HL 18: Plasmons, plasmonic laser, and spaser

Time: Monday 15:45–17:15 Location: EW 203

HL 18.1 Mon 15:45 EW 203

Metal-Organic Microcavities: Utilizing Tamm-Plasmon-Polaritons for Observing Photonic Bloch States — •Andreas Mischok[1], Robert Brückner[1], Alexander A. Zakhidov[1,2], Vadim G. Lyssenko[1], Hartmut Fröb[1], and Karl Leo[1] — [1]Institut für Angewandte Photophysik, Technische Universität Dresden, George-Bähr Str. 1, 01069 Dresden — [2]Texas State University, 601 University Drive, San Marcos, Texas, United States

Organic small molecule semiconductors provide large oscillator strengths, high quantum efficiencies and broad tunable emission spectra, ideal for an application in low-threshold microcavity lasers. We fabricate such cavities and add a photolithographically patterned silver layer next to the organic emitter system. Embedding metallic layers into such a microcavity leads to the interaction of the optical cavity-state in the organic layer and the neighbouring metal which red-shifts the cavity resonance, creating a Tamm-Plasmon-Polariton state. A patterning of the metal can in turn be exploited to fabricate deep photonic wells of micron-size, that efficiently confine light in the lateral direction [1]. In periodic arrays of silver wires we can create a Kronig-Penney-like optical potential in the cavity and in turn observe optical Bloch states spanning over several of these photonic wires [2]. We modify the Kronig-Penney theory to analytically describe the full far-field emission dispersion of our cavities and show the emergence of either zero- , π-, or 2π- phase-locking in the system [3].

[1] APL **105**, 051108; [2] Advanced Optical Materials **2**(8), 746;
[3] Nature Photonics **6**, 322.

HL 18.2 Mon 16:00 EW 203

Influence of Tamm plasmons on the light-matter interaction in ZnSe-based microcavities — •SK. Shaid-Ur Rahman[1], Merle Cornelius[1], Thorsten Klein[2], Carsten Kruse[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, P.O. Box 330440, 28334 Bremen, Germany

Strong light-matter interactions in semiconductor microcavities (MCs) introduce cavity polaritons. ZnSe-based MCs are very promising to realize polariton devices at elevated temperatures due to high oscillator strengths and large excitonic binding energies. By depositing a metallic layer on the DBR, electromagnetic modes called Tamm plasmons can be formed at the semiconductor-metal interface. We will discuss the influence of Tamm plasmons on the optical properties of ZnSe-based MCs. The cold MC consists of a 12-fold bottom DBR, a $\lambda/2$ cavity and a 1.5-fold top DBR. The hot unfolded MC is built of an 18-fold bottom DBR and a λ cavity including 3 ZnSe QWs. Ag layers with thicknesses between 30 and 50 nm are deposited on the MC samples. Micro-reflectivity measurements on the cold MC covered by a 30 nm Ag layer show a shift of the cavity resonance of about 26 meV compared to the metal-free areas, due to the influence of Tamm plasmons. For the hot MC, besides the shift an anticrossing between the generated cavity resonance and QW excitons is observed in temperature dependent measurements. The observed energy shift and the anticrossing are in agreement with simulations based on the transfer-matrix method.

HL 18.3 Mon 16:15 EW 203

Photonic and plasmonic coupled CdS nanowire lasing — •Lukas Trefflich[1], Robert Röder[1], Themistoklis Sidiropoulos[2], Rupert F. Oulton[2], and Carsten Ronning[1] — [1]Institut für Festkörperphysik, Friedrich- Schiller- Universität Jena, Max- Wien- Platz 1, 07743 Jena — [2]Imperial College London, Prince Consort Road, UK-SW7 2BZ London, UK

Conventional electronic circuitry has driven the technological progress for decades by progressive miniaturization of the structure. However, facing its limits concerning the minimal size of the structures an alternative approach might be provided utilizing nanophotonic elements. The building of such devices for optical data processing urgently requires nanoscale light sources like nanolasers. Compound semiconductor nanowires made of zinc oxide (ZnO) or cadmium sulfide (CdS) are well known as coherent nano-lightsources. Especially, CdS nanowires emitting in the green spectral range show room temperature lasing as well as cw operation [Geburt et al, Nanotechnology 23, 365204 (2012), Röder et al, Nano Letters 13, 3602 (2013)]. However, these nanowire lasers are limited in size and maximal switching speed due to the diffraction limit and the relatively slow light-matter interactions. Confining the guided electric field by coupling it to surface plasmons accelerates the spontaneous and stimulated emission through the Purcell- effect, making ultrafast, sub- wavelength nanolasers possible. Therefore, the polarization properties as well as the temporal dynamics of cadmium sulfide nanowires on photonic and plasmonic surfaces are investigated.

HL 18.4 Mon 16:30 EW 203

Theoretical studies on a plasmonic nano-laser: plasmon excitation and emission line narrowing due to the presenec of many molecules — •Yuan Zhang and Volkhard May — Institut für Physik, Humboldt Universität zu Berlin, Netonstrasße 15, D-12489 Berlin, Germany

Strong plasmon excitation and photon emission is demonstrated for a plasmonic nano-laser (SPASER) consisting of a gold nano-sphere coated by many dye molecules. An exact description of this system in the framework of density matrix theory becomes possible if all molecules are treated as identical units. Due to their external and simultaneous excitation the molecules overcome the huge plasmon damping. By increasing the number of molecules, the photon emission intensity increases and the emission line-shape becomes narrowed. Thus, such results can be related to plasmonic lasing. Beside optical pumping of the molecules also a mechanism of electrical pumping is considered. It is realized via electron transfer between the molecules and two leads forming a molecular junction. The exact quantum-dynamics simulations are extended up to 20 molecules covering the nano-sphere.

HL 18.5 Mon 16:45 EW 203

Atomistic Modeling of Excitation Energy Transfer in a Metal Semiconductor Core Shell Nanostructure — •Dirk Ziemann and Volkhard May — Institut für Physik, Newtonstr. 15, Humboldt Universität zu Berlin, D-12489 Berlin, Germany

The interaction of metal nanoparticle plasmons with semiconductor excitons is well studied in literature. As a consequence of this coupling the properties of semiconductor excitons are strongly modified. In this talk special attention is paid to the combination of both systems in close proximity, particularly a core shell system with a metal core and a semiconductor shell. The influence of the metal on the electronic structure of the semiconductor nanostructure is modeled on an atomistic level and the interaction of semiconductor excitons and metal plasmons is discussed. It is shown that exciton quenching due to excitation energy transfer from the semiconductor shell to the metal core is in line with recent experiments (ACS Nano 8(2014),352-361).

HL 18.6 Mon 17:00 EW 203

Numerically exact solution of the many emitter – cavity laser problem: application to the fully quantized spaser emission — •Michael Gegg, T. Sverre Theuerholz, Andreas Knorr, and Marten Richter — Institut für Theoretische Physik, Nichtlineare Optik und Quantenelektronik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

Open many body quantum systems consisting of N quantum emitters (QEs), e.g. dye molecules or quantum dots, coupled to a lossy cavity/optical mode have been subject to extensive research for decades. These systems are described by a Tavis-Cummings/Dicke model in the Lindblad formalism for open quantum systems. This provides access to a manifold of interesting applications, such as lasers, parametric amplifiers, atomic coherent states etc.

For instance, in the field of quantum plasmonics, the model system was utilized to address the feasibility of spasing – i.e. surface plasmon amplification by stimulated emission of radiation. In this context, we develop an exact and numerically scalable solution to the Tavis-Cummings/Dicke Lindblad equation.