HL 90: Poster Session: Quantum information systems; Optical properties; Ultrafast phenomena

Presenters are kindly asked to be near their posters at least 17:00–18:00 or to leave a note at the poster indicating a time period of availability for discussions. — Beverages will be served starting at 18:00.

Time: Thursday 16:00–20:00 Location: Poster A

HL 90.1 Thu 16:00 Poster A

Strong bipartite and multipartite entanglement from planar microcavities — •Daniel Pagel[1], Holger Fehske[1], Jan Sperling[2], and Werner Vogel[2] — [1]Institut für Physik, Ernst-Moritz-Arndt-Universität Greifswald, 17487 Greifswald, Germany — [2]Institut für Physik, Universität Rostock, 18051 Rostock, Germany

The emission of entangled light from planar semiconductor microcavities is studied. In doing so, their nonclassical correlations are analyzed and quantified. Entanglement arises due to phase matching of the intracavity scattering dynamics of polaritons for multiple pump beams or pulses. We show, how parametric processes involving the lower polariton branch only, give rise to 2^N-partite entangled photons in W states, being the equal-weighted superposition of all pure states with one excited qubit and $2^N - 1$ qubits in the ground state. A second scenario that involves both polariton branches can generate multiple pairs of photons which are frequency entangled. By a decomposition into two parties, their nonclassical correlations can be identified as a bipartite entanglement, which is quantified by Schmidt number witnesses. We discuss to which extent the resources of the originally strongly entangled light field are diminished by dephasing in propagation channels.

HL 90.2 Thu 16:00 Poster A

Optical superresolution microscopy of individual spin defects in diamond — •Matthias Pfender, Nabeel Aslam, Gerald Waldherr, Philipp Neumann, and Jörg Wrachtrup — 3. Physikalisches Institut, Universität Stuttgart, Germany

The nitrogen-vacancy defect center in diamond is one of the major candidates for a room temperature quantum processor. By optical microscopy the quantum state of individual defects can be readout and initialized. This includes charge states as well as electron and nuclear spin states. As the spins associated with the NV center possess favorable coherence properties first quantum information tasks have already been implemented. In addition to quantum information processing this spin system is also applied for metrology purposes (i.e. nanoscale sensing of magnetic and electric fields as well as temperature). When the average distance of NV centers in these quantum devices is decreased below the diffraction limit individual addressing becomes challenging. Here we demonstrate a novel method for farfield optical superresolution imaging of NV centers with a resolution below 10 nm which is applicable to dense clusters of defects. Our method exploits recent novel insight into the charge state dynamics of this defect. Furthermore, additional spin manipulation allows for further resolution improvements and nanoscale metrology without the need for scanning probe techniques.

HL 90.3 Thu 16:00 Poster A

Temperature dependent dielectric function of yttria stabilized zirconia and alumina — •Tobias Lühmann, Tammo Böntgen, Helena Franke, Rüdiger Schmidt-Grund, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstraße 5, 04103 Leipzig

We present the dielectric function (DF) of yttria stabilized zirconia (YSZ) and Al_2O_3 thin films in the spectral range 1 - 7.5 eV for temperatures between 10 K and room temperature. The DF spectra of the pulsed laser deposited thin films where obtained by means of spectroscopic ellipsometry with subsequent layer model analysis using model dielectric functions. Special attention is devoted to differences in the absorption properties in the near band gap spectral range for films grown at low and high temperature, respectively. It was found that the structural properties, and thus the absorption properties, differ considerably. The low temperature grown materials are found to be amorphous whereas the high temperature grown films are nano-crystalline.

The near band gap absorption properties of these materials have great impact on the usability of these materials for dielectric mirrors, so-called distributed Bragg reflectors, which are used in ZnO-based microcavities [1].

[1] H. Franke, C. Sturm, R. Schmidt-Grund, G. Wagner, and M. Grundmann, New J. Phys. **14**, 013037 (2012).

HL 90.4 Thu 16:00 Poster A

THz-Transmission Spectroscopy of Charge Carriers in Surface Electric Fields — •Shovon Pal, Nathan Jukam, and Andreas D. Wieck — Applied Solid State Physics, Ruhr University Bochum, Germany

Intersubband transitions take place between quasi-two-dimensional electronic states called subbands, which are formed due to confinement of electrons in the growth direction. Confined electrons in the ground subband absorb incident infrared radiation and are excited to higher subbands, resulting in absorption maxima at intersubband resonance (ISR) frequencies. The absorption wavelength of accumulation and inversion layers lie in the THz domain and hence THz-transmission spectroscopy of these 2D charge carriers serves as an effective tool. A lot of work has been done on intersubband transitions with metallic Schottky gates. But these gates suffer from low breakdown voltages, low transmittance and fails to grow lattice-matched and epitaxially on most compound semiconductors. Epitaxial, complementary doped gates open the possibility to control the charge carrier density to observe the ISR with better optical access. The experimental set-up is being built, which uses a Bruker IFS 113V spectrometer. Semiconductor heterostructures were grown by molecular beam epitaxy (MBE). In the beginning, deposition of a 5 nm semi-transparent gold gate was accomplished by means of UV-photolithography and metallization techniques. The deposition of complementary p-doped gates were performed inside the MBE. The characterization of the heterostructures was done by Hall measurement technique at 300 K and 4.2 K.

HL 90.5 Thu 16:00 Poster A

Phase resolved near field measurements on surface plasmons — •Lena Simone Fohrmann, Jens Ehlermann, Jan Siebels, and Stefan Mendach — Institute of Applied Physics, University of Hamburg, Germany

As Surface plasmons can be confined to small nanostructure sized areas - much smaller than the wavelength of the exciting free space photons - they are thought to combine the benefits of photonics and microelectronics, i.e. high frequency and small dimensions, in future integrated devices [1].

Scanning near field optical microscopy is an outstanding tool to investigate the interaction of surface plasmons with nanostructures prepared on metal films. In combination with heterodyne detection it is possible to directly detect the amplitude and phase of near field distributions on sample surfaces [2][3].

Here we present phase resolved near field measurements of surface plasmons propagating on gold films and their interaction with plasmonic nanostructures.

We gratefully acknowledge financial support of the Deutsche Forschungsgemeinschaft via the Graduiertenkolleg 1286.

[1] D. Chang et al., Nature Physics, 3, 807-812 (2007)
[2] M.L.M. Balistreri et al., Phys. Rev. Lett. 85, 294 (2000)
[3] A. Nesci et al., Optics Letters, 26, 208-210 (2001)

HL 90.6 Thu 16:00 Poster A

Photocapacitance of metal-bilayer oxide-semiconductor capacitors — •Varun John[1], Danilo Bürger[1,2], Ilona Skorupa[2], Gyyörgy.J. Kovacs[2], Martin Schuster[3], Oliver G. Schmidt[4], and Heidemarie Schmidt[1] — [1]University of Technology Chemnitz, Faculty of Electrical Engineering and Information Technology, 09107 Chemnitz, Germany — [2]Helmholtz-Zentrum Dresden-Rossendorf e.V., Institute of Ion Beam Physics and Materials Research, Germany — [3]NaMLab gGmbH, 01187 Dresden, Germany — [4]Institute for Integrative Nanosciences, IFW Dresden, 01069 Dresden, Germany

Photocapacitance-voltage measurements have been performed on metal-VO2/SiO2-p-Si semiconductor capacitors under illumination in the spectral range from 300 nm to 800 nm. For depletion and inversion bias mode we observe that for energies smaller than 2.5 eV, i.e. for energies below the transition energy between a set of oxygen 2p orbitals and the Fermi energy of VO2 [1], the photocapacitance is larger than the capacitance without illumination. Furthermore, the photocapacitance has a broad maximum in the spectral range from 650

nm to 750 nm. For the accumulation bias mode the photocapacitance equals the capacitance without illumination. The drift of photogenerated charge carriers is used to discuss the observed photocapacitance effects in SiO2 single layer and VO2/SiO2 bilayer semiconductor capacitors with varying thickness of the PLD grown VO2 [2] and the thermally grown SiO2 layers. [1] C.N. Berglund and H.J. Guggenheim, Phys. Rev. 185 (1969); [2] György J. Kovács, D. Bürger et al., J. Appl. Phys. 109 (2011)

HL 90.7 Thu 16:00 Poster A

Effects of reduced symmetry on the Raman spectra of Cu_xO_y — •Christian Reindl, Thomas Sander, Christian Heiliger, and Peter J. Klar — I. Physikalisches Institut, Justus-Liebig-Universität Gießen, Heinrich-Buff-Ring 16, 35392 Gießen

Raman spectra of copper oxide make it possible to clearly indentify the three individual phases Cu_2O, Cu_4O_3, and CuO. These assignments are in good aggreement with results of X-ray diffraction measurements performed. Each copper oxide phase possesses a different crystal symmetry leading to typical unique Raman modes. However, in the particular case of Cu_2O, the spectra obtained reveal modes being forbidden in the perfect crystal.

The presented Raman spectra of copper oxide were recorded with a Renishaw InVia Raman microscope using excitation lasers of 325 nm, 532 nm, and 633 nm, respectively. The samples were grown by sputter deposition, CVD, and MBE. Group theory considerations show that reduction of symmetry, originating from vacancies and interstitials within the crystal lattice, leads to a relaxation of selection rules making forbidden modes allowed. This will be discussed with respect to the modes observed.

Furthermore DFT calculations for Raman modes of Cu_2O with various defects such as copper vacancies support this idea.

HL 90.8 Thu 16:00 Poster A

Imaging interferometry of excitons in two-dimensional structures — •Heinrich Stolz, Maria Kaupsch, Dirk Semkat, and Günter Manzke — Institut für Physik, Universität Rostock, 18051 Rostock

Recently, spontaneous coherence of excitons in two-dimensional systems has been claimed from measurements of interference contrast using different setups like double slit, shift and mirror interferometers [1,2]. Using the theory of imaging with partial coherent light, we derive general expressions for these setups. We show that in all cases the interference patterns depend not only on the point spread function of the imaging setup but also strongly on the spatial emission pattern of the sample. Taking the experimentally observed emission patterns into account, we can reproduce at least qualitatively all the observed interference structures, which have been interpreted as signatures for spontaneous long range coherence of excitons, already for incoherent emitters. This requires a critical reexamination of the previous work. [1] High A. A.; Leonard J. R.; Remeika M.; Butov L. V.; Hanson M.; Gossard A. C. *Nano Lett.* **12**, 2605 (2012). [2] High A. A.; Leonard J. R.; Butov L. V.; Gossard A. C. *Nature* **483**, 584 (2012). [3] Semkat, D.; Sobkowiak, S.; Manzke, G.; Stolz, H. *Nano Lett.* **12**, 5055 (2012).

HL 90.9 Thu 16:00 Poster A

Interferometric measurements of luminescence from Bose-Einstein condensates of trapped excitons in Cu_2O — •Maria Kaupsch, Rico Schwartz, Frank Kieseling, Gerd Rudlof, and Heinrich Stolz — Institut für Physik, Universität Rostock, D-18051, Rostock, Germany

Recent measurements of the luminescence from Cu_2O at ultra low temperatures show strong evidences of an excitonic Bose-Einstein condensation (BEC) [1,2]. One direct proof of the BEC is the spatial coherence of the luminescence. First measurements were realised with a Michelson interferometer, whereby the image is superimposed with the flipped one. The measurements were made at different cw-excitation powers and temperatures. We observe a rather complicated interference pattern, which depends critically on the optical delay. The results already support the assumption that the luminescence differs from that of a thermal light source. There are also first theoretical approaches for describing the imaging interferometry of ultracold exciton gases [3] which stress the importance of maximum spatial resolution. We discuss first experiments using an aspheric lens close to the Cu_2O sample inside the mixing chamber of the used $^3He/^4He$ dilution cryostat.

[1] R. Schwartz, N. Naka, F. Kieseling, and H. Stolz, New J. Phys, 14, 023054 (2012); [2] H. Stolz, R. Schwartz, F. Kieseling, S. Som, M. Kaupsch, S. Sobkowiak, D. Semkat, N. Naka, Th. Koch, and H. Fehske, New J. Phys. 14, 105007 (2012); [3] D. Semkat, S. Sobkowiak, G. Manzke, and H. Stolz, Nano Lett. 12, 5055 (2012)

HL 90.10 Thu 16:00 Poster A

Feedback loop for in-situ reflection measurement analysis and optimization during material processing of fs-laser structured silicon — •Anna Lena Baumann[1], Wolfgang Schippers[1], Thomas Gimpel[1], Stefan Kontermann[1], and Wolfgang Schade[1,2] — [1]Fraunhofer Heinrich Hertz Institute, EnergieCampus, Am Stollen 19B, 38640 Goslar, Germany — [2]Clausthal University of Technology, EFZN, EnergieCampus, Am Stollen 19B, 38640 Goslar

Through femtosecond-laser pulse processing the absorption of silicon can be increased considerably and through incorporation of sulfur also extended in the infrared wavelength range. The increase in absorption in the visible wavelength range is due to a decrease in reflection of the surface structures that arise through the laser process. A setup for spot-by-spot femtosecond-laser scanning and realtime reflection measurement analysis is designed. Using a two axis stage system, a continuous wave laser reflection for feedback and a genetic algorithm for signal analysis, the optimal pulse shape for a tailored sample reflection can be found.

HL 90.11 Thu 16:00 Poster A

Strong light-matter coupling between photons and several excitonic states in ZnO-based microcavities — •Martin Thunert, Hannes Krauss, Helena Franke, Chris Sturm, Rüdiger Schmidt-Grund, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstr. 5, 04103 Leipzig

We report on the observation of strong coupling between cavity-photons and free single particle excitonic states as well as bound or free exciton-complex states in ZnO-based microcavities via PL and reflectivity measurements. While the coupling to the free exciton states is present in each case, the coupling to the two types of complex excitonic structures seems to be present in two situations:

1.) In the case of a low-temperature grown but annealed cavity we have observed the additional coupling of the cavity-photon to the donor bound excitons (D^0,X), which are strongly localized.

2.) In a cavity grown at high temperature, we have observed coupling to exciton-phonon complexes. Each of both contributions to the polaritons are observed by an additional branch in the polariton dispersion. While the coupling to the (D^0,X) has a low coupling strength due to its low density in the cavity, the coupling strength for the exciton-phonon complexes is found to be similar to that for the free excitons.

The different excitonic contributions could be ascribed to different crystal quality of the cavity material for the two types.

HL 90.12 Thu 16:00 Poster A

Ultrafast Dynamics of the Phase Transition in GST Phase Change Materials — •Lutz Waldecker[1], Simon Wall[2], and Ralph Ernstorfer[1] — [1]Fritz-Haber-Institut der MPG, Berlin, Germany — [2]ICFO - Institut de Ciències Fotòniques, Castelldefels (Barcelona), Spain

The fast and reversible optically induced switching between amorphous and crystalline states of $Ge_xSb_yTe_z$ (GST) and similar compounds has found numerous applications in modern data storage technology. However, the microscopic mechanism of the switching process is still subject to debate. By applying two different pump-probe techniques, we investigate the ultrafast optical as well as structural properties of GST as the phase transition occurs. Combining femtosecond transient reflectivity spectroscopy and time-resolved electron diffraction allows for investigating the correlation between structure and function in phase change materials as well as for addressing the question whether the phase transition is thermally or non-thermally driven.

HL 90.13 Thu 16:00 Poster A

Studying Ultrafast Quasiparticle Dynamics by Inelastic Scattering of Electromagnetic Waves: Part 1 Visible Light — •André Bojahr, Marc Herzog, Jevgenij Goldshteyn, Steffen Mitzscherling, Lena Maerten, and Matias Bargheer — Intstitut für Physik und Astronomie, Universität Potsdam, Germany

Collective excitations in crystalline materials lead to complex physical phenomena such as metal-insulator or magnetic phase transitions. Phonons often have a participating or driving role in such transitions. Therefore studying phonons and their coupling among each

other and to other subsystems of the material is very important for the understanding of the underlying physics. Here we show new experiments which support a generalized view on scattering of electromagnetic waves from quasiparticles. In particular we study phonons and phonon-polaritons in different perovskite oxides such as SrTiO3 or LiNbO3. We use three different excitation schemes to generate ultrashort quasi-monochromatic phonons and phonon-polaritons. After excitation we probe the quasiparticle dynamics in real time by Brillouin- and Raman scattering. We discuss the experiments in a unified view, where the pump- and probe-process are disentangled and the inelastic aspect of the scattering is emphasized. We observe the quasiparticle dynamics including the phonon damping and nonlinear interaction in real time, and compare the results to simulations in a nonlinear masses-and-springs model.

HL 90.14 Thu 16:00 Poster A

Studying Ultrafast Quasiparticle Dynamics by Scattering of Electromagnetic Waves: Part 2 X-rays — •Marc Herzog[1], André Bojahr[1], Daniel Schick[1], Roman Shayduk[2], Hengameh Navirian[2], Jevgenij Goldshteyn[2], Wolfram Leitenberger[1], Peter Gaal[2], and Matias Bargheer[1,2] — [1]Institut für Physik und Astronomie, Universität Potsdam, Potsdam, Germany — [2]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Berlin, Germany

Materials exhibiting different types of collective physical phenomena such as metal-insulator transitions or (multi)ferroic behavior are of particular physical and technological interest. The related phase transitions are often mediated by the lattice and can in many cases be transiently triggered by ultrashort laser pulses. A thorough understanding of the ultrafast structural dynamics after laser excitation is therefore crucial for the optical control of material properties.

In general, a suitable experimental method to study ultrafast structural dynamics is the scattering of electromagnetic waves. This contribution summarizes the investigation of laser-induced coherent acoustic phonons in metal-insulator heterostructures by time-resolved scattering of hard x-rays. We use different excitation schemes and sample geometries to generate high-amplitude sub-THz quasi-monochromatic phonons in $SrTiO_3$. We observed linear and nonlinear propagation effects which can be accurately simulated by an anharmonic linear chain model.

HL 90.15 Thu 16:00 Poster A

Ab-initio MD-simulation of large TiO_2 supercells after fs-laser excitation — •Sergej Krylow, Fairoja Cheenicode Kabeer, Eeuwe S. Zijlstra, and Martin E. Garcia — Theoretical Physics, University of Kassel, Heinrich-Plett-Str. 40, 34132 Germany

Using the computer program CHIVES(Code for Highly-excited Valence Electron Systems), which is based on electronic temperature dependent density functional theory, pseudopotentials and localized atom centered basis functions, we performed MD-simulations of TiO_2 in order to determine its structural response to intense fs-laser excitation. We pay particular attention to different types of electronic forces driving the coherent phonons as well as to their decay as a function of time due to phonon-phonon interactions. We compare our results to recent experiments.

HL 90.16 Thu 16:00 Poster A

Nonlinear Phononics — •Matthias Gohlke, André Bojahr, and Matias Bargheer — Department of Physics and Astronomy, Potsdam University, Germany

This contribution discusses simulations of nonlinear phononics in SrTiO3 (STO) crystals using realistic parameters. These parameters were derived from ultrafast Brillouin scattering experiments, where a thin metallic film was excited by femtosecond laser pulses to generate large-amplitude hypersound waves[1]. Using the anharmonic linear chain model tested in this publication, we investigate realistic scenarios for nonlinear phononics in full analogy to photonics: We demonstrate second harmonic generation (SHG) as well as difference and sum frequency mixing (DFG and SFG) of quasi-monochromatic phonons synthesized by optical multipulse excitation. We discuss potential applications of such nonlinear techniques, e.g. for the fundamental analysis of phonon-phonon interaction.

[1] A. Bojahr et al., Calibrated real time detection of nonlinearly propagating strain waves, Phys. Rev. B 86,144306 (2012)

HL 90.17 Thu 16:00 Poster A

Difference in structure and sulfur content of silicon, structured with shaped double femtosecond-laser pulses — •Anna Lena Baumann[1], Kay-Michael Guenther[2], Thomas Gimpel[1], Stefan Kontermann[1], and Wolfgang Schade[1,2] — [1]Fraunhofer Heinrich Hertz Institute, EnergieCampus, Am Stollen 19B, 38640 Goslar, Germany — [2]Clausthal University of Technology, EFZN, EnergieCampus, Am Stollen 19B, 38640 Goslar

Double femtosecond-laser pulses of different pulse distances, shaped by a phase-only pulse shaper, were used to structure the surface of silicon under sulfur hexafluoride atmosphere. When using only one pulse per sample spot (pink silicon), the morphology changes decrease with growing pulse distance, as does the sulfur content in the sample. The absorption changes from single to double pulses, but stays the same in the visible and near infrared range for all investigated pulse distances. The relative sulfur content dependence is investigated with SIMS measurements, which indicate a dependence correlated with the morphology changes. Samples irradiated with 5 pulses per sample spot show a greater dependence on the double pulse distance in the visible as well as in the infrared wavelength range.

HL 90.18 Thu 16:00 Poster A

Generating squeezed phonons by repeated ultrafast excitations of a quantum dot — •Daniel Wigger[1], Doris E. Reiter[1], Vollrath Martin Axt[2], and Tilmann Kuhn[1] — [1]Institut für Festkörpertheorie, Universität Münster, Wilhelm-Klemm-Str. 10, 48149 Münster — [2]Theoretische Physik III, Universität Bayreuth, 95440 Bayreuth

We study theoretically squeezing properties of phonon wave-packets generated by ultrafast optical excitations of a semiconductor quantum dot (QD). We model the QD in the strong confinement limit as an electronic two-level system coupled to longitudinal acoustic (LA) phonons via deformation potential. An ultrashort laser pulse creates an exciton in the QD, which leads to a shift of the equilibrium position of the lattice ions. Thus, a static lattice deformation in the QD area builds up forming a polaron state. Due to the rapid contraction of the lattice an additional strain pulse leaves the QD. Manipulating the exciton with a second laser pulse another phonon wave packet is emitted. Depending on the time delay and relative phase between the two laser pulses the fluctuation properties of the second wave packet can fall below their vacuum limit, i.e., squeezing may occur. In contrast to optical phonons, which are confined to the QD, here the squeezing feature is imprinted to the second traveling wave packet and leaves the QD.