Q 45: Plasmonics and Metasurfaces

Time: Thursday 11:00–13:00 Location: P 3

Invited Talk Q 45.1 Thu 11:00 P 3

Quantum geometry in plasmonic metasurfaces and signatures of collective quantum phenomena — •Javier Cuerda — Institut für Angewandte Physik, TU Darmstadt, Hochschulstraße 4A, D-64289 Darmstadt, Germany — Department of Applied Physics, Aalto University School of Science, Aalto FI-00076, Finland

Plasmonic nanoparticles radiatively coupled in two-dimensional lattices, combined with organic quantum emitters, enable strong light-matter coupling, lasing, and BEC [1]. Their highly dispersive, polarization-dependent band structure, combined with time-reversal-symmetry breaking [2], produces a non-trivial quantum geometry. The organic emitters feature vibrational modes, hinting at novel collective light-matter coupling effects.

We present recent progress on these aspects. We have measured the quantum geometric tensor of a plasmonic lattice, finding a non-trivial quantum metric and a purely non-Hermitian Berry curvature [3]. We also show how vibrational modes affect dynamical superradiance in a cavity [4], enabling studies on collective quantum coherence in plasmonic metasurfaces.

[1] A. I. Väkeväinen, *et al.* Nature Comm. **11**, 3139 (2020).

[2] F. Freire-Fernández, J. Cuerda, *et al.* Nature Phot. **16**, 27 (2022).

[3] J. Cuerda, J. M. Taskinen, N. Källman, L. Grabitz, and P. Törmä. Phys. Rev. Res. **6** (2), L022020 (2024).

[4] L. Freter, P. Fowler-Wright, J. Cuerda, B. W. Lovett, J. Keeling, and P Törmä. Accepted for publication. arXiv:2305.13244 (2025).

Q 45.2 Thu 11:30 P 3

UV-Compatible Mie Void Metasurfaces — •Serkan Arslan, Julian Schwab, Harald Giessen, and Mario Hentschel — University of Stuttgart, 4th Physics Institute

In recent years, metasurface design has increasingly shifted toward dielectric platforms rather than plasmonic systems. While plasmonic resonances are limited by intrinsic ohmic losses in metal nanostructures, high-refractive-index dielectrics support low-loss Mie resonances in the infrared and visible spectral ranges. However, this advantage diminishes in the ultraviolet (UV), where nearly all dielectric materials become highly absorptive at sufficiently high photon energies. Consequently, UV metasurface research has largely focused on identifying wide-bandgap materials with minimal absorption.

Here, we take a different approach based on Mie void resonances, which have emerged as a complementary concept in dielectric nanophotonics. By confining light in air within a high-refractive-index host, Mie voids circumvent material losses and enable dispersion-free resonance tuning extending into the UV.

We introduce polarization-dependent elliptical Mie voids and investigate their polarization-resolved resonances and mode formation. Exploiting this polarization degree of freedom, we fabricate Pancharatnam-Berry (PB) phase metasurfaces on GaAs substrates. These metasurfaces demonstrate 90° off-axis reflective focusing in the visible range with numerical apertures up to 0.25, as well as orbital angular momentum (OAM) generation.

Q 45.3 Thu 11:45 P 3

A new framework for topological plasmonics — •Julius T. Gohsrich[1,2], Norman S. Israel[3], Lora Ramunno[3], and Flore K. Kunst[1,2] — [1]Max Planck Institute for the Science of Light, Erlangen, Germany — [2]Department of Physics, Friedrich-Alexander Universität Erlangen-Nürnberg, Erlangen, Germany — [3]Department of Physics and Nexus for Quantum Technologies Institute, University of Ottawa, Ottawa, Canada

Plasmonics is the study of the interaction between light and free electrons at metal-dielectric interfaces at the nanoscale. A versatile platform in this field are systems of coupled metallic nanoresonators (MNRs), which are for example used to construct metasurfaces for sensing applications. Topological phenomena can provide novel functionalities to the already rich physics of such structures.

I will present a new framework to analyze the topology of coupled MNRs. Having all relevant properties of the constituent MNRs, the properties of the coupled MNR system are encoded in the solutions of a non-Hermitian eigenvalue problem. Employing our method, we analyze a plasmonic SSH model, and compare our results with full-wave numerics. Our approach allows different approximations, resulting in computational efficiency and scalability compared to full-wave numerics, making it a powerful tool for analyzing topological plasmonic structures and shaping our understanding of these. Beyond that, the presented methods allow for the optimization and design of topological plasmonic nanostructures with potential applications in sensing, microscopy and optical communication.

Q 45.4 Thu 12:00 P 3

Periodic light meets periodic matter — •Frieder Lindel[1,2,3], Carlos J. Sánchez Martínez[1,2], Johannes Feist[1,2], and Francisco García-Vidal[1,2] — [1]Departamento de Física Teórica de la Materia Condensada, Universidad Autónoma de Madrid, Spain — [2]Condensed Matter Physics Center (IFIMAC), Universidad Autónoma de Madrid, Spain — [3]Institute for Theoretical Physics, ETH Zürich, Switzerland

Strong light-matter coupling is a key requirement for many quantum technologies, typically achieved through field enhancement in optical cavities or antennas. It leads to the hybridisation of light and matter excitations into polaritons.

In my talk, the concept of crystal polaritons will be introduced [1], which arise when collective excitations of periodic arrays of quantum emitters are strongly coupled to the light modes supported by a metasurface. We will construct an ab initio few-mode quantization scheme for metasurface resonances based on macroscopic quantum electrodynamics, which provides a framework for analyzing the emergence of strong light-matter coupling in metasurfaces and the formation of crystal polaritons. We will see how the interactions between crystal polaritons lead to single photon nonlinearities for extremely low polariton densities, allowing resonant quantum light generation orders of magnitude higher than in state-of-the-art nonlinear metasurfaces.

[1] F. Lindel, C. J. S. Martínez, J. Feist, F. J. Garcia-Vidal, arXiv preprint: arXiv:2508.00797 (2025).

Q 45.5 Thu 12:15 P 3

Interaction of Structured Light with Nanostructured Matter — •Noah Apostolico, Leander Siegle, Luca Schmid, Tim-Dominik Gómez, Mario Hentschel, and Harald Giessen — 4th Physics Institute and Research Center SCoPE, University of Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

Although structured light has been extensively studied, its interaction with nanoscale matter has remained largely unexamined. Here, we demonstrate a symmetry-dependent interaction between structured light and nanostructured absorbers by investigating the orbital-angular-momentum-dependent extinction of gold nanodisk oligomers. Using a rigorous design framework, we fabricate diffractive optical elements via two-photon-polymerization grayscale lithography to generate three distinct flower-like beam modes. Scanning these beams across oligomers of different symmetries reveals that extinction is maximized when the beam and structure share the same rotational symmetry and reduced otherwise. A semi-analytical overlap model reproduces the observed trends with deviations consistently below 10%, confirming the robustness of the symmetry-based interaction mechanism.

Q 45.6 Thu 12:30 P 3

Nanoscale free-electron dynamics in plasmonic nanostructures — •Fabian Scheidler, Jessica Meier, and Bert Hecht — Experimental Physics 5, University of Würzburg, Am Hubland, 97074 Würzburg, Germany

Intense laser pulses give rise to strong-field phenomena, where the external electromagnetic field exceeds the binding field of electrons in matter [1]. At sharp metallic nanotips, this leads to a nonlinear photocurrent driven by multiphoton and strong-field photoemission [2].

Plasmonic nanoantennas fabricated by focused helium ion beam milling from monocrystalline gold microplatelets provide large field enhancements stemming from both an asymmetric nanotip-shaped gap and plasmonic hotspots [3]. Such structures have been shown to yield a geometry-dependent photocurrent across small gaps when driven by a femtosecond Ti:Sa laser in the visible to infrared spectral regime.

Our goal is to employ nanoantenna systems as local electron sources with designed plasmonic near fields for electron control. To describe the free-electron dynamics, we develop a semiclassical simulation scheme to analyze free-electron motion as well as the resulting nonlinear photocurrent.

(1) Dombi, P. et al. Rev. Mod. Phys. 2020, 92, 025003.
(2) Krüger, M. et al. Journal of Physics B: Atomic, Molecular and Optical Physics 2018, 51, 172001.
(3) Meier, J. et al. Advanced Optical Materials 2023, 11, 2300731.

Q 45.7 Thu 12:45 P 3

Near-field metasurfaces for light shaping — •Luca Schmid[1], Julian Schwab[1], Chi Li[2], Kaijian Xing[2], Stefan Maier[2], Harald Giessen[1], Haoran Ren[2], and Mario Hentschel[1] — [1]4th Physics Institute and Research Center SCoPE, University of Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [2]School of Physics and Astronomy, Monash University, Clayton, Victoria, Australia

Plasmonic and dielectric nanophotonic building blocks allow for shaping the flow of light at boundaries and interfaces. They have opened the field of metasurfaces, which until now mostly allow for the creation of nearly arbitrary intensity distributions in the far-field. Drawing inspiration from this concept, we introduce metasurfaces for near-field light shaping. Desired near-field intensity distributions can be created by engineering the distribution of individual scatterers on metallic surfaces and hence the interference of the individually launched surface plasmons. Using this ansatz, we demonstrate metasurfaces which enable to direct, focus, and demultiplex incident light. We implement these structures by a peel-off process from molds, which results in ultra-smooth metallic surfaces, maximizing the plasmon propagation length. Far-field measurements based on a k-space spectroscopy setup allow us to image the local near-field and show excellent agreement with modelling and simulation. We envision that the creation of nearly arbitrary near-field distributions will enable nanoscale routing and sorting of light based on polarization, orbital angular momentum, and wavelength, as well as help realize novel coupling schemes to emitters and nanoscale systems.