HL 10: Plasmonics and Nanooptics: Light-Matter Interaction

Time: Monday 10:30–13:15 Location: S054

Invited Talk HL 10.1 Mon 10:30 S054

Hybrid plasmonic-photonic resonances for emitter control — •Femius Koenderink — Center for Nanophotonics, FOM Institute AMOLF, Amsterdam, The Netherlands

Plasmonic nanostructures match light to molecular length scales by hybridizing photons with charge density oscillations in noble metals. Plasmonics is pursued for many prospective uses ranging from sensing, spectroscopy, and microscopy, to the development of ultrabright single photon sources and broadband cavity QED for quantum information processing. I will report on our effort to use plasmonics to completely control when, into which direction, and with what polarization and wavefront single nanosources emit. I will particularly focus on Fourier-space polarimetry on single nano-antenna structures, as well as distributed periodic and quasiperiodic plasmonic structures for directional fluorescent, and lasing sources. Also, I will discuss the surprising physics of hybridizing plasmonics and dielectric nanophotonics. Recently we showed that, counter to conventional cavity perturbation theory, plasmonic structures can improve the quality factor of an already high-Q (exceeding 1 million) microtoroid. Finally, I will argue that hybrid plasmon-cavity structures can combine cavity Q-factors with plasmonic mode volumes.

HL 10.2 Mon 11:00 S054

Coherent and periodic energy transfer between widely separated and cavity-coupled nanoantennas — Martin Aeschlimann[1], Tobias Brixner[2], Benjamin Frisch[1], Bert Hecht[3], Bernhard Huber[2], •Matthias Hensen[4], Christian Kramer[2], Enno Krauss[3], Thomas Löber[5], Walter Pfeiffer[4], Martin Piecuch[1], and Philip Thielen[1] — [1]Department of Physics and Research Center OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Department of Physical and Theoretical Chemistry, Würzburg University, 97074 Würzburg, Germany — [3]Experimental Physics 5, Würzburg University, 97074 Würzburg, Germany — [4]Faculty of Physics, Bielefeld University, 33615 Bielefeld, Germany — [5]Nano Structuring Center, TU Kaiserslautern, 67663 Kaiserslautern, Germany

We present a device that couples two widely separated ($d \approx 2\lambda_0$) nanoantennas via an extended plasmon mode in a metallic cavity of elliptical shape. As predicted by finite-difference time-domain simulations a coherent back and forth transfer of energy between the antennas is observed in experiments. Samples were made out of atomically-flat single crystalline gold plates and the temporal dynamics of plasmonic excitations was investigated by time-resolved photoelectron emission microscopy. The device depicts an all-plasmonic analogue of the quantum mechanical Tavis-Cummings model and it is particularly suited to study the interaction of deterministically positioned quantum systems coupled to the incorporated nanoantennas.

HL 10.3 Mon 11:15 S054

Far-field interferometry of weak plasmonics scatterers — •Christian Dicken[1], Daniela Wolf[1], Thorsten Schumacher[1], Klas Lindfors[2], Harald Giessen[3], and Markus Lippitz[1] — [1]Institute of Experimental Physics III, University of Bayreuth, Germany — [2]Department of Chemistry, Nanooptics Group, University of Cologne, Germany — [3]Institute of Experimental Physics IV, University of Stuttgart, Germany

Low-loss noble metals like gold and silver are at the heart of plasmonics. Yet, many applications focus on metals with higher losses and less pronounced optical response. We discuss how a simple mirror and a dielectric spacer layer turn a transmission experiment into an interferometer. This scheme is used by us in a simple model to optimize the sensitivity to small changes of the optical response of weak scatterers. In particular, we present interferometrically detected magnetic hysteresis loops of sub-100nm nickel disks and compare the data with our model.

HL 10.4 Mon 11:30 S054

Photoluminescence Enhancement by laterally ordered Ag/Alq$_3$:ZnPc/Ag Nanocavities — •Verena Kolb[1] and Jens Pflaum[1,2] — [1]Experimental Physics VI, Julius Maximilian University of Würzburg, 97074 Würzburg — [2]Center of Applied Energy Research (ZAE Bayern), 97074 Würzburg

Plasmonic nanostructures provide a perfect possibility to tailor the photoluminescence (PL) of organic semiconductors. In this contribution we present PL investigations on silver nanoprism arrays prepared by shadow nanosphere lithography and resonantly coupled to the luminescence of ZnPc (zinc phthalocyanine) molecules. Confocal PL measurements revealed a strong increase of the fluorescence of ZnPc thin films deposited on top of the nanoprisms. Co-evaporation into an Alq$_3$ (tris(8-hydroxyquinoline)aluminum) matrix at low concentrations of 4% leads to further increase, which can be explained by the reduction of non-radiative processes caused by exciton-exciton-annihilation and quenching at metal/organic interface. Lateral structuring of the organic layer and capping by silver result in periodically ordered Ag/Alq$_3$:ZnPc/Ag hybrid structures with PL enhancement factors up to 700 after geometrical correction. Complementary FDTD simulations confirm the pronounced spectral overlap between the localized surface plasmon resonance and the highest PL mode and thus, are able to prove the enhancement to be of plasmonic origin.

HL 10.5 Mon 11:45 S054

Optical rotation reversal and circular dichroism in resonantly and off-resonantly coupled plasmonic nanosystems — •Mario Hentschel[1,2], Vivan E. Ferry[3], A. Paul Alivisatos[1], and Harald Giessen[2] — [1]Materials Science Division, Lawrence Berkeley National Laboratory, Berkeley, CA, United States — [2]4th Physics Institute and Research Center SCoPE, University of Stuttgart, Germany — [3]Department of Chemical Engineering and Materials Science, University of Minnesota, Minneapolis, United States

In a system consisting of two resonant L-shaped particles we show that the sign of the circular dichroism spectrum in a plasmonic system can be controllably changed through small geometric perturbations that change the energetic ordering of the hybridized modes [1]. This mechanism is distinct from geometrical changes that explicitly change the handedness of the system. Secondly, we investigate the role of resonant coupling in chiral plasmonic systems, and whether the formation of collective plasmonic modes in a handed assembly of metallic nanostructures is a necessary condition for a chiroptical response. We show in experiment and simulation that off-resonant coupling between spectrally detuned nanostructures arranged with structural chirality leads to a clear yet weak chiroptical response [2]. We interpret our results in the framework of scattering between the individual constituents that in turn leads to a chiroptical farfield response. [1] M. Hentschel et al., ACS Photonics 2, 1253 (2015) [2] V. E. Ferry, M. Hentschel, and A. Paul Alivisatos, Nano Lett. 15, DOI 10.1021/acs.nanolett.5b03970

HL 10.6 Mon 12:00 S054

Enantiomorphic chiral near-fields in locally chiral plasmonic lattices — •Martin Schäferling, Xinghui Yin, Maxim Nesterov, Harald Giessen, and Thomas Weiss — 4th Physics Institute and Research Centers SCoPE and SimTech, University of Stuttgart, Germany

Chiral near-fields, which interact strongly with chiral molecules, can be obtained by illuminating geometrically chiral plasmonic nanostructures with circularly polarized light [1,2]. Fields with opposite handedness can be used to probe the chiroptical properties of chiral molecules with enhanced sensitivity. However, the field pairs generated by periodic arrangements of chiral nanostructures are, in general, not enantiomorphic. Additionally, such structures exhibit a chiroptical far-field response even in absence of chiral probe molecules. Both effects hamper the implementation of plasmonically enhanced chiroptical spectroscopy schemes.

In this contribution, we discuss periodic arrangements of simple achiral building blocks where the resulting superstructure is geometrically achiral, but still provides left- and right-handed geometrically chiral substructures. Due to their symmetry, such configurations provide enantiomorphic chiral near-fields, but no chiroptical far-field response. We show how to identify all such arrangements of plasmonic nanodiscs in a 4×4 unit cell that additionally provide C_4 symmetry and compare the simulated chiroptical near-field response of selected examples.

[1] Y. Tang and A. E. Cohen, Science **332**, 333 (2011).
[2] M. Schäferling et al., Phys. Rev. X **2**, 031010 (2012).

HL 10.7 Mon 12:15 S054

Circular Dichroism Spectroscopy on Individual Plasmonic

Nanoparticles — •Julian Karst[1], Nikolai Strohfeldt[1], Mario Hentschel[1], Harald Giessen[1], and Na Liu[2] — [1]4th Physics Institute and Research Center SCoPE, University of Stuttgart, Germany — [2]Max-Planck-Institute for Intelligent Systems, Stuttgart, Germany

Chirality is one of the most important basic principles of nature. We analyze the chiroptical response of single chiral plasmonic nanostructures. We utilize dark field circular dichroism spectroscopy to study the response of individual 3D chiral plasmonic Au-nanostructures. A customized spectroscopy setup for the visible spectral range is used. Transmission and scattering spectra are measured with a bright field and dark field spectroscopy setup, respectively. With large area ensembles of achiral and chiral plasmonic nanostructures we determine the influence of several optical components in the light path as well as the influence of fabrication defects. We show that individual chiral plasmonic oligomers in C_1 and C_4 configuration exhibit a mirror symmetry in the circular dichroism spectra for the right- and left-handed enantiomers. However, we see clear differences in the response of C_1-symmetric Au-nanostructures compared to the polarization conversion suppressing C_4-symmetric structures. The successful measurements of the chiroptical response of single chiral three dimensional plasmonic oligomers pave the way for studying more complex individual DNA based chiral plasmonic nanostructures.

HL 10.8 Mon 12:30 S054

Device design from stacked metasurfaces by use of a modified S-Matrix formalism — •Jan Sperrhake, Christoph Menzel, and Thomas Pertsch — Institut für angewandte Physik, Abbe Center of Photonics, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena

Artificial subwavelength structures called metamaterials (MM) are one of the most promising approaches in modern photonics for full control of light with respect to its polarization and spectral properties. By using MM made of complex shaped 3D elements almost arbitrary optical functionalities can be integrated into thin films. However, as the fabrication of 3D MM is usually difficult, complexity of the optical response might be achieved instead by choosing 2D metasurfaces (MS) and stacking them. In this contribution, we propose a method for efficiently treating and optimizing stacked complex homogeneous MS to create integrated, highly functional optical devices. A theoretical framework for fast numerical calculation is given by means of a modified scattering matrix formalism providing full information about phase, amplitude and polarization of the desired reflected and transmitted fields. As we will show with some examples this will pave the way towards simpler structures and easier fabrication, while maintaining and even increasing the range of accessible optical functionalities. A preprint of the paper is available at http://arxiv.org/abs/1511.09239.

HL 10.9 Mon 12:45 S054

Efficiency analysis of a finite-difference modal method for the derivation of electromagnetic fields — •Izzatjon Allayarov, Martin Schäferling, Maxim Nesterov, and Thomas Weiss — 4th Physics Institute and Research Center SCoPE, University of Stuttgart, Germany

Accurate numerical derivation of electromagnetic fields is important for many questions such as modeling the enhanced spontaneous emission due to the Purcell effect. Finite element methods (FEM) offer high accuracy, but are slow and tedious to implement. For periodic systems, the Fourier modal method (FMM) is a fast and reliable alternative. However, the underlying Fourier basis cannot resolve high contrasts of the dielectric constant accurately, which is especially problematic when fields close to such interfaces should be calculated.

We present an implementation of a finite difference basis for modal methods (FDMM) [1], which can exactly model arbitrary steps in the dielectric constant. We compare the accuracy and the calculation time to standard FMM as well as to FEM. Our results indicate that the accuracy of the fields is higher for the FDMM compared to the FMM for comparable calculation times.

Additionally, we will discuss the possibility to combine this finite-difference basis with the coordinate transformation methods that have already been applied to the FMM [2]. This will allow for precise calculations of non-rectangular geometries using the FDMM.

[1] I. Semenikhin, and M. Zanuccoli, JOSA A **30**, 2531 (2013).
[2] T. Weiss et al., Opt. Express **17**, 8051 (2009).

HL 10.10 Mon 13:00 S054

Analytical model for hybrid magnetoplasmonics — •Dominik Floess[1], Thomas Weiss[1], Sergei Tikhodeev[2], and Harald Giessen[1] — [1]4th Physics Institute and Research Center SCoPE, University of Stuttgart, Germany — [2]A. M. Prokhorov General Physical Institute, Russian Academy of Sciences, Moscow

In recent years, the hybrid plasmonic construction kit was expanded by magneto-optical materials, which offer magnetic tuning and non-reciprocal effects. By utilizing localized surface plasmons, the magneto-optical response of dielectric thin films can be resonantly amplified and spectrally tailored. While the experimental realization of such systems received considerable attention, so far there is no profound theoretical description that goes beyond numerical simulations. Here we present an intrisically non-reciprocal coupled oscillators model that reveals the underlying physics inside such systems and yields analytical expressions for the resonantly enhanced magneto-optical response. The predictions of the model are in good agreement with full numerical simulations of typical sample geometries as well as experiments. This includes modal dispersion, optical rotation and ellipticity.