HL 49: Ultrafast Phenomena

Time: Wednesday 9:30–11:45 Location: EW 202

HL 49.1 Wed 9:30 EW 202

Intra-excitonic extreme nonlinear optics — •Martin Teich[1], Martin Wagner[1], Dominik Stehr[1], Harald Schneider[1], Manfred Helm[1], Sangam Chatterjee[2], Hyatt Gibbs[3], and Galina Khitrova[3] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstr. 400, 01328 Dresden — [2]Faculty of Physics and Material Sciences Center, Philipps University, Renthof 5, 35032 Marburg — [3]University of Arizona, 1630 East University Boulevard, Tucson, Arizona 85721 USA

A fundamental problem in light-matter interaction is the coupling of an intense, monochromatic electromagnetic wave with a quantum mechanical two-level system. One effect related to this is the Autler-Townes or AC Stark effect. Originally observed and described in molecular spectroscopy the effect refers to a splitting of an energy level that is resonantly coupled via intense radiation to an adjacent level, i.e. the states get "dressed" by the light-matter interaction. We investigate this effect using a free-electron laser (FEL) driven intra-excitonic transition between the 1s and 2p states in a semiconductor multiple quantum well [1]. We have observed distinct intensity- and wavelength-dependent Rabi sidebands of the heavy-hole hh(1s) exciton line when the FEL was tuned around the 1s-2p transition. We also present measurements at higher electric fields exploring the regime beyond the rotating-wave approximation.

[1] M. Wagner, H. Schneider, D. Stehr, S. Winnerl, A. M. Andrews, S. Schartner, G. Strasser, and M. Helm, Phys. Rev. Lett. 105, 167401 (2010).

HL 49.2 Wed 9:45 EW 202

Two dimensional photon echo spectroscopy applied to quantum well intersubband dynamics — •Thi Uyen-Khanh Dang, Carsten Weber, Sebastian Eiser, Andreas Knorr, and Marten Richter — Institut für Theoretische Physik, Technische Universität Berlin, Deutschland

A thorough understanding of correlation effects and many-body interactions is an important issue for the investigations of intersubband dynamics in semiconductor quantum wells. The two dimensional photon echo spectroscopy is capable of tracking relaxation processes inside the material since it gives a mapping of excitation and response frequency [1]. Here, we calculate the two-dimensional photon echo signal, applied on the dynamics of a single n-doped GaAs/AlGaAs quantum well. Our model calculations are carried out within a density matrix approach using correlation expansion until second order Born including a non-Markovian treatment of electron-phonon interaction [2]. Our results reveal the temporal dynamics of the system for the regime of low carrier densities.

[1] Abramavicius et al., Chem. Rev. 109, (2009)
[2] S. Butscher et al., Phys. Rev. B. 72, (2005)

HL 49.3 Wed 10:00 EW 202

THz control of matter states: Coherent excitons beyond the Rabi-splitting — •Benjamin Ewers[1], Niko S. Köster[1], Ronja Woscholski[1], Martin Koch[1], Sangam Chatterjee[1], Galina Khitrova[2], Hyatt M. Gibbs[2], Andrea C. Klettke[3], Mackillo Kira[3], and Stephan W. Koch[3] — [1]Faculty of Physics and Materials Sciences Center, Philipps-Universität Marburg, Renthof 5, D-35032 Marburg, Germany — [2]College of Optical Sciences, The University of Arizona, 1630 E. University Blvd., Tucson, Az, 85719-0094, USA — [3]Faculty of Physics and Materials Sciences Center, Philipps-Universität Marburg, Mainzer Gasse 33, D-35032 Marburg, Germany

Strong external electromagnetic fields can be used to induce highly nonlinear modifications of the electronic matter states. We show experimentally and theoretically how optically induced excitonic polarization in semiconductors is modified and controlled by intense, single-cycle terahertz (THz) pulses. A resonant low-intensity excitation of GaAs-type direct-gap semiconductors induces coherent excitons with s-like orbital symmetry. The additional application of an electromagnetic field in the range of THz frequencies allows for a direct coupling of the coherent excitons to polarization states with p-type symmetry. By monitoring the low-intensity optical pulse we find a pronounced bleaching of the 1s-exciton resonance, a THz-induced Rabi-splitting, and a pronounced modulation on the high-energy side of the 1s-exciton resonance. All these features are fully explained by our quantum-mechanical many-body theory.

HL 49.4 Wed 10:15 EW 202

Localization of light-modes in disordered ZnO nanoneedle-arrays — •David Leipold and Erich Runge — Technische Universität Ilmenau, 98693 Ilmenau, Germany

Whereas Anderson localization of electrons and excitons in solids is well established for about half a century, the localization of light is notoriously hard to observe in experiments due to weak variations of the dielectric properties and/or the presence of absorption.

We present calculations of localized light-modes in dense random arrays of vertically aligned ZnO nanoneedles. This material provides strong scattering accompanied by low absorption and enables experiments to map the localized wavefunction. We present results of full 3D solutions of Maxwell's equations for our model system. We observe light modes whose intensity is concentrated in small spatial areas and, correspondingly, non-Gaussian intensity histograms. Positive correlation between long lifetimes and the degree of localization is observed. The correlation is strongest for the most localized modes.

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HL 49.5 Wed 10:30 EW 202

Control of transverse polariton patterns in semiconductor microcavities — •Przemyslaw Lewandowski, Andreas Lücke, and Stefan Schumacher — Physics Department and Center for Optoelectronics and Photonics Paderborn (CeOPP), Universität Paderborn, Paderborn, Germany

Transverse optical patterns are suitable for realising very efficient all-optical switches in atomic vapour systems [1], e.g. Rubidium. Here, we theoretically analyse to which extent the underlying concept of wave-mixing induced coherent transverse patterns and their control can be transferred to a semiconductor-based system. We study quantum-well based planar semiconductor microcavities as promising candidates.

Our theoretical investigation of the coherently-driven nonlinear polariton dynamics is based on a direct time-domain solution of the Maxwell and semiconductor Bloch-equations in the coherent limit and mean-field approximation for the excitonic component (resembling an extended two-component Gross-Pitaevskii-type equation). We (i) analyse in detail the stability and bistability of the spatially homogenous stationary solutions of these nonlinear equations and (ii) present fully two-dimensional numerical calculations showing transverse pattern formation in spatially anisotropic systems. We also demonstrate the all-optical control of these patterns in analogy to what was achieved in atomic vapour systems before [1].

[1] A.M.C. Dawes, D.J. Gauthier, S. Schumacher, N.H. Kwong, R. Binder, and A.L. Smirl, Transverse optical patterns for ultra-low-light-level all-optical switching, Laser & Photonics Reviews 4, 221 (2010).

HL 49.6 Wed 10:45 EW 202

Femtosecond thermomodulation in Cu — •Johanna Flock[1], Markus Beyer[1], Manuel Obergfell[1], Christian Monachon[2], Thomas Dekorsy[1], and Jure Demsar[1,2,3] — [1]Dept. of Physics and CAP, Univ. of Konstanz, D-78457 — [2]Laboratory for Mechanical Metallurgy, EPFL CH-1015 — [3]Complex Matter Dept., Jozef Stefan Institute, SI-1000

Since discrepancies between the two temperature model[1] in the thermomodulation (TM) scenario[2] and experimental data exist[3], we have performed systematic measurements of the time-evolution of the dielectric function in Cu thin films over broad spectral range (1.5-2.5eV) as a function of photoexcitation energy (1.55eV and 3.1eV) and density. Here excitation with 1.55eV results in intraband transitions within the sp-band while in the case of 3.1eV interband processes from the narrow d-band 2eV below the Fermi level to the sp-band dominate. For both excitation energies the spectral changes are consistent with the fs-TM scenario. Only for the case of the intraband excitation the predicted excitation density dependence of the e-ph thermalization rate[1] is observed. For 3.1eV excitation energy the relaxation dynamics is excitation density independent. These results imply that the relaxation strongly depend

on the initial electron distribution function, and point out that numerous recent studies on high-Tc superconductors[4] need to be revisited. [1]Kaganov, Sov.Phys.JETP4,(1957); Allen, PRL59,(1987). [2]Brorson, PRL64,(1990). [3]Kabanov, PRB78,(2008); Gadermaier, PRL105,(2010). [4]Brorson, Sol.Stat.Comm.74,(1990); Perfetti, PRL99,(2007);Mansart, PRB82,(2010).

HL 49.7 Wed 11:00 EW 202

Time-resolved vibrational dynamics in a single Si_3N_4 Nanostructure — •Oliver Ristow, Martin Grossmann, Mike Hettich, Elaine Barretto, Martin Schubert, Axel Bruchhausen, Elke Scheer, and Thomas Dekorsy — Departement of Physics and Center of Applied Photonics, University of Constance, D-78457 Konstanz, Germany

In this work we present time domain all-optical investigations of single Si_3N_4 nanostructures using high-speed asynchronous optical sampling (ASOPS). In order to achieve a high spatial resolution a microscope objective is used with the ASOPS system, which allows for resolving and addressing single nanostructures as well as to scan over large sample areas. We demonstrate the capabilities to investigate two dimensional confined nanostructures, such as nanomechanical systems (NEMS). As one example we show the results of pump-probe experiments analyzing the time-resolved vibrational properties of the nanomechanical resonators' beam based on Si_3N_4 and gold. The typical dimensions of such a nanostructure are 100 nm by 100 nm in cross section and 2-3 micron in length. These systems constitute an ideal model system for the investigation of phonon dissipation in NEMS. With this all optical method especially the high frequency range (GHz) is accessible. Due to the high spatial resolution of our system we are able to accurately address different parts of the structures and investigate in the spatial distribution of the different vibrational modes. By combining the measurements with finite element simulations we obtain a good insight on the acoustical dynamics of these structures.

HL 49.8 Wed 11:15 EW 202

Squeezed thermal phonons precurse nonthermal melting of silicon — •Tobias Zier, Eeuwe S. Zijlstra, and Martin E. Garcia — Theoretical Physics, University of Kassel, Germany

Femtosecond laser pulses can be used to practically instantaneously manipulate bonds in solids through the creation of a hot electron plasma. At sufficiently high fluences, some phonon modes may even become unstable, causing acceleration of the atoms, followed by a disordering within several 100's of femtoseconds. This ultrafast solid-to-liquid phase transition is called nonthermal melting and has been observed in silicon, germanium, gallium arsenide, indium antimonide, and bismuth. It is, however, not known which physical process leads up to nonthermal melting at fluences below the melting threshold. Here we show for silicon that in this regime the room temperature phonons become thermally squeezed. We found that the origin of this effect is the sudden femtosecond-laser induced softening of interatomic bonds, which can also be described in terms of a modification of the potential energy surface. We further found in ab initio molecular dynamics simulations on laser-excited potential energy surfaces that the atoms move in the same directions during the first stages of nonthermal melting at high fluences and thermal phonon squeezing at lesser fluences. Our results demonstrate that thermal phonon squeezing is the precursor to nonthermal melting in silicon. Based on the general nature of the underlying bond softening mechanism we believe that this relation between thermal squeezing and nonthermal melting is not material specific, but should occur in all materials exhibiting the latter process.

HL 49.9 Wed 11:30 EW 202

Spectrally resolved photon echo measurements in CdTe QWs — •L. Langer[1], S. Poltavtsev[2], I. A. Yugova[1,2], G. Karczewski[3], T. Wojtowicz[3], J. Kossut[3], D. R. Yakovlev[1,4], I. A. Akimov[1,4], and M. Bayer[1] — [1]Experimentelle Physik 2, Technische Universität Dortmund, 44221 Dortmund, Germany — [2]Physical Faculty of St. Petersburg State university, 198504 St. Petersburg, Russia — [3]Institute of Physics, Polish Academy of Sciences, 02668 Warsaw, Poland — [4]A.F. Ioffe Physical-Technical Institute, Russian Academy of Sciences, 194021 St. Petersburg, Russia

We report on trion and exciton decoherence in epitaxially grown, 20 nm thick CdTe/CdMgTe quantum wells using degenerate transient four wave mixing (TFWM) technique with heterodyne detection.Use of spectrally narrow picosecond pulses allows measuring the FWM signal for exciton and trion resonances separately. Time-resolving the FWM signal provides direct information on reversible and irreversible dephasing in the system under study. The measured photon-echo behavior for both inhomogeneously broadened exciton- and trion resonances reveals decoherence times of $\tau_X = 5$ ps and $\tau_T = 24$ ps at temperature T = 2 K. Depending on the polarization configuration of two beams, different light induced gratings can be generated. For colinearly polarized beams, a population grating is induced while for crossed-linearly polarized beams a spin grating is formed. While a magnetic field of up to 0.7 T applied in Voigt geometry does not alter the population grating, the spin grating's FWM signal is modulated at the Larmor frequency.