HL 36: II-VI- and III-V-semiconductors

Time: Thursday 9:30–13:00 Location: H31

HL 36.1 Thu 9:30 H31

Optical properties of ZnSe-based microcavities — •Wilken Seemann[1], Alexander Kothe[1], Gesa Schmidt[2], Alexander Pawlis[2], and Jürgen Gutowski[1] — [1]Institute of Solid State Physics, Semiconductor Optics, University of Bremen, 28359 Bremen, Germany — [2]Peter Grünberg Institute (PGI-9), Forschungszentrum Jülich, 52425 Jülich, Germany

In the past years microcavities and microdisks have been shown to be a well-suited platform for the realization of low-threshold and thresholdless lasers since a small volume of the gain medium and strong containment of light can be achieved [1]. Particular interest has been directed towards whispering gallery modes (WGM) in microdisks which propagate along the border of the disk by total reflection and are therefore strongly contained. Such lasing modes were also realized in VCSEL-micropillar structures with quantum dots as gain medium [2].

Here, we analyse II-VI micropillar-microcavities and microdisks by means of micro-photoluminescence (μPL) and time-resolved μPL studies. The micropillar-microcavities were manufactured by cutting vertical 1λ-cavities with three quantum wells situated between distributed Bragg reflectors (DBRs) through focused ion beam (FIB) etching. Both the micropillar-microcavities and the microdisks exhibit diameters of a few micrometers. The results obtained from microdisk and micropillar structures are compared and their influence on the containment and the modes is discussed.

[1] L. He et al.: Laser & Photonics reviews 7(1), 2013, 60.

[2] V. N. Astratov et al.: Applied Physics Letters 91(7), 2007, 071115.

HL 36.2 Thu 9:45 H31

Photoluminescence Excitation Spectroscopy with Two-Photon Absorption on Excitons in Cu_2O — •Andreas Farenbruch, Johannes Mund, Dietmar Fröhlich, Dmitri R. Yakovlev, and Manfred Bayer — Technische Universität Dortmund, Germany

Exciton states in Cu_2O semiconductor are investigated by means of the photoluminescence excitation spectroscopy with two photon absorption (2P-PLE). Picosecond laser pulses are used to address the excitons with principal quantum numbers of 2, 3 and 4 in three different crystal directions. Comparison with second harmonic generation (SHG) spectra shows, that 2P-PLE can be allowed in SHG forbidden directions. Rotational anisotropy diagrams of the 2P-PLE signal in linear polarizations are measured and compared to model calculations based on group theory. The studies are also performed for magneto-excitons in magnetic fields up to 10 Tesla.

HL 36.3 Thu 10:00 H31

Second Harmonic Generation from the yellow 1S exciton in Cu_2O in symmetry forbidden geometries — •Johannes Mund, Christoph Uihlein, Dietmar Fröhlich, Dmitri R. Yakovlev, and Manfred Bayer — Experimentelle Physik 2, Technische Universität Dortmund, Germany

We observe second harmonic generation (SHG) from the 1S exciton resonance of the yellow exciton series in Cu_2O in four crystal orientations. For the light k-vector orientation parallel to [001] and $[\bar{1}10]$ SHG should be symmetry forbidden [1]. The observed signals are explained by a band structure induced splitting of the 1S components and their mixing by residual strain in the samples. Measurements at the higher exciton resonances and a microscopic theory confirm that this effect can only be observed at the 1S exciton of relatively long lifetime, while the SHG of higher excited excitons is properly described by group theory.

[1] J. Mund et al., PRB 98, 085203 (2018)

HL 36.4 Thu 10:15 H31

Proof of principle experimental proposal for orbital control of exchange interactions between dopants in silicon — •Eleanor Crane[1], Alexander Schuckert[2], Nguyen Le[3], and Andrew Fisher[1] — [1]London Centre for Nanotechnology, University College London, London WC1H 0AH, United Kingdom — [2]5 Department of Physics, Technical University of Munich, 85748 Garching, Germany — [3]Advanced Technology Institute and Department of Physics, University of Surrey, Guildford GU2 7XH, United Kingdom

Randomly-doped silicon has many competitive advantages in the context of quantum computation; not only is it fast to fabricate but it could naturally contain high numbers of qubits and logic gates. One such logic gate relies on Heisenberg interactions between donor orbital states of two different dopant species. We use the Moving Average Cluster Expansion technique to make predictions for a proof of principle experiment demonstrating the control of one species by the orbital excitation of another.

15 min break

HL 36.5 Thu 10:45 H31

Molecular Beam Epitaxy Growth and Temperature-Dependent Electrical Characterization of Carbon-Doped GaAs on GaAs(111)B — •Tobias Henksmeier, Alexander Trapp, Stepan Shvarkov, and Dirk Reuter — Department of Physics, University of Paderborn, Warburger Straße 100, Germany

Molecular beam epitaxy (MBE) of III-V semiconductors on (111)-oriented surfaces has gained much interest in recent years due to the high symmetry of this surface. Carbon serves as a suitable p-type dopant on such surfaces.

We present a study of carbon doping of GaAs layers on (111)B semi-insulating 3" GaAs substrates with a 1° miscut towards (211) employing a heated graphite filament carbon source. GaAs(111)B samples of different carbon concentrations up to $N = 3 \times 10^{20}$ cm^{-3} were fabricated. Atomic force microscopy revealed smooth surfaces up to the highest carbon concentration. The overall carbon concentration was determined by SIMS and Hall measurements in van-der-Pauw geometry revealed p-type conductivity for all samples. Carrier freeze out was observed for low carbon concentrations at low temperatures while an almost temperature-independent conductivity and hole concentration is observed above $N = 1 \times 10^{19}$ cm^{-3} which indicates degeneracy. Almost 100 % of the carbon is incorporated as an acceptor up to $N = 1 \times 10^{19}$ cm^{-3}. For higher concentrations, compensation sets in. The carbon activation energy in the GaAs(111)B oriented sample is determined by photoluminescence measurements to 26.3 meV and is verified by a hole density Arrhenius plot.

HL 36.6 Thu 11:00 H31

XPS and Disorder Analysis of Quaternary Ga1-xInxAs1-yBiy Semiconductor Alloys — •Julian Veletas[1], Thilo Hepp[2], Kerstin Volz[2], and Sangam Chatterjee[1] — [1]Institute of Experimental Physics I and Center for Materials Research, Justus-Liebig-University Giessen, D-35392 Giessen — [2]Faculty of Physics and Materials Sciences Center, Philipps-Universität Marburg, D-35032 Marburg

The incorporation of small fractions of bismuth atoms in III-V semiconductors such as Ga1-xInxAs1-yBiy leads to a decrease of the band gap energies and increase of the spin-orbit splitting energies of the alloy. This is attributed to an anti-crossing between the Bi-level with the valence bands of the matrix. Eventually the band gap energies may even get smaller than the spin-orbit splitting energy beyond certain fractions of bismuth incorporation into Ga1-xInxAs1-yBiy alloys. This is expected to lead to a suppression of non-radiative Auger recombination. However, growth of such materials remains challenging due to the required low growth temperatures. Furthermore, characterization is challenging due to similar influences of In and Bi incorporation on major electronic and structural properties, such as the band gap energy and the lattice constant.

In this study, we complement standard characterization techniques with XPS. We show the influence of different partial pressures of the MOVPE growth on the bismuth segregation process as well, as on the alloy elemental composition. Using the VBAC model, the optical spectroscopy data reassemble the determined composition and a connection between disorder signatures and growth conditions is made.

HL 36.7 Thu 11:15 H31

Role of Bismuth in the Bandstructure of Ga(As,Bi) studied by Photomodulated Reflectance Spectroscopy — •Frederik Otto[1], Julian Veletas[1], Lukas Nattermann[2], Kerstin Volz[2], and Sangam Chatterjee[1] — [1]Institute of Experimental Physics I, Justus-Liebig-University Giessen, Heinrich-Buff-Ring 16, D-35392 Giessen, Germany — [2]Faculty of Physics and Materials Sciences Center, Philipps-Universität Marburg, Hans-Meerwein-Str., D-35032 Marburg, Germany

Dilute bismuth-containing III-V semiconductor alloys exhibit several novel electronic properties, such as a rapidly reducing band gap with increasing bismuth concentration. This allows for a wide scope of band gap engineering in the near infrared (NIR) region. This is of significant interest for optimizing the efficiency of semiconductor lasers in the NIR. In particular, the incorporation of bismuth increases the spin-orbit split-off energy. This, in turn, potentially suppresses non-radiative Auger recombination. In addition, the incorporation of bismuth causes a heavy-hole (hh) and light-hole (lh) splitting at the Γ-point due to a reduction in tetrahedral symmetry of the zinc-blende structure. We conducted photomodulated reflectance and photoluminescence spectroscopy on a series of MOVPE grown Ga(As,Bi)-samples with varying bismuth concentration in order to get detailed information about the bismuth-induced change in band gap energy and the optical properties connected to the lifting of the hh-lh degeneracy at the Γ-point.

HL 36.8 Thu 11:30 H31

Tunable plasmonics in heavily doped GaAs via ion implantation and sub-second annealing — •juanmei duan[1,2], mao wang[1,2], manfred helm[1], wolfgang skorupa[1], shengqiang zhou[1], and slawomir prucnal[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Institute of Ion Beam Physics and Materials Research, Bautzner Landstrasse 400, D-01328 Dresden, Germany — [2]Technische Universität Dresden, D-01062 Dresden, Germany

Semiconductors with ultra-high doping level are attractive for the near- and mid-infrared plasmonics. The III-V compound semiconductors are characterized by high electron mobility and low effective mass, where the plasma edge can be tuned by tailoring the doping level. In this work, we present the formation of heavily doped p- and n-type GaAs utilizing ion implantation of Te, S and Zn, followed by sub-second annealing. We demonstrate that either the millisecond range flash lamp annealing (solid phase epitaxy) or nanosecond range pulsed laser annealing (liquid phase epitaxy) is able to recrystallized the implanted layers and electrically activate the dopants.The carrier concentration in the heavily doped p- and n-type GaAs with sub-second annealing treatment is in the range of 1019~1020 cm-3. The plasmonic properties of implanted and annealed GaAs samples were investigated by Fourier transform infrared spectroscopy (FTIR) and Raman spectroscopy. The obtained ultra-highly GaAs films display a room-temperature plasma frequency above 2200 cm-1, which enables to exploit the plasmonic properties of GaAs for sensing in the mid-infrared spectral range.

HL 36.9 Thu 11:45 H31

Zeeman splitting features of novel III-V wurtzite materials — •Paulo E. Faria Junior[1], Davide Tedeschi[2], Marta De Luca[2,3], Benedikt Scharf[1,4], Antonio Polimeni[2], and Jaroslav Fabian[1] — [1]University of Regensburg — [2]Sapienza Università di Roma — [3]University of Basel — [4]University of Würzburg

The behavior of semiconductors under external magnetic fields provides valuable insight into their spin-dependent properties. Here, we investigate the Zeeman splitting features of novel III-V wurtzite materials, namely InP, InAs, and GaAs[1]. First, we present the values of the effective g-factors highlighting the important contribution of spin-orbit coupling effects. Moving to the Landau level picture, we discuss the intrinsic common features that give rise to the nonlinear Zeeman splitting, recently explained in magneto photoluminescence experiments for InP nanowires[2]. Focusing on the important Landau level coupling we derive an analytical model to fit the experimental nonlinear Zeeman splitting, applying it to InP and GaAs. We show that our analytical model correctly describes the physics of the nonlinear features and extrapolating our results, we predict the Zeeman splitting to reach a maximum value at magnetic fields larger than 30 T. [1] Faria Junior et al., arXiv:1811.09288 (2018). [2] Tedeschi et al., arXiv:1811.04922 (2018). Supported by: Alexander von Humboldt Foundation, Capes (grant No. 99999.000420/2016-06), SFB 1277 (B05), SFB 1170 'ToCoTronics', the ENB Graduate School on Topological Insulators, Awards2014 and Avvio alla Ricerca (Sapienza Università di Roma).

HL 36.10 Thu 12:00 H31

1D photonic bandgap structures for high-power GaN/InGaN laser devices — •Prabha Sana[1], Christoph Berger[1], Marc Peter Schmidt[2], Gordon Schmidt[1], Armin Dadgar[1], Jürgen Bläsing[1], Martin Deckert[2], Hartmut Witte[1], Jürgen Christen[1], and André Strittmatter[1] — [1]Institut für Physik, Otto-von-Guericke Universität, Universitätsplatz 2, 39106 Magdeburg, Germany — [2]Fakultät für Elektrotechnik und Informationstechnik, Otto-von-Guericke Universität Magdeburg, Universitätsplatz 2, 39106 Magdeburg, Germany

Work reports the development of InGaN/GaN edge emitting laser with single mode 400-460 nm emission using the concept of photonic band gap crystals (PBC) to achieve vertical fundamental mode operation up to maximum power injection and reduction in vertical far field divergence. The laser structure consists of three InGaN/GaN quantum wells (QWs) as active region grown on a PBC superlattice of 35-pairs of lattice-matched GaN (220 nm)/InAlN (30 nm). The PBC periodically modulates the refractive index in the lower n-doped waveguide section, which helps to discriminate the higher order modes to obtain single mode lasing action. Basic PBC optimization parameters i.e. number of PBC pairs and layer thicknesses are obtained by CAMFR simulation. Investigations on doping of the PBC with Si or Ge were performed in order to achieve low optical losses and reduce the series resistance. Furthermore, the InGaN/GaN multi quantum well region and design of the Mg-doped AlGaN electron blocking layer were studied to achieve a reduced penetration of the optical mode into the p-doped cladding.

HL 36.11 Thu 12:15 H31

Colloidal InP-based Quantum Dot Emitters: Limiting Factors for Color Purity — •Michael Binder[1], Alexander F. Richter[1], Alexander S. Urban[2], Itai Lieberman[3], Thomas Eberle[3], and Jochen Feldmann[1] — [1]Chair for Photonics and Optoelectronics, LMU München — [2]Nanospectroscopy Group, LMU München — [3]Merck KGaA, Darmstadt

Colloidal quantum dots (cQDs) with an InP-based core/shell structure are promising for light emitting applications as non-toxic alternatives to colloidal cadmium-based QDs. Up to now it is still a challenge to compete with the narrower emission bandwidth of Cd-cQDs which is needed for high color purity in applications such as displays. Here, we investigate the nature of photoluminescence (PL) peak broadening by means of single cQD spectroscopy. It turns out that the PL bandwidth of individual InP-based cQDs is comparable to their Cd-based counterparts. Therefore broadening of the ensemble emission bandwidth can only be attributed to larger size-inhomogeneity. The latter is also responsible for non-radiative energy transfer between closely-spaced cQDs which red-shifts the ensemble PL peak. This effect can be dynamically followed in the spectrally resolved PL-decay. Altogether we conclude that there are no intrinsic drawbacks for InP cQDs regarding color purity of a light emitting device as compared to Cd-based cQDs.

HL 36.12 Thu 12:30 H31

Tunneling in coupled co-directional polariton waveguides — •Johannes Beierlein[1], Martin Klaas[1], Holger Suchomel[1], Tristan H. Harder[1], Karol Winkler[1], Monika Emmerling[1], Oleg Egorov[1], Hugo Flayac[2], Christian Schneider[1], Sebastian Klembt[1], and Sven Höfling[1,3] — [1]Technische Physik, Universität Würzburg, Germany — [2]Institute of Theoretical Physics, EPFL,Lausanne, Switzerland — [3]School of Physics and Astronomy, University of St. Andrews, United Kingdom

We investigate the coupling of waveguides supporting exciton-polariton condensates. A relevant and most simple device to study is the codirectional coupling device, where two waveguides are connected by a half-etched section which facilitates tunable coupling of the adjacent channels. This evanescent coupling of the two macroscopic wavefunctions in each waveguide reveals itself in oscillations of the condensate. By designing gap width and channel length, the exit port of the polariton flow can be chosen. Continuing from here, we show numerical simulations, sample designs and first experimental results for waveguide-arrays with the goal of observing Bloch oscillations and realizing a topologically protected mode in a Su-Schrieffer-Heeger framework with polariton waveguides.

HL 36.13 Thu 12:45 H31

Laser-assisted local metalorganic vapor phase epitaxy — •Max Trippel, Matthias Wieneke, Armin Dadgar, and André Strittmatter — Institut für Physik, Otto-von-Guericke Universität Magdeburg- Universitätsplatz 2, 39106 Magdeburg Germany

Up to now, an unsolved problem of integration between Si and III/V semiconductor materials is the misfit between optimum III/V growth conditions and Si electronics. We propose laser-assisted local III/V epitaxy based on metalorganic vapor phase epitaxy (MOVPE) to resolve the growth-temperature related incompatibility of both worlds. GaAs-on-Si has been chosen as the first epitaxial system to study due to its well-known behavior in MOVPE.

In order to identify conditions where local epitaxial GaAs growth proceeds similar to full wafer growth, finite element multi-physics simulations were performed. We therefore calculated temperature profiles, distribution of species, and resulting reaction rates within the heated area. A reduced lateral extension of the growth area with respect to the heated area is found which correlates with the pyrolithic decomposition of the metalorganics.

Accordingly, we have developed our own MOVPE tool. Our epitaxy system comprises a conventional gas mixing cabinet, a stainless-steel vertical growth reactor, a xyz-movable substrate holder, and a temperature-controlled laser-heater. The substrate is clamped vacuum-tight against a non-rotating susceptor plate and can be cooled with helium. Pyrometric temperature measurement is done in the center of the laser spot being as small as 150 m in diameter.