HL 7: Single Photon Sources and Qbits

Time: Monday 11:00–12:30 Location: FOE Anorg

HL 7.1 Mon 11:00 FOE Anorg

Hyperfine interaction in electron spin qubits in quantum dots coupled via an optical cavity — •Julia Hildmann and Guido Burkard — Fachbereich Physik, Universitaet Konstanz, D-78457 Konstanz, Deutschland

Electron spin states in semiconductor structures represent good candidates for implementing quantum bits (qubits) [1]. Logical gates between distant qubits can be realized using a high finesse cavity and an adjustable laser field [2]. Virtual Raman transitions between an electron in the conduction band and a heavy hole in the valence band provide a controllable mechanism for single and two qubit operations. However there are several processes in semiconductor quantum dots leading to decoherence. In the time scale for the optical control of the qubit states the main source of the decoherence is due to Fermi contact hyperfine interaction with the surrounding nuclear spins (e.g. Overhauser shift of the Zeeman frequency) [3]. Here we calculate the fidelities of the two qubit operations in the presence of the nuclear spins. [1] D. Loss and D. P. DiVincenzo, Phys Rev. A 57, 120 (1998). [2] A. Imamoglu et al, Phys. Rev. Lett. 83, 4204 (1999). [3] W. A. Coish and J. Baugh, Phys. Stat. Solidi (b) 149, 1443 (2009).

HL 7.2 Mon 11:15 FOE Anorg

Single Photon Emission from a Quantum Dot in a Photonic Crystal Waveguide — •Simon Pütz, Arne Laucht, Thomas Günthner, Norman Hauke, Max Bichler, Michael Kaniber, and Jonathan J. Finley — Walter Schottky Institut, Technische Universität München, Am Coulombwall 4, D-85748 Garching, Germany

We experimentally investigate a single self-assembled InGaAs quantum dot embedded in a GaAs photonic crystal W1 waveguide as a source of single photons. We locate the position of the quantum dot by performing spatially-resolved photoluminescence experiments. Low temperature measurements performed with detection perpendicular to the surface and with detection at the cleaved end of the waveguide allow us to qualitatively compare the emission properties of the same quantum dot for the different geometries. While the relative emission intensity depends on the coupling strength of the quantum dot to the waveguide, power-dependent and time-resolved measurements show similar characteristics. Most importantly, autocorrelation measurements prove the single photon character of emission, making such a system an ideal candidate for on-chip photonic applications.

HL 7.3 Mon 11:30 FOE Anorg

Single photon emission from ultralow density InP/GaInP quantum dots — •Stefan Kremling[1], Asli Ugur[2], Sven Höfling[1], Lukas Worschech[1], Fariba Hatami[2], Ted Masselink[2], and Alfred Forchel[1] — [1]Technische Physik, Wilhelm Conrad Röntgen Research Center for Complex Material Systems, Physikalisches Institut, Universität Würzburg, Am Hubland, D-97074 Würzburg — [2]Department of Physics, Humbold Universität zu Berlin, Newtonstrasse 15, D-12489 Berlin

We have investigated ultralow-density InP quantum dots (QDs) in $In_{0,48}Ga_{0,52}P$. The QDs were grown using gas-source molecular-beam epitaxy (GSMBE) with ultralow growth rate. InP QDs emitting in the visible red spectral range and therefore they are ideal candidates for free space single photon applications, as Si avalanche photodiodes (APD) have their maximum efficiency in this spectral region.

Autocorrelation measurements under cw excitation were performed with a single QD and a pronounced antibunching dip was observed. Furthermore we investigated the electronic structure and magneto-optical properties. In-plane anisotropy will reduce the point group symmetry and therefore annihilate the spin degeneration and the bright exciton doublet splits into two linearly combined states, separated by a fine structure splitting. At zero magnetic field, the quantum dots show a large perpendicular linearly polarized fine structure splitting up to $320\mu eV$. Magneto-optical measurements in Faraday geometry exhibit a diamagnetic shift of $4\mu eV/T^2$ and Zeeman splitting with an effective exciton g-factor of ≈ 1.

HL 7.4 Mon 11:45 FOE Anorg

Excitation pulse width dependence of triggered single–photon emission from InP/(Al,Ga)InP quantum dots — •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

Compact and efficient single–photon sources are a key component for future applications such as quantum cryptography and quantum communication. Electrically excited semiconductor quantum dots (QDs) are a promising approach and cover a wide emission wavelength range, depending on the material system. Recently, it was demonstrated, that InP QDs, which emit in the technologically important red spectral range, show triggered single photon emission ($g^{(2)}(0) = 0.24$) up to 200 MHz excitation rate [1]. However, the nonzero $g^{(2)}(0)$–value could not fully be assigned due to background emission.

Here we demonstrate the influence of the finite excitation pulse width on the second–order correlation function and thereby the quality of the single–photon emission. We propose that a second exciton is captured if recombination occurs prior the end of the excitation pulse and thus leading to emission of a second photon. This mechanism is compared to a theoretical model and a good agreement is found.

[1] M. Reischle et al., APL 97, 143513 (2010)

HL 7.5 Mon 12:00 FOE Anorg

Spectroscopy of electrically controlled intentionally positioned and shape engineered single InAs quantum dots — Minisha Mehta[1], Dirk Reuter[2], Andreas D. Wieck[2], Stefan Michaelis de Vasconcellos[1], Artur Zrenner[1], and •Cedrik Meier[1] — [1]Physics Department ,Paderborn, Germany — [2]Applied Solid State Physics, Ruhr-University of Bochum, Bochum, Germany

Precise control of position and electronic/excitonic states of self-assembled quantum dots (QDs) might open exciting options towards single QD devices. We report the realization of an electrically driven single photon source by integrating an epitaxial InAs QD within a micron sized GaAs based p-i-n junction device. Two different growth techniques were employed: QD position control was achieved using site-selective growth of InAs QDs on focused ion beam (FIB) patterned GaAs surfaces. Engineering of electronic/excitonic states was achieved utilizing the growth of flushed InAs QDs on smooth GaAs surface via MBE. After the complete growth of p-i-n diode-like structure, FIB patterning and etching was used to fabricate LEDs having active area of 2×2 μm^2. Then, carrier injection and subsequent radiative recombination from site-selective and flushed InAs QDs was investigated individually. Few or single dots are expected to be electrically addressed in these devices. The result from micro-electroluminescence (EL) shows single dot characteristics from both devices. The EL spectra consist of sharp emission lines and their dependence on injection current is presented. Thus, these results suggest a promising pathway for quantum devices [1]. [1] M. Mehta et al., Appl. Phys. Lett. 97, 143101 (2010).

HL 7.6 Mon 12:15 FOE Anorg

SiGe-quantum dot arrays for Single Photon Detection — •Jürgen Moers[1,2], Natalia P. Stepina[3], Julian Gerharz[1,2], Anatoly V. Dvurechenskii[3], and Detlev Grützmacher[1,2] — [1]Institute of Bio- and Nanosystems, Forschungszentrum Jülich, D 52425 Jülich, Germany — [2]Jülich Aachen Research Alliance — [3]Institute of Semiconductor Physics, Russian Academy of Science, 630090 Novosibirsk, Russia

Emission and detection of single photons is required for a broad range of future device applications. In this work a Si based single photon detector employing hopping transport in densely packed Ge quantum dot (Ge-QD) arrays is proposed. The hopping transport through a high-density Ge-QDs array crucially depends on the average occupation of the Ge-QD array. Changing the charge state of one QD by illumination causes a change in the conductance of the whole array. Thus, step-like variations of the conductance due to the absorption of single photons and hence carrier generation in one single dot is noticeable. Time resolved 4-point measurements of the conductance of the device at 4.2K were performed. A fiber coupled laser with 1.55 μm wavelength and initial laser power of 1 mW was used for illumination.

To get extremely low light intensity the initial laser power was attenuated up to 60 dB. The conductance traces of the device show step like changes due to single Ge-QD charging and discharging. It could be shown, that the number of these events depends linearly on the light intensity, which is a prerequisite for single photon detection.