Q 13: Quantum information: Atoms and ions II

Time: Monday 14:00–16:00 Location: UDL HS3038

Group Report Q 13.1 Mon 14:00 UDL HS3038
Nano-Photonic Quantum Interfaces for Cold Neutral Atoms — •Philipp Schneeweiss, Bernhard Albrecht, Christoph Clausen, Christian Junge, Rudolf Mitsch, Daniel Reitz, Clement Sayrin, Michael Scheucher, Jürgen Volz, and Arno Rauschenbeutel — Vienna Center for Quantum Science and Technology, TU Wien – Atominstitut, Vienna, Austria

I will describe recent experimental work on the quantum mechanical coupling of light and matter using the evanescent field surrounding specially designed optical fibers. In a first experiment, we trap and optically interface laser-cooled cesium atoms in a two-color evanescent field around a silica nanofiber. The atoms are localized in a one-dimensional optical lattice 200 nm above the nanofiber surface and can be efficiently interrogated with light which is sent through the nanofiber [1,2]. In a second experiment, single atoms are strongly coupled to a whispering-gallery-mode microresonator. There, the light exhibits a strong longitudinal polarization component which fundamentally alters the interaction with matter [3]. Taking advantage of this effect, we recently demonstrated highly efficient switching of signals between two optical fibers controlled by a single atom [4]. Finally, I will discuss possible applications of our nanofiber-based quantum interfaces as practical building blocks in an optical fiber quantum network.

[1] E. Vetsch et al., Phys. Rev. Lett. 104, 203603 (2010).
[2] D. Reitz et al., Phys. Rev. Lett. 110, 243603 (2013).
[3] C. Junge et al., Phys. Rev. Lett. 110, 213604 (2013).
[4] D. O'Shea et al., Phys. Rev. Lett. 111, 193601 (2013).

Q 13.2 Mon 14:30 UDL HS3038
Towards the light-phonon quantum interface with an atomic array in a cavity — •Oxana Mishina and Giovana Morigi — Saarland University, Saarbruecken 66123, Germany

This work explores theoretically the accessibility of the multimode quantum interface, involving the modes of collective motion on the atomic array and a single mode optical cavity. This system is similar to thous experimentally implemented in the works [1,2]. The controlability of the array motion is theoretically demonstrated by cooling all the atoms to the ground state of the individual traps with experimentally feasible conditions. Together with the theoretical model developed in this work it sets the basis for the further exploration of the quantum optomechanical interface and, possibly, generation of novel non-classical states of collective atomic motion.

[1] S. Gupta, K. Moore, K. Murch, and D. Stamper-Kurn Phys. Rev. Lett. 99 213601 (2007) [2] Optomechanical Cavity Cooling of an Atomic Ensemble M.H., Schleier-Smith, I.D. Leroux, H. Zhang, M.A. Van Camp, and V. Vuletić, Phys. Rev. Lett. 107, 143005 (2011)

Q 13.3 Mon 14:45 UDL HS3038
A quantum gate between a flying optical photon and a single trapped atom — •Norbert Kalb, Andreas Reiserer, Bastian Hacker, Mahmood Sabooni, Stephan Ritter, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85478 Garching

The steady increase in control over individual quantum systems has led to the dream of a quantum technology that provides functionality beyond any classical device. Over the past decade, two major directions have been extensively studied. First, the use of flying optical photons for secure quantum communication over large distances. Second, the use of atomic spins for quantum computation. While each of the individual systems has its own advantages, a hybrid system might be required to achieve scalability.

Here we present a hybrid two-qubit gate between the spin state of a single atom and the polarization state of a photon. To this end, an ^{87}Rb atom is trapped at the centre of an optical cavity in the strong-coupling regime. The gate is performed by reflecting a resonant photon off the cavity. We will present results characterizing the gate, e.g. by the production of atom-photon entangled states from separable input states.

Q 13.4 Mon 15:00 UDL HS3038
Deterministische nanometergenaue Fokussierung eines Strahls aus einzelnen lasergekühlten Ionen — •Georg Jacob, Karin Groot-Berning, Sebastian Wolf, Stefan Ulm, Johannes Rossnagel, Johannes Verst, Ferdinand Schmidt-Kaler und Kilian Singer — QUANTUM ,Institut für Physik, Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany

Auf der Grundlage dopplergekühlter $^{40}Ca^{+}$ Ionen in einer linearen Paulfalle ist es uns möglich eine deterministische Einzelionenquelle zu realisieren [1,2]. Ein somit erzeugter Strahl mit einer Extraktionsenergie von 3keV weist eine longitudinale Geschwindigkeitsverteilung von 8 m/s und eine Divergenz von 30 μrad auf. Mittels einer elektrostatischen Einzellinse konnte dieser Strahl auf einen Radius von 8 nm fokussiert werden. Dabei erlaubt die Anwendung von bayesscher Statistik die Informationsausbeute einer Fokusmessung zu maximieren. Weiterhin bestätigte eine Bestimmung der Zweiwertvarianz in der lateralen Fokusposition die Stabilität des System über einen Zeitraum von mehreren Stunden.

Zusammen mit der erfolgreichen deterministischen Extraktion von Stickstoff sind nun sämtliche Voraussetzungen für eine Einzelionenimplantation zur Erzeugung von Stickstoff Farbzentren in Diamant erfüllt. Darüber hinaus wurde die Eignung des Systems zur Transmissionsmikroskopie bei einer minimalen Anzahl verwendeter Sonden gezeigt.

[1] W. Schnitzler *et al.*, Phys. Rev. Lett. **102**, 070501 (2009)
[2] W. Schnitzler, *et al.*, New Journal of Physics **12**, 065023 (2010).

Q 13.5 Mon 15:15 UDL HS3038
Surface-electrode Paul trap with optimized near-field microwave control — •Martina Carsjens[1,2], Matthias Kohnen[1,2], Timko Dubielzig[2], Sebastian Grondkowski[2], Kai Voges[2], and Christian Ospelkaus[2,1] — [1]PTB, Braunschweig, Germany — [2]Institut füt Quantenoptik, Hannover, Germany

We describe the design of a microfabricated Paul trap with integrated microwave conductors for quantum simulation and entangling logic gates. We focus on an approach where near-field amplitude gradients of microwave fields from conductors in the trap structure induce the required spin-motional couplings. This necessitates a strong amplitude gradient of the microwave near-field at the position of the ions, while the field itself needs to be suppressed as much as possible. We introduce a single meander-like microwave conductor structure which provides the desired field configuration. We optimize its parameters through full-wave microwave numerical simulations of the near-fields. The microwave conductor is integrated with additional dc and rf electrodes to form the actual Paul trap. We discuss the influence of the additional electrodes on the field configuration. To be able to fine-tune the overlap of the Paul trap rf null with the microwave field minimum, our trap design allows relative tuning of trap rf electrode amplitudes. Our optimized geometry could achieve a ratio of sideband-to-carrier excitations comparable to experiments with focused laser beams.

Q 13.6 Mon 15:30 UDL HS3038
Towards quantum simulations in a triangular surface trap — •Manuel Mielenz, Henning Kalis, Ulrich Warring, and Tobias Schaetz — Physikalisches Institut, Albert-Ludwigs Universität Freiburg

Laser-cooled ions, trapped in a Paul Trap have proven to be an ideal system for quantum simulations [1]. While various experiments with a small number of ions have been demonstrated, scaling to large systems still poses a major challange. A promising approach to overcome this limition, is to use surface traps, whose electrode lies entirely in a plane [2]. Optimized electrodes allow to trap ions in an arbitrary pattern with each ion in an indiviual potential well [3], allowing for instance the simulation of extended lattices of spins or charged particles in a gauge field [4]. Our group, in collaboration with Sandia National Labs, recently demonstrated trapping ions in a novel kind of surface trap. Here, three ions are triangularly arranged in separated wells, still being close enough (40 μm) to exhibit sufficient interaction to allow for simulations of simple two-dimensional quantum systems. In my talk, first results will be presented.

[1] Ch. Schneider *et al.*, Rep. Prog. Phys. **75**, 024401 (2012)
[2] S. Seidelin *et al.*, Phys. Rev. Lett. **96**, 253003 (2006)
[3] R. Schmied *et al.*, Phys. Rev. Lett. **102**, 233002 (2009)
[4] A. Bermudez *et al.*, Phys. Rev. Lett. **107**, 150501 (2011)

Q 13.7 Mon 15:45 UDL HS3038

Coherent manipulation of a single-spin rare-earth qubit in a crystal — •Roman Kolesov[1], Petr Siyushev[1], Kangwei Xia[1], Rolf Reuter[1], Mohammad Jamali[1], Nan Zhao[2], Ning Yang[3], Changkui Duan[4], Nadezhda Kukharchyk[5], Andreas Wieck[5], and Jörg Wrachtrup[1] — [1]Universität Stuttgart, Pfaffenwaldring 57, 70182 Stuttgart, Germany — [2]Beijing Computational Science Research Center, Beijing 100084, China — [3]Institute of Applied Physics and Computational Mathematics, P.O. Box 8009(28), 100088 Beijing, China — [4]University of Science and Technology of China, Hefei, 230026, China — [5]Ruhr-Universität Bochum, Universitätsstraße 150, Gebäude NB, D-44780 Bochum, Germany

Rare-earth doped crystals are known to be excellent spin memories for quantum information storage. However, inability to address individual spins makes these materials hard to implement for quantum information processing. We report on efficient optical initialization, coherent manipulation, and subsequent readout of the coherent state of a single electron spin of a cerium dopant ion in yttrium aluminium garnet. The initialization step is accomplished by polarization selective optical pumping while coherent manipulations of the electron spin are performed by means of microwaves resonant with the spin transition. Rigorous studies ofthe coherence properties of cerium spin showed that while the spin-lattice relaxation time is 3.8ms, the decoherence time is only 240ns. By means of efficient dynamic decoupling of the cerium spin from the surrounding nuclear spin environment, the lifetime of cerium spin coheremce is extended 4 orders of magnitude to 2ms.