HL 64: Poster II

This poster session includes contributions from the following topics: - Quantum dots and wires - Semiconductor lasers - Spin phenomena in semiconductors. - Focus Session: Integrated Quantum Photonics

Please put up your poster at the beginning of the sessions and remove the poster immediately after the session. The person peresenting the poster should attend it for at least half of the session duration (90 minutes) and indicate the time when to find him/her at the poster.

Time: Thursday 10:00–13:00 Location: P1A

HL 64.1 Thu 10:00 P1A

Unidirectional optical frequency comb injection of multi-section quantum well lasers — •Jan Lautenschläger[1], Christoph Weber[1], Dominik Auth[1], Andreas Klehr[2], Andrea Knigge[2], and Stefan Breuer[1] — [1]Institute of Applied Physics, Technische Universität Darmstadt, 64289 Darmstadt, Germany — [2]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Straße 4, 12489 Berlin, Germany

Unidirectional optical injection is a versatile concept to transfer optical properties from a master optical frequency comb laser into a slave optical frequency comb laser. Thereby the optical frequency comb stability of the slave device could be improved and the optical comb broadened. By studying optical injection of two similiar multi-section monolithic quantum-well lasers emitting at 1070 nm with different biasing schemes, an optical frequency comb generated by passive mode-locking is injected into a single-mode laser and the optical and radio-frequency properties of the light emitted by the slave laser are studied. We identify an optical frequency comb generation in the slave device and analyze regimes of injection locking.

HL 64.2 Thu 10:00 P1A

Continuous-wave room-temperature tunable THz-generating laser — •Ksenia Fedorova, Heyang Guoyu, Matthias Wichmann, Christian Kriso, Fan Zhang, Wolfgang Stolz, and Arash Rahimi-Iman — Faculty of Physics and Materials Sciences Center, Philipps-Universität Marburg, Renthof 5, D-35032 Marburg, Germany

High-performance, room-temperature, continuous-wave (CW), tunable terahertz (THz) lasers are desirable sources for THz applications ranging from THz spectroscopy and imaging to safety and security applications. So far, THz-generation at room temperature has been mostly targeted by direct quantum cascade lasers. An alternative to that has been provided by THz-generating semiconductor disk lasers (SDLs) based on intracavity frequency conversion in periodically-poled nonlinear crystals. They can allow the demonstration of efficient THz emission in the 0.8-to-2-THz spectral window based on difference-frequency generation. Several studies have so far demonstrated non-tunable THz output from such SDL-based devices with remarkable beam quality. Here, a room-temperature, CW, tunable THz-generating SDL is demonstrated. We employ a dual-wavelength SDL with an intracavity aperiodically-poled lithium niobate crystal for difference-frequency generation in the 0.8-to-1.1 THz spectral window.

HL 64.3 Thu 10:00 P1A

Dispersion effects in passivley mode-locked lasers — •Jan Hausen[1], Christian Schelte[2,3], Julien Javaloyes[2], Svetlana V. Gurevich[2,3], and Kathy Lüdge[1] — [1]TU Berlin, Hardenbergstrasse 36, 10623 Berlin — [2]Universitat de les Illes Balears, Cra. de Valldemossa, km 7.5. Palma (Illes Balears) — [3]WWU Münster, Wilhelm-Klemm-Strasse 9, 48149 Münster

Haus master equation approaches have been utilized to unravel the dynamics of many different types of mode-locked lasers. Their key advantages are an intuitive understanding of the interplay of different effects such as gain and absorption as well as the fact that chromatic dispersion can be included much more easily than in the delay differential equations framework. However, to justify the validity of such Master equations for passively mode-locked lasers with an external cavity geometry that is neither in the long nor in the short cavity limit, a special set of dynamical boundary conditions is developed. The resulting system of coupled partial and ordinary differential equations allows for a uniform approach for studying instabilities either induced by dispersive effects or gain saturation in mode-locked laser irrespective of the cavity lengths.

HL 64.4 Thu 10:00 P1A

Voltage source control for passively mode-locked semiconductor lasers — •Pascal Sauer, Dominik Auth, Christoph Weber, and Stefan Breuer — Institute of Applied Physics, Technische Universität Darmstadt, 64289 Darmstadt, Germany

Monolithic passively mode-locked semiconductor lasers are compact versatile light sources emitting ultrashort optical pulses at high repetition rate. For pulse generation a forward biased gain section and a reverse biased saturable absorber section are implemented in one device. The negative voltage applied to the absorber does not need to be modulated, but is injected using a standard low-noise voltage source. In this contribution, we present a micro-controller based robot which can be interfaced by standard laboratory control software for automatic high-resolution mode-locking performance mapping using non-remote voltage sources.

HL 64.5 Thu 10:00 P1A

Nanowire lasers modified by electron irradiation — Gesine Theess, •Francesco Vitale, Maximilian Zapf, and Carsten Ronning — Institute of Solid State Physics, Friedrich Schiller Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany

Understanding the linear and nonlinear optical properties of semiconductor nanowires (NWs) is crucial for their envisaged integration into next-generation optoelectronic devices. In this work, the emission of optically pumped VLS-grown ZnO NW lasers was examined in situ in a cathodoluminescence apparatus as a function of the electron beam irradiation. A contrasting behavior between measurements in the spontaneous and stimulated emission regime was found: the spontaneous emission shows a distinct maximum after several minutes of irradiation, followed by a substantial decrease before saturation, while the stimulated emission decreases monotonically. In particular, the influence of defects was studied in relation to the modification of the optical and electronic properties induced by the electron beam.

HL 64.6 Thu 10:00 P1A

Electron pair charging in gate-defined quantum dots in indium antimonide nanowires — Felix Jekat[1], Benjamin Pestka[1], Sasa Gazibegovic[2,3], Diana Car[2,3], Sebastian Heedt[3], •Marcus Liebmann[1], Thomas Schäpers[4], Erik Bakkers[2,3], and Markus Morgenstern[1] — [1]II. Phys. Inst. B, RWTH Aachen Univ., Germany — [2]Dept. of Appl. Phys., Eindhoven Univ., The Netherlands — [3]Qutech and Kavli Inst. of Nanoscience, Delft, The Netherlands — [4]PGI-9, FZ Jülich, Germany

We investigate InSb nanowires placed on bottom gates with mechanically exfoliated hexagonal boron nitride (h-BN) as a dielectric. The sample consists of five 50 nm wide finger gates with a spacing of 30 nm. The h-BN is placed on top of the finger gates. The nanowires are then placed mechanically onto h-BN. We present transport measurements on gate-defined quantum dots at temperatures down to 300 mK. Due to the dielectric, the time stability of our device improved to around 5 μeV/h. The charge stability diagram shows Coulomb diamonds with a charging energy of 2.3 meV and an orbital energy of 0.3 meV. In a perpendicular magnetic field, the zero bias state splits at around 380 mT with a doubling of the gate-periodicity below and above the transition field. This splitting resembles the one reported on nanowires partially covered by superconductors. But since in our sample there is no superconductor involved, the doubling is of unknown origin. However, the change in periodicity implies a change of the pairing mechanism, possibly triggered by electron-electron interaction.

HL 64.7 Thu 10:00 P1A

Extended quasiparticle picture for quantum wires in the high-density limit — •Klaus Morawetz[1,2], Vinod Ashokan[3], Renu Bala[4], and Kare Narain Pathak[5] — [1]Münster University of Applied Sciences,Stegerwaldstrasse 39, 48565 Steinfurt, Germany — [2]International Institute of Physics- UFRN,Campus Universitário Lagoa nova,59078-970 Natal, Brazil — [3]Department of Physics, Dr.

B.R. Ambedkar NationalInstitute of Technology, Jalandhar (Punjab) - 144 011, India — [4]Centre for Advanced Study in Physics, Panjab University, 160014 Chandigarh, India — [5]Department of Physics, MCM DAV College for Women, 160036 Chandigarh, India

The high-density limit of quantum wires are considered and an extended quasiparticle picture is developed. This allows to calculate the reduced density, the pair correlation function and the effective mass. A non-universal behaviour of the Tan constant is reported for the Coulomb limit. The structure factor is obtained analytically which provides the exact correlation energy. [Eur. Phys. J. B 91 (2018) 29, Phys. Rev. B 97 (2018) 155147, arXiv:1909.09331]

HL 64.8 Thu 10:00 P1A

Characterization of the charge carrier transport in single GaN nanowire field-effect transistors — •Hannes Hergert[1,2], Patrick Uredat[1,2], Matthias T. Elm[1,2,3], and Peter J. Klar[1,2] — [1]Center for Materials Research, Justus Liebig University, 35392 Giessen, Germany — [2]Institute of Experimental Physics I, Justus Liebig University, 35392 Giessen, Germany — [3]Institute of Physical Chemistry, Justus Liebig University, 35392 Giessen, Germany

In the field of semiconductor technology the classical transistors are close to the limit of miniaturisation set by the laws of thermodynamics. For further optimisation new methods are necessary. Due to their high electron mobility and direct bandgap gallium nitride nanowires are a promising material system for future nanoelectronic applications, such as nanowire field-effect transistors (NWFETs). For the device realisation the electrical transport characteristics of such NWFETs need to be investigated. We prepared field-effect transistors of single nanowires by a combination of photo- and electron-beam lithography and characterized the transport properties of single GaN-nanowires. Their electrical resistance increases linearly with decreasing temperature, which is attributed to the high doping concentration and an associated activation energy. We determined the carrier concentration and the electron mobility from cryogenic temperatures to room temperature.

HL 64.9 Thu 10:00 P1A

Resolving the 1D subband structure of wurtzite GaAs wires by inelastic light scattering and PLE — •Sebastian Meier, Paulo de Faria Junior, Ferdinand Haas, Florian Dirnberger, Viola Zeller, Jaroslav Fabian, Dominique Bougeard, and Christian Schüller — Universität Regensburg, 93040 Regensburg, Germany

Resonant Raman scattering and photoluminescence excitation (PLE) measurements have been performed to measure the subband energies of wurtzite GaAs nanowires. Our wires were grown by MBE using the VLS method and have a GaAs core of down to 25 nm thickness which is protected by an AlGaAs shell. For laser excitation, we use a Ti:Sapphire laser, which can be tuned continuously in the energy region of the band gap.

In our Raman experiment, we find a number of peaks which are resonantly enhanced at different excitation energies. According to selection rules and resonance behaviour we interpret the peaks to stem from intersubband excitations of photoexcited electrons. Furthermore, we are able to identify the first excited absorption peak by PLE. Finally, we provide a theoretical account of the measured peaks considering realistic k·p calculations for the nanowire band structure.

HL 64.10 Thu 10:00 P1A

Fabrication and electrical characterization of top-gated RFETs — •Sayantan Ghosh, Muhammad Bilal Khan, Artur Erbe, and Yordan M. Georgiev — Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden, Germany

Following Moore's Law, the idea of "Beyond CMOS" came into picture, which incorporated emerging research and technology. One such idea is the reconfigurable field effect transistor (RFET). An RFET can be dynamically programmed to p or n polarity by the application of electrostatic potential. This is a silicon nanowire (SiNW) based transistor with two gates - one is used to tune the device polarity while the other modulates the flow of charges. In this work, SiNWs were fabricated using electron beam lithography and inductively coupled plasma etching. Subsequently, optimization of oxide shell/gate dielectric around the nanowires was carried out for better control over the conduction of charge carriers. Afterwards, nickel was deposited at both ends of the nanowire and flash lamp annealing was performed to create $NiSi_2$-Si-$NiSi_2$ Schottky junctions. In the next step, two top gates will be fabricated on the junctions followed by electrical characterization of device parameters. Such novel devices have the prospect of establishing efficient circuits and systems.

HL 64.11 Thu 10:00 P1A

Photoluminescence (PL) spectroscopy of a droplet self-assembled quantum dot (SAQD) coupled to a quantum well — •Christine Barthelmes[1], David Ficker[1], Zheng Zeng[1], Hendrik Bluhm[2], and Kardynal Beata[1] — [1]Peter Grünberg Institute (PGI-9), Forschungszentrum Jülich, Germany — [2]JARA-Institute for Quantum Information, RWTH Aachen University, Germany

Realisation of the full potential of quantum networks depends on the ability to send photon qubits between quantum processors separated by long distances. One of the challenges of such a network is interfacing scalable qubits with photonic qubits. A viable protocol to transfer a quantum state between a photonic qubit and electrically controlled spin qubit in a GaAs/AlGaAs heterostructure has been recently proposed. In the protocol a GaAs/AlGaAs gate-defined double quantum (GDQD) hosts the spin qubit and it is tunnel coupled to a SAQD, which serves as a photon qubit receiver. Here, we present the results of optimization of the electron transfer process between the SAQD grown using droplet epitaxy and the quantum well (QW) in which the GDQD is to be defined. We tune the relative energies of electronic states in the In(Ga)As QD and the QW to achieve electron tunneling between them. Based on the time-energy uncertainty principle, we measure the competing processes of radiative recombination and carrier tunneling escape from the homogenous linewidth in PL of selected SAQDs. Furthermore, we explore this effect for different spacer distances between the SAQDs and the QWs to tune the tunnel coupling, which is necessary to achieve high fidelity coherent spin transfer in the hybrid device under development.

HL 64.12 Thu 10:00 P1A

Simulation of Mode Competition Phenomena in Nitride Laser Diodes — •Eduard Kuhn, Lukas Uhlig, Matthias Wachs, Ulrich T. Schwarz, and Angela Thränhardt — Institut für Physik, Technische Universität Chemnitz

Due to their small separation of longitudinal modes, Fabry-Pérot type laser diodes show rich mode competition effects. For example streak camera measurements show cyclic mode hopping, where the currently active longitudinal mode changes from lower to higher wavelengths. This effect can be explained by beating vibrations of the carrier densities in the quantum wells. In this work we simulate the mode dynamics using a model based on the semiconductor Bloch equations and compare the results with streak camera measurements. We also discuss the influence of the cavity length on the mode dynamics and how different scattering terms affect the interaction between longitudinal modes.

HL 64.13 Thu 10:00 P1A

Passively mode-locked p-doped quantum dot lasers for stable optical pulse trains — •Dominik Auth[1], Vladimir V. Korenev[2,3], Artem V. Savelyev[2], Mikhail V. Maximov[2,3], Alexey E. Zhukov[2,3], and Stefan Breuer[1] — [1]Institute of Applied Physics, Technische Universität Darmstadt, 64289 Darmstadt, Germany — [2]St. Petersburg Academic University RAS, ul. Khlopina 8/3, 194021 St. Petersburg, Russia — [3]Peter the Great St. Petersburg Polytechnic University, St. Petersburg 195251, Russia

Monolithic mode-locked edge-emitting semiconductor quantum dot lasers emitting at 1.25 micrometer are ideal sources for the generation of short optical pulses for short-reach inter and intra data-center links. In this contribution, the emission dynamics of InAs/InGaAs quantum dot lasers with different gain-to-absorber section lengths and different p-doping concentrations in the GaAs barrier sections are investigated. The focus is on spectral, radio-frequency and time-domain analysis highlighting the influence of the absorber section length and the doping concentration on the pulse train stability and obtained mode-locking area in dependence on the gain injection current and absorber reverse bias voltage for these devices. This work is supported by the Russian Foundation for Basic Research (project #18-502-12081).

HL 64.14 Thu 10:00 P1A

Electric field dependence of the biexciton decay in a single quantum dot — •Björn Jonas, Sebastian Krehs, Alex Widhalm, Kai Spychala, Timo Langer, Dirk Reuter, and Artur Zrenner — Physics Department, Paderborn University, Warburger Straße 100, 33098 Paderborn, Germany

The decay of biexcitons in single quantum dots is commonly used to

generate polarization entangled photon paires. In order to gain control over the emission energy, the QDs are often embedded in diode structures. This allows for tuning via the quantum confined stark effect. Aside from the beneficial effect of energy tuning, the applied electric fields can also induce single particle tunneling and hence charging of the QD. Both effects can decrease the efficiency of quantum light sources. In this work we studied the decay of biexcitons in a single QD embedded in a symmetric PIN-diode. We resonantly excited the biexciton-state via 2-photon absorbtion with a cw-laser and observed its optical decay depending on the applied electric field. This data was then compared with electric field dependend photocurrent measurements.
We find that under forward bias the intensities of the XX- and X-emission are equaly affected by negative charging of the QD. Under reverse bias the X-emission is selectively decreased by tunneling. Furthermore the faster tunneling rate of the electrons leads to the generation of positivly charged excitons, which is clearly detected by an emerging trion line. Based on these results we propose a tailored sample structure, that symmetrises the tunneling times of electrons and holes and therefore increases the efficiency of the light source.

HL 64.15 Thu 10:00 P1A

Resonance fluorescence on plasmon-quantum dot hybrids — •Gerhard Johannes Schäfer[1], Armando Rastelli[2,3], and Markus Lippitz[1] — [1]Experimentalphysik III, Universität Bayreuth, Bayreuth, Germany — [2]Institute for Integrative Nanosciences, IWF Dresden, Dresden, Germany — [3]Institute of Semiconductor and Solid State Physics, Johannes Kepler University Linz, Linz, Austria

Resonance fluorescence spectroscopy is a well-established tool to investigate single quantum dots in bulk experiments. I present experiments on single GaAs quantum dots using a high NA microscope objective in a closed cycle cryostat. In a next step these structures are coupled to plasmonic structures.

HL 64.16 Thu 10:00 P1A

Self-assembled low-density InAs quantum dots/quantum dot molecules — •Akshay Kumar Verma, Timo Langer, and Dirk Reuter — Paderborn University, Department Physik, Warburger Str. 100, 33098 Paderborn

In recent years, low-density InAs Quantum dots (QDs)/Quantum dot molecules (QDMs) have been fabricated and studied by single dot spectroscopy for their unique optical and electrical properties. For single dot based experiments, the density requirement is around 10^8 QDs/cm^2 ($\sim$1QD/μm^2) or below for which a dot does not interact with neighbouring dots and can optically be addressed individually. Self-assembled InAs quantum dot layer(s) were grown on GaAs (100) substrates by molecular beam epitaxy (MBE) using two growth approaches, In-gradient approach, and annealing approach, resulting in densities from 10^8-10^{10} QDs/cm^2. The size, shape, and density of QDs were controlled by a variation of the growth parameters. In the annealing approach, we deposit a subcritical InAs amount with continuous substrate rotation, with subsequent annealing. The transition energies can be tuned by using the In-flush technique. We have grown two vertically InAs QDs layers separated by GaAs barrier, so called QDMs. The QDs have been analyzed by atomic force microscopy and photoluminescence (PL). By carefully adjusting the substrate temperature and In amount, we were able to obtain QD densities of $\sim 10^7$-10^8 QDs/cm^2 homogenously over an entire 3" wafer. We suggest that the low-density InAs QDs/QDMs grown by annealing approach provide us a large fraction of the wafer for further experiments.

HL 64.17 Thu 10:00 P1A

Gain, dispersion and alpha measurements of p-doped quantum dot lasers — •Felix Wilke[1], Matteo Angelozzi[2], Paolo Bardella[2], Christoph Weber[1], Dominik Auth[1], Vladimir V. Korenv[3,4], Artem V. Saveleyev[3], Mikhail V. Maximov[3,4], Alexey E. Zhukov[3,4], and Stefan Breuer[1] — [1]Institute of Applied Physics, Technische Universität Darmstadt, 64289 Darmstadt, Germany — [2]Department of Electronics and Telecommunications, Politecnico di Torino, 10129 Torino, Italy — [3]St. Petersburg Academic University RAS, ul. Khlopina 8/3, 194021 St. Petersburg, Russia — [4]Peter the Great St. Petersburg Polytechnic University, St. Petersburg 195251, Russia

We report on the experimental investigations on the role of p-doping on the spectrally resolved modal gain and absorption, group delay dispersion and linewidth enhancement factor in two-section InAs/InGaAs semiconductor quantum dot lasers emitting at around 1250 nm. The net modal gain curves are obtained during post-processing and three methodologies are employed: namely Fourier-transform infrared spectroscopy [Hofstetter et al. PTL 11,1372 (1999)], Hakki-Paoli [Hakki et al. JAP 46,1299 (1975)] and mode sum [Cassidy JAP 56, 3096 (1984)]. This work is supported by the Russian Foundation for Basic Research (project #18-502-12081).

HL 64.18 Thu 10:00 P1A

Ultrashort dynamics of an InP/AlGaInP QD SESAM — •Marius Grossmann[1], Julian Obermeier[2], Roman Bek[3], Thorsten Schumacher[2], Markus Lippitz[2], Michael Jetter[1], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Center for Integrated Quantum Science and Technology (IQST) and Research Center SCoPE, University of Stuttgart, Allmandring 3, 70569 Stuttgart, Germany — [2]Department of Physics, University of Bayreuth, 95440 Bayreuth, Germany — [3]Twenty-One Semiconductors, Kiefernweg 4, 72654 Neckartenzlingen, Germany

Mode-locked vertical external-cavity surface-emitting lasers (VECSELs) provide ultrashort pulses across a wide wavelength range. Furthermore, semiconductor bandgap engineering allows the additional flexibility to custom-tailor the pulse train properties.

To this end quantum dots (QDs) are a key component because their 0D-nature contributes beneficial properties when employed in a semiconductor saturable absorber mirror (SESAM). These include independently adjustable saturation fluence and modulation depth as well as a fast relaxation, all advantageous for mode locking of VECSELs.

In this contribution we present the ultrafast properties of an InP/AlGaInP QD SESAM investigated via degenerate pump-probe spectroscopy in the red spectral range.

HL 64.19 Thu 10:00 P1A

Comparison of optical excitation schemes for InAs/In(Ga)As/ GaAs quantum dots emitting in the telecom C-band — •Richard Schaber, Cornelius Nawrath, Fabian Olbrich, Michael Jetter, Simone Luca Portalupi, and Peter Michler — Institut für Halbleiteroptik und Funktionelle Grenzflächen, Center for Integrated Quantum Science and Technology (IQST) and SCoPE, University of Stuttgart, Allmandring 3, 70569 Stuttgart

Semiconductor quantum dots (QDs) exhibit excellent non-classical emission properties, most notably high single photon purity and photon indistinguishability values as well as a high fidelity of entangled photon pairs. With these, the essential prerequisites as light sources for applications in quantum communication are fullfilled.

We present InAs/In(Ga)As/GaAs QDs emitting at 1550nm (telecom C-band) wavelengths which matches the absolute absorption minimum of standard silica fibers. Coherence properties of the emitted photons are compared under different optical excitation schemes. Non-resonant (above band) excitation is investigated as well as (quasi-)resonant schemes, highlighting the superior suitability of the latter for possible appplications regarding coherence.

HL 64.20 Thu 10:00 P1A

1550 nm quantum dots grown in an InGaAs well — •Marcel Schmidt[1], Aimeric Courville[2], Andreas D. Wieck[1], and Arne Ludwig[1] — [1]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Germany — [2]CNRS, Université Côte d'Azur, CRHEA, France

Self-assembled quantum dots (QDs) emitting at 1.55 μm are very promising for future optical fiber transmitted quantum information exchange as the attenuation in the optical fiber has an absolute minimum at this wavelength. The QDs are nearly ideal sources for single indistinguishable photons or entangled photon pairs which can be used for quantum information purposes like quantum key distribution or quantum repeaters. We present first results of QDs grown in an asymmetric InGaAs quantum well[1]. The QDs are grown on a pseudomorphic InGaAs layer. By stopping the rotation during QD growth, both the InAs quantity and the deposition rate are modified. As a result, the QD density and morphology varies along the growth gradient. A further layer of InGaAs, with a higher In content than the subsequent layer, is applied on top of the QDs. Photoluminescence maps preformed on the so embedded QDs indicate regions with lower intensity along the gradient. AFM measurements taken from these spots show a higher density of ripened islands and thus potentially more dislocations serving as non-radiative recombination channels.

1.) Zhang et al., 1.55 μm InAs/GaAs quantum dots and high repe-

tition rate quantum dot SESAM mode-locked laser. Scientific reports **2**, 477 (2012).

HL 64.21 Thu 10:00 P1A

Grating Couplers on a III-V Semiconductor Platform for Quantum Photonic Applications — •Stephanie Bauer, Simone Luca Portalupi, Michael Jetter, and Peter Michler — Institut für Halbleiteroptik und Funktionelle Grenzflächen, Center for Integrated Quantum Science and Technology (IQ^{ST}) and SCoPE, University of Stuttgart, Allmandring 3, 70569 Stuttgart

Quantum photonic integrated circuits are a compact and promising platform for quantum information technologies. In contrast to silicon-based systems, photonic circuits on a III-V semiconductor platform bear the advantage of the direct implementation of quantum dots with their outstanding properties as non-classical light sources. However, some applications require the coupling of light into single mode fibers e.g. for the connection of distinct quantum nodes. For this task, grating couplers are very promising due to the outstanding coupling efficiencies(<85%) and good fiber alignment tolerances.

Here, we present the fabrication and characterisation of waveguide integrated grating couplers on a GaAs/AlGaAs platform. Their coupling efficiency is optimized for a wavelength in the near infrared regime, matching the emission wavelength of InAs quantum dots.

HL 64.22 Thu 10:00 P1A

Time-resolved high-frequency Lock-In transport measurements on self-assembled quantum dots — •Felix Schaumburg[1], Jens Kerski[1], Jakob Penner[1], Arne Ludwig[2], Andreas D. Wieck[2], Martin Geller[1], and Axel Lorke[1] — [1]Faculty of Physics and CENIDE, University Duisburg-Essen, Germany — [2]Chair of Applied Solid State Physics, Ruhr-University Bochum, Germany

Time-resolved transconductance measurements on self-assembled quantum dots (QDs) can be used to access excited spin- and charge states in an all-electrical measurement [1], an important step towards quantum state manipulation and detection for future quantum information technologies. For fast and high-fidelity measurements, the signal-to-noise ratio (SNR) of the read-out signal is of great importance. We present transconductance measurements with an significantly increased SNR up to single-shot measurements. For this, we combined transconductance with a Lock-In measurement scheme using the resonance frequency of an LC circuit. We use a high-mobility electron transistor (HEMT) with a layer of QDs, which are coupled to a two-dimensional electron gas (2DEG). This allows us to observe the tunnelling dynamics between the 2DEG and the QDs. A sinusoidal MHz-ac-voltage in resonance with the LC circuit is applied to the 2DEG in the Lock-In measurement. The transmitted signal is analysed with a Lock-In-Amplifier, exhibiting the regular transients of transconductance with an enhanced SNR.
[1] K. Eltrudis et al., Appl. Phys. Lett. **111**, 092103 (2017).

HL 64.23 Thu 10:00 P1A

Self mode-locked single section quantum dot optical frequency comb laser subject to short optical self-injection — •Matthias Hagen[1], Dominik Auth[1], Christoph Weber[1], Benedikt Schwarz[2,3], Luke F. Lester[4], and Stefan Breuer[1] — [1]Institute of Applied Physics, Technische Universität Darmstadt, 64289 Darmstadt, Germany — [2]Institute of Solid State Electronics, TU Wien, 1040 Vienna, Austria — [3]John A. Paulson School of Engineering and Applied Sciences, Harvard University, Cambridge, Massachusetts 02138, USA — [4]Bradley Department of Electrical and Computer Engineering, Virginia Polytechnic Institute and State University, Blacksburg, Virginia, 24061, USA

Frequency modulated optical frequency comb generation in self-mode locked single section quantum dot lasers with short fabry-perot cavity lengths of 1 mm have been studied experimentally and by simulation [Weber et al., Optics Letters 44(14), pp. 3478-3481 (2019)]. Ultra short optical self-injection of optical frequency comb quantum cascade lasers has been reported to change and control the group delay dispersion of the optical frequency comb [Hillbrand et al., Optics Letters 43(8), pp. 1746-1749 (2018)]. In this contribution we study the impact of ultrashort optical self-injection onto frequency-modulated optical frequency combs in self-mode locked quantum dot lasers with respect to change in group delay dispersion and intermode-beat-frequency tuning.

HL 64.24 Thu 10:00 P1A

Examination of self-assembled quantum dots in a density-modulated pattern with capacitance-voltage spectroscopy — •Nikolai Spitzer, Nikolai Bart, Andreas Wieck, and Arne Ludwig — Ruhr-Universität Bochum, Lehrstuhl für Angewandte Festkörperphysik - Universitätsstraße 150, 44801 Bochum

Self-assembled InAs quantum dots (QDs) on GaAs with a QD density modulation were grown by molecular beam epitaxy. The QDs can be arranged in stripe patterns whose properties can be changed by a gradient in the GaAs sublayer beneath the QDs. We suspect that the formation of QDs is favoured by atomic rough areas as opposed to flat areas during molecular epitaxial growth. The differences in the sublayer are due to the profile of the molecular beam. Capacitance-voltage spectroscopy is used to investigate the properties of the quantum dots arranged in this way at different densities.

HL 64.25 Thu 10:00 P1A

Manipulating quantum dot luminescence via strong THz fields — •Moritz Heindl and Georg Herink — Experimental Physics VIII, University of Bayreuth, Germany

The investigation and manipulation of ultrafast electron dynamics at the nanoscale requires precise characterization of local electric field transients. For this purpose, the field-dependent change of the luminescence of semiconductors due to the quantum confined Stark effect can be employed. Here, we present an experimental scheme to locally modify quantum dot luminescence by field enhancement at planar nanostructures, e.g. micro-antennas and micro-slits. For ultrafast probing and control, we employ high-field single-cycle THz pulses based on the tilted-pulse front scheme.

HL 64.26 Thu 10:00 P1A

Spin noise spectroscopy in single InGaAs quantum dots — •Kai Hühn, Julia Wiegand, Jens Huebner, and Michael Oestreich — Inst. for Solid State Physics, Leibniz University Hannover, Appelstraße 2, 30167 Hannover, Germany

In this work we present Spin noise spectroscopy measurements of single Quantum Dots in high magnetic fields reaching from 300mT to 1.4 T. Some theory for the magnetic field dependence of the heavy-hole spin lifetime has been formulated. Additionally the Zeeman splitting and the diamagnetic shift has been investigated to determine Trion g-factor of 1.25. A new fit model has been established, which connects the spin noise power with the spin noise width. This enabled a new way of extrapolating the intrinsic lifetime of an Lorentzian shaped inhomogenius broadened quantum dot.

HL 64.27 Thu 10:00 P1A

Fast switching of quantum dot photons in a Mach-Zehnder interferometer — •Fabio Rimek[1], Pia Lochner[1], Hendrik Mannel[1], Arne Ludwig[2], Andreas D. Wieck[2], Martin Geller[1], and Axel Lorke[1] — [1]Faculty of Physics and CENIDE, University Duisburg-Essen, Germany — [2]Chair of Applied Solid State Physics, Ruhr-University Bochum, Germany

A Mach-Zehnder interferometer can be used to measure the coherence of a photon stream by a two-path experiment. In the ultimate limit of a single photon in the interferometer, it is also a realization for the so-called which-path experiment, where a single photon occupies both paths of the interferometer.
In this contribution, we will use single photons from a single self-assembled quantum dot in the Heitler regime with coherence lengths exceeding the dimensions of the interferometer to realize a time-resolved which-path experiment. A major challenge is an electro-optical polarization switch in the wavelength range of the photons from the self assembled InAs/GaAs quantum dots (∼950 nm). The polarisation switch should switch the photon polarisation faster than the photon residence time in the Mach-Zehnder interferometer. Depending on the polarization, the path can be determined in the interferometer. The switching of the polarization is caused by a superposition of two perpendicularly polarized waves, exhibiting a phase difference that can be varied by an electro-optic modulator (EOM). The polarization is stabilized by an PID controlled feedback loop, which eliminates fluctuations of the phase due to other influences.

HL 64.28 Thu 10:00 P1A

Semiclassical modelling of coupled quantum dot-cavity systems: From polariton-like dynamics to Rabi oscillations — •Kevin Jürgens, Frank Lengers, Tilmann Kuhn, and Doris E. Reiter — Institut für Festkörpertheorie, Universität Münster, Münster

Semiconductor quantum dots (QDs) in a photonic cavity are strongly coupled light-matter systems with numerous applications in quantum information technology. Due to the photonic confinement, the interaction of the QDs with the cavity mode is increased. Here we present a semiclassical model to describe the dynamics of the coupled QD-light system: The QDs are modelled as a planar ensemble of quantum mechanical two-level systems coupled to the electric field and the light field is described by Maxwell's equations in one dimension. We explicitly take into account the coupling between the QD polarization and the electric field, i.e. we solve the coupled Maxwell-Bloch equations. We show that, depending on the initial value of the light field amplitude, a sharp transition between two regimes with fundamentally different dynamics and spectra emerges. For low amplitudes we find exciton polariton-like dynamics and for high amplitudes Rabi oscillations. The spectrum of the exciton polariton shows the typical anticrossing behavior when tuning the transition frequency of the QD through resonance, and for high amplitudes we see the energy splitting of the dressed states. We confirm our findings in an analytical model.

HL 64.29 Thu 10:00 P1A

Frequency Shift of Electronic Resonances in Self Assembled InAs Quantum Dots — •Ibrahim A. Engin, Ismail Bölükbaşı, Sven Scholz, Andreas D. Wieck, and Arne Ludwig — Lehrstuhl für Angewandte Festkörperphysik, Ruhr-UniversitätBochum, D-44780 Bochum, Germany

Self-assembled InAs quantum dots (SAQD) proved promising semiconductor structures as single-photon sources and provide possibilities for quantum memories. Therefore understanding the physical properties is important and in progress. We investigate electronic resonances in InAs SAQDs by using C(V)-spectroscopy.

The thermal shift of the s-states has been reported and described with a master equation [1], which has been improved further to model excitonic and non-equilibrium states in such SAQD [2]. The model shows contrarily shifting in dependence of frequency and temperature.

Here we investigate both s- and p-states in dependence of temperature and frequency to measure the shifting characteristics of p-peaks and observe the dominancy of the frequency shift for s-states. The superposition of thermal and frequency shift are being analyzed. Adjustments to the master equation model are needed.

[1] Brinks, F. et al., "Thermal shift of the resonance between an electron gas and quantum dots: what is the origin?" New J. Phys. 18, 123019 (2016).

[2] Valentin, S. et al., "Illumination-induced nonequilibrium charge states in self-assembled quantum dots", Phys. Rev. B 97, 045416 (2018).

HL 64.30 Thu 10:00 P1A

Ridge-width dependent beam profile analysis of InAs/InGaAs quantum dot lasers — •Adrian Hamel[1], Christoph Weber[1], Dominik Auth[1], Vladimir V. Korenev[2,3], Artem V. Savelyev[2], Mikhail V. Maximov[2,3], Alexey E. Zhukov[2,3], and Stefan Breuer[1] — [1]Institute of Applied Physics, Technische Universität Darmstadt, 64289 Darmstadt, Germany — [2]St. Petersburg Academic University RAS, ul. Khlopina 8/3, 194021 St. Petersburg, Russia — [3]Peter the Great St. Petersburg Polytechnic University, St. Petersburg 195251, Russia

Monolithic mode-locked edge-emitting semiconductor quantum dot lasers with narrow ridge widths to broad ridge widths emitting at 1.25 micrometer are ideal sources for the generation of broad optical frequency combs for short-reach inter and intra data-center links. In this contribution, the beam profile of InAs/InGaAs quantum dot lasers with 5 micrometer, 10 micrometer and 50 micrometer broad ridge waveguides and different doping concentration in the GaAs barriers are studied experimentally. The work focuses on the comparison of near and far field beam profile. This work is supported by the Russian Foundation for Basic Research (project #18-502-12081).

HL 64.31 Thu 10:00 P1A

Telecom wavelength InP-based quantum dots for quantum communication — Andrei Kors, Johann Peter Reithmaier, and •Mohamed Benyoucef — Institute of Nanostructure Technologies and Analytics (INA), CINSaT, University of Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany

Self-assembled semiconductor quantum dots (QDs) emitting at optical fiber communication wavelengths, particularly in the telecom C-band, which offers the lowest attenuation losses in silica fibers is highly interesting for quantum communication applications.

Here, we report our effort on the growth of low density InAs/InP QDs using molecular beam epitaxy, fabrication of InP-based microcavities emitting at telecom wavelengths, and their optical properties. Fabrication of symmetric QDs with low density is obtained by careful control of various growth parameters. Low-temperature single-dot spectroscopy exhibits high-intensity sharp excitonic emission lines with vanishing fine-structure.

HL 64.32 Thu 10:00 P1A

Photoluminescene Spectroscopy of Self-Assembled InAs/GaAs Quantum Dots grown in a Density-Modulated Pattern by Molecular Beam Epitaxy — •Peter F. Zajac, Nikolai Bart, Andreas D. Wieck, and Arne Ludwig — Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Universitätsstraße 150, 44801 Bochum

Self-assembled InAs/GaAs Quantum Dots (QDs) with a modulation of QD density perpendicular to the growth direction were grown by molecular beam epitaxy (MBE). The modulation corresponds to a striped pattern, whose properties can be modified by varying the growth parameters of the buffer layers underneath the QDs. It is proposed that the pattern is caused by the deposition profile of the molecular beam causing the formation of atomically rough and smooth surface areas which lead to an earlier nucleation of QDs at rougher regions in comparison to flat surfaces. With Photoluminescence Spectroscopy (PL) measurements at room temperature and 100 K the properties of such grown QDs in the different regimes of QDs density are studied in order to understand the growth process and to tune the QD emission.

HL 64.33 Thu 10:00 P1A

Sensing electrical fields in nanostructures via quantum dot luminescence — •Sofie Krietenstein and Georg Herink — Experimental Physics VIII, University of Bayreuth, Germany

Quantum dot luminescence can be modified in the presence of external electrical fields, particularly due to the Quantum-Confined-Stark-Effect.

In this contribution, we present a detection scheme for sensing local electrical fields in nanostructures via changes of luminescence spectra and lifetimes. Specifically, we employ the Dispersive Fourier Transform based on the group velocity dispersion of optical fibers to map spectral information to the temporal domain. We present measurements on colloidal quantum dots embedded in voltage-biased gold nanostructures using different detection schemes.

HL 64.34 Thu 10:00 P1A

Probing the time dynamics of a continuously driven quantum dot under the influence of phonons — •Doris E. Reiter — Institut für Festkörpertheorie, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany

Semiconductor quantum dots are ideal object to study light-matter interaction in a quantum system. When a quantum mechanical two-level system is driven by a continuous wave excitation after an instantaneous switch on, the dynamics shows Rabi oscillations. These Rabi oscillations could be probed by an ultrashort laser pulse resulting in a Mollow triplet-like spectrum for resonant driving. The Mollow triplet consists of a single peak at the driving frequency and two peaks at the Rabi frequency with half the amplitude. In contrast to an atomic system, the quantum dot is embedded in the solid state matrix and therefore is subject to the interaction with phonons. The electron-phonon interaction results in a damping of the Rabi oscillations and accordingly the optical spectrum after the damping exhibits only the two side peaks. We derive analytical equations to describe both the dynamics and the probe signals of the system within a simple rate equation model. We validate our model by comparison with solution using a standard correlation expansion. The analytical results allow to scrutinize the influence of phonons on optically excited quantum dots.

HL 64.35 Thu 10:00 P1A

Chirped single photons from a semiconductor quantum-dot — •David Bauch[1], Dirk Heinze[1], Artur Zrenner[1], and Stefan Schumacher[2] — [1]Department of Physics and CeOPP, Paderborn University, Paderborn, Germany — [2]College of Optical Sciences, University of Arizona, Tucson, AZ 85721, USA

On demand sources for controlled single photon emission are essential for quantum information theory. Exciton emission or cascaded biexciton-exciton emission in semiconductor quantum dots offer the potential for optically controlled generation of a single photon [1] and

polarization-entangled twin photons [2]. In contrast to pure optical control, externally applied time-dependent electrical fields enable control of the (bi-)exciton resonance (electronic chirp), resulting in changes of the excitation dynamics and the resulting photon emission. Combining both optical and electronic control of the photon emission might be significant for future integration into optoelectronic devices. Here we investigate the influence of electronic chirps on the generation of single photons via (bi-)exciton (two-)photon emission and biexciton-exciton emission cascades and determine quantum properties and spectral characteristics of the emitted photons in a high- and low-quality resonator. For exciton emission we show suppression of Rabi-splitting in high-quality cavities and on-demand triggering of photon emission while retaining spectral properties.

[1]: Heinze, D., Breddermann, D., Zrenner, A., Schumacher, S. Nat. Commun. 6, 8473 (2015). [2]: Heinze, D., Zrenner, A., Schumacher, S. Phys. Rev. B 95, 245306 (2017).

HL 64.36 Thu 10:00 P1A

Multi-particle theory of magneto-optical properties of GaAs/AlGaAs quantum dots — •Diana Csontosová[1,2], Armando Rastelli[3], and Petr Klenovský[1,2,4] — [1]Department of Condensed Matter Physics, Faculty of Science, Masaryk University, Kotlářská 267/2, 61137 Brno, Czech Republic — [2]Czech Metrology Institute, Okružní 31, 63800 Brno, Czech Republic — [3]Institute of Semiconductor and Solid State Physics, Johannes Kepler University Linz, Altenbergerstr. 69, 4040 Linz, Austria — [4]Central European Institute of Technology, Masaryk University, Kamenice 753/5, 62500 Brno, Czech Republic

We have theoretically studied the size effect of GaAs/AlGaAs quantum dots on magneto-optical properties of neutral excitonic states. We employed a combination of the envelope function approximation based on 8-band $\mathbf{k}\cdot\mathbf{p}$ theory and the method of configuration interaction similar to Ref [1]. The magnetic field was applied in the growth direction. The results of our calculations are in very good agreement with available experimental data. [2] By comparing the results of single- and multi-particle calculations, we find that correlations play crucial role on the magneto-optical properties of our dots.

[1] Huber, D., *et al.*, arXiv:1909.04906 (2019).
[2] Löbl, M. C., *et al.*, Phys. Rev. B **100**, 155402 (2019).

HL 64.37 Thu 10:00 P1A

Interal photo-emission of electrons from a quantum dot — •Pia Lochner[1], Jens Kerski[1], Annika Kurzmann[1], Andreas D. Wieck[2], Arne Ludwig[2], Martin Geller[1], and Axel Lorke[1] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen, Germany — [2]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Germany

Resonance fluorescence (RF) on excitonic transitions in confined quantum systems (like self-assembled quantum dots) is ideally free of any charge generation in the environment. The light field from the laser should only couple to the optical transitions. However, it as been shown recently that even under resonant excitation, free electrons can be generated in the environment by intra-band electron excitation from a nearby charge reservoir. These electrons can be *captured* by the dot and quench the exciton transition of the RF signal [1].

In this contribution, we demonstrate by time-resolved RF measurements on a single self-assembled quantum dot an internal photo-effect that *emits* electrons from the QD by an intraband excitation. The dot is in our sample only weakly-coupled to an electron reservoir with tunneling rates below 1/ms. We show a linear dependence of the optically-generated emission rate on the excitation intensity and use a rate equation model to deduce the involved rates. Our results demonstrate that also under resonant excitation, free electrons can be generated by an internal photo-effect that can influence the optical properties of a dot.

[1] A. Kurzmann, et al., APL **108**, 263108 (2016).

HL 64.38 Thu 10:00 P1A

Carrier and energy transfer in colloidal quantum dot semiconductor hybrids — •Mikko Wilhelm, Shyam Kommadath, Salwa Khokhar, and Wolfram Heimbrodt — Philipps-Universität Marburg

Colloidal quantum dots are attractive for functionalization of semiconductors in electronic and opto-electronic devices like solar cells, field effect transistors or spintronic devices. CdS/ZnS and CdSe/ZnS core/shell quantum dots of different sizes synthesized in solution are deposited via knife coating on different semiconductor substrates. Depending on the band alignment between the quantum dots and the semiconductor substrate, energy and charge transfer is observed. The interaction between the quantum dots and semiconductor substrate is studied with optical spectroscopy. The results of continuous wave and time resolved photoluminescence measurements at different temperatures from 10K to room temperature are presented and discussed.

HL 64.39 Thu 10:00 P1A

Magneto-optical studies of manganese doped collodial core shell CdS/ZnS quantum dots — •Johannes Röder[1], Mikko Wilhelm[1], Nadeem Sabir[1], Wolfgang Parak[2], and Wolfram Heimbrodt[1] — [1]Philipps-Universität Marburg, 35032 Marburg, Germany — [2]Universität Hamburg, 22761 Hamburg, Germany

The magnetic field dependency of the photoluminescence of colloidal core shell CdS/ZnS quantum dots doped with manganese in the ZnS shell are investigated. The focus of this investigations was on the influence of the Mn position in the core shell dots on the magneto-optical properties. There are 2 different samples and 2 reference samples investigated: One were Mn is directly grown on the CdS core together with a ZnS shell and another were Mn is introduced after the CdS core is already covered with a ZnS shell. Samples were Mn is directly grown on the CdS core without a ZnS shell and a CdS core with 2 shell layers of ZnS without any Mn are used as reference samples. To investigate the temperature dependency the quantum dots were transferred from solution via drop casting on a quartz substrate. The results of these measurements will be discussed in detail.

HL 64.40 Thu 10:00 P1A

Tracking the mixing of single-particle states in correlated multi-particle complexes of quantum dots — •Diana Csontosová[1,2] and Petr Klenovský[1,2,3] — [1]Department of Condensed Matter Physics, Faculty of Science, Masaryk University, Kotlářská 267/2, 61137 Brno, Czech Republic — [2]Czech Metrology Institute, Okružní 31, 63800 Brno, Czech Republic — [3]Central European Institute of Technology, Masaryk University, Kamenice 753/5, 62500 Brno, Czech Republic

By deconvolution of the Configuration interaction (CI) calculation of the electronic states in the quantum dots (QDs), we investigate (i) the content of single-particle states in multi-particle eigenstates of excitonic complexes, (ii) the heavy-light hole mixing in those, and (iii) their probability densities. Our approach enables us to track the aforementioned parameters for arbitrary size of the CI basis, i.e., including the effects of correlation. This provides us a way to find the most probable final states of excited trions or more precise determination of heavy-light hole mixing in the CI states. Our method enables a more precise study of the effects of tuning of emission properties of QDs using externally applied fields (electric, magnetic, strain).

HL 64.41 Thu 10:00 P1A

Conductance spectroscopy on quantum dot molecules — •Carsten Ebler, Giang N. Nguyen, Alexander R. Korsch, Andreas D. Wieck, and Arne Ludwig — Ruhr-Universität Bochum, 44801 Bochum, Germany

Quantum dot molecules (QDM) have shown to be a good approach increasing the T2 time in quantum bits [1]. For a controlled charging of QD charge states and a better understanding of the interaction and crosstalk inside the QDM, we use two epitaxially grown self-assembled InAs quantum dot layers (SAQD) in close tunnel contact to each other. We establish the QDM in tunnel contact with an inverted GaAs/Al0.3Ga0.7As HEMT structure containing a 2-dimensional electron gas (2DEG), manipulate the system with electronical and optical pulses and perform time resolved conductance measurements [2] of the 2DEG to readout the charge occupation of the QDMs. The charge state is read out over conductivity changes in the channel of the HEMT and the resulting transient contains multi-exponential components. We make use of the inverse Laplace transformation to distinguish between the different time constants representing tunnel contributions into the different quantum dot layers.

[1] Weiss et. al, PRL 109 (2012) [2] Marquardt et. al, APL 95 (2009)

HL 64.42 Thu 10:00 P1A

Influence of electric and magnetic fields on the line broadening of semiconductor quantum dots — •Tim Strobel, Jonas H. Weber, Hüseyin Vural, Julian Maisch, Simone L. Portalupi, and Peter Michler — Institut für Halbleiteroptik und Funktionelle Grenzflächen, Center for Integrated Quantum Science and Technology (IQST) and SCoPE, University of Stuttgart, Allmandring 3, 70569

Stuttgart, Germany

Photonic quantum technologies, such as quantum networks and quantum computing are based on two-photon interference (TPI). Implementations of actual TPI experiments inevitably require single photons with high indistinguishability. Semiconductor quantum dots (QDs) are an excellent choice with respect to such quantum applications. They can be used for on-demand emission of indistinguishable photons, a property, which is inevitable to successfully implement two-photon inteference experiments with up-scaled complexity using multiple sources. QD emission spectra with a linewidth reaching the transform limit are desired to yield maximum indistinguishability of photons from remote sources. Charge and spin noise, inherent to the semiconductor device, can drastically increase the linewidth to a multiple of the transform limit. Those two sources of noise are subject of current research and scientific discussion. Optimizing the perfomance demands an understanding of the noise sources. Here, we present an investigation on the influence of electric and magnetic fields on the QD emission linewidth. In this talk, measurement techniques to uncover the behaviour of those effects will be presented.

HL 64.43 Thu 10:00 P1A

Capacitance-voltage spectroscopy on no-wetting layer quantum dots — •Ismail Bölükbasi, Sven Scholz, Andreas D. Wieck, and Arne Ludwig — Ruhr-Universität Bochum, D-44780 Bochum, Germany

Quantum dots have interesting physical properties and allow research in zero dimensional systems. They are used in modern displays and may become important for the progress of semiconductor and information technology in the form of qubits in quantum computers and quantum memories or quantum communication applications.

Quantum dots are created by molecular-beam-epitaxy (MBE) in Stranski-Krastanov growth. InAs is deposited epitaxially onto GaAs and grows without relaxation to up to 1.5 monolayers of InAs. This layer is called the wetting layer, on top of which the self-organized quantum dots form.

We find, that a monolayer of AlAs after the growth of the quantum dots can suppress certain states in this wetting layer[1], allowing to purify their photoluminescence spectra from electronic contributions such as for example a two-dimensional-electron gas would induce. Capacitance-voltage and photoluminescence measurements are carried out to investigate the effects of this monolayer of AlAs on the physical properties of the quantum dots and the modified charging behaviour around flat band conditions.

[1] Löbl, M. C. et al. Excitons in InGaAs quantum dots without electron wetting layer states. Commun. Phys. 2, 93 (2019)

HL 64.44 Thu 10:00 P1A

Spin Noise Spectroscopy Setup for single GaAs Quantum Dots resonant at the Rb D-line — •Tianjiao Sun, An Zhao, Xin Cao, Fei Ding, Jens Hübner, and Michael Oestreich — Institute for Solid State Physics,Appelstraße 2, D-30167 Hannover, Germany

Electrons and holes confined in single quantum dots (QDs) have attracted much attention since they are potential candidates for semiconductor quantum information qubits. We use spin noise spectroscopy, to access the spin dynamics of confined carriers in single quantum dots, as well as the interaction of single confined carriers with the nuclear environment[1]. In addition, a recent report shows for (InGa)As QDs an occupation noise contribution in resonant spin noise measurements which reveals the dynamics of charge exchange between the QD and its environment due to Auger recombination[2]. Here, we aim for the investigation of the intrinsic spin and charge dynamics in a new type of symmetric GaAs QDs[3]. The low strain in these QDs can enable a prolonged spin coherence time compared to (InGa)As QDs. Furthermore, the optical transition at the Rb D-line is promising for a potential realization of coherent coupling of solid-state and atomic qubit implementations.

[1] J. Hübner, F. Berski, R. Dahbashi, and M. Oestreich, physica status solidi (b) 251, 1824 (2014).

[2] J. Wiegand, D. S. Smirnov, J. Osberghaus, L. Abaspour, J. Hübner, and M. Oestreich, Phys. Rev. B 98, 125426(2018).

[3] R. Keil, M. Zopf, Y. Chen, B. Höfer, J. Zhang, F. Ding, and O. G. Schmidt, Nat. Commun. 8, 15501 (2017).

HL 64.45 Thu 10:00 P1A

Carbon nanodots: Luminescence properties tuned by microcavity devices — •Lukas Trefflich[1], Nicole Weizenmann[2], Frank Dissinger[3], Gabriele Benndorf[1], Chris Sturm[1], Rüdiger Schmidt-Grund[1,4], Siegfried R. Waldvogel[3], Ralf Seidel[2], and Marius Grundmann[1] — [1]Felix Bloch Institute for Solid State Physics, Universität Leipzig — [2]Peter Debye Institute for Soft Matter Physics, Universität Leipzig — [3]Institute for Organic Chemistry, Johannes Gutenberg Universität Mainz — [4]now at: Institute of Physics, Technische Universität Ilmenau

The carbon nanodots (cdots) made from citric acid and a stabilizing amine component emit bright light in the spectral range between 390 nm and 600 nm. To investigate their size-dependent luminescence properties, we separate them with gel-electrophoresis and perform time- and energy-resolved photoluminescence (PL). We propose a streched exponential law [1] for the emission decay. The mean luminescence lifetime depends on the emission wavelength (cf. [2]) and the particle size. We obtain lifetimes in the range of 0.6 ns to 2 ns. The emission of the cdots can be enhanced by incorporating them in a planar microcavity. That allows to tune the emission wavelength of the device by varying the optical thickness of the cavity layer. We produce such a device with pulsed laser deposition and characterize it with power dependent PL. The power-dependence fits to a multimode laser-model [3], indicating lasing, with a threshold intensity of 32 MW cm^{-2}. [1] Milovanov et al., Phys. Rev. B, 2007, **76** [2] Kahn and Kim, Sci. Rep., 2019, **9** [3] Casperson, J. Appl. Phys., 1975, **46**

HL 64.46 Thu 10:00 P1A

Excited States in Bilayer Graphene Double Quantum Dots — •Alexander Rothstein[1], Luca Banszerus[1,2], Samuel Möller[1], Eike Icking[1,2], Kenji Watanabe[3], Takashi Taniguchi[3], Christian Volk[1], and Christoph Stampfer[1,2] — [1]JARA-FIT and 2nd Institute of Physics, RWTH Aachen University, 52074 Aachen, Germany, EU — [2]Peter Grünberg Institute (PGI-9), Forschungszentrum Jülich, 52425 Jülich, Germany, EU — [3]National Institute for Materials Science, 1-1 Namiki, Tsukuba, 305-0044, Japan

Due to its small spin orbit interaction and negligible hyperfine coupling as well as the possibility to open up a band gap, bilayer graphene (BLG) offers a promising platform for future spin-based quantum computation devices. Recent progress in the fabrication techniques and the possibility to fully pinch off current in BLG allow to electrostatically confine single- and double quantum dots by a smooth potential, which can be studied with regard to their electronic configuration.* Here, we present a remarkable degree of control of finger-gate based double quantum dots structure enabling to modify controllably the electron number in each of the quantum dots from zero up to a few electrons. We show an increasing inter dot tunnel coupling, as well as an increasing capacitive interdot coupling with a growing dot occupation. At a finite bias voltage, we can resolve the excited state spectrum of the first electrons in the double quantum dot and extract their energies as function of an applied out-of-plane magnetic field.

HL 64.47 Thu 10:00 P1A

Homodyne Spin Noise Spectroscopy of Single Quantum Dots — •Pavel Sterin, Kai Hühn, Julia Wiegand, Jens Hübner, and Michael Oestreich — Institut für Festkörperphysik, Leibniz Universität Hannover, Appelstr. 2, D-30167 Hannover, Germany

Spin noise spectroscopy (SNS) is a technique that can be used to investigate the spin dynamics of sensitive semiconductor systems in a quasi-non-perturbative way. However, for the most delicate systems like, e.g., single InGaAs quantum dots it seemed that SNS had reached its limits: classic setups exhibit an electrical noise that dominates the measurements at intensities low enough to keep the residual absorption acceptable [1]. Further reduction of the intensity is limited by prohibitively long integration times [3].

We propose a setup that employs homodyne SNS as first demonstrated by [2],[3] and [4]. An all optical amplification is realized by coupling the experiment to a homodyne interferometer. This modification enables efficient integration times and a quantum-limited, i.e., optimal, signal-to-noise ratio. Finally, the new setup will allow us to gain insight into unperturbed spin dynamics of single quantum dots.

[1] Dahbashi, et al. Phys. Rev. Lett. 112, 156601, (2014).
[2] Cronenberger, et al. Rev. Sci. Instrum. 87, 093111 (2016).
[3] Sterin, et al. Phys. Rev. Applied 9, 034003 (2018).
[4] Petrov, et al. Phys. Rev. B 97, 125202 (2018).

HL 64.48 Thu 10:00 P1A

Negatively charged silicon vacancies V_{Si}^- in 4H-silicon carbide for quantum applications — •Julius Röwe and Martin S. Brandt — Walter Schottky Institut and Physik-Department, Technische Universität München, Garching, Germany

Since many, in particular bipolar electronic devices can be fabricated from silicon carbide, color centers such as the negatively charged silicon vacancy V_{Si}^- are intensively studied in this material for possible applications in quantum-based information and sensing. However, to make full use of the technological advantage, an efficient spin-to-current conversion is crucial for the coherent electrical read-out of these color centers. We study the fundamental properties of V_{Si}^- in 4H-SiC by photoconductivity measurements under near-resonant illumination and observe two-photon excitation of the ground state into the conduction band. Raster scanning of the detection volume allows spatial and lateral resolution of the photoconductivity in the micrometer range and an understanding of the properties of the electrical contacts to the SiC photoconductor. In addition, we will discuss the possibility to locally generate V_{Si}^- e.g. by helium ions.

HL 64.49 Thu 10:00 P1A

Nuclear spin dynamics in n-GaAs — •Lida Abaspour, Pavel Sterin, Jan Gerrit Lonnemann, Eddy Rugeramigabo, Jens Hübner, and Michael Oestreich — Institute for Solid States Physics, Leibniz University of Hannover, Appelstraße 2, D-30167 Hannover

Interaction of electron and nuclear spins in semiconductors became more important over the last few years for applications in spin based quantum information [1, 2]. However, the knowledge to understand the exact spin dynamics of such a complex system is not complete.

In this work, we measure the nuclear spin relaxation rate in a set of n-GaAs samples in a magnetic field much larger than the local fields. In this way the dipolar and quadrupolar effects can be ignored. The interaction of the nuclei with localized impurities (insulating samples) is different from conduction band electrons (metallic samples). In order to unravel the complex processes involved in the spin dynamics of this system, we use the results from magnetotransport measurements of the same samples [3] which yield access to the fraction of the localized doping in each sample. This helps us to explain the behavior of the nuclear spin relaxation rate in dependence of doping. The temperature dependence in insulating sample gives us more information about the spin dynamics of the system in terms of phonon interaction.

[1] F. Berski et al.,Phys. Rev. Lett, 115, 176601 (2015).
[2] M. Vladimirova, et al. Phys. Rev. B, 95, 125312 (2017).
[3] J. G. Lonnemann, et al. Phys. Rev. B, 96, 045201 (2017).

HL 64.50 Thu 10:00 P1A

Optically detected magnetic resonance spectroscopy of excitons in porous silicon and partially hydroxylated silicane — •Jonathan Zerhoch and Martin S. Brandt — Walter Schottky Institut and Physik-Department, Technische Universität München

Porous silicon and partially hydroxylated silicane, also known as siloxene, exhibit the strongest luminescence of any silicon-based material. We employ both continuous wave and pulsed optically detected magnetic resonance spectroscopy (ODMR) to study the recombination processes in these materials. In both, we observe a luminescence enhancing signature of the allowed $\Delta m_s = \pm 1$ and the forbidden $\Delta m_s = \pm 2$ transitions of triplet excitons and use the former to estimate their diameter. In addition, the resonance of dangling bond defects overlapping the triplet exciton signature and quenching the luminescence is observed. The technique of pulsed ODMR enables coherent control of the spin systems and, as expected, we find that the $\Delta m_s = \pm 1$ transition of the triplet exhibits a Rabi frequency which is a factor of $\sqrt{2}$ higher than the Rabi frequency of the spin-1/2 dangling bond defect. The observed dipolar broadened Pake-doublet gives rise to a wide distribution of electron-hole distances that appears to suppress the observation of Rabi oscillations at the $\Delta m_s = \pm 2$ resonance. Furthermore, we investigated the dynamical properties of the spin-1 and spin-1/2 systems providing T_2 times and the timescales of the different recombination processes.

HL 64.51 Thu 10:00 P1A

Manipulation of exceptional points in planar anisotropic photonic structures — •E. Krüger[1], C. Sturm[1], S. Richter[1,2], J. Zúñiga-Pérez[3], H.-G. Zirnstein[4], L. Trefflich[1], C. Deparis[3], B. Rosenow[4], R. Schmidt-Grund[1,5], and M. Grundmann[1] — [1]Universität Leipzig, Felix-Bloch-Institut für Festkörperphysik, Germany — [2]ELI Beamlines/Fyzikální Ústav AV ČR, Czech Republic — [3]Université Côte d'Azur, CRHEA-CNRS, France — [4]Universität Leipzig, Institut für Theoretische Physik, Germany — [5]TU Illmenau, Leipzig, Institut für Physik, Germany

We present different approaches for establishing exceptional points (EP) in planar dielectric microcavities with broken cylindrical symmetry, realized by using anisotropic cavity layer materials.

Such EPs represent non-Hermitian degeneracies in momentum space, related to a local complex-square-root topology of the resonator eigenenergies. The eigenmodes coalesce along these directions, yielding degeneracy in energy, broadening and polarization.

We prove the exceptional-point nature experimentally and theoretically for ZnO-based microcavities by monitoring the square-root topology around such an EP. Furthermore, we show how the crystal symmetry and the crystal orientation of the cavity layer material as well as the geometrical cavity design influence the occurence and the position of the EPs in momentum space. We discuss also different approaches for breaking the system reciprocity in the cavity plane, thereby paving the way for topological non-trivial photonic systems.

[1] S. Richter et al., Phys. Rev. Lett. **123** (2019)