HL 68: Metal-Semiconductor Hybrids

Time: Thursday 9:30–12:30 Location: H10

Invited Talk HL 68.1 Thu 9:30 H10

Modifications of material and chemical properties of organic molecules driven by QED phenomena — •Francisco Garcia-Vidal — Departamento de Fisica Teorica de la Materia Condensada and Condensed Matter Physics Center (IFIMAC), Universidad Autonoma de Madrid, Madrid 28049 (Spain)

In this talk we will show how some material and chemical properties of molecules can be tuned and modified by taking advantage of the phenomenon of collective strong coupling. First we will show how exciton conductance in organic materials can be enhanced by several orders of magnitude when the molecules are strongly coupled to an EM confined mode [1]. We furthermore show that by designing the electric field profile of the EM mode that provides the strong coupling, the transport properties can be tuned to achieve exciton harvesting and funneling, i.e., to guide excitons from a collection area to a specific location [2]. Finally, we analyze under which conditions the molecular properties under strong coupling can be understood by the modification of the potential energy surfaces determining nuclear dynamics under the Born-Oppenheimer approximation. In addition, we demonstrate that the nuclear dynamics of the molecules in electronic dark states, which are only weakly coupled to the EM mode, are nonetheless affected by the formation of collective strong coupling [3].

[1] J. Feist and F. J. Garcia-Vidal, Phys. Rev. Lett. 114, 196402 (2015). [2] C. Gonzalez-Ballestero, J. Feist, Esteban Moreno, and F. J. Garcia-Vidal, Phys. Rev. B 92, 121402(R) (2015). [3] J. Galego, F. J. Garcia-Vidal, and J. Feist, Phys. Rev. X 5, 041022 (2015).

HL 68.2 Thu 10:00 H10

Coherent coupling between excitons and surface plasmon polaritons reduces inhomogeneous broadening in a J-aggregate thin film at room temperature — Xuan Trung Nguyen[1,2], •Antonietta De Sio[1,2], Julia Witt[2,3], Gunther Wittstock[2,3], and Christoph Lienau[1,2] — [1]Institut für Physik, Carl von Ossietzky Universität Oldenburg, Germany — [2]Center of Interface Science, Carl von Ossietzky Universität Oldenburg, Germany — [3]Institut für Chemie, Carl von Ossietzky Universität Oldenburg, Germany

Organic molecular aggregates are of particular interest for the development of novel nanostructures for technological applications spanning from artificial light harvesting to all-optical plasmonic switching. The optical spectra of these molecular aggregates are often dominated by structural disorder effects resulting in inhomogeneously broadened absorptive lineshapes at room temperature. By using broadband spectral interferometry we show that inhomogeneous broadening in a model J-aggregate cyanine dye is significantly reduced in the presence of an ultrathin sub-10-nm gold layer and the resulting optical spectra show almost perfect Lorentzian line shapes at room temperature. This surprising result is accompanied with the reduction of electron-phonon interactions (vibronic resonances) and increased delocalization of the wavefunction due to strong electronic coupling to surface plasmon polaritons.

HL 68.3 Thu 10:15 H10

Strong light-matter interaction between Tamm plasmons and exciton-polaritons in ZnSe-based microcavities — •SK. Shaid-Ur Rahman[1], Thorsten Klein[2], Sebastian Klembt[2], Detlef Hommel[2], Jürgen Gutowski[1], and Kathrin Sebald[1] — [1]Semiconductor Optics — [2]Semiconductor Epitaxy, Institute of Solid State Physics, University of Bremen, Bremen, Germany

Cavity polaritons are half-light-half-matter quasi-particles, resulting from strong coupling between quantum well (QW) excitons and cavity photons. One can modulate the polariton eigenenergies by utilizing Tamm plasmons (TPs) which are formed, e.g., at the interface between a metal and the distributed Bragg reflector (DBR) of a microcavity (MC). We will discuss the influence of TPs on the optical properties of ZnSe-based MCs. The MC consists of a 12-fold top DBR, a λ cavity including 3 ZnSe QWs, and a 18-fold bottom DBR. A layer of 40 nm Ag is deposited on top of the MC sample. Anti-crossing between the TP and the cavity mode has been observed in the micro-reflectivity measurements performed for different top layer thicknesses at RT. This built hybrid state possesses a splitting energy of about 40 meV. Measurements at 4K show four resonances due to the hybrid states of Tamm plasmons, heavy-hole, and light-hole exciton-polaritons. On resonance between the TP and the cavity mode the lowest hybrid eigenenergy is about 9 meV red-shifted from the spectral position of the lower polariton energy in the Ag layer free sample. All experimental observations are in good agreement with calculations based on the transfer-matrix method as well as on the coupled-oscillator model.

HL 68.4 Thu 10:30 H10

Proposal of detecting non secular processes through coherent nanooptical spectroscopy — Markus Krecik, Sven M. Hein, Mario Schoth, and •Marten Richter — Institut für Theoretische Physik, Technische Universität Berlin, Germany

Relaxation or coherence conversion processes are often induced by system-bath interactions. In the theoretical description, it is often sufficient to keep only conversion processes between (excitonic) coherences and populations involving nearly resonant density matrix elements (secular processes). However interesting Non-Markovian signatures potentially involve secular and non secular processes. The dissection of secular and non secular processes is routinely carried out in theory, but the identification of a pure non secular observable in experiment is pending. We propose an experimental signal only with contributions from non secular processes. The signal uses a combination of coherent multidimensional spectroscopy and nanoplasmonic metal structures. For controlling the optical selection rules (required by the protocol) the nanooptical structure provides dynamical switches between spatial constant optical fields and field gradients. The signal is calculated for the example of a colloidal semiconductor quantum dot.

[1] Phys. Rev. A 92, 052113 (2015)

30 min. Coffee Break

HL 68.5 Thu 11:15 H10

Plexciton dynamics studied by Transient Absorption Spectroscopy — •Emanuele Minutella[1,2], Florian Schulz[1,2], Christian Strelow[1], Horst Weller[1,2], and Holger Lange[1,2] — [1]Institut für Physikalische Chemie, Universität Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Hamburg, Germany

Hybrid nanosystems composed of semiconductor nanoparticles (NPs) and metal NPs have different properties then each component of its own. In case of strong coupling, the exciton-plasmon coupling can lead to a collective state, also called plexciton. It is strongly influenced by the energy difference between the two systems, the size of the NPs and their distance. Although this system gives amazing possibilities, e.g. for defined charge and energy transfer in solar cells, experiments on this system remain rare.

To address the dynamics of this system the method of choice is femtosecond transient absorption spectroscopy. By varying the pump wavelength it is possible to perform resonant excitation, either within the exciton or the plasmon, or to excite both off-resonant simultaneously.

Au NPs and CdSe NPs were synthesized by wet chemical synthesis enabling to adjust their size. To control the interparticle distance the CdSe NPs were embedded in a stiff polymer shell with a variable thickness. We show first results on individual Au and CdSe NPs as well as their aggregates.

HL 68.6 Thu 11:30 H10

Control of optical processes in organometal halide perovskites using plasmonic nanoantennas — •Aurora Manzi, Lakshminarayana Polavarapu, Alexander Urban, and Jochen Feldmann — Chair for Photonics and Optoelectronics Ludwig-Maximilians-Universität (LMU), München, Germany

Fluorescence enhancement through the interaction of an emitting material with plasmonic nanostructures has been widely investigated for fluorophores ranging from dye-molecules to quantum dots for various applications. Plasmonic nanoparticles that are in the proximity of an emitting material change the local field and hence the absorption and photoluminescence characteristics of the material.

Perovskites are new materials that have recently attracted strong interest due to their fluorescence properties and possible applications in light emitting devices1. The interaction of perovskite nanocrystals with plasmonic structures could open new pathways for the application of such perovskite nanocrystals in various fields. However, there have not been many studies towards this direction.

In our studies we investigate the effect of plasmonic nanostructures on the photoluminescence of two-dimensional perovskite nanoplatelets. Bowtie nanoantennas were prepared with e-beam lithography and used as plasmonic resonators to study their influence on the optical properties of $CH_3NH_3PbX_3$ (X=Br, I) platelets.

HL 68.7 Thu 11:45 H10

Helicity sensitive terahertz radiation detection by dual-grating-gate high electron mobility transistors — •Philipp Faltermeier[1], Peter Olbrich[1], Willibald Probst[1], Leonhard Schell[1], Takayuki Watanabe[2], Stephane Albon Boubanga Tombet[2], Taiichi Otsuji[2], and Sergey Ganichev[1] — [1]University of Regensburg, Regensburg, Germany — [2]Tohoku University, Sendai, Japan

We report on the observation of a radiation helicity sensitive photocurrent excited by terahertz (THz) radiation in dual-grating-gate (DGG) InAlAs/InGaAs/InAlAs/InP high electron mobility transistors (HEMT). For a circular polarization the current measured between source and drain contacts changes its sign with the inversion of the radiation helicity. For elliptically polarized radiation the total current is described by superposition of the Stokes parameters with different weights. Moreover, by variation of gate voltages applied to individual gratings the photocurrent can be defined either by the Stokes parameter defining the radiation helicity or those for linear polarization. We show that artificial non-centrosymmetric microperiodic structures with a two-dimensional electron system excited by THz radiation exhibit a *dc* photocurrent caused by the combined action of a spatially periodic in-plane potential and spatially modulated light. The results provide a proof of principle for the application of DGG HEMT for all-electric detection of the radiation's polarization state. [1] P. Faltermeier *et al.*, Journal of Applied Physics **118**, 084301(2015)

HL 68.8 Thu 12:00 H10

Electrochemical approaches for controlling plasmonic nanostructures — •Gilles Bourret[1], Tuncay Ozel[2], Martin Blaber[2], George Schatz[2], and Chad Mirkin[2] — [1]Paris-Lodron University, Salzburg, Austria — [2]Northwestern Universty, USA

The optical and electrical properties of heterogeneous nanowires are profoundly related to their composition and nanoscale architecture. However, the intrinsic constraints of conventional synthetic and lithographic techniques have limited the types of multi-compositional nanowires that can be created and studied in the laboratory. Our recent progress in templated syntheses of one-dimensional nanostructures will be briefly disccussed in the context of plasmonics.[1-3] In particular, we report a high-throughput technique that can be used to prepare coaxial nanowires with sub-10 nm control over the architectural parameters in both axial and radial dimensions. The method, which is termed coaxial lithography (COAL),[3] relies on templated electrochemical synthesis and can create coaxial nanowires composed of combinations of metals and semiconductors. The optoelectronic properties of a plasmonic nanoring embedded hybrid core-shell semiconductor nanowire were studied. This demonstrates the potential of this new synthetic technique to radically change nanowire fabrication.

References. [1] G. R. Bourret, T. Ozel, M. Blaber, C. Shade, G. C. Schatz and C. A. Mirkin Nano Lett. 2013, 13, 2270. [2] T. Ozel, G. R. Bourret, A. Schmucker, K. Brown and C. A. Mirkin Adv. Mater. 2013, 25, 4515. [3] T. Ozel, G. R. Bourret and C. A. Mirkin Nature Nanotech. 2015, 10, 319.

HL 68.9 Thu 12:15 H10

Interaction of Porous Silicon Photonic Crystals and Plasmonic Nanostructures for Applications in Surface-Enhanced Raman Spectroscopy — •Martin Fränzl, Stefan Moras, and Dietrich R.T. Zahn — Semiconductor Physics, Technische Universität Chemnitz, Germany

We fabricated porous silicon photonic crystals by electrochemical etching of p-doped silicon in hydrogen fluoride solution. By applying a periodic etching current we obtain a periodic change of the porosity and thus a periodic variation of the effective refractive index. This represents a photonic crystal in one dimension and results in a very high reflectance in the photonic band gap. The plasmonic structures were fabricated using nanosphere lithography leading to metallic nanostructure arrays. These ordered structures show a collective plasmonic resonance with a high absorbance and a very low transmission. We combined these structures by using the porous silicon photonic crystal as substrate for the nanosphere lithography and designed both structures so that the plasmonic resonance is located in the center of the photonic band gap. The properties of the structures were measured using spectroscopic ellipsometry and simulated using effective medium theories and finite-element methods. The high reflectance of the photonic crystal and the absorbance at the plasmonic resonance results in a strong confinement and enhancement of electric fields at the interface. We performed surface-enhanced Raman spectroscopy (SERS) measurements by depositing a thin layer of CoPc on top of the composite structure and report a giant SERS enhancement factor in the order of 10^5.