

O 90: Sensing, Active Structures and other Applications

Time: Thursday 15:00–18:30

Location: MA 144

O 90.1 Thu 15:00 MA 144

Active Plasmonics using Molecular Switches — ●MALTE GROSSMANN¹, ALWIN KLICK¹, CHRISTOPH LEMKE¹, MEHDI HEDAYATI KESHAVARZ², AHNAF USMAN ZILLOHU², JACEK FIUTOWSKI³, ARKADIUSZ GOSZCZAK³, JACOB KJELSTRUP-HANSEN³, MADY ELBAHRI², FRANZ FAUPEL², HORST-GÜNTER RUBAHN³, and MICHAEL BAUER¹ — ¹Institute for Experimental and Applied Physics, University of Kiel, Germany — ²Faculty of Engineering, NanoSYD, University of Kiel, Germany — ³Mads Clausen Institute, NanoSYD, University of Southern Denmark, Denmark

Photochromic molecules have been successfully used in the past to achieve reversible control of optical transmission [1] and plasmonic damping [2] at metal-dielectric interfaces. In this paper we provide experimental evidence that in the same manner also the propagation of surface plasmon polaritons (SPP) can be steered. Switchable metal-dielectric interfaces are prepared from a gold substrate coated with polystyrene films doped with spirophenanthrooxazine molecules. Changes in the SPP dispersion relation at illumination with light of different wavelength are measured using photoemission electron microscopy [3] evidencing a substantial and reversible switching of SPP group and phase velocity. The results imply the realization of non-volatile plasmonic switching units providing new and complex functionalities.

[1] M. Jamali et al., *Adv. Materials* 23 (2011), 4243.[2] R.A. Pala et al., *Nano Lett.* 8 (2008), 1506.[3] C. Lemke et al., *Appl. Phys. B* 116 (2013), 585.

O 90.2 Thu 15:15 MA 144

Active mid-IR plasmonic metasurfaces: Tunable and switchable chirality and flat-surface beam steering — ●XINGHUI YIN¹, MARTIN SCHÄFERLING¹, ANN-KATRIN MICHEL², ANDREAS TITTL¹, MATTHIAS WUTTIG², THOMAS TAUBNER², and HARALD GIESSEN¹ — ¹4. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart — ²1. Physikalisches Institut (IA), RWTH Aachen, Sommerfeldstr. 14, 52074 Aachen

The first metamaterials were fully static, i.e., their geometrical and therefore optical properties were predefined by their design. In order to gain greater control over the effective material behavior, it is desirable to introduce handles that allow for subsequent tailoring of certain material properties. In this work, we demonstrate a tunable and switchable mid-IR chiral metamaterial that utilizes the particularly transparent representative Ge₃Sb₂Te₆ (GST-326) of the chalcogenide phase change material family. When this material is brought into proximity with a plasmonic nanoantenna, the difference in the dielectric environment leads to a large spectral shift (19%) of the plasmon resonance position. Hence, a suitable combination of this material with a chiral metamaterial leads to a shifting circular dichroism signal. Additionally, we demonstrate that precise design of a passive bias-type layer superimposed on the active metamaterial achieves the effect of enantiomer switching. Furthermore, we explore plasmonic beam steering using active plasmonic metasurfaces to emphasize the versatility of hybrid metamaterials comprising plasmonic elements and phase change materials.

O 90.3 Thu 15:30 MA 144

Light-induced field enhancement in polyacenes — ●LUCA BURSI^{1,2}, ARRIGO CALZOLARI^{2,3}, STEFANO CORNI², and ELISA MOLINARI^{1,2} — ¹Dipartimento di Fisica, Informatica e Matematica, Università di Modena e Reggio Emilia, I-41125 Modena, Italy — ²Istituto Nanoscienze CNR-NANO-S3, I-41125 Modena, Italy — ³Department of Physics, University of North Texas, Denton, TX 76203

High attention has been devoted recently to the optical, absorption and plasmonic properties of C-based nanostructures (i.e., graphene-derived), in view of their possible applications as sensors, amplifier antenna and light harvesting devices, alternative to standard metallic systems (e.g. Au, Ag). The way the excitation properties transform, scaling down from macro- to nano-systems, is far from being understood, and it is a field of great current interest.

Using (TD)DFT first-principles approaches, we studied the electric field enhancement in single and coupled polyacene molecules, upon illumination [1]. We demonstrate that optical transitions may generate oscillating dipolar response charge, giving rise to an induced electric

field near the molecule, which thus acts as a plasmon-like nanoantenna. While the field amplification in the vicinity of single acenes is rather small and decreases when the size of the system is increased, it may be selectively enhanced in the case of acenes' assemblies. This paves the way for the design of more complex C-based architectures explicitly conceived to improve the amplification factor.

[1] L. Bursi et al., *ACS Photonics*, 1, (2014) 1049.

O 90.4 Thu 15:45 MA 144

Tunable and switchable thin film Faraday rotation in magnetoplasmonic waveguides: experiments and coupled oscillator model — ●DOMINIK FLOESS¹, THOMAS WEISS¹, SERGEI TIKHODEEV², and HARALD GIESSEN¹ — ¹4th Physics Institute and Research Centre SCOPE, University of Stuttgart, 70569 Stuttgart, Germany — ²A. M. Prokhorov General Physical Institute, Russian Academy of Sciences, 119991 Moscow, Russia

A static magnetic field can alter the optical response of materials. For instance, an external magnetic field is capable of changing the rotation of polarization by a layer of magneto-optical material, which is termed Faraday effect in transmission geometry and polar Kerr effect in reflection geometry. Faraday rotators are of high practical interest because of their application in magnetic field sensing, optical modulation and, most importantly, as core elements in optical isolation devices. The highly demanded miniaturization of such devices is usually limited by insufficient rotation capabilities of available magneto-optical materials. We experimentally and theoretically demonstrate the enhancement of thin-film Faraday rotation in EuSe-Au nanostructures exhibiting waveguide-plasmon-polaritons. A rotation tuning range of 8.4 deg is achieved for magnetic fields of 5 T at 30 K. The waveguide material EuSe provides strong magnetooptical response and simple fabrication which is desirable for further studies in the emerging field of magnetoplasmonics. Using a classical harmonic oscillator model, we are able to obtain profound understanding of the magneto-optical response of the hybrid structures.

O 90.5 Thu 16:00 MA 144

Correlation between near-field distribution and enhanced magneto-optical Kerr effect in a patterned magnetoplasmonic Ni sample — ●MARKUS ROLLINGER¹, EVANGELOS PAPAIOANNOU¹, PHILIP THIELEN¹, PASCAL MELCHIOR¹, BJÖRN OBRY¹, EMIL MELANDER², ERIK ÖSTMAN², VASSILIOS KAPAKLIS², MIRKO CINCHETTI¹, and MARTIN AESCHLIMANN¹ — ¹Physics Department and OPTIMAS, University of Kaiserslautern, Germany — ²Department of Physics and Astronomy, Uppsala University, Sweden

The combination of magnetic and plasmonic nanostructures can be used to modify magneto-optical properties leading to an enhancement of the observed polar and transverse magneto-optic Kerr effect (MOKE) [Opt. Expr. 19,23867]. Thin metallic film with a periodic array of holes are a commonly used structure exhibiting extraordinary optical properties due to the presence of plasmonic excitations [Nature 391,667].

We investigate Si / Ti (2 nm) / Ni (100 nm) / Au (2 nm) samples that are patterned with a two-dimensional hexagonal array of holes (anti-dots) with a diameter of $d = 275$ nm and a pitch size of $a = 470$ nm. The magnetic Ni layer gives rise to a MOKE signal while the periodic nanopattern in principle supports surface propagating plasmons (SPP). We show the correlation between the enhanced MOKE signal and the electric near-field distribution, which is spatially detected by photoemission electron microscopy (PEEM) for different excitation wavelengths and polarization directions with respect to the anti-dot lattice geometry.

O 90.6 Thu 16:15 MA 144

Plasmonic chirality and chiral sensing: effects and limitations — ●MAXIM NESTEROV, XINGHUI YIN, MARTIN SCHÄFERLING, THOMAS WEISS, and HARALD GIESSEN — 4th Physics Institute and Research Centre SCOPE, University of Stuttgart, 70550 Stuttgart, Germany

Objects which cannot be superimposed with their mirror image are called chiral. Many bio-molecules such as, e.g., the essential amino acids are chiral. One common method to probe their chiral nature is the interaction with circularly polarized light, which leads to a dif-

ference in the absorption depending on both the handedness of the molecule and that of the light. However, this so-called circular dichroism (CD) signal is small for most molecules, which renders such analysis rather challenging, especially when small volumes should be probed.

It has been suggested to use plasmonic structures to enhance the light-matter interaction of the chiral analyte. Following this approach, we present thorough numerical investigations of the electrodynamic interaction between chiral media and chiral plasmonic structures in planar as well as in three-dimensional configurations. We find that chiral plasmonic resonances can significantly enhance the chiral response of bio-molecule solutions. A detailed analysis of the CD enhancement mechanisms shows the dominating role of induced chirality.

O 90.7 Thu 16:30 MA 144

Poly-peptide sensing with nanoantenna-assisted surface-enhanced infrared spectroscopy — ●ROSTYSLAV SEMENYSHYN¹, FRANK NEUBRECH¹, FELIX WEIHER¹, CHRISTOPH STANGLMAIR², CLAUDIA PACHOLSKI², and HARALD GIESSEN¹ — ¹4th Physics Institute and Stuttgart Research Center SCoPE, University of Stuttgart — ²Department of New Materials and Biosystems, Max Planck Institute for Intelligent Systems, University of Stuttgart

Surface-enhanced infrared absorption (SEIRA) which uses the enhanced electromagnetic near-fields of resonantly excited metal nanoantennas is a powerful technique to detect minute amounts of molecular substances based on their material-specific vibrations. We used mercaptoundecanoic acid (MUA) functionalized nanoantennas in order to selectively bind poly-L-lysine to gold surface and covered other nanoantennas with specially designed collagen peptides. A tailored flow cell was used to allow for the control of molecular adsorption on the nanostructures and in-situ SEIRA in aqueous solutions. For antennas with different lengths the plasmonic resonance coincides with the amide I and amide II bands of the poly-peptides. Depending on the ratio of the vibrational and plasmonic excitation we observe differently enhanced vibrational amide signals with Fano-type line shapes, confirming the plasmonic nature of the enhancement. In comparison to conventional infrared spectroscopy, such vibrational signals are enhanced by up to four orders of magnitude. This opens up the pathway towards studies of single layers of proteins and their folding behavior.

O 90.8 Thu 16:45 MA 144

Resonant optical antennas for directional Raman studies of carbon nanotubes — ●NICOLA PARADISO, FATEMEH YAGHOBIAN, CHRISTOPH LANGE, TOBIAS KORN, CHRISTIAN SCHÜLLER, RUPERT HUBER, and CHRISTOPH STRUNK — Institut für Experimentelle und Angewandte Physik, University of Regensburg

We use optical nano-antennas in order to manipulate light on the sub-wavelength scale. These nanoplasmonic excitations allows us to fully control both amplitude and polarization direction for the incident and scattered light in micro-Raman experiments. Our directional antennas are particularly promising when applied to carbon nanotubes (CNTs), owing to the strongly anisotropic optical behavior of CNTs. In particular nano-antennas enable the Raman characterization of individual CNTs that would be otherwise not optically detectable. Our experimental results are discussed together with numerical simulations which reproduce the observed amplification and rotation of the incident optical field.

O 90.9 Thu 17:00 MA 144

Plasmonic copper nanodisks for monitoring electrochemical redox-reactions — ●VENLA MANNINEN, NIKOLAI STROHFELDT, FLORIAN STERL, and HARALD GIESSEN — 4th Physics Institute and Research Center SCoPE, University of Stuttgart, 70550 Stuttgart, Germany

Oxidation of copper under air-exposure has been studied well in colloidal films. As a noble metal, copper nanoparticles can produce strong localized surface plasmon resonances (LSPRs) when illuminated at the resonance frequency. Thus, a few reports have shown that the oxidation of copper nanoparticles can be monitored as changes in the spectral position and intensity of their LSPR.

Furthermore, electrochemical redox-reactions of copper in alkaline solutions have been studied in colloidal films. We therefore fabricated copper nanodisks with a very narrow homogeneous size distribution via colloidal hole-mask lithography on conductive substrates. The plasmonic behaviour of these structures was investigated via absorption and scattering spectroscopy in a bright field microscope. The changes in the LSPR of our copper nanodisks were monitored during their electrochemical oxidation and reduction reactions.

Since copper is widely used as catalyze in various chemical reactions, it is highly interesting to investigate the plasmonic response to (photo-)chemical reactions taking place on the surface of single particles, observable in dark-field microscopy. Potential applications of this principle include the plasmonic detection of electrochemically induced reactions on metal catalyze.

O 90.10 Thu 17:15 MA 144

Bimetallic plasmonic nanosensors: DNA self-assembly and core-shell nanocrystals — ●ANDREAS TITTL¹, NA LI², DOMENICO PAONE¹, SONG YUE³, CHEN SONG², JUSTUS BACK⁴, SABINE LUDWIG⁴, BAOQUAN DING², NA LIU³, and HARALD GIESSEN¹ — ¹4th Physics Institute and Research Center SCOPE, University of Stuttgart, Germany — ²National Center for Nanoscience and Technology, Beijing, China — ³Max Planck Institute for Intelligent Systems, Stuttgart, Germany — ⁴IPOC - Functional Polymers, University of Stuttgart, Germany

We present DNA-assembled bimetallic plasmonic nanostructures and demonstrate their application for the all-optical detection of hydrogen. Gold (Au) nanorods are functionalized with DNA strands, which serve both as linkers and seeding sites for the growth of palladium (Pd) nanocrystals and facilitate reliable positioning of Pd satellites around a Au nanorod at an ultrashort spacing in the nanometer range. Dark-field scattering spectra of single Au-DNA-Pd nanorods were recorded during controlled cycles of hydrogen gas exposure, and an unambiguous concentration-dependent optical response was observed. Our method enables, for the first time, the all-optical detection of hydrogen-induced phase-change processes in sub-5 nm Pd nanocrystals at the single-antenna level. By substituting the Pd satellites with other functional materials, our sensor platform can be extended to plasmonic sensing of a multitude of chemical and biological reagents, both in liquid and gaseous phases. Furthermore, we demonstrate core-shell Au-Pd nanocrystals with hydrogen-induced spectral shifts exceeding 100 nm.

O 90.11 Thu 17:30 MA 144

Magnesium for UV plasmonics and chemical reaction sensing — ●FLORIAN STERL, ANDREAS TITTL, NIKOLAI STROHFELDT, RAMON WALTER, and HARALD GIESSEN — 4th Physics Institute and Research Center SCoPE, University of Stuttgart, Pfaffenwaldring 57, D-70550 Stuttgart, Germany

Plasmonic structures with resonances in the visible and NIR region can be fabricated from various metals and have been investigated extensively. However, fabricating structures with resonances in the blue and UV region presents a much more challenging task. A promising candidate for UV plasmonics is magnesium, with predicted resonances below 350 nm at intensities comparable to those found for silver. For this reason, we fabricated magnesium nanoantennas via colloidal hole-mask etching as well as electron beam lithography and subsequent electron beam physical vapour deposition. The plasmonic behaviour of these structures was investigated via absorption and scattering spectroscopy. Since Mg is a highly reactive metal, it is highly interesting to investigate the plasmonic response to chemical reactions taking place on the particle surface. To do this experimentally, we continuously record the spectrum of Mg particles during exposure to controlled environments with varying atmospheric contaminants. In this way, we are able to monitor, over extended periods of time, the modification of Mg structures due to oxidation, carbonization, water absorption from humid air, and hydrogen uptake. Potential applications of this principle include the plasmonic detection of various atmospheric compounds.

O 90.12 Thu 17:45 MA 144

Strip Gratings for Surface Enhanced Infrared Absorption Spectroscopy (SEIRAS) — ●TOBIAS MASS¹, TAO WANG¹, VU HOA NGUYEN², UWE SCHNAKENBERG², and THOMAS TAUBNER^{2,3} — ¹I. Institute of Physics (IA), RWTH Aachen University — ²Institute of Materials and Electrical Engineering I, RWTH Aachen University — ³Fraunhofer Institute for Laser Technology (ILT)

Metallic nanoantennas efficiently couple light into a region of subwavelength size. Antenna arrays designed for surface enhanced infrared absorption spectroscopy (SEIRA) enable the detection of molecular vibration with high sensitivity [1-3]. In a previous publication we demonstrated the spectral tuning of gold strip grating resonances by changing the period and demonstrated significant enhancement of a PMMA absorption band [4]. In this contribution, the spectral response as well as the local near field enhancement of the gratings are analysed via FTIR spectroscopy and FDTD simulations, respectively. Especially the dependence of local field enhancement on the strip width of the gratings

as well as the influence of different incident angles is investigated.

- [1] Adato et al. *PNAS* **2009** 106(46), 19227-19232
- [2] K. Chen et al. *ACS Nano* **2012** 6, 7998-8006
- [3] Neubrech et al. *Phys. Rev. Lett.* **2008** 101, 157403
- [4] Wang et al. *Opt. Express* **2013** 21(7), 9005-9010

O 90.13 Thu 18:00 MA 144

Fabrication of plasmonic nanoantennas by femtosecond direct laser writing lithography - effects of near field coupling on SEIRA enhancement — ●FRANK NEUBRECH, SHAHIN BAGHERI, KSENIA WEBER, TIMO GISSIBL, and HARALD GIESSEN — 4th Physics Institute and Research Centre SCOPE, University of Stuttgart, Germany

We demonstrate the use of femtosecond two-photon direct laser writing lithography (2D printing) for fast and homogeneous large-area fabrication of plasmonic nanoantennas on a substrate by creating patterned polymer as an etch mask. Subsequent Argon-ion beam etching provides nanoantennas with feature sizes below the diffraction limit of the laser light, exhibiting tunable high quality plasmon resonances in the mid-infrared spectral range which are ideally suited for surface-enhanced infrared absorption (SEIRA). In the present work, we demonstrate the reliable and simple fabrication of a wide variety of antenna arrays and examine particularly the influence of plasmonic coupling between neighboring antennas on the SEIRA enhancement effect. More specifically, we measure the enhanced infrared vibrational bands of a 5 nm thick 4,4'-bis(N-carbazolyl)-1,1'-biphenyl (CBP) layer evaporated on arrays with different longitudinal and transversal spacings between an-

tennas. An optimum SEIRA enhancement per antenna of four orders of magnitude was found close to the collective plasmon excitation in the nanoantenna array. This ideal distance is giving higher signals than simply the highest antenna density.

O 90.14 Thu 18:15 MA 144

Fast SEIRA Detection on Nanoantenna Arrays with Various Geometry on One Chip — ●ANTON HASENKAMPF, NIELS KRÖGER, ARTHUR SCHÖNHALS, WOLFGANG PETRICH, and ANNEMARIE PUCCI — Universität of Heidelberg, Kirchhoff-Institut für Physik, Im Neuenheimer Feld 227, 69120 Heidelberg, Germany

The main tool for surface-enhanced infrared absorption (SEIRA) spectroscopy was the Fourier transform infrared (FTIR) spectrometer with a global source. It allows spectroscopy of a sample over a broad spectral range, which in our case covers 1 μm to 20 μm . The disadvantage of this system is very low spectral power density of the global. This can be partially compensated by long measurement times. In this work, we present a setup with a tunable quantum cascade laser as the light source in mid-infrared range. The 10^8 times higher spectral power density as compared to a global reduces measurement time drastically. The combination of the quantum cascade laser with a microbolometer array for infrared light enables to map an area $2.8 * 3.1\text{mm}^2$ with a spatial resolution of about 9 μm , a bandwidth from 1170 to 1300cm^{-1} , and a spectral resolution of 2.5cm^{-1} within 5 minutes versus 16 hours using the conventional FTIR microscope with a comparable spatial and spectral resolution.