactions. Furthermore, we reveal fluence-dependent polariton dynamics, indicative of significant coupling beyond the harmonic approximation. This identification of strong light-matter interactions in electro-optic cavities opens an important new testing ground for measuring novel, light-matter-entangled states.

O 49.3 Tue 15:00 HSZ/0403

Femtosecond and attosecond correlations in multi-electron pulses — •Rudolf Haindl[1,2], Valerio Di Giulio[1,2], Armin Feist[1,2], and Claus Ropers[1,2] — [1]Max Planck Institute for Multidisciplinary Sciences, Göttingen, Germany — [2]4th Physical Institute, University of Göttingen, Göttingen, Germany

In femtosecond electron emission from nanoscale field emitters, Coulomb interactions result in structured few-electron states exhibiting strong correlations in energy [1,2], transverse momentum [1], and time [3]. Here, we combine femtosecond-gated, event-based detection with inelastic electron-light scattering to directly map the phase-space distribution of two-electron states [4].

Our experiments reveal a bimodal structure in longitudinal phase space, distinguishing contributions from interparticle interaction and dispersion. Furthermore, we demonstrate that global phase modulation coherently shapes the few-electron distribution to exhibit attosecond temporal correlations. We show how this controlled phasing drives a multi-electron quantum walk, a phenomenon that can be harnessed to produce tailored excitations and super-radiance via two-electron energy post-selection.

[1] R. Haindl et al., Nat. Phys. 19, 1410-1417 (2023).
[2] S. Meier et al., Nat. Phys. 19, 1402-1409 (2023).
[3] J. Kuttruff et al., Sci. Adv. 10, eadl6543 (2024).
[4] R. Haindl et al., Phys. Rev. Lett. 135, 165002 (2025).

O 49.4 Tue 15:15 HSZ/0403

Quantum-electrodynamical density-functional theory for periodic solid-state materials — •Benshu Fan[1], I-Te Lu[1], Michael Ruggenthaler[1], and Angel Rubio[1,2] — [1]Max Planck Institute for the Structure and Dynamics of Matter — [2]Center for Computational Quantum Physics (CCQ), The Flatiron Institute

Quantum-electrodynamical density-functional theory (QEDFT) has emerged as a powerful first-principles framework for describing properties of materials coupled to quantized electromagnetic fields. While it has been successfully applied to capture cavity-induced modifications of electronic structures mainly for atoms and molecules, a consistent treatment of phonon-related and optical properties for periodic solids remains elusive. In this work, we present a unified QEDFT framework that incorporates collective light-matter coupling in the electronic ground state, density functional perturbation theory for phonons, and real-time time-dependent QEDFT for optical excitations. This approach enables ab initio calculations of cavity-modified electronic and phononic dispersions, Born effective charges, dielectric tensors, and both non-resonant and resonant optical absorption spectra for solids. Using wurtzite gallium nitride (GaN) embedded in an optical cavity as an example, we show how the quantized vacuum field reshapes electronic and phononic properties and gives rise to possible experimentally observable signatures in the dielectric function and absorption spectra. Our results establish QEDFT as a general first-principles framework for exploring and predicting cavity-modified properties of quantum materials.

O 49.5 Tue 15:30 HSZ/0403

Anyonic Chern Insulator in Graphene Induced by Surface Electromagnon Vacuum Fluctuations — •Xinle Cheng[1], Emil Viñas Boström[1], Frank Y. Gao[2], Edoardo Baldini[2], Dante M. Kennes[1,3], and Angel Rubio[1,4] — [1]Max Planck Institute for the Structure and Dynamics of Matter, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]Department of Physics, The University of Texas at Austin, Austin, Texas, 78712 — [3]Institute for Theory of Statistical Physics, RWTH Aachen University, 52056 Aachen, Germany — [4]Initiative for Computational Catalysis, The Flatiron Institute, Simons Foundation, New York City, NY 10010, USA

Sub-wavelength cavities have emerged as a promising platform to realize strong light-matter coupling in condensed matter systems. Previous studies are limited to dielectric sub-wavelength cavities, which preserve time-reversal symmetry. Here, we lift this constraint by proposing a cavity system based on magneto-electric materials, which host surface electromagnons with non-orthogonal electric field and magnetic field components. The quantum fluctuations of the surface electromagnons drive a nearby graphene monolayer into an anyonic Chern insulator, characterized by anyonic quasi-particles and a topological gap that decays polynomially with the graphene-substrate distance. Our work opens a path to controllably break time-reversal symmetry and induce exotic quantum states through cavity vacuum fluctuations.