HL 24: Quantum Dots and Wires, Optical Properties II: Single Photon Sources

Time: Tuesday 11:30–12:45 Location: H17

HL 24.1 Tue 11:30 H17

Electrically driven quantum dot-micropillar single photon source with 34% overall efficiency — •Tobias Heindel, Christian Schneider, Matthias Lermer, Soon-Hong Kwon, Tristan Braun, Stephan Reitzenstein, Sven Höfling, Martin Kamp, Lukas Worschech, and Alfred Forchel — Technische Physik, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany

The realization of efficient single photon sources (SPSs) is a driving force in the development of quantum dot - microcavity structures. In fact, the outcoupling efficiency of a quantum dot (QD) can be strongly enhanced in the presence of a high quality microcavity providing three dimensional photon confinement. In this context, QD-micropillar cavities are of special interest due to predicted photon extraction efficiencies of up to 70%. In light of possible applications of SPSs, e.g. in quantum key distribution systems, and the associated device integration it is crucial to establish an electrical pumping scheme capable for high frequency operation.

We report on triggered single photon emission from low mode volume electrically driven quantum dot-micropillar cavities at repetition rates of up to 220 MHz. Due to an optimized layout of the doped planar microcavity and an advanced lateral current injection scheme, highly efficient single photon sources are realized. While $g^{(2)}(0)$-values as low as 0.13 ± 0.05 and a Purcell-factor of 4 are observed for a 2 μm diameter micropillar, single photon emission at a rate of (35 ± 7) MHz and an overall efficiency of (34 ± 7)% are demonstrated for a 3 μm device.

HL 24.2 Tue 11:45 H17

Quantum-dot-based, electrically-driven single-photon sources with 1 GHz excitation rate and with site-controlled quantum dot — •Jan A. Töfflinger[1], Erik Stock[1], Anatol Lochmann[1], Waldemar Unrau[1], Dieter Bimberg[1], Askhat K. Bakarov[2], Aleksandr I. Toropov[2], Aleksandr K. Kalagin[2], Vladimir A. Haisler[2], Paola Atkinson[3], and Oliver G. Schmidt[4] — [1]Institut für Festkörperphysik, TU-Berlin, 10623 Berlin, Germany — [2]Institute of Semiconductor Physics, 630090 Novosibirsk, Russia — [3]MPI für Festkörperforschung, 70569 Stuttgart, Germany — [4]IIN, IFW Dresden, 01069 Dresden, Germany

For future quantum cryptography systems the development of highly efficient, electrically pumped single-photon sources with high repetition rates is of utmost importance. We have developed InGaAs/GaAs-quantum dot (QD) based Resonant-Cavity LEDs (RC-LED). A built-in AlGaOx current aperture allows electrical excitation of a single QD. The resonant cavity leads to increased external quantum efficiency and due to the Purcell effect to an increase of the spontaneous emission rate allowing us to electrically pump the single QD at 1 GHz repetition rate. To further optimize our single photon sources and to increase the device yield we also demonstrate a new electrically pumped LED with a site-controlled MBE-grown InGaAs/GaAs-QD on pre-patterned GaAs substrate. Electroluminescence measurements show pure spectrum with only lines from a patterned QD and demonstrate single photon emission with a second order correlation function $g^2(0) \leq 0.4$. This work is partly funded by SfB 787 and NATO SfP 982735.

HL 24.3 Tue 12:00 H17

Triggered single–photon emission from electrically driven InP/(Al,Ga)InP quantum dots — •Christian Kessler, Matthias Reischle, Wolfgang-Michael Schulz, Marcus Eichfelder, Robert Rossbach, Michael Jetter, and Peter Michler — Institut für Halbleiteroptik und Funktionelle Grenzflächen, Universität Stuttgart, Allmandring 3, 70569 Stuttgart, Germany

Semiconductor quantum dots (QDs) are a promising approach to realize a single–photon source. To avoid bulky and expensive laser systems for future applications, electrical excitation is desirable. InP QDs are especially suited, as they emit in the red spectral range and therefore in the optimal range of commercial detectors. Additionally, they have been shown to be capable of emitting single photons up to 80 K [1]. Thus, we embedded InP QDs in the intrinsic region of a p–i–n diode. To form single devices, 100 μm mesas were etched and supplied with electrical contacts. We investigated the electroluminescence from single QDs and performed second-order auto correlation measurements to verify single–photon emission. To prevent expensive helium cooling and reach operation above 80 K, we investigated the influence of elevated temperature on the performance of our device. Since triggered single–photon emission is required for most applications, sub–nanosecond pulses were applied and pulsed single-photon ($g^{(2)}(0) = 0.24$) emission was observed up to 200 MHz.

[1] M. Reischle et al., Opt. Express 16, 12771 (2008)

HL 24.4 Tue 12:15 H17

Nanowire quantum dots as an ideal source of entangled photon pairs — •Ranber Singh and Gabriel Bester — Max-Planck-Institut für Festkörperforschung, Heisenbergstrasse 1, 70569 Stuttgart, Germany

We predict that semiconductor nanostructures grown along the [111] direction such as self-assembled quantum dots or nanowire quantum dots have vanishing fine structure splitting on the grounds of their symmetry and therefore, are ideal candidates for the generation of entangled photon pairs. We confirm this predicton by million-atom empirical pseudopotential calculations on *realistic* InAsP/InP and InGaAs/GaAs structures. We further study how robust the results are against deformations. Through the control of size, shape and composition the InAsP/InP nanostructures would emit at the optical fiber communication wavelength (*conventional C band*) of 1.55 μm (0.8 eV) which should boost their attractiveness.

HL 24.5 Tue 12:30 H17

Coherent optoelectronic manipulation of single excitons — •Steffen Michaelis de Vasconcellos[1], Simon Gordon[1], Dirk Mantei[1], Max Bichler[2], Torsten Meier[1], and Artur Zrenner[1] — [1]CeOPP, Universität Paderborn, Paderborn, Germany — [2]WSI, TU München, Garching, Germany

The coherent state manipulation of single quantum systems is a fundamental requirement for the implementation of quantum information devices. As recently shown, excitons in semiconductor quantum dots are an interesting qubit implementation for coherent optoelectronic devices, especially due to their excellent control by ultrafast laser pulses.

In our contribution, we present the coherent manipulation of an exciton in a single QD by electric signals. The new scheme employs a fixed optical clock signal and a synchronous electric gate signal, which is applied to a single QD photodiode and controls the coherent manipulation of the exciton qubit. A first picosecond laser pulse turns the qubit in a coherent superposition state. Afterwards, the phase of the qubit is manipulated by applying a 2.4 GHz electric signal, which is phase locked to the laser pulses. A second laser pulse is used to analyze the quantum state after the coherent manipulation. We are able to achieve a quantum phase shift of π by varying the electric phase of the 2.4 GHz signal. To verify the experimental data, we performed theoretical calculations based on the optical Bloch equations. These show a very good agreement with the experimental data.