HL 53: Ultra fast phenomena

Time: Friday 11:00–13:45 Location: H15

HL 53.1 Fri 11:00 H15

Aspects of heavy-hole light-hole band mixing effects on the coherent optical generation of charge and spin currents in semiconductor heterostructures — •Bernhard Pasenow[1], Huynh Thanh Duc[1,2], Torsten Meier[1], and Stephan W. Koch[1] — [1]Department of Physics and Material Sciences Center, Philipps University, Renthof 5, D-35032 Marburg — [2]Ho Chi Minh City Institute of Physics, Viet Nam Center for Natural Science and Technology, 1 Mac Dinh Chi, Ho Chi Minh City, Vietnam

The coherent optical injection and temporal decay of spin and charge currents in semiconductor heterostructures has be described on a microscopic basis including Coulomb and phononic effects up to the level of second-order Born contributions [1,2]. In this talk the previously used two-band effective mass approach is extended to a multi-band approach using realistic microscopic kp matrix elements. Furthermore, the influence of heavy-hole light-hole band-mixing contained in the kp calculation and its effects on the microscopic semiconductor dynamics is demonstrated and discussed [3].

[1] H.T. Duc, T. Meier, and S.W. Koch, Phys. Rev. Lett. 95, 086606 (2005).
[2] H.T. Duc, Q.T. Vu, T. Meier, H. Haug, and S.W. Koch, Phys. Rev. B 74, 165328 (2006)
[3] B. Pasenow, T. Meier, and S.W. Koch, unpublished

HL 53.2 Fri 11:15 H15

Investigation of Coulomb induced coupling in semiconductor nanostructures using 2D Fourier-Transform-Spectroscopy — •Irina Kuznetsova[1], Peter Thomas[1], Torsten Meier[1], Tianhao Zhang[2], and Steven T. Cundiff[2] — [1]Fachbereich Physik, Philipps Universiät Marburg, Renthof 5, 35032 Marburg, Germany — [2]JILA, University of Colorado and National Institute of Standards and Technology, Boulder, CO 80309-0440, USA

Two-Dimensional Fourier-Transform-Spectroscopy (2DFTS) has been used for the experimental investigation of many-body interactions in semiconductor quantum wells [1]. Our theoretical description used for the interpretation of the experimental data is based on a one-dimensional tight-binding model. By comparing Hartree-Fock results with $\chi^{(3)}$ coherent many-body calculations we can identify signatures, which are related to various Coulomb effects. We found that due to Coulomb correlations 2DFTS is strongly dependent on polarization directions of excitation pulses [2]. Dipole matrix elements, dephasing times, delay times, polarization directions of the pulses, and their spectral characteristics strongly influence the signatures at the excitonic resonances, i.e., heavy hole, light hole and mixed ones. This demonstrates that this method provides a wide spectrum of information about Coulomb induced couplings in various systems.

[1] X. Li, T. Zhang, C. N. Borca, and S. T. Cundiff, Phys. Rev. Lett. 96, 057406 (2006).
[2] I. Kuznetsova, P. Thomas, T. Meier, T. Zhang, X. Li, R. P. Mirin, and S. T. Cundiff, submitted to Solid State Comm.

HL 53.3 Fri 11:30 H15

Nonequilibrium Green's functions approach to artificial atoms: Equilibrium properties — •Karsten Balzer[1], Michael Bonitz[1], Nils-Erik Dahlen[2], and Robert van Leuween[2] — [1]ITAP, Universität Kiel, Leibnizstr. 15, 24098 Kiel, Germany — [2]Theoretical Chemistry, Materials Science Center, Rijksuniversiteit Groningen, Nijenborgh 4, 9747 AG Groningen, The Netherlands

Quantum confined particles, such as electrons and excitons in semiconductor nanostructures [1], valence electrons in metal clusters or trapped ultra-cold atomic and molecular gases, can be seen as artificial atoms. In order to self-consistently treat confinement and correlation effects we have developed a nonequilibrium Green's functions (NEGF) approach which can be efficiently applied to these systems.

We present results for the correlated equilibrium state for the example of N charged fermions in an oscillator potential which serve as initial data for studying the response to external fields [see poster: K. Balzer et al.]. Extending previous applications for quasi-homogeneous systems [2], we here start in thermal equilibrium at finite densities, solving the Dyson equation on the imaginary branch of the Keldysh-contour. We demonstrate the advantages of using an appropriate basis representation of the NEGF. Throughout, correlation effects are taken into account in full diagrammatically second order, including exchange.

[1] P. Ludwig, A. Filinov, M. Bonitz, and H. Stolz, phys. stat. sol. (b) 243, No. 10 (2006). [2] Introduction to Computational Methods in Many-Body Physics, M. Bonitz and D. Semkat (Eds.) Rinton Press (2006).

HL 53.4 Fri 11:45 H15

Theoretical description of the lattice dynamics in laser-excited InSb — •Jessica Walkenhorst, Christian Gilfert, Christian Sippel, Waldemar Töws, Eeuwe Sieds Zijlstra, and Martin Garcia — Theoretische Physik, Fachbereich Naturwissenschaften, Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany

We performed an *ab initio* study of the softening of optical transverse and longitudinal phonons in InSb due to femtosecond laser excitation. We calculated the frequencies of the optical phonons at the Γ point and at the zone boundary as a function of the number of excited carriers. Our study was based on all-electron density functional calculations. We found an increasing softening of the phonon modes for increasing laser fluence. However, the drop of the studied phonon frequencies did not exceed 30% of the initial value, even for very high excitation energies (electronic temperatures). We concluded that no dramatic flattening of the potential surface occurs, as was suggested by recent experiments.

HL 53.5 Fri 12:00 H15

Ultrafast hole-spin dynamics in bulk GaAs — •Michael Krauss and Hans Christian Schneider — Physics Department, Kaiserslautern University, P. O. Box 3049, 67663 Kaiserslautern, Germany

This talk presents theoretical results on hole-spin dynamics in bulk GaAs after optical excitation. The coupled dynamics of spin and orbital angular momentum is determined by solving dynamical Boltzmann equations for carrier-carrier scattering, which include the effect of spin-orbit coupling on the level of a 4-band Luttinger Hamiltonian. Hole-spin relaxation takes place in two stages. In the first regime, on a timescale of a few hundred femtoseconds, pure momentum scattering dominates the dynamics and the anisotropic contributions to the orbital angular momentum, which are created by the optical excitation, are evened out. In the second regime, on a timescale of a few picoseconds, energy relaxation dominates. The hole-spin dynamics can be approximated by a different relaxation time for each of the two regimes. The fast spin relaxation-time in the first regime is in agreement with experimental results for heavy-hole spin relaxation.

HL 53.6 Fri 12:15 H15

Terahertz radiation from a large-area photoconductive device — •Falk Peter, Sven Nitsche, Stephan Winnerl, André Dreyhaupt, Harald Schneider, and Manfred Helm — Institute of Ion-Beam Physics and Materials Research, Forschungszentrum Dresden-Rossendorf, 01314 Dresden, Germany

We present studies of the radiation properties of a photoconductive terahertz (THz) structure [1]. It consists of an interdigitated electrode structure fabricated on GaAs. Illuminating this structure by a femtosecond laser pulses yields accelerated photocarriers, which are the source of THz radiation. For avoiding destructive interference of radiation generated in regions of opposite field direction a second metallization isolated from the first one covers every second electrode spacing. Intense THz radiation with fields of the order of 1 kV/cm is observed.

We use a photoconductive detection antenna for measuring the spatial profile. The detection antenna is placed in a distance of 13 mm from the emitter. The beam profile is resolved for spectral components in the range from 0.5 to 1.5 THz. All beam profiles have Gaussian shape. The divergence increases with decreasing frequency. For wavelengths significantly smaller than the excitation spot size, the results can be well described by Gaussian optics. However, at longer wavelength, where the paraxial approximation fails, diffraction has to be considered in a more general way.

[1] A. Dreyhaupt, S.Winnerl, M.Helm, T. Dekorsy, Opt. Lett. 31, 1546 (2006)

HL 53.7 Fri 12:30 H15

Ultrafast electron relaxation-dynamics in p-doped GaAs —

•Yao-Hui Zhu, Hans Christian Schneider, and Martin Aeschlimann — Fachbereich Physik, TU Kaiserslautern, 67663 Kaiserslautern

Ultrafast electron dynamics in p-doped GaAs is studied by energy- and time-resolved two-photon-photoemission (2PPE). Using this surface sensitive technique allows one to study the carrier dynamics over a wide energy range in the band-bending region at (001) surfaces. Electron relaxation-dynamics is monitored by measuring the energy distribution of photoemitted electrons after an initial nonequilibrium electron distribution has been created by the ultrashort pump laser up to 2 eV above the conduction band minimum. To separate the contributions of the degenerate pump and probe beams to the photoemitted electrons, an electron spin-analyzer and different light polarizations and are used.

The dependence of the observed electron dynamics on the excitation energy is explained well by Boltzmann equation calculations that take into account the carrier-carrier Coulomb interaction. It is found that electron relaxation by scattering of heavy holes into the light-hole band is dominant for the electron relaxation process. Moreover, dynamic screening is crucial for the relaxation of the highly excited electrons at a doping density of $1 \times 10^{19}\,\mathrm{cm}^{-3}$.

HL 53.8 Fri 12:45 H15

Ultrafast dynamics of coherent opticalphonons in α-quartz — •Konrad von Volkmann, Tobias Kampfrath, Lucca Perfetti, Jan Nötzold, Christian Frischkorn, and Martin Wolf — Freie Universität Berlin, Berlin, Germany

Femtosecond laser excitation of coherent phonons gives rise to an oscillatory modulation of the real and imaginary part of the refractive index of α-quartz $\tilde{n}_{quartz} = n + i\,k$. Optical phonon modes are found at 3.9, 6.3, 10.5, 12.2, and 13.9 THz. The observed amplitudes significantly depend on the probe method, either transient absorption (yielding k) or ellipsometry (leading to n).

For both probe mechanisms, we present polarization, pump-wavelength and temperature dependent data and discuss the observed dynamics in terms of impulsive stimulated Raman scattering as excitation mechanism. We find that the phonon peaks shift with temperature towards lower energies accompanied by a drop of the lifetime of the phonons. Together with a pump-fluence independent lifetime, this indicates that the decay mechanism of the phonons is phonon-phonon scattering, rather than electron-hole pair excitation.

HL 53.9 Fri 13:00 H15

Dynamik kohärenter akustischer Phononen in Halbleiterheterostrukturen — •Florian Hudert[1], Thomas Dekorsy[1] und Klaus Köhler[2] — [1]Fachbereich Physik, Universtät Konstanz, 78457 Konstanz — [2]Fraunhofer-Institut für Angewandte Festkörperphysik, 79108 Freiburg

In diesem Beitrag werden wir Untersuchungen zur Dynamik kohärenter akustischer Phononen in Halbleiterheterostrukturen vorstellen. Zu den untersuchten Strukturen gehören AlGaAs/GaAs-Heterostrukturen sowie AlAs/GaAs-Übergitter, die unter anderem auch für die Realisierung von Phononcavities [1] herangezogen werden könnten. Die Dynamik der Phononen wurde dabei mittels Zwei-Farben-Pump-Probe-Spektroskopie in Reflexionsanordnung untersucht, wobei das bereits eingeführte ASOPS (asynchronous optical sampling)-Verfahren angewendet wurde, bei dem zwei asynchron gekoppelte Ti-Saphir Oszillatoren zur Erzeugung von Anrege- und Abfragepuls verwendet werden [2]. Dies ermöglicht Messungen im Bereich zwischen 750 nm und 850 nm mit einer Auflösung von ca. 100 fs über ein Zeitfenster von 1 ns. Es konnten unter Anderem erste Anzeichen für die Entstehung von Cavitymoden beobachtet werden. Diese Experimente liefern wichtige Grundlagen für weitergehende Arbeiten zur Realisierung optisch gepumpter Phononcavities.

[1] A. Huynh, N. D. Lanzillotti-Kimura, B. Jusserand, B. Perrin, A. Fainstein, M. F. Pascual-Winter, E. Peronne, and A. Lemaître, Phys. Rev. Lett. 97, 115502 (2006) [2] A. Bartels, F. Hudert, C. Janke, T. Dekorsy and K. Köhler, Appl. Phys. Lett. 88, 041117 (2006)

HL 53.10 Fri 13:15 H15

Ultraschnelle Ladungsträgerdynamik in GaAsN — •Gregor Klatt[1], Florian Hudert[1], Thomas Dekorsy[1] und Klaus Köhler[2] — [1]Fachbereich Physik, Universität Konstanz, 78457 Konstanz — [2]Fraunhofer-Institut für Angewandte Festkörperphysik, 79108 Freiburg

Es werden Untersuchungen zur Ladungsträgerdynamik optisch angeregter Ladungsträger in stickstoffhaltigem GaAs anhand zeitaufgelöster Transmissionsmessungen vorgestellt. Ein Zwei-Farben Pump-Probe Aufbau mit einer zeitlichen Auflösung von etwa 100 fs ermöglicht dabei das Anregen und Abfragen bei unterschiedlichen Energien. Das Probelicht wird dazu in einer photonischen Kristallfaser spektral verbreitert, so dass anschließend ein Energiebereich von 1,2-1,45 eV zur Verfügung steht. Damit ist es möglich, die Transmissionsänderungen im Bereich der Bandlücke einer Probe mit 1,4% N-Gehalt (E_g = 1,258 eV) zu untersuchen. Für Zustände weit entfernt vom Bandminimum wird die Ladungsträgerdynamik durch die Emission von LO-Phononen dominiert, nahe des Bandminimums zeigt sich hingegen eine stark verzögerte Dynamik. Diese verzögerte Dynamik basiert auf der Relaxation in lokale Potentialmimima, die auch in der cw-Photolumineszenz bei tiefen Temperaturen beobachtet werden.

HL 53.11 Fri 13:30 H15

All-optical generation and coherent control of ballistic electrical currents in silicon — •Louis Costa[1,2], Markus Betz[1,2], Marko Spasenovic[1], Alan Bristow[1], and Henry van Driel[1] — [1]Physics Department and Institute for Optical Sciences, University of Toronto, M5S 1A7 Toronto, Canada — [2]Physik-Department, Technische Universität München, 85748 Garching

We report all-optical injection of ballistic currents in unbiased clean silicon at room temperature by using quantum interference between phonon-assisted one- and two-photon absorption pathways. The pump field consists of harmonically related fundamental pulses in the near-infrared ($\lambda = \frac{2\pi c}{\omega} = 1420 \rightarrow 1800$ nm, pulse duration 150 fs) and corresponding second harmonic pulses. As a consequence, we induce indirect optical transitions in silicon, which satisfy $\hbar\omega < E_{\mathrm{G,indirect}} = 1.12\ \mathrm{eV} < 2\hbar\omega < E_{\mathrm{G,direct}} = 3.5\ \mathrm{eV}$. The generated ultrafast currents emit terahertz radiation which is detected via electro-optic sampling in the far-field. Both the direction and the amplitude of the currents can be coherently controlled by changing the phase parameter $\Delta\phi = 2\phi_\omega - \phi_{2\omega}$ ($\phi_{\omega,2\omega}$ are the phases of the individual pump fields). The mechanism is a third-order nonlinear optical process which already served for the generation of ballistic currents in direct semiconductors like GaAs accomplished in previous theoretical and experimental work. With our experiments we show that this scheme can also surprinsingly be used to generate currents in silicon although phonon participation is present in the optical creation process of the carriers in the indirect semiconductor.