HL 61: Plasmonics and Nanooptics VII: Applications and Other Aspects

Time: Wednesday 15:00–18:00 Location: TRE Ma

HL 61.1 Wed 15:00 TRE Ma

Hydrogen Sensing using Chemically Grown Plasmonic Nanorods in a Dust-on-Film Geometry — •Domenico Paone[1], Martin Mayer[2], Nikolai Strohfeldt[1], Florian Sterl[1], Tobias König[2], and Harald Giessen[1] — [1]4th Physics Institute and Research Center SCoPE, University of Stuttgart — [2]Institute of Physical Chemistry and Polymer Physics, Dresden

Noble metal nanostructures are able to confine electromagnetic radiation on a subwavelength nanometer scale. The resonant excitation of localized surface plasmons in such nanostructures gives rise to strong light absorption and scattering. These optical properties can be used in a rich variety of practical applications such as gas sensing. In this work, we present a dust-on-film sensing geometry by drop coating gold nanoparticles on active hydrogen absorbing films. The nanoparticles are fabricated by a seed-mediated growth method that enables the synthesis of nanorods with a wide variation of lengths. We employ these nanorods as optical antennas to investigate locally the hydrogen catalysis and absorption of palladium and magnesium films. To study our dust-on-film system, we perform single-particle dark-field spectroscopy on the individual gold nanorods. We are able to find pronounced spectral shifts upon exposure to different hydrogen concentrations, leading the way toward the development of inexpensive chemical reaction sensors with high sensitivity.

HL 61.2 Wed 15:15 TRE Ma

Directional Emission from Active Dielectric Nanoantennas — •Manuel Peter[1], André Hildebrandt[2], Christian Schlickriede[3], Thomas Zentgraf[3], Jens Förstner[2], and Stefan Linden[1] — [1]Physikalisches Institut, University of Bonn, Nußallee 12, D-53115 Bonn, Germany — [2]Department of Electrical Engineering, University of Paderborn, Warburger Strasse 100, D-33098 Paderborn, German — [3]Department of Physics, University of Paderborn, Warburger Strasse 100, D-33098 Paderborn, Germany

Here, we report on the directional light emission from an active dielectric nano antenna. The leaky-wave antennas are made from Hafnium dioxide. Colloidal semiconductor quantum dots with an emission wavelength of 780 nm are deposited with a lithographic technique from an aqueous solution into the feed gap of the antenna. Quantum dots serve as dipole sources. Their fluorescence is guided by the director that acts as a leaky waveguide which emits the light in a narrow angle distribution into the substrate. A reflector is used to increase the efficiency of the antenna. By imaging the back-focal plane of a high NA microscope objective, we can directly map the angular distribution of the fluorescence. In our experiment we observe a strong effect of the antennas with a main lobe of the fluorescence pointing into the substrate with a longitudinal angle of θ=21°. Additionally we will present results on the polarization of the directed light and the change of directivity for antennas with different dimensions. All the measured angular intensity distributions are in good agreement with the numerical calculations.

HL 61.3 Wed 15:30 TRE Ma

Plasmonic analog of electromagnetically induced absorption leads to giant thin-film Faraday rotation — •Dominik Floess, Mario Hentschel, Thomas Weiss, and Harald Giessen — 4th Physics Insitute and Research Centre SCoPE, University of Stuttgart, Stuttgart, Germany

We demonstrate the realization of a hybrid magnetoplasmonic thin film structure that resembles the classical optical analog of electromagnetically induced absorption. In transmission geometry our Au nanostructure embedded in an EuS film induces giant Faraday rotation of up to 14° for a thickness of below 150 nm for $B = 5$ T. Crucial for our achievement is the introduction of EuS as a new material for magnetoplasmonics. At low temperatures, it enables the realization of complex magnetoplasmonic structure geometries, which would not be feasible with commonly used magneto-optic materials. Our concept will lead to important, highly integrated, non-reciprocal photonic devices for light modulation, optical isolation, and magnetic field optical sensing. The simple fabrication of EuS nanostructures also enables more sophisticated and intriguing future designs of magnetoplasmonic systems and three-dimensional magneto-optic metamaterials.

HL 61.4 Wed 15:45 TRE Ma

Anderson localization in disordered plasmonic waveguide arrays — •Cherpakova Zlata, Felix Bleckmann, and Stefan Linden — Physikalisches Institut, Rheinische Friedrich-Wilhelms-Universität Bonn, Nußallee 12, 53115 Bonn, Germany

We report on the observation of Anderson localization in disordered arrays of evanescently coupled dielectric-loaded surface plasmon polariton (SPP) waveguides. The samples are fabricated by negative-tone gray-scale electron beam lithography. On-diagonal disorder is introduced to the arrays by randomly altering the waveguides effective refractive index which is a monotonous function of the waveguide height. Thus, by choosing the maximum variation of the waveguide height we can control the degree of disorder. SPPs were excited by shining a highly focused laser beam on the grating, deposited on top of the central waveguide. The spatial evolution of the SPP field intensity is monitored by real space leakage radiation microscopy (LRM). The corresponding momentum-resolved spectra which reveal the information on the energy spectrum of an equivalent condensed matter system is measured as well by making use of Fourier space LRM. With these techniques we experimentally demonstrate the transverse localization of the SPP with increasing degree of disorder both in real and Fourier space.

HL 61.5 Wed 16:00 TRE Ma

Ultrafast imaging of electric fields around nanostructures — •Jan Vogelsang, Germann Hergert, Petra Gross, and Christoph Lienau — Institut für Physik, Carl von Ossietzky Universität, 26129 Oldenburg, Germany

The combination of high spatial resolution electron microscopes and high temporal resolution laser spectroscopy promises experiments in unexplored spatio-temporal regimes. E.g., many fundamental photoinduced processes such as coherent charge and energy transport phenomena occur on few-fs time scales. However, in today's ultrafast electron microscopes the time resolution is so far limited to ~100fs: The electrons propagate over mesoscopic distances, which gives rise to electron pulse broadening due to dispersion.

Recently, we demonstrated a new, plasmon-driven electron source that tackles this challenge: Adiabatic nanofocusing of surface plasmons on sharply etched metallic tapers concentrates light in a nanometric volume and efficiently induces electron emission. Direct illumination of the emission site is avoided and hence the apex-sample-distance can be chosen arbitrarily small (Nano Lett. 15, 4685, 2015).

Here, we show first ultrafast electron micrographs with few-nm spatial and few-ten-fs temporal resolution. We record an ultrafast change of the electric field near carbon nanostructures after laser excitation. It deflects the probing electrons which directly maps the field distribution to the 2d electron detector. The results prove that the simple, but efficient working principle of a lensless point-projection microscope is ideal for maintaining the ultrashort duration of electron pulses.

HL 61.6 Wed 16:15 TRE Ma

Spectral imaging of topologically protected edge states in plasmonic waveguide arrays — •Felix Bleckmann[1], Andrea Alberti[2], and Stefan Linden[1] — [1]Physikalisches Institut, Rheinische Friedrich-Wilhelms-Universität Bonn, Nußallee 12, 53115 Bonn, Germany — [2]Institut für Angewandte Physik, Rheinische Friedrich-Wilhelms-Universität Bonn, Wegelerstr. 8, 53115 Bonn, Germany.

The Su-Schrieffer-Heeger (SSH) model, i.e., a chain of lattice sites coupled via alternating strong and weak bonds, is the prototypical one-dimensional system with nontrivial topological character. It supports two different dimerizations with distinct topological properties. At any interface between both, one topologically protected edge state exists.

We report on the observation of topologically protected edge states in evanescently coupled plasmonic waveguide arrays employed to implement the SSH model. The arrays are fabricated on top of a gold film by negative-tone grey-scale electron-beam lithography. Alternating strong and weak bonds were realized by choosing two different separations between neighboring plasmonic waveguides. We created an interface between the two dimerizations of the SSH model by repeating the larger separation twice.

Surface plasmon polaritons are excited directly at the interface. Their spatial evolution as well as their momentum-resolved spectra are measured by making use of real and Fourier space leakage radi-

ation microscopy. We demonstrate that the topologically protected edge state is localized at the interface and has a midgap position in the momentum-resolved spectrum.

HL 61.7 Wed 16:30 TRE Ma

Resonant Plasmonic Antenna-Enhanced Far-IR and Terahertz Spectroscopy — •Ksenia Weber[1], Maxim Nesterov[1], Thomas Weiss[1], Michael Scherer[2], Mario Hentschel[1], Jochen Vogt[3], Christian Huck[3], Weiwu Li[4], Martin Dressel[4], Harald Giessen[1], and Frank Neubrech[3] — [1]4th Physics Institute, University of Stuttgart, Stuttgart — [2]InnovationLab GmbH, Heidelberg, Germany — [3]Kirchhoff Institute for Physics, Heidelberg University, Germany — [4]1st Physics Institute, University of Stuttgart, Stuttgart

Terahertz spectroscopy is a technique with a vast range of sensing applications, based on material-specific absorption features of molecular vibrations. However, the low absorption cross section of these excitations strongly limits its sensitivity. The possibility to increase the sensitivity of spectroscopic methods via the enhanced electromagnetic near fields provided by plasmonic nanoantennas has been shown before for surface-enhanced infrared spectroscopy (SEIRA). In the present work we transfer the concept of SEIRA to single digit terahertz frequencies. We use plasmonic nanoantennas for the enhancement of molecular vibrations with frequencies in a spectral region from 4.5 to 45 THz We therefore fabricated arrays of rectangular gold antennas by electron beam lithography and coated them with thin layers of the fullerenes C_{60} and C_{70}, as well as the amino acid threonine. The samples were investigated with Fourier transform infrared spectroscopy using a bolometer as detector. An increased SEIRA enhancement of one two orders of magnitude is found for antennas resonant at 6.7 THz when compared to 45 THz, corresponding to a λ^3 scaling.

HL 61.8 Wed 16:45 TRE Ma

Watching hydride formation in single plasmonic magnesium nanoparticles — •Florian Sterl, Heiko Linnenbank, Nikolai Strohfeldt, and Harald Giessen — 4th Physics Institute and Research Center SCoPE, University of Stuttgart, Germany

Magnesium (Mg) has recently demonstrated its potential for active plasmonics in the visible wavelength range via the absorption of hydrogen. We have shown that this can be achieved by using Mg nanoantennas with a catalytic palladium (Pd) capping layer. Upon hydrogenation, Mg forms non-metallic magnesium hydride (MgH_2). In this system, the plasmonic resonance can be switched off and back on via exposure to hydrogen and oxygen gas, with switching times on the order of tens of seconds. On one hand, this leads to potential applications such as tunable plasmonic displays. On the other hand, the system can be used to investigate the hydrogenation of Mg.

MgH_2 is considered a promising candidate for solid-state hydrogen storage, owing to its high hydrogen content of up to 7.6 wt%, and can also be considered a model system for other energy storage materials. We aim for a better understanding and characterization of the hydrogen diffusion in Mg at the nanoscale, using different techniques: We investigate the time dynamics of the Mg-MgH_2 phase transition using the optical far field of Mg/Pd nanoantennas, and probe the optical near field of individual Mg nanostructures to observe the evolution of hydrogenated domains during this transition. We furthermore address the mechanical deformation due to the hydrogen-induced expansion of the Mg crystal lattice.

HL 61.9 Wed 17:00 TRE Ma

Palladium Nanopatches - Size-dependent Hydrogen Kinetics — •Nikolai Strohfeldt[1], Florian Sterl[1], Ronald Griessen[2], and Harald Giessen[1] — [1]4th Physics Institute and Research Center SCoPE, University of Stuttgart, Stuttgart, Germany — [2]Faculty of Sciences, Division of Physics and Astronomy, VU University, Amsterdam, The Netherlands

Nanoparticles exhibit many potentially interesting properties that are relevant for key applications such as storage of energy in batteries or data in non-volatile memories. Especially the storage of hydrogen in nanomaterials has stimulated the development of powerful new investigation methods. Electron-beam lithography makes it possible to create essentially monodisperse ensembles of particles, which can conveniently be studied with optical and plasmonic methods. In nanoparticles, H desorption occurs fully coherently only for small crystalline nanocubes (typically smaller than 50 nm) at temperatures sufficiently close to the critical temperature. For larger particles, it is partially incoherent, where dilute α-PdH_x and high concentration β-PdH_x phases coexist. In polycrystalline particles, larger than 200 nm, the H absorption occurs at much lower pressures than in nanocubes. With a newly developed localized surface plasmon resonance method we succeeded in determining the size dependence of the hydrogen induced in-plane and out-of-plane expansion. With increasing size the in-plane expansion of these particles is increasingly hampered. The knowledge gathered with Pd-H nanoparticles is at the basis of recent developments of active plasmonic elements based on the Y-H and Mg-H systems.

HL 61.10 Wed 17:15 TRE Ma

Polaronic nature of charge carriers at the LAO/STO interface — •Vladimir N. Strocov[1], Claudia Cancellieri[2], Adrian Husanu[1], Ulrich Ashauer[3], and Andrey Mishchenko[4] — [1]Swiss Light Source, Paul Scherrer Insitute, Switzerland — [2]EMPA, Switzerland — [3]University of Bern, Switzerland — [4]RIKEN Center for Emergent Matter Science, Japan

2D electron system emergent at the paradigm buried oxide interface $LaAlO_3/SrTiO_3$ (LAO/STO) is explored with soft-X-ray ARPES, which combines resolution in electron energy and momentum with enhanced probing depth and chemical specificity [1]. Accentuated with resonant photoexcitation of the interface Ti^{3+} ions, ARPES response of the interface charge carriers resolves the manifold energy band structure of t_{2g}-derived subbands formed in the interface quantum well. The temperature dependent peak-dip-hump spectral lineshape manifests polaronic nature of the interface electrons, where the breathing-mode LO3 phonon at 118 meV limits low-temperature mobility of the interface charge carriers, and the polar TO1 one, changing its frequency from 18 to 14 meV across the antiferrodistortive phase transition, causes a dramatic mobility drop with temperature [2]. Doping with oxygen vacancies, affecting electron-phonon coupling, opens ways to tune the interfacial mobility at oxide interfaces in view of their potential device applications.

1. V.N. Strocov *et al*, Synchr. Rad. News 27, N2 (2014) 31
2. C. Cancellieri *et al*, Nature Comm. 7 (2016) 10386

HL 61.11 Wed 17:30 TRE Ma

Attosecond time-resolved photoelectron spectroscopy of hybrid nanoresonators — •Julia Hengster and Thorsten Uphues — ARS, CFEL, Luruper Chaussee 149, 22761 Hamburg

Understanding plasmons as collective oscillations of the free-electron gas density important questions related to their propagation, damping, charge and energy localization came up. Nevertheless the behaviour of hybrid nanostructures approaching the monolayer limit raises a new type of questions concerning their plasmonic behaviour in space and time, following the complex dynamics of the electromagnetic field.

Attosecond time-resolved experiments are on the way to resolve subcycle electron dynamics from plasmonic interaction of ultrashort driving pulses in surfaces and nanostructures. Our approach of attosecond photoscopy demonstrates a reliable route to extend attosecond technology to surface and nanostructure dynamics. Hybrid nanostructures exhibit complex plasmonic properties sensitive to parameters as geometrical aspect ratios or material compositions. Vertically aligned disk nano-resonators belong to a group of tailored systems demonstrating field enhancement with strong localization. We found a remarkably sensitive behaviour in the coupling of surface and bulk plasmons with respect to the outer geometry of the resonators with ultrafast subcycle dynamics.

As proof-of-concept we demonstrate attostreaking from gold films with significant deviation to gas-phase streaking. Furthermore we developed non-destructive preparation procedures for nanoparticle samples as requirement for attosecond photoscopy.

HL 61.12 Wed 17:45 TRE Ma

Monitoring of structural changes of polypeptides using resonant surface enhanced infrared spectroscopy — •Rostyslav Semenyshyn[1], Mario Hentschel[1], Jochen Vogt[2], Christian Huck[2], Christoph Stanglmair[3], Claudia Pacholski[3], Frank Neubrech[1,2], and Harald Giessen[1] — [1]4th Physics Institute, University of Stuttgart — [2]Kirchhoff Institute for Physics, University of Heidelberg — [3]Max Planck Institute for Intelligent Systems, Stuttgart

Infrared (IR) vibrational spectroscopy is a powerful tool for the identification of chemical and structural composition of molecules. Its detection limit can be improved by several orders of magnitude using surface-enhanced IR absorption (SEIRA) with resonant nanoantennas. Here, we demonstrate the capability of SEIRA for the ultra-sensitive detection of minute amounts of a polypeptide, namely poly-L-lysine (PLL). Furthermore, we applied SEIRA to monitor structural changes

of the molecules introduced by injecting sodium dodecyl sulfate as well as varying the pD value. For this purpose, we functionalized nanoantenna arrays with mercaptoundecanoic acid (MUA) and mercaptoundecanol (MUoL) in order to bind PLL molecules to the gold surface. The combination of MUA and MUoL ensures a sufficient flexibility, allowing for structural changes. Such changes are detected based on a detailed analysis of the amide-I vibrations. Hence, we tuned the plasmonic resonances of nanoantennas to the amide-I band of PLL and performed in-vitro SEIRA measurements in D_2O based solutions. Following this approach, we monitored the reversible change between α-helix and β-sheet structural states of PLL in low concentrations.