Q 19: Quanteninformation: Festkörper und Photonen

Time: Monday 16:30–18:45 Location: V38.04

Q 19.1 Mon 16:30 V38.04

Long-range quantum gates for nitrogen-vacancy defect centers in diamond — •Hendrik Weimer, Norman Yao, Chris Laumann, and Mikhail Lukin — Physics Department, Harvard University, Cambridge, MA, USA

Nitrogen-vacancy (NV) defect centers in diamond are a promising platform for room-temperature quantum computation. However, the coupling of individual NV qubits remains a challenge as the distances required for optical addressing are much larger than the typical interaction scales. We propose to realize long-range quantum gates through interactions with an intermediate NV spin ensemble. We show that engineering the many-body spin ensemble allows to achieve high-fidelity gates even in the presence of strong disorder [1].

[1] H. Weimer et al., arXiv:1109.1003 (2011).

Q 19.2 Mon 16:45 V38.04

Electron spin entanglement in diamond at room temperature — •Florian Dolde[1], Ingmar Jakobi[1], Boris Naydenov[1,2], Sebastien Pezzagna[3], Jan Meijer[3], Christina Trautmann[4], Philipp Neumann[1], Fedor Jelezko[2], and Jörg Wrachtrup[1] — [1]3. Physikalische Institut Universität Stuttgart — [2]Institut für Quantumoptik Univrsität Ulm — [3]Rubion Ruhr-Universität Bochum — [4]GSI Darmstadt

Negatively charged centers (NV) in diamond are one of the most remarkable colour defect centres owing to their unique properties. The electron and nuclear spin state of a single NV can be initialized, readout and manipulated even at room temperature. Moreover, NVs show very long electron spin coherence times, which make them ideal candidates for solid state quantum bits (qubits). Quantum register based on two coupled NVs has been already demonstrated [1], but due to short coherence times of that NVs, it was not possible to create entanglement.

Here we report the preparation of different entangled states between two NVs produced by nitrogen ion implantation in an isotopically purified ^{12C} diamond. The entangled state were used to conduct global phase measurements and an entanglement storage scheme using the intrinsic ^{15}N nuclear spin was implemented

[1]P. Neumann et al., Nat. Phys. 6, 249 (2010).

Q 19.3 Mon 17:00 V38.04

Silicon-Vacancy color centers in diamond nanowires — •Carsten Arend[1], Elke Neu[1], Jennifer Choy[2], Birgit Hausmann[2], Thomas Babinec[2], Marko Loncar[2], Martin Fischer[3], Stefan Gsell[3], Matthias Schreck[3], and Christoph Becher[1] — [1]Universität des Saarlandes, FR 7.2 Experimentalphysik, D-66123 Saarbrücken — [2]Harvard University, School of Engineering and Applied Sciences, Cambridge, MA 02138 — [3]Universität Augsburg, Lehrstuhl für Experimentalphysik 4, D-86135 Augsburg

Color centers in diamond are promising sources for single photons because of their photostability and room temperature operation. Silicon-Vacancy (SiV)-centers are particularly interesting, since they feature narrow zero-phonon-lines (ZPLs) in the near infrared (738 nm), low phonon coupling and high brightness [1]. To gain high brightness single photon sources nanowires (NWs) in single crystal diamond have been used to significantly enhance the collection efficiency of color center fluorescence [2]. We here report for the first time on SiV-centers in diamond NWs. The NWs are produced by structuring a heteroepitaxial CVD diamond film containing in-situ created SiV-centers. SiV-centers in NWs feature count rates up to 4 Mcps and ZPLs down to 0.9 nm at room temperature. At cryogenic temperature, the fine structure splitting of the ZPL unambigously identifies the SiV-centers. Due to a reduced emission angle, these devices should allow for efficient photon collection using low NA systems.

[1] E. Neu et al., New. J. Phys. 13, 025012 (2011)
[2] T. Babinec et al., Nature Nanotech. 5, 195 (2010)

Q 19.4 Mon 17:15 V38.04

Realization of a fiber based microcavity for coupling a single N-V center in diamond — •Roland Albrecht[1], Christian Deutsch[2], Jakob Reichel[2], Tim Schröder[3], Andreas W. Schell[3], Oliver Benson[3], and Christoph Becher[1] — [1]Fachrichtung 7.2, (Experimentalphysik), Universität des Saarlandes, Campus E2.6, 66123 Saarbrücken — [2]Laboratoire Kastler Brossel, ENS/UPMC-Paris 6/CNRS, 24 rue Lhomond, 75005 Paris, France — [3]Institut für Physik, AG Nanooptik, Humboldt-Universität zu Berlin, Newtonstraße 15, 12489 Berlin

Fiber based Fabry-Perot cavities [1] are promising candidates for coupling a single N-V center in diamond to a micro-cavity. On the fiber facets spherical imprints have been produced either by CO_2 laser machining or by focussed ion beam milling respectively prior to deposition of a dielectric coating. We achieve radii of curvature as small as $15\mu m$ and a depth of $1\mu m$ with a sub-nm surface roughness.
We investigate two different cavity setups: 1.) The cavity is built with one fiber mirror and a plane mirror onto which diamond nanocrystals containing single N-V centers have been spincoated. 2.) A cavity consisting of two fiber mirrors onto one of them a preselected diamond nanocrystal containing a single N-V center has been deposited.
These cavities are easily tunable and are automatically fiber-coupled. We have realized cavities with a Finesse of up to 4000 and a mode volume of less than $15\lambda^3$.

[1] D. Hunger et al.,New J. Phys. 12, 065038 (2010)

Q 19.5 Mon 17:30 V38.04

Microwave structures surrounding nano-fabricated solid immersion lenses registered to single emitters in diamond on demand — •Luca Marseglia[1], Florian Striebel[1], Andreas Häussler[1], Boris Naydenov[1], Jan Meijer[2], and Fedor Jelezko[1] — [1]Institut für Quantenoptik, Universität Ulm, Albert-Einstein-Allee 11, 89081 Ulm - Germany — [2]Ruhr-Universität Bochum, Universitätsstraße 150, 44801, Bochum, Germany

The negatively charged Nitrogen Vacancy colour centre (NV) is a spin active defect with a long spin lifetime at room temperature. It is a three level system which ground state spin can be efficiently readout and controlled at the single atom level. In addition, long coherence time associated with single spin in spin-free diamond lattice make this centre an excellent candidate as qubit for quantum information purpose. To the whole power of the NV the control we aim to have a microwave structures precisely positioned on the colour centre. Furthermore, in order to improve the optical detection of single spins we formerly developed a technique to fabricate solid immersion lenses (SILs), using Focus Ion Beam (FIB) system, that allows to avoid any refraction at the diamond-air interface. Using combination of lithography and FIB technologies we will create a microwave circuit surrounding the SIL, previously etched and coupled to the colour centre in the diamond on demand. This allows us to increase the collection of the light from the NV centre and in the same time to drive the splitting of its ground state, in a precise, scalable integrated way.

Q 19.6 Mon 17:45 V38.04

Single Pr3+ ion in yttrium aluminum garnet (YAG) nanocrystals — Roman Kolesov[1], •Kangwei Xia[1], Rolf Reuter[1], Rainer Stöhr[1], Jan Meijer[2], Hemmer Philip[3], and Joerg Wrachtrup[1] — [1]3. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, Stuttgart, D-70569, Germany — [2]Ruhr-Universität Bochum, RUBION, Bochum, D-44780, Germany — [3]Department of Electrical & Computer Engineering, Texas A&M University, College Station, TX 77843-3128, USA

Rare-earth crystals are widely studied and considered as good candidates for solid state optical quantum computing [1] due to long decoherence time of electron and nuclear spins and well resolved electronic structures [2]. For realizing spin qubit based on rare earth impurities, optical detection of a single rare-earth emitter is required. However, single rare-earth ion in crystals has not been demonstrated so far. Here, we report on observation of single Pr3+ ion doped YAG nanocrystals by using visible-to-ultraviolet upconversion at room temperature [3]. Optical properties of single Pr: YAG are also presented. Future experiments on single Pr3+ ions at low temperature are discussed. Reference [1] M.P. Hedges, J.J. Longdell, Y. Li, and M.J. Sellars, Nature 465, 1052 (2010) [2] J.B. Gruber, M.E. Hills, R.M. Macfarlane, C.A. Morrison, and G.A. Turner, Chem. Phys. 134, 241 (1989) [3] G. *Ozen, O. Forte, and B. Di Bartolo, Optical Materials 27, 1664 (2005)

Q 19.7 Mon 18:00 V38.04

Quantum dot resonance fluorescence: the complete spectrum — •Clemens Matthiesen, Peter Humphreys, Anthony Nickolas Vamivakas, and Mete Atature — Cavendish Laboratory, University of Cambridge, JJ Thomson Avenue, Cambridge CB3 0HE, United Kingdom

Quantum dot resonance fluorescence provides direct access to resonantly generated photons and has proven to be a useful technique in recent years for studying self-assembled QD spin dynamics [1-2]. Taking advantage of the optical selection rules of QD transitions and linear optical elements we achieve a signal to background ratio exceeding 1000 when driving a transition at saturation. We proceed to study the coherence of QD resonance fluorescence directly via first-order correlation measurements and via spectral measurements over six orders of magnitude in excitation power.

While first-order correlations reveal a marked dephasing dependence on the excitation power in the limit of strongly dressed states, we recover the properties of textbook atomic systems in the low power limit, where emission is dominated by elastic scattering [3]. Here, the single photons emitted by the QD are no longer restricted to obey the T2<2T1 relationship and show coherence times of tens of nanoseconds, ultimately limited by laser coherence. Applications of elastic scattering to shaping spectra of single photons will be discussed.

[1] C.-Y. Lu et al., Phys. Rev. B 81, 035332 (2010)
[2] A. N. Vamivakas et al., Nature 467, 297 (2010)
[3] C. Matthiesen et al., arXiv:1109.3412v1 (2011)

Q 19.8 Mon 18:15 V38.04

Cooperative Emission in Transport Setting through a Quantum Dot — •Martin J. A. Schuetz, Eric M. Kessler, Geza Giedke, and Juan Ignacio Cirac — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, D-85748 Garching, Germany

We theoretically show that intriguing features of coherent many-body physics can be observed in electron transport through a quantum dot (QD). In particular, we show that electron transport in the Pauli-blockade regime is coherently enhanced by hyperfine interaction with the nuclear spin ensemble in the QD. For an initially polarized nuclear system this leads to a strong current peak in close analogy with superradiant emission of photons from atomic ensembles. This effect could be observed with realistic experimental parameters and would provide clear evidence of coherent HF dynamics of nuclear spin ensembles in QDs.

Q 19.9 Mon 18:30 V38.04

Magnetic Strong Coupling of an Ensemble of NV- Defect Centers to a Superconducting Resonator — •Christian Koller, Robert Amsüss, Andreas Maier, Tobias Nöbauer, Stefan Putz, Jörg Schmiedmayer, and Johannes Majer — Vienna Center for Quantum Science and Technology, Atominstitut, TU Wien, Vienna, Austria

Reversible transfer of quantum information between long-lived memories and quantum processors is a favorable building block of scalable quantum information devices. We present recent experimental results of strong coupling between an ensemble of nitrogen-vacancy center electron spins in diamond and a superconducting microwave coplanar waveguide resonator [1]. Although the coupling between a single spin and the electromagnetic field is typically rather weak, collective enhancement allows entering the strong coupling regime. We are able to directly observe this characteristic scaling of the collective coupling strength with the square root of the number of emitters. Additionally, we measured the hyperfine coupling to 13C nuclear spins, which is a first step towards a nuclear ensemble quantum memory. Using the dispersive shift of the cavity resonance frequency, we measured the relaxation time T1 of the NV center at millikelvin temperatures. In addition we will present recent results using novel lumped element resonators. [1]Amsüss et al., Phys. Rev. Lett. 107, 060502 (2011)