Q 17: Quantum Information: Atoms and Ions I

Time: Tuesday 14:00–16:30 Location: E 214

Group Report Q 17.1 Tu 14:00 E 214

Coherent spectroscopy involving Rydberg states in microcells — •Thomas Baluktsian[1], Bernhard Huber[1], Harald Kübler[1], Andreas Kölle[1], Christian Urban[1], James P. Shaffer[2], Robert Löw[1], and Tilman Pfau[1] — [1]5. Physikalisches Institut, Universität Stuttgart, Germany — [2]Homer L. Dodge Department Of Physics And Astronomy, University of Oklahoma, USA

Micron sized glass cells filled with atomic vapor are promising candidates for quantum devices based on the Rydberg blockade. Due to the strong interaction between two Rydberg atoms, only one Rydberg excitation is possible within a certain volume characterized by the blockade radius (typically few microns), that is determined by the laser bandwidth and the interaction strength. This effect also provides a nonlinearity that is an essential tool for proposals to entangle mesoscopic ensembles and to realize single photon sources. In order to probe coherent dynamics it is necessary for the excitation times to be shorter than typical dephasing timescales. This can be realized by utilizing a bandwidth limited pulsed laser system which allows for the creation of high enough Rabi-frequencies. We report on the first coherent Rydberg excitation in a homemade 2D rubidium vapor cell with a thickness of 1 μm including investigation of effects due to confinement in the vapor cell [1]. Furthermore EIT measurements on rubidium vapor in micron sized channels show that coherent dynamics and narrow linewidths are possible. First measurements with a pulsed laser system showed evidence of coherent dynamics on the ns-timescale.

[1] H. Kübler et al., accepted by Nature Photonics, arXiv:0908.0275

Group Report Q 17.2 Tu 14:30 E 214

Scalable Architecture for Quantum Information Processing with Neutral Atoms — •Jens Kruse, Malte Schlosser, Peter Schauss, Benedikt Baumgarten, Sascha Tichelmann, and Gerhard Birkl — Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt

Ultra-cold atoms in two-dimensional dipole trap arrays represent highly controllable and scalable systems for quantum information processing with long coherence times. In our experiment, we use sets of optical micro-potentials created by micro-fabricated lens arrays as the architecture for a scalable quantum processor. Advanced schemes for atom detection allow us to observe single atoms with high efficiency and reliability in a site-selective and state-specific fashion.

We report on a series of important advances: For flexible architectures, we implement a spatial light modulator in front of a microlens array as a pixel-addressable intensity modulator for the realization of arbitrary trapping configurations. We demonstrate the initialization and coherent manipulation of small ensembles of ^{85}Rb atoms at separatly addressable sites by applying coherent Raman coupling between hyperfine ground states. We also present an experimental scheme compensating for the differential lightshift induced by the trapping light. This "magic-wavelength" behavior synchronizes the coherent evolution and results in an increase of the spectroscopic resolution and a strong suppression of dephasing. The scheme is extendable to all alkali elements where no standard "magic-wavelength" is available and opens new avenues in metrology and quantum computing.

Q 17.3 Tu 15:00 E 214

Lossless qubit state detection of single neutral atoms — •Joerg Bochmann, Martin Mücke, Christoph Guhl, Carolin Hahn, Stephan Ritter, David Moehring, and Gerhard Rempe — MPI für Quantenoptik, Garching, Germany

Trapped neutral atoms are among the most promising resources for quantum information science. In a single trapped atom, the quantum bit (qubit) is typically encoded in or mapped onto atomic hyperfine states. However, hyperfine qubit read-out has proven remarkably difficult for neutral atoms. Existing protocols do not obtain an answer in every read-out attempt or suffer from loss of the atom during detection. We introduce a state detection scheme based on cavity-enhanced fluorescence. It makes use of the Purcell effect to establish a controlled coupling between qubit and environment. In an experiment with a single trapped Rubidium atom, we achieve a hyperfine state detection fidelity of 99.4% in 85 μs while a result is obtained in every read-out attempt. Most important, the qubit can be interrogated many hundred times without loss of the atom. This presents an essential advancement for the speed and scalability of quantum information protocols based on neutral atoms. Our scheme can be generalized to all systems in which the qubit is optically accessible.

Q 17.4 Tu 15:15 E 214

Loading atoms into a blue-box trap from a dark MOT: towards long lived quantum memory — •Fan Yang[1], Huan Nguyen[1], Torsten Mandel[1], Maximilian Plenert[1], Alexander Göbel[1], Shuai Chen[2], Zhen-Sheng Yuan[1,2], and Jian-Wei Pan[1,2] — [1]Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Philosophenweg 12, 69120 Heidelberg, Germany — [2]Hefei National Laboratory for Physical Sciences at Microscale and Department of Modern Physics, University of Science and Technology of China, Hefei, Anhui 230026, China

Quantum memories are fundamental ingredients for quantum information processing systems. Of key importance is the requirement of long-lived quantum memories in a long-distance quantum communication network composed of atomic ensembles and linear optical elements. We discuss the various decoherence mechanisms existing in a cold-atomic-ensemble based quantum memory. Solutions to maintain the coherence of the stored quantum state are proposed accordingly. Cold atoms confined in a blue detuned optical dipole trap are expected to extend the lifetime of quantum memory to the order of several hundred milliseconds. We report here the preliminary experimental results of loading cold atoms of 87Rb from a dark magneto-optical trap into a blue-box trap which will serve as a medium for long-lived quantum memories. High optical depth is observed and expected to boost the retrieve efficiency of a quantum memory and meanwhile offers more chances for studying quantum simulation.

Q 17.5 Tu 15:30 E 214

Multipartite W states for chains of atoms conveyed through an optical cavity — •Denis Gonta[1] and Stephan Fritzsche[2,3] — [1]Max-Planck-Institut für Kernphysik, Postfach 103980, D-69029 Heidelberg — [2]Department of Physical Sciences, P.O Box 3000, Fin-9014, University of Oulu, Finland — [3]GSI Helmholtzzentrum für Schwerionenforschung, D-64291 Darmstadt

Optical cavities provide a perspective tool to produce the interaction between neutral atoms which are coupled simultaneously to the same cavity mode. An excellent control of the atomic motion is essential for such interaction and can be realized especially by using optical lattices (conveyor belts), which have recently been utilized in various setups of cavity QED. The combination of such a lattice with the cavity QED setup, however, make it necessary to analyze how the velocity and the spacing between the atoms in the chain will affect the formation of entanglement.

In this contribution, we propose a scheme to generate the entangled W_N state between the qubits associated with N three-level atoms in the Λ-type configuration. The atoms are supposed to be equally separated from each other and conveyed through the cavity by means of an optical lattice. This scheme works in a completely deterministic way and is robust with respect to small oscillations in the atomic motion as caused by the thermal motion of atoms in the optical lattice [1].

[1] D. Gonta and S. Fritzsche, J. Phys. B **42**, 145508 (2009).

Q 17.6 Tu 15:45 E 214

Coherent Transport of Atomic Quantum States in a Scalable Shift Register — •Malte Schlosser, Jens Kruse, Andre Lengwenus, Sascha Tichelmann, and Gerhard Birkl — Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt

The coherent control of the internal and external quantum states of ultra-cold neutral atoms represents an important experimental approach towards quantum information processing. An attractive architecture is given by physically independent qubits arranged in a scalable quantum register. In our experiment we obtain a suitable system of two-dimensional periodic potentials employing microfabricated lens arrays. While coherent storage and single-site adressability, offering the direct manipulation of individual qubits, are inherent for this design one has to implement techniques to connect distinct traps in order to perform two qubit operations. A natural way is to precisely control interaction by actively arranging the positions of individual qubits. We present the controlled coherent transport of two-dimensional arrays of small ensembles of ^{85}Rb atoms. The scalable shift register is an all optical device which offers precise control of the position of trapped neutral atoms. The shift operation is based on consecutive loading, moving and reloading of two independently controllable arrays of traps. We show the scalability of our architecture and of the transport process by demonstrating the repeated hand-over of atoms from trap to trap. We investigate the processes of transport and reloading in detail and demonstrate the conservation of coherence during transport.

Q 17.7 Tu 16:00 E 214

Digital Coherent and Dissipative Quantum Simulations with Rydberg Atoms — •Hendrik Weimer[1], Markus Müller[2], Igor Lesanovsky[3], Peter Zoller[2], and Hans Peter Büchler[1] — [1]Institut für Theoretische Physik III, Universität Stuttgart — [2]Institut für Theoretische Physik, Universität Innsbruck, und Institut für Quantenoptik und Quanteninformation der Österreichischen Akademie der Wissenschaften, Innsbruck — [3]School of Physics and Astronomy, The University of Nottingham

A universal quantum simulator is a controlled quantum device which efficiently reproduces the dynamics of any other many particle quantum system with short range interactions. Based on a recent proposal for a many-body gate using strong interactions between Rydberg atoms [1], we present an implementation of a digital quantum simulator in an optical lattice with large lattice spacing [2]. Special focus is on the efficient simulation of Hamiltonians with local many-body interactions, including exotic spin models such as Kitaev's toric code, string nets, and lattice gauge theories. In addition, we show that the formalism also provides the simulation of dissipative terms taking the Lindblad form with many-body jump operators. These dissipative terms allow for the efficient ground state cooling and state preparation.

[1] M. Müller et al., Phys. Rev. Lett. **102**, 170502 (2009).
[2] H. Weimer et al., arXiv:0907.1657 (2009).

Q 17.8 Tu 16:15 E 214

Generation of macroscopic singlet states in atomic ensembles — •Geza Toth[1,2,3] and Morgan W. Mitchell[4] — [1]Theoretical Physics, The University of the Basque Country, E-48080 Bilbao, Spain — [2]IKERBASQUE, Basque Foundation for Science, E-48011 Bilbao, Spain — [3]Research Institute for Solid State Physics and Optics, H-1525 Budapest, Hungary — [4]ICFO, Institut de Ciencies Fotoniques, Mediterranean Technology Park, E-08860 Castelldefels (Barcelona), Spain

We study squeezing of the spin uncertainties by quantum nondemolition (QND) measurement in non-polarized spin ensembles. Unlike the case of polarized ensembles, the QND measurements can be performed with negligible back-action, which allows, in principle, perfect spin squeezing as quantified by [G. Toth et al., Phys. Rev. Lett. 99, 250405 (2007)]. The generated spin states approach many-body singlet states, and contain a macroscopic number of entangled particles, even when individual spin is large. We introduce the Gaussian treatment of unpolarized spin states and use it to estimate the achievable spin squeezing for realistic experimental parameters. Our proposal might have applications for quantum memories storing information in decoherence free subspaces.