HL 104: Quantum Dots and Wires: Optical Properties V (mainly Indiviual Photons)

Time: Friday 11:45–14:00 Location: EW 201

HL 104.1 Fri 11:45 EW 201

Contactless carrier transport and photon anti-bunching emission in GaAs-based nanowires using surface acoustic waves — •Alberto Hernández-Mínguez[1], Michael Möller[2], Steffen Breuer[1], Carsten Pfüller[1], Claudio Somaschini[1], Snežana Lazić[1], Oliver Brandt[1], Alberto García-Cristóbal[2], Mauricio M. de Lima Jr.[2], Andrés Cantarero[2], Lutz Geelhaar[1], Henning Riechert[1], and Paulo V. Santos[1] — [1]Paul-Drude-Institut für Festkörperelektronik, Berlin, Germany — [2]Materials Science Institute, University of Valencia, Valencia, Spain

The oscillating piezoelectric field of a surface acoustic wave (SAW) has proven to be very useful in capturing and transporting photogenerated charges as well as spin ensembles in 2-D semiconductor heterostructures. In this contribution we demonstrate that the piezoelectric potential generated by a SAW propagating on a $LiNbO_3$ substrate can transport photoexcited carriers in GaAs-based nanowires (NWs) deposited on it, leading to remote exciton recombination in the form of sub-ns light pulses synchronized with the SAW frequency. This contactless manipulation of carriers by SAWs opens interesting perspectives for NW applications in opto-electronic devices operating at GHz frequencies. As an example, we demonstrate a high-frequency source of anti-bunched photons based on the acoustic transport of electrons and holes photoexcited on one end of the NW and their recombination in quantum-dot-like centers created by the introduction of In at the opposite end.

HL 104.2 Fri 12:00 EW 201

Photons on demand from an electrically driven single quantum dot under pulsed excitation — •Matthias Florian[1], Paul Gartner[1], Christopher Gies[1], Christian Kessler[2], Fabian Hargart[2], Matthias Reischle[2], Wolfgang-Michael Schulz[2], Marcus Eichfelder[2], Robert Rossbach[2], Michael Jetter[2], Peter Michler[2], and Frank Jahnke[1] — [1]Institut für Theoretische Physik, Universität Bremen — [2]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Universität Stuttgart

Electrically driven, integrated single-photon sources are key components for applications in quantum information. Cavity-enhanced quantum dots (QDs) offer fast relaxation and recombination times, enabling high repetition rates. Short electrical excitation pulses, on the other hand, are a challenge. In a collaboration between theory and experiment, we study the influence of electrical excitation-pulse parameters on the single photon emission from a single QD. On the basis of the time-integrated photon autocorrelation function, the anti-bunching is determined. The theoretical description is based on a solution of the von-Neumann equation, where we consider the single-particle states of the QD, together with many-body effects introduced by the Coulomb and light-matter interaction. The electrical pump pulse creates carriers in the delocalized barrier or WL states, from which we model the capture into the localized QD states, as well as intraband scattering and dephasing, via Lindblad terms. The reduction of the anti-bunching with increasing pulse width is in quantitative agreement with our experiments and defines the operational regime for practical applications.

HL 104.3 Fri 12:15 EW 201

Influence of the excitation pulse width on the purity of single-photon emission from light emitting diodes — •Fabian Hargart[1], Christian Kessler[1], Matthias Reischle[1], Wolfgang-Michael Schulz[1], Marcus Eichfelder[1], Robert Rossbach[1], Michael Jetter[1], Paul Gartner[2], Matthias Florian[2], Christopher Gies[2], Frank Jahnke[2], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Universität Stuttgart, Allmandring 3, 70569 Stuttgart — [2]Institut für Theoretische Physik, Universität Bremen, Postfach 330 440, 28334 Bremen

For many applications in quantum computing and quantum cryptography single-photons on demand are desirable. Electrically driven semiconductor quantum dots are a promising solution due to their tailorable emission energy and the possible integration in well-known semiconductor devices.

Present-day pulse generators feature pulse widths only down to several 10 ps which is comparatively long to ordinary laser pulses. Therefore we determine the influence of the electrical excitation pulses on the purity of single-photon emission from InP/GaInP quantum dots. For rising widths we observe an increasing $g^{(2)}(0)$ - value and on account of this we assume an increasing probability of further excitations during one single cycle. Using autocorrelation measurements with high temporal resolution we can distinguish the background contribution from re-excitation processes on the non-vanishing $g^{(2)}(0)$-value. Theoretical investigations are in a good agreement with the experimental results.

HL 104.4 Fri 12:30 EW 201

Triggered indistinguishable photons from site-controlled In(Ga)As quantum dots — •Markus Müller[1], Klaus D. Jöns[1], Paola Atkinson[2,3], Matthias Heldmaier[1], Sven M. Ulrich[1], Oliver G. Schmidt[3], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen and Research Center SCoPE, University of Stuttgart, Allmandring 3, 70569 Stuttgart, Germany — [2]Institut des Nanosciences de Paris, UPMC, CNRS UMR 7588, 4 Place Jussieu, 75252 Paris Cedex 05, France — [3]Institute for Integrative Nanosciences, IWF Dresden, Helmholtzstraße 20, 01069 Dresden, Germany

Self-assembled quantum dots (QDs) as solid-state single-photon sources are promising candidates for quantum information applications with particular respect to the generation of indistinguishable photons. For integration into emitter devices, individual control of the QD position is desirable. We investigate samples which consist of two vertically stacked layers of In(Ga)As QDs, where the local strain fields of the lower "seed" dot layers (SQDs) act as nucleation sites for QDs on top. The SQDs are grown on a pre-patterned GaAs substrate with a 12.5 x 12.5 μm^2 grid of small pits. Micro-photoluminescence maps of QD and SQD layers verify their mutual correlation of position. High-resolution photoluminescence reveals ultra-narrow single QD emission linewidths of ~ 10 μeV. Under quasi-resonant p-shell excitation we observe nearly background-free single-photon emission with $g^{(2)}(0) = 0.02$ and demonstrate the generation of triggered indistinguishable photon pairs with a high visibility up to 61%.

HL 104.5 Fri 12:45 EW 201

Two-photon emission from single GaN quantum dots — •Gordon Callsen[1], Juri Brunnmeier[1], Andrei Schliwa[1], Johannes Settke[1], Christian Kindel[1], Erik Stock[1], Alexander Dreismann[1], Satoshi Kako[2], Yasuhiko Arakawa[2], and Axel Hoffmann[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, Germany — [2]Institute of Industrial Science, University of Tokyo, Japan

Recent reports on single photon emission of MOCVD grown GaN quantum dots embedded in an AlN matrix at elevated temperatures ($>$ 200 K) resulted rising interest in such quantum dots with large exciton binding energy, oscillator strength and band-offset. Simultaneous observation of excitonic and biexcitonic emission in μPL-spectra allows direct determination of the strain state and size of the quantum dot. As characteristic for wurzite GaN/AlN quantum dots the biexciton binding energy varies between +3 meV and -11 meV. This transition of the biexciton binding energy from the binding to the antibinding case facilitates a spectral window in which the technologically desirable colour-coincidence of the exciton and the biexciton can be observed. We analyse the exciton-biexciton cascade in single GaN quantum dots which yields the observation of the emission of a photon couple in a narrow ($<$ 2 ns) time interval as demonstrated by photon-correlation measurements based on a Hanbury-Brown & Twiss setup. In detail analysis of the bunching signal of the autocorrelation experiments allows us to deduce the temporal evolution of the cascade process depending on temperature and excitation density variation.

HL 104.6 Fri 13:00 EW 201

Single photon emission from site-controlled InP quantum dots — Vasilij Baumann, •Christian Schneider, Florian Stumpf, Stefan Kremling, Lukas Worschech, Alfred Forchel, Sven Höfling, and Martin Kamp — Wilhelm Conrad Röntgen Center for Complex Material Systems, Technische Physik, Universität Würzburg

Single semiconductor quantum dots (QDs) turned out to be promising candidates to realize building blocks in the prospering research field of quantum information. Pronounced effects of light matter interaction between a single QD and an optical microcavity mode have been demonstrated and already exploited to fabricate single photon sources of high efficiency. A main obstacle towards the scalable fabrication of such devices is the self assembled growth method commonly applied to grow high quality quantum dots on GaAs substrates. Here, we discuss recent progress in the realization of well ordered arrays of InP quantum dots emitting in the visible spectral range. The QDs are ordered on nanohole lattices with pitches up to 1.25 μm. The large periods allow us to address overgrown single QDs via spatially resolved microphotoluminescence. While the average single QD emission linewidth amounts to 550 μeV, their bright emission features close to the detection maximum of highly efficient single photon detectors allows to carry out photon correlation measurments in an Hanbury Brown and Twiss configuration. We could extract a $g^{(2)}(\tau=0)$ value as small as 0.13, clearly demonstrating the single photon emission from such a QD.

HL 104.7 Fri 13:15 EW 201

Growth and Analysis of Quantum Dots with highly reduced Fine Structure Splitting — •Julian Treu, Alexander Huggenberger, Christian Schneider, Alfred Forchel, Sven Höfling, and Martin Kamp — Technische Physik, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

Quantum key distribution for secure communication requires efficient sources of single or entangled photons. A possible source for entangled photons is the biexciton-exciton cascade in semiconductor quantum dots (QDs). In this case, the fine structure splitting (FSS) has to be less than the homogenous linewidth. For InGaAs/GaAs QDs grown on common (100) substrates it can be shown that piezoelectric fields reduce the symmetry and often a reduction of the FSS by post-growth annealing or the application of an electric/magnetic field is required. Therefore, QDs with an inherently vanishing FSS are highly desirable.

We have investigated the growth of self organized, low density quantum dots (QDs) on high index substrates like (111) GaAs where such a reduction of symmetry is not existent. Microphotoluminescence spectroscopy (μPL) measurements reveal single QD lines in the range 850-900nm and linewidths below $100\mu eV$. The measured FSS $<10\mu eV$ is limited by the resolution of our setup.

HL 104.8 Fri 13:30 EW 201

Quantum key distribution using electrically triggered quantum dot - micropillar single photon sources — •Tobias Heindel[1], Markus Rau[2], Christian Schneider[1], Martin Fürst[2,3], Sebastian Nauerth[2,3], Matthias Lermer[1], Henning Weier[2,3], Stephan Reitzenstein[1,5], Alfred Forchel[1], Sven Höfling[1], Harald Weinfurter[2,4], and Martin Kamp[1] — [1]Technische Physik and Wilhelm Conrad Röntgen Research Center for Complex Material Systems, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany — [2]Fakultät für Physik, Ludwig-Maximilians-Universität, 80799 Munich, Germany — [3]qutools GmbH, 80539 Munich, Germany — [4]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany — [5]Present address: Institut für Festkörperphysik, Technische Universität Berlin, 10623 Berlin, Germany

In 1984, Bennett and Brassard proposed a secret key-distribution protocol (BB84) that uses the quantum mechanical properties of single photons to avoid the possibility of eavesdropping on an encoded message. So far, most quantum key distribution (QKD) experiments have been performed with strongly attenuated lasers due to the lack of efficient single photon sources. First experiments utilizing optically pumped solid state based single photon sources affirmed the great potential of QKD but still suffered from the drawbacks of this excitation scheme. In this work we report on a QKD experiment using electrically triggered quantum dot - micropillar single photon sources. These optimized devices generate sifted key rates of up to 35.4 kBits/s at a quantum bit error rate of 3.8 % and $g^{(2)}(0)$-values down to 0.148.

HL 104.9 Fri 13:45 EW 201

Semiconductor theory for higher order photon autocorrelation functions of quantum dot microcavity lasers — •Heinrich A. M. Leymann, Alexander Foerster, and Jan Wiersig — Otto-von-Guericke-Universität Magdeburg

Semiconductor quantum dots (QDs) are of considerable interest due to their potential for device applications such as lasers [1] and nonclassical light sources, as well as fundamental studies. We present a theory for the higher order photon auto-correlation functions $g^{(3)}(0)$, $g^{(4)}(0)$ based on an equation of motion technique. Starting from the semiconductor model described in [2] we present a general method to expand this theory to higher orders. The coherence properties of light emitted by QD based microcavity lasers are discussed. Also the convergence of the cluster expansion technique is investigated. Furthermore, photon anti-bunching for high fidelity cavity lasers near the threshold is discussed.

[1] J. Wiersig et al. , Nature (London) 460 245 (2009)
[2] C. Gies et al., Phys. Rew A 75 013803 (2007).