HL 48: Poster 2

Time: Thursday 15:00–17:30 Location: P2

HL 48.1 Thu 15:00 P2

Scanning tunneling microscopy and spectroscopy of phase change alloys — •Dinesh Subramaniam[1], Christian Pauly[1], Marco Pratzer[1], Marcus Liebmann[1], Pascal Rausch[2], Michael Woda[2], Matthias Wuttig[2], and Markus Morgenstern[1] — [1]II. Physikalisches Institut B, RWTH Aachen, Otto-Blumenthal-Straße, 52074 Aachen — [2]I. Physikalisches Institut A, RWTH Aachen, Otto-Blumenthal-Straße, 52074 Aachen

Phase change random access memory (PCRAM) is a very promising candidate for the next generation of memories. In contrast to the standard Si-based RAM, PCRAM is a non-volatile storage system which exploits the high electrical contrast between the amorphous and the crystalline phase. However, the origin of this contrast is not well understood. Scanning tunneling microscopy gives insight into the local atomic structure and the electronic properties of phase change materials. Using the topography mode of STM, we realized images of $Ge_1Sb_2Te_4$ on the nanometer down to the atomic scale, revealing the morphology as well as the complex atomic arrangement of the sputter-deposited material. The spectroscopy mode enabled us to analyse the local density of states in the amorphous and crystalline phase. The band gap varied continuously from 0.5 eV in the amorphous phase to 0.2 eV in the crystalline phase. The Fermi level moved from the center of the gap in the amorphous phase into the valence band within the crystalline phase.

HL 48.2 Thu 15:00 P2

Lattice dynamics in thermoelectric materials — •Anne Möchel[1], Werner Schweika[1], Karin Schmalzl[2], Jörg Voigt[2], and Raphaël P. Hermann[1] — [1]Institut für Festkörperforschung, Streumethoden, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany — [2]Institut für Festkörperforschung, JCNS, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany

Peltier elements are well known and commonly used for noiseless cooling or heating without any cryogenic agent nor mechanical movement. The thermoelectric materials used in these Peltier elements can also be used to recover waste heat, e.g. from exhaust gas of cars or industry, in order to protect our environment.

The application of thermoelectric materials as power converter is still rare, because of the poor efficiency in today's known and used materials. A good thermoelectric material must show a high electric conductivity, but it has to be a poor thermal conductor on the same time and an increase in efficiency requires, among other tuning, a decrease of the thermal conductivity.

Therefore a good understanding of the lattice dynamics in thermoelectric materials is necessary. New classes of promising thermoelectric materials are filled skutterudites and clathrates. We have studied the lattice dynamics in filled gallium germanium clathrates and ytterbium skutterudites with macroscopic methods, such as heat capacity measurements and resonant ultrasound spectroscopy, and neutron and X-ray scattering.

HL 48.3 Thu 15:00 P2

Surface plasmons in terahertz metamaterials — Guillermo Acuna[1], Stephan Heucke[1], Florian Kuchler[1], •Stefan Schloegl[1], How Tong Chen[2], Anton J. Taylor[2], and Roland Kersting[1] — [1]Photonics and Optoelectronics Group & Center for NanoScience, University of Munich, 80799 Munich, Germany — [2]Los Alamos National Laboratory, MPA-CINT, MS K771, Los Alamos, New Mexico 87545, USA

Many metamaterials consist of miniaturized electronic circuits, which are arranged in periodic patterns. Most commonly, the electromagnetic response of such lattices is attributed to the properties of the circuit within an individual unit cell. Examples are the resonances given by the inductances and capacitances (fundamental modes) or other modes within the unit cell such as Mie resonances. In this contribution, we will show that surface plasmons contribute to the overall response of metamaterials and in some cases even modify the fundamental response. We present an experimental study on metamaterials using terahertz near-field microscopy. The extreme subwavelength resolution of our technique provides the local properties of the individual resonances in all detail. The results show the fundamental mode as well as a resonance at higher frequency. Our study reveals that this resonance, which is commonly interpreted to be a Mie resonance, in fact results from the excitation of surface plasmons [1]. [1] G. Acuna, et al., *Surface plasmons in terahertz metamaterials*, Optics Express Vol. 16, 23, pp.18745-18751 (2008)

HL 48.4 Thu 15:00 P2

Simulation of wurtzite-type nanostructures with an Effective Bond-Orbital model — •Stefan Barthel, Daniel Mourad, and Gerd Czycholl — ITP Universität Bremen

Empirical Tight-Binding models use a discrete set of atomic orbitals on each atomic position in order to calculate the electronic structure of a given material, while the hopping matrix elements are fitted in a self consistent way to empirical parameters. An Effective Bond-Orbital model (EBOM) uses the Tight-Binding approach, but considers the Bravais lattice instead of the atomic basis. This results in a less dimensional Hamiltonian, which reduces the computational time drastically e.g. for the simulation of nanostructures. In this work an EBOM for wurtzite type semiconductors is developed from scratch for nearest and second-nearest neighbour couplings in a basis set of sp^3 orbitals. The LCAO-method or two-center-integral approximation has been extended to the needs of the wurtzite structure and is applied in order to relate all hopping parameters to a complete and known set of kp-parameters as well as critical point energies in the first BZ. Spin-orbit-coupling and crystal-field splitting is included too. Results for GaN and InN are in good agreement with existing Tight-Binding and ab-initio bandstructure calculations throughout the whole BZ and reproduce the accuracy of the kp-model around the zone-center exactly. This model is applied for the simulation of GaN/InN quantum dots by diagonalizing the Hamiltonian directly in the set of atomic orbitals. Nearest- and Second-Nearest-Neighbour results are compared to existing Tight-Binding calculations with focus on computational speed.

HL 48.5 Thu 15:00 P2

Theoretical investigation of Cu-Containing with different valance structure type $BaCu_2S_2$, Li_2CuSb and LiCuS. — •S. Soliman[1], Gerhard H. Fecher[1], A. Elfalaky[2], and Claudia Felser[1] — [1]Institute of Inorganic and Analytical Chemistry, Johannes Gutenberg - University, 55099 Mainz — [2]Department of Physics, Faculty of Science, Zagazig University, Zagazig, Egypt

This work reports on the structural investigation of Cu-containing, with different ternary structure type $BaCu_2S_2$, Li_2CuSb and LiCuS. The unusual semiconductor properties exhibited by these Cu-contaning have attracted much attention. Using the scalar-relativistic full potential linearized augmented plane wave method (FLAPW).The exchange-correlation functional was evaluated within the GGA, using the Perdew-Burke-Ernzerhof parametrization. The investigation on the equilibrium lattice parameters, the equilibrium atomic position in the unit cell, and inter atomic distances is bing carried out. The band structure and density of states (DOS) have been calculated and compered to the available experimental and theoretical results.

The authors gratefully acknowledge financial support by the DfG (Research Unit 559).

HL 48.6 Thu 15:00 P2

OEP-DFT computation of spin current densities and Wigner transition in a one-dimensional ring — •Thorsten Arnold, Marc Siegmund, and Oleg Pankratov — Lehrstuhl für Theoretische Festkörperphysik - Institut für Theoretische Physik IV - Staudtstr. 7-B2 - 91058 Erlangen

We investigate by exchange-only DFT, using the OEP-method in the KLI-approximation, a quasi one-dimensional Wigner crystallisation transition. We consider interacting electrons on a ring, assuming a Fermi liquid behaviour of the electron system. The transition from a gas-like to a pinned (by an impurity potential) crystal state can be identified totally within DFT, i.e. using collective variables (density and current) only, and not employing the correlation function. This is achieved by calculating a persistent current in magnetic field. Varying the electron-electron interaction strength in terms of parameter r_s, we found that the current decays exponentially for $r_s > r_s^c$. In a case of spinless electrons, we found a critical value of $r_s^c = 2.05$ (for 10 electrons). [1]

In this work, the model is extended for particles with spin. Fixing

the total spin moment, we found both spin subsystems undergoing the Wigner transition successively at r_s^c of the order of 0.1. The ground state magnetisation for 10 electrons rises from $S = 0$ for $r_s < 0.1$ (gas state) to $S = 1$ ($0.1 < r_s < 0.2$) in a crystalline state.

[1] M. Siegmund, M. Hofmann, and O. Pankratov, arXiv:0711.2937v1

HL 48.7 Thu 15:00 P2

A Treasure Map for Phase-Change Materials — •Dominic Lencer[1], Martin Salinga[1], Blazej Grabowski[2], Tilmann Hickel[2], Jörg Neugebauer[2], and Matthias Wuttig[1] — [1]JARA-FIT, RWTH Aachen, I. Physikalisches Institut (IA), 52056 Aachen — [2]Max-Planck Institut für Eisenforschung, 40237 Düsseldorf

Phase-change materials are characterized by a unique property portfolio well suited for data storage applications. They exhibit a pronounced optical and electrical contrast between the crystalline and the amorphous state. In a recent study, we have identified the occurrence of resonance bonding in the crystalline state as being responsible for the optical contrast. The search for novel phase-change materials can hence be redirected to materials exhibiting resonance bonding. In order to supplement this effort, we introduce a coordinate scheme [1] based on the work of P. B. Littlewood. It is spanned by two coordinates calculated just from the composition. These coordinates represent the degree of ionicity and the tendency towards hybridization (covalency) of the bonding. A small magnitude of both quantities is an inherent characteristic of phase-change materials and marks the region of this map, where resonance bonding occurs. Furthermore, this map also enables a prediction of trends for the physical properties upon changing stoichiometry.

[1] Lencer, D., Salinga, M., Grabowski, M., Hickel, T., Neugebauer, J. & Wuttig, M. A Map for Phase-Change Materials. Nature Materials, in the press (2008).

HL 48.8 Thu 15:00 P2

Photocapacitance measurements on MOS light emitting devices — •Michael Seeger, Danilo Bürger, Lars Rebohle, Wolfgang Skorupa, Manfred Helm, and Heidemarie Schmidt — Institute of Ion Beam Physics and Materials Research, Forschungszentrum Dresden-Rossendorf, P.O. Box 510119, 01314 Dresden (Germany)

The photocapacitance (PC) has been probed on MOS diodes with an Eu-implanted SiO_2 layer. In general, rare earth implanted SiO_2 layers in MOS diodes are of great interest for possible applications in integrated metal-oxide-semiconductor light emitting devices (MOSLEDs). For example, green and ultraviolet electroluminescence has been probed on SiO_2:Tb-MOSLEDs and SiO_2:Gd-MOSLEDs, respectively. MOSLEDs reach external quantum efficiencies between 1% and 16%, and the electroluminescence peaks are typically ascribed to 4f-intrashell transitions of trivalent rare earth ions. A clear capacitance change has been observed for different wavelengths under monochromatic illumination. Some of the detected peaks correspond to the energies of 4f-intrashell transitions of the Eu ions. According to this, the number of active luminescence centers in MOSLEDs may be determined from PC measurements. Some 4f-intrashell transitions have been also observed by means of electroluminescence measurements on the same MOSLEDs. To emphasize the physical significance of the PC data recorded on SiO_2:Eu-MOSLEDs, we also compare PC data recorded on different MOSLEDs implanted with other rare earth ions.

HL 48.9 Thu 15:00 P2

Experimental investigation of InN-based terahertz surface emitters — •Jan Wallauer, Hanspeter Helm, and Markus Walther — Department of Molecular and Optical Physics, University of Freiburg

Owing to its characteristic material properties, such as a strong optical absorption, a small band gap, and its unusual band structure, indium nitride (InN) promises a much stronger terahertz emission than present terahertz surface emitters [1]. This makes InN to a very promising terahertz radiation source, suitable for potential applications in research and industry. Here we investigate photo-induced terahertz surface emission from epitactically grown InN. Our study is based on femtosecond laser pulse excitation and broadband terahertz detection [2]. By systematically varying the excitation conditions we aim to characterize and optimize the emitted terahertz radiation. The influence of various parameters, such as laser spot size or excitation angle are discussed. Our results for InN are compared with the emission from standard surface emitters like indium arsenide (InAs).

[1] V. Cimalla et al., Phys. Stat. Sol. (b) 244, 1829 (2007)

[2] C. Winnewisser, P. Uhd Jepsen, M. Schall, V. Schyja, and H. Helm, Appl. Phys. Lett. 70, 3069 (1997)

HL 48.10 Thu 15:00 P2

Spatially resolved resonance fluorescence from quantum wells: A tool to study exciton wavefunctions — •Gerolf K. G. Burau — Universität Rostock, Institut für Physik, D-18055 Rostock, Germany

The nature of the electronic states in weakly disordered quantum wells recently has received considerable attention, both from experiment [1,2] and theory [3]. A very promising method for experimental investigation is to spatially and spectrally resolve the elastic part of the resonance fluorescence from the exciton states while varying the excitation wavelength. Here the measured intensity is directly proportional to the modulus to the fourth power of the exciton center of mass wave function. This was demonstrated in [2], unfortunately with a rather low spatial resolution. We have developed a new setup using high numerical aperture objectives giving a spatial resolution of 350 nm. As the setup is able to detect light emitted into different sides of a quantum well (4pi- microscope, [3]), the resolution can be improved by using the full potential of the microscope (with immersion lenses) to about 85 nm which will be comparable to that of a near-field setup [1] but allows much lower temperatures (< 5K).

[1] K. Matsuda, T. Saiki, S. Nomura, M. Mihara, Y. Aoyagi, S. Nair, and T. Takagahara, Phys. Rev. Lett. 91, 177401 (2003), [2] D. Schwedt, R. Schwartz, H. Stolz, D. Reuter, and A. Wieck, phys. stat. sol. (c) 3, 2477 (2006), [3] P. Bozsoki, P. Thomas, M. Kira, W. Hoyer, T. Meier, S. W. Koch, K. Maschke, I. Varga, and H. Stolz, Phys. Rev. Lett. 97, 227402 (2006)

HL 48.11 Thu 15:00 P2

Development of Photonic Sensors for Parallel Molecule Detection on the Basis of Toroidal Microresonators — •Tobias Grossmann, Christian Schäfer, Cristian Gohn-Kreuz, Torsten Beck, Mario Hauser, and Heinz Kalt — Universität Karlsruhe (TH), Karlsruhe, Germany

We report on the progress of the development of a versatile photonic sensor for label-free detection of proteins and DNA sequences based on toroidal semiconductor microresonators.

The detection principle bases on the shift of the frequency of optical whispering gallery modes (WGMs). Each resonator will be functionalized by fixing proteins to its perimeter which can selectively bind to well defined partners as in the case for complementary DNA sequences or antigen/antibody combinations. The evanescent field of the WGM polarizes a molecule attached to the resonator which in return shifts the mode frequency.

For detection of the modal shift of WGMs a setup using a tapered single mode fiber will be shown. An approach for the fabrication of a microfluidic channel and integrated waveguides passing the resonators in a small distance will be presented. First results of the fabrication and characterization of the optical modes will be discussed.

HL 48.12 Thu 15:00 P2

Carrier spin dynamics in GaAs/AlGaAs quantum wells, studied by time-resolved Kerr rotation — •Liudmila Fokina[1], Vladimir Petrov[3], Dmitri Yakovlev[1,2], and Manfred Bayer[1] — [1]Experimental Physics 2,Technical University Dortmund, 44221 Dortmund, Germany — [2]A.F. Ioffe Physico-Technical Institute, 194017 St. Petersburg, Russia — [3]Saint-Petersburg State University, 198504 Saint-Petersburg, Russia

In recent years, electron-spin orientation in semiconductors is considered as a promising way of realization of quantum information processing in solid-state systems. Therefore, the problem of lifetime and relaxation mechanisms of spin coherence in real systems becomes highly topical. We study experimentally electron spin coherence in GaAs/AlGaAs quantum wells with a low-dense as well as with high dense two-dimensional electron gas by means of pump-probe time-resolved Kerr rotation technique. To explore spin relaxation mechanisms, we have performed a systematic study of the spin dephasing time as a function of temperature, magnetic field and electron concentration. Electron spin beats have been measured in magnetic field up to 10 T, which allows to determine the transverse component of the electron g-factor. In case when the spin dephasing times becomes longer than several ns, we used the technique of the resonant spin amplification (RSA), which has been developed to extract spin lifetimes that exceed the pulse repetition interval of 13.2 ns. Finally we describe an unusual behaviour of the RSA signal in vicinity of zero magnetic field, which is caused by interaction of the electron spins with the

nuclei.

HL 48.13 Thu 15:00 P2

Photoluminescence of extremely dilute Si nanoparticle films — •Matthias Offer[1], Cedrik Meier[1,3], Martin Geller[1], Axel Lorke[1], and Hartmut Wiggers[2] — [1]Experimental Physics and CeNIDE, University of Duisburg-Essen, Duisburg — [2]IVG and CeNIDE, University of Duisburg-Essen, Duisburg — [3]Experimental Physics, University of Paderborn

Light-emitting silicon nanoparticles are attractive candidates for future optoelectronic applications. For the realization of such devices, a detailed knowledge of the recombination dynamics is an important prerequisite. The photoluminescence (PL) of silicon nanoparticles exhibits an interesting exitonic fine structure with a bright and a dark state, which, surprisingly, have very similar radiative recombination lifetimes [1]. To elucidate the intriguing excitonic properties of Si nanoparticles, it is highly desirable to investigate single particles or few-particle ensembles to answer questions regarding homogeneous line broadening and Zeeman shift. We have dispersed Si nanoparticles in organic solvents and deposit extremely dilute films of Si particles on arbitrary surfaces. These can be covered by metallic micro-apertures ($\approx 1\mu m$ in diameter), which make it possible to study the optical properties of ensembles of about 100 particles and below. Furthermore, a scanning micro-PL setup was designed and realized to map out the local optical properties of nanoscopic semiconductor structures. First results of spatially resolved PL on nanoparticles will be presented and compared to spectra of large-scale ensembles.

[1] S. Lüttjohann et al., Europhys. Lett. **79**, 37002 (2007)

HL 48.14 Thu 15:00 P2

Optical spectroscopy of Ga(N,As,P)/GaP MQW structures — •Christian Karcher, Andreas Schneider, Bernardette Kunert, Kerstin Volz, Wolfgang Stolz, and Wolfram Heimbrodt — Dept. Physics and Material Sciences Center, Philipps-University of Marburg, Germany

Pseudomorphically grown multiple-quantum-well heterostructures of the dilute nitride Ga(NAsP)/(Ga,B)P material system have been studied by means of modulation-, photoluminescence- (PL) and PL excitation - spectroscopy. It is a promising system to achieve integrated optoelectronic devices on Si substrates. By applying hydrostatic pressure upon the samples we are able to determine the offsets of the direct Ga(N,As,P)-bandgap with regard to the indirect bandgap of the GaP-barrier. The obtained results yield additional knowledge about the band structure of the quantum wells, which is essential for achieving room-temperature lasing in the near future. Furthermore, we perform spatially-resolved Raman- and PL-measurements on a sub-μm-level to gain insight into the potential fluctuations caused by the varying composition within the quaternary QWs. By observing significant features such as the Ga-N vibration mode as well as the excitonic PL it is possible to map the mean distribution of Nitrogen and Phosphorous within the sample, which helps to identify statistical effects such as formation of N-clusters within the crystal.

HL 48.15 Thu 15:00 P2

Excitonic Rayleigh scattering spectra for metallic single-walled carbon nanotubes — •Ermin Malic[1], Stephanie Reich[2], and Andreas Knorr[1] — [1]Institut für Theoretische Physik, Technische Universität Berlin — [2]Fachbereich Physik, Freie Universität Berlin

We present a microscopic calculation of the excitonic Rayleigh scattering cross section for metallic single-walled carbon nanotubes. Our approach combines the density matrix formalism including the Coulomb and electron-light interaction with the tight-binding approximation. We go beyond the two-band picture taking all nanotube subband contributions into account.

Due to the strong screening in metallic tubes, the Coulomb interaction is weak resulting in smaller excitonic binding energies (around 100 meV) in comparison to semiconducting nanotubes with a similar diameter. In agreement with experiments, the Rayleigh spectra of metallic nanotubes are shown to have a double-peaked structure caused by the triangular equi-energy contour around the K point (trigonal warping effect). Furthermore, the non-resonant contributions of the optical susceptibility account for the asymmetry of Rayleigh peaks towards lower energies.

HL 48.16 Thu 15:00 P2

Characterization of Spatially Indirect Excitons in Coupled Quantum Wells — Georg Schinner[1], •Markus Stallhofer[1], Katarzyna Kowalik[1], Dieter Schuh[2], Werner Wegscheider[2], Alexander Holleitner[1,3], and Jörg Kotthaus[1] — [1]Fakultät für Physik and Center for NanoScience, LMU Munich, Geschwister-Scholl-Platz 1, D-80539 München, Germany — [2]Institut für Angewandte und Experimentelle Physik, Universität Regensburg, Universitätsstraße 31, D-93040 Regensburg, Germany — [3]TU Munich, Walter Schottky Institut, Am Coulombwall 3, 85748 Garching, Germany

In coupled quantum wells photo-generated and spatially indirect excitons can be widely manipulated via an externally applied voltage. The quantum-confined Stark effect (QCSE) results in a large enhancement of excitonic lifetime and a red shift in energy. A number of photoluminescence (PL) experiments have been performed on indirect excitons in GaAs double quantum wells (DQW) that were tuned via a metallic top gate. We characterize an especially designed InGaAs DQW-heterostructure with PL and transmission experiments at liquid Helium temperatures. The QCSE was measured with PL and determined to be around 150 meV/V, a very high value compared to literature. Therefore, it is possible to achieve a large energy shift by applying relatively low voltages in our sample. In a confocal microscope we perform transmission experiments on the indirect excitons in a field-effect structure with a semitransparent titanium top gate. They allow investigating electron-hole pairs under resonant excitation.

HL 48.17 Thu 15:00 P2

Collective fluorescence of quantum dot molecules and arrays — •Anna Sitek[1,2] and Pawel Machnikowski[1] — [1]Institute of Physics, Wroclaw University of Technology, Wroclaw, Poland — [2]Institute for Theoretical Physics, Technical University of Berlin, Berlin, Germany

The optical properties of quantum dot molecules (QDMs) are affected by collective interaction of the QDs with radiation modes. In atomic systems, such collective effects lead to pronounced superradiant fluorescence [1]. Superradiance has also been observed in a QD sample [2]. In contrast to a gas of atoms, the properties of QDs are never exactly uniform. On the other hand, QDs can be arranged in regular arrays.

In this presentation, we study the collective interaction of excitons in closely spaced QDMs and small arrays of nearly identical QDs with electromagnetic modes. We discuss how collective fluorescence builds up in the presence of a small mismatch of the transition energy and study the resulting optical properties (decay of luminescence) of quantum dot molecules. It turns out that the collective effects are very sensitive to the difference between the dots but coupling between the dots may stabilize the collective fluorescence if the dots are arranged in a regular way [3].

[1] M. Gross et al., Phys. Rep. 93, 301 (1982).
[2] M. Scheibner et al., Nature Physics 3, 106 (2007).
[3] A. Sitek et al., Phys. Rev. B 75, 035328 (2007).

HL 48.18 Thu 15:00 P2

Plasmons in graphene — •Antonio Hill, Sergey A. Mikhailov, and Klaus Ziegler — Institut für Physik, Universität Augsburg, D-86135 Augsburg, Germany

Electromagnetic response of graphene (the dielectric function) and the spectrum of collective excitations in it are studied as a function of wave vector and frequency. Our calculation is based on the full band structure, calculated within the tight-binding approximation. As a result, we find plasmons whose dispersion is similar to that obtained in the single-valley approximation [1,2] but in contrast to the latter, we find a stronger damping of the plasmon modes due to inter-band absorption. Our calculation also reveals effects due to deviations from the linear Dirac electronic spectrum as we increase the Fermi energy, indicating an anisotropic behavior with respect to the wave vector of the external electromagnetic field.

[1] E. H. Hwang and S. Das Sarma, **75**, 205418 (2007)
[2] B. Wunsch et al, New J. Phys. **8**, 318 (2006)

HL 48.19 Thu 15:00 P2

Defect Induced Photoluminescence from Dark Excitonic States in Individual Single-Walled Carbon Nanotubes — •Tobias Gokus[1], Hayk Harutyunyan[2], Alexander A. Green[3], Mark C. Hersam[3], Maria Allegrini[2], and Achim Hartschuh[1] — [1]Department Chemie und Biochemie, Ludwig-Maximilians-Universität München and CeNS, 81377 München, Germany — [2]Dipartimento die Fisica "E. Fermi", Universitá di Pisa and CNISM, Largo Pontecorvo 3, 56127 Pisa, Italy — [3]Department of Chemistry, Northwestern University, Evanston, Illinois 60208-3108, USA

We show that new low-energy photoluminescence (PL) bands (ΔE$\sim$30-190 meV) can be created in the spectra of individual semiconducting single-walled carbon nanotubes (SWNT) by intense pulsed laser irradiation at room temperature. These new bands are attributed to emission from different nominally dark excitons that are "brightened"due to defect-induced mixing of states with different parity and/or spin. Time-resolved PL studies on single nanotubes reveal a significant reduction of the bright exciton lifetime (1-40 ps) upon brightening of the dark excitons. The lowest energy dark state (ΔE$\sim$190 meV) has longer lifetimes up to 177 ps and is not in thermal equilibrium with the bright state. In addition we show that the same satellite bands can be observed by exposure of the SWNTs to a gold solution, and using low power CW laser excitation, indicating that the lowest energy emission is due to triplet exciton recombination facilitated by magnetic defects or impurities.

HL 48.20 Thu 15:00 P2

Electroluminescence from silicon nanoparticle layers — •Jens Theis[1] and Cedrik Meier[2] — [1]Experimental Physics, University of Duisburg-Essen, Duisburg — [2]Group Nanophotonics and Nanomaterials, Department of Physics, University of Paderborn

We have fabricated an electroluminescence devices using silicon nanoparticles as an emitter by using a micropatterned GaAs heterostructure as a template. The Si nanoparticles have been fabricated from the gas phase in a low-pressure microwave plasma using SiH4 as a precursor. The nanoparticles have been dispersed onto the patterned GaAs sample from an aqueous solution. For carrier injection, the sample has been placed in a capacitor-like structure, where a transparent oxide layer served as the top-electrode. By applying an AC-voltage, field-emission of electrons and holes from the electrodes leads to electron-hole pairs in the nanoparticles. Thus, optical emission from both Si nanoparticles and GaAs is observed. We study the influence of various parameters on the electroluminescence, such as waveform, frequency and amplitude.

HL 48.21 Thu 15:00 P2

Tailoring the Emission Properties and the Axial Light Confinement in Microtube Resonators — •Christian Strelow, Kay Dietrich, Christoph Schultz, Hagen Rehberg, Christian Heyn, Detlef Heitmann, and Tobias Kipp — Institut für Angewandte Physik und Zentrum

Microtube resonators are optical cylindrical microresonators which are formed by rolled-up strained InGaAs/GaAs bilayers [1]. We demonstrate that these structures are microresonators whose properties can be tailored very precisely. The growth by molecular beam epitaxy allows to integrate diverse optical internal emitters like quantum wells or self-assembled InAs quantum dots. Another very interesting possibility is that due to the strong evanescent fields of the very thin walls also external emitters like chemically synthesized nanoparticles can be coupled to the resonator modes. Samples with different semiconductor compositions and thus strain field and bandstructure have been tailored to control the emission properties and the confinement of the light for the particular emitters are compared. We present several mechanisms of axial light confinement experimentally and prove these by spatially and energetically resolved photoluminescence measurements. We acknowledge financial support by the Deutsche Forschungsgemeinschaft via SFB 508 "Quantum Materials"and GK 1286 "Functional Metal-Semiconductor Hybrid Systems".

[1] Ch. Strelow et al., Phys. Rev. Lett. **101**, 127403 (2008)

HL 48.22 Thu 15:00 P2

Temperature Tuning of Nonlinear Photoluminescence in Gallium Selenide — •Christoph Angermann[1], Lothar Kador[1], Kerim R. Allakhverdiev[2,3], Tarik Baykara[2], and Eldar Salaev[3] — [1]University of Bayreuth, Institute of Physics and BIMF, 95440 Bayreuth, Germany — [2]Marmara Research Centre of TÜBİTAK, Materials Institute, P. K. 21, 41470 Gebze/Koçaeli, Turkey — [3]Institute of Physics, Azerbaijan National Academy of Sciences, Baku, Azerbaijan

The non-centrosymmetric ϵ modification of the layered semiconductor gallium selenide (GaSe) is characterized by a very high coefficient $\chi^{(2)}$ of quadratic optical nonlinearity. Photoluminescence spectra of the material were investigated with a HeNe laser as excitation source, whose quantum energy is slightly lower than the band edge. Hence, the photoluminescence is ascribed to second-harmonic generation in the laser focus causing the excitation of electrons into the conduction band and, subsequently, the formation and radiative decay of Wannier excitons. With increasing temperature, the band edge shifts to lower energies across the laser line. The concomitant strong increase of the photoluminescence signal is interpreted in terms of resonance enhancement of the $\chi^{(2)}$ coefficient. The photoluminescence studies are supplemented by Maker fringe data recorded with different cw diode lasers.

HL 48.23 Thu 15:00 P2

Influence of uniaxial pressure on the optical properties of Tl_2S single crystals — •H. Danylyuk, Y. Stakhira, and V. Belyukh — Ivan Franko Lviv National University, Department of Electronics Dragomanov Str. 50, UA-79005 Lviv, Ukraine

Tl_2S single crystals were grown by the Bridgman-Stockbarger method. Samples with $50-130\mu m$ of thickness were freshly cleaved along the (00.1) cleavage plane from the ingot. In all investigated samples the absorption edge shape is good described by Urbach's rule. The energy gap of Tl_2S crystal was determined by sharp change of slope of the absorption spectrum curve: $E_g \approx 1eV$. To study the low-dimensional effects in layered Tl_2S crystals we have investigated influence of uniaxial pressure on Tl_2S optical properties in absorption edge range. Pressure (0,3-1 MPa) was applied in c-axis direction. We have observed considerable increase of the absorption coefficient in transparency range near fundamental absorption edge after 1-2 days of pressure effect. For long-continued (10-12 days) pressure effect on samples, the absorption coefficient increased in a few times. However, the optical properties of Tl_2S single crystals are partly restored after stopping of pressure effect. This restoring was the better, the shortly the pressure effected the samples. For long-continued pressure effect on samples the absorption edge shape is also changed, but still it is described by Urbach's rule. However, the characteristic Urbach's parameters are changed.

HL 48.24 Thu 15:00 P2

Transport through the quantum dot connected to external leads — •Agnieszka Donabidowicz-Kolkowska[1,2] and Tadeusz Domanski[1] — [1]Institute of Physics, Maria Curie-Sklodowska University,Lublin, Poland — [2]Institute for Theoretical Physics, Technische Universität Dresden,Germany

In this work we study the transport properties of a single level quantum dot connected to two normal electrodes and/or one normal (N) and one superconducting (S) lead using the nonequilibrium Green*s function formalism. For a description of the N-QD-N/S junction we consider the single impurity Anderson model.The effects of the electron pair coherence, Coulomb interactions are discussed with a particular account of their influence on a charge tunnelling through the quantum dot. We observe that the long range off-diagonal superconducting order induces the proximity effect in the quantum dot due to a particle-hole mixing at small energies . Influence of the proximity effect on transport properties of the systems manifests itself in the Andreev conductance. Additionally, in presence of the strong on-dot correlations some qualitatively new features were observed. One of them is the zero bias anomaly which occurs due to formation of the Kondo state at sufficiently low temperatures. We show that quantum transport in superconducting devices is controlled by the interplay between the Kondo effect and Andreev reflection processes.

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Electrolyte Gated Silicon Nanowire FETs — •Oren Knopfmacher, Michel Calame, and Christian Schönenberger — University of Basel, Department of Physics, Klingelbergstrasse 82, CH-4056 Basel, Switzerland

Silicon Nanowire field effect transistors (SiNW FETs) have been shown to be very sensitive to charged molecules adsorbed on their surface and therefore are ideal candidates for basic sensing units in integrated bio- or chemical sensors [1]. The disadvantage linked to the positioning of grown nanowires on a substrate can be circumvented by using a top-down approach where SiNW are directly etched in silicon-on-insulator (SOI) wafers [2]. This approach allows parallel processing at the wafer scale while opening the possibility to integrate the sensing units with signal conditioning electronics. In our system, a gate voltage can be applied via the Si substrate (back gate, as for conventional FETs,) while a liquid cell system brings the liquid in contact with the nanowire surface. By inserting an additional electrode in the liquid cell, we benefit from an additional handle to control the response of the SiNW FET. We compare the combined effects of the back gate and liquid gate on the transport characteristics of the SiNW FET and show that both gates are essential to perform well-defined sensing experiments.

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Gate-controlled conductance fluctuations in InN nanowires — •Sergio Estévez Hernández[1,2], Gunnar Petersen[1,2], Robert Frielinghaus[1,2], Ralph Meijers[1,2], Raffaella Calarco[1,2], Thomas Schäpers[1,2], and Detlev Grützmacher[1,2] — [1]Institute for Bio- and Nanosystems (IBN-1), Research Centre Jülich GmbH, 52425 Jülich Germany — [2]JARA-Fundamentals of Future Information Technology

Nanowires based on InN are interesting because of their large surface conductivity and their low energy band gap. For nanoscaled devices operated at low temperatures electron interference effects can largely affect the transport properties. Typical phenomena are universal conductance fluctuations or weak localization. The characteristic fluctuation pattern observed in the conductance was employed to obtain information on phase-coherent transport. The conductance fluctuations were measured at low temperatures as a function of the gate voltage at fixed magnetic fields. By analyzing the root mean square and the correlation field of the conductance fluctuations at various temperatures, the phase-coherence length was determined. From the conductance traces as a function of gate voltage the variance of the conductance var(G) was determined at different magnetic fields. The largest variance was found close to zero magnetic field while at finite magnetic fields var(G) is reduced to almost half value. This reduction can be explained by the broken time-reversal symmetry in the presence of a magnetic field.

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Phase-coherent transport and spin-orbit coupling in InN nanowires connected in parallel — •Shima Alagha[1,2], Sergio Estévez Hernández[1,2], Raffaella Calarco[1,2], Thomas Schäpers[1,2], and Detlev Grützmacher[1,2] — [1]Institute for Bio- and Nanosystems (IBN-1), Research Centre Jülich GmbH, 52425 Jülich Germany — [2]JARA-Fundamentals of Future Information Technology

Semiconductor nanowires based on InN are interesting candidates for future nanolelectronic devices because the surface accumulation layer guarantees a highly conductive channel. However, the spin-transport properties are basically unknown for this material system. In order to obtain information regarding the spin transport, we investigated the low-temperature magnetoconductance of InN nanowires connected in parallel. Usually, phase-coherent transport in small conductors results in conductance fluctuations. By connecting N nanowires in parallel a considerable decrease of the fluctuation amplitude and a reduction of the variance proportional to $\sqrt{N}$ can be achieved. This suppression of the fluctuations permits to study weak localization and weak antilocalization effects which are manifested in negative and positive magnetoconductivity around zero magnetic fields, respectively. From these features, information about the phase-coherence length and the spin-orbit scattering length can be obtained. At low magnetic fields we found a clear signature of the weak antilocalization effect indicating the presence of spin-orbit coupling in InN nanowires.

HL 48.28 Thu 15:00 P2

Tunable transverse rectification in density-modulated 2D-Systems: Ballistic of thermoelectric effect? — •Arkadius Ganczarczyk[1], Christian Notthoff[1], Martin Geller[1], Axel Lorke[1], Dirk Reuter[2], and Andreas Wieck[2] — [1]Experimental Physics and CeNIDE, Universität Duisburg-Essen — [2]Ruhr-Universität Bochum

We investigate tunable transverse rectification in a density-modulated two-dimensinal electron gas (2DEG) at low temperatures (4.2 K). The 2DEG is patterned into a long narrow conductive channel with source and drain contacts and a voltage probe on each side of the channel. Using gate electrodes we induce two stripes of different charge carrier density running parallel to the channel. The resulting density gradient perpendicular to the channel induces a transverse voltage, which - due to the symmetry of the device - does not change polarity when the current direction is reversed. We observe that the rectified transverse voltage increases with increasing density modulation and is proportional to $1/n_1$ - $1/n_2$, where n_1 and n_2 are the charge carrier densities in the two stripes. The observed transverse voltage can attributed to two different physical phenomena: Ballistic rectification and a thermoelectric effect. The results are discussed by using a billiard model, which describes the propagation of ballistic electrons in density-modulated 2D-systems. Furthermore, possible thermoelectric effects in the structure are discussed. Both models are compared in order to obtain a deeper insight into this novel rectification effect.

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Manipulation of minority-majority mobility-lifetime-product behavior in microcrystalline silicon by field effect — •Oliver Neumann, Rudolf Brüggemann, and Gottfried H. Bauer — Institut für Physik, Carl von Ossietzky Universität Oldenburg, D-26111 Oldenburg

Mobility-lifetime-products ($\mu\tau$) of minority and majority carriers are a general criterion for the quality of semiconductors. The particular magnitudes can be separately analyzed by photoconduction experiments e.g. with the steady-state photocarrier grating technique (SSPG) [1] for the minority-carrier ($\mu\tau$) products and traditional photoconductivity studies for the majority-carrier ($\mu\tau$) products. The share between electrons and holes is used to be governed by the Fermi level which as well decides on minority and majority status.

We have performed SSPG (for minority ($\mu\tau$)-products) as well as photoconductivity measurements on different hydrogenated microcrystalline silicon (μc-Si:H) samples with simultaneous application of an electric field in field-effect configuration for carrier depletion respectively accumulation. By this approach we proof experimentally with our SSPG- and photoconductivity-experiments to increase majority densities and decrease minority concentrations and we accordingly also shift the original majority behavior of electrons towards minority behavior. From our experiments we deduce the necessary electric field strengths for inversion in nominally undoped μc-Si:H.

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HL 48.30 Thu 15:00 P2

Electrical Properties of Phase Change Memory Cells — •Daniel Krebs[1,2], Martin Salinga[1,2], Stephan Kremers[1], Hanno Volker[1], Matthias Wuttig[1,2], Simone Raoux[2], Charles T. Rettner[2], Robert M. Shelby[2], and Geoffrey W. Burr[2] — [1]I. Physikalisches Institut IA, RWTH Aachen University, 52056 Aachen, Germany — [2]IBM/Macronix PCRAM Joint Project: IBM Almaden Research Center, 650 Harry Road, San Jose, California 95120

Phase change random access memory has become one of the most promising candidates for future non-volatile memory applications, prompting an intensive search for suitable phase change materials with optimized properties. Attaining both rapid cyclability and long-term retention requires the proper combination of fast crystallization speed yet high crystallization temperature. In addition, it has been observed that the resistance of the amorphous phase tends to increase slowly yet significantly after device programming, which complicates multilevel storage. In this work, the phase change memory candidates $Ge_{15}Sb_{85}$, Ag and In doped Sb_2Te, $Ge_2Sb_2Te_5$, GeTe and thin Sb are systematically analyzed by electrical and optical testing of bridge cell devices and thin films. We show that the as-deposited and melt-quenched amorphous phases exhibit pronounced differences in crystallization speed and temperature. Our experimental evidence shows clearly that the critical parameter for threshold switching is a critical electrical field rather than a threshold voltage. The post-programming resistance dynamics of bridge cells are also analyzed, and linked to electrical and structural relaxation in the phase change material.

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Transverse Peltier effect in $Pb-Bi_2Te_3$ multilayer structures — •Christina Reitmaier, Franziska Walther, Amir Kyarad, and Hans Lengfellner — University of Regensburg, 93040 Regensburg, Germany

Metal-semiconductor multilayer structures show, according to model calculations, large anisotropy in their electrical and thermal transport properties. Multilayer stacks consisting of alternating layers of Pb and n-type Bi_2Te_3 and prepared by a heating procedure displayed large thermoelectric anisotropy up to $\Delta S \approx 200\mu V/K$, depending on the thickness ratio $p = d_{BiTe}/d_{Pb}$, where d_{BiTe} and d_{Pb} are the thicknesses of Bi_2Te_3 and Pb layers, respectively. From multilayer stacks, tilted samples with layers inclined with respect to the sample surface where obtained by cutting stacks obliquely to the stack axis. Non-zero off-diagonal elements in the Seebeck-tensor describing the thermopower of tilted samples allow for the occurance of a transverse Peltier effect. Experimental results demonstrate cooling by the transverse Peltier effect and are compared to model calculations.

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Electronic transport at the interface between diamond and aqueous electrolyte — Markus Dankerl, Eberhard Ulrich Stützel, •Andreas Lippert, Martin Stutzmann, and Jose Antonio Garrido — Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching.

Undoped single crystalline diamond with a hydrogen-terminated surface shows a p-type surface conductivity. This surface conductivity is based on a two-dimensional hole channel formed by the band bending beneath the surface. It is not only stable in electrolyte but can also be modulated by an applied potential through the electrolyte, enabling the design of solution gate field effect transistors (SGFETs). Owing to the remarkable stability and biocompatibility of diamond, SGFETs based on diamond are highly interesting for biosensing and medical applications. We have investigated the surface conductivity of hydrogen-terminated single crystalline diamond using in-liquid Hall effect measurements under potential control. Thus, we were able to independently determine the carrier concentration and the carrier mobility. We observe that the mobility shows different variations with the carrier concentration at different levels of the carrier concentration. We discuss this in the context of localization and scattering mechanisms e.g. surface scattering. Studies on the effect of temperature on the mobility reveal no activated behavior beyond the influence of the carrier concentration. The effect of temperature on the concentration of carriers itself fits the concept of an interfacial capacitance at the diamond/electrolyte interface.

HL 48.33 Thu 15:00 P2

Magnetotransport properties of epitaxial graphene — •Sonja Weingart[1], Claudia Bock[1], Ulrich Kunze[1], Konstantin V. Emtsev[2], Thomas Seyller[2], and Lothar Ley[2] — [1]Werkstoffe und Nanoelektronik, Ruhr-Universität Bochum — [2]Lehrstuhl für Technische Physik, Friedrich-Alexander Universität Erlangen-Nürnberg

We have investigated the magnetotransport properties of epitaxial graphene films grown on 6H-SiC(0001). We demonstrate that the temperature dependence of the charge carrier density and mobility is correlated to the annealing conditions during the graphitisation process. Devices in a Hall-bar geometry are characterised in a perpendicular magnetic field up to 8 T at temperatures between 1.5 K and 110 K. The electron density is determined from Shubnikov de Haas oscillations of the longitudinal resistance R_{xx} and, for comparison, from Hall-effect measurements of the transverse resistance R_{xy}. The mobility is derived from the conductivity. For graphene films annealed in an Ar atmosphere close to atmospheric pressure (sample A) a mobility (charge carrier density) of $2400\,\mathrm{cm^2(Vs)^{-1}}$ ($3\cdot10^{12}\,\mathrm{cm^{-2}}$) at 4.2 K is extracted. Whereas for sample B annealed under a reduced pressure a lower mobility of $1000\,\mathrm{cm^2(Vs)^{-1}}$ and a slightly higher charge carrier density of $4\cdot10^{12}\,\mathrm{cm^{-2}}$ is estimated. Sample A shows a nearly constant carrier mobility for low temperatures (1.5 K up to 60 K) and a linear decrease for higher temperatures. The charge carrier density is constant in the temperature range. For sample B with rising temperature the mobility (charge carrier density) decreases (increases).

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Herstellung und Charakterisierung von Nanosäulen für silizium basierte Thermoelektrika — •Andrej Stranz, Ünsal Sökmen, Erwin Peiner und Andreas Waag — Institut für Halbleitertechnik, TU Braunschweig, Deutschland

Si-basierte Nanosäulen unterschiedlicher Durchmesser, Höhe und Morphologie werden durch Strukturierung mit Nanoimprint und anschließendes anisotropes Trockenätzen hergestellt. Die Herstellung der niederdimensionalen Strukturen beruht auf der kontrollierten top-down Strukturierung. Durch diese Herstellungsmethode lässt sich die thermische Leitfähigkeit über die Variation der Durchmesser der Nanosäulen gezielt einstellen. Durch die Reduktion der thermischen Leitfähigkeit kann die Effizienz (ZT) von Si-basierten thermoelektrischen Kühlern und Generatoren erheblich verbessert werden. Die hergestellten Nanosäulen haben Durchmesser im sub-μ Bereich, eine Höhe bis 80μ, und sie sind in einem Säulen-Feld angeordnet mit einem Abstand von 700nm bis 10μ zueinander. Neben der Herstellung und der strukturellen Charakterisierung von Silizium-Nanosäulen wird die Messung thermoelektrischer Eigenschaften einzelner Nanosäulen, sowie von Nanosäulenarrays beschrieben. Für die Messung von Kräften auf der sub-μN Skala wurden piezoresistive Silizium-Cantilever-Sonden entwickelt und realisiert. Sonden mit Spitzenradien von wenigen zehn Nanometern wurden für die Vermessung von Nanosäulen in einem Rasterelektronenmikroskop mit Hilfe von Nanomanipulatoren eingesetzt. In der Messsonde wurden für die Messung der Temperatur ein Thermowiderstand bzw. ein Thermoelement an der Spitze integriert.

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Comparison of different techniques to determine long spin lifetimes in slightly n-doped GaAs bulk and GaAs/AlGaAs quantum wells — •Michael Griesbeck, Andreas Maurer, Sebastian Fehringer, Robert Schulz, Tobias Korn, Dieter Schuh, Werner Wegscheider, and Christian Schüller — Universität Regensburg, Germany

A key issue of spintronics research is the search for materials with long spin lifetime. The commonly used technique for the determination of spin lifetimes, ultrafast time-resolved Faraday/Kerr rotation (TRFR/TRKR), is limited to a short time window of a few ns by some reasons like the pulse repetition rate of the used pulsed laser or the length of the available delay line.Here we present a study about the comparison of the well-known TRFR technique with two other optical techniques, the so-called resonant spin amplification technique (RSA) on the one hand and Hanle-MOKE measurements on the other hand. The measurements are done on samples of slightly n-doped GaAs bulk and Mn-doped GaAs/AlGaAs quantum wells, where long spin lifetimes were detected earlier. We compare the results for spin lifetime from the different techniques in 3D and 2D systems. Spin lifetimes were extracted for different excitation and probing intensities for different Laser spot sizes, partially using a microscope setup, focussing the spot down to a few microns. The observed spin lifetimes range from about 1 ns to 120 ns and could be measured with an accuracy of a few percent.

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Spin dynamics in symmetric high-mobility GaAs/AlGaAs quantum wells, grown in (110) direction — •Michael Griesbeck, Sebastian Fehringer, Tobias Korn, Dieter Schuh, Werner Wegscheider, and Christian Schüller — Universität Regensburg, Germany

In semiconductor spintronics research, there is growing interest on (110)-grown GaAs/AlGaAs quantum wells because of the long spin lifetime in such systems, which results from the geometry of the Dresselhaus spin-orbit coupling. If the Rashba spin-orbit interaction is suppressed by symmetrical growth and doping of the quantum well, the spin lifetime is no longer limited by the D'yakonov-Perel mechanism and very long spin lifetimes can be observed. We investigate the spin dynamics in symmetric high-mobility (110)-grown GaAs/AlGaAs quantum wells using ultrafast time-resolved Faraday rotation (TRFR) and time-resolved photoluminescence (TRPL). In measurements at low temperatures and high magnetic fields we study the dependence of the spin lifetime on the strength of the applied external magnetic field.

HL 48.37 Thu 15:00 P2

Observing and controlling hole spin dynamics in 2D hole systems at sub-Kelvin temperatures — •Michael Kugler, Tobias Korn, Sebastian Fehringer, Anton Wagner, Robert Schulz, Christian Gerl, Marika Kubova, Dieter Schuh, Werner Wegscheider, and Christian Schüller — Institut für Experimentelle und Angewandte Physik, Universität Regensburg

In recent years, due to the rapidly growing field of semiconductor spintronics, much interest has been focused on the spin dynamics of electrons in semiconductors, while the hole spin dynamics have not been investigated as rigorously. Here, we report on time-resolved Faraday rotation (TRFR) measurements on 2D hole systems within p-doped GaAs quantum wells (QWs) of different width. In the TRFR measurements, the sample is excited by a circularly-polarized laser pulse tuned to the exciton energy. A large in-plane magnetic field is applied within the sample plane, causing a precession of the photocreated carriers. At sample temperatures below 4 K, superimposed on the electron spin dynamics, we observe the long-lived precession of hole spins, which becomes even more pronounced at 400 mK. In the narrower QWs, the energy splitting between light and heavy hole is increased, leading to a reduced hole state mixing, which increases the hole spin lifetime further. In a gated sample, we observe a pronounced shift of the hole precession frequency as the gate voltage is changed. This indicates that the hole g factor may be strongly dependent on the growth-axis symmetry of the QW, which can be changed by the applied voltage.

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Coherent LO phonons in optically excited double quantum wells — •Thomas Papenkort[1], Tilmann Kuhn[1], and Vollrath

Martin Axt[2] — [1]Institut für Festkörpertheorie, Universität Münster, Wilhelm-Klemm-Str. 10, 48149 Münster — [2]Institut für Theoretische Physik III, Universität Bayreuth, 95440 Bayreuth

In a double quantum well with a sufficiently thin barrier between the wells the two wells couple, i.e. the subbands are no longer localized in one of the wells but extend over both. By optically exciting such a double well under the influence of a static electric field an electron density can be obtained which is localized in one of the two wells. Because of tunneling the electrons oscillate between the two wells with the frequency of the subband splitting. This causes an oscillating polarization which couples strongly to a polar lattice, thereby creating coherent LO phonons.

We present numerical calculations of this efficient phonon generation process in an AlGaAs-GaAs double quantum well. Using a quantum kinetic approach we calculate both the dynamics of the electronic subsystem driven by a semi-classical laser field and of the phonons created via the Fröhlich interaction. We study the coherent amplitude and the fluctuations of the generated phonon states. They depend on the subband structure, which is defined by the dimensions of the double quantum well and the strength of the electric field, as well as on the exact excitation conditions.

HL 48.39 Thu 15:00 P2

Non-classical acoustic phonon states from the decay of optical phonons — •Jonas Daniels[1], Tilmann Kuhn[1], and Vollrath Martin Axt[2] — [1]Institut für Festkörpertheorie, Universität Münster, Wilhelm-Klemm-Str. 10, 48149 Münster — [2]Institut für Theoretische Physik III, Universität Bayreuth, 95440 Bayreuth

While in quantum optics non-classical states of photons, such as squeezed states, have already been intensively studied, their investigation in phonon systems is only at the beginning. Besides fundamental interest in quantum effects in interacting many-particle systems, well-prepared non-classical phonon states could have applications e.g. for phonon based communications between nanostructures.

Here we consider fluctuation and coherence properties of non-equilibrium phonons after optical excitation in quantum dots. The optical excitation is accompanied by the generation of coherent optical phonons. These phonons in turn decay into acoustic phonons, which are the subjects of our investigation. From studies in bulk semiconductors it is known that this decay may lead to the formation of squeezed acoustic phonon states. While in the bulk only optical modes with $q = 0$ can be generated, in quantum dots also modes with nonvanishing q occur, corresponding to spatially inhomogeneous displacement fields. In our calculations we analyze the spatio-temporal dynamics of the acoustic phonon distributions including their fluctuation properties resulting from the decay of coherent optical phonons in a quantum dot.

HL 48.40 Thu 15:00 P2

Collinear generation of few-cycle UV and XUV laser pulses for studying electron dynamics in solids — •Elisabeth Bothschafter[1], Ulrich Graf[1], Eleftherios Goulielmakis[1], Ralph Ernstorfer[1,2], Reinhard Kienberger[1,2], and Ferenc Krausz[1,3] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Strasse 1, D-85748 Garching, Germany. — [2]Lehrstuhl für Experimentalphysik I (E11, Experimentalphysik), Technische Universität München, James Franck Strasse, D-85748 Garching, Germany. — [3]Department für Physik, Ludwig-Maximilians-Universität, Am Coulombwall 1, D-85748 Garching, Germany.

The generation of isolated attosecond XUV pulses has been established in recent years [1]. More recently, the generation of few-cycle low-order harmonics has been demonstrated: sub-4 fs UV pulses are produced by third and fifth harmonic generation of few-cycle near-infrared (NIR) laser pulses in a gas target [2]. Now we investigate the possibility of the simultaneous generation of low-order harmonics and high-harmonic by two subsequent gas targets in a collinear geometry. Future experiments employing these unique light pulses for the study and control of electronic motion in nano-structured semiconductors will be discussed.

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[2] U. Graf, M. Fieß, M. Schultze, R. Kienberger, F. Krausz, and E. Goulielmakis, Opt. Express 16, 18956-18963 (2008)

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Emission from s- and p-states in self-assembled InAs quantum dots — Andreas Schramm[1,2], Christian Heyn[2], and •Wolfgang Hansen[2] — [1]Optoelectronics Research Centre, Tampere University of Technology, Finland — [2]Institute of Applied Physics, University of Hamburg, Germany

We study the temperature- and electric-field dependence of the electron emission from charged InAs quantum dots. The semiconductor quantum dots are grown with molecular beam epitaxy on (001) GaAs and embedded in Schottky diodes designed for high-resolution transient capacitance spectroscopy. The emission rates of s- and p-shell electrons are determined at different electric fields controlled by the bias voltage at the Schottky diode. Our data demonstrate that the emission rate not only strongly depends on the shell the carrier is emitted from but also on its charge state. The observed behaviour of the emission rates can be quantitatively understood with a model for thermionic-tunnelling through a Coulomb barrier. The tunnel-barrier height is given by charge state independent s- or p-shell binding energies and its shape is assumed to arise from the Coulomb potential of the dot charge and a bias voltage controlled triangular contribution.

HL 48.42 Thu 15:00 P2

Fabrication of nanoholes and rings by local droplet etching with In_xGa_{1-x} — •Andrea Stemmann, Christian Heyn, and Wolfgang Hansen — Institut für Angewandte Physik, Jungiusstr. 11C, 20355 Hamburg

We fabricate nanoholes and quantum rings on GaAs and AlGaAs surfaces by local droplet etching (LDE) with In_xGa_{1-x}. During the LDE process liquid metal droplets consisting of an In_xGa_{1-x} alloy are deposited on (001) GaAs at substrate temperatures ranging from 450 °C to 540 °C without an As flux. Subsequently, the samples are heated up to 600 °C in the absence of As and the liquid material is removed. In this way deep nanoholes are formed at the position of the initial droplets. The nanohole openings are surrounded by walls which act as quantum rings with tuneable size and composition. The nanostructures are inspected with atomic force microscopy. The technique is compatible for in-situ overgrowth of the nanostructures with molecular beam epitaxy in order to fill the holes with optical active material and to cap the structures with barrier material. We find a strong dependence of hole density, depth, and diameter as well as of the wall structural properties on process temperature T and In content x. Interestingly, with increasing In content x the hole density is reduced up to a factor of 0.1. On the other hand, the hole and wall diameter and the hole depth strongly increase.

HL 48.43 Thu 15:00 P2

HSQ e-beam lithography for ultrasmall single electron transistors on SOI — •Walter Daves, Matthias Ruoff, Monika Fleischer, David A. Wharam, and Dieter P. Kern — Institut für Angewandte Physik, Eberhard Karls Universität Tübingen

Single electron transistors (SETs) are a widely investigated alternative to MOSFET devices for sub-10 nm regime because of outstanding properties such as low power consumption and huge scaling potential. In this work SET devices on Silicon on Insulator (SOI) substrate were fabricated, using electron beam lithography (EBL) with Hydrogen Silsesquioxane (HSQ) as a high-resolution negative resist. The developed HSQ patterns were directly transferred into the active Si layer by Reactive Ion Etching (RIE). Geometric constriction sizes in the sub-10 nm range and dot diameters between 20 and 30 nm were achieved without the need of further oxidation of the nanostructures. Transport measurements on the fabricated SET devices showed clear blockade characteristics at room temperature. This process represents thus a promising candidate for efficient fabrication of SET devices operating at high temperatures.

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Selective molecular epitaxial growth of InAs quantum dots on pre-patterned GaAs substrates — •Mathieu Helfrich and Daniel M. Schaadt — Institut für Angewandte Physik/DFG-Center for Functional Nanostructures (CFN), Universität Karlsruhe (TH), 76128 Karlsruhe, Germany

To successfully integrate quantum dot structures into optoelectronic devices and for possible future applications such as quantum computing it is crucial to control different parameters in the formation of quantum dots. It has been shown that size, shape and distribution of quantum dots can be influenced by patterning the substrate on which the quantum dots are formed. Nonetheless, the mechanisms to control the formation by pre-patterning are not fully investigated yet. In

our work we grow self-assembled InAs quantum dots on pre-patterned GaAs (100) substrates by molecular beam epitaxy. The substrates are pre-structured by electron beam lithography. We focus on the pre-patterning of substrates and study the influence of various growth parameters and post-growth treatment. The aim is to achieve good size and shape homogeneity. Scanning electron microscopy, atomic force microscopy and photo-luminescence measurement techniques are used to analyse the quality of the grown quantum dots.

HL 48.45 Thu 15:00 P2

Self-catalyzed molecular beam epitaxy growth and electrical characterization of InAs nanowires — •Sonja Heiderich[1,2], Mihail Ion Lepsa[1], Jakob Wensorra[1], Thomas Richter[1], Hans Lüth[1], and Detlev Grützmacher[1] — [1]Institute of Bio- and Nanosystems (IBN-1) and JARA-Fundamentals of Future Information Technology, Forschungszentrum Jülich GmbH, D-52425 Jülich — [2]Universität Hamburg, Institut für Angewandte Physik, Jungiusstr. 11, D-20355 Hamburg

Semiconductor nanowires (NW) have become an attractive research field both for novel device concepts and the investigation of fundamental physical aspects regarding the electronic transport in quasi-one-dimensional quantum systems. InAs NW present a special interest related to the material related properties: low effective mass, narrow gap, high electron mobility and strong electron accumulation layer on its surface. Based on previous experiences obtained for the growth of GaAs NW by molecular beam epitaxy (MBE, we have successfully grown InAs NW using In droplets as a seed. The NW have been grown both on InAs and GaAs (100) substrates covered with a thin hydrogen silsesquioxan (HSQ) film. After the growth, they have been transferred on a Si substrate with SiO2 on the surface. By mean of e-beam lithography, the NW have been connected to large pads using nonalloyed Ti/Au metallization. DC electrical measurements carried out at room temperature show ohmic, linear I-V characteristics and low resistance. Using a field effect transistor configuration with back gate, the nanowire carrier concentration and mobility have been estimated.

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SAW driven ratchet-like effects in AlGaAs/GaAs nanostructures — •Marcin Malecha[1], Jens Ebbecke[2], Hubert J. Krenner[1], and Achim Wixforth[1,3] — [1]Institut für Physik, Universität Augsburg, 86135 Augsburg — [2]Heriot-Watt University, School of EPS-Physics, EH14 4AS, Edinburgh — [3]Center for NanoScience (CeNS), Geschwister-Scholl-Platz 1, 80539 München

Recently we have reported our results [1] on electron transport through strong coupled quantum dots on AlGaAs/GaAs heterostructures. The major feature is a strong Coulomb interaction which leads to broken electron-hole symmetry. Due to the designed lateral asymmetry of the quantum dots and applied surface acoustic waves for driving electrons the whole system is highly non-symmetric and thus ratchet effects are expected. The experimental data clearly shows one of the most prominent ratchet effects - the current reversal - when a SAW is applied. For further investigations, a new sample design is developed where more parameters can be tuned separately - from the height of the barriers to the shape and coupling strength of the quantum dots. Details of the new sample design and first measurements will be presented.

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HL 48.47 Thu 15:00 P2

Formation of molecular clusters of selenium as an alternative to precipitation of CdSe nanoparticles in a borosilicate glass — •Yuriy Azhniuk[1], Vasyl Lopushansky[1], Yuriy Hutych[1], Alexander Gomonnai[1], and Dietrich R. T. Zahn[2] — [1]Institute of Electron Physics, Ukr. Nat. Acad. Sci., Uzhhorod, Ukraine — [2]Chemnitz University of Technology, Semiconductor Physics, D-09107 Chemnitz, Germany

Solid-state precipitation in a borosilicate glass is a well-elaborated technique for obtaining II-VI semiconductor nanocrystals. The obtained nanocrystal size depends on the growth conditions (heat treatment temperature and duration). Here we present Raman evidence for an alternative process, precipitation of molecular clusters of selenium, which is also possible at certain growth conditions.

Decoloured CdSe-doped borosilicate glass samples were subjected to thermal treatment at 625 to 700^{o}C during 2 to 12 h. Resonant micro-Raman measurements were performed using a Dilor XY 800 spectrometer and different Ar^+ laser lines for excitation. Besides the CdSe LO and 2LO phonon bands, the Raman spectra of the samples obtained at thermal treatment duration and temperature beyond the range, most suitable for the formation of CdSe nanocrystals, contained pronounced features at 323 and 646 cm^{-1}. Based on their frequency positions, widths, intensities, and resonant behaviour, these features are attributed to Se_2 clusters being formed in the glass during the thermal treatment.

HL 48.48 Thu 15:00 P2

MOVPE growth studies for InGaN quantum dots — •Michael Högele[1], Christian Meissner[1,2], Simon Ploch[1], Markus Pristovsek[1], and Michael Kneissl[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstr. 36, EW6-1, 10623 Berlin — [2]ISAS - Institute for Analytical Sciences, Albert-Einstein-Str. 9, 12489 Berlin

The growth of InGaN for uncapped quantum dots (QDs) on GaN/sapphire templates was studied in a horizontal and a close coupled showerhead metal-organic vapour phase epitaxy (MOVPE). At a reactor pressure of 100 mbar and a N_2 atmosphere the growth temperature was varied between 620°C and 740°C. For a fixed ammonia partial pressure of 2500 Pa different ratios of trimetylindium (TMIn) and trimethylgallium (TMGa) or triethylgallium (TEGa) were used. The InGaN growth process was investigated by in-situ spectroscopic ellipsometry (SE). After growth the samples were analysed by X-ray diffraction (XRD) and atomic force microscopy (AFM).
For pure InN quantum dots we found a Volmer-Weber growth mode. With increasing gallium content in the InGaN nanostructures a transition to the Stranski-Krastanov growth mode is expected due to the decreasing lattice mismatch to the GaN templates.

HL 48.49 Thu 15:00 P2

Spectroscopy on charge-tunable InGaAs quantum dots — •Dennis Franz[1], Tim Köppen[1], Andreas Schramm[2], Christian Heyn[1], Detlef Heitmann[1], and Tobias Kipp[1] — [1]Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Germany — [2]Optoelectronics Research Center, Tampere University of Technology, Finland

We investigate electronic excitations in charge-tunable InGaAs quantum dots by resonant Raman and resonant photoluminescence spectroscopy in magnetic fields. In contrast to earlier measurements at the $E_0 + \Delta$ gap [1,2], we excite resonantly at the fundamental E_0 gap. Exploiting capacitance-voltage measurements one can control the electron number in the quantum dots. We study the zero, one, and two electron case and observe strongly resonant emission signals. For the one and two electron case, besides photoluminescence resonant electronic Raman transitions are identified.

This project is supported by the Deutsche Forschungsgemeinschaft via SFB 508 “Quantenmaterialien”.

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HL 48.50 Thu 15:00 P2

Fine structure tuning in self-assembled (In,Ga)As quantum dots by uniaxial stress — •Klaus D. Jöns[1], Robert Hafenbrak[1], Sven M. Ulrich[1], Lijuan Wang[2], Armando Rastelli[3], Oliver G. Schmidt[3], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Universität Stuttgart, Allmandring 3, 70569 Stuttgart, Germany — [2]Max-Planck-Institut für Festkörperforschung, Heisenbergstraße 1, 70569 Stuttgart, Germany — [3]Institute for Integrative Nanosciences, IFW Dresden, Helmholtzstraße 20, 01069 Dresden, Germany

Entangled photon pairs are an important prerequisite to implement e.g. quantum cryptography. The biexciton-exciton cascade in (In,Ga)As quantum dots (QDs) is a promising source of such quantum states. Still, intrinsic quantum dot fine structure splitting inhibits entanglement. Therefore, the fine structure splitting as a limiting factor has to be reduced using a post-growth technique. In our work we present fine structure tuning of self-assembled (In,Ga)As QDs by uniaxial stress. For this purpose we glued the sample tightly on a piezo actuator and applied tunable uniaxial stress along a crystal axis parallel to the sample surface. Our setup enables us to apply both tensile and compressive stress on the sample in a helium-flow cryostate so the confining potential can be tuned in two directions to achieve zero fine structure. The photoluminescence was detected by a high resolution setup using a Fabry-Pérot interferometer. Our results at 8K temperature show that the spectral emission of the QDs shifts by applying piezo voltage and that the fine structure splitting can be tuned considerably.

HL 48.51 Thu 15:00 P2

Optical Investigations of the Mode Spectra of InP–Quantum Dots Embedded in (Al_xGa_{1-x})InP Micro Pillars. — •Moritz Bommer[1], Tim Thomay[2], Wolfgang–Michael Schulz[1], Martin Tomas[2], Robert Rossbach[1], Michael Jetter[1], Alfred Leitenstorfer[2], Rudolf Bratschitsch[2], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Allmandring 3, D-70569 Stuttgart, Germany — [2]1. Department of Physics and Center for Applied Photonics, University of Konstanz, D-78464 Konstanz, Germany

InP–quantum dots (QDs) are promising sources of single–photons and as active laser medium, emitting in the red part of the visible spectrum and thus in the range of the highest sensitivity of current silicon detectors.

The self assembled QDs were grown by metal organic vapor phase epitaxy and are embedded in between distributed Bragg reflectors (DBRs), afterwards the sample was processed by a Focused Ion Beam to fabricate micro–pillars. The DBRs and the high refractive index step between pillar and air results in a three dimensional mode confinement and highly directed emission and thus higher intensity.

We have investigated the mode spectra by micro–photo luminescence measurements for different pillar diameters and compared the spectra with a theoretical model showing up good consistency. Q–factors up to 3600 were achieved.

HL 48.52 Thu 15:00 P2

Interferometric measurement of polarization dynamics in QDs — •Manuel Huber[1,2], Christian Wolpert[1,2], and Markus Lippitz[1,2] — [1]Max Planck Institute for Solid State Research, Stuttgart — [2]4th Physical Institute, University of Stuttgart

Most coherent experiments on excitonic states in QDs investigate an absolute value of the polarization. We want to be able to measure both the real and imaginary part to fully reconstruct the azimuthal state of the Bloch-vector. To achieve this aim we propose a method for a pump-probe setup using an interferometer, inspired by differential interference contrast microscopy. The interference of superposed reference and signal pulses is used to either perform phase- or amplitude-sensitive measurements.
We will show the principle of the setup and theoretical simulations as well as first experimental results for pump-induced excitonic states.

HL 48.53 Thu 15:00 P2

Photon statistics as a probe for exciton correlations in Coulomb-coupled quantum dots — •Alexander Carmele[1], Malek Bagheri Harouni[2], Marten Richter[1], and Andreas Knorr[1] — [1]Institut für Theoretische Physik, AG Nichtlineare Optik und Quantenelektronik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Physics Department, Quantum Optics Group, University of Isfahan, Isfahan, Iran

Recently, quantum optical spectroscopy of semiconductor nanostructures is suggested [1]. Within a density-matrix approach, we include Coulomb-contributions in coupled quantum dots via an exciton basis [2] and investigate for fixed light intensity the impact of photon statistics on the creation of optically active excitons. We find measurable differences for the creation efficiency. Furthermore, we calculate the degree of entanglement of photon pairs from radiative cascades of biexcitons [3] in dependence on different Coulomb-coupling mechanisms.

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HL 48.54 Thu 15:00 P2

Ultrafast gain dynamics in InGaAs quantum dot based semiconductor optical amplifiers — Jordi Gomis-Bresco[1], Sabine Dommers[1], Vasily Temnov[1], Ulrike Woggon[1], Matthias Lämmlin[2], Dieter Bimberg[2], •Ermin Malic[3], Marten Richter[3], Eckehard Schöll[3], and Andreas Knorr[3] — [1]Institut für Optik und Atomare Physik, Technische Universität Berlin — [2]Institut für Festkörperphysik, Technische Universität Berlin — [3]Institut für Theoretische Physik, Technische Universität Berlin

The application of quantum dot (QD) semiconductor optical amplifiers (SOAs) in high-speed ethernet networks demands a high frequency response. To understand the elementary processes limiting the recovery time in quantum dot based SOAs, we present pump-probe studies of femtosecond pulse trains with up to 1 THz repetition rates and investigate the gain response of a QD-SOA at high electrical injection current and elevated device temperatures.

We discuss fundamental limits for THz optical pulse train amplification based on semiconductor Bloch equations including microscopically calculated, temperature-dependent Coulomb scattering rates between quantum dot and wetting layer states.

HL 48.55 Thu 15:00 P2

The impact of strain waves travelling across a quantum dot on the optical response of the dot — •Jan Huneke[1], Vollrath Martin Axt[2], and Tilmann Kuhn[1] — [1]Institut für Festkörpertheorie, Universität Münster, Wilhelm-Klemm-Str. 10, 48149 Münster — [2]Institut für Theoretische Physik III, Universität Bayreuth, 95440 Bayreuth

We analyze the influence of phonon wave packets travelling across a semiconductor quantum dot on the optical response resulting from the lowest dot transition. For this purpose we compare two different structures: (i) a phonon wave packet is generated by the optical excitation of a single quantum dot near a surface, which after reflection at the surface reenters the dot; (ii) a phonon wave packet is generated by the excitation of a nearby second dot and then travels across the quantum dot.Our theoretical model includes pure dephasing interactions between electronic and phononic degrees of freedom in quantum dot systems that are driven by ultrafast laserpulses. We discuss the linear response as well as pump-probe and four-wave-mixing signals for both situations. It is shown that the phonon wave packets leave a distinct signature which allows their detection in time-integrated as well as time-resolved regimes. We study the dependence of the signals on the origin of the phonon wave packets and find, although the strain fields are very similar, clear differences in the optical response allowing for a distinction between wave packets of different origins.

HL 48.56 Thu 15:00 P2

Monitoring threshold dynamics by ultrafast direct observation of correlations between individual photon emission events in microcavity lasers — •Marc Assmann[1], Thorsten Berstermann[1], Manfred Bayer[1], Jan Wiersig[2,5], Christopher Gies[2], Frank Jahnke[2], Caroline Kistner[3], Stephan Reitzenstein[3], Christian Schneider[3], Sven Höfling[3], Alfred Forchel[3], Carsten Kruse[4], and Detlef Hommel[4] — [1]Experimentelle Physik II, Technische Universität Dortmund, 44221 Dortmund, Germany — [2]Institute for Theoretical Physics, University of Bremen, 28334 Bremen, Germany — [3]Technische Physik, University of Würzburg, 97074 Würzburg, Germany — [4]Institute for Solid State Physics, University of Bremen, 28334 Bremen, Germany — [5]Institute for Theoretical Physics, University of Magdeburg, 39016 Magdeburg, Germany

The onset of coherent emission in lasers is identified by a change in the photon statistics. In semiconductor lasers the short coherence times below the lasing threshold complicate such measurements as the temporal decay of correlations is considerably faster than the time resolution of usual photodiodes. A novel experimental approach using a streak camera allows us to overcome this problem with a time resolution of 2 ps. This allows for a very detailed characterization of microcavity lasers and enables us to describe the lasing process in detail. Especially around the lasing threshold phenomena like the emission of nonclassical light in few-QD-VCSELs, dynamical antibunching and relaxation oscillations in the second order correlation function are found.

HL 48.57 Thu 15:00 P2

Theory of Electron Phonon Interaction for Relaxation and Luminescence in Semiconductor Quantum Dots — •Matthias–René Dachner, Janik Wolters, Andreas Knorr, and Marten Richter — Institut für Theoretische Physik, Technische Universität Berlin

Using an effective Hamiltonian approach in which the states of a quantum system are divided into relevant and remote states, we derive equations of motion to describe higher order phonon processes.

As an application we calculate relaxation and dephasing times of electron-hole excitations in self assembled quantum dots where the energetic gaps between wetting layer and discrete states are on the order of several phonon energies.

Additionaly we discuss the influence of pure dephasing through acoustic phonons on the quantum dot luminescence. We stress that the choice of the quantum dot wavefunction is crucial for coupling matrix elements comparing calculated luminescence spectra with spectra from single quantum dot spectroscopy.

HL 48.58 Thu 15:00 P2

Theory of indirect spin dephasing in optically driven semiconductor quantum dots — •Anna Grodecka[1], Paweł Machnikowski[2], and Jens Förstner[1] — [1]Computational Nanophotonics Group, Theoretical Physics, University Paderborn, Paderborn, Germany — [2]Institute of Physics, Wrocław University of Technology, Wrocław, Poland

Optically driven spin control schemes in quantum dot (QD) systems exploiting spin dependent charge evolution are considered as the most promising candidates for quantum computers. We show that even in the absence of direct spin-reservoir coupling, the spin state of a confined carrier in QD can undergo dephasing. The indirect dephasing process is studied in detail for specific optical spin control protocols using off-resonant trion excitations in doped semiconductor QDs [1,2]. The microscopic description of the interaction between charges and their phonon reservoir as well as its non-Markovian nature is included. Moreover, the decoherence channels resulting from radiative decay of the trion and imperfections of an adiabatic evolution are discussed.

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HL 48.59 Thu 15:00 P2

Theory of electron-phonon coupling in semiconductor quantum dots: non-diagonal coupling, phonon memory and initial correlations — •Marten Richter and Andreas Knorr — Institut für Theoretische Physik, AG Nichtlineare Optik und Quantenelektronik, Technische Universität Berlin, Hardenbergstraße 36 EW 7-1, 10623 Berlin

Memory effects play an important role in the theory of dephasing processes of semiconductor quantum dots. To describe strong electron-phonon coupling (e.g. in nitrid materials) beyond perturbation theory, typically methods such as generating functions, cumulant expansion, time convolution less theories (TCL) are used. These methods are usually restricted to a diagonal electron-phonon interaction, that does not include transitions between different electronic levels. Non-diagonal electron-phonon coupling is of dramatic importance, if coupled quantum dots or several levels contribute to the optical response. In order to address this problem, we present an extended TCL theory, which makes an inclusion of nondiagonal electron-phonon coupling to the calculation of the nonlinear optical response function possible.

HL 48.60 Thu 15:00 P2

Theory of Time-resolved Raman and Fluorescence Emission of Semiconductor Quantum Dots — •Julia Kabuss[1], Stefan Werner[2], Axel Hoffmann[2], Andreas Knorr[1], and Marten Richter[1] — [1]Institut für Theoretische Physik, Technische Universität Berlin — [2]Institut für Festkörperphysik, Technische Universität Berlin

Resonant light scattering experiments provide information about the optical and electronic properties of semiconductor quantum dots. We develope a quantized description for the spontaneous light emission of a coupled phonon-semiconductor quantum dot system after resonant optical excitation. A perturbative approach to the density matrix leads to an analytic expression for the quasi-stationary spectrum, while the time-dependent spectrum is computed numerically. Our results allow the simultaneous discussion of Raman scattering and Fluorescence. They can be discriminated from each other by their spectral properties and their decay times respectively as both processes occur simultaneously in a resonant scattering experiment. Our results are compared to experimental data.

HL 48.61 Thu 15:00 P2

Optical spin switching in a Mn doped QD under influence of a magnetic field — •Doris E. Reiter[1], Vollrath Martin Axt[2], and Tilmann Kuhn[1] — [1]Institut für Festkörpertheorie, Westfälische Wilhelms-Universität Münster, Wilhelm-Klemm-Str. 10, 48149 Münster — [2]Theoretische Physik III, Universität Bayreuth, 95440 Bayreuth

The combination of semiconducting and ferromagnetic materials has interesting possible applications in the field of spintronics. In a CdTe quantum dot doped with a single Mn atom the exciton line in photoluminescence spectra splits into six lines clearly demonstrating the strong exchange interaction between the exciton and the Mn spin. As we have shown recently the Mn spin state can be controlled in an indirect optical way by a sequence of laser pulses, which create, destroy or manipulate excitons in the system. Thus the Mn spin can be driven from a given initial value into all the other spin states. By adding a magnetic field in Faraday configuration the efficiency of this process can be strongly enhanced and the total switching time can be reduced from 100 ps to about 40 ps, when dark and bright excitons are brought to resonance. The timescales for the switching process are of the order of the lifetime of the bright exciton. Therefore we consider a model which includes radiative decay in terms of a decay time. In this contribution we discuss the influence of the finite lifetime of the exciton as well as the influence of magnetic fields on the optical switching process.

HL 48.62 Thu 15:00 P2

Time-resolved electroluminescence measurement setup for single quantum dots — •J. Zimmer, P. Asshoff, H. Füser, H. Flügge, W. Löffler, M. Hetterich, and H. Kalt — Institut für Angewandte Physik, Universität Karlsruhe (TH), and DFG Center for Functional Nanostructures, CFN, D-76128 Karlsruhe

We describe a time-correlated single-photon counting setup for the analysis of the spin-injection process in spin-injection light-emitting diodes (spin-LEDs). We are able to measure the temporal electroluminescence polarization dynamics of the quantum dot ensemble and even single dots. To get optical access to single quantum dots, we use gold submicron apertures located on top of the spin-LEDs. The electroluminescence polarization dynamics of the quantum dots exhibit remarkable characteristics. We relate this to certain non-equilibrium effects in the device.

HL 48.63 Thu 15:00 P2

Self-assembled lateral GaAs quantum dot molecules — •Lijuan Wang[1], Armando Rastelli[2], Suwit Kiravittaya[1], Mohamed Benyoucef[2], and Oliver G. Schmidt[2] — [1]Max-Planck-Institut für Festkörperforschung,Heisenbergstr. 1, D-70569 Stuttgart, Germany — [2]Institute for Integrative Nanosciences, IFW Dresden,Helmholtzstr. 20, D-01069 Dresden, Germany

Semiconductor quantum dot molecules (QDMs) is an exciting area of research since they are ideal candidates for the possible implementation of quantum gates for quantum computation. Two main classes of QDMs have been explored, i.e. vertical and lateral QDMs according to the spatial arrangement of two quantum dots (QDs) composing a QDM. Here we demonstrate that using a multi-step growth technique, strain-free GaAs/AlGaAs lateral QDMs can be created. The QDMs are formed by filling two laterally spaced AlGaAs holes with GaAs.

The optical properties of such QDMs and single GaAs QDs grown in a similar way are characterized by photoluminescence. Different QDMs show similar spectral features. Because of fluctuations inherent in the self-assembled growth, the two QDs composing a QDM are generally not identical and thus their mutual coupling is tuned by an external electric field parallel to the QDM axis. The comparison between the emission of single QD and QDMs in a lateral electric field indicates the existence of lateral coupling.

HL 48.64 Thu 15:00 P2

Resonant Raman Profiles in GaAs and AlGaAs Nanowires at the Bandgap — •Oliver Schimek[1], Megan Brewster[2], Silvija Gradecak[2], and Stephanie Reich[1] — [1]Fachbereich Physik, Freie Universität, Berlin — [2]Massachusetts Institute of Technology, Cambridge

The properties of low dimensional systems like nanowires hold promise for novel electronic devices like nanowire-based transistors, sensors and single photon sources. Here we are investigating the physical properties like electron-phonon coupling by means of Raman spectroscopy. We present resonance data of GaAs and AlGaAs nanowires at the bandgap energy. The photoluminescence is effectively quenched in nanowires and therefore the bandgap can directly be probed. Such nanowires show an unexpectedly strong second order LO phonon such that the ratio 2LO:1LO reaches values up to 6 under resonant conditions. We also present a model of two phonon resonant Raman scattering via excitons. This model explains the observed 2LO resonance profile. The resonance data of the AlGaAs nanowires show a dip in the 1LO curve at the position of the 2LO maximum which suggests that the 2LO intensity occurs at expense of the 1LO intensity. Additionally, we present data of Si doped GaAs nanowires whose increased concentration of free carriers results in a interference known as the Fano effect.

HL 48.65 Thu 15:00 P2

Time-resolved Phonon Interactions in InAs/GaAs Quantum

Dots — •Stefan Werner, Patrick Zimmer, Julia Kabuss, Martin Richter, Axel Hoffmann, and Andreas Knorr — Institut für Festkörperphysik, TU Berlin, EW 5-1, Hardenbergstraße 36, 10623 Berlin, Deutschland

We present a time- and temperature-resolved photoluminescence study of different carrier-phonon interactions in self-organized InAs/GaAs quantum dots (QD) under resonant excitation of the QD system. Resonant excitation leads to an enhancement of cross-sections of processes attributed to phonon interactions, like Raman scattering or hot-electron luminescence. Resonant PL techniques enable us to retrieve the energies of localized phonon modes. Time-resolved PL measurements allow us to differentiate between coherent and incoherent phonon-coupled processes. For the QD LO-phonon mode (34.6 meV), a very short radiative lifetime of under 30 ps is found, giving proof of the coherent character of the Raman scattering. In addition, temperature-dependent measurements are performed. Our results are compared with theoretical calculations.

HL 48.66 Thu 15:00 P2

Excited state spectroscopy of single laterally coupled InGaAs quantum dot molecules — •Matthias Heldmaier[1], Claus Hermannstädter[1], Marcus Witzany[1], Wolfgang-Michael Schulz[1], Marcus Eichfelder[1], Robert Rossbach[1], Michael Jetter[1], Lijuan Wang[2], Armando Rastelli[3], Oliver Schmidt[3], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Allmandring 3, 70569 Stuttgart — [2]Max-Planck-Institut für Festkörperforschung, Heisenbergstr. 1, 70569 Stuttgart — [3]Institut für Integrative Nanowissenschaften, IFW Dresden, Helmholtzstr. 20, 01069 Dresden

The investigated structures contain self-assembled laterally coupled InGaAs quantum dots embedded in a planar microcavity, which are grown using a combination of metal-organic vapor phase and molecular beam epitaxy. The individual quantum dot molecules (QDMs) consist of two single dots that are coupled along the [1-10] crystal direction via electron tunneling. The coupling strength and the ground and excited state energies of the QDMs can be manipulated applying a lateral electric field. A change in the relative intensities of the excitonic emission lines is observed in the photoluminesence (PL) spectra. PL excitation measurements were conducted using a wide-range tunable Ti:sapphire laser to obtain spectra of the excited QDM states as a function of electric field tuning. Pumping an excited exciton state (p-shell) at increasing pulse amplitudes leads to oscillatory behavior in the detected excitonic s-shell recombination. Special pulse amplitudes ($\pi/2$, π, etc.) can be extracted and used for subsequent coherent experiments.

HL 48.67 Thu 15:00 P2

Non-local control of cotunneling currents in a two-impurity Kondo system — •Daniel Tutuc[1], Matthias Reinwald[2], Werner Wegscheider[2], and Rolf J. Haug[1] — [1]Institut für Festkörperphysik, Leibniz Universität Hannover, 30167 Hannover — [2]Angewandte und Experimentelle Physik, Universität Regensburg, 93040 Regensburg

We present measurements on non-local cotunneling current control in a system of two magnetic impurities - realized by two quantum dots - coupled through an open conducting region, which can be attributed to the influence of the effective interaction between magnetic moments [1-3]. The sample consists of two lateral quantum dots connected via an open region of about 300 nm, created by Local Anodic Oxidation with an AFM on a GaAs/AlGaAs heterostructure with a 2DEG 34nm beneath the surface. The measurements have been performed with the standard lock-in technique, in a dilution refrigerator, at about 100 mK electron temperature. We investigate the effective interaction between magnetic moments in dependence on the dot coupling to the central region and on an in-plane magnetic field. The interaction between the magnetic moments is destroyed for weak dot coupling to the central region and for magnetic fields higher than 8T.

[1] N. J. Craig *et al.*, Science **304**, 565 (2004)
[2] P. Simon, *et al.*, Phys. Rev. Lett. **94**, 086602 (2005)
[3] M. G. Vavilov and L. I. Glazman, Phys. Rev. Lett. **94**, 086805 (2005)

HL 48.68 Thu 15:00 P2

Ballistic rectification in an asymmetric Si/SiGe cross junction with modulated electron density — •Daniel Salloch[1], Ulrich Wieser[1], Ulrich Kunze[1], and Thomas Hackbarth[2] — [1]Werkstoffe und Nanoelektronik, Ruhr-Universität Bochum, D-44780 Bochum — [2]DaimlerCrysler Forschungszentrum Ulm, D-89081 Ulm

The influence of the electron density on the output characteristic of ballistic rectifiers is investigated. The rectifier is a nanoscale four-terminal Ψ-shaped cross junction consisting of a straight voltage stem (200 nm wide and 2 μm long) and two opposing 200 nm wide branches which merge under 45° into the central stem. Different devices are fabricated from a high-mobility Si/SiGe heterostructure by using a mix-and-match process which combines high-resolution electron-beam lithography and UV-lithography. With a low-damage CF_4/O_2 plasma step the resist pattern is transferred into the heterostructure. After the preparation of ohmic contacts a nanoscale Schottky gate is locally deposited on top of the voltage stem. A rectified inertial ballistic voltage develops between the upper and lower end of the central stem if a current is injected between the branches [1]. At $T = 4.2\,\mathrm{K}$ we observe an increase of the rectified signal with decreasing electron density in the voltage stem achieved by applying a negative voltage at the local Schottky gate. The improved efficiency at low electron density is tentatively attributed to a reduced screening of the stationary dipole.
[1] M. Knop *et al.*, Appl. Phys. Lett. **88**, 082110 (2006)

HL 48.69 Thu 15:00 P2

Electronic transport in InAs nanowires controlled by high-k dielectric gates — •Karl Weis[1,2], Sergio Estévez Hernández[1,2], Mihail Ion Lepsa[1,2], Masashi Akabori[1,2], Kamil Sladek[1,2], Stefan Trellenkamp[1,2], Jürgen Schubert[1,2], Thomas Schäpers[1,2], Hilde Hardtdegen[1,2], and Detlev Grützmacher[1,2] — [1]Institute of Bio- and Nanosystems (IBN-1), Research Centre Jülich, 52425 Jülich, Germany — [2]JARA, Fundamentals of Future Information Technology

Quantum dots in semiconductor nanowires are promising candidates for the realization of quantum bits. It is well known that using gate electrodes is a convenient way to form and tune quantum dots.

Here, the electronic transport properties of n-doped InAs nanowires grown by MBE and MOVPE are examined. For a sample of 22 wires, the length and diameter are (1700 ± 400) nm and (170 ± 20) nm, respectively. The tunability of the carrier concentration in the conductive channel is compared for different gate geometries, e. g. fingers or nearly wrapping gates. Furthermore, we investigate if gate performance can be improved by using a high-k dielectric, namely $GdScO_3$, instead of SiO_2. Four-terminal transport measurements are performed both at room temperature and at low temperatures down to 300 mK.

Preliminary field effect transistor measurements were performed at room temperature for the aforesaid sample of 22 wires. We used a SiO_2 back gate, varied the gate voltage and measured the drain current. At a source-drain bias of 0.1 V, the pinch-off voltage was $U_{\mathrm{th}} = (-40 \pm 20)\,\mathrm{V}$ and the maximum transconductance $g_{\mathrm{m}} = (1.6 \pm 0.8) \times 10^{-6}\,\mathrm{S}$.

HL 48.70 Thu 15:00 P2

Wavefunctions in the valence band of InAs quantum dots — •Razvan Roescu[1], Dirk Reuter[1], Andreas D. Wieck[1], Ulrich Zeitler[2], and Jan C. Maan[2] — [1]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Universitätsstr. 150, 44780 Bochum, Germany — [2]High Field Magnet Laboratory, Radboud University Nijmegen, Toernooiveld 7, 6525 ED Nijmegen, The Netherlands.

Magneto-capacitance spectroscopy of InAs self-assembled quantum dots allows the momentum space wavefunctions mapping of conduction and valence band states. To do this, a magnetic field is varied (strength and direction) in the base plane of the quantum dots.

The perpendicular magnetic field would also influence the wavefunctions, therefore capacitance-voltage spectroscopy in a tilted field should reveal this effect.

We will present the result of such experiments performed on self-assembled InAs/GaAs quantum dots embedded in a Schottky diode with a carbon doped p-type back contact. The results cannot be explained by a simple model and possible consequences are discussed.

HL 48.71 Thu 15:00 P2

Investigations of a photovoltaic power generator in an Electromagnetic Ambience — •Markus Drapalik[1], Julian Schmid[1], Erika Kancsar[1], Viktor Schlosser[1], and Gerhard Klinger[2] — [1]Faculty of Physics, University of Vienna, 1090 Vienna, Austria — [2]Department of Meteorology and Geophysics, University of Vienna, 1090 Vienna, Austria

Up to date little attention has been paid to the interaction of photovoltaic solar cell arrays with electromagnetic fields. Primary arrays of solar panels can act as passive shields, reflectors and antennas for

RF radiation. The reception of electromagnetic radiation from the ambience by the solar modules introduces electrical noise into the subsequent system. Under laboratory conditions we currently investigate electrical AC signals detected at the terminals of single solar cells and small modules under well controlled ambient parameters. The signals are introduced by RF radiation emitted by function generators in the range between 10Hz and 4GHz. Beside the laboratory examinations an outdoor facility on the roof top of the department building in central Vienna was equipped with the necessary instruments to record RF signals from the ambience and the electrical noise of a solar module under realistic operating conditions. Results of these investigations will be discussed in order to evaluate the contributions of solar arrays to electromagnetic ambience.

HL 48.72 Thu 15:00 P2

Determination of the a.c. parameters of photovoltaic solar cells — •Erika Kancsar, Markus Drapalik, Julian Schmid, and Viktor Schlosser — Faculty of Physics, University of Vienna, 1090 Vienna, Austria

Photovoltaic solar cells are widely used for direct sunlight to electricity conversion. Principally a solar cell generates a current which is proportional to the incident light intensity which includes current fluctuations caused by photon noise. A solar power generator therefore may become a significant source of electromagnetic distortion which can cause malfunction of other electrical equipment and increase biological risks associated with a higher level of electromagnetic noise in the ambience. In order to predict the response of a solar cell to light fluctuations, the transfer function or the equivalent circuit must be known. In this work we investigate the a.c. behaviour of single solar cells and small modules connected to a simple load circuit in order to evaluate the necessary elements which describe the equivalent a.c. circuit under operating conditions. The results will be discussed with respect to different designs of photovoltaic devices.

HL 48.73 Thu 15:00 P2

Investigations of the response of a photovoltaic power generator to mechanical vibrations — •Julian Schmid[1], Erika Kancsar[1], Markus Drapalik[1], Viktor Schlosser[1], and Gerhard Klinger[2] — [1]Faculty of Physics, University of Vienna, 1090 Vienna, Austria — [2]Department of Meteorology and Geophysics, University of Vienna, 1090 Vienna, Austria

Due to their large area and the exposure to wind forces photovoltaic solar modules are subjected to mechanical vibrations which can generate electrical oscillations. The resulting electromagnetic signal is partly emitted to the ambience and partly carried through the leads to the power conditioning system of the solar power generator. Purpose of the current work is (i) to investigate the response of photovoltaic devices to mechanical vibrations in the laboratory under well controlled conditions and (ii) to perform exemplary outdoor studies of the mechanical vibrations caused by wind forces in Vienna. The results collected so far will be presented and discussed with respect to the impact of mechanical vibrations of solar arrays on the level of electromagnetic distortion.

HL 48.74 Thu 15:00 P2

Sputter deposition of Cu_2O thin films from oxidic targets — •Swen Graubner, Daniel Reppin, Angelika Polity, Detlev Hofmann, and Bruno K. Meyer — I. Physikalisches Institut, Justus-Liebig-Universität Giessen, Heinrich-Buff-Ring 16, D-35392 Giessen

Cu_2O is an intrinsic p-type semiconductor with energy of the band gap in the visible spectral range. Thus it is considered to be a promising material for thin film solar cell applications. Our approach is to deposit Cu_2O films using ceramic targets and to explore the parameter space in comparison to the deposition from metallic targets. The first step was to develope a sinter technique to produce a stoichiometric and stable sputter target. We deposited layers using this ceramic target by a RF sputter process. Morphological investigations of the films by x-ray diffraction (XRD) show a strong $Cu_2O < 200 >$ reflex. Carrier concentrations were determined by Hall-measurements to $10^{13} - 10^{14}$ cm^{-3}. The use of oxygen as reactive sputter gas leads to higher carrier concentrations, a direct and forbidden bandgap of $1,9$ to $2,0$ eV and an improved morphological quality. Oversized O_2 flows lead to the formation of CuO thin films. Using a nitrogen/argon mixture as sputter gas changes the electrical and morphological properties.

HL 48.75 Thu 15:00 P2

Hard x-ray photoelectron spectroscopy of chalcopyrite based solar cells — •Christian D.R. Ludwig[1], Catherine A. Jenkins[2], Xuefang F. Dai[3], Andrei Gloskovskii[3], Gerhard H. Fecher[3], Claudia Felser[3], Benjamin Johnson[4], Joachim Klaer[4], Iver Lauermann[4], and Raquel Caballero[4] — [1]Institute for Physics, Johannes Gutenberg - University, 55099 Mainz — [2]Department of Materials Science and Engineering, University of California, Berkeley, 94720, USA — [3]Institute of Inorganic and Analytical Chemistry, Johannes Gutenberg - University, 55099 Mainz — [4]Helmholtz-Zentrum für Materialien und Energie, 14109 Berlin

Chalcopyrite based solar modules combine advantages of thin-film technology with the high efficiency and stability of conventional crystalline silicon cells. Hard x-ray photoemission spectroscopy (HAXPES) allows the investigation of a total buffer/absorber/substrate device stack, due to a mean free path of the excited electrons of a few tens of unit cells. The chalcopyrite compounds $Cu(In,Ga)Se_2$ and $CuInS_2$ with a CdS capping were investigated at BESSY, Berlin and at SPring8, Japan. The excitation energy was varied from 2.2 keV to 8 keV. The experimental results are compared to first principle electronic structure calculations based on density functional theory. The densities of states of the valence bands of uncapped compounds agree well with photoemission spectroscopy data and it is shown that HAXPES is a technique capable of resolving the valence bands of interfaces, buried under a CdS capping. This work is funded by the Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (project 0327665A).

HL 48.76 Thu 15:00 P2

New buffer layer materials for CIGS solar cells — •Thomas Gruhn[1], David Kieven[2], and Claudia Felser[1] — [1]Institute of Inorganic and Analytical Chemistry, Johannes Gutenberg University, 55099 Mainz — [2]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Glienicker Str. 100, 14109 Berlin

Test

HL 48.77 Thu 15:00 P2

New buffer layer materials for CIGS solar cells. — •Thomas Gruhn[1], David Kieven[2], and Claudia Felser[1] — [1]Institute of Inorganic and Analytical Chemistry, Johannes Gutenberg University, 55099 Mainz — [2]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Glienicker Str. 100, 14109 Berlin

The compound semiconductor $CuIn_xGa_{(1-x)}Se_2$ (CIGSE) are used as absorber material in thin-film photovoltaic cells. In conventional CIGSE based solar cells a thin CdS layer (buffer) significantly improves the photovoltaic performance and efficiencies up to 19.9% have been realized. Since Cd is a toxic heavy metal there is a demand for suitable substitute materials. The first requirements for these materials are an adequate band gap, a crystal structure compatible to that of CIGSE, and an n-type conductivity. An interesting class of materials are half-Heuslers, which are ternary compounds with a $C1_b$ MgAgAs structure. For many half-Heusler compounds the crystal structure matches well with the [100] layer of the tetragonal CIGS unit cell. Using ab initio calculations based on B3LYP hybrid functionals, we have studied electronic properties of the most promising half-Heusler materials. Our results affirm the band gap rule for 8-electron half-Heuslers presented in [1].
The authors gratefully acknowledge financial support by the DfG (Research Unit 559).

[1] H. C. Kandpal, C. Felser, and R. Seshadri, J. Phys. D: Appl. Phys. **39**, 776 (2005).

HL 48.78 Thu 15:00 P2

Electronic bandstructure of the ZnTe absorber material — Daniel Fritsch[1] and •Heidemarie Schmidt[2] — [1]Leibniz Institute for Solid State and Materials Research IFW Dresden, PO Box 270116, D-01171 Dresden, Germany — [2]Forschungszentrum Dresden-Rossendorf, PO Box 510119, D-01314 Dresden, Germany

Due to its large absorption coefficient, zinc telluride proved to be useful for the production of high-efficiency multi-junction solar cells. Nowadays ZnTe with a mixture of zincblende and wurtzite phases is fabricated by thin film growth techniques. The optical properties of both phases have been extensively studied by ab initio density functional methods [1]. Here we focus on the question whether the effective electron and hole mass in ZnTe are small enough to meet the high-efficiency expectation of the ZnTe absorber material in solar cells and present direction dependent effective mass and Luttinger and Luttinger-like

parameters of cubic and wurtzite ZnTe, respectively. Making use of the transferability of ionic model potential parameters [2] and the experimentally known transition energies of different II-VI compounds ZnX (X=O, S, Se, Te), we obtained one single set of cationic model parameters for the Zn atom. The calculations have been performed by means of the empirical pseudopotential method using a simple empty core model potential. [1] S. Zh. Krazhanov, P. Ravindran, A. Kjekshus, H. Fjellvåg, and B.G. Svensson, Phys. Rev. B 75, 155104 (2007). [2] D. Fritsch, H. Schmidt, M. Grundmann, Appl. Phys. Lett. 88, 124104 (2006), Phys. Rev. B 69, 165204 (2004)

HL 48.79 Thu 15:00 P2

Surface Modification of ZnO-Films as Transparent Conductive Oxide Layer for Silicon Thin Film Solar Cells — •Florian Lükermann[1], Viola Mönkemöller[1], Armin Brechling[1], Marc Sacher[1], Ulrich Heinzmann[1], Henning Kurz[2], Frank Hamelmann[2], and Helmut Stiebig[2] — [1]Molecular and Surface Physics, Bielefeld University, Germany — [2]Malibu GmbH, Bielefeld, Germany

Transparent conductive oxides are used as front electrode in thin film solar cells. Especially ZnO deposited by Low Pressure Chemical Vapor Deposition provides useful features for solar cells. On the one hand ZnO shows a good conductivity and on the other hand a rough surface consisting of pyramidal grains which possess a good light scattering capability.[1]

To influence this light scattering, two different kinds of treatments have been applied on the ZnO surface: etching with diluted HCl and Reactive Ion Etching with Ar and O_2. The main interest is focused on the change of surface morphology and the resulting changes in light scattering and transmission. HCl etching leads to an increasing surface roughness as well as diffuse transmittance. Ar/O_2 bombardment decreases the roughness and thus the scattering. The lowered roughness enhances the growth of the a-Si absorber layer and reduces the formation of pinholes. Finally the properties of amorphous silicon solar cells deposited on treated ZnO-films are compared with those deposited on untreated films.

[1] Addonizio et al., Proc. of the 22nd EPVSEC, 2129 (2007).

HL 48.80 Thu 15:00 P2

Microscopic investigations of the damp-heat degradation of Al-doped ZnO on structured surfaces — •Uli F. Wischnath[1], Thomas Madena[1], and Dieter Greiner[2] — [1]Univ. Oldenburg, Inst. f. Physik, C. v. Ossietzky Str., 26129 Oldenburg — [2]Helmh. Zent. Berlin, Glienicker Str. 100, 14109 Berlin

The conductivities of unencapsulated Al-doped ZnO (ZAO) thinfilm layers on structured surfaces show a strong degradation under damp-heat stress. From earlier investigations [1] it was deduced that extendend grain boundaries are the prevalent source of this phenomenon. The extended grain boundaries are regions where the growth of the ZAO is perturbated due to the underlying microstructure. They have been realized for the current investigations as parallel rectangular ridges. We show here AFM-based investigations of the local potential on the structured ZAO samples. These measurements allow insight into the microscopic processes causing the macroscopic detectable degradation.

[1] Greiner et al., Thin Solid Films, article in press, (2008)

HL 48.81 Thu 15:00 P2

Spectral photoluminescence from semiconductor emitters without temporal and spatial coherence — •Sebastian Wilken, Sebastian Knabe, and Gottfried H. Bauer — Institute of Physics, University of Oldenburg, Germany

Photoluminescence (PL) provides means to determine physical semiconductor properties, such as spectral absorption, defect densities and their respective energy levels, and excess carrier densities which might be expressed in terms of quasi-Fermi levels. However, the luminescence emission from locally sufficiently extended emitters is lacking of temporal as well as of spatial coherence. For the modeling of those pl-photon fluxes which occur e. g. in luminescence photon coupling between tandem solar cell absorbers or in absorbers overcoated by photonic stop gaps we have applied a finite difference time domain algorithm for the photon flux in and around the semiconductor and the Fraunhofer approximation for the far field of the photon flux.

We have numerically reproduced the wavelength dependent local photon fluxes emitted from a x-tal Si waver overcoated with a one-dimensional grid on one surface and compared the numerical results with the experimental pl-fluxes detected versus angle dependence.

HL 48.82 Thu 15:00 P2

Optical and electrical characterisation of InP-based multi-junction solar cells — •Nadine Szabo, Erol Sagol, Christian Höhn, Marinus Kunst, Klaus Schwarzburg, and Thomas Hannappel — Helmholtz Zentrum Berlin, Glienicker Str. 100, 14109 Berlin

Currently, triple-junction solar cells realized from III-V semiconductor compounds hold the solar energy conversion efficiency world record. To improve the efficiency significantly, it is necessary to increase the number of junctions and to involve a subcell with an absorber layer in the band gap range of 1eV. We show on the example of the low band gap tandem cell how the choice of the materials, the quality of the bulk, the optimization of the band gap energies and the preparation of the critical interfaces are essential to build a high efficiency solar cell. A four-junction device can be realized by mechanically stacking of a GaAs-based GaInP/GaAs tandem cell with a InP-based InGaAsP/InGaAs tandem cell. We have grown InGaAsP and InGaAs-layers lattice matched to InP substrates, and investigated the properties of the absorber bulk material. We will present time resolved photoluminescence measurements of low band gap InGaAs and InGaAsP double heterostructures and I-V curves of InGaAs/GaAsSb tunnel junctions. Our results show that the InGaAsP/InGaAs tandem cells reach efficiencies above 10% under GaAs, which is considerably higher than a conventional germanium subcell.

HL 48.83 Thu 15:00 P2

Influence of damp-heat exposure on the electronic properties of Cu(In,Ga)(S,Se)$_2$ thin film solar cells — •Robin Knecht, Martin Knipper, Ingo Riedel, and Jürgen Parisi — Energy and Semiconductor Research Laboratory, Department of Physics, University of Oldenburg, 26111 Oldenburg, Germany

Thin film solar cells made of the chalcopyrite compound semiconductor Cu(In,Ga)(S,Se)$_2$ (CIGSSe) exhibit strong potential for achieving high efficiency at relatively low production costs. Volume production of CIGSSe-modules started in different companies because of their favorable attributes, e.g. low cost and good efficiency.

Environmental stability of the entire solar cell structure is a major issue for the competetiveness of chalcopyrite thin film photovoltaics. In particular long-term stress by heat and humidity could play an important role for the device degradation. We carried out climate stress tests on CIGSSe-solar cells and characterized the samples in situ via current-voltage (dark/illuminated) as well as capacitance-voltage measurements. These measurements were supported by defect spectroscopic techniques in order to investigate the interplay of damp-heat exposure on the extrinsic changes of the electronic properties.

HL 48.84 Thu 15:00 P2

Influence of thermal annealing and light soaking on the electronic properties and device performance of Cu(In,Ga)Se$_2$ thin film solar cells — •David Adelmann[1], Nils Könne[1], Konstantin Kloppstech[1], Janet Neerken[1], Martin Knipper[1], Jürgen Parisi[1], Robert Kniese[2], and Michael Powalla[2] — [1]Energy- and Semiconductor Research Laboratory, Department of Physics, University of Oldenburg, D-26111 Oldenburg, Germany — [2]Zentrum für Sonnenenergie- und Wasserstoff-Forschung (ZSW), Industriestr. 6, D-70565 Stuttgart, Germany

We have investigated the effect of mid-temperature annealing and light soaking on the metastable device performance of Cu(In,Ga)Se_2 thin film solar cells. Thermal treatments at 85°C and 165°C as well as exposure to intense broadband photon flux have been carried out under inert gas atmosphere. A variety of identically processed devices have been investigated by measurements of current-voltage, capacitance *voltage and their spectral response. The changes of the device performance as well as of the diode characteristics upon exposure to heat and light are discussed. Moreover, thermal annealing was found to induce a significant shift of the activation energy of electronic defect states as confirmed by impedance spectroscopy. Although these studies are not finished yet we will try to deliver a consistent explanation of our experimental findings.

HL 48.85 Thu 15:00 P2

Characterization of Cu(In,Ga)S_2-thin film solar cells with varied gallium concentration — •Stephanie Malek[1], Janet Neerken[1], Martin Knipper[1], Saoussen Merdes[2], Roland Mainz[2], Ingo Riedel[1], and Jürgen Parisi[1] — [1]Energy and Semiconductor Research Laboratory, Department of Physics, University of Oldenburg, D-26111 Oldenburg, Germany — [2]Helmholtz-Zentrum Berlin für Ma-

terialien und Energie, Glienicker Straße 100, D-14109 Berlin, Germany

During the last decades interest in thin film solar cells based on chalcopyrite semiconductors (e.g. $Cu(In,Ga)(S,Se)_2$) has steadily increased. Particularly, chalcopyrite compounds exclusively based on sulfides are of interest because of their low cost potential as compared to selenium-containing devices. In this contribution we present recent investigations of $Cu(In,Ga)S_2$ thin film solar cells with varied gallium incorporation in the absorber layer. Doping the absorber with gallium has twofold meaning: moderate gallium concentrations lower the increase of the efficiency by decreasing the band gap energy while high concentrations result in a decrease of the open circuit voltage. We investigate the effects of Ga-doping by admittance spectroscopy and capacity-voltage measurements. These methods were chosen to get information about the local doping concentration and activation energies of the traps.

HL 48.86 Thu 15:00 P2

Lateral Inhomogeneities and Potential Fluctuations in Chalcopyrite Thin-Films and Solar Cells — •Thomas Unold, Markus Wendt, Christina Manclus, Raquel Caballero, Christian Kaufmann, and Hans-Werner Schock — Helmholtz-Zentrum Berlin für Materialien und Energie Gmbh, Berlin, Germany

Polycrystalline chalcopyrite-type semiconductors such as Cu(In,Ga)Se2 show great potential for use in photovoltaic devices with 20% solar conversion efficiency demonstrated for small area thin film devices. These devices exhibit micrometer grain sizes which are of the same order as the film thickness and are found to exhibit significant lateral inhomogenities in their recombination properties. In addition it is found that the highest conversion efficiencies are reached for copper-poor material composition with Cu/III < 0.8, where a large number of defects and compensation is present. We investigate a series of Cu(In,Ga)Se2 thin-film devices with constant gallium content but varying Cu/In+Ga content by temperature-dependent photoluminescence spectroscopy and micro-photoluminencence imaging. We find that the copper-poor samples show much less spatial fluctuations in the recombination properties than the material which is close to stochiometry. The results will be discussed in view of current models of potential fluctuations in chalcopyrite-type thin films.

HL 48.87 Thu 15:00 P2

Molecular beam epitaxy of InN layers on Sapphire, GaN and indium tin oxide — •Christian Denker[1], Boris Landgraf[1], Henning Schuhmann[1], Jaime Segura-Ruiz[2], Maribel Gomez-Gomez[2], Joerg Malindretos[1], Michael Seibt[1], Andres Cantarero[2], and Angela Rizzi[1] — [1]IV.Physikalisches Institut, Georg-August-Universität Göttingen, 37077 Göttingen, Germany — [2]Materials Science Institute, University of Valencia, 46980 Paterna (Valencia), Spain

Among the group-III nitrides semiconductors, InN is the one with the narrowest gap (0.67 eV), lowest effective electron mass and highest peak drift velocity. It is therefore a very interesting material for several applications, in particular semiconductor solar cells. Furthermore, the high electron affinity makes it suitable also as electrode material for organic solar cells.

InN layers were grown by molecular beam epitaxy on MOCVD GaN templates, on bare c-plane sapphire and on polycrystalline indium tin oxide. On all substrates the III-V ratio as well as the substrate temperature was varied. A RHEED analysis of InN growth on GaN showed a relatively sharp transition from N-rich and columnar growth to In-rich growth with droplet formation by increasing the In flux impinging on the surface. The InN layers on single crystalline substrates were characterized by SEM, AFM, XRD, PL and Raman. The InN layers on ITO were mainly analyzed with respect to the surface morphology with SEM. HRTEM in cross section gives insight into the structure of the interface to the ITO substrate.

HL 48.88 Thu 15:00 P2

Kelvin probe force and scanning capacitance microscopy on MOS structures — •Christine Baumgart[1], Stefan Jaensch[2], Manfred Helm[1], and Heidemarie Schmidt[1] — [1]Institute of Ion Beam Physics and Materials Research, Forschungszentrum Dresden-Rossendorf, P.O. Box 510119, 01314 Dresden (Germany) — [2]ElKiDo, v/ Stefan Jaensch, stre Alle 73, DK-6900 Skjern (Danmark)

As the size of semiconductor devices is decreasing permanently, new techniques are required to probe their dopant profile reliably on a nanometer scale. Kelvin probe force microscopy (KPFM) and scanning capacitance microscopy (SCM) are the most promising techniques for this demand. KPFM (LevelAFM from Anfatec) enables the detection of the contact potential difference (CPD) between tip and sample and SCM (DI3100 from Veeco Instruments) probes the capacitance of the metal oxide structures formed in contact. In order to demonstrate the complementary information obtained by KPFM and SCM measurements, we used the pn junction in a static random access memory integrated circuit device where the n-well with a donor concentration of $2*10^{17}$ cm^{-3} has been fabricated by implanting the p-epi with a nominal acceptor concentration of $2*10^{16}$ cm^{-3} with P^+ ions of energy 900 keV and a fluence of $1.7*10^{13}$ cm^{-2} [1]. As expected, KPFM yields a smooth variation of the CPD between the p-epi and the n-well amounting to 230 meV. SCM clearly shows the boxlike doping profile of this pn junction. The CPD variation can be modelled by assuming a partially compensated donor concentration in the n-well. [1] M.W. Nelson et al., Electrochemical and Solid-State Letters 2 (1999) 475.

HL 48.89 Thu 15:00 P2

Work Function and Electron affinity of Some Layered Transition Metal Dichalcogenide Materials — •Mohamed Moustafa, Alexander Paulheim, Michael Niehle, Karl Mildner-Spindler, Christoph Janowitz, and Recardo Manzke — Institut für Physik, Humboldt-Universität zu Berlin, Newtonstraße 15, 12489 Berlin.

Work function and electron affinity values of various semiconducting and metallic layered transition metal dichalcogenides (TMDCs) which might be suitable for the photovoltaic applications (such as ZrS_xSe_{2-x} where $0 \leq x \leq 2$, $HfSe_2$, HfS_2, $TiTe_2$, $NbTe_2$, TaS_2) have been measured using photoemission spectroscopy and vibrating capacitor Kelvin probe techniques [1, 2]. All samples were single crystals grown by the chemical vapour transport method with iodine as a transport agent. The measured values are compared to the previously reported empirical and calculated values based on various band models, and proved good agreement for most of the materials.

[1] G. Ertl and J. Küppers, Low Energy Electrons and Surface Chemistry. Verlag. Chemie, Weinheim, (1985).

[2] P.P. Craig and V. Redeka, Rev. Sci. Instrum. 41,(1970).

HL 48.90 Thu 15:00 P2

Electronic contacts to nanostructures by FIB-deposited metals — •Sebastian Thunich, Leonhard Prechtel, and Alexander Holleitner — Technische Universität München, Walter Schottky Institut, Am Coulombwall 3, 85748 Garching, Germany

Focused ion beam (FIB) lithography is a field of growing interest, as it allows etching as well as the deposition of insulating and conducting films on a submicron scale. We show that nanostructures, such as carbon nanotubes, can be electronically contacted using ion beam induced deposition (IBID) and we provide a systematic characterization of the obtained deposits. For our work, we used a 30kV Ga^+ FIB system (NVision40, Zeiss) together with tungsten hexacarbonyl [W(CO)6], a common precursor for conductive deposits. Generally, the yield of the presented method strongly depends on several beam and scanning parameters, such as beam current, pixel size and dwell time, as well as substrate composition. For the purpose of electric contacts to nanostructures, a low resistivity and a low contact resistance also to gold electrodes is required. We have found resistivity of tungsten deposits to be $\sim 5\ \Omega\ \mu$m, and the contact resistance to vary between 30 Ω and 100 Ω.

HL 48.91 Thu 15:00 P2

Barrier height measurements of $In_xAl_{1-x}N$ — •Christian Barth, Mareike Trunk, and Daniel M. Schaadt — Institut für Angewandte Physik, Universität Karlsruhe (TH), and DFG Center for Functional Nanostructures, CFN, D-76128 Karlsruhe

InN - metal contacts show no Schottky barrier due to Fermi level pinning in the conduction band. AlN - metal contacts however form Schottky barriers. By changing the In to Al ratio, the barrier height could be adjusted over a large range. However, it also known that InAlN shows the tendency to demix into InN and AlN and that it is therefore difficult to obtain high quality films. The defects will likely decrease the ideality of the contact. Therefore barrier height measurements require a robust setup which can cope with non ideal diodes. By performing capacitance - voltage measurements at different frequencies, we can obtain the series resistance (spreading resistance) and parallel resistance (due to leakage paths along defects) for non-ideal diodes. Incorporating these parameters in a combined model, reliable barrier height extraction with little temperature dependence is possible. The setup consists of a LCR-meter and a linear power supply which are controlled from a measurement program. This program allows volt-

age and frequency dependant measurements and directly calculates the barrier height. A verification of this method with measurements on known barrier heights of Au on Si and GaAs as well as results for $In_xAl_{1-x}N$ is presented