HL 82: Ultrafast Phenomena

Time: Thursday 14:30–17:15 Location: POT 251

HL 82.1 Thu 14:30 POT 251

Interaction of intersubband transitions and ponderomotive responce in doped GaAs/AlGaAs multiple quantum wells at the THz regime — •Matthias Baudisch, Martin Wagner, Manfred Helm, and Dominik Stehr — Institute for Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf (HZDR), P.O. Box 510119, 01314 Dresden, Germany.

In the present work we investigate the line shape of the broadband terahertz (THz) response in doped multiple quantum wells by means of field-resolved detection. In an optically excited structure we recently observed a Fano-like shape of the THz response [1]. This results from the superposition of the broad continuous ponderomotive response and the sharp intersubband transition. The first originates from the force that takes effect on carriers in an oscillating electromagnetic field.

The applied spectroscopy technique is time-resolved ultrabroadband THz spectroscopy. The THz radiation is generated by phase-matched optical rectification of 10 fs near-infrared pulses in 50 μm thin GaSe crystals. The pulses are tuneable in a range from 15 to 40 THz with a width (FWHM) of up to 15 THz. The field-resolved detection is done by phase-matched electro optic sampling. The applied detection method is crucial for observing the effect since the ponderomotive current can only be seen as a lossless phaseshift of the transmitted THz radiation while the intersubband transition leads to an absorption. Thus we are able to observe directly the superposition of ponderomotive current and intersubband transition in the time-domain.

[1] D. Golde et al., Phys. Rev. Lett. 102, 127403 (2009).

HL 82.2 Thu 14:45 POT 251

Ultrafast Dynamics of ZnO and ZnO-BaTiO3 thin films — •Snigdhatanu Acharya[1], Sumedha Chouthe[1], Tammo Böntgen[2], Rüdiger Schmidt-Grund[2], Marius Grundmann[2], and Gerhard Seifert[1] — [1]Institute of Physics, Martin-Luther-University, Halle-Wittenberg, Von-Danckelmann Platz 3, D-06120, Halle, Germany. — [2]Institute for Experimental Physics-II, University of Leipzig, Linnestraße 5, D-04103 Leipzig, Germany.

Femtosecond pump-probe spectroscopy was performed at room temperature on ZnO thin film and a double layer thin film structure of BaTiO3/ZnO, to investigate coupling between the layers via the charge carrier dynamics. Frequency-doubled Ti:Sa laser pulses (150fs, 400nm) were used as pump; induced transmission changes were probed by supercontinuum (320-600nm) fs pulses. For ZnO, two photon absorption as well as direct excitation to the trap states close to the conduction band edge leads to transfer of carriers to the conduction band. The displaced carriers relax rapidly to the bottom of conduction band, and bleaching at 375nm attributed to population of discrete exciton A is observed. Further increase in the density at exciton levels lead to a stimulated emission at ~390 nm due to exciton-exciton scattering. Changes in refractive index induced by pump-pulse generates interferometric transmission changes between 400-600 nm. Similar contributions to the transient spectra are observed in BaTiO3/ZnO. BaTiO3 does not show any femtosecond response. Difference in the dynamical behaviour of the contributions in ZnO and BaTiO3/ZnO gives an indication of coupling between ZnO and BaTiO3.

HL 82.3 Thu 15:00 POT 251

Time-resolved photoluminescence from GaAs/AlGaAs multiquantum wells quenched by pulsed mid-infrared radiation — •Sabine Zybell, Harald Schneider, Stephan Winnerl, and Manfred Helm — Helmholtz-Zentrum Dresden-Rossendorf, Germany

Several groups have demonstrated the suppression of photoluminescence (PL) from semiconductor quantum wells (QWs) by intense mid-infrared radiation (MIR). Since most of the previous studies are done on time-integrated PL the ultrafast changes in the radiative state population are not well understood. We present a detailed study on time-resolved PL from an undoped GaAs/AlGaAs QW sample quenched by MIR pulses from a free-electron laser, which was tuned to the intersubband transition (ISBT) energy. At the arrival time of the MIR pulse a clear sharp dip appears in the PL transient. Free carrier absorption and ISBT are the two processes that take place under MIR excitation and result in an abrupt drop of the radiative state population and consequently in an ultrafast quenching of the PL. Performing polarization sensitive measurements, we were able to discriminate the contributions of free carrier absorption from that of ISBT. A quantitative analysis of the PL dip depth and recovery time as a function of MIR fluence was done using a model based on rate equations.

HL 82.4 Thu 15:15 POT 251

Coherent Lattice Vibrations in TiO_2 — •Elisabeth Bothschafter[1,2], Alexander Paarmann[3], Nicholas Karpowicz[2], Reinhard Kienberger[1,2], Ralph Ernstorfer[1,2,3], and Ferenc Krausz[2,4] — [1]Fakultät für Physik, TUM, Garching — [2]Max-Planck-Institut für Quantenoptik, Garching — [3]Fritz-Haber-Institut der MPG , Berlin — [4]Department für Physik, LMU, Garching

Ultrafast time-resolved reflectivity measurements with femtosecond pulses allow investigations of the fast interplay between electronic and structural dynamics triggered by nonequilibrium electron distributions (e.g. [1]).

Here we study the ultrafast optical reflectivity changes of the rutile TiO_2(110) surface with sub-5-fs ultraviolet pump and probe pulses centered at 5 eV. At the overlap of pump and probe the reflected intensity drops by 3.5% and is subsequently modulated at the frequency of the A_{1g} phonon at 18.1 THz [2]. The above bandgap excitation represents an effective charge transfer within the unit cell as the valence band density of states (DOS) is dominated by O_{2p} states whereas the conduction band has mainly Ti_{3d} character [3]. We assume that the abrupt change in the potential energy surface upon excitation induces the observed coherent lattice oscillation.

[1] M. Hase, M. Kitajima, A. M. Constantinescu, H. Petek, Nature 426(6), 51 (2003). [2] C. Lee et al., Phys. Rev. B 50, 13379 (1994). [3] H. Wang, J.P. Lewis, J. Phys., Condens. Matter 18, 421-434 (2006).

HL 82.5 Thu 15:30 POT 251

Modulation of photoluminescence kinetics of InGaAs quantum dots embedded into a microcavity using picosecond acoustics — •C. Brüggemann[1], T. Berstermann[1], A.V. Scherbakov[2], M. Bombeck[1], S. Höfling[3], C. Schneider[3], A. Forchel[3], A.V. Akimov[2], D.R. Yakovlev[1,2], and M. Bayer[1] — [1]Experimentelle Physik 2a, Technische Universität Dortmund, 44227 Dortmund, Germany — [2]A.F. Ioffe Physical Technical Institute, Russian Institute of Sciences, 194021 St. Petersburg, Russia — [3]Lehrstuhl für Technische Physik, Universität Würzburg, 97074 Würzburg, Germany

We use picosecond acoustics to modulate the photoluminescence (PL) kinetics of quantum dots (QDs) embedded into a microcavity (MC).

The distributed bragg reflector MC with a layer of $In_{0.3}Ga_{0.7}As$ QDs at the center is grown on a GaAs(100) substrate. An Al-film has been evaporated on the backside. It is used to excite and inject a picosecond strain-pulse into the substrate, by illumination of the film with an intense femtosecond laser pulse. The strain pulse propagates through the substrate and reaches the cavity structure at a specific time after the PL excitation, which can be variably delayed. While the strain-pulse propagates through the MC the PL kinetics are perturbated, which is monitored by a streak camera in the time- and spectral domain.

We observe a strong modulation of the PL intensity under pulsed and steady state PL excitation conditions, due to the strain-pulse perturbation. In the latter case we are able to decrease the PL intensity by a factor of 20 and later increase it up to a factor of 6 for ~100 ps.

15 min. break

HL 82.6 Thu 16:00 POT 251

Extreme Nonlinear Optics in Semiconductors with Shaped Laser Pulses — •Matthias Reichelt[1], Andrea Walther[2], and Torsten Meier[1] — [1]Department of Physics and CeOPP, University of Paderborn, Warburger Str. 100, D-33098 Paderborn, Germany — [2]Institut für Mathematik, Universität Paderborn, Warburger Str. 100, D-33098 Paderborn, Germany

If a two-level system is excited with an intense light field of several times the Rabi frequency, the well-known Mollow triplets appear in the emitted radiation spectrum. [1] We show that the pattern of the emission spectrum can be changed by using appropriately shaped [2] laser pulses. The effect is also observable for a more realistic description of a semiconductor system [3].

[1] B.R. Mollow, Phys. Rev. **188**, 1969 (1969).
[2] M. Reichelt and T. Meier, Opt. Lett. **34**, 2900 (2009).
[3] D. Golde, T. Meier, and S.W. Koch, Phys. Rev. B **77** (2008).

HL 82.7 Thu 16:15 POT 251

Coulomb-induced relaxation dynamics in single-walled carbon nanotubes — •Eike Verdenhalven, Andreas Knorr, and Ermin Malić — Institut für Theoretische Physik, Technische Universität Berlin, Germany

We investigate the ultrafast Coulomb-induced relaxation dynamics of optically excited charge carriers in arbitrary single-walled carbon nanotubes. Using a density-matrix formalism we derive a corresponding Boltzmann equation in Born-Markov approximation. The bandstructure is obtained using the zone-folded tight-binding wave functions of graphene. Complying with the low dimensionality of nanotubes the Coulomb interaction is treated by a parametric interaction potential. Our approach allows to track (time- and momentum resolved) the relaxation paths of non-equilibrium electrons in metallic and semiconducting nanotubes of arbitrary chirality.

HL 82.8 Thu 16:30 POT 251

Microscopical calculation of non-linear polarization spectra of light-harvesting complexes — •Mario Schoth[1], Marten Richter[1], Thomas Renger[2], and Andreas Knorr[1] — [1]Institut für Theoretische Physik, Nichtlineare Optik und Quantenelektronik, Technische Universität Berlin, Germany — [2]Institut für Theoretische Physik, Theoretische Biophysik, Johannes Kepler Universität Linz, Austria

Ultrafast spectroscopic techniques, such as nonlinear polarization spectroscopy [1], are used to investigate photosynthetic systems of higher plants. Performed in the frequency domain, non-linear polarization spectroscopy (NLPF) permits simultaneous measurements of dephasing and energy relaxation rates down to tens of femtoseconds. Within a Bloch equation approach [2], we calculate NLPF spectra of light-harvesting complexes such as the water-soluble chlorophyll binding protein complex (WSCP) microscopically. Hereby, we include self-consistently structural data for the excitonic couplings of pigments and the spectral density of exciton-vibrational coupling [3]. Furthermore we show that NLPF is suited to compensate effects of inhomogeneous broadening.

[1] W. Beenken, V. May, J. Opt. Soc. Am. B. 14, **11**, 2804 – 2810 (1997)
[2] M. Richter, T. Renger, G. Renger, A. Knorr, J. Chem. Phys. **127**, 075105 (2007)
[3] T. Renger et al., J. Phys. Chem. B, **111**, 10487 – 10501 (2007)

HL 82.9 Thu 16:45 POT 251

First principles of phonon squeezing in silicon — •Tobias Zier, Eeuwe S. Zijlstra, and Martin E. Garcia — Theoretische Physik, Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany

When silicon is excited by an intense ultrashort laser pulse, an extreme nonequilibrium state is induced, which consists of hot electrons (several 1000 K) and cold ions (near room temperature). The excited carriers change the potential energy surface seen by the ions, leading to a softening of the phonon modes and phonon squeezing. On the basis of density functional theory we perform a study of these effects, treating the phonons both quantum mechanically and classically, including anharmonic effects in the latter case by means of large-scale molecular dynamics simulations. Our results indicate that the initial ionic temperature before the laser excitation should not exceed approximately 77 K in order to observe quantum effects. At higher temperatures the anharmonicities amplify the classical phonon squeezing and cannot be ignored.

HL 82.10 Thu 17:00 POT 251

Intensity dependence of optically induced electron charge currents in quantum wells — •michał pochwała, huynh thanh duc, jens förstner, and torsten meier — Department of Physics and CeOPP, University of Paderborn, Warburger Str. 100, D-33098 Paderborn, Germany

We numerically investigate the intensity dependence of electron charge currents generated by perpendicular circularly polarized femtosecond laser pulse in (110)-grown semiconductor quantum wells GaAs/AlxGa1-xAs. Our analysis is based on a 14 band kp model [1] in combination with multisubband semiconductor Bloch equations [2-4]. The analysis shows that the generated electron charge currents depend on the intensity of the incident laser pulse in a highly nonlinear fashion. Oscillatory behavior of the electron charge current transients is predicted and explained.

[1] R. Winkler, Spin-Orbit Coupling Effects in Two Dimensional Electron and Hole Systems (Springer, Berlin, 2003).
[2] B. Pasenow, H. T. Duc, T. Meier, and S. W. Koch, Solid State Commun. 145, 61 (2008).
[3] H. T. Duc, J. Förstner, and T. Meier, Phys. Rev. B. 82, 115316 (2010).
[4] S. Priyadarshi, A. M. Racu, K. Pierz, U. Siegner, M. Bieler, H. T. Duc, J. Förstner, and T. Meier, Phys. Rev. Lett. 104, 217401 (2010).