O 66: Plasmonics and nanooptics: Applications and other aspects II

Time: Wednesday 15:00–17:45 Location: MA 041

O 66.1 Wed 15:00 MA 041

Compact, Cheap, and Fully Optical Nanoplasmonic Gas Detection Scheme Demonstrated by Means of Hydrogen and CO_2 — •Tobias Pohl, Ediz Herkert, Florian Sterl, Nikolai Strohfeldt, and Harald Giessen — 4th Physics Institute and Research Center SCOPE, University of Stuttgart, D-70569 Stuttgart, Germany

Current gas detection systems are often bulky, expensive, and complex. Furthermore, many of these systems use electrical readout that poses a danger as possible ignition source. We introduce a novel general nanooptical gas detection scheme based on a plasmonic perfect absorber. The absorber, consisting of a mirror, a spacer layer and plasmonic disks, absorbs almost all light at a designed wavelength and can incorporate gas-sensitive materials to form a highly efficient detector. The fabrication method of colloidal etching lithography allows for cheap, large area, and mass production. We demonstrate the device capability through detection of hydrogen using palladium nanodisks and carbon dioxide by employing titanium dioxide as gas sensitive spacer layer. Incorporated into a custom-made compact sensing device with a simple combination of LED and photodiode, we studied the time-, concentration-, and temperature-dependent behavior of the fabricated sensor chips. In the future the generality of our platform will also enable us to expand its use to many different other gases by simply exchanging one material.

O 66.2 Wed 15:15 MA 041

Numerical modeling of second harmonic generation in metal nanoantennas — •Josselin Defrance and Thomas Weiss — 4th Physics Institute and Research Centers SCoPE, University of Stuttgart, Germany

Metallic nanoantennas can concentrate light into sub-wavelength volumes resulting in strong nonlinear responses. In order to understand and enhance this nonlinear optical phenomena, numerical methods play a crucial role. Different approaches have been developed to model the nonlinear interaction between the electromagnetic field and matter. The so-called Fourier modal method offers a fast and accurate calculation of far-field responses. It has been shown that the Fourier modal method can be extended in order to calculate the generation of higher harmonics [1,2]. However, convergence problems arise for complex geometries and at metal-dielectric interfaces. Therefore, we have combined this method with adaptive spatial resolution and matched coordinates [3] for calculating the nonlinear optical response of nanostructures with complex geometries. Furthermore, we will present our implementation of the hydrodynamic model in order to account for nonlocal contributions to the second-harmonic generation in metallic nanoantennas [4].

[1] T. Paul et al., J. Opt. Soc. B, Vol. 27, Issue. 5, pp. 1118 (2010).
[2] B. Bai et al., J. Opt. Soc. Am. B 24, pp. 1105-1112 (2007).
[3] T. Weiss et al., Opt. Express 17, pp. 8051 (2009).
[4] T. Paul et al., J. Mod. Opt. 58, 5-6, pp. 438-448 (2011).

O 66.3 Wed 15:30 MA 041

Large-area, disordered perfect absorber with multiple resonances in the visible and near infrared — •Ramon Walter and Harald Giessen — 4th Physics Institute, University of Stuttgart

Plasmonic devices with a very high absorption over a wide wavelength range, so-called perfect absorbers, have the potential for many applications as light trapping, photo catalysis and as black background for novel displays. Such systems show a very high absorption at their resonance, just by optimizing their impedance to vacuum values.

Such perfect absorbers can be fabricated on large-area scale, with low-cost, and a high throughput by using colloidal lithography, where nanospheres acting a mask for a dry-etching process. Due of the randomize dispersion of our nanostructures the absorption of the system remains very high over a wide range of incident angles, nearly independently of the polarization.

In this work, we investigate the potential of such devices for multiple resonances. Using nanospheres of different sizes should lead to various sizes of nanostructures and consequently to multiple resonances independently of the polarization. We investigate the interaction between two neighboring resonances in materials with different plasmonic characteristics, like e.g. gold or copper as typical plasmonic materials and nickel or palladium as representative *bad* plasmonic materials.

We believe that our investigations can lead to several designs with the potential for many applications. Systems with a high absorption over a width wavelength regime are also possible as reflectors for a narrow spectral area.

O 66.4 Wed 15:45 MA 041

Niobium as Alternative Material for Refractory Plasmonics and Hydrogen Sensing — •Shahin Bagheri[1], Nikolai Strohfeldt[1], Audrey Berrier[2], Michael Merker[3], Gunter Richter[4], Michael Siegel[3], and Harald Giessen[1] — [1]4 Physics Institute and Research Center SCoPE, University of Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [2]1 Physics Institute and Research Center SCoPE, University of Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany. — [3]Institute of Micro- and Nanoelectronic Systems, Karlsruhe Institute of Technology (KIT), Hertzstraße 16, 76187 Karlsruhe, Germany — [4]Max-Planck-Institut für Intelligente Systeme, D-70589 Stuttgart, Germany

Niobium is mainly known as a superconductive material, however, it exhibits similar plasmonic properties of noble metals such as gold. We utilize electron beam lithography combined with a plasma etching technique to fabricate nanoantenna arrays of Niobium. Tailoring of the Niobium antenna geometry enables precise tuning of the plasmon resonances from the near to the mid-infrared spectral range. The hydrogen absorptivity as well as high-temperature stability of the antennas has additionally been investigated. Great advantages of Niobium such as superconductivity, high-temperature stability, and hydrogen absorptivity, make Niobium highly attractive for plasmonic devices in the near future.

O 66.5 Wed 16:00 MA 041

Principal component analysis for SEIRA-based monitoring of structural changes in polypeptides — •Rostyslav Semenyshyn[1], Mario Hentschel[1], Jochen Vogt[2], Christian Huck[2], Christoph Stanglmair[3], Tanja Teutsch[4], Cristina Tarin[4], Claudia Pacholski[5], Harald Giessen[1], and Frank Neubrech[1,2] — [1]4th Physics Institute, University of Stuttgart, Germany — [2]Kirchhoff Institute for Physics, University of Heidelberg, Germany — [3]Max Planck Institute for Intelligent Systems, Stuttgart, Germany — [4]Institute for System Dynamics, University of Stuttgart, Germany — [5]Institute of Chemistry, University of Potsdam, Germany

Metal nanoantennas with plasmon resonances tuned to the infrared spectral region are perfectly suited for surface enhanced infrared absorption (SEIRA), which has already been applied to chemical analysis and biochemical sensing. Here, we demonstrate the capability of SEIRA for in-vitro observation of folding and unfolding processes of polypeptides monolayers by monitoring the enhanced amid vibrations of the molecules. As a model system, poly-L-lysine (PLL) was bond to the surface of gold nanoantennas utilizing a mixed monolayer of different thiols. We tuned the length of nanoantennas to be resonant at frequency of the amide-I band of PLL and performed SEIRA measurements in D_2O based solutions. To analyse the folding process, a principle component analysis (PCA) was applied. PCA is a powerful tool for tracking time evolutions in dynamic systems and is sensitive to slight changes. Applying this approach, we monitored the reversible folding and unfolding of PLL in ultra-low concentrations.

O 66.6 Wed 16:15 MA 041

Band structure engineered layered metals for low-loss plasmonics — •Morten Gjerding — DTU Physics, Fysikvej building 311, 2800 Kgs. Lyngby

Plasmonics currently faces the problem of seemingly inevitable optical losses occurring in the metallic components that challenges the implementation of essentially any application. In this work, we show that Ohmic losses are reduced in certain layered metals, such as the transition metal dichalcogenide TaS_2, due to an extraordinarily small density of states for scattering in the near-IR originating from their special electronic band structure. On the basis of this observation, we propose a new class of band structure engineered van der Waals layered metals composed of hexagonal transition metal chalcogenide-halide layers with greatly suppressed intrinsic losses. Using first-principles calculations, we show that the suppression of optical losses lead to improved performance for thin-film waveguiding and transformation optics.

15 min. break

O 66.7 Wed 16:45 MA 041

Geometry optimizaton of optical cavities and plasmonic resonators using quasinormal modes — •Philip Kristensen[1] and Kurt Busch[1,2] — [1]Institut für Physik - Humboldt-Universität zu Berlin, 12489 Berlin. — [2]Max-Born-Institut, 12489 Berlin.

Optical cavity modes and localized surface plasmon polaritons can be conveniently modeled by so-called quasinormal modes (QNMs), defined as the source free solutions to Maxwell's equations with the additional requirement of a radiation condition. The QNMs capture most - if not all - the properties typically expected from open electromagnetic resonators. In particular, the radiative loss and material absorption result in complex resonance frequencies, from which the quality factors Q can be calculated directly. From a modeling perspective, one can use perturbation theory with QNMs to estimate the change in resonance frequency due to small changes in the material making up the resonator. In this work, we present a geometry optimization algorithm for controlled tuning of electromagnetic resonators. At each step of the algorithm, we use QNM perturbation theory to calculate the optimum variational change in the resonator boundary required to iteratively shift the complex resonance frequency towards a desired value. This approach alleviates the need for extensive variational testing at each iteration step and provides a stable and efficient overall improvement of the optimization metric. The resulting resonators show interesting and non-trivial organic shapes and support QNMs with optimized parameters, such as increased Q factors.

O 66.8 Wed 17:00 MA 041

Applications of plasmonic standing waves — Petr Dvořák, Michal Kvapil, Zoltán Édes, Petr Bouchal, Tomáš Šamořil, •Vlastimil Křápek, and Tomáš Šikola — CEITEC, Brno University of Technology, Purkyňova 123, CZ 61200 Brno, Czech Republic

We demonstrate formation of plasmonic standing waves on top of a gold layer. Subwavelength slits fabricated in the gold layer by focused ion beam milling serve as sources of propagating surface-plasmon-polariton waves when illuminated from bottom. By proper arrangement of the slits it is possible to form a desired interference pattern, which is then imaged using scanning near-field optical microscopy (SNOM).

We demonstrate several applications of the plasmonic standing waves. (1) We performed spectroscopic measurements of plasmon interference patterns by an aperture-type SNOM setup equipped with a supercontinuum laser and a polarizer. The series of wavelength- and polarization-resolved measurements, together with results of numerical simulations, then allowed us to identify the role of individual near-field components (in-plane, out-of-plane) in formation of SNOM images [1,2]. (2) We demonstrate (plasmo)luminescence of optical emitters located near the interference maxima. (3) Using spatial light modulator to modify the phase of the wave illuminating the slits we are able to reconstruct the phase of the plasmonic standing wave.

[1] P. Dvořák *et al.*, Nano Lett **13**, 2558 (2013).
[2] P. Dvořák *et al.*, Opt. Express **25**, 16560 (2017).

O 66.9 Wed 17:15 MA 041

Electroluminescence from optical Yagi-Uda antennas — •Maximilian Ochs, René Kullock, Philipp Grimm, Monika Emmerling, and Bert Hecht — NanoOptics & Biophotonics Group, Experimental Physics 5, University of Würzburg, Germany

Light-based on-chip communication promises much higher data transfer rates than conventional electrical circuitry. One promising approach is the use of directional antennas, e.g. Yagi-Uda antennas which are very common in the radio frequency regime. Downscaling these systems to nanometer size would enable directional radiation of light, however, since for these frequencies no conventional electrical generators exist, so far they have only been driven optically [1].

Here, we demonstrate electrically-driven optical Yagi-Uda antennas based on dipole antennas [2], radiating directional with FB-ratios of around 5 dB. Light emission is facilitated by the quantum shot noise of electrons tunneling across the antenna gap upon applying a voltage. The presented fabrication yields a high reproducibility and we show that the directivity as well as the properties of the electroluminescence can be controlled by the antenna geometry. Our work paves the road for wireless communication on the nanometer scale between a set of individual antennas.

[1] A. Curto et al.,*Science 329, 5994 (2010)*
[2] J. Kern et al.,*Nat. Photonics 9, 9 (2015)*

O 66.10 Wed 17:30 MA 041

Influence of surface plasmons on energy dissipation in laser-excited materials — •Pavel N. Terekhin[1,2], Sebastian T. Weber[1], and Baerbel Rethfeld[1] — [1]Department of Physics and Research Center Optimas, University of Kaiserslautern, Erwin-Schroedinger-Strasse 46, 67663 Kaiserslautern, Germany — [2]National Research Centre "Kurchatov Institute", Kurchatov Sq. 1, 123182 Moscow, Russia

In our work we simulate the excitation and decay of surface plasmons during and after ultra-short laser irradiation. In our sample system, surface plasmons can be created in two different ways: at an interface between an absorbing metal and a dielectric coating as well as at edges and defects of a metal surface.

We want to take into account the field enhancement of the electrical field resulting from the surface plasmons. Then, we extend the two-temperature model (TTM) to describe the interaction of hot electrons with an additional plasmon subsystem. The aim is to obtain the time evolution of the energy transfer between plasmons, electrons and the crystal lattice. Our approach will shed light on the fundamental mechanisms of the materials' excitation, and, additionally, it will give promising perspectives for the technological controlling of the nanostructuring of material surfaces.