# O 3: Plasmonics and nanooptics I

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

O 3.1 Mon 10:30 MA 005

**SHG imaging of gold nanocones in focused beams of different polarisations.** — •Philipp Reichenbach[1], Dominik Gollmer[2], Monika Fleischer[2], Dieter Kern[2], and Lukas Eng[1] — [1]Institut für Angewandte Photophysik, Technische Universität Dresden, George-Bähr-Straße 1, 01069 Dresden — [2]Institut für Angewandte Physik, Eberhard Karls Universität Tübingen, Auf der Morgenstelle 10, 72076 Tübingen

Nanostructures with sharp tips provide strong dipolar second-harmonic (SHG) light sources due to the combination of extreme field enhancement and breaking the centro-symmetry. We present second-harmonic measurements at gold nano-cones that are illuminated by a radially polarized, focused femtosecond beam at 800 nm in order to excite the tip. Nevertheless, we observe second-harmonic radiation emission either from the tip or from the cones's bottom edges, depending on the cone size and surrounding medium. This behavior can be readily explained through numerical calculations of the field enhancement at the tip apex and the bottom face of the cones.

Furthermore, our measurements with a radially polarized focused beam are compared to measurements with linear or azimuthal polarization. Thus, the z-component of the electric field exciting the cone tip can be purposely switched on and off. Hence, we are able to clearly discriminate between SHG emission from the bottom edges and from the tip apex.

O 3.2 Mon 10:45 MA 005

**Enhancement of non-linear effects using nano-wires** — •Woyten Tielesch[1], Mathieu Gentile[1], Mario Hentschel[2], Harald Giessen[2], and Manfred Fiebig[3] — [1]HISKP, Universität Bonn, Germany — [2]4. Physikalisches Institut and Research Center SCoPE, Universität Stuttgart, Germany — [3]Departement of Materials, ETH Zürich, Switzerland

Gold nano-wires are artificial sub-wavelength materials with tailored optical properties. Experimental and theoretical investigations show amplified local fields on the nanoscale. In a non-linear material this makes nano-wires act as an optical catalyst. We present a method using such a catalyst to enhance non-linear functionality of a given material.

Our sample consists of fields of regularly spaced gold nano-wires on a $Cr_2O_3$ substrate. $Cr_2O_3$ shows second-harmonic generation (SHG) for incident light peaked around 1.05 eV and has been intensively characterized for reference. Accordingly, the wires have linear resonances between 0.9 eV and 1.5 eV. In our experiment we use amplified 120 fs laser pulses to investigate the influence of the wires on the SHG spectrum of the substrate. Fundamental wavelengths from 0.8 eV to 1.1 eV are used.

A significant modification of SHG due to the wires is observed. We demonstrate that the spectral profile of the SHG signal is strongly correlated to the linear spectrum of the wires. In addition, we show that a strong signal occurs in a direction where the bare substrate shows no signal at all, a fact still requiring theoretical explanation.

O 3.3 Mon 11:00 MA 005

**Adiabatic nanofocusing of ultrashort light pulses.** — •Slawa Schmidt[1], Björn Piglosiewicz[1], Diyar Sadiq[1], Javid Shirdel[1], Jae Sung Lee[2], Parinda Vasa[1], Namkyoo Park[2], Dai-Sik Kim[3], and Christoph Lienau[1] — [1]Institut für Physik, Carl von Ossietzky Universität, Oldenburg, Germany — [2]Photonic System Laboratory, School of EECS, Seoul, Korea — [3]Center for Subwavelength Optics and Department of Physics and Astronomy, Seoul, Korea

We demonstrate the use of a novel ultrasharp and ultrasmooth single-crystalline gold taper for adiabatic nanofocusing of few-cycle light pulses. We show that the grating-induced launching of spectrally broadband surface plasmon polariton wavepackets onto the shaft of such a taper generates isolated, point-like light spots with 10 femtosecond duration and sub-10-nm diameter at its very apex. This nanofocusing is so efficient that nano-localized electric fields exceeding the atomic field are reached with conventional high-repetition rate laser oscillators. Strong optical nonlinearities are induced at the tip end and we use here the resulting second harmonic to fully characterize the time structure of the localized electric field in frequency-resolved interferometric autocorrelation measurements. The conclusions drawn from our experiments are beautifully confirmed by numerical simulation based on the finite-difference time-domain (FDTD) method. Our results strongly suggest that these nanometer-sized ultrashort, light spots will enable new experiments probing the dynamics of optical excitations of individual metallic, semiconducting and magnetic nanostructures.

O 3.4 Mon 11:15 MA 005

**Trapping light in random ZnO nanorod arrays - Localization of light in space and time** — •Manfred Mascheck[1], Slawa Schmidt[1], Martin Silies[1], David Leipold[2], Erich Runge[2], Takashi Yatsui[3], Kokoro Kitamura[3], Motoichi Ohtsu[3] und Christoph Lienau[1] — [1]Carl-von-Ossietzky-Universität, Oldenburg — [2]Technische Universität Ilmenau — [3]University of Tokyo

A random array of ZnO nanorods is used to directly visualize the weak localization of light in space and time. In an ultrafast second harmonic microscope pairs of 6-fs laser pulses at variable delay are focused to the diffraction limit onto the ZnO nanorod array in a dispersion-balanced set-up. The generated SH emission is collected in reflection geometry and detected as a function of the spatial position of the laser focus as well as for the delay between the pulses. Pronounced spatial intensity fluctuations of the SH due to multiple random scattering within the array and a distinct modification of the correlated time structure of the local electric field are observed as predicted for the localization of light. By using the one parameter scaling theory the histogram of the intensity values gives evidence for being near the transition between weak- and strong localisation.

O 3.5 Mon 11:30 MA 005

**Revealing nonlinear plasmon-photon interactions using k-space spectroscopy** — •Jan Heckmann, Nicolai B. Grosse, and Ulrike Woggon — Institut für Optik und Atomare Physik, Technische Universität Berlin

Surface plasmon (SP) excitation in metal-dielectric structures is exemplified by an enhanced local electromagnetic field, which boosts nonlinear effects. Since the first demonstration of SP-related second-harmonic generation (SHG) by Simon et al., understanding the microscopic origin of the nonlinearity has remained an active research topic.

We propose that all permutations of plasmon (p) and photon (f) are allowed in the second-order nonlinear process of SHG (which can generate either p or f), and that each process can be identified by its own requirement for nonlinear k-vector-matching. Hence, the type of nonlinear interaction can be identified by resolving the SHG intensity as a function of exit angle, while the fundamental excitation angle is varied. To test this hypothesis, we built a k-space spectrograph that analysed SHG from a thin metal film in the Kretschmann geometry which was driven by femtosecond-pulsed laser light.

Our experimental results show that for excitation angles in the vicinity of the SHG peak, there is an off-diagonal component which is consistent with the signature of the pp-f interaction. This is in contrast to the purely photonic ff-f interaction which lies on the diagonal. Hence, in plasmon SHG, two plasmons at the fundamental frequency are annhiliated to create a second-harmonic photon.

O 3.6 Mon 11:45 MA 005

**Non - Linear Optical Imaging of Gold Nano - Cones with a Parabolic Mirror Microscope** — •Anke Horneber[1], Dai Zhang[1], Monika Fleischer[2], Kai Braun[1], Dieter P. Kern[2], and Alfred J. Meixner[1] — [1]Institute of Physical Chemistry,Eberhard Karls University Tübingen, Germany — [2]Institute for Applied Physics, Eberhard Karls University Tübingen, Germany

Governed by the lightning rod effect and localized surface plasmon resonances, linear optical properties of metallic nanoantennas have been widely investigated [1]. In our latest work, we have combined a femtosecond erbium fibre laser (774 nm) with a home-built parabolic mirror (NA 0.998) assisted confocal optical microscope [2] to investigate the non-linear optical effects from nano structures of different materials, and geometries. Due to the intensely confined electric field at the tip apex and its centrosymmetry breaking geometry, single gold nano-cone showed dramatic non-linear optical properties, which depend sensitively on the polarization condition. Combined with numerical simulation, we will demonstrate and analyse systematically the non-linear optical imaging of individual gold nano-cones.

[1] M. Fleischer, C. Stanciu, F. Stade, J. Stadler, K. Braun, A. Heeren, M. Haeffner, D. P. Kern and A. J. Meixner, Appl. Phys. Lett. 93 (2008) 111114. [2] J. Stadler, C. Stanciu, C. Stupperich, and A. J. Meixner, Opt. Lett. 33 (2008) 681.

O 3.7 Mon 12:00 MA 005

**Towards Synthesis and Investigation of Surface Plasmon Polariton Lasers** — •Günter Kewes[1], Andreas Ott[1,2], Yan Lu[1,2], Matthias Ballauff[1,2], and Oliver Benson[1] — [1]Humboldt Universität Berlin — [2]Helmholtz Zentrum Berlin

Surface plasmons attract a lot of research interests because of their wide range of applications in nanophotonics, but the field is gathering for an active element, e.g. a surface plasmon polariton laser (spaser) [1]. Coherent amplification of radiation through excitation of surface plasmons in dye-doped Au-SiO2 core-shell nanoparticles is investigated to synthesize a spaser. Spherical and rod-like Au nanoparticles with tuneable plasmon resonances are covered with a silica shell by a modified Stöbe method. A suitable dye (according to the surface plasmon excitation) is incorporated to generate a gain medium that compensates for the absorption loss in the metal [2]. The emission of the nanoparticles is observed through a home-built confocal microscope with single molecule sensitivity where the nanoparticles can be identified and manipulated by an atomic force microscope at the same time [3].

References: [1] M. A. Noginov, et al., Nature 460, 1110 (2009). [2] W. Ni, et al., J. Am. Chem. Soc. 132, 4806 (2010). [3] S. Schietinger, et al., Nano Lett. 9, 1694 (2009).

O 3.8 Mon 12:15 MA 005

**Optical Nanoantennas for Ultrafast Spectroscopy of Single Nanoobjects** — •Thorsten Schumacher[1,2], Daniela Ullrich[1,2], Mario Hentschel[1,2], Harald Giessen[2], and Markus Lippitz[1,2] — [1]Max Planck Institute for Solid State Research, Stuttgart — [2]4th Physics Institute, University of Stuttgart

Ultrafast nonlinear spectroscopy investigates the deviations from linear light-matter interaction on very short timescales. The already weak signals are reduced further when single nanoobjects such as quantum dots, molecules, or nanoparticles are the systems of interest. Considering the example of a mechanically oscillating single gold nanodisc, we demonstrate how such a weak nonlinear response can be enhanced by one order of magnitude using an optical nanoantenna. Our numerical model explains all experimantally observed effects of the antenna. Furthermore it allows us to perform optimization studies to obtain more effective antenna structures to reach higher enhancement factors. Finally we give an outlook on our work on enhancing the nonlinear response of colloidal quantum dots.

O 3.9 Mon 12:30 MA 005

**Nanoscale heat flux for hyperbolic materials** — •Svend-Age Biehs and Maria Tschikin — Institut für Physik, Carl von Ossietzky Universität Oldenburg, D-26111 Oldenburg

We consider the radiative heat flux between two hyperbolic media for distances much smaller than the thermal wavelength. Based on a generalization of the heat flux expression derived by Polder and van Hove for anisotropic media we study the influence of so called hyperbolic modes by using a Maxwell-Garnett effective medium description for the material properties. In particular, we will show that these modes give a maximal transmission over a broad band of frequencies and for large lateral wave vectors due to photon tunneling. We demonstrate that the heat flux associated with these modes can be very close to the fundamental limit derived by P. Ben-Abdallah and K. Joulain at the nanoscale. Hence, hyperbolic materials can be considered as very good candidates for realizing a black body in the near-field regime.

O 3.10 Mon 12:45 MA 005

**Präparation und Anordnung von Goldnanopartikeln zur Untersuchung von nichtlinearen optischen Prozessen** — •Valerie Mondes[1], Antonia Menski[1], Matthias Buchholz[1], Matthias Kling[2], Christina Graf[1], Jürgen Plenge[1] und Eckart Rühl[1] — [1]Freie Universität Berlin, Institut für Chemie und Biochemie, Physikalische und Theoretische Chemie, Takustr. 3, 14195 Berlin — [2]Max-Planck Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching

Geordnete Strukturen von metallischen Nanopartikeln können hohe plasmonische Feldverstärkungseffekte bei der Anregung durch Femtosekundenlaserstrahlung aufweisen. Sie sind daher ideale Systeme zur Untersuchung von nichtlinearen optischen Prozessen. Alternativ zu den oft verwendeten lithographisch hergestellten Strukturen wurden in dieser Arbeit Goldnanopartikel mit Methoden der Kolloidchemie hergestellt und durch induzierte Selbstorganisation auf Saphirträgern in Monolagen angeordnet. Die Form und Größe der Nanopartikel wurde variiert und Nanostrukturen aus kugel-, würfel- bzw. prismenförmigern Goldnanopartikeln aufgebaut. Die Strukturen wurden mittels Transmissions- und Rasterelektronenmikroskopie charakterisiert.

Die in Monolagen angeordneten Goldnanopartikel wurden mit Femtosekundenlaserstrahlung ($\lambda = 804$ nm, $\tau = 80$ fs) angeregt. Die Zwei-Photonen-Photolumineszenz und Frequenzvervielfachung an den Nanostrukturen wurden genutzt, um plasmonische Feldverstärkungseffekte für Strukturen mit unterschiedlichen Geometrien zu charakterisieren.