HL 32: Quantum dots and wires: Optical properties II

Time: Wednesday 15:00–17:30 Location: A 151

HL 32.1 Wed 15:00 A 151

Tuning Radiation Pattern and Polarization Anisotropy of Stacked Quantum Dots — •Ludwig Albrecht Thorsten Greif, Stefan Thomas Jagsch, and Andrei Schliwa — Technische Universität Berlin, Institut für Festkörperphysik

Control over the spatial radiation characteristics of individual photon emitters constitutes a promising way of optimizing various kinds of photonic devices. We show that the direction of predominant emission of stacked InGaAs quantum dots (QDs) as well as their polarization anisotropy can be tuned via two parameters: The number of stacked dots n and the height of the barrier layer h_b. Our simulations in the framework of 8-band $\mathbf{k}\cdot\mathbf{p}$-theory reveal that the wavefunctions form delocalized states when the separating barrier thickness is smaller than the height of a QD. We demonstrate how the collective aspect ratio AR_col of such closely stacked QDs can be used to tailor the average biaxial strain in the wavefunction region and consequently the radiation pattern itself.

HL 32.2 Wed 15:15 A 151

Multi-particle electronic structure of $\mathbf{In_{1-x}Ga_xAs_ySb_{1-y}/GaP}$ quantum dots — •Petr Klenovský[1,2], Petr Steindl[1,2], Elisa Maddalena Sala[3], Benito Alén[4], and Dieter Bimberg[3] — [1]Department of Condensed Matter Physics, Faculty of Science, Masaryk University, Kotlářská 2, 61137 Brno, Czech Republic — [2]Central European Institute of Technology, Masaryk University, Kamenice 753/5, 62500 Brno, Czech Republic — [3]Institut für Festkörperphysik Technische Universität Berlin, Hardenbergstraße 36 10623 Berlin, Germany — [4]Instituto de Micro y Nanotecnología, IMN-CNM, CSIC Isaac Newton, 8 PTM Tres Cantos 28760 Madrid

We investigate the multi-exciton structure of InGaAsSb/GaP quantum dots for different Ga and As compositions using the configuration interaction method with basis single-particle states obtained within the envelope function approximation based on k.p method. Depending on the dot composition the system is found to be of type-I or type-II nature. The type of transition in case of electrons originating from Γ, L, and X points of k-space and holes from Γ is, furthermore, calculated for different excitation intensities. Obtained emission energies and oscillator strengths of the transitions are compared to results of pumping-dependent photoluminescence measurements.

HL 32.3 Wed 15:30 A 151

GaN Nanowires for Optoelectronic Control of Nitrogen Vacancy Centers in Diamond — •Theresa Hoffmann[1], Martin Hetzl[1], Jakob Wierzbowski[1], Max Kraut[1], Verena Zuerbig[2], Christoph E. Nebel[2], Jonathan J. Finley[1], and Martin Stutzmann[1] — [1]Walter Schottky Institut and Physics Department, Technische Universität München, Garching, Germany — [2]Fraunhofer-Institut für Angewandte Festkörperphysik IAF, Freiburg, Germany

Nitrogen vacancy centers (NVs) are color centers in diamond with highest coherence times of their excited states which makes them promising candidates for quantum computing applications. However, charge state instabilities of surface-near NVs lead to optical blinking and spin state instabilities. Moreover, the high refractive index of diamond is unfavorable for their optical read-out.

We demonstrate an efficient method for the optical read-out of the NVs via GaN nanowire (NW) arrays as optical waveguides. Selective area growth of n-GaN NW arrays on a i-p-diamond (111) by molecular beam epitaxy allows the variation of the NW dimensions and position. Numerical simulations of the light propagation have been performed to optimize these parameters to obtain a maximum extraction efficiency of the NV PL signal through the NW array. In addition, p-i-diamond/n-GaN nano diodes have been implemented to stabilize and control the NV charge state via an externally applied voltage.

HL 32.4 Wed 15:45 A 151

Dynamical Tuning of Nanowire Laser Spectra [1] — •Maximilian Zapf[1], Robert Röder[1], Karl Winkler[2], Lisa Kaden[1], Johannes Greil[2], Marcel Wille[3], Marius Grundmann[3], Rüdiger Schmidt-Grund[3], Alois Lugstein[2], and Carsten Ronning[1] — [1]Institute for Solid State Physics, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena — [2]Institute of Solid State Electronics, TU Wien, Floragasse 7, A-1040 Vienna, Austria — [3]Felix Bloch Institute for Solid State Physics, Universität Leipzig, Linnéstraße 5, 04103 Leipzig, Germany

The availability of coherent light sources on the nanoscale has recently brought up visionary concepts of integrated photonic circuits, nanospectroscopy, and nanosensing. These concepts will tremendously benefit from a dynamically tunable laser spectrum. Semiconductor nanowires (NWs) can provide both continuous wave laser emission and ultrafast modulation capabilities but individual NW laser devices currently suffer from fixed emission spectra determined by the material band gap. Therefore, we demonstrate an individual nanowire laser based device, which can be gradually tuned by reversible length changes of the nanowire such that uniaxial tensile stress is applied to the respective semiconductor gain material. By straining the device, the spontaneous excitonic emission of the nanowire shifts to lower energies caused by the bandgap reduction of the semiconductor. Moreover, the optical gain spectrum of the nanolaser can be precisely strain-tuned in the high excitation regime. [1] Zapf et al. Nano Lett., 17, 6637 (2017)

HL 32.5 Wed 16:00 A 151

Atomistic pseudopotential calculations of the excitonic fine structure of InP and CdSe quantum dots — •Hanh Bui[1,2], Anastasia Karpulevich[1,2], and Gabriel Bester[1,2] — [1]Institut für Physikalische Chemie, Universität Hamburg, Grindelallee 117, D-20146 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, D-22761 Hamburg, Germany

Using the atomic effective pseudopotentials (AEPs) [1,2] and a small modification of the non-local part of pseudopotential to obtain the correct band-gaps, we perform the screened configuration interaction (CI) calculations and study the exciton fine structure of InP and CdSe quantum dots with hundreds to thousands of atoms. The strong confinement of particles in quantum dots enhances the electron-hole exchange interaction which splits the band-edge exciton into bright and dark exciton states, resulting in the so-called exciton fine structure. Our results fit well with experimental data.

[1] J. R. Cardenas and G. Bester, Phys. Rev. B 86, 115332 (2012).

[2] A. Karpulevich, H. Bui, D. Antonov, P. Han, G. Bester, Phys. Rev. B 94, 205417 (2016).

15 min. break.

HL 32.6 Wed 16:30 A 151

Coherence of a dynamically decoupled quantum-dot hole spin — •Lukas Huthmacher, Robert Stockill, Claire Le Gall, and Mete Atatüre — Cavendish Laboratory, University of Cambridge, JJ Thomson Avenue, Cambridge, CB3 0HE, UK

Single spins in self-assembled InGaAs quantum dots are promising candidates for the implementation of distributed quantum information processing. For the electron the strong hyperfine coupling to the surrounding nuclei dephases the spin states in a few ns, hindering the quality of the spin-photon interface. In contrast, a hole spin is expected to couple less to the nuclear spin bath, providing a promising alternative. While it has been shown that holes can offer a longer dephasing time, T_2^* [1], future progress hinges on what coherence times can be achieved through decoupling.

In this work, we establish the regimes that allow for a highly coherent hole spin in this system. We observe a pick-up and decay with external magnetic field for both the inhomogeneous dephasing time, T_2^*, as well as the coherence time, T_2. We show that the decoherence of the hole is still dictated by the hyperfine coupling to the nuclear spin environment for fields up to a few Tesla, whereas electrical noise dominates at higher fields. We implement dynamic decoupling in the latter regime to actively protect the hole spin, allowing us to achieve $T_2 = 4.4\,\mu$s, the longest for any spin in this system. Finally, we independently determine the local electrical environment which quantitatively supports the improvement of coherence we achieve with dynamic decoupling.

[1] D. Brunner *et al.* Nature **456**, 218 (2008)

HL 32.7 Wed 16:45 A 151

Indirect (In,Al)As/AlAs quantum dots: Carrier spin dynamics and recombination — •Janina Rautert[1], Sergey Nekrasov[2], Timur Shamirzaev[3], Jörg Debus[1], Dmitri

Yakovlev[1,2], Yuri Kusrayev[2], and Manfred Bayer[1,2] — [1]Experimentelle Physik 2, Technische Universität Dortmund, Germany — [2]Ioffe Institute, St. Petersburg, Russia — [3]Rzhanov Institute of Semiconductor Physics, Novosibirsk, Russia

Spin memory systems realized within a semiconductor application require structures that provide both long carrier lifetimes and spin relaxation times in the range of microseconds. Promising but little known candidates for that aim are (In,Al)As quantum dots (QDs) with an indirect band gap in the k-space. Here the direct band gap material is transformed to an indirect one by decreasing the QD size. Samples with a broad distribution of dot diameters allow the investigation of both types of QDs under selective excitation. Photoluminescence (PL) measurements in which the laser energy is tuned through the inhomogenously broadened dot ensemble show an increasing circular polarization degree up to 40% for indirect QDs speaking for a high spin relaxation time. Polarization degrees up to 90% can be reached by applying a small longitudinal field (mT-range) that suppress the nuclear spin fluctuations. In transverse magnetic fields however, the width of the Hanle curve corresponds to spin relaxation times of only a few nanoseconds. Therefore direct measurements of the spin dynamics and the exciton lifetime via time resolved PL are planned for the near future.

HL 32.8 Wed 17:00 A 151

Prospects of Quantum Dot based Quantum Cascade Lasers — •Alexander Mittelstädt and Andrei Schliwa — Technische Universität Berlin, Institut für Festkörperphysik

The examination of the electronic structure of stacked and strongly coupled quantum dots (QDs) serves as groundwork for the development of quantum cascade lasers [1] consisting of quantum dot chains as gain material [2]. We show intradot excited state to ground state transitions in stacks of 14 and 20 InGaAs QDs embedded in a GaAs matrix. Simulations of large scale systems at various biases are accomplished via a 'linear combination of atomic orbitals' type of approximation based on single quantum dot eight-band k*p-wavefunctions.

[1] J. Faist, F. Capasso, et al. Science, 264(5158):553-556, 1994.

[2] R. A. Suris. In Future Trends in Microelectronics, pp. 197-208. Springer Netherlands, 1996.

HL 32.9 Wed 17:15 A 151

Quantum dot rapid adiabatic passage by ultrafast Stark tuning — Amlan Mukherjee[1], Alex Widhalm[1], •Björn Jonas[1], Sebastian Krehs[1], Nand Lal Sharma[1], Peter Kölling[2], Andreas Thiede[2], Jens Förstner[2], Dirk Reuter[1], and Artur Zrenner[1] — [1]Physics Department, University of Paderborn, Warburger Straße 100, Paderborn 33098, Germany — [2]Department of Electrical Engineering, University of Paderborn, Warburger Straße 100, Paderborn 33098, Germany

For the case of pulsed laser fields and in the absence of decoherence, an exciton in a single QD represents a qubit, which can be tuned by electric fields. Robust state preparation has been achieved so far by using polarization tailored pulses [1] or chirped pulses for the realization of a rapid adiabatic passage (RAP) [2,3].

Here we demonstrate state preparation by RAP, using fast transient Stark shift of the exciton energy. Our system is based on self-assembled InGaAs QDs embedded in a low capacitance Schottky-photodiode. The photodiode is closely connected to a SiGe:C BiCMOS chip, which delivers transients as fast as 4.7 mV/ps at low temperature. The ps electric transient is synchronized to the optical pulse. The occupancy of the QD can be read out by photocurrent detection. We are able to observe the transition from an un-chirped Rabi scenario to a clear RAP signature when the electric chirp is applied.

[1] D. Mantei et al., Sci. Rep. 5, S. 10313 (2015)

[2] Yanwen Wu et al., PRL 106, 067401 (2011)

[3] C.M. Simon et al., PRL 106, 166801 (2011)