Q 47: Quantum Information: Quantum Computing and Communication I

Time: Thursday 11:00–13:00 Location: e214

Q 47.1 Thu 11:00 e214

Germanium vacancy centres and the "smart search" for perfect diamond qubits — •Lachlan J. Rogers and Fedor Jelezko — Institute for Quantum Optics and IQST, Ulm University, Ulm, Germany

Colour centres in diamond are attractive qubit architectures, but the currently available candidates are not perfect. The nitrogen vacancy (NV) centre is famous as an optically addressable electron- and nuclear-spin qubit. However, the NV fluorescence spectrum exhibits a number of undesirable characteristics including a strong phonon sideband and, typically, spectral diffusion of the zero-phonon line (ZPL). More recently the related silicon vacancy (SiV) centre has been shown to have exceptional optical properties, but a fundamentally limited spin coherence time of only 40 ns.

While it is possible to search randomly for attractive spin properties among other reported colour centres, the development in understanding NV and SiV centres over the last decade has begun to enable a "smart search". Here we present germanium vacancy centres as an example of this process. There is a tantalising possibility that germanium vacancies could combine the excellent spin coherence properties of NV with the superb spectral properties of SiV, leading to an almost perfect diamond qubit.

Q 47.2 Thu 11:15 e214

Investigating spectral properties of Silicon-Vacancy centers in Nanodiamonds — •Andrea Kurz[1], Lachlan J. Rogers[1], Daniel Rudnicki[2], Uwe Jantzen[1], Ou Wang[1], Valery Davydov[3], Viatcheslav Agafonov[4], Alexander Kubanek[1], and Fedor Jelezko[1] — [1]Institut fuer Quantenoptik, Universitaet Ulm, Deutschland — [2]Institute of Physics, Jagiellonian University, Krakow, Poland — [3]Institute for High Pressure Physics, Russian Academy of Science, Moscow, Russia — [4]Greman, Universit F. Rabelais, Tours, France

Over the last decade color centers in diamond have proven to be good candidates for quantum optics applications. One of these color centers, the silicon-vacancy (SiV) center has shown exceptional spectral properties, with more than 70% of the emitted photons contributing to its strong zero phonon line (ZPL). The strong, sharp and distinct ZPL transitions together with the weak sideband makes the SiV center a promising candidate for single photon generation.

These exceptional properties for centers in bulk are not necessarily preserved in Nanodiamonds (NDs). Even though the SiV fluoresces in NDs as small as 1.7nm, it is not yet known how the center is influenced by strain and the environment that starts to play a more important role at these sizes.

We investigate the properties of NDs grown by High Pressure and High temperature and correlate their size with their spectral behavior at cryogenic temperatures. We see the narrowest spectral lines measured so far in NDs with a width of 344 MHz.

Q 47.3 Thu 11:30 e214

Generation of Entangled Photon strings using Color centers in Diamond — •Durga B Rao Dasari[1,2], Sen Yang[1], and Jörg Wrachtrup[1,2] — [1]3. Physikalisches Institut, Universität Stuttgart, Stuttgart — [2]Max Planck Institute for Solid State Research, Stuttgart

Color centers in diamond make a robust quantum hybrid system comprising different species of quantum bits where, one kind couples strongly to the optical photons and the other has ultra long coherence times. While such hybrid devices can naturally be used as storage units for optical photons in a quantum network [1], they on the otherhand can also be used to mediate entanglement between subsequent photons with which the color center interacts [2].

In this talk I will present a scheme to generate entangled photons using nitrogen vacancy (NV) centers in diamond. We show how the long-lived nuclear spin in diamond can mediate entanglement between multiple photons, thereby increasing the length of the entangled photon string. With the proposed scheme one could generate both n-photon GHZ and cluster states. An experimental scheme realizing the same and estimates for the rate of entanglement generation both in the presence and absence of a cavity will also be shown.

[1]. Sen Yang et al. arXiv:1511.04939 [quant-ph]
[2]. D. D. Bhaktavatsala Rao et al. Phys. Rev. B 92, 081301(2015)(R)

Q 47.4 Thu 11:45 e214

High-rate source of Ca^+-resonant heralded single photons — •Stephan Kucera, Jan Arenskötter, Pascal Eich, Matthias Kreis, Philipp Müller, and Jürgen Eschner — Experimentalphysik, Universität des Saarlandes, Saarbrücken, Germany

We present a source of heralded single photons for quantum communication experiments with single trapped $^{40}Ca^+$ ions [1]. The photons are generated at 854 nm wavelength by cavity-enhanced spontaneous parametric down conversion in a doubly resonant bow-tie resonator. In 10 MHz cavity line-width we achieve a fiber-coupled brightness of $4 \cdot 10^4/(s \cdot mW)$ ion-resonant photons, about 500 times more than without resonator [2]. Compatibility with the ion resonance is demonstrated by correlation, coherence, and absorption measurements.

[1] Kurz et al., Nat. Commun. **5**, 5527 (2014)
[2] Piro et al., Nat. Phys. **7**, 17 (2011)

Q 47.5 Thu 12:00 e214

Programmable atom-photon quantum interface — •Pascal Eich, Christoph Kurz, Michael Schug, Philipp Müller, Matthias Kreis, and Jürgen Eschner — Experimentalphysik, Universität des Saarlandes, Saarbrücken, Germany

We report on the implementation of a programmable atom-photon quantum interface, employing a single trapped $^{40}Ca^+$ ion and single photons. Depending on its mode of operation, the interface serves as a bi-directional atom-photon quantum-state converter [1,2], as a source of entangled atom-photon states, or as a quantum frequency converter of single photons. The interface lends itself particularly to interfacing ions with SPDC-based single-photon sources or entangled-photon-pair sources [3,4]. In the experimental procedure, we generate an initial superposition state in the meta-stable $D_{5/2}$ level of the ion, using a narrow-band laser at 729 nm. Upon the absorption of a single photon at 854 nm, the ion undergoes a Raman transition to its $S_{1/2}$ ground state, emitting a single photon at 393 nm. The coherent evolution from the initial to the final quantum state of atomic superposition and photon polarization is utilized for the interface protocol.

[1] P. Müller, J. Eschner, Appl. Phys. B **114**, 303 (2014).
[2] C. Kurz et al., Nat. Commun. **5**, 5527 (2014).
[3] A. Lenhard et al., arXiv:1504.08303, to appear in Phys. Rev. A.
[4] J. Brito et al., arXiv:1508.01029, to appear in Appl. Phys. B.

Q 47.6 Thu 12:15 e214

A single ion coupled to UV fiber-cavity — •Timothy Ballance[1,2], Ashwin Boddeti[1], Matthias Steiner[4], Hendrik M. Meyer[1], Jakob Reichel[3], and Michael Köhl[1] — [1]Physikalisches Institut, Universität Bonn — [2]Cavendish Laboratory, University of Cambridge — [3]Laboratoire Kastler-Brossel, ENS Paris — [4]Present Address: Centre for Quantum Technologies, National University of Singapore

We investigate a single trapped ion coupled to an optical fiber-cavity for use as a node in a quantum network. So far ions and fiber-cavities have been successfully combined in the infra-red spectral range. Since the strongest transitions in ions are within the ultra-violet, the extension of ion traps to work with UV fiber-cavities paves the way to larger coupling factors, which are of great interest for single photon production as well as for cavity based state detection. We will present our latest results on trapping Ytterbium ions inside approximately 150μm long fiber-cavities, which are resonant with the $S_{1/2} - P_{1/2}$ electric dipole transition at 370nm.

Q 47.7 Thu 12:30 e214

Microwave near-field control of $^9Be^+$ qubits in a surface-electrode ion trap — •Martina Wahnschaffe[1,2], Henning Hahn[1,2], Giorgio Zarantonello[1,2], Sebastian Grondkowski[2], Timko Dubielzig[2], Amado Bautista-Salvador[1,2], Matthias Kohnen[1,2], and Christian Ospelkaus[1,2] — [1]QUEST Institute for Experimental Quantum Metrology, PTB, Bundesallee 100, D-38116 Braunschweig — [2]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, D-30167 Hannover

We describe experiments employing microwave near-fields from conductors embedded in a surface-electrode ion trap [1]. Our optimized trap geometry features a single conductor to induce all the required spin-motional couplings typically used in multi-qubit quantum operations [2]. We load $^9Be^+$ ions via two-photon ionization from an ablation plume created by single shots of a pulsed laser. Our experiment operates at 22.3 mT where the $|F=2, m_F=1\rangle$ and $|F=1, m_F=1\rangle$ states form a first-order field-independent qubit for long coherence times. We demonstrate initialization and control of the qubit. We perform a spatial characterization of the microwave near-field employing a modified Ramsey / echo sequence with a single ion as a local field probe and find good agreement with full-wave numerical simulations. Using the spatial variation of the microwave near-field, we demonstrate motional sideband transitions on our field-independent qubit as a basic prerequisite for entangling multi-qubit quantum logic gates.

[1] C. Ospelkaus *et al.*, Phys. Rev. Lett. **101**, 090502 (2008)
[2] M. Carsjens *et al.*, Appl. Phys. B **114**, 243 (2014)

Q 47.8 Thu 12:45 e214

Quantum Information Processing with Segmented Ion Traps — •Ulrich Poschinger, Thomas Ruster, Henning Kaufmann, Vidyut Kaushal, Jonas Schulz, Christian Schmiegelow, and Ferdinand Schmidt-Kaler — QUANTUM, Universität Mainz

Segmented ion traps offer the possibility to scale up quantum information processing with trapped ion quantum bits via local coherent manipulation of small ion crystals and shuttling of ions within the trap structure. This enables novel schemes for quantum computing, simulation, communication and sensing. We briefly review the current state-of-the-art of the required technology and methods. Our approach to scalability requires ion shuttling operations which do not affect the fidelity of entangling gates. This in turn requires either slow operation times or a substantial control overhead[1,2]. We show how to circumvent this by carrying out entangling gates on radial motional modes of vibration, which are not excited throughout shuttling operations. Furthermore, we demonstrate how entangled ions in conjunction with shuttling operations can be used for sensing inhomogeneous magnetic fields, with nanometer resolution in position and pT field resultion. Finally, we show how shuttling operations can be harnessed to lock the ion position to an optical free-space standing wave [3], which allows for the realization of phase-controlled spin-dependent optical forces. Additional applications of this technique include precise mapping of electric trap potentials and improved addressing of qubit registers.

[1] H. Kaufmann et al., NJP 16, 073012 (2014) [2] T. Ruster et al., PRA 90, 033410 (2014) [3] C. Schmiegelow et al., arXiv:1507.05207