O 40: Focussed session: Coherence and coherent control in nanophotonics and plasmonics I

Time: Wednesday 10:30–12:45 Location: MA 005

Topical Talk O 40.1 Wed 10:30 MA 005

Active control of light propagation in nanophotonic structures — •Kobus Kuipers — FOM Institute AMOLF, Science Park 104, 1098 XG Amsterdam, The Netherlands

With recent advances in nanofabrication it has become possible to control the flow and/or concentration of light at the nanoscale with proper combinations of geometry and materials. This has led to the unprecedented concentration of light in hot spots of only a fraction of a wavelength cubed and the controlled propagation of light at group velocities several orders of magnitude smaller than c. However, in the majority of cases the control over the light is "static", i.e., for a given choice of geometry and materials, the resulting light control is what it is. This lecture will present our latest progress in gaining active control of light fields at the nanoscale. For example, by using amplitude and phase control obtained through spatial light modulators we are able to position plasmonic "hot spots" at arbitrary positions in a "plasmonic arena". Active control of the photonic bandstructure allows changing the "color" of slow light, control over its group velocity and spectral compression. Through a combination of active control and fixed geometry we are able to achieve an "indirect" transition between photonic eigenstates that can be expoited to control the timing of individual ultrashort pulses originally separated in time by mere picoseconds.

Topical Talk O 40.2 Wed 11:00 MA 005

Coherent exciton-plasmon coupling in metal-dye hybrid nanostructures — •Erich Runge — Technische Universität Ilmenau, 98693 Ilmenau, Germany

At nano-structured metal surfaces, light can be localized to spatial regions well below the diffraction limit by the excitation of surface plasmon polaritons (SPPs). A major challenge for future devices employing SPPs is the fact that SPPs travel only over very short distances, since they are strongly damped in the metal. One approach to overcome this problem is to compensate the damping by coupling of the SPPs to active media, e.g., dyes or quantum wells [P. Vasa et al., Phys. Rev. Lett. 110 (2008) 116801].

Based on recent experiments in the Lienau group at Oldenburg University, I discuss in detail the coupling of quantum mechanical excitations in a j-aggregated dye with the SPP excitation at a metal grating [P. Vasa et al., ACS Nano, 4 (2010), pp. 7559]. The strong coupling (energy transfer) of the SPP and the excitonic dye resonance manifests itself as avoided crossing in the dispersion relation. At resonance, the coupled eigenmodes show excitonic as well as plasmonic features. They inherit a ultrafast strongly non-linear response (saturation and induced biexcitonic absorption) from their excitonic parent, i.e., from the organic dye. If the dye is saturated, its excitonic polarizability vanishes and so does its coupling to the plasmon. The hybridization gap in the mixed-mode dispersion relation closes. This allows for reflectivity changes by about 40% on and off in less than a picoseconds, arguably making the sample the fastest switchable metallic mirror ever made.

Topical Talk O 40.3 Wed 11:30 MA 005

Control and spectroscopy of plasmonic systems using ultrafast pulse shaping — •Tobias Brixner[1], Martin Aeschlimann[2], and Walter Pfeiffer[3] — [1]Institut für Physikalische und Theoretische Chemie, Universität Würzburg, Am Hubland, 97074 Würzburg — [2]Fachbereich Physik and Research Center OPTIMAS, TU Kaiserslautern, Erwin-Schrödinger-Str. 46, 67663 Kaiserslautern — [3]Fakultät für Physik, Universität Bielefeld, Universitätsstr. 25, 33615 Bielefeld

Coherent control concepts using shaped femtosecond laser pulses have originally been developed for controlling the dynamics of molecular systems, and coherent two-dimensional spectroscopy provides insight into molecular electronic couplings. Recently, these principles have been extended to the realm of nano-optics. This adds new degrees of freedom through the control of spatial properties of electromagnetic near-fields in the vicinity of nanostructures. It is now possible to manipulate spatial-temporal and transport phenomena as well as to measure electronic coherences, both on a subdiffraction length scale. This talk provides a comparison between molecular and plasmonic implementations of coherent control and coherent multidimensional spectroscopies, discussing analogies and differences and showing exemplary realizations.

O 40.4 Wed 12:00 MA 005

Monitoring strong light-molecule coupling at field level — •Wei Wang[1], Parinda Vasa[1,2], Robert Pomraenke[1], and Christoph Lienau[1] — [1]Institut für Physik, Carl von Ossietzky Universität Oldenburg, Germany — [2]Department of Physics, Indian Institute of Technology Bombay, Mumbai 400076, India

The radiative coupling between quantum emitters and surface plasmon polaritons (SPPs) plays a key rule in designing hybrid plasmonic devices with active functionalities such as ultrafast all-optical switching, lasing as well as energy transfer and storage. We investigate the strong coupling between surface plasmon polaritons and excitons in metal-molecular aggregate hybrid nanostructures by linear spectroscopy combined with spectral interferometry. The spectral amplitude and phase information are used to reconstruct the response function of the hybrid system which provides an effective way to monitor the polarization response on the field level and gives a complete picture and accurate evaluation of the optical property of the strongly radiatively coupled exciton-SPP system. Model calculations confirm our experimental results and reveal novel features of these interactions such as the formation of sub- and superradiant states. Our field-level investigation of such coupled hybrid systems is expected to be of importance for understanding and manipulating the light-molecule interaction as well as for future implementations of active plasmonic devices.

O 40.5 Wed 12:15 MA 005

Time-domain simulation of quantum systems coupled to plasmonic nano-structures — Richard Ciesielski, •Andreas Hille, René Kullock, Stefan Grafström, and Lukas M. Eng — TU Dresden, Institut für Angewandte Photophysik, 01062 Dresden

Plasmonic nanostructures deserved an increased attention for the last 20 years due to their appealing optical properties such as high field concentration, enhanced optical transmission or negative refraction. Nevertheless, the most severe drawback of these (mostly metallic) nanostructures are their very high Ohmic losses, which for instance prevent bulk plasmonic applications, e.g. in metamaterials. In 2003, Bergman and Stockman proposed the so-called SPASER concept which compensates losses using optical gain media. This approach is very appealing; however, to date no clear proof of really (over-) compensating these losses in bulk plasmonic materials has been shown. We contribute here to this question by theoretically calculating how gain media couple to plasmonic nanostructures on the quantum mechanical (QM) level using the Discontinuous Galerkin (DG) method. DG is a relatively novel but very powerful numerical tool to model optical nanostructures with linear or non-linear optical properties, especially when combined with curved elements. By using time-dependent DG calculations, we study here QM emitters as the gain medium that couple to plasmonic nanoantennas. The nanoantenna is formed by spherical nanoparticles with a diameter of 40 - 100 nm while the QM emitters were chosen to be standard dye molecules.

O 40.6 Wed 12:30 MA 005

Combining spatiotemporal controlled optical excitations with coherent spectroscopy for coupled quantum dots — •Felix Schlosser[1], Mario Schoth[1], Sven Burger[2], Frank Schmidt[2], Andreas Knorr[1], Shaul Mukamel[3], and Marten Richter[1] — [1]Institut für Theoretische Physik, Technische Universität Berlin, Germany — [2]Zuse-Institut Berlin, Germany — [3]Department of Chemistry, University of California, Irvine, USA

Combining pulse shaping techniques for ultrashort laser pulses with nanoplasmonics enables spatiotemporal control of electronic excitations with subwavelength precision [1].

We investigate the quality of different structures to achieve controlled localizations of electric excitations. For one selected setup we present our simulation methods: Field distributions are calculated by a Maxwell solver (JCMsuite) in frequency domain and are composed to simulate time resolved distributions of shaped pulses. The pulse shapes needed to localize the electric field on a nanometer scale are found using a genetic algorithm [2].

We take advantage of this method to examine the excited states of coupled quantum dots: Extending a coherent spectroscopy method [3] (double quantum coherence) by the additional spatial control reveals more information about the system than without spatial control.

[1] M. Aeschlimann et al., Nature 446 (7133), 301-304 (2007)
[2] M. Reichelt and T. Meier, Opt. Lett. 34 (19), 2900-2902 (2009)
[3] L. Yang and S. Mukamel, Phys. Rev. Lett. 100, 057402 (2008)