O 60: Plasmonics and Nanooptics: Fabrication, Characterization and Applications I

Time: Wednesday 10:30–12:45 Location: H8

O 60.1 Wed 10:30 H8

Infrared beam-shaping via geometric phase metasurfaces with the plasmonic phase-change material In_3SbTe_2 — •Lukas Conrads, Florian Bontke, Matthias Wuttig, and Thomas Taubner — I. Institute of Physics (IA), RWTH Aachen University

Conventional optical elements are bulky and limited to specific functionalities, contradicting the increasing demand of miniaturization and multi-functionalities. Optical metasurfaces enable tailoring light-matter interaction at will, especially important for the infrared spectral range which lacks commercially available beam-shaping elements. While the fabrication of those metasurfaces usually requires cumbersome lithography techniques, direct laser writing promises a simple and convenient alternative. Here, we exploit the non-volatile laser-induced insulator-to-metal transition of the plasmonic phase-change material In_3SbTe_2 (IST) [1] for optical programming of large-area metasurfaces for infrared beam-shaping. We tailor the geometric phase of metasurfaces with rotated crystalline IST rod antennas to achieve beam steering, lensing, and beams carrying orbital angular momenta. Finally, we investigate multi-functional and cascaded metasurfaces exploiting enlarged holography, and design a single metasurface creating two different holograms along the optical axis. Our approach facilitates fabrication of large-area metasurfaces within hours, enabling rapid-prototyping of customized infrared meta-optics for sensing, imaging and quantum information.[2] [1] Heßler et al. *Nat. Com.* **12**, 924 (2021) [2] Conrads et al. *arXiv:2408.05044* (2024)

O 60.2 Wed 10:45 H8

Investigation of lithiated carbon as active plasmonic material system — •Valentin Maile, Mario Hentschel, and Harald Giessen — 4th Physics Institute, University of Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

Active plasmonic structures are integral to recent advancements in optical technologies due to their ability to confine and manipulate light on the nanoscale, enabling the miniaturization of optical devices. A pivotal aspect of future devices is the switchability and tunability of their optical resonances. However, only very few material systems can intrinsically switch the ability of the individual resonator to support plasmonic resonances via a metal-to-insulator transition.

Here, we introduce a novel concept based on lithium-intercalated carbon, a material system widely studied in battery research. The electrically driven, reversible lithium intercalation in the carbon lattice leads to an increase in charge carrier density and a corresponding shift in the optical material properties, visibly changing its color from black to golden. This unique optical modulation demonstrates its potential for integrating dynamic plasmonic functionalities.

In this work, lithiated forms of carbon and their change in optical reflectance are investigated as a switchable material system for plasmonics. Furthermore, we explored multiple fabrication techniques for nanostructuring the material, demonstrating that the nanostructures can be electrically switched while maintaining their structural integrity. This approach promises to expand the toolkit of active plasmonic structures for metasurfaces and nano-optics.

O 60.3 Wed 11:00 H8

Hybrid resonant metasurfaces combining dielectric nanocup metasurfaces and plasmonic networks — Jelena Wohlwend, Anna Hilti, Claudiadele Polinari, Ralph Spolenak, and •Henning Galinski — Laboratory for Nanometallurgy Department of Materials ETH Zurich, 8093 Zurich, Zurich Switzerland

State-of-the-art dielectric metasurfaces commonly consist of geometric primitives, such as cylinders or nanofins, and their integration into hybrid systems is fundamentally limited as confinement of light occurs only in their interior. In this talk, we report on a simple fabrication scheme that unlocks a new degree of freedom in the optical design space, as it enables the design of complex metasurfaces that break the out-of-plane symmetry [1]. We showcase the versatility of this approach on the specific example of nanocup metasurfaces made of amorphous silicon. We outline the extraordinary modal properties of these resonant sub-wavelength structures including confinement of light in air, lattice resonances and optical non-reciprocity. Creating complex hybrid metasurfaces, which combine such ordered silicon nanocups and disordered plasmonic networks [2, 3], we demonstrate that the generation of configurable structural colors can be tailored by the local near-field coupling between the ordered and disordered optical elements.

References: [1] Adv. Optical Mater. 2024, 12, 2401501. [2] Adv. Optical Mater. 2023, 11, 2300568. [3] Nano Letters 2022, 22 (2), 853-859

O 60.4 Wed 11:15 H8

Optical programming of Hyperbolic Phonon Polariton Resonators with the plasmonic phase-change material In_3SbTe_2 — •Aaron Moos, Lina Jäckering, Lukas Conrads, Matthias Wuttig, and Thomas Taubner — I. Institute of Physics (IA), RWTH Aachen University, Germany

Tailoring light at the nano scale is mandatory for creating new nanophotonic devices and is achievable with polaritons. Hexagonal Boron Nitride (hBN), a 2d van der Waals material, hosts Hyperbolic Phonon Polaritons (HPPs) featuring high volume-confinement and low losses [1]. Restricting HPPs to resonators enables ultra-confined resonances, but their fabrication requires cumbersome etching processes [2]. Instead, resonators can be fabricated via optical programming of a phase-change material like In_3SbTe_2 (IST) with a metallic and a dielectric state in the infrared enabling rapid fabrication and reconfigurability. IST resonators combined with surface polaritons on bulk SiC were exploited before [3]. Here, we show optical programming of circular IST resonators below 2d hBN and investigate the HPP mode structures with scattering-type scanning near-field optical microscopy (s-SNOM). Influences of hBN thickness and resonator-size on resonances are studied. Furthermore, we show focussing of free propagating HPPs launched by a crystalline IST structure with tuneable focal length by reconfiguring. Our results enable rapid prototyping of confined polariton resonators for infrared nanophotonics. [1] Dai et al., *Science* **343**, 1125-1129 (2014), [2] Sheinfux et al., *Nat. Mat.* **23**, 499-505 (2024), [3] Conrads et al., *Nat. Com.* **15**, 3472 (2024)

O 60.5 Wed 11:30 H8

Optical Response of High-refractive Index Nanodisk Arrays with Hyperuniform Disorder — •Davy Tesch, Koundinya Upadhyayula, Bodo Fuhrmann, Alexander Sprafke, and Ralf Wehrspohn — Martin Luther University Halle-Wittenberg, 06120 Halle, Germany

Light-scattering metasurfaces with tailored disorder, in particular hyperuniform disorder (HUD), have recently attracted interest in the photonics community. HUD promises several properties that were previously associated only with either periodic or random structures. The combination of the strong diffraction of periodic structures and the broadband spectral response of disordered structures holds promise for tailored light scattering.

In this work, we use a scalable fabrication process to experimentally fabricate HUD nanodisk arrays using hydrogenated amorphous silicon (a-Si:H) optimised for low absorption as the nanodisk material. Optical measurements of such fabricated samples show a strong dependence of the scattering response on the form factor of the individual scatterers and their HUD arrangement, given by the structure factor. By tuning these quantities, we were able to tailor the scattering response. One of the most striking results is the ability of the fabricated samples to suppress scattering at small angles (below 45°) due to the HUD arrangement and to enhance scattering at large angles (up to 80°) due to the dominance of electric dipoles in single a-Si:H scatterers.

We have also studied a more complex system: nanodimers consisting of two stacked nanodisks, separated by a spacer layer.

O 60.6 Wed 11:45 H8

Edge-state imaging of high-precision plasmonic SSH chains — Benedikt Schurr[1], Luisa Brenneis[2], Philipp Kessler[2], Jin Qin[1], Victor Lisinetskii[2], •Matthias Hensen[2], Ronny Thomale[3], Tobias Brixner[2], and Bert Hecht[1] — [1]NanoOptics & Biophotonics Group, Experimental Physics 5, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany — [2]Institut für Physikalische und Theoretische Chemie, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany — [3]Institute for Theoretical Physics and Astrophysics, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

Topological nanophotonics offers the possibility to precisely control nanoscale light–matter interaction via states that are topologically protected from disorder and impurities. A prominent example are Su–Schrieffer–Heeger (SSH) chains, in which the staggered nearest-neighbor coupling strength leads to topologically protected and localized edge states. Here, we present plasmonic SSH chains of nanoslot dipole antennas fabricated by helium ion-beam milling in a single-crystal Au micro-platelet. The chains are characterized by individual antenna distances down to 12 nm, strong coupling amplitudes, and negligible next-nearest-neighbor coupling. Furthermore, the near-field distribution of plasmonic eigenmodes is consistent with the amplitude distribution of the eigenfunctions of a quantum mechanical SSH model. We prove the existence of topological edge states experimentally by imaging corresponding mode patterns with aberration-corrected photoemission electron microscopy (PEEM) under wide-field excitation.

O 60.7 Wed 12:00 H8

Analytical study of Mie void resonances — Timothy J. Davis[1,2], •Julian Schwab[1], Harald Giessen[1], and Mario Hentschel[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

The preferential light scattering at particular wavelengths by mall particles is a well know phenomenon since the introduction of an analytical theory by Gustav Mie in 1908. Over the decades, this theory has helped in understanding, designing, and optimizing a multitude of plasmonic and dielectric nanophotonic systems. Just recently it was shown that Mie scattering can also be observed from voids in high-index dielectric media, such as silicon or gallium arsenide. This phenomenon is particularly counterintuitive as the void sizes are on the order of the resonant wavelength, rendering full-wave simulations and thus a deeper understanding challenging. Here, we present a new analytical model to study and understand the resonance properties of Mie voids. In particular, we derive analytical expressions of the electric field distribution based on solutions of Maxwell's equations for cylindrical holes in the substrate. These solutions are used in a simple three-layer model of the void that gives predictions of the void resonances, the observed spectra, as well as the microscopic appearance. Our model will aid in the future design of Mie-void based systems and applications, such as nanophotonic sensors, metasurfaces, and nanoscale detection.

O 60.8 Wed 12:15 H8

In-situ Plasmonic Sensing of Surfactant Structures — •Esmée Berger[1], Narjes Khosravian[1], Ferry Nugroho[2], Joakim Löfgren[3], Christoph Langhammer[1], and Paul Erhart[1] — [1]Department of Physics, Chalmers University of Technology, Gothenburg, Sweden — [2]Department of Physics, Universitas Indonesia, Depok, Indonesia — [3]Department of Applied Physics, Aalto University, Espoo, Finland

Surfactants play an important role in many areas of chemistry and have immense technological relevance. Their functionality is dictated by their frequently complex phase diagrams, which are very difficult to probe, especially *in situ*. Here, by combining experiment and multiscale modeling, we demonstrate that the structure and dynamics of surfactant layers can be very efficiently probed using plasmonic sensing. Considering a prototypical surfactant-surface system (CTAB on silica), we show that the plasmonic response not only reveals changes in the structure of the surfactant layer as the CTAB concentration varies but also provides access to the kinetics of the phase transition. The approach demonstrated in the present work is minimally intrusive, efficient, and widely applicable. It thus constitutes a very powerful tool for exploring surfactant-surface structures, representing a large step forward in understanding these systems of enormous scientific and technological importance.

O 60.9 Wed 12:30 H8

Optical Sieve for Nanoplastic Detection — •Dominik Ludescher[1], Lukas Wesemann[2], Julian Schwab[1], Julian Karst[1], Shaban B. Sulejman[2], Monika Ubl[1], Ann Roberts[2], Harald Giessen[1], and Mario Hentschel[1] — [1]4th Physics Institute and Research Center SCoPE, University of Stuttgart, Germany — [2]ARC Center of Excellence for Transformative Meta-Optical Systems (TMOS), The University of Melbourne, Australia

Micro- and nanoplastics contaminate marine ecosystems and endanger aquatic life, even in remote locations. These minute synthetic fragments, persisting for hundreds of years, infiltrate the food chain, posing potential health risks due to toxic chemicals. Besides improving the quality of plastic disposal and reducing plastic production, determining the existence of micro- and nanoplastics in aqueous environments like water or blood is essential for biological studies. We present an optical sieve for nanoplastic detection based on the recently discovered Mie void resonances. Our devices are able to detect, size, and count nanoplastic particles by observing apparent color changes of the emitted light in the presence of a sphere in the void. The proposed method profits from its simplicity and only requires a conventional microscope setup with CMOS RGB imaging sensor.