HL 89: Optical Properties II

Time: Friday 10:15–13:30 Location: POT 251

HL 89.1 Fri 10:15 POT 251

Electric-field-induced second harmonic generation in GaAs — •Marco Lafrentz[1], David Brunne[1], Benjamin Kaminski[1], Dmitri R. Yakovlev[1,2], Victor V. Pavlov[2], Roman V. Pisarev[2], and Manfred Bayer[1] — [1]Experimentelle Physik 2, Technische Universitaet Dortmund, D-44221 Dortmund, Germany — [2]Ioffe Physico-Technical Institute, Russian Academy of Sciences, 194021 St. Petersburg, Russia

We report on electric-field-induced second-harmonic generation (SHG) in the GaAs semiconductor in the vicinity of the band gap. The light has been send along 001-crystallographic direction. In this geometry SHG is forbidden in electric-dipole approximation. In applied electric field the SHG signal arises due to field-induced symmetry breaking causing new optical nonlinearities. Electric-field and temperature investigations assign the strong signal at $E(2\omega) = 1.517$ eV for $T = 2$ K to excitonic resonance. This phenomenon is a supplementary tool for detailed investigation of complex suscebtibilities we have reported on in the past [1,2].

[1] V. V. Pavlov, A. M. Kalashnikova, R. V. Pisarev, I. Sänger, D. R. Yakovlev, and M. Bayer, Phys. Rev. Lett. **94**, 157404 (2005)

[2] I. Sänger, D. R. Yakovlev, B. Kaminski, R. V. Pisarev, V. V. Pavlov, and M. Bayer, Phys. Rev. B **74**, 165208 (2006)

HL 89.2 Fri 10:30 POT 251

Optical third-harmonic spectroscopy of the magnetic semiconductor EuTe — •David Brunne[1], Marco Lafrentz[1], Benjamin Kaminski[1], Victor Pavlov[2], Andre Henriques[3], Roman Pisarev[2], Dmitri Yakovlev[1], and Manfred Bayer[1] — [1]TU Dortmund — [2]A. F. Ioffe physical-technical Institute — [3]Instituto de Fisica, Universidade de Sao Paulo

EuTe possesses the centrosymmetric crystal structure m3m of rock-salt type in which the second harmonic generation (SHG) is forbidden in electric-dipole approximation, but the third harmonic generation (THG) is allowed. We studied the THG spectra of this material and observed several resonances in the vicinity of the band gap at $2.2-2.5$eV and at higher energies up to 4eV, which are related to four photon THG processes. The observed resonances are assigned to specfic combinations of electronic transitions between the ground $4f^7$ state at the top of valence band and excited $4f^6 5d^1$ states of Eu^{2+} ions, which form the lowest energy conduction band. Temperature, magnetic field and rotational anisotropy studies allowed us to distinguish crystallographic and magnetic field induced contributions to the THG. A strong modification of the THG intensity was observed in applied magnetic fields at particular resonances due to interference of crystallographic and magnetic field induced contributions. A microscopic quantum mechanical model of the THG response was developed and its conclusions are in good agreement with the experimental results.

HL 89.3 Fri 10:45 POT 251

A simulated reflectivity experiment: theoretical optical spectrum of strained-lattice bulk SrTiO3 — •Lorenzo Sponza[1,2], Valérie Véniard[1,2], Adriano Verna[3], and Stefano Nannarone[3,4] — [1]LSI - Ecole Polytechnique, 91128 Palaiseau, France — [2]European Theoretical Spectroscopy Facility (ETSF) — [3]IOM-CNR lab. TASC Area Science Park, Basovizza, Italy — [4]Università di Modena e Reggio Emilia, Italy

Reflectivity and absorption measurements are powerful techniques to investigate microscopic properties of matter as structural configuration. An interpretation of measured data can be given through the macroscopic dielectric constant, even if such an interpretation is complicated.

Here we present a theoretical study carried on the optical properties of bulk SrTiO3 (STO) with two different lattice structures: one is the cubic structure (a=3.905 Angstrom) and one is a strained configuration. We present the computation of the macroscopic dielectric tensor of STO performed in the framework of Time Dependent Density Functional Theory (TDDFT) and Many Body Perturbation Theory (MBPT) in the G0W0 approximation and solving Bethe-Salpeter equation. Comparison with experimental data has been also carried out.

Using a C++ code written ad hoc to compute the reflectivity of anisotropic materials, we will display the difference in signal due to the structural strain and we will link it to the difference between the two theoretical dielectric tensors.

HL 89.4 Fri 11:00 POT 251

Air-Gap Heterostructures — •Jochen Kerbst, Matthias Schmidt, Stephan Schwaiger, Andrea Stemmann, Stefan Mendach, Wolfgang Hansen, and Christian Heyn — Institut für Angewandte Physik, Jungiusstr 11, 20355 Hamburg

We demonstrate the fabrication of a novel type of heterostructure providing epitaxial semiconductor layers which are separated by thin air gaps. The air gaps with thickness ranging from 4 to 8 nm are stabilized by low-density nanopillars. The nanopillars are generated by a combination of self-assembled droplet etching (LDE) [1,2] during molecular beam epitaxy (MBE) and post-growth selective etching. In particular, first a thin AlAs layer is grown on a GaAs substrate. Afterwards, local etching with Ga droplets forms nanoholes deeper than the thickness of the AlAs layer. The nanoholes are filled with GaAs and finally overgrown with a 50 or 100 nm thick GaAs film. After removal of the samples from the MBE system, wet chemical selective etching of only the AlAs layers yields the formation of the air-gab heterostructures. The thickness of the air gaps is precisely controlled by the thickness of the initial AlAs layers. Reflectivity measurements confirm the existence of the air gaps and the gap thickness.

[1] Zh. M. Wang, B. L. Liang, K. A. Sablon, and G. J. Salamo, Appl. Phys. Lett. 90, 113120 (2007).

[2] Ch. Heyn, A. Stemmann, and W. Hansen, Appl. Phys. Lett. 95, 173110 (2009)

HL 89.5 Fri 11:15 POT 251

Refractive Index matching of $BaTiO_3$/$SrTiO_3$ Heterostructures — •Tammo Böntgen, Jan Zippel, Rüdiger Schmidt-Grund, Michael Lorenz, and Marius Grundmann — Universtät Leipzig, Institut für Experimentelle Physik II, Linnéstr. 5

By altering the growth parameters for $BaTiO_3$/$SrTiO_3$ heterostructures we achieved matching of the refractive index for selected wavelengths. Using spectroscopic ellipsometry we have determined the optical properties of these heterostructures and their constituting layers. By systematically varying the growth parameters, the refractive index of the STO layer was tuned such that it crosses the refractive index of BTO. The index matching leads to a vanishing reflectivity at the crossing wavelength. The crossing wavelength varies with the choice of the growth parameters. X-Ray diffraction measurements were carried out on the heterostructures to probe the effect of the growth conditions on the STO lattice parameters. A dependence of the lattice constant on the growth parameters was found, linking the change in the optical properties to the lattice deformation. This kind of index matching can in principal also be achieved for other perovskite $ATiO_3$ hetero- or multilayer structures. This work was supported by Deutsche Forschungsgemeinschaft in the framework of Sonderforschungsbereich 762 "Functionality of Oxidic Interfaces".

HL 89.6 Fri 11:30 POT 251

Effect of localized boron impurities on the line shape of the fundamental band gap transition in photomodulated reflectance spectra of (B,Ga,In)As — •Thomas Sander[1], Jörg Teubert[1], Peter J. Klar[1], Andrew Lindsay[2], and Eoin P. O'Reilly[2,3] — [1]Institute of Experimental Physics I, Justus-Liebig-University Giessen, Germany — [2]Tyndall National Institute, Lee Maltings, Cork, Ireland — [3]Department of Physics, University College Cork, Ireland

Photomodulated reflectance (PR) spectra of (B,Ga,In)As epilayers reveal unusual changes of the fundamental band gap PR line shape with temperature and hydrostatic pressure. We show that these changes arise because temperature variation or hydrostatic pressure shifts the conduction band edge (CBE) into resonance with boron-related cluster states. The resulting line shape changes are described by a level repulsion model which yields states of mixed character with an exchange of oscillator strengths. This model is corroborated by theoretical calculations which show a finite density of boron cluster states above the CBE at room temperature, with appropriate symmetry to couple to the CBE states.

15 min. break

HL 89.7 Fri 12:00 POT 251

Surface acoustic wave induced electron tunneling from an InGaAs/GaAs wetting layer — •Jens Pustiowski[1], Florian J.R. Schülein[1], Dirk Reuter[2], Andreas D. Wieck[2], Max Bichler[3], Kai Müller[3], John J. Finley[3], Achim Wixforth[1], and Hubert J. Krenner[1] — [1]Lehrstuhl für Experimentalphysik I, Universität Augsburg, 86159 Augsburg, Germany — [2]Lehrstuhl für Angewandte Festkörperphysik, 44780 Bochum, Germany — [3]Walter-Schottky-Institut, 85748 Garching, Germany

We report on a stroboscopic technique to probe the dynamic modulation controlled by a surface acoustic wave (SAW) of the photoluminescence (PL) of a wetting layer which is formed during the growth of InGaAs/GaAs quantum dots. A short laser pulse ($\tau < 100$ps) is actively phase locked to the frequency of the SAW and the relative phase between laser excitation and SAW can be precisely controlled [1]. Thus, we are able to map one complete cycle of the SAW and study the PL quenching and its modulation in the time domain. For low SAW powers the observed modulation with the fundamental period of the SAW arises from different mobilities of electrons and holes. This imbalance leads to different ionization efficiencies in the type-II band gap modulation induced by the SAW. At high SAW power levels, the modulation period doubles which can be readily explained by SAW induced tunneling induced by the vertical piezoelectric field component.

[1] S. Völk et al., arxiv:1011.1898 (2010).

HL 89.8 Fri 12:15 POT 251

Optical orientation of Mn^{2+} ions in GaAs — •Lukas Langer[1], Ilya A. Akimov[1,2], Roslan I. Dzhioev[2], Vladimir L. Korenev[2], Yuri G. Kusrayev[2], Victor F. Sapega[2], Dmitri R. Yakovlev[1,2], and Manfred Bayer[1] — [1]Experimentelle Physik 2, Technische Universität Dortmund, 44221 Dortmund, Germany — [2]A.F. Ioffe Physical-Technical Institute, Russian Academy of Sciences, 194021 St. Petersburg, Russia

We report on optical orientation of Mn^{2+} ions in bulk GaAs under application of weak longitudinal magnetic fields ($B \leq 150\,\mathrm{mT}$). The studied samples were grown by liquid phase epitaxy and Czochralski method and were doped with a low Mn acceptor concentration of $8 \times 10^{18}\,\mathrm{cm}^{-3}$. Time resolved measurements of circular polarization for donor-acceptor photoluminescence in Faraday geometry reveal nontrivial spin dynamics of donor localized electrons. Initially the degree of polarization of the electron spins is 40%. It then decays within some tens of ns to reach a plateau. The plateau is absent at $B = 0\,\mathrm{T}$ and saturates at $B = 150\,\mathrm{mT}$ reaching the value of 35%. It's sign changes with the helicity of incident light. It follows that the s-d exchange interaction with optically oriented electrons induces a steady state nonequilibrium polarization of the Mn^{2+} ions. The latter maintain their spin and return part of the polarization back to the electron spin system, resulting in the plateau. This provides a long-lived electron spin memory in GaAs doped with Mn. The dynamical polarization of ionized Mn acceptors was also directly monitored using spin flip Raman scattering spectroscopy, in agreement with time-resolved data.

HL 89.9 Fri 12:30 POT 251

Nanoscale Optical Imaging of Semiconductor Nanowires — •Miriam Böhmler[1], Anton Myalitsin[2], Alf Mews[2], and Achim Hartschuh[1] — [1]Department Chemie & CeNS, Ludwig-Maximilians-Universität München — [2]Department Chemie, Universität Hamburg

Inorganic semiconducting nanowires (NWs) feature size-related optical properties which make them interesting for a wide range of applications, e.g. nanoscale optoelectronics, sensors, and photovoltaics. Their relevant length scales that are determined by nanowire diameter and exciton Bohr radius, however, can not be resolved by conventional diffraction limited methods.

We illustrate the prospects of tip-enhanced near-field optical microscopy (TENOM) [1] as a method to investigate single nanowires. In TENOM a sharp metallic tip acts as optical antenna thereby enhancing the detected signal and increasing the optical resolution to about 15 nm. We present our investigations of CdSe NWs which have been grown by the wet chemical solution liquid solid technique [2]. Here, TENOM provides the possibility to simultaneously image photoluminescence (PL) as well as Raman scattering of individual NWs with nanoscale resolution. We observe spatial variations of the PL intensity and energy on a length scale of about 15 nm indicating crystal phase transitions and diameter fluctuations.

[1] A. Hartschuh, "Tip-enhanced near-field optical microscopy", Angew. Chemie (Int. Edition) 47, 8178 (2008). [2] Z. Li, et.al., "Controlled Synthesis of CdSe Nanowires by Solution-Liquid-Solid Method", Adv. Funct. Mater. 19, 3650-3661 (2009).

HL 89.10 Fri 12:45 POT 251

Excitonic Absorption Spectra with Energetic Disorder — •Dirk Heinze, Jens Förstner, Matthias Reichelt, and Torsten Meier — Department of Physics and CeOPP, University of Paderborn, Warburger Str. 100, 33098 Paderborn

Using a time-domain real-space tight-binding approach[1], we calculate linear absorption spectra for a semiconductor quantum wire model system in the presence of energetic disorder. To model the energetic disorder a Gaussian distribution of random numbers is taken to represent a spatial disorder potential. The influence of the strength and spatial correlation of the energetic disorder is analysed. Extending previous studies, e. g. [2], a smooth spectrum is achieved by self-averaging over a sufficiently large system.

[1]T. Meier, P. Thomas, and S. W. Koch. Coherent Semiconductor Optics - From Basic Concepts to Nanostructure Applications. Springer, 2007

[2]I. Kuznetsova et al., Modeling excitonic line shapes in weakly disordered semiconductor nano-structures.. Phys. Rev. B 81, 075307 (2010)

HL 89.11 Fri 13:00 POT 251

Exciton dynamics in potential traps and the possibility of Bose-Einstein condensation — •Rico Schwartz[1], Nobuko Naka[2,3], Jan Brandt[4], Christian Sandfort[4], and Heinrich Stolz[1] — [1]Institut für Physik, Universität Rostock, D-18051 Rostock, Germany — [2]Department of Physics, Kyoto University, Kyoto 606-8502, Japan — [3]PRESTO, JST, 4-1-8 Honcho Kawaguchi, Saitama 332-0012, Japan — [4]Fakultät Physik, Technische Universität Dortmund, D-44221 Dortmund, Germany

Experiments on excitons in Cu_2O confined in a stress-induced potential trap [1] at subkelvin temperatures are reported. The paraexcitons were created by resonant excitation of orthoexcitons followed by ortho-para conversion. We excited with a pulsed laser (linewidth 1 GHz, repetition rate 1 kHz, pulse length 50 ns). With a gated CCD time dependent spatially resolved luminescence spectra were observed. A fit of the data with a simple rate equation model leads to bimolecular decay rates of the para- and orthoexcitons which are at least 5 orders of magnitude lower than those from literature [2]. Concomitant, we reached exciton numbers in the order of 10^9 in the trap. The effective temperature of the excitons was determined by fitting the high energy flank in the spectra with a Bose distribution. This temperature decreases after the excitation pulse to the bath temperature (0.15 K), which is well below the critical temperature of BEC at these exciton numbers. We also discuss whether the shape of the spectra points to an excitonic BEC.

[1] N. Naka and N. Nagasawa, Phys. Rev. B 65, 075209 (2002)
[2] K. Yoshioka et al., Phys. Rev. B 82, 041201(R) (2010)

HL 89.12 Fri 13:15 POT 251

Zero-magnetic-field spin-splitting and the warping in the valence band of highly p-doped asymmetric AlGaAs/GaAs Quantum Wells — •Michael Hirmer, M. Hirmer, D. Schuh, W. Wegscheider, T. Korn, and C. Schüller — Institut für Experimentelle Physik, Universität Regensburg, 93040 Regensburg

Zero-Magnetic-Field-Spin-Splitting (ZMFSS) in 2D quantum wells (QW) induced by the structure inversion asymmetry, and its control, are of major importance for both fundamental research and spintronic applications. In hole systems, the asymmetry leads to a ZMFSS of the heavy hole (HH) states in third order of the in-plane wave vector $k_{||}$ [1]. In our experiments, we focus on highly p-doped asymmetric AlGaAs/GaAs QW. We utilize electronic intersubband Raman measurements in backscattering geometry. In all samples we observe a low-energy spin-density excitation (SDE) with energies in the range of 0-3 meV. Samples with higher hole density show a two-component SDE. Comparing these excitation energies to 8 band k·p calculations [2] of the valence subbands , the SDE can be interpreted as an intersubband excitation of the spin-split HH ground state, reflecting directly the ZMFSS. The two components can be attributed to different HH dispersions in different crystallographic directions, the so-called warping. We found that the observed spin splitting increases systematically with increasing hole density p, or by an external electric field. Measurements of the Shubnikov de Haas oscillations showed similar results.

[1] R. Winkler, Phys. Rev. B 62, 073309 (2000).

[2] Nextnano^3 by Stefan Birner