8 NCCR Quantum Photonics

Tuesday, 22.06.2010, Room 120

Time	ID	Quantum Photonics *Chair: A. Weis, Uni Fribourg*
13:15	**801**	**Towards single-spin quantum jumps in a self-assembled InAs/GaAs quantum dot** *Parisa Fallahi, Selman Tunc Yilmaz, Atac Imamoglu, Institute of Quantum Electronics, ETH Zürich, Wolfgang-Pauli-Strasse 16, 8093 Zürich* Electron spins trapped in solid state quantum dots (QDs) are among major candidates for a quantum bit. Among the many proposed schemes for spin based quantum computation, the all-optical computation schemes offer the possibility of initialization and readout on much faster time scales than spin decay and decoherence in optically active QDs. Recent years has seen great progress towards full optical control of the electron spin in self-assembled QDs, including the experimental demonstration of optical spin initialization, readout, and coherent manipulation. However a single-shot optical read out of the electron spin is yet to be achieved. In this work we report on the demonstration of a spin measurement where we identify one of the spin states with a confidence level exceeding 99% upon detection of a photon in a sub-microsecond timescale. A resonant excitation laser is focused down to a diffraction limited spot on a single InAs/GaAs QD inside a He bath cryostat and the reflected light is collected through an optical fiber and detected with an avalanche photo detector (APD). We detect resonant fluorescent photons from the QD by canceling the background resonant laser up to 6 orders of magnitude. Every time the electron spin is up, a quantum dot photon is detected on the APD with 5% probability, allowing us to observe on average 5% of the spin quantum jumps to the up state. The laser background is sufficiently suppressed such that detection of a photon on the APD corresponds to a spin up state with more than 99% probability.
13:30	**802**	**Optically driven electron pump using InAs quantum dots** *Laurent Nevou [1], Valeria Liverini [1], Peter Friedli [2], Fabrizio Castellano [1], Alfredo Bismuto [1], Hans Sigg [2], Jérôme Faist [1]* *[1] Institute of Quantum Electronics, Physics Department, ETH Zürich, Wolfgang-Pauli-Str. 16, 8093 Zürich* *[2] Lab. for Micro- and Nanotechnology, Paul Scherrer Institut, 5232 Villigen PSI* The discovery of the Josephson effect and of the quantum Hall effect have revolutionized the metrology of electrical quantities. As a result, there is an increased interest in closing the metrological triangle [1] by the construction of an electron pump in which N electrons of charge q are pumped individually at a frequency f. We propose the use of an InAs/(In)GaAs self-assembled quantum dot (QD) based photovoltaic infrared detector pumped by a pulsed laser as an electron pump. Our device consists of one plane of self-assembled InAs QDs coupled to an InGaAs quantum well as an injector. An infrared laser periodically ionises the QDs and as a result, when the laser pulse duration is shorter than the time required to refill the electrons into the QDs, the number of electrons generated are counted. [1] J. Flowers, Science, 306, 1324 (2004).

13:45	803	**Multicolor-magnetically assisted quantum cascade laser emitting from 730GHz to 1.4THz and 3.2THz** *Dana Turcinkova, Giacomo Scalari, Maria Ines Amanti, James Lloyd-Hughes, Milan Fischer, Mattias Beck, Jerome Faist* *Institute of Quantum Electronics, ETH Zürich, Wolfgang Pauli Str. 16, 8093 Zürich* Investigation of THz Quantum Cascade Lasers (QCLs) in the presence of strong magnetic field provides keys to the improvement of performances of these devices. We present results from application of magnetic field perpendicular to THz QCL showing gain enhancement on different optical transition and laser action over a large range of frequencies from 730 GHz to 3 THz. The structure [1] based on three wells using the resonant phonon depopulation emitts at 3 THz at B=0 T. Magnetic confinement influences the intersubband scattering mechanisms, leading in our case of design to effective quenching of thermally activated non-radiative processes and finaly laser emission at 1 THz is observed at temperature 115 K. The results are discussed with respect to [2]. [1] G. Scalari, M. I. Amanti, M. Fisher, R. Terazzi, C. Walther, M. Beck and J. Faist, Appl. Phys. Lett. 94, 041114 (2009) [2] A. Wade, G. Fedorov, D. Smirnov, S. Kumar, B. S. Williams, Q. Hu and J. Reno, Nature Photonics 3, 41 (2009)
14:00	804	**Mapping multiple photonic qubits into and out of one solid-sate atomic ensemble** *Imam Usmani, Mikael Afzelius, Hugues de Riedmatten, Christoph Clausen, Nicolas Gisin* *Groupe de Physique Appliquée, Université de Genève, 20 rue de l'école médecine, 1211 Genève* Quantum communication, for instance quantum key distribution, is today limited to about 200km because of exponential transmission losses in fibres. Future long-distance quantum communication (>500km) is possible via quantum repeaters. A key component in these is a quantum memory, which is a storage device for single photons. The entanglement distribution rates in quantum repeaters would greatly benefit from multi-mode quantum memories capable of storing many single photons in multiple modes. Here we present our work towards achieving such quantum memory. As host materials, we work with rare-earth-doped crystals. To achieve the storage and retrieval of light, we use a photon-echo type protocol: the atomic frequency comb (AFC). This is an intrinsically multimode protocol. We have recently mapped around 64 different temporal modes, at the single photon level, onto a crystal. That can be used to encode time-bin qubits and analyse them. The final goal is to store single photons which could distribute entanglement.

14:15	**805**	**Coupling single electron spins** *Kathrina Weiss, Jeroen Elzerman, Javier Miguel-Sanchez, Atac Imamoglu, Institut für Quantenelektronik, ETH Zürich, Wolfgang-Pauli-Str. 16, HPT, 8093 Zürich* Recently it has become possible to grow stacks of two vertically coupled InGaAs quantum dots (CQD), which offers the possibility to explore coupled electron spins. CQDs are supposed to have longer coherence times, when they are charged with one electron respectively. This leads to hybridization into four ground states, which exhibit singlet-triplet splitting. When the splitting is large enough, the hyperfine interaction can be suppressed. We have performed high-resolution laser spectroscopy on a system of coupled electron spins, finding spin singlet and triplet eigenstates.
14:30	**21**	***Winner of the SPS Award for General Physics, sponsored by ABB***
14:45	**23**	***Winner of the SPS Award for Applied Physics, sponsored by OC Oerlikon***
15:00		***END***
15:30		***Coffee Break***

ID	QUANTUM PHOTONICS POSTER
811	**Charge controlled self-assembled Quantum Dots coupled to photonic crystal cavities** *Dorothea Pinotsi, Parisa Fallahi, Javier Miguel Sanchez, Atac Imamoglu* *Department of Physics, IQE, ETH, Wolfgang Pauli Strasse 16, 8093 Zürich* Electron spins in Quantum Dots (QDs) have emerged as potential candidates for qubits in quantum information processing systems.Coupling the QD to a nanocavity mode enhances the interaction between photons and the electron spin in the QD allowing for more efficient information exchange between the QD and the cavity as well as enhancement of light extraction from the QD. Electrically gated structures that allow for QD charge-control as well as high-Q cavity modes are fabricated. The InGaAs QDs are embedded in the intrinsic region of a p-i-n structure. By contacting the heavily doped n and p GaAs layers separately, gate voltage control of the QD charging state is achieved and ensures that the lowest energy states of the QD-cavity system are the electron spin states. Photonic crystal cavities with quality factors of more than 6000 have been fabricated. In order to achieve QD-cavity coupling, spatial and spectral matching is required. Several tuning strategies are employed; temperature tuning or adsorption of Nitrogen at low temperatures. Additionally in these structures the quantum confined Stark effect is employed to tune reversibly the dot-nanocavity coupling by varying the gate voltage. We have explored the coupling of QDs to various cavities by measuring the Purcell enhancement of the QD radiative decay rate and using time resolved photon counting techniques. A clear Purcell enhancement of up to 7 is seen for QDs coupled to a cavity. Having demonstrated QD-cavity coupling and controlled charge tuning of the QDs, we aim at using these structures for single electron spin manipulation and measurement. Deterministic

charging allows us to work in the singly charged state of the QD. We expect an increase in the overall signal from the QD when coupled to a cavity, due to the cavity induced enhancement of the number of scattered photons from the QD and the improved collection efficiency through the cavity.

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Optical control of nuclear spin flips

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Electron spins confined in semiconductor quantum dots (QD) are promising candidates for quantum bits because of their long coherence time [1]. The main decoherence mechanism forthe electron spin is given by its strong hyperfine coupling with the randomly fluctuating nuclear spins. For a better understanding of the decoherence process a further investigation of the electron-nuclear-spin system in a QD is necessary.
We have observed bidirectional locking of QD resonances to the incident laser frequency at magnetic fields exceeding 1T. This indicates a nuclear spin polarization. Theoretical analysis suggests narrowing of the nuclear spin distribution which which will in turn enhance the T2* time [2]. Our coherent population trapping measurements aim at measuring this narrowing. The ultimate goal is to control and measure nuclear spin flips with an accuracy approaching that of a single nuclear spin.

[1] J. R. Petta et al., Coherent Manipulation of coupled Electron Spins in Semiconductor Quantum Dots. Science 306, 2180-2184 (2005).
[2] C. Latta et al., Confluence of resonant laser excitation and bidirectional quantum-dot nuclear-spin polarization. Nature Physics 5, 758-763 (2009).