HL 74: Focus Session: Semiconductor-based Quantum Communication I

Recent advances in the field of photonic quantum dot structures allow now for the implementation of semiconductor-based quantum optical functionalities, which are essential for future quantum communication networks. Within the scope of this focus-session, leading groups in the field will present their latest results on single photon physics and technologies to a broader audience. (Organizers: Manfred Bayer, University of Dortmund, and Artur Zrenner, University of Paderborn)

Time: Thursday 9:30–12:30 Location: ER 164

Invited Talk HL 74.1 Thu 9:30 ER 164
A highly efficient single photon - single quantum dot interface — •P. Senellart, O. Gazzano, S. Michaelis de Vasconcellos, C. Arnold, V. Loo, A. Nowak, A. Dousse, A. Lemaitre, I. Sagnes, J. Bloch, P. Voisin, and L. Lanco — CNRS, Laboratoire de Photonique et de Nanostructures, UPR20, 91460 Marcoussis, France

A quantum dot (QD) in a microcavity is a promising system to build a solid-state quantum network. It can be an efficient quantum light source as well as a quantum memory, a Bell-state analyser or a remote photon entangler when the QD embeds a spin. However, for these applications, one needs a perfect interface between the QD and the external electromagnetic field. We report on the scalable fabrication of ultrabright sources of indistinguishable single photons. Full control of the coupling of QDs to well designed micropillar cavity modes allows to obtain sources with collection efficiencies as high as 70%. Moreover, the Purcell effect as well as the spectral filtering of the QD emission by the cavity mode allows to further increase the effective brightness of the source by an order magnitude. Indistinguishability of the photons is demonstrated with a mean-wave packet overlap around 75%. Using high quality factor cavities operating in the strong coupling regime, we also report on resonant reflectivity measurements. When increasing the excitation power, optical non-linearities are observed when the intracavity photon number reaches 0.5. The good matching of the pillar mode with a Gaussian laser beam ensures that one out of three external photons couples to the quantum dot optical transition.

Topical Talk HL 74.2 Thu 10:00 ER 164
Electro-elastic Control of Excitons in Semiconductor Quantum Dots — •Armando Rastelli[1], Rinaldo Trotta[1], Paola Atkinson[1], Eugenio Zallo[1], Johannes D. Plumhof[1], Santosh Kumar[1], Fei Ding[2], Andreas Herklotz[2], Kathrin Dörr[1], and Oliver G. Schmidt[1] — [1]Institute for Integrative Nanosciences, IFW Dresden, Helmholtzstr. 20, 01069 Dresden, Germany — [2]Institute for Metallic Materials, IFW Dresden, Helmholtzstr. 20, 01069 Dresden, Germany

Optically active semiconductor quantum dots (QDs) fabricated by epitaxial growth are excellent quantum emitters which may find application in the field of quantum communication. Unavoidable fluctuations inherent to the fabrication process, which lead to a spread in the light emission properties of QD ensembles, hinder the use of most QDs in advanced quantum optics experiments. Post-growth techniques are therefore required to fine-tune the electronic structure of single QDs.

In this talk we will introduce new hybrid devices obtained by integrating semiconductor diode-membranes with embedded QDs onto piezoelectric actuators made of lead magnesium niobate-lead titanate (PMN-PT) single crystals. This combination allows us on one hand to study in detail the effects produced by variable tensile and compressive strains (with magnitude up to about 0.2%) on the excitonic emission of single QDs and on the other to control the emission properties in a broad range by simultaneous application of electric fields and stress. Obtained results and envisioned perspectives will be discussed.

Topical Talk HL 74.3 Thu 10:30 ER 164
Electrically contacted quantum dot - micropillars: building blocks for future quantum communication systems — •Stephan Reitzenstein[1,2], Tobias Heindel[2], Peter Gold[2], Manuel Gschrey[2], Christian Schneider[2], Sven Höfling[2], Martin Kamp[2], and Alfred Forchel[2] — [1]Present address: Institut für Festkörperphysik, Technische Universität Berlin, Berlin, Germany — [2]Technische Physik, Universität Würzburg, Würzburg, Germany

Future quantum communication systems such the a quantum repeater will rely strongly on the availability of compact quantum light sources, quantum memories and interfaces for the interconversion between local qubits and flying qubits. In this respect, quantum dot (QD) - microcavity systems exploiting cavity quantum electrodynamics (cQED) effects are of particular interest. Indeed, cQED effects allow one to enhance the efficiency of QD based single photon sources and to realize coherent coupling between light and matter.

In this contribution, we will address the potential of high quality electrically contacted QD - micropillar cavities to act as building blocks for quantum communication systems. We will show that these structures can act as highly efficient single photon emitters and as such are very suitable sources for quantum key distribution systems. Moreover, electrically contacted QD - micropillars could pave the way for qubit interconversion which will be demonstrated by means of single quantum dot photocurrent spectroscopy.

Coffe Break (30 min)

Invited Talk HL 74.4 Thu 11:30 ER 164
Semiconductor photonics for quantum information applications — •Andrew Shields — Toshiba Research Europe, 208 Cambridge Science Park, Milton Road, Cambridge UK

We discuss recent progress in generating and detecting quantum states of light using semiconductor devices. Single photon light emitting diodes (LEDs) generate quantum light states via the electroluminescence of a single self-assembled quantum dot. Recently the viability of these sources for quantum information applications has been greatly enhanced by voltage-controlled wavelength tuning that allows indistinguishable photons to be generated from different, spatially-separated devices. Quantum dot LEDs may also be used to generate polarization-entangled photon pairs. Semiconductor detection technology has also advanced remarkably in recent years, now allowing high efficiency detection with photon number resolution. We discuss the application of these devices to photonic quantum logic and long distance quantum communication.

Topical Talk HL 74.5 Thu 12:00 ER 164
Towards On-Chip Quantum Optics using Superconducting Single Photon Detectors coupled to Photonic Crystal Waveguides — •Günther Reithmaier[1], Jörg Senf[1], Arne Laucht[2], Max Bichler[1], Rudolf Gross[3], and Jonathan Finley[1] — [1]Walter Schottky Institut, TU München, Germany — [2]Centre for Quantum Computation Communication Technology, Sydney, Australia — [3]Walther-Meißner-Institut, TU München, Germany

We report on-chip generation of single photons in a GaAs 2D photonic crystal waveguide (PCW) and progress towards integration with NbN superconducting nanowire single photon detectors (SNSPDs) [2]. Single self-assembled InGaAs QDs inside the waveguide are located using spatially resolved microscopy. Detection from the waveguide facet shows a 55x more efficient coupling to the PWG mode compared to detection along an axis perpendicular to the sample surface. Time-resolved PL measurements show that the fraction of all spontaneous emission emitted into the waveguide mode is 85-96% and clean single photon emission is observed. We also describe first steps to integrate SNSPDs directly onto such a GaAs photonic crystal. SNSPDs combine high detection efficiency, low dark count rates and picosecond timing resolution [1], properties that depend strongly on the crystal quality of the NbN film [2]. By optimizing the nitrogen pressure and substrate temperature, NbN films on GaAs exhibit a superconducting T_c=11.2K and ΔT=0.5K. [1]G. N. Goltsman et al., APL 79,6 (2001) [2]F. Marsili et al., Supercond. Sci. Technol. 22 (2009) 095013