HL 108: Poster: Ultra-fast phenomena / Optical properties / Semiconductor laser / Devices and device concepts

Time: Thursday 17:00–20:00 Location: P1

HL 108.1 Thu 17:00 P1

Laserinduced heating of nanocrystalline graphene monitored by Ultrafast Electron Diffraction — Silvio Morgenstern[1], Christian Gerbig[1], •Xaver Holzapfel[1], Christan Sarpe[1], Arne Senftleben[1], Matthias Wollenhaupt[2], and Thomas Baumert[1] — [1]University of Kassel, Institute of Physics and Center of Interdisciplinary Nanostructure Science and Technology (CINSaT), D-34132 Kassel, Germany — [2]University of Oldenburg, Institute of Physics, D-26111 Oldenburg, Germany

Ultrafast Electron Diffraction (UED) has lately become one of the most promising techniques to directly provide insights into fundamental dynamics in solids at the microscopic level and on the pico- to subpicosecond timescale [1,2].

In this contribution we present our UED-setup to reach a high spatial and temporal resolution below 200 fs [3]. Additionally we present first results of time-resolved diffraction experiments on nanocrystalline graphene [4] and discuss the possibility of time-resolved observations of out-of-plane dynamics in such materials [5]. Finally we compare our results to results from CVD-graphene [6].

[1] A. H. Zewail, J. Phys. Chem. 98, 2782-2796 (1994)
[2] B. Siwick & D. Miller, Science 302, (5649), 1382-1385 (2003)
[3] C. T. Hebeisen, Opt. Letters Vol. 31, No. 23, 3571 (2006)
[4] A. Truchanin, ACS Nano Vol. 5, No. 5, 3896 (2011)
[5] J. C. Meyer, Nature 446, 60-63 (2007)
[6] M. Schäfer, New J. Phys. 13, 063030 (2011)

HL 108.2 Thu 17:00 P1

Resolution studies on a compact femtosecond transmission electron diffractometer and phonon decay in single crystalline graphite — Christian Gerbig[1], Silvio Morgenstern[1], •Marlene Adrian[1], Christian Sarpe[1], Arne Senftleben[1], Matthias Wollenhaupt[2], and Thomas Baumert[1] — [1]University of Kassel, Institute of Physics (CINSaT), D-34132 Kassel, Germany — [2]University of Oldenburg, Institute of Physics, D-26111 Oldenburg, Germany

Time-resolved diffraction, using x-ray or electron probes, has become a promising technique to directly provide insights into dynamics at the molecular level with ultrafast precision [1]. We study dynamical processes in single crystalline graphite by means of ultrafast electron diffraction in order to expand the understanding of phonon generation and decay mechanisms being essential for future carbon based electronic devices [2]. Our highly compact DC electron diffractometer is fully characterized by experiments and N-body simulations. At balanced conditions a temporal resolution of 200 fs along with high-definition diffraction is achieved for dynamical studies on graphite single crystals in a maintainable measurement time [3]. We further present generation and decay processes of incoherent as well as coherent phonons in graphite as a function of film thickness down to few-layer graphene.

[1] M. Chergui and A. H. Zewail, Chem. Phys. Chem. 10, 28 (2009).
[2] T. Kampfrath et al., Phys. Rev. Lett. 95, 187403 (2005).
[3] C. Gerbig et al., submitted (2013).

HL 108.3 Thu 17:00 P1

Towards Nonlinear Phononics, probing acoustic phonon wave packets with X-ray and visible light — •Andre Bojahr[1], Matthias Gohlke[2], Marc Herzog[3], Daniel Schick[1], Peter Gaal[4], and Matias Bargheer[1,4] — [1]Institut für Physik und Astronomie, Universität Potsdam, Karl-Liebknecht-Str. 24-25, 14476 Potsdam/Golm, Germany — [2]Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Str. 38, 01187 Dresden, Germany — [3]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Faradayweg 4-6, 14195 Berlin, Germany — [4]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Wilhelm-Conrad-Röntgen Campus, Albert-Einstein-Str. 15, 12489 Berlin, Germany

We use ultrashort visible and hard X-ray pulses as a real-time probe of the occupation of phonon modes constituting large amplitude phonon wave packets. These time-domain Brillouin scattering experiments permit the time-resolved observation of the phonon dynamics including phonon damping and nonlinear interaction. High strain fields lead to nonlinear phenomena like sum and difference-frequency mixing, which depend strictly on the shape of the excited phonon wave packet. Via multiple pumping of an epitaxially grown metal transducer film on a $SrTiO_3$ substrate we generate spectrally narrow phonon wave packets. The nonlinear evolution such a wave packet can be understood by difference and sum-frequency mixing of its spectral components, explaining the amplitude dependent damping of phonon wave packets. Our measurements are supported by calculations of a nonlinear masses and springs model, which describes the experiments quantitatively.

HL 108.4 Thu 17:00 P1

Incoherent Phonon Heating Model derived from the system Hamiltonian — •Messan Afande, Eeuwe S. Zijlstra, and Martin E. Garcia — Theoretische Physik, Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany

The purpose of the current work is the derivation of the equation of motion of atoms in solid state materials with emphasis on incoherent phonon heating. The modeling is based upon the application of the Ehrenfest theorem by considering the overall system Hamiltonian, in particular, including electron-phonon interactions. In the following, it is planned to integrate the derived model into an ab initio Molecular Dynamics simulation code for studying lattice vibrations in solid state materials after femtosecond-laser excitation.

HL 108.5 Thu 17:00 P1

Formation and hybridization of Bloch and plasma oscillations — •Klaus Morawetz — Münster University of Applied Sciences, Stegerwaldstrasse 39, 48565 Steinfurt, Germany — International Institute of Physics (IIP), Avenida Odilon Gomes de Lima 1722, 59078-400 Natal, Brazil — Max-Planck- Institute for the Physics of Complex Systems, 01187 Dresden, Germany

Using a conserving relaxation-time approximation an analytic formula is derived which describes the time dependence of the dielectric function in a plasma created by a short intense laser pulse with an additional external electric field bias. This formula reproduces universal features of the formation of collective modes seen in experimental data of femtosecond spectroscopy (Phys. Rev. B 72 (2005) 233203). Due to the electric field Bloch oscillations in a semiconductor are created which form a hybridization with plasma oscillations. This short-time expansion of lower-order quantum perturbation theory can be used to describe the dynamics of strongly correlated classical systems (Phys. Rev. E 66 (2002) 022103).

HL 108.6 Thu 17:00 P1

Terahertz two-photon quantum well infrared photodetectors — •Carsten Franke[1,2], Harald Schneider[1], and Martin Walther[3] — [1]Helmholtz-Zentrum Dresden-Rossendorf — [2]TU Dresden — [3]Fraunhofer IAF Freiburg

Two-photon quantum well infrared photodetectors (QWIPs) are nonlinear detectors for the investigation of ultrashort pulses in the mid-infrared and THz-regime. In these devices the photocurrent shows a quadratical dependence on the intensity of the incoming radiation which is useful in autocorrelation experiments.

We are currently investigating two-photon QWIPs based on the GaAs/AlGaAs material system with an aluminum content lower than 5% in the barrier, which leads to intersubband absorption energies below 25 meV.

Here we present results of interferometric autocorrelation experiments performed with the free-electron laser FELBE at photon energies of 15 to 25 meV.

HL 108.7 Thu 17:00 P1

Optical characterization of CuI films — •Katharina Rudisch, Friedrich-Leonhard Schein, Gabriele Benndorf, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstraße 5, 04103 Leipzig

CuI is a transparent semiconductor with a wide band gap of 3.1eV. It features intrinsic p-conductivity and a large exciton binding energy that make it attractive for future semiconductor applications [1].

We have produced CuI thin films by exposing sputtered copper thin films on glass substrates to iodine vapour until CuI was formed. From

X-ray diffraction measurements of the CuI film a cubic zincblende crystal structure could be confirmed. For a characterization of optical properties of CuI, photoluminescence and transmission measurements were performed from 2K to room temperature. Low temperature emission spectra exhibit transitons of free and bound excitons and donor acceptor pair recombinations with phonon coupled transitions. In transmission spectra a splitting of the light and heavy hole excitonic transitions is observed at low temperatures and discussed in terms of crystal structure.

[1] M. Grundmann, F.-L. Schein, M. Lorenz, T. Böntgen, J. Lenzner und H. von Wenckstern, phys. stat. sol. (a) 210(9), 1671-1703 (2013)

HL 108.8 Thu 17:00 P1

Parametric scattering in a multimode polariton system — •Rüdiger Schmidt-Grund[1], Christof P. Dietrich[1], Tom Michalsky[1], Robert Johne[2], Paul Eastham[3], Helena Franke[1], Chris Sturm[1], Martin Lange[1], and Marius Grundmann[1] — [1]Universität Leipzig, Institut für Experimentelle Physik II, Leipzig, Germany — [2]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany — [3]Trinity College Dublin, Dublin, Ireland

We present the observation of parametric scattering of whispering gallery mode exciton-polaritons in a ZnO micro-wire resonator at low temperature. In this geometry, in contrast to a planar microcavity, many polariton modes exist, and furthermore the ground state is energetically well separated from the exciton energy. In this complex many-mode system, we observe the formation of a polariton Bose-Einstein condensate with some special features. First, it is resonantly fed by the radiative decay of defect bound excitons and secondly it appears in polariton branches energetically close to this defect bound exciton state. By increasing the excitation power, the occupation of this initial state becomes very high and a parametric scattering process sets in. Thereby, a relaxation of the condensed polaritons into states with lower energy and higher momentum occurs. The experimental findings are in good agreement with theoretical simulations taking into account polariton-polariton scattering in a multi-mode system.

HL 108.9 Thu 17:00 P1

Time-resolved photo-ellipsometry studies of exciton-polaritons in a planar ZnO-based microcavity — •Steffen Richter, Chris Sturm, Helena Franke, Rüdiger Schmidt-Grund, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstr. 5, 04103 Leipzig, Germany

Exciton-polaritons are composite quasi-particles which arise from strong coupling between excitons and photons. They inherit exciton spin as well as light polarization which both are expressed by means of the pseudospin of a polariton ensemble. The pseudospin is subject to various effective magnetic fields whereof one in particular can be related to population imbalances of polariton states with different pseudospin orientation.

We present investigations of the exciton-polariton pseudospin in a planar microcavity. The influence of the occupation of the lower polariton branch on the evolution of the eigenmode polarization is studied using pulsed laser excitation combined with time-resolved ellipsometry. Ellipsometry probes the density of states (DOS) while the combination with photoluminescence allows to deduce the dependence of the DOS on the states' occupation. Furthermore, despite non-resonant excitation, the polarization of the laser can influence the occupation as well. The consequences are examined.

The planar microcavity consists of a $\lambda/2$ layer of ZnO with a slight thickness gradient. The splitting between the TE- and TM-polarized eigenmodes has values of up to 20meV for 37° emission angle while the detuning between exciton and cavity photon energy is negative.

HL 108.10 Thu 17:00 P1

Influence of metal layers on the optical properties of Bragg reflectors — •Merle Cornelius[1], SK. Shaid-Ur Rahman[1], Tim Schönfeld[2], Thorsten Klein[2], Carsten Kruse[2], Detlef Hommel[2], Jürgen Gutowski[1], and Katrin Sebald[1] — [1]Institute of Solid State Physics, Semiconductor Optics, University of Bremen, P.O. Box 330440, 28334 Bremen, Germany — [2]Institute of Solid State Physics, Semiconductor Epitaxy, University of Bremen, P.O. Box 330440, 28334 Bremen, Germany

Polaritons being generated in a planar microcavity structure by strong light-matter interaction can be controlled and manipulated through an additional lateral confinement applied. This can result in an increase of their relaxation probability being highly advantageous for polariton lasers. Such a confinement can be achieved by a metal grating on top of the upper distributed Bragg reflector (DBR) of the planar microcavity since in this case, Tamm plasmons, being photon modes localized at the interface, can be optically generated. Their excitation results in a change of the cavity photon energy and thus in a lateral polariton confinement. In this contribution we report on the influence of metal layers with different thicknesses on the optical properties of DBRs grown by MBE and consisting of ZnMgSSe as high-index material and a superlattice consisting of MgS/ZnCdSe as low-index material. The metal layers, being gold or silver stripes with thicknesses between 40 nm to 60 nm, were generated by lithography. By performing reflectivity measurements changes of the spectral position of the DBR oscillations as well as of the center of the stopband are analyzed.

HL 108.11 Thu 17:00 P1

Design and fabrication of acoustic devices in ZnO/SiO2 planar microcavities — •Jakov Buller[1], Odilon D. D. Couto Jr.[2], Edgar A. Cerda-Méndez[1], Sander Rauwerdink[1], Abbes Tahraoui[1], and Paulo V. Santos[1] — [1]Paul-Drude-Institut für Festkörperelektronik, Berlin, Germany — [2]Universidade Estadual de Campinas, Campinas, Brazil

Optical resonances in semiconductor microcavities (MC) have been exploited to enhance the light emission from single emitters, while surface acoustic waves (SAWs) have been used to modulate the band gap of semiconductor nanostructures. In this work, we investigate the acousto-optical effects in planar ZnO/SiO2 MCs rf-sputtered on sapphire. The sample design is based on numerical calculations which show that: (i) the refractive index contrast of ZnO and SiO2 leads to high optical confinement; (ii) the piezoelectricity of ZnO enables the electric generations of SAWs for modulation of the MC resonance.

The fabricated two types of MCs consisting of a $\lambda/2$ active region spacer sandwiched by $\lambda/4$ ZnO/SiO2 distributed Bragg mirrors (DBRs). In the first one, the $\lambda/2$ spacer consists of an electron beam resist (HSQ). SEM measurements demonstrate successful resist planarisation, leading to homogeneous cavity spacers. In the second type, the upper DBR is mechanically glued on the lower one, thus forming air-gap MCs. Reflectivity measurements in MCs demonstrate quality (Q) factors of up to 2000, which are in reasonable agreement with transfer-matrix calculations. The process allows the insertion of light emitters into the MC active region and their manipulation by SAWs.

HL 108.12 Thu 17:00 P1

Time-resolved spectroscopy of defect luminescence in aluminium nitride — •Tristan Koppe, Oliver Beck, Hans Christian Hofsäss, and Ulrich Vetter — II. Physikalisches Institut, Georg-August-Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen

We report on defect luminescence studies in HPHT synthesized or epitaxial grown aluminium nitride. The samples are excited with a femtosecond laser system at various UV-wavelengths and the luminescence is collected with a Streak Camera in the wavelength range of 200-800 nm at different time scales with a temporal resolution up to 20 ps. A special focus is drawn on the temperature dependence of intensity and lifetime in a range between 12 K and room temperature.

HL 108.13 Thu 17:00 P1

The importance of an absolutely calibrated confocal photoluminescence setup — •Hendrik Sträter, Rudolf Brüggemann, Niklas Nilius, and Gottfried H. Bauer — Carl von Ossietzky Universität Oldenburg, Institut für Physik, D-26111 Oldenburg

Photoluminescence (PL) measurements provide a contact-less method to determinate the opto-electronic properties of a semiconductor and its potential as solar cell absorber material. From the recorded PL-spectrum it is possible to extract the integrated PL yield, splitting of quasi-Fermilevels (QFL), optical threshold, Urbach energy, and subgap absorption. Especially the QFL-splitting is an important quantity, since it can be interpreted as the maximum open circuit voltage (V_{oc}), which can be achieved with a finally fabricated solar cell. Laterally resolved PL measurements are a powerful tool to determine fluctuations of the opto-electronic properties and correlations between the opto-electronic properties. Up to now it is often assumed that a spectrally calibrated PL setup is sufficient for determination of the variation of the QFL-splitting. This contribution shows that this is not always the case and that fluctuations of the QFL-splitting and all quantities correlated to it heavily depend on the absolute calibration function of the PL setup. A mathematical framework is presented which proves that even small deviations from the ideal calibration function can lead to arbitrary wrong results. Simulated and experimental PL results give an idea of the outcome of a wrong calibrated PL setup and a possible solution to the problem is presented.

HL 108.14 Thu 17:00 P1

Controlled lasing from active optomechanical resonators — •Thomas Czerniuk[1], Christian Brüggemann[1], Jan Tepper[1], Sebastian Brodbeck[2], Christian Schneider[2], Martin Kamp[2], Sven Höfling[2], Boris Glavin[3], Dimitri Yakovlev[1,4], Andrey Akimov[4], and Manfred Bayer[1] — [1]Experimentelle Physik 2a, TU Dortmund, Dortmund, Germany — [2]Technische Physik, Universität Würzburg, Würzburg, Germany — [3]V. E. Lashkaryov Institute of Semiconductor Physics, Kiev, Ukraine — [4]A. F. Ioffe Physical-Technical Institute, Russian Academy of Sciences, St. Petersburg, Russia

We report an effective emission intensity modulation of a microcavity laser (VCSEL) with frequencies of up to 40 GHz at room temperature. We investigate a planar microcavity laser, whose active medium are GaAs quantum wells while the DBRs are built out of alternating layers of AlAs/GaAlAs. Due to the acoustic impedance mismatch of these material system, the DBRs possess not only optical, but also acoustic resonances. In a laser with such an optomechanical resonator, the interaction between the three excitations -photons, phonons and excitons- is drastically enhanced, providing control of the emission intensity: by injecting a broadband strain pulse into the cavity, the long living resonant phonon modes are excited. For different delays between strain pulse injection and pulsed optical excitation of the VCSEL, the emission intensity is monitored. The result shows prominent oscillations with frequencies corresponding to the acoustic resonances of the optomechanical device.

HL 108.15 Thu 17:00 P1

Toward high-power passively mode-locked VECSELs in the red spectral range — •Grizelda Kersteen, Roman Bek, Hermann Kahle, Thomas Schwarzbäck, Michael Jetter, and Peter Michler — Institut für Halbleiteroptik und Funktionelle Grenzflächen and Research Center SCoPE, Universität Stuttgart, Allmandring 3, 70569 Stuttgart, Germany

Research during the past decade focusing on semiconductor saturable absorber mirrors (SESAMs) and vertical external-cavity surface-emitting lasers (VECSELs) has been extremely thorough in optimizing pulse duration and output power in the infrared region. However, in 2013 our group could realize the first mode-locked VECSEL in the red spectral range emitting sub-250 fs pulses with a repetition rate of 836 MHz at around 664 nm. Due to the plane diamond heatspreader bonded onto the gain structure, side pulses appear reducing the peak power.

In this contribution, we present different approaches for improvements of this first setup. To suppress the Fabry-Pérot etalon induced side pulses, we use an anti-reflection coated wedged diamond instead. The effect of an increased repetition rate on the mode locking operation is investigated by reducing the cavity length. Furthermore, we investigate different gain and absorber structures containing quantum dots instead of quantum wells inside. These provide more flexibility concerning both the gain and the absorber properties such as temperature behavior and saturation fluence.

HL 108.16 Thu 17:00 P1

Harmonically self-mode-locked vertical-external-cavity surface-emitting laser — •Mahmoud Gaafar[1], Christoph Möller[1], Matthias Wichmann[1], Bernd Heinen[1], Bernardette Kunert[2], Arash Rahimi-Iman[1], Wolfgang Stolz[1], and Martin Koch[1] — [1]Material Sciences Center and Department of Physics, Philipps-Universität Marburg, Marburg D-35032, Germany — [2]NAsP III/V GmbH, Am Knechtacker 19, Marburg D-35041, Germany

We present a sesam-free harmonically mode-locked vertical-external-cavity surface-emitting laser. Mode-locking is initiated by introducing a slit near to the high reflective end mirror of our Z-shaped laser cavity. Beside single pulse operation we observed second as well as third harmonic mode-locking for higher pump powers. Our system features pulse durations penetrating the femtosecond regime at a wavelength of 1014 nm.

HL 108.17 Thu 17:00 P1

Non-heating losses and thermal resistance of VECSELs — •Dalia Al Nakdali[1], Mohammad Khaled Shakfa[1], Bernd Heinen[1], Bernardette Kunert[2], Wolfgang Stolz[1], Stephan W. Koch[1], Jörg Hader[3], Jerome V. Moloney[3], Arash Rahimi-Iman[1], and Martin Koch[1] — [1]Faculty of Physics and Material Sciences Center, Philipps-University of Marburg, Renthof 5, 35032 Marburg, Germany — [2]NAsP-III/V GmbH., Am Knechtacker 19, 35041 Marburg, Germany — [3]College of Optical Sciences, University of Arizona, Tucson, Arizona 85721, USA

Optically-pumped vertical-external-cavity surface-emitting lasers (VECSELs) have recently received much attention due to their potential for application in scientific and industrial fields. Particularly, they are promising for continuous-wave (cw) high power operation. However, only a considerable improvement of the thermal management allows us to obtain cw VECSEL output-powers in excess of 100 W. Besides heating losses, non-heating power losses need to be analyzed for a deeper understanding of power-limiting factors in a VECSEL and for the improvement of its performance. In our present work, a standard V-cavity VECSEL configuration is employed. Input-output characteristics are recorded for different plane out-coupling mirrors and for varying heat sink temperatures. Here, we take into account optical-scattering losses to improve a theoretical model from which we extract the VECSEL-chips thermal resistance as well as its scattering coefficient from experimental input-output characteristics.

HL 108.18 Thu 17:00 P1

Microintegrated Laser Systems at 767 nm and 780 nm — •Kai Lampmann[1,2], Max Schiemangk[1,2], Erdenetsetseg Luvsandamdin[1], Andreas Wicht[1], Achim Peters[1,2], Götz Erbert[1], Günther Tränkle[1], and The LASUS Team[1,2,3,4] — [1]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Berlin — [2]Institut für Physik, HU Berlin — [3]Institut für Quantenoptik, LU Hannover — [4]Institut für Laserphysik, U Hamburg

We present hybrid integrated laser modules in the near infrared at wavelengths of 767 nm and 780 nm suitable for atom optic applications. For narrow linewidth emission with high optical output power in the Watt range, a master oscillator power amplifier (MOPA) concept is used. A distributed feedback semiconducter laser diode (DFB) serves as the master oscillator, which provides excellent spectral properties. The light is injected into a tapered amplifier (TA), which increases the output power while preserving the linewidth of the amplified light at the same time. The laser chips, microlenses and an optical isolator are integrated on an AlN substrate with a footprint of 10×50 mm^2 using special positioning techniques with an accuracy better than 1 μm.

The LASUS project is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant numbers 50WM 1237 - 1240.

HL 108.19 Thu 17:00 P1

Continuous-wave operation of a buried-heterostructure quantum cascade laser — •Mikaela Elagin, Yuri V Flores, Sergii Kurlov, Anna Aleksandrova, Grygorii Monastyrskyi, Jan F Kischkat, Mykhaylo P Semtsiv, and W Ted Masselink — Humboldt University Berlin, Institute of Physics, Newtonstr.15, 12489 Berlin, Germany

We report the continuous wave (cw)-operation of a buried-heterostructure (BH) strain-compensated quantum cascade laser (QCL) using gas-source molecular beam epitaxy both for the growth of the active region as well as for the InP:Fe regrowth of the laser ridge sidewalls. Starting the InP:Fe regrowth directly on the sides of the laser ridge leads to a number of void defects which have a significant impact on heat extraction capabilities of devices. These defects are mostly located at the arsenide-phosphide interface between the active region and the regrown insulating material. Using a 20 nm-thin InAlAs layer between the laser ridge sidewalls and the InP:Fe insulating layers we improve the crystal quality of the interface while preserving the high electrical-resistivity of the overgrownmaterial. This optimized regrowth sequence has led to cw-operation in the 100-210 K temperature range of a 7 μm-wide BH-QCL with an emission wavelength of 5.4 μm. The measured thermal conductance in this temperature range is Gth = 1400-500 W/Kcm2, which is comparable with the state of the art BH-QCLs regrown using metal-organic vapor-phase epitaxy (MOVPE).

HL 108.20 Thu 17:00 P1

Impact of elastic- and inelastic scattering on the performance of quantum-cascade lasers — •Yuri V. Flores, Sergii S. Kurlov, Mikaela Elagin, Grygorii Monastyrskyi, Mykhaylo P. Semtsiv, and W. Ted Masselink — Department of Physics, Humboldt University Berlin, Newtonstr. 15, D-12489 Berlin, Germany

Elastic- and inelastic scattering are the principal components of the leakage current in quantum-cascade lasers. Their understanding is very important, since the leakage current has a considerable impact on the overall performance of quantum-cascade lasers. In particular, this current affects two vital characteristics: The threshold current and the quantum efficiency. A large leakage current reduces the injection efficiency into the upper laser state which implies that more electrons need to be injected into the device in order to achieve the required population inversion, increasing ultimately the threshold current and reducing the quantum efficiency.

In this contribution, we analyze the relative magnitudes of the elastic- and inelastic components of the leakage current. The inelastic part is modeled as a two-particle process involving an electron and a LO-phonon. The elastic non-radiative process considers that an electron can increase- or lose its potential energy due to the roughness of the layers' interfaces. These two components are modeled and its dependence on the lattice and electron-temperatures is analyzed.

HL 108.21 Thu 17:00 P1

Phenomenological model for simulation of mid-infrared quantum cascade lasers — •Sergii S. Kurlov, Yuri V. Flores, Mikaela Elagin, Mykhaylo P. Semtsiv, and W. Ted Masselink — Humboldt University Berlin, Institute of Physics, Newtonstrasse 15, D-12489 Berlin, Germany

A phenomenological scattering-rate model for THz quantum cascade lasers is extended for mid-infrared (MIR) quantum cascade lasers (QCLs) by accounting for the energy dependence of the intersubband scattering rate beyond the phonon energy. This energy dependence is obtained from the fit of the intersubband scattering rates based on published life-times of a number of MIR QCLs. The model is currently built under assumption of low temperature, i. e., neglecting the phonon absorption by charge carriers. Using the model and solving the rate equations with periodical boundary conditions we found a good agreement with a number of published MIR QCLs in terms of current-voltage-, power-current-, and spectral-gain-characteristics. We demonstrate the matching of the modelled results and the low-temperature experimental data for a broad-gain quantum cascade laser, where gain broadening with the current (voltage) is essential.

HL 108.22 Thu 17:00 P1

Characterization of Quantum Cascade Lasers in the Terahertz Regime — •Negar Hekmat[1,2], Hanond Nong[1], Shovon Pal[1,2], Michael Kwiatek[2], Arne Ludwig[2], Paul Dean[3], Edmund Linfield[3], Andreas D. Wieck[2], and Nathan Jukam[1] — [1]AG Terahertz-Spektroskopie und Technologie, Ruhr-Universität Bochum, Germany — [2]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Germany — [3]School of Electrical Engineering, University of Leeds, UK

Quantum cascade lasers (QCLs) are powerful radiation sources in mid- and far-infrared regions with potential applications in imaging, sensing and spectroscopy. QCLs are unipolar semiconductor devices based on intersubband transitions. The active region of the QCL is a periodic sequence of modules made of multiple quantum wells. The electrons are transported in a 'cascading' scheme where several photons are generated by a single electron. QCLs are often fabricated by Molecular Beam Epitaxy (MBE), which precisely controls the thickness of the quantum wells and barriers. Terahertz time domain spectroscopy (THz-TDS) was used to characterise a THz QCL operating at 2.26 THz. The GaAs/AlGaAs QCL was cleaved and mounted on a cryostat sample holder. The Current-Voltage characteristic of the QCL was investigated in the range of 10-70 K. The gain of THz QCL was also studied with and without radio frequency (RF) pulses. Gain clamping was observed when the RF pulse was off and the QCL was biased above threshold. However, with the RF pulse on and the QCL biased below threshold, the THz pulse amplitude through the QCL increased.

HL 108.23 Thu 17:00 P1

Sub-Monolayer-Control in Epitactic Growth of Quantum Cascade Lasers — •Michael Kwiatek[1], Negar Hekmat[1,2], Arne Ludwig[1], Nathan Jukam[2], and Andreas D. Wieck[1] — [1]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Deutschland — [2]AG Terahertz-Spektroskopie und Technologie, Ruhr-Universität Bochum, Deutschland

A quantum cascade laser (QCL) consists of multiple vertically stacked semiconductor modules including several well-dimensioned quantum wells. In QCLs intersubband transitions in the conduction band generate the laser light. Due to QCL's cascading structure, one electron generates multiple photons. The production of good QCLs sets high demands on the fabricating process, especially on the layer quality of the quantum wells and barriers, why QCL fabrication is often performed with Molecular Beam Epitaxy (MBE). A known problem in MBE is the shutter transient of the effusion cells (EC). When the EC-shutter is closed, the heat of the EC is reflected back in itself. If the shutter is opened, more power is needed to stabilize the temperature and hence the material flux of the EC. For QCLs very thin material layers of only a few monolayers with high precision are crucial. The time the EC needs to stabilize leads to a change in the growth rate for those thin layers. Our goal is the reduction of the shutter transient effect on the QCL's layer structure. Therefore we want to investigate the time dependent growth rate change of the EC and apply countermeasures like aligned PID control parameters and/or an adapted shutter design.

HL 108.24 Thu 17:00 P1

Photocapacitance change in YMnO3-based MIFS in the visible light regime — •O S Choudhary[1], A Bogusz[1], L P Selvaraj[1], V John[1], D Bürger[1], I Skorupa[1], A Lawerenz[2], O G Schmidt[1,3], and H Schmidt[1] — [1]Faculty of Electrical Engineering and Information Technology, Chemnitz University of Technology, 09107 Chemnitz, Germany — [2]CiS Forschungsinstitut für Mikrosensorik und Photovoltaik GmbH, 99099 Erfurt, Germany — [3]Institute for Integrative Nanosciences, IFW Dresden, 01069 Dresden, Germany

YMnO3 is one of the few materials that exhibit ferroelectricity and antiferromagnetism. Metal-YMnO3-metal thin film structures can be switched between a high resistance state (HRS) and a low resistance state (LRS), when a positive and negative writing bias is applied, respectively. This work investigates the effect of light-irradiation on the capacitance of YMnO3-based metal-ferroelectric-insulator-semiconductor (MFIS) structures. The DC bias for the capacitance measurements was swept from +10 to -20 V and back under different light-irradiation at a sweep rate of ca. 103 mV/s. It has been found that under dark conditions two nonvolatile capacitance minima exists at -11 and at -3.55 V, possibly when the YMnO3 is in the LRS and HRS state, respectively. If we rewrite the +10 and -20 V branch in shorter period of time then, low capacitance state (LCS) is non-volatile and pseudo volatile, respectively. Under illumination the capacitance at the two minima increases in the visible spectral range, depending on the wavelength illumination, YMnO3 thickness and YMnO3 capacitance state.

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In-Plane-Gate transistors as gas sensors — •Benjamin Feldern, Arne Ludwig, and Andreas Wieck — Ruhr-Universität Bochum, Bochum, Deutschland

We propose In-Plane-Gate transistors [1] based on MBE grown GaAs/Al_xGa_{1-x}As heterostructures with etched trenches for the detection of gases and liquids[2] at the surface of our devices. Additionally the gases or liquids are to be irradiated with THz light for the excitation of resonant states of the molecules.

It is to be determined whether the structures are capable of analyzing the gases and liquids by their dielectric function. Different gases and liquids shall be analyzed using these structures and the THz radiation. Possible interaction with passivated surfaces shall be examined.

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[2]] J. Kettle, S. Whitelegg, A.M. Song, D.C. Wedge, L. Kotacka, V. Kolarik, M.B. Madec, S.G. Yeates, and M.L. Turner, "Fabrication of planar organic nanotransistors using low temperature thermal nanoimprint lithography for chemical sensor applications", Nanotechnology 21 075301 (2010).

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GaAs nanowires based avalanche photo diodes — Stepan Shvarkov[1], •Wadim Quiring[2], Artur Zrenner[2], Arne Ludwig[3], Andreas Dirk Wieck[3], and Dirk Reuter[1] — [1]Optoelektronische Materialien und Bauelemente, Universität Paderborn, D-33098 Paderborn — [2]Optoelektronik und Spektroskopie an Nanostrukturen, Universität Paderborn, D-33098 Paderborn — [3]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, D-44780 Bochum

Modern planar Si-based avalanche photo diodes (APD) show very high multiplication factors and low dark currents, which makes Si-based planar APDs a versatile detector for single photon detection (SPD). However, in the optical C-band (1.55 μm), these detectors cannot be used and planar APDs based on III-V semiconductors show rather high dark currents. This is a severe drawback for applications in quantum communications. APDs based on nanowires can be an approach to overcome this problem. In the current work we present GaAs nanowire APDs based on planar MBE growth. The nanowires are realized in several nanofabrication steps. First a lateral p-i-n junction is defined by implanting a nominally undoped GaAs layer on an $Al_{0.95}Ga_{0.05}As$ buffer layer with Be and Si. The length of the i-region is approximately 10 μm.By electron beam lithography and reactive ion etching nanowires are defined so that one end of the wire is lying in p- and another in n-type regions of the GaAs. The resulting devices show a clear rectifying current-voltage characteristic and allow for large reverse bias before breakdown. Under illumination a large internal amplification is observed, which is attributed to avalanche multiplication.

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Transparent *p*-CuI/*n*-ZnO heterojunction diodes — •Friedrich-Leonhard Schein[1], Tammo Böntgen[1,2], Jörg Lenzner[1], Michael Lorenz[1], Holger von Wenckstern[1], and Marius Grundmann[1] — [1]Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnéstraße 5, 04103 Leipzig, Germany — [2]present address: Laser Zentrum Hannover e.V., Hollerithallee 8, 30419 Hannover, Germany

We have investigated the wide bandgap ($E_g = 3.1\,\text{eV}$) *p*-type semiconductor γ-copper(I)-iodide (CuI) [1,2] as an alternative candidate to *p*-type transparent semiconducting oxides like SnO [3] or $ZnCo_2O_4$ [4]. Two facile methods were used to fabricate CuI thin-films, either iodization of metallic Cu films or thermal evaporation of CuI powder. Hall-effect measurements of these transparent CuI films revealed a hole mobility of about $5-15\,\text{cm}^2/\text{Vs}$, a hole density of $(0.2-3)\times10^{19}\,\text{cm}^{-3}$ and a resistivity of $0.1-0.2\,\Omega\text{cm}$. Atomic force and scanning electron microscopy as well as X-ray diffraction and optical transmission measurements of CuI on glass substrates and on *c*-ZnO will be discussed.

Heterostructures consisting of *p*-CuI on pulsed-laser deposited *n*-ZnO were fabricated on *a*-sapphire substrates and characterized electrically. The diodes showed large rectification ratios $I_f/I_r > 10^7$ at $\pm2\,\text{V}$ and ideality factors down to 1.5.

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ZnO-based inverter as biosensors — •Agnes Holtz, Fabian Klüpfel, Holger von Wenckstern, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Abteilung Halbleiterphysik, Linnéstr. 5, 04103 Leipzig

Transparent semiconducting oxides find application as switching transistor within active-matrix displays. Another interesting field of application is the integration of such transistors within multi electrode biosensor arrays. These can be used to measure the change of membrane potential of externally stimulated nerve cells cultivated on the transparent amplifier. This would permit to synchronously study the nerve cells visually and electrically providing means to establish connections between the arrangement of cells and their "communication" behavior. The inverter amplifies the cell signals directly at the measurement electrodes. This might result in a higher signal-to-noise ratio due to the short path between electrode and amplifier. The ZnO layer was deposited by pulsed-laser deposition on a-plane sapphire substrate. We compared inverters comprising field effect transistors with different gate materials such as Au, PtO_x or $ZnCo_2O_4$. The epoxy based photo resist SU 8 was used to encapsulate the chip against the elektrolyte. The inverters were characterized electrically by IU and frequency dependent measurements at room temperature. The maximal slope we measure is 80. We use simple inverters consisting of two transistors because of the high amplification and the low space requirements. To ensure measuring at the point of highest amplification of the inverter characteristics an external amplifier circuit was developed.

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Optical gas sensing by micro-photoluminescence on single ZnO nanowires — •Julian Jakob, Manfred Madel, Sebastian Bauer, Florian Huber, and Klaus Thonke — Institute of Quantum Matter / Semiconductor Physics Group, Ulm University

Nanostructures are very promising candidates for gas sensing applications due to their high surface to volume ratio. Adsorption of oxidative and reductive gases causes a typical band bending near the surface, which leads to a change in the thickness of the depletion layer. In micro-photoluminescence measurements this results in a change of the emission intensity when switching between different ambient gas atmospheres.

An improvement of the sensitivity could be achieved by the use of different metal catalysts evaporated onto the nanowire surface. Investigations of single nanowires enable conclusions of the effect of nanowire form and diameter, and the sensitivity relating to different gas-atmospheres.

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Fast read and write operations in quantum dot-based memory devices — •C. Pillich[1], D. Zhou[1], A. Beckel[1], D. Bimberg[2], T. Nowozin[2], M. Geller[1], and A. Lorke[1] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen, Lotharstraße 1, 47057 Duisburg, Germany — [2]Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

Self-assembled quantum dots (QDs) are ideally suited as building blocks for memory devices. Large localization energies enable long information storage and times up to 1.6 s at room temperature have already been demonstrated.[1]

Here we use a memory structure with a layer of QDs as floating gate in a high electron mobility transistor (HEMT). The HEMT is used to prepare and read the charge information of the QDs filled with 0, 2 or up to 6 electrons each, with single charging state resolution.[2]

In comparison with conventional flash memory, high bandwidth capability for writing and reading operations is desirable. Here we demonstrate read-out times down to 3 ns at a temperature of $T = 4$ K and the capability of writing the information by hot charge injection, which can be used to enhance the ratio between writing and storage times.

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Low-density InP-based quantum dots emitting at 1.5 μm telecom wavelength range — •Matusala Yacob, Johann Peter Reithmaier, and Mohamed Benyoucef — Institute of Nanostructure Technologies and Analytics (INA), Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Germany

Self-assembled semiconductor quantum dots (QDs) can be used as building blocks of quantum information processing. For this application low density circular QDs operating in the telecom wavelength bands should be realized. The InP material system is a possible candidate to achieve this goal due to its low lattice mismatch (3.2%) to the InAs QD material. In this work, low-density InAs QDs are grown using post-growth annealing on AlGaInAs surfaces lattice matched to InP by solid-source molecular beam epitaxy. The dots are then covered with an AlGaInAs layer using a special capping procedure. Spatially separated largely sized QDs with a surface dot density of 5 dots per square μm are obtained using this technique. Optimized QD structures grown on a distributed Bragg reflector exhibit single QD emission at around 1.5 μm with a narrow excitonic linewidth below 50 μeV.