HL 52: Optical properties & Photonic crystals

Time: Friday 9:30–12:45 Location: EW 201

HL 52.1 Fri 9:30 EW 201

Gyrotropic effects in trigonal tellurium studied from first principles — •Stepan S. Tsirkin[1,2], Pablo Aguado Puente[1,2], and Ivo Souza[1,3] — [1]Centro de Física de Materiales, Universidad del País Vasco, 20018 San Sebastián, Spain — [2]Donostia International Physics Centre, 20018 San Sebastián, Spain — [3]Ikerbasque Foundation, 48013 Bilbao, Spain

We present a combined *ab initio* study of several gyrotropic effects in *p*-doped trigonal tellurium (effects that reverse direction with the handedness of the spiral chains in the atomic structure). The key ingredients in our study are the Berry curvature and the orbital magnetic moment induced in the Bloch states by the broken spatial inversion symmetry of the crystal structure.

We show that the observed sign reversal of the circular photogalvanic effect with temperature can be explained by the presence of Weyl points near the bottom of the conduction band acting as sources and sinks of Berry curvature. The passage of a current along the trigonal axis induces a parallel magnetization, leading to the occurence of Faraday rotation alongside natural optical rotation. In agreement with experiment, we find that when infrared light propagates antiparallel to the current at low doping, the induced Faraday effect enhances the natural optical rotation. The plane of polarization rotates in the opposite sense to the bonded atoms in the spiral chains, in agreement with a recent experimental determination of the handedness of a Te crystal that contradicts earlier reports.

The work is published as arXiv:1710.03204.

HL 52.2 Fri 9:45 EW 201

Rydberg-like states in organic semiconductor rods — •Aswin Asaithambi[1], Daichi Okada[2], Guenther Prinz[1], Yohei Yamamoto[2], and Axel Lorke[1] — [1]Lotharstrasse 1, Faculty of Physics, CENIDE, University of Duisburg-Essen, Duisburg 47057, Germany — [2]Division of Material Science, Faculty of Pure and Applied Sciences, University of Tsukuba, Tsukuba, Japan

Organic semiconductor Borondipyrromethene (BODIPY) derived samples have drawn much attention in recent years in the field of bioimaging due to their good photo-physical properties such as high extinction coefficient and quantum yield. BODIPY molecules, under certain conditions, can be grown into rods. Different growth methods result in BODIPY rods with different photo-emission wavelengths.

In this contribution we show photo-luminescence (PL) spectra from different rods under 405nm laser excitation. Emitted light from the rods can travel through the rod due to total internal reflection, combining their excellent PL properties with waveguide physics. The light intensity emitted at the end of the rod shows an exponential decrease as the distance between end of the rod and the excitation spot is increased. This is attributed to reabsorption and scattering. We quantify the extinction parameter for different rods and compare them. Interestingly, the PL spectrum from the green emitting rod, shows, besides a broad luminescence, a set of peaks with energies that follows a $1/n^2$ rule. Such behavior, known from Rydberg atoms comes unexpected. The spectra will be discussed using different models such as Rydberg excitons or charge accumulation in the crystal.

HL 52.3 Fri 10:00 EW 201

Sorting exciton polariton vortices by their orbital angular momentum — •Bernd Berger[1], Marius Kahlert[1], Daniel Schmidt[1], Marc Assmann[1], Martin Kamp[2], Christian Schneider[2], Sven Höfling[2], and Manfred Bayer[1] — [1]Experimentelle Physik 2, Technische Universität Dortmund, D-44221 Dortmund, Germany — [2]Technische Physik, Physikalisches Institut, Wilhelm Conrad Röntgen Research Center for Complex Material Systems, Universität Würzburg, D-97074 Würzburg, Germany

Vortices are elementary excitations in exciton polariton condensates that consist of a low-density core and a phase rotation of a multiple of 2π around it. In our experiment a light beam carrying orbital angular momentum (OAM) is utilized to excite exciton polariton vortices in a GaAs microcavity at cryogenic temperatures. Thereby the topological charge of the vortex directly corresponds to the quantized OAM of the incident light beam. In a sophisticated approach, the sample signal is sorted by the vortex topological charge and resolved in time without the need of a phase reference. Thus the dynamics of vortices with different topological charges are investigated.

HL 52.4 Fri 10:15 EW 201

Microscopic theory of two-photon absorption and stimulated emission in direct-gap semiconductors — •Wolf-Rüdiger Hannes and Torsten Meier — Department of Physics and CeOPP, University of Paderborn, Warburger Str. 100, D-33098 Paderborn, Germany

Two-photon absorption (TPA) rates in semiconductors are analyzed within a simple two-band model. The light-matter interaction is treated non-perturbatively using the semiconductor Bloch-equations extended by the intraband accelaration [1], which is shown to cause a significant enhancement of the $\chi^{(3)}$ nonlinear response as compared to the two-photon transition rate from second-order perturbation theory. [2] The enhancement is particularly strong for widely-nondegenerate signal and idler photons. Our results are in agreement with experimental spectra for both TPA [3] and stimulated two-photon emission. [4]

[1] H. T. Duc, T. Meier, and S. W. Koch, Phys. Rev. Lett. **95**, 086606 (2005); E. Sternemann, T. Jostmeier, C. Ruppert, H. T. Duc, T. Meier, and M. Betz, Phys. Rev. B **88**, 165204 (2013)
[2] M. Sheik-Bahae, D. C. Hutchings, D. J. Hagan, and E. W. Van Stryland, IEEE Journal of Quantum Electronics **27**, 1296 (1991).
[3] C. M. Cirloganu, L. A. Padilha, D. A. Fishman, S. Webster, D. J. Hagan, and E. W. Van Stryland, Opt. Express **19**, 22951 (2011).
[4] M. Reichert, A. L. Smirl, G. Salamo, D. J. Hagan, and E. W. Van Stryland, Phys. Rev. Lett. **117**, 073602 (2016)

HL 52.5 Fri 10:30 EW 201

Functionalized Nanoporous Au Particles for Enhanced Optical Nonlinearities — •Jue-min Yi[1], Dong Wang[2], Felix Schwarz[3], Germann Hergert[1], Jan Vogelsang[1], Petra Gross[1], Peter Schaaf[2], Erich Runge[3], and Christoph Lienau[1] — [1]Carl von Ossietzky Universität, Oldenburg — [2]TU Ilmenau, Ilmenau — [3]TU Ilmenau, Ilmenau

Nanoporous Au particles (nanosponges) have promising optical properties due to their percolated nanoporous structure with disorder and nanometers-sized pores where coherent multiple scattering of light can form a series of localized hot spots with large field enhancement. Here we have systematically studied the nonlinear optical effects from nanosponges and their functionalization with ZnO materials. In particular, we have performed time-resolved photoemission measurements on single nanosponges using ultrashort laser pulse excitation. The long-lived electron emission with high excitation efficiency proves the existence of localized plasmon states on the surface of the nanoporous particles with lifetimes of more than 20 fs [1]. We have further investigated their potential as disordered nanoantennas by depositing ZnO into nanometers-sized pores. Strong second harmonic emissions from ZnO in the vicinity of nanosponges have been observed. Our results indicate that individual nanosponges are robust disordered nanoantennas with strong local resonances, and shed new light on tailoring disorder with functional materials for specific applications.[1] G. Hergert, et al., Light: Science &Applications 6, e17075 (2017).

HL 52.6 Fri 10:45 EW 201

Routing of exciton-polaritons in microcavity waveguides — •Johannes Beierlein[1], Sebastian Klembt[1], Martin Klaas[1], Monika Emmerling[1], Holger Suchomel[1], Karol Winkler[1], Sebastian Brodbeck[1], Hugo Flayac[2], Christian Schneider[1], and Sven Höfling[1,3] — [1]Technische Physik, Universität Würzburg, Germany — [2]Institute of Theoretical Physics, EPFL, CH-1015 Lausanne, Switzerland — [3]School of Physics and Astronomy, University of St. Andrews, KY 16 9SS, United Kingdom

Exciton-polaritons have been in the centre of scientific investigation due to their hybrid light-matter nature. It allows for large propagation distances while maintaining a strong non-linearity. This work sheds light on the functionality of two passive exciton-polariton routing devices. First, two microcavity waveguides (WGs), which are realized by etching the top and bottom DBRs, are evanescently coupled. Due to the evanescent coupling, a Josephson oscillation manifests itself. This oscillation is clearly displayed in real-space due to the propagat-

ing nature of the condensate. Depending on the device parameters a different phase at the end of the coupling area can be achieved, resulting in different routing ratios. Further, we discuss two WGs which are coupled by a microcavity disc. A propagating condensate along one WG can be transmitted into the disc where it circulates and eventually exits into the other wire. Both of those tunneling events are energy dependent. The size parameters of the disc as well as the WGs influences the energy transmission pattern and therefore allows for energy controlled reshaping of the condensate.

HL 52.7 Fri 11:00 EW 201

Time-resolved spectroscopic ellipsometry with sub-ps resolution — •Steffen Richter[1], Oliver Herrfurth[1], Shirly Espinoza[2], Mateusz Rębarz[2], Miroslav Kloz[2], Jakob Andreasson[2,3], Marius Grundmann[1], and Rüdiger Schmidt-Grund[1] — [1]Universität Leipzig, Felix-Bloch-Instiut für Festkörperphysik, Linnéstr. 5, 04103 Leipzig, Germany — [2]ELI beamlines, Za Radnicí 835, Dolní Břežany, Czech Republic — [3]Chalmers tekniska högskola, Institutionen för fysik, Kemigården 1, 41296 Göteborg, Sweden

Knowledge of the temporal evolution of the complex optical properties in response to optical excitation is crucial for understanding of fundamental physical processes inherent in semiconductors. We demonstrate time-resolved ellipsometry in a pump-probe scheme employing continuum white-light probe and UV pump pulses. The ellipsometric approach allows to obtain the dynamics of the dielectric function in a broad spectral range with an estimated time resolution of 170fs. We will stress on essential experimental requirements and show data obtained from ZnO samples. We will also give an outlook on the pump-probe VUV ellipsometer being built up at ELI beamlines.

15 min. break.

HL 52.8 Fri 11:30 EW 201

Invisible excitons in hexagonal Boron Nitride — •Claudio Attaccalite[1,4], Lorenzo Sponza[2], Myrta Gruning[3], Hakim Amara[1], and François Ducastelle[1] — [1]CINaM UMR 7325, Aix-Marseille University - CNRS, Marseille, France — [2]LEM UMR 104, ONERA - CNRS, Chatillon, France — [3]Queen's University, Belfast, UK — [4]Universita Tor Vergata, Roma, Italy

In this work we study excitations in hexagonal Boron Nitride that are invisible in linear optical response. We show that these dark states can be measured with other spectroscopic techniques and they play an important roles in the response of h-NB. Our results clarify the indirect nature of h-BN and its excitation spectra.

HL 52.9 Fri 11:45 EW 201

Radiative versus non-radiative color conversion in an InGaN/polymer hybrid material system — •Niklas Mutz, Emil J. W. List-Kratochvil, and Sylke Blumstengel — Hybrid Devices Group, Institut für Physik, Institut für Chemie und IRIS Adlershof, Humboldt-Universität zu Berlin

White light generation in InGaN/GaN based light-emitting diodes (LEDs) is commonly achieved by so called external color conversion, where blue light emitted from an InGaN quantum well (QW) is subsequently partially absorbed by an inorganic phosphor material and reemitted in the yellow-orange spectral region to yield white light. In this process, the overall yield of converted photons is limited by the product of the quantum yield of the involved constituents. As an alternative, more efficient process, non-radiative Förster-like energy transfer from the inorganic QW to an organic acceptor can be used for the color conversion.

Here we investigate energy transfer from an InGaN/GaN single QW to a thin top layer of a light-emitting polymer, a cyano-ether-poly(p-phenylen-vinylen) (Cn-ether-PPV). We experimentally find that Cn-ether-PPV can be efficiently excited through the InGaN/GaN single QW when the organic polymer layer is in close proximity to the InGaN/GaN single QW. By means of time-resolved and -integrated photoluminescence spectroscopy at various temperatures we quantify the contribution of radiative and non-radiative energy transfer to the color conversion observed in this hybrid material system.

HL 52.10 Fri 12:00 EW 201

Trapping potentials for Rydberg excitons in cuprous oxide (Cu_2O) — •Sjard Ole Krüger and Stefan Scheel — Institut für Physik, Universität Ro- stock, D-18059 Rostock, Germany

The trapping of neutral atoms by optical dipole potentials is an established experimental technique. For semiconductor excitons, similar traps can be created by a spatially inhomogeneous strain field and have been applied in the pursuit of BEC of the excitonic ground state in Cu_2O. These strain traps offer a great variety achievable geometries, depending on the stressor, its orientation relative to the crystal axes, the stress and the excitonic state in question. In this talk, calculations of a strain-induced waveguide potential [1] for the Rydberg excitons of the yellow series in Cu_2O [2] will be presented and conditions for the formation of such traps will be evaluated. Additionally, the possibility of using optical dipole potentials to trap excitons will be discussed.

[1] S. O. Krüger and S. Scheel, http://arxiv.org/abs/1711.06639
[2] T. Kazimierczuk et al. , Nature 514, 343 (2014)

HL 52.11 Fri 12:15 EW 201

Wafer-scale metallic two-dimensional superlattice photonic crystals for light trapping — •Rui Xu, Huaping Zhao, and Yong Lei — Am Ehrenberg 2, 98693 ilmenau

Two-dimensional (2D) superlattice PhCs of alumina are found to be formed when preparing perfectly-ordered porous alumina membranes by anodizing surface-nanopatterned aluminium foils. Through a two-step replication process, we successfully replace alumina with metals (e.g., nickel, gold, silver, cobalt) to obtain wafer-scale metallic 2D superlattice PhCs. The geometrical and structural parameters of metallic 2D superlattice PhCs can be precisely tuned based on those of alumina counterparts, and finally leading to tailorable light trapping properties. As an example, nickel 2D superlattice PhCs can achieve stably strong (over 90%) light absorption below the steep cut-off wavelength which is controlled in the wavelength range of 600 - 1500 nm. Numerical simulations and systematic experiments reveal that the surface plasmon resonance and cavity resonance stemming from both nanopores and nanoconcaves are fundamentally responsible for light trapping.

HL 52.12 Fri 12:30 EW 201

Resonant state expansion for disordered claddings in photonic crystal fibers — •Swaathi Upendar[1], Izzatjon Allayarov[1], Guangrui Li[2], Markus Schmidt[2,3], and Thomas Weiss[1] — [1]4th Physics Institute and Research center SCoPE, University of Stuttgart, Germany — [2]Leibniz Institute of Photonic Technology, Jena, Germany — [3]Otto Schott Institute of Material Research, Friedrich Schiller University, Jena, Germany

Photonic crystal fibers guide light in a central defect core surrounded by a periodic cladding using a bandgap effect. We would like to study how disorder in the cladding affects the properties of an all solid photonic crystal fiber. As effects originating from disorder need to be averaged over many realizations, fast simulation techniques are required.

In this contribution we show how to adapt the so-called resonant state expansion [1] to such fiber geometries. Resonant states are solutions of Maxwell's equations with outgoing boundary conditions in the absence of source terms. For resonant state expansion, the resonant states need to be normalized correctly. The difficulty is that modes in hollow-core photonic crystal fibers radiate in the direction normal to the fiber axis, so that the electromagnetic fields of the modes grow exponentially with distance to the core and cladding. We demonstrate the correct normalization of the modes in such fibers and use the normalized modes to derive the propagation constants of modes in perturbed and thus, disordered systems.

[1] M. B. Doost, W. Langbein, and E. A. Muljarov, Phys. Rev. A **87**, 043827 (2013).