CPP 81: Plasmonics and Nanooptics V: Tunable Structures and Nanoparticles (joint session O/CPP)

Time: Wednesday 15:30–18:15 Location: WIL A317

CPP 81.1 Wed 15:30 WIL A317

Thermally regulated smart mid-infrared modulators enabled by phase-change materials and phase-transition materials — Xinrui Lyu[1], Andreas Hessler[1], Xiao Wang[2], Alfred Ludwig[2], Matthias Wuttig[1], and •Thomas Taubner[1] — [1]Institute of Physics (IA), RWTH Aachen University — [2]Institute for Materials, Ruhr-University Bochum

Phase-change materials (PCMs) and phase-transition materials (PTMs) both show a large contrast in their optical properties upon switching, enabling compact optical components with diverse functionalities like sensing, thermal imaging and data recording. However, their switching properties differ significantly, i.e., non-volatile for PCMs while volatile for PTMs. For the first time, we combined PCMs, $Ge_3Sb_2Te_3$ (GST) or $In_3Sb_1Te_2$ (IST), with the PTM VO_2 as active layers in the design of the smart mid-infrared modulators with switchable absorption, reflection, and transmission. The VO_2 is employed as a dynamic mirror, switching between transmission (semiconducting VO_2) and absorption modes (metallic VO_2) with continuously tuned amplitudes up to 90%. Meanwhile, the PCMs on top of the VO_2 are used either for continuously shifting the absorption peak (up to 1.8 μm) by switching GST or for switching between reflection (R=0.85) and absorption modes (A=0.99) by switching IST. Merging the concepts of static (PCMs) and dynamic (PTMs) thermal modulation, the presented combination of non-volatile PCMs and volatile PTMs empowers new generation optical components like dynamic thermal imaging and optical switches.

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Programmable Phase-Change Plasmonics with $In_3Sb_1Te_2$ — •Andreas Hessler[1], Sophia Wahl[1], Till Leuteritz[2], Matthias Wuttig[1], Stefan Linden[2], and Thomas Taubner[1] — [1]I. Institute of Physics (IA), RWTH Aachen — [2]Physikalisches Institut, University of Bonn

The high optical contrast of non-volatile phase-change materials (PCMs) between their switchable amorphous and crystalline structural phases enables exciting nanophotonic functionalities [1,2]. So far, the employed PCMs mostly have dielectric optical properties in both phases. Now, we introduce the next-generation PCM $In_3Sb_1Te_2$ (IST) for reconfigurable nanophotonics. In contrast to the commonly used PCMs, its optical properties change from dielectric to metallic upon crystallization in the whole infrared spectral range. We show how resonant metallic nanostructures can be directly written and erased in an IST thin film by a pulsed switching laser, enabling direct and reconfigurable lithography. With this new technology, we demonstrate striking resonance shifts of plasmonic nanoantennas of more than 4 μm, a programmable mid-infrared perfect absorber with nearly 90% absorptance as well as screening and nanoscale "soldering" of metallic nanoantennas. Our novel concepts of programmable phase-change plasmonics could enable inexpensive fabrication and improved designs of programmable plasmonic devices for infrared optics, sensing and telecommunications.

[1] M. Wuttig et al., *Nature Photonics* **11**, 465-476 (2017)
[2] F. Ding et al., *Advanced Optical Materials* **7**, 1801709 (2019)

CPP 81.3 Wed 16:00 WIL A317

Tunable Heterostructure Polaritonic Cavity — •Mohsen Janipour[1], Matthias Hensen[2], and Walter Pfeiffer[3] — [1]Fakultät für Physik, Universität Bielefeld, Universitätsstr. 25, Bielefeld 33615, Germany — [2]Institut für Physikalische und Theoretische Chemie, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany — [3]Fakultät für Physik, Universität Bielefeld, Universitätsstr. 25, Bielefeld 33615, Germany

Realizing and designing of tunable cavities at the infrared frequencies is crucial for achieving novel integrated photonic circuits. In the infrared regime, semiconductors like GaAs can support the excitation of surface phonon polaritons in the Reststrahlen band with the ability to tune through carrier concentration. In this study, we explore a novel heterostructure cavity composed of a hollow circular hole drilled in an Ag film which is stacked on a GaAs substrate. We show that this cavity can support two types of resonant modes consisting of circular cavity resonant modes and the surface modes due to the excitation of polaritonic modes in the Reststrahlen band. We indicate that the polaritonic modes can be tuned through controlling the distribution of the substrate*s carriers in the Reststrahlen band.

CPP 81.4 Wed 16:15 WIL A317

Silicon Metasurfaces for Nonlinear Holography and Wavefront Control — •Bernhard Reineke[1], Basudeb Sain[1], Ruizhe Zhao[2], Luca Carletti[3], Bingyi Liu[4], Lingling Huang[2], Costantino De Angelis[5], and Thomas Zentgraf[1] — [1]Department of Physics, Paderborn University, Warburger Straße 100, D-33098 Paderborn, Germany — [2]School of Optics and Photonics, Beijing Institute of Technology, Beijing 100081, China — [3]Department of Information Engineering, University of Padova, 35131 Padova, Italy — [4]Institute of Modern Optics, Department of Physics, Harbin Institute of Technology, Harbin 150001, China — [5]Department of Information Engineering, University of Brescia, 25123 Brescia, ItalyNational Institute of Optics (INO), CNR, 25123 Brescia, Italy

Metasurfaces based on dielectric nanostructures are an ideal platform for nonlinear optical experiments (such as third-harmonic generation). They provide high damage thresholds and strong nonlinear responses; Therefore, many works show progress dielectric metasurfaces with high nonlinear conversion efficiency. However, in achieving nonlinear wavefront control, less progress has been made. Therefore, we show the nonlinear wavefront control for the third-harmonic generation with a silicon metasurface. We choose a geometric phase approach to encode phase gradients and holographic images on a dielectric metasurface. In our experiment, we demonstrate the wavefront control and the multiplexed reconstruction of holograms at the third-harmonic wavelength. Our approach provides a simple principle for designing metasurfaces for nonlinear optical applications with dielectric building blocks.

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Polarization-selective orbital angular momentum multiplexed meta-hologram — •Basudeb Sain[1], Hongqiang Zhou[2], Yongtian Wang[2], Christian Schlickriede[1], Lingling Huang[2], and Thomas Zentgraf[1] — [1]Department of Physics, Paderborn University, Warburger Straße 100, 33098 Paderborn, Germany — [2]School of Optics and Photonics, Beijing Institute of Technology, Beijing, 100081, China

Metasurface holography has the advantage of realizing complex wavefront modulation together with the progressive technique of computer-generated holographic imaging. Despite of having the well-known light parameters, like amplitude, phase, polarization and frequency, the orbital angular momentum (OAM) of a beam can be regarded as another important degree of freedom. Utilizing the orthogonality between different OAM modes and the OAM conservation law, here, we demonstrate orbital angular momentum multiplexed polarization-encrypted holography using a birefringent metasurface. The polarization selectivity of such metasurface relies on the birefringent response of the incident light. The holographic information can only be reconstructed with exact topological charge and a specific polarization state, providing an unprecedented advantage for holographic encryption. By using an incident beam with different topological charges as erasers, we mimic a super-resolution case for the reconstructed image, in analogy to the well-known stimulated emission depletion (STED) technique in microscopy. Such technique can open new avenues for beam shaping, optical camouflage, data storage, and dynamic displays.

CPP 81.6 Wed 16:45 WIL A317

Mode conversion in tilted plasmonic nanocones confirmed by second harmonic imaging — Christoph Dreser[1], Dominik A. Gollmer[1], Godofredo Bautista[2], Xiaorun Zang[2], Dieter P. Kern[1], Martti Kauranen[2], and •Monika Fleischer[1] — [1]Institute for Applied Physics and Center LISA+, Eberhard Karls University of Tübingen, Germany — [2]Laboratory of Photonics, Tampere University, Finland

Plasmonic nanocones offer strong, highly localized near-fields at the cone apex that can be utilized for applications in microscopy and sensing. However, for an efficient excitation of the tip mode the electric field vector of the exciting electromagnetic wave needs to have a significant component parallel to the vertical axis. To enable the excitation of the tip mode under vertical illumination, two processes for the nanofabrication of tilted gold nanocones with defined tip displacements are presented. The asymmetric geometry supports the transformation of an in-plane electric far-field to an out-of-plane plasmonic excitation. Extinction spectra and corresponding simulations will be shown, in which cones with different tilting angles are illuminated under various illumination angles. The tip excitation is confirmed by the nonlinear optical properties of the nanocones observed in second harmonic generation scanning microscopy with cylindrical vector beams.

[C. Dreser et al., Nanoscale 11, 5429 (2019)]

CPP 81.7 Wed 17:00 WIL A317

Hydrogen Sensing with Palladium-based Perfect Absorber under variable ambient pressures — •Ramon Walter[1], Florian Stern[1], Ediz Herkert[1,2], Tobias Pohl[1], and Harald Giessen[1] — [1]University of Stuttgart, Germany — [2]ICFO - The Institute of Photonic Sciences, Castelldefels (Barcelona), Spain

The increasing C02-content makes it necessary to replace the fossil energy carrier by alternative climate-neutral energy sources. Hydrogen has the potential to be one of this new energy sources. However, this gas has a high potential risk when mixed with oxygen. A reliable and sensitive sensor is needed to reduce this risk and safe lives.

Previous works showed that palladium is an ideal material for such a sensor. Nanoparticles made out of palladium will change under hydrogen pressure their lattice constant and consequently their dielectric properties. This will have a measurable influence of their optical properties depending on the hydrogen content in the lattice.

In this work, we investigate the potential of such palladium based perfect absorber devices as hydrogen sensor under different variable ambient pressures, which is required for a number of technically relevant applications. We believe that this should extend the range of possible applications without increasing a potential risk, as the sensor works pure optical and is completely separated by any kind of evaluation electronics. Furthermore, means to shield the sensor from contamination with other gases and the consequences for our sensing geometry are discussed.

CPP 81.8 Wed 17:15 WIL A317

Colloidal quantum dots coupled to electrically connected optical antennas — •Patrick Pertsch, René Kullock, Monika Emmerling, and Bert Hecht — NanoOptics & Biophotonics Group, Experimental Physics 5, University of Würzburg, Germany

Semiconductor quantum dots (QDs) attract a lot of interest due to their tunable light emission, high efficiency and single-photon characteristics. Combining them with optical antennas can not only lead to strong coupling [1] but also to enhanced and directional emission. To achieve that the QDs have to be positioned accurately within the antenna which, in the past, has been realized by complex and time consuming processes [2,3].

Here we report on a much simpler process, utilizing dielectrophoresis, to load the gap of electrically connected antennas with colloidal QDs. The QDs are positioned accurately inside the 30-nm gaps of the antennas, show strong photoluminescence and are promising for electro-optical applications. The reported method allows the preparation of QD-antenna systems within a few minutes.

[1] H. Groß et al., Science Advances 4, eaar4906 (2018)
[2] A. G. Curto et al., Science 329, 930-933 (2010)
[3] E. Tranvouez et al., Nanotechnology 20, 165304 (2009)

CPP 81.9 Wed 17:30 WIL A317

Plasmonic K-Au nanoparticles from helium droplet synthesis — •Roman Messner[1], Daniel Knez[2], Ferdinand Hofer[2], Wolfgang Ernst[1], and Florian Lackner[1] — [1]Technische Universität Graz, Institut für Experimentalphysik, 8010-A — [2]Technische Universität Graz, Institut für Elektronenmikroskopie und Nanoanalytik, 8010-A

We report on experiments on K-Au nanoparticles produced under UHV conditions by synthesis in helium nanodroplets. The particles are fabricated by coagulation of metal atoms after pickup by the cold droplets. The employed experimental techniques encompass in-situ spectroscopy as well as ex-situ investigations via transmission electron microscopy (TEM). Plain K clusters solvated in helium droplets exhibit a strong resonance at about 600 nm. The position of the resonance, thereby, depends on the K partial pressure in the pickup region, i.e. the size of the nanoparticles. After adding a gold shell-layer to the potassium particles, a blue shift of the resonance is observed, towards the well-known localized plasmon resonance of plain Au nanoparticles. An important aspect of our current research is to test the possibility of passivating the highly reactive K clusters with a Au shell, which would allow for the preparation of K-Au nanoparticle decorated substrates that can be investigated outside the UHV. First TEM investigations show promising results, opening up new perspectives for the production of novel material combinations for plasmonics with helium droplet based nanoparticle synthesis.

CPP 81.10 Wed 17:45 WIL A317

Synthesis of plasmonic Ag@ZnO core@shell nanoparticles inside superfluid helium droplets — •Alexander Schiffmann[1], Thomas Jauk[1], Daniel Knez[2], Harald Fitzek[2], Ferdinand Hofer[2], Florian Lackner[1], and Wolfgang E. Ernst[1] — [1]Institute of Experimental Physics, Graz University of Technology, Petersgasse 16, A-8010 Graz, Austria — [2]Institute of Electron Microscopy and Nanoanalysis & Graz Centre for Electron Microscopy, Graz University of Technology, Steyrergasse 17, A-8010 Graz, Austria

Plasmonic Ag@ZnO core@shell nanoparticles in the sub 10 nm size regime have been synthesized in a unique way by employing the helium nanodroplet approach. A peculiarity of this low temperature technique, where the particles are formed within a superfluid helium environment, is the complete absence of solvents and surfactants. Scanning transmission electron microscopy (STEM) and energy dispersive X-ray spectroscopy (EDS) give insight into the composition and structure of the particles, revealing a very uniform thickness and shape of the ZnO shells surrounding the Ag cores. The oxidation state of the shell was investigated by ultraviolet photoelectron spectroscopy (UPS). Photoelectron spectra of Ag@ZnO, ZnO, and Ag nanoparticles have been recorded by two-photon photoelectron (2PPE) spectroscopy. The employed laser with a photon energy of 3 eV is resonant to the localized surface plasmon in Ag. In the case of Ag and Ag@ZnO an excitation of this plasmon gives rise to an increased yield of electrons with high kinetic energy.

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Helium Droplet Mediated Synthesis of Rhodamine B Functionalized Au Nanoparticles — Roman Messner[1], Harald Fitzek[2], Wolfgang E. Ernst[1], and •Florian Lackner[1] — [1]Institute of Experimental Physics, Graz University of Technology, Petersgasse 16, 8010 Graz, Austria — [2]Institute of Electron Microscopy and Nanoanalysis & Graz Centre for Electron Microscopy, Graz University of Technology, Steyrergasse 17, 8010 Graz, Austria

Helium nanodroplets provide a new route for the synthesis of plasmonic nanoparticles. [1] Metal atoms are picked up by the droplets and agglomerate to particles, subsequent deposition on surfaces allows for the fabrication of plasmonic nanoparticle films without any solvents or surfactants. We show that the approach can also be used to produce complexes consisting of a plasmonic nanoparticle surrounded by a shell of molecules on the example of Au particles and rhodamine B. Surface enhanced Raman spectroscopy (SERS) indicates that the formed complexes stay intact after deposition. Our current efforts are geared towards the study of interactions between plasmon oscillations in the metal particles and the attached molecules. Therefore, experiments are carried out in-situ, while the particles are solvated in the helium droplets, employing laser induced fluorescence spectroscopy. The rhodamine B dye molecules are excited by a 532 nm laser, the detected fluorescence signal is found to be strongly quenched as soon as Au nanoparticles are added to the helium droplet.

[1]...Eur. Phys. J. D, 73 (5), 104 (2019)