HL 43: Optical Properties II

Time: Thursday 9:30–11:45 Location: EW 561

HL 43.1 Thu 9:30 EW 561

Polarized room-temperature polariton lasing in elliptical microcavities filled with fluorescent proteins — •Marti Struve[1], Christoph Bennenhei[1], Sven Stephan[1,2], Nils Kunte[1], Victor N. Mitryakhin[1], Falk Eilenberger[3], Jürgen Ohmer[4], Utz Fischer[4], Martin Silies[2], Christian Schneider[1], and Martin Esmann[1] — [1]Institute for Physics, Carl von Ossietzky University of Oldenburg, Germany — [2]University of Applied Sciences Emden/Leer, Germany — [3]Institute of Applied Physics, Abbe Center of Photonics, Friedrich Schiller University Jena — [4]Department of Biochemistry, University of Würzburg, Germany

Excitons in organic semiconductors can couple strongly to cavity photons forming exciton polaritons at ambient conditions. In artificial photonic potentials they are an emerging platform to study polariton lasing and Bose-Einstein condensation [1,2]. In this work, we study the polarization properties of fluorescent proteins enclosed by distributed Bragg reflectors with elliptical indentations [3]. We show experimentally and numerically that the structural anisotropy of the elliptical potential and the internal TE-TM splitting of dielectric Bragg reflectors leads to a distinct polarization splitting. This splitting enforces condensation into one polaritonic mode with linear polarization. Our devices have relevant applications for the engineering and tuning of polarization in room temperature polariton lasers through additional degrees of freedom. References [1] S. Betzold et al. ACS Photonics 7, 384 (2020). [2] M. Dusel et al. Nano Lett. 21, 6398 (2021). [3] C. Bennenhei, M. Struve et al. Opt. Mater. Express 13, 2633 (2023).

HL 43.2 Thu 9:45 EW 561

Optical realization of Shubnikov - de Haas and other quantum oscillations in THz transmission — •Maksim Savchenko — Vienna University of Technology

Due to causality-related correspondence between static and dynamic properties of physical systems, quantum oscillation observed in a DC response must reveal their counterpart in the optical domain.

In the talk, I will present the optical analogues of three types of the DC transport quantum oscillations. First, the optical realization of the microwave-induced resistance oscillations that are measured in the optical response, sub - terahertz transmittance of a two-dimensional system [1]. Second, the optical counterpart of the transport Shubnikov - de Haas oscillations, where we reveal two distinct types of oscillation nodes: 'universal' nodes at integer ratios of radiation and cyclotron frequencies and 'tunable' nodes at positions sensitive to all parameters of the structure. We analyse the nodes in both real and imaginary parts of the measured complex transmittance using a dynamic version of the static Lifshitz-Kosevich formula. And third, I will present the optical oscillations that have the same origin as transport magneto-intersubband oscillations.

These results reveal another advantage of the optical studies that provide a simultaneous access to quantization- and interaction-induced renormalization effects. And in conclusion, I will also discuss current opportunities and challenges to observe other well-known in DC transport effects in the optical domain.

[1] M. L. Savchenko et al., PRR 3, L012013 (2021).

HL 43.3 Thu 10:00 EW 561

Coherence of magnetic-field-coupled $1S$ excitons in Cu_2O — •Andreas Farenbruch[1], Nikita V. Siverin[1], Gülistan Uca[1], Dietmar Fröhlich[1], Heinrich Stolz[2], Dmitri R. Yakovlev[1], and Manfred Bayer[1] — [1]TU Dortmund, Dortmund, Germany — [2]Universität Rostock, Rostock, Germany

The coherence of the $1S$ exciton state in cuprous oxide (Cu_2O) is investigated using difference frequency generation with two-photon excitation (2P-DFG) for varying temperatures and excitation powers. The pulses of the first laser induce a coherent exciton population via a two-photon excitation process. The pulses of the second laser stimulate the emission of photons with the energy difference between the excitons and the stimulating photons. By delaying the pulses of the second laser, the 2P-DFG signal is measured as a function of time. This technique is used to measure the coherence times of the magnetic-field coupled $1S$ exciton states at magnetic fields of up to 10 T in Voigt configuration.

Characteristic polarization selection rules for this process are derived through group theoretical considerations and experimentally confirmed by measuring the full polarization dependence. Chosen linear polarization settings allow for a selective measurement of the decay of a single exciton state or additional two- or three-level quantum beats. The dependence of the coherence times is investigated for temperatures in the range of 1.4 to 2 K and excitation powers between 3 and 30 mW.

HL 43.4 Thu 10:15 EW 561

Intensity modulation of a light beam by excitation of 1S-excitons in Cu_2O in a cavity — •Simon Siegeroth, Binodbihari Panda, Mariam Harati, Julian Heckötter, and Marc Assmann — Department of physics, TU Dortmund, Dortmund 44227, Deutschland

Excitons in Cu2O are a suitable platform to study Rydberg physics. By reaching a high principal quantum number up to 25[1], many characteristic properties increase by orders of magnitude compared to ground state excitons, such as the radius ($r \propto n^2$), the lifetime ($t \propto n^3$) or the blockade volume ($V \propto n^7$). Here we report on the interaction between Rydberg excitons and ground state excitons (1S). By exciting 1S-exctions via a two-color pump probe setup we observed modulation of the laser intensity of the transmitted probe beam in spectral dependency. The modulation is dependent on pump laser energy & power and also visible in the reflected probe beam. This phenomenon is investigated for a set of parameters such as pump-power, angle, probe-polarization, probe-power and overlap. The oscillations do only appear when the sample is mounted strain free between two glass plates with a low reflectivity of around 4% at each surface which are forming a (bad) cavity. Interestingly the oscillations appear as well when the probe laser is tuned out of resonance.

[1] T. Kazimierczuk, D. Fröhlich, S. Scheel, H. Stolz, and M. Bayer. "Giant Rydberg excitons in the copper oxide Cu2O." Nature 514 (2014), pp. 343-347.

15 min. break

HL 43.5 Thu 10:45 EW 561

Organic room-temperature polariton condensate in a higher-order topological lattice — •Christoph Bennenhei[1], Hangyong Shan[1], Marti Struve[1], Nils Kunte[1], Falk Eilenberger[2], Jürgen Ohmer[3], Utz Fischer[3], Xuekai Ma[4], Christian Schneider[1], and Martin Esmann[1] — [1]Institute of Physics, Universität Oldenburg, Germany — [2]Fraunhofer-Institute for Applied Optics and Precision Engineering IOF, Jena, Germany — [3]Department of Biochemistry, Universität Würzburg, Germany — [4]Department of Physics, Paderborn University, Germany

Organic molecule exciton-polaritons in artificial photonic lattices have emerged as a versatile platform to emulate unconventional phases of matter at ambient conditions, including protected interface modes in topological insulators [1]. We investigate bosonic condensation in the most prototypical higher-order topological lattice, a 2D-version of the Su-Schrieffer-Heeger (SSH) model, which supports both zero- and one-dimensional topological defect modes. Using spatially resolved photoluminescence spectroscopy, we observe the topological defect modes of fluorescent protein-filled distributed Bragg reflector cavities with a fabricated lattice of hemispherical indentations defining a staggered photonic trapping potential. We observe bosonic condensation into topologically protected interface modes and demonstrate spatial first-order coherence in the protected 1D channels via interferometric measurements. Our findings pave the way towards organic on-chip polaritonics using higher-order topology as a tool for the generation of robustly confined lasing states. [1] Nano Lett. 2021, 21, 15, 6398-6405

HL 43.6 Thu 11:00 EW 561

Cumulant expansion of the electronic polarizability: beyond the static Bethe-Salpeter equation — •Pier Luigi Cudazzo — University of Trento (Italy)

One of the big challenges of theoretical condensed matter physics is the description, understanding, and prediction of the correlation effects induced by the mutual interaction between particles on materials properties. In both electronic and optical spectra the Coulomb interaction and the electron-phonon coupling cause a renormalization of the energies and change of spectral weight. Most importantly, they induce

a finite lifetime on the quasi-particle (QP) excitations and can lead to new structures, often called satellites. The latter are pure many body effects and can be linked to the coupling of excitations, also termed dynamical effects. Standard methods developed in the framework of many body perturbation theory namely GW and the Bethe-Salpeter equation (BSE) are often not able to capture this complex physics. Instead, approaches based on a picture of electron-boson coupling such as the cumulant expansion are promising for the description of plasmon and phonon satellites. Motivated by the recent success of the cumulant expansion of the one particle Green's function in the description of photoemission spectra, we generalized the cumulant approach to the evaluation of the electronic polarizability. In this way we provide a new full ab-initio tool to include dynamical effects beyond the standard BSE in the description of neutral excitations as measured in optical absorption, photoluminescence, electron energy loss and inelastic X-rays scattering spectroscopies.

HL 43.7 Thu 11:15 EW 561

Hyper-Raman effect on magnetic-field coupled $1S$ exciton polaritons in Cu_2O — •Gülistan Uca[1], Andreas Farenbruch[1], Dietmar Fröhlich[1], Heinrich Stolz[2], Dmitry Yakovlev[1], and Manfred Bayer[1] — [1]TU Dortmund, Dortmund, Germany — [2]Universität Rostock, Rostock, Germany

We analyzed the polarization dependence of the hyper-Raman effect for magnetic field-coupled $1S$ exciton polaritons in cuprous oxide (Cu_2O), a material recently recognized for hosting Rydberg excitons with high principal quantum numbers. The hyper-Raman effect is a coherent process consisting of a two-photon excitation on the polariton branch and an emission of both a phonon and a photon. Characteristic polarization selection rules for this process are derived through group theoretical considerations. Applying this approach, the full polarization dependence of this process was simulated and measured for the hyper-Raman effect at a magnetic field of 10 T in Voigt configuration involving the Γ_3^- phonon. Further investigations focused on the hyper-Raman effect with a sideband emission involving the Γ_5^- phonon, as well as the longitudinal-transverse split Γ_4^- phonon mode.

HL 43.8 Thu 11:30 EW 561

Phonon-phonon interactions in the polarization dependence of Raman scattering — •Nimrod Benshalom[1], Noam Pinsk[1], Maor Asher[1], Olle Hellman[2], and Omer Yaffe[1] — [1]Department of Chemical and Biological Physics, Weizmann Institute of Science, Rehovot 76100, Israel — [2]Department of Molecular Chemistry and Material Science, Weizmann Institute of Science, Rehovot 76100, Israel

Inelastic light scattering offers an experimentally robust and accessible method to probe the potential surface governing ionic motion in crystals. Its analysis, however, usually relies on harmonic theory that predicts Lorentzian line shapes, monotonic temperature trends and strict selection rules. Since the spectra of dynamically disordered crystals can violate all of these, new evaluation schemes are required to realize the potential for physical insight dormant in light scattering experiments.

We have found that the polarization dependence of Raman scattering in organic crystals at finite temperatures can only be described by a fourth-rank tensor formalism. This generalization of the second-rank Raman tensor stems from the effect of off-diagonal components in the crystal self-energy on the light scattering mechanism. We thus establish a novel manifestation of phonon-phonon interaction in inelastic light scattering, markedly separate from the better-known phonon lifetime.