HL 59: Optical Properties II

Time: Wednesday 14:45–18:30 Location: H10

HL 59.1 Wed 14:45 H10

Electro-optical polariton transistor switch — •Holger Suchomel[1], Sebastian Brodbeck[1], Timothy Liew[2], Martin Klaas[1], Sebastian Klembt[1], Martin Kamp[1], Sven Höfling[1,3], and Christian Schneider[1] — [1]Technische Physik and Wilhelm-Conrad-Röntgen-Research Center for Complex Material Systems, Universität Würzburg, D-97074 Würzburg, Am Hubland, Germany — [2]Division of Physics and Applied Physics, Nanyang Technological University, 63737 Singapore, Singapore — [3]SUPA, School of Physics and Astronomy, University of St. Andrews, St. Andrews, KY 16 9SS, United Kingdom

We study the propagation of an optically injected exciton-polariton condensate along a one dimensional wire under the influence of a local, electrical gate. Applying a gate voltage, results in a general redshift of the emission along the wire superimposed by a local potential dip underneath the contact. Tuning of the trap depth and taking advantage of the detuning gradient along the wire is sufficient to block the polariton flow through the contact. As a consequence of the switching process and increased field ionization of excitons, the device shows a negative differential resistance and features a pronounced bistability in the probed photocurrent.

The combination of lithographic and electro-optical potential landscape engineering results in a compact device. It works as a polariton transistor switch which is operated by an external electric field rather than a control laser beam. This makes the approach suitable for on-chip applications and complex polariton circuits.

HL 59.2 Wed 15:00 H10

Probing the carrier reservoir across the polariton condensation and photon lasing transitions in a quantum well microcavity — •Sebastian Brodbeck[1], Holger Suchomel[1], Matthias Amthor[1], Theresa Steinl[1], Martin Kamp[1], Christian Schneider[1], and Sven Höfling[1,2] — [1]Technische Physik, Physikalisches Institut and Wilhelm Conrad Röntgen-Research Center for Complex Material Systems, Universität Würzburg, Am Hubland, 97074 Würzburg — [2]SUPA, School of Physics and Astronomy, University of St. Andrews, St. Andrews, KY 16 9SS, United Kingdom

We monitor the free carrier reservoir in a GaAs-based quantum well microcavity under non-resonant pulsed optical pumping by measuring the photocurrent between lateral contacts deposited directly on the quantum wells that are partially exposed by wet chemical etching. We identify two clear thresholds in the input-output characteristic of the photoluminescence signal which can be attributed to polariton condensation and photon lasing, respectively. The power dependence of the probed photocurrent shows a distinct kink at the threshold power for photon lasing due to increased radiative recombination of free carriers as stimulated emission into the cavity mode sets in. At the polariton condensation threshold on the other hand, the nonlinear increase of the luminescence is caused by stimulated scattering of exciton-polaritons to the ground state which do not contribute directly to the photocurrent. In the strong coupling regime, the system can be described by a rate equation model which includes field ionization related losses.

HL 59.3 Wed 15:15 H10

Investigation of the binding energy of $Al_xGa_{1-x}As/Al_yGa_{1-y}As$ quantum wells for high temperature polariton lasers — •Stefanie Kreutzer[1], Holger Suchomel[1], Sebastian Brodbeck[1], Maciej Pieczarka[2], Grzegorz Sęk[2], Christian Schneider[1], and Sven Höfling[1,3] — [1]Technische Physik, Physikalisches Institut and Wilhelm Conrad Röntgen-Research Center for Complex Material Systems, Universität Würzburg, Am Hubland, 97074 Würzburg — [2]Institute of Physics, Wroclaw University of Technology, Wybrzeze Wyspianskiego 27, 50-370 Wroclaw, Poland — [3]SUPA, School of Physics and Astronomy, University of St. Andrews, St. Andrews KY16 9SS, United Kingdom

We study the exciton binding energy in $Al_xGa_{1-x}As/Al_yGa_{1-y}As$ quantum wells for various aluminium concentrations in well and barrier as well as well widths. Binding energies are determined by comparing calculated transition energies to experimental values obtained from photoluminescence and photoreflectance studies. We find a strong enhancement of the binding energy compared to $GaAs/Al_xGa_{1-x}As$ quantum wells with increasing transition energy until the type I-type II-transition crossover with values exceeding 25 meV.

When integrating these quantum wells into microcavities, we observe a normal mode splitting between excitons and photons. Strong coupling persists at elevated temperatures with a measured Rabi splitting of 5meV at 230K.

HL 59.4 Wed 15:30 H10

InP-based photonic crystal microcavities embedded with InAs quantum dots for telecom wavelengths — •Andrei Kors, Matusala Yacob, Johann P. Reithmaier, and Mohamed Benyoucef — Institute of Nanostructure Technologies and Analytics (INA), CINSaT, University of Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany

Self-assembled semiconductor quantum dots (QDs) embedded in photonic crystals can be used as building blocks for future quantum information processing. Here, we report on the fabrication and optical characterization of InP-based photonic crystal microcavities embedded with InAs/InP QDs. Medium InAs/InP QD density emitting at the telecom wavelengths is grown by solid source molecular beam epitaxy. Using special capping technique and temperature processing after the dot formation, density of about 10^9 cm^{-2} is obtained. L3 photonic crystal air-bridge cavities are fabricated by electron beam lithography, inductively coupled plasma reactive ion etching and wet etching technique. Optical properties of microcavities such as polarization, emission wavelengths and quality factors are determined by microphotoluminescence measurements. Results reveal sharp cavity modes at telecom wavelengths.

HL 59.5 Wed 15:45 H10

Carrier density driven lasing dynamics in ZnO nanowires — •Marcel Wille[1], Chris Sturm[1], Tom Michalsky[1], Robert Röder[2], Carsten Ronning[2], Rüdiger Schmidt-Grund[1], and Marius Grundmann[1] — [1]Institut für Experimentelle Physik II, Universität Leipzig, Linnéstraße 5, 04103 Leipzig — [2]Institut für Festkörperphysik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena

The laser on-time of semiconductor nanowires was currently found to be in the range of 1 - 3 ps [1]. However, the emission onset characteristics of lasing semiconductor nanowires is not yet understood in detail because of the high demand on the temporal and spatial resolution of the detection technique. We report on the lasing dynamics of CVD grown ZnO nanowires from cryogenic temperatures up to room temperature using time-resolved micro-photoluminescence (μ-PL) technique. Our studies focus on the investigation of the temperature dependent emission onset-time (t_{on}). It turns out that t_{on} depends strongly on the excitation power and becomes smallest in the lasing regime, with values below 5 ps. Furthermore, we observed a red shift of the dominating lasing modes in time, which was described by a carrier density induced change of the refractive index dispersion after the optical excitation. For the qualitative analysis of the observed phenomena, we extended an existing model to calculate the carrier density dependent refractive index as well as the extinction coefficient for different temperatures. [1] T.P.Sidiropoulos et al., Nature Phys. 10, 870 (2014)

Invited Talk HL 59.6 Wed 16:00 H10

Discontinuous Galerkin Methods in Nano-Photonics — •Kurt Busch — Humboldt Universität zu Berlin, Institut für Physik, AG Theoretische Optik & Photonik, 12489 Berlin and Max-Born-Institut, 12489 Berlin, Germany

Discontinuous Galerkin (DG) methods facilitate efficient computations of nano-photonic systems [1] by combining the flexibility of finite element approaches with efficient time-stepping capabilities. While the former allows for an accurate representation of complex geometries, the latter requires material models that are amenable to auxiliary differential equations techniques. This latter aspect specifically includes material models for magneto- [2] and/or nonlinear-optical properties. In this talk, the present state of Discontinuous Galerkin Time-Domain (DGTD) approaches to nano-photonic systems is presented. This includes (i) methodic aspects such as convergence properties of DGTD computations with regards to the above-mentioned material models as well as (ii) selected applications such as the computation electron energy loss spectra [3,4] and modified emission dynamics [5], and the

nonlinear-optical properties of plasmonic nanostructures [6,7].

[1] K. Busch et al., Laser Photon. Rev. **5**, 773 (2011)
[2] C. Wolff et al., Opt. Express **21**, 12022 (2013)
[3] F. von Cube et al., Nano Lett. **13**, 703 (2013)
[4] B. Schröder et al., Phys. Rev B **92**, 085411 (2015)
[5] A.W. Schell et al., Nano Lett. **14**, 2623 (2014)
[6] A. Hille et al., J. Phys. Chem. C, in press
[7] D. Huynh et al., Appl. Phys. B, in press

30 min Coffee Break

HL 59.7 Wed 17:00 H10

Radiative modes in anisotropic planar microcavities — •Steffen Richter, Tom Michalsky, Chris Sturm, Helena Franke, Marius Grundmann, and Rüdiger Schmidt-Grund — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstr. 5, 04103 Leipzig, Germany

We present dispersions and polarizations of modes in microcavities with optically uniaxial cavity material, as e.g. wide gap oxides.

Using a 4×4 transfer matrix ansatz we compute mode energies and broadenings, i.e. lifetimes, as matrix poles. In contrast to the separation into transversal electric (TE) and transversal magnetic (TM) polarization, which is commonly done for the isotropic case, we can obtain the mode polarizations without any prior restriction. We show that an optical anisotropic cavity material does not change the number of eigenmodes compared with an isotropic one, i.e. two for a $\lambda/2$ cavity. Most strikingly, in non-trivial anisotropic configurations the modes are no longer orthogonally polarized to each other but tend both to TM polarization with increasing in-plane wavevectors $k_{||}$. Further, for configurations with the propagation direction almost, but not exactly, parallel or perpendicular to the optical axis of the cavity layer, circular polarization contributions of more than 90% can occur at large $k_{||}$.

HL 59.8 Wed 17:15 H10

Raman Tensor Formalism for Anisotropic Crystals — •Christian Kranert, Chris Sturm, Rüdiger Schmidt-Grund, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Semiconductor Physics Group, Leipzig, Germany

In optically anisotropic materials, the polarization of incident and scattered radiation changes within the crystal along the propagation direction due to birefringence. Consequently, the polarization state at an individual scattering event varies. This prohibits the direct application of the "standard" Raman tensor formalism and causes experimental Raman intensities to generally depend on specifics of the experiment such as focus depth and depth resolution. Therefore it was assumed that the Raman intensities for polarizations, which are not parallel to a principal axis of the dielectric indicatrix, cannot be analytically described. If done anyway, the polarization dependence was modeled using ad-hoc complex phase parameters for the individual Raman tensor elements without connection to a physical property.

We present a modified Raman tensor formalism which allows to model the Raman intensity in dependence on the polarization configuration for any crystal symmetry. It further establishes the complex phase parameters as special case for uniaxial crystals and explains their physical meaning. We explain that for an integration over a sufficiently large depth range, which is fulfilled for bulk samples and typical experimental setups, the depth dependence vanishes. We further discuss the case of an integration over a smaller depth range which is for example required for thin films.

HL 59.9 Wed 17:30 H10

Theory for the edge-state optical absorption in two-dimensional transition metal dichalcogenide flakes — •Maxim Trushin — University of Konstanz, Konstanz, Germany

The edge states provide electrical conductivity in quantum Hall systems and other two-dimensional (2d) topological insulators. Their role in optical and transport properties of other 2d materials, like 2d transition metal dichalcogenides [1], still remains illusive. There are indications that the optical absorption in MoS_2 at excitation energies below the band gap could be due to the edge states [2]. Here, we elaborate this problem from the theoretical point of view. We model the border between semiconductor and vacuum by means of the spatially dependent band gap: It is finite within the semiconducting region but infinite outside [3]. This model neglects the detail of the edge at the atomic level, but offers an analytical formula for the linear as well as saturable absorption. We show that the relative absorption of a single 50 nm-size MoS_2 flake is of the order of 0.01 % that corresponds to the absorption of a MoS_2-enriched polymer film of a few percent. We also find that at high radiation intensities the edge-state electron temperature can reach a few thousands Kelvin, whereas the bulk electrons and holes remain at lattice temperature. Our outcomes can be directly utilized for understanding of the subgap absorption in MX_2 flakes [2] and pave the way towards application of MS_2-based optoelectronic devices. [1] K.F. Mak et al. Phys. Rev. Lett. **105**, 136805 (2010). [2] R. I. Woodward et al. Photon. Res. **3**, A30 (2015). [3] M.V. Berry and R.J. Mondragon. Proc. R. Soc. (London) A **412**, 53 (1987).

HL 59.10 Wed 17:45 H10

Optical constants of Ge and GeO2 from ellipsometry — T. Nathan Nunley, Nalin Fernando, Jaime Moya, and •Stefan Zollner — New Mexico State University, Las Cruces, NM, USA

We studied the optical constants of GeO2 and Ge using spectroscopic ellipsometry. Ge substrates were prepared for oxidation by ozone cleaning at 150C for 90 minutes, followed by an ultrasonic clean in DI water, and then in isopropanol. The samples were then annealed in ultra high purity oxygen at 550C at a pressure of 25 psi at a flow rate of 1 l/min. The ellipsometric angles and depolarization were measured using a rotating analyzer ellipsometer with a computer controlled Berek waveplate compensator from 0.5-6.6 eV. X-ray reflectance with Cu radiation was performed to obtain thickness, roughness, and electron density independently. Measurements of the optical phonons were performed at CINT Sandia using FTIR ellipsometry. Samples with 0.1-200 nm GeO2 on Ge were studied, and it was found that the oxidation rate at this pressure was more than twice that previously reported in the literature. The optical constants of GeO2, assumed to be independent of thickness, and the Ge substrate are decoupled by varying the oxide thickness allowing for an optical constant optimization of both the film and the substrate. Using this method we have been able to obtain the optical constants for thermal GeO2 and Ge in the mid infrared and from 0.5-6.6 eV. These data sets will be crucial for the design of Ge based optoelectronic devices and for thickness measurements of thin films on Ge substrates.

HL 59.11 Wed 18:00 H10

Determination of optical and electronic structure properties of Sr2Si5N8:Eu2+ and Ce3+ phosphors — •sikander azam[1] and jan minar[2] — [1]New Technologies-Research Center, University of West Bohemia, Univerzitni 8, 306 14 Pilsen, Czech Republic — [2]Dept. of Chemistry, University of Munich, Germany

Upon doping with lanthanide ions (e.g. Eu2+, Ce3+), a number of nitridosilicates and oxonitridosilicates emerged as highly efficient luminescent materials (phosphors) that found considerable industrial application in white light emitting diodes (LEDs). It is found that the nitride (alumo) silicates *Sr2Si5N8:Eu2+* found broad industrial application as highly efficient red-emitting phosphor materials in pc-LEDs [1-3]. Using density functional theory (DFT) within the GGA+U form we investigated the structural, electronic and optical properties of Eu2+ and Ce3+ doped Sr2Si5N8. The total energy has been optimized as a function of the unit cell volume. Electronic structure like e.g. the density of state (DOS), the band structure and the linear optical susceptibility are calculated for the relaxed structure applying the optimized lattice constant. It will be shown that for the calculation of optical properties, which are closely related to the corresponding electronic structure our results are in very good agreement with experimental data. Concerning calculations we have to discuss it in a detail. References [1] Martin Zeuner, Peter J. Schmidt, Wolfgang Schnick, Chem. Mater., Vol. 21, No. 12, 2009 [2] Zeuner, M.; Schmidt, P. J.; Schnick, W. Chem. Mater. 2009, 21,2467. [3] Zeuner, M.; Pagano, S.; Schnick, W. Angew. Chem., Int. Ed. 2011, 50, 7754

HL 59.12 Wed 18:15 H10

THE INVESTIGATION OF PRESSURE EFFECT ON THE OPTICAL PROPERTIES, SPONTANEOUS POLARIZATION AND EFFECTIVE MASS OF BaHfO3: AB INITIO STUDY — •chaimae azahaf — Laboratory of Magnetism and High Energy Physics (URAC 12), Faculty of Sciences, Mohammed V University, B.P. 1014, Rabat, Morocco

Through first principles calculations, the optical properties, spontaneous polarization and the effective mass of the cubic perovskite BaHfO3 under pressure effect have been investigated, using the Full Potential Linearized Augmented Plane Wave (FP-LAPW) method implemented in the WIEN2K code, in connection with the Generalized Gradient Approximation (GGA). During this study, the effect of pres-

sure is seen on the electronic and optical properties such as: The band gap value (Eg) of the perovskite BaHfO3 is reduced and it becomes indirect instead of direct band gap as pressure increased. From the band structure we have also computed the variation of effective masse (m*) which increases to the same effect as the pressure. The results of the optical study, shows that the absorption coefficient increases and the spontaneous polarization (Ps) increases in a quasi-linear behavior as pressure increases. Our conclusion is that BaHfO3 is a piezoelectric material; also this material could be applicable in optoelectronic applications.