HL 59: SKM Symposium: Semiconductor Nanophotonics - Quantum Optics and Devices (SYNP)

Time: Wednesday 14:30–17:15 Location: TRE Ma

Invited Talk HL 59.1 Wed 14:30 TRE Ma

Quantum Optics on Photonic Chips — •Dirk Englund[1], Brendan Shields[2], Hongkun Park[2], Mikhail Lukin[2], Kelley Rivoire[3], Jelena Vuckovic[3], and Fariba Hatami[4] — [1]Columbia University — [2]Harvard University — [3]Stanford University — [4]Humboldt University

Nanoscale optical structures present a path towards controlling the interaction of photons with single emitters in solids, such as semiconductor quantum dots or color centers. I will describe how this controlled light matter interaction may enable the construction of basic components for quantum information science. I will discuss recent work on cavity-enhanced generation of single photons; nonlinear optical interactions at the single photon level; and some recent work towards cavity-enhanced optical interactions with long-lived spin states in the diamond nitrogen vacancy center.

Invited Talk HL 59.2 Wed 15:00 TRE Ma

Two-photon Interference from Separate Quantum Dots — Edward Flagg, Andreas Muller, Sergey Polyakov, Alexander Ling, Alan Migdall, and •Glenn S. Solomon — Joint Quantum Institute, NIST & University of Maryland, Gaithersburg, MD USA

Semiconductor quantum dots (QDs) are attractive sources of single photons. When single photons emitted by two separate QDs are indistinguishable they will interfere when brought together at a beam splitter in a Hong-Ou-Mandel (HOM)-type experiment. This two-photon interference is needed in many proposed schemes for quantum computation and quantum networking involving quantum repeaters. However, while photons emitted by a single QD in a microcavity have been shown to be highly indistinguishable, mutually indistinguishable photons from separate QDs have only recently been produced [1].

Here we discuss results from an HOM experiment in which interference of photons from two QDs located in different samples is observed and is below the classical limit. We use strain-induced InAs QDs excited by a common pulsed laser. One QD is embedded in a planar optical microcavity of fixed resonant frequency, the other QD resides in a fiber-semiconductor tunable cavity. Despite having non-identical emission properties, the photons emitted from the QDs interfere in the HOM experiment. We obtain a probability of coalescence of the two photons of 18 %, which is increased to 47 % when post-selection within a small detection time window is applied. Dephasing processes limiting the coalescence, and extension to other quantum interfaces will be discussed. [1] E. B. Flagg, et al., Phys. Rev. Lett. 104, 137401 (2010).

Invited Talk HL 59.3 Wed 15:30 TRE Ma

Coherent optoelectronic control of a single exciton qubit — •Artur Zrenner[1], Steffen Michaelis de Vasconcellos[1], Simon Gordon[1], Dirk Mantei[1], Wadim Quiring[1], Mohannad Al-Hmoud[1], Torsten Meier[1], Max Bichler[2], Andreas D. Wieck[3], and Dirk Reuter[3] — [1]Universität Paderborn, D-33095 Paderborn — [2]Walter Schottky Institut, Technische Universität München, D-85748 Garching — [3]Ruhr-Universität Bochum, D-44780 Bochum

Due to their excellent coupling to light, excitons in semiconductor quantum dots are in particular interesting for the implementation of coherent optoelectronic devices. In our present contribution we present results on the coherent manipulation of an exciton by fast electric signals. The new scheme employs fixed optical clocking and a synchronous electric gate signal, which is designed to coherently control the phase of the exciton qubit. A first picosecond laser clock pulse turns thereby the qubit in a coherent superposition state. Afterwards, the phase of the qubit is manipulated by an electric signal, which is phase locked to the laser pulses. A second laser pulse and subsequent state projection by tunneling are used to analyze the quantum state after the coherent manipulation. Using this protocol, we are able to achieve a quantum phase shift of up to pi by varying the electric signal. To verify the experimental data we performed calculations based on the optical Bloch equations. Such voltage controlled qubit manipulations seem to be essential for new types of scalable optoelectronic quantum phase gates and novel applications in the field of coherent optoelectronics.

Coffee Break

Invited Talk HL 59.4 Wed 16:15 TRE Ma

Generation of non-classical states of light with site- and potential-controlled pyramidal quantum dots — •Eli Kapon — Ecole Polytechnique Fédérale de Lausanne Laboratory of Physics of Nanostructures 1018 Lausanne, Switzerland

Generation of non-classical states of light, such as single photons, bunched photons and entangled photos, using semiconductor quantum dots (QDs) has been of major interest both for fundamental studies as well as for applications in quantum information processing. Here we review recent progress of such light generation using (In)GaAs/(Al)GaAs pyramidal QDs grown on patterned (111)B GaAs substrates, for which the location on a substrate, the heterostructure potential, and the emission wavelength can be controlled to a large extent. The control over nucleation site and 3D heterostructure configuration permits the design of the QD states energies and barriers, as well as the polarization of the emitted photons. The site- and emission wavelength-control make possible the integration of the QDs with optical nano-cavities in a reproducible and scalable manner. The (111) substrate orientation yields QDs of higher (C3v) symmetry as compared with most conventional QD systems, which leads to virtually vanishing fine structure splitting and high yield of 2X-X entangled photons emission. Recent results on polarization-entangled photon emission [1] and first observation of phonon-assisted coupling of 3D-confined excitons with optical cavity modes [2] will be presented and discussed. [1] A. Mohan et al., Nature Photonics 4, 302 (2010). [2] M. Calic et al., submitted (2010).

Invited Talk HL 59.5 Wed 16:45 TRE Ma

Semiconductor Devices for Quantum Photonics — •Andrew Shields[1], Anthony Bennett[1], Mark Stevenson[1], Cameron Salter[1,2], Raj Patel[1,2], Ian Farrer[2], Christine Nicoll[2], and David Ritchie[2] — [1]Toshiba Research Europe Ltd, 208, Cambridge Science Park, Milton Rd, Cambridge CB40GZ. UK — [2]Cavendish Laboratory, University of Cambridge, Madingley Road, Cambridge CB30HE. UK

Often referred to as "artificial atoms", quantum dots possess discrete energy levels that make them viable hosts for electronic qubits or sources of photonic qubits. However, unlike atoms, no two quantum dots are alike, a complication for quantum information schemes requiring either indistinguishable electronic states in different quantum dots, or indistinguishable photons emitted from different quantum dots. We demonstrate here that the transition energy of a quantum dot can be continuously varied, over a range much larger than the linewidth, using an electric field applied in a diode structure. By tuning individual quantum dots to identical energies we demonstrate two-photon interference of photons emitted from truly remote, independent quantum dots, thereby overcoming a significant barrier to scalable quantum information processing. Quantum dots may be used not only to generate single photons, but also polarization entangled pairs. We demonstrate here an electrically-driven entangled light source, based upon the electroluminescence of a single quantum dot in a semiconductor light emitting diode (LED). The device can be operated with continuous or pulsed current injection, with an entanglement fidelity in the latter case of up to 0.83+/-0.03. We also observe a violation of Bell's inequality with the device emission.