Q 42: Quanteninformation: Atome und Ionen II

Zeit: Donnerstag 10:30–12:30 Raum: Audi-B

Q 42.1 Do 10:30 Audi-B

Ion traps with enhanced optical and physical access — •Robert Maiwald[1], Dietrich Leibfried[2], Joe Britton[2], J.C. Bergquist[2], Gerd Leuchs[1], and D.J. Wineland[2] — [1]Institut für Optik, Information und Photonik (IOIP), Universität Erlangen-Nürnberg, Staudtstr. 7/B2, 91058 Erlangen, Germany — [2]National Institute of Standards and Technology (NIST), Boulder, CO 80305, USA

Small, controllable and highly accessible quantum systems that are well isolated from their environment can serve as a probe at the single quantum level to study a multitude of effects, including fundamental processes of nature. We present a novel radio-frequency ion trap geometry that provides largely unrestricted optical access of up to 96% of 4π in one of the experimentally tested traps. We discuss fabrication of these traps, their characterization by use of single laser cooled ions and potential applications of similar trap structures in quantum optics and electric and magnetic field sensing.

Q 42.2 Do 10:45 Audi-B

Sub microsecond, highly efficient ionisation detection of single ^{87}Rb atoms — •Florian Henkel[1], Michael Krug[1], Norbert Ortegel[1], Julian Hofmann[1], Wenjamin Rosenfeld[1], Markus Weber[1], and Harald Weinfurter[1,2] — [1]Department für Physik der LMU, Schellingstrasse 4/III, 80799 München — [2]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Strasse 1, 85748 Garching

Fast and efficient state detection of qubits stored in single atoms represents an integral part regarding future implementations of quantum computation with neutral atoms [1].

In order to realise such a readout, single neutral ^{87}Rb atoms are ionised out of the background gas in a two-photon process ($\lambda_1 = 780$ nm, $\lambda_2 = 473$ nm). The charged ionisation fragments (e^- and $^{87}Rb^+$) are accelerated into two channel electron multipliers. Observing both fragments we are able to detect single ^{87}Rb atoms with an absolute efficiency of $\sim$93.7 % within 460 ns after ionisation being considerably faster than conventional fluorecence detection schemes.

This technique is a promising approach as an atomic readout unit for a final, loophole-free test of Bells inequality [2]. In principle, this detection should also be applicable to atomic arrays [3] or atoms in optical lattices [4].

[1] D. P. DiVincenzo, Fortschritte der Physik 48, 771-784 (2000)
[2] J. Volz et al., Phys. Rev. Lett. 96, (2006)
[3] Y. Miroshnychenko et al., Nature 442, 151 (2006)
[4] I. Bloch, Nature 453, 1016-1022 (2008)

Q 42.3 Do 11:00 Audi-B

Manipulation und Kontrolle von Ionen in einer mikrostrukturierten Paulfalle — •Ulrich Poschinger, Gerhard Huber, Frank Ziesel, Markus Deiss, Max Hettrich, Kilian Singer und Ferdinand Schmidt-Kaler — Institut für Quanteninformationsverarbeitung, Universität Ulm

Wir präsentieren experimentelle Ergebnisse zu essentiellen Teilschritten der Realisierung eines skalierbaren Quantencomputers basierend auf einer mikrostrukturierten, segmentierten Ionenfalle[1]. Eine Änderung der Fallenkontrollspannungen erlaubt die Steuerung der Ionen-Position und dessen Einschluss in segmentierten Mikrofalle. Über Laserpulse auf dem $^{40}Ca^+$ $S_{1/2} - D_{5/2}$ Quadrupolübergang und dem Ramanübergang zwischen beiden Zeemanniveaus $S_{1/2}$ Zustands kühlen wir ein Ion nahe an den quantenmechanischen Grundzustand und realisieren ein Qubit. In Kombination dieser kohärenter Zustandsmanipulation durch Laserpulse und einer schnellen Ansteuerung von Fallen-Kontrollelektroden können wir Qubits an jeden Ort der Falle bewegen und dort die Fallenfrequenz bestimmen. Zukünftige Schritte im Sinne der Skalierbarkeit beeinhalten das Kühlen, Manipulieren und Auslesen von Zwei-Ionen Kristallen.

[1] S. Schulz, U. Poschinger, F. Ziesel and F. Schmidt-Kaler, NJP 10, 045007(2008)

Q 42.4 Do 11:15 Audi-B

Ionentransport in einer mikrostrukturierten segmentierten Y-Oberflächenfalle — •S. A. Schulz, A. Bautista-Salvador, F. Ziesel, M. Hettrich und F. Schmidt-Kaler — Universität Ulm, Institut für Quanteninformationsverarbeitung, Albert-Einstein-Allee 11, 89069 Ulm

Experimentelle Quanteninformationsverarbeitung mit mikrostrukturierten Ionenfallen beschränkt sich bisher auf die Verwendung nur weniger Qubits - ein skalierbarer Ansatz zur Kontrolle vieler Qubits stellt die Unterteilung mikrostrukturierter Ionenfallen in verschiedene Speicher- und Prozessorbereiche dar. Die Adressierbarkeit einzelner Qubits ist fundamental für die Realisierung von räumlich verteilter Verschränkung auf der Basis des Transports einzelner Qubits. Eine Vielzahl von segmentierten Kontrollelektroden erlaubt die Untersuchung komplexer Quantenalgorithmen mittels Verschiebeoperationen vieler Qubits.

Wir stellen ein Design, numerische Simulationen und die Entwicklung einer planaren linearen Paulfalle auf der Basis einer Y-Geometrie vor. Drei voneinander unabhängige lineare Fallenbereiche sind über eine Kreuzung miteinander verbunden. Lineare Verschiebeoperationen können über 58 individuell ansteuerbare Kontrollelektroden durchgeführt werden. Dabei werden Frequenzen der axialen Bewegung im Bereich einiger MHz erwartet. Es werden numerische Simulationen für Ionentransporte mit konstanter Axialfrequenz diskutiert. Der stabile Transport einzelner Ionen über die Kreuzung unter Berücksichtigung der Axialfrequenz zeigt die Skalierbarkeit der vorgestellten Ionenfalle.

Q 42.5 Do 11:30 Audi-B

Simulating the Quantum Magnet Reloaded — •Christian Schneider[1], Hector Schmitz[1,2], Martin Enderlein[1], Thomas Huber[1], Axel Friedenauer[1], and Tobias Schaetz[1] — [1]Max-Planck-Institut für Quantenoptik — [2]LMU München

The simulation of the dynamics of quantum mechanical systems on a classical computer is a hard task, because the requirements of computational power increase exponentially with (linearly) increasing number of quantum mechanical constituents. One possibility to cope with that problem is a quantum simulator. In 2008 our group successfully demonstrated in a proof-of-concept experiment all building blocks for the simulation of Quantum Spin Hamiltonians with trapped Mg ions [1] based on a proposal by Porras and Cirac [2]. The simulation of an adiabatic evolution of two spins from paramagnetic ($|\rightarrow\rightarrow\rangle$) to ferromagnetic order ($|\uparrow\uparrow\rangle$ or $|\downarrow\downarrow\rangle$) of the Quantum Ising Hamiltonian was performed with a fidelity exceeding 98%. Recently we achieved the initialization of up to five ions in the motional ground state in the radial degrees of freedom and a phase gate [3] with two ions with a fidelity exceeding 90%. We will present our results, talk about our future plans of one- and two-dimensional simulations of Quantum Spin Hamiltonians [2, 4] and discuss the challange of scalability.

[1] A. Friedenauer, H. Schmitz et al., Nat. Phys. **4**, 757, 2008
[2] D. Porras and J.I. Cirac, Phys. Rev. Lett. **92**, 207901, 2004
[3] D. Leibfried et al., Nature **422**, 412, 2003
[4] T. Schaetz et al., J. Mod. Opt. **54**, 2317, 2007

Q 42.6 Do 11:45 Audi-B

Scalable Architecture for Quantum Information Processing with Atoms — •Jens Kruse, Malte Schlosser, Christoph Ewen, Peter Schauss, Christian Gierl, and Gerhard Birkl — Institut für Angewandte Physik, Technische Universität Darmstadt, Schloßgartenstr. 7, 64289 Darmstadt

Quantum information processing with neutral atoms represents an important experimental approach complementing systems based on trapped ions. By using ultra-cold atoms in two-dimensional dipole trap arrays, one can realize highly controllable and scalable systems 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. Due to the large lateral separation of neighboring potential wells, each trap is individually addressable. For flexible architectures, we implement a liquid crystal display in front of a microlens array as a pixel-addressable intensity modulator. By this we are able to control each potential well separately and produce arbitrary trap configurations. We demonstrate the flexible site-specific initialization and coherent manipulation of separated small ensembles of ^{85}Rb atoms in two-dimensional trap arrays by applying coherent Raman coupling between hyperfine ground states, representing the qubit states.

Advanced schemes for scalable atom observation allow us to detect single atoms in two-dimensional sets of dipole traps with high efficiency and reliability.

Q 42.7 Do 12:00 Audi-B

Optimized two-dimensional microtrap arrays for quantum simulation with trapped ions — •Roman Schmied[1], J. Ignacio Cirac[1], Janus H. Wesenberg[2], and Dietrich Leibfried[3] — [1]MPI für Quantenoptik, Garching, Germany — [2]Department of Materials, University of Oxford, England — [3]National Institute of Standards and Technology, Boulder, U.S.A.

Trapped ions are a promising system for building quantum simulators. For a given simulation problem, it is advantageous if we can individually trap the ions in a well-defined spatial arrangement with specified trap curvatures. We introduce an efficient method for constructing arbitrary two-dimensional (single- and multi-layered) arrays of electric microtraps by calculating and optimizing the shapes of the necessary electrodes. Our method allows for large-scale periodic microtrap designs with maximal trapping depths for a given simulation unit cell. In addition to the general method, we present several examples, including a quantum simulator for the Kitaev toric code [1].

[1] A. Kitaev, Ann. Phys. 321 (2006) 2

Q 42.8 Do 12:15 Audi-B

Perspectives of simulating spin-Boson systems with trapped ions — •Martin Enderlein[1], Hector Schmitz[2], Christian Schneider[1], Thomas Huber[1], and Tobias Schaetz[1] — [1]Max-Planck-Institut für Quantenoptik — [2]LMU München

Under certain conditions, the Hamiltonian describing the electronic structure as well as the Coulomb interaction of trapped ions resembles the spin-Boson Hamiltonian which, e.g., describes quantum dissipation in solid-state physics. We aim for a quantum simulation where the spin is represented by two laser-coupled electronic levels of one ion and the phonons in a crystalline chain of ions play the role of the Bosonic bath [1]. Since trapped atomic ions provide a very clean system with a wide range of tunable parameters, this might also allow the experimental access to the strong coupling regime of the spin-Boson model (SBM), inaccessable in typical solid-state systems.

In this presentation we would like to discuss interesting features of the SBM and the perspectives of simulating them in our setup [2]. Since we recently achieved the initialisation of five ions in the radial motional ground state, we hope to observe behaviour characteristic for the SBM in a feasibility study.

[1] D. Porras *et al.*, Physical Review A **78**, 010101 (2008)
[2] A. Friedenauer *et al.*, Nature Physics **4**, 757 (2008)