O 26: Plasmonics and nanooptics II

Time: Tuesday 10:30–13:00 Location: MA 005

O 26.1 Tue 10:30 MA 005

Evolutionary optimization of plasmonic nano antennas — •Thorsten Feichtner, Oleg Selig, Markus Kiunke, and Bert Hecht — Nano-Optics & Biophotonics Group, Experimentelle Physik 5, Physikalisches Institut, Wilhelm-Conrad-Röntgen-Center for Complex Material Systems, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany

Various aspects of light-matter interaction can be optimized by means of plasmonic nanoantennas. This includes excited-state lifetime of antenna-based super emitters as well as spectral and directional aspects of the emitted light. So far the design of elementary nano-antennas was inspired by radio-frequency (rf-) technology.

However, at optical frequencies material properties and experimental settings need to be re-considered, so alternative antenna designs can optimize certain aspects of light-matter interaction. In order to find such optimized designs we use a checkerboard-type array of gold cubes. We show that evolutionary optimization can be used to find unexpected antenna geometries that optimize a desired quantity, such as the near-field intensity enhancement, yielding a performance that surpasses that of a conventional rf-based optical antenna design and demonstrate, that this system can be used to achieve more complex functionalities, such as a rotation of the polarization from far field to near field by 90° while maintaining a 1000-fold intensity enhancement. Additionally we identify a new but simple structure combining split ring and dipolar antenna features resulting in enhanced near fields compared to the known dipolar nano antennas.

O 26.2 Tue 10:45 MA 005

Polarizing Beam Splitter - A new approach based on transformation optics — •Jonathan Mueller[1] and Martin Wegener[1,2] — [1]Institut für Angewandte Physik and DFG-Center for Functional Nanostructures (CFN), Karlsruhe Institute of Technology (KIT), 76128 Karlsruhe, Germany — [2]Institut für Nanotechnologie, Karlsruhe Institute of Technology (KIT), 76021 Karlsruhe, Germany

Standard optical elements (*e.g.* lenses, prisms) are mostly designed of piecewise homogeneous and isotropic dielectrics. However, in theory one has far more possibilities to influence electromagnetic waves, namely all the components of the permittivity and permeability tensors. In the past few years, on the one hand, new microfabrication methods allowed for new freedom in controlling the optical parameters using so called artificial metamaterials. On the other hand, the theory of transformation optics has given a somewhat intuitive approach for the design of such structures. In our work, we focus on purely dielectric structures in a non-resonant and therefore non-lossy regime.

A polarizing beam splitter is chosen as the object of study since the use of transformation optics in this case provides some features that may be of interest for applications. Namely, the deviation angle does not vary as a function of tilts or shifts of the structure with respect to the incoming beam. Finite element simulations of a full metamaterial structure have been carried out and a practical method for the fabrication of the device using direct laser writing is proposed.

O 26.3 Tue 11:00 MA 005

Optical Force Stamping Lithography — •Spas Nedev, Alexander S. Urban, Andrey A. Lutich, and Jochen Feldmann — Ludwig-Maximilians-Universität München

Optical lithography techniques are widely used for fabrication of nanoscale devices. The ability to fabricate such structures with arbitrary size and shape is essential for their wide applications in optoelectronics, biological and medical sciences. The conventional far-field lithography is a diffraction limited technique which is not suitable for structures with lateral feature size beyond the diffraction limit. Some far-field lithography techniques can go beyond this limit, but they do not allow arbitrary pattern formation. Scanning near-field optical microscopy techniques can also be used for nanostructure production beyond the diffraction limit. However, they are characterized by low throughput, due to their scanning nature and pose restriction for maximal structure size.

Here we introduce a new optical lithography technique, optical force stamping lithography (OFSL) [1]. This approach employs optical forces on single nanoparticles in multiple focused Gaussian beams produced by a spatial light modulator. The so formed optical stamp provides rapid immobilization of single nanoparticles onto a substrate with positioning accuracy well beyond the diffraction limit. OFSL is not restricted to nanoparticle type or substrate. We believe that these evident advantages of the optical force stamping lithography will make it a standard tool for fabrication on nanodevices.

[1] Nano Lett., 2011, 11 (11), pp 5066-5070

O 26.4 Tue 11:15 MA 005

Electrically connected resonant optical antenna — •Jord C. Prangsma[1], Martin Kamp[2], Johannes Kern[1], Alexander Knapp[1], and Bert Hecht[1] — [1]Experimental Physics 5, University of Würzburg, Germany — [2]Technical Physics, University of Würzburg, Germany

Interaction of quasi-static electric fields and localized plasmon resonances is of interest for various applications such as plasmon-enhanced optoelectronics and photovoltaics, electro-optical switching as well as nonlinear optics. Two-wire optical antennas provide an ideal platform for such applications since the antenna arms may in principle be used as dc electrical leads. However, when attaching electrical leads care must be taken in order to maintain the favourable resonant near-field intensity enhancement afforded by two-wire optical antennas.

Here, we propose a design that allows us to electrically connect two-wire optical antennas with hardly any effect on its bonding-mode resonance. The design provides a perfect spatial overlap between the near-field intensity enhancement region and the quasi-static electric field which is produced by applying a voltage to the connecting leads, essential for a large interaction between both in the gap region. Besides numerical studies of the structures optical response we demonstrate the fabrication of connected optical antennas on glass substrates and characterize their optical properties which are in line with the simulations. The design opens new avenues for realizing electro-plasmonic interfaces for applications in quantum optics and nonlinear optics.

O 26.5 Tue 11:30 MA 005

Fabrication of highly ordered nanostructures by controlling the local near fields of gold nanoparticles — •Frank Hubenthal[1], Sören Maag[1], Abdul Jamali[2], Bernd Witzigmann[2], Thomas Baumert[3], and Frank Träger[1] — [1]Experimental Physics I, Clusters and Nanostructures, Institute of Physics and CINSaT, University of Kassel — [2]Computational Electronics and Photonics and CINSaT, University of Kassel — [3]Experimental Physics III, Femtosecond Spectroscopy and Ultrafast Laser Control, Institute of Physics and CINSaT, University of Kassel

Generation of highly ordered nanostructures with dimensions well below the diffraction limit in a parallel process is a great challenge in modern nanotechnology. One possibility to achieve this goal is irradiation of spherical or triangular gold nanoparticles with laser light and exploit the local near fields, which are strongly influenced by the excitation of surface plasmons. In our experiments spherical and triangular gold nanoparticles supported on fused silica were irradiated with laser light with a pulse duration of 35 fs and a central wavelength of 790 nm. The irradiation causes a strongly localized ablation of the fused silica surface and nanostructures with dimensions well below the diffraction limit are generated. Finally, we present first studies applying two pulses with different polarisation directions, with the aim to generate complex but predetermined nanostructures. In addition, varying the time delay between the two pulses permits to estimate the nanoparticle ablation time, by investigating the generated structures as a function of time delay.

O 26.6 Tue 11:45 MA 005

Quantitative measurement of scattering and absorption cross-sections of individual nano-objects — •Martin Husnik[1], Stefan Linden[2,3], Richard Diehl[4], Jens Niegemann[4], Kurt Busch[4,5], and Martin Wegener[1,3] — [1]Institut für Angewandte Physik and DFG-Center for Functional Nanostructures (CFN), Karlsruhe Institute of Technology (KIT), 76128 Karlsruhe, Germany — [2]Physikalisches Institut, Universität Bonn, 53115 Bonn, Germany — [3]Institut für Nanotechnologie, Karlsruhe Institute of Technology (KIT), 76344 Eggenstein-Leopoldshafen, Germany — [4]Institut für Theoretische Festkörperphysik and DFG-Center for Functional Nanostructures (CFN), Karlsruhe Institute of Technology (KIT), 76128 Karlsruhe, Germany — [5]Institut für Physik, Humboldt-Universität zu

Berlin, and Max-Born-Institut, 12489 Berlin, Germany

The physics and applications of nanostructures are a rapidly growing field of research in photonics. Determining the scattering and absorption cross-sections of individual particles quantitatively would significantly increase the understanding of the optical properties of nanoparticles.

Here, we combine a previously developed spatial modulation technique with a polarization-sensitive common-path interferometer. This enables the simultaneous measurement of both the absolute scattering and absorption cross-sections of single particles. Example spectra of individual straight antennas, split-ring resonators, and intermediates will be presented and compared with numerical calculations based on a Discontinuous Galerkin Time-Domain (DGTD) approach.

O 26.7 Tue 12:00 MA 005

Bottom-up Synthesis of Bowtie Nanoantenna Arrays for SERS Imaging and Spectroscopy — •Paul Kühler, Thomas Becker, Enrico Da Como, Theobald Lohmüller, and Jochen Feldmann — FB Physik, Ludwig Maximilian Universität, München

We present a novel high-throughput strategy for the bottom-up synthesis of large arrays of strongly coupled plasmonic nanostructures as reliable substrates for surface enhanced Raman scattering (SERS) imaging and spectroscopy.

We demonstrate the synthesis of billions of bowtie-shaped gold nanoantennas on a single solid substrate by using a refined combination of colloid lithography and plasma processing. With this approach, we are able to precisely control the tip-to-tip distance and the shape of the triangular gold nanoantennas for various particle sizes on a length scale well below 30 nm. We demonstrate the broad applicability of these nanostructures for SERS spectroscopy by confocal Raman imaging of graphene monolayers and substrate supported membranes. In addition to experimental studies, we have done numerical modeling to investigate the influence of shape and interparticle distance of realistic particle geometries on the propagation of SERS enhancement at the nanoantenna junctions.

This approach is a favorable alternative to current state-of-the-art fabrication technology for generating SERS active substrates over a large surface area and with high accuracy.

O 26.8 Tue 12:15 MA 005

Highly doped ZnO films with tailored plasma frequency grown by atomic-layer deposition for three-dimensional infrared metamaterials — •Andreas Frölich[1,2,3] and Martin Wegener[1,2,3] — [1]Institut für Angewandte Physik, Karlsruhe Institute of Technology (KIT), 76128 Karlsruhe, Germany — [2]DFG-Center for Functional Nanostructures (CFN), Karlsruhe Institute of Technology (KIT) — [3]Institut für Nanotechnologie, Karlsruhe Institute of Technology (KIT)

We use atomic-layer deposition to grow ZnO films doped with Al (and Ti) at different concentrations and study their optical spectra. The measured spectra are well described by fits using a Drude free-electron model and the derived plasma frequencies are consistent with the expected amount of doping. The losses (damping) are also quantified.

We demonstrate that control of the doping concentration allows for continuously and controllably tunable plasma frequencies spanning almost an octave from 193 THz to 383 THz. In order to demonstrate the applicability of our approach for three-dimensional designs we have also deposited smooth, conformal coatings on three-dimensional polymer templates made by direct laser writing. Altogether, Al:ZnO appears as an attractive “tunable metal” for three-dimensional infrared metamaterials or transformation-optics architectures.

O 26.9 Tue 12:30 MA 005

Ordered nanostar arrays as reliable substrates for surface enhanced Raman scattering (SERS) — •Lidiya Osinkina, Theobald Lohmüller, Frank Jäckel, and Jochen Feldmann — Photonics and Optoelectronics Group, Department of Physics and CeNS, Ludwig-Maximilians-Universität München, 80799, Munich, Germany

Multispiked metallic nanoparticles, or "nanostars" - are intriguing substrates for surface enhanced Raman scattering (SERS) spectroscopy due to the strong field enhancements that are emerging on their tips upon excitation with light at their resonance frequency. Exciting optical properties can appear in ordered arrays of SERS active nanoparticles, and arrays of metallic nanostars should therefore have high potential as substrates for sensing and imaging applications.

Here we present a two-step approach to efficiently produce large ordered arrays of gold nanostars by using a combination of block copolymer nanolithography and seeded growth. First, hexagonally ordered arrays of gold nanoparticle seeds are produced on top of a glass substrate. The interparticle distance between the seeds can be changed in a range of 65-100 nm. Second, nanostars, with the average size of 50 nm are grown from these seeds by one-pot synthesis in the aqueous solution. In this work, we will demonstrate that the size of the nanostar and the distances between the particles can be tuned independently, influencing the optical properties and the performance of the SERS active substrates.

O 26.10 Tue 12:45 MA 005

Gold Nanocones for Biosensing Applications — •Christian Schaefer, Andreas Horrer, Katharina Broch, Frank Schreiber, Dieter Kern, and Monika Fleischer — Eberhard Karls Universitaet Tuebingen, Institut fuer Angewandte Physik, Auf der Morgenstelle 10, 72076 Tuebingen

The localized surface plasmons in gold nanostructures give rise to strong and strongly localized near-fields which can for example be used to enhance the Raman signal of molecules by several orders of magnitude. We present the fabrication of a highly efficient Raman signal enhancing surface consisting of gold nanocones with tip radii of 10 nm or less. The properties of the cones will be shown by Raman measurements on samples with arrays of nanocones covered by thin layers of Pentacene. With regard to further application in biosensors, the cones can be integrated in microfluidic channels which opens the opportunity to handle small amounts of solutions. Further steps for the capture of molecules out of solution by dielectrophoresis will be presented.