Q 5: Quantum information: Atoms and ions I

Time: Monday 10:30–12:30 Location: UDL HS3038

Group Report Q 5.1 Mon 10:30 UDL HS3038

Group report: Wiring up charged particles — Dylan Gorman, Soenke Moeller, •Philipp Schindler, Sankar Sankaranarayanan, Anthony Ransford, Josselin Bernardoff, Ahmed Abdelrahman, Ishan Talukdar, Nikos Daniilidis, and Hartmut Haeffner — Deparment of Physics, University of California Berkeley, USA

We present our recent results on coupling trapped $^{40}Ca^{+}$ ions to electronic circuits with the long term goal of realizing a scalable quantum information processor. Our experiment aims to couple single trapped ions to an LC-resonator. We see this as a first step towards a hybrid quantum information device combining the advantages of trapped ions and superconducting devices. As a first application we will cool the resonant mode of a superconducting high-quality resonant circuit by coupling it to a laser-cooled ion.

A second experiment aims to couple the motion of two distant ions via a conducting wire. As a prerequisite for the coupling process, we investigate the influence of the wire on a single trapped ion as the wire-ion distance is reduced. In order to realize this coupling at a single quantum level, noise processes originating from the surface of the ion traps need to be significantly reduced. We report on an experiment that reduces the heating rate due to surface contaminants by a factor of 50 after cleaning the surface.

Q 5.2 Mon 11:00 UDL HS3038

Trapping and cooling of two-species ion chains for quantum control — •Hsiang-Yu Lo, Daniel Kienzler, Ben Keitch, Ludwig de Clercq, Vlad Negnevitsky, Frieder Lindenfelser, Florian Leupold, Joseba Alonso, Matteo Marinelli, Christa Flühmann, and Jonathan Home — Institute for Quantum Electronics, Zurich, Switzerland

I will describe a flexible setup for the control of beryllium-calcium ion chains in a micro-structured segmented linear Paul trap. We have loaded multi-species ion strings, and imaged both species simultaneously using a bi-chromatic imaging system. We measure a heating rate for calcium ions of 10 quanta per second in a room-temperature trap with a 180 micron ion-electrode distance. For high-fidelity control of beryllium ions, we have built a solid-state laser system which generates 2 W of continuous-wave light at 313 nm. The main advantage of using two species of ion is that we can individually control each species without disturbing the internal states of the other, due to the large wavelength difference between the transitions in the ions. This provides a variety of opportunities for quantum control.

Q 5.3 Mon 11:15 UDL HS3038

Cryogenic surface-electrode ion trap apparatus — •Timko Dubielzig[1], Matina Carsjens[1,2], Matthias Kohnen[2,1], Sebastian Grondkowski[1], and Christian Ospelkaus[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany — [2]Physikalisch Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

In this talk we describe the infrastructure necessary to operate a surface-electrode ion trap with integrated microwave conductors for near-field quantum control of $^{9}Be^{+}$ in a cryogenic environment. These traps are promising systems for analog quantum simulators and for quantum logic applications. Our group recently developed a trap with an integrated meander-like micowave guide for driving motional sidebands on an $^{9}Be^{+}$ ion [1]. The trap will be operated in a cryogenic vacuum chamber. We will discuss the vibrational isolated closed cycle cryostat and the design of the vacuum chamber with all electrical supplies necessary to apply two different microwave currents, dc voltages and three independent rf supplies to generate a reconfigurable rf trapping potential. We will also discuss the used hyperfine qubit and the laser systems required to cool and repump. Furthermore we will present the cryogenic, high aperture and fully acromatic imaging system.

[1] Applied Physics B - 10.1007/s00340-013-5689-6 (2013)

Q 5.4 Mon 11:30 UDL HS3038

Electromagnetically-induced-transparency cooling in a segmented ion trap — •Regina Lechner[1], Thomas Monz[1], Christian Roos[1,2], Michael Brownnutt[1], and Rainer Blatt[1,2] — [1]Institut für Experimentalphysik, Universität Innsbruck, 6020 Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation der Österreichischen Akademie der Wissenschaften, 6020 Innsbruck, Austria

Trapped ions are one of the most promising implementations towards a fully functional quantum computer. For the construction of traps capable of holding many ions in a linear string, one solution widely used within the community consists in segmenting the trap electrodes. The segmentation permits the generation of anharmonic potentials which can stabilize ions in equidistant positions. This is of interest for both quantum computation and quantum simulation. Large ion crystals have already been realized in segmented traps but effective methods of groundstate-cooling strings and thereby making them more accessible to useful algorithms are still under investigation. One promising scheme to achieve the desired cooling is electromagnetically-induced-transparency (EIT) cooling. This technique offers the advantage of cooling several modes simultaneously which renders the scheme more efficient than conventionally used sideband cooling, especially for larger ion crystals with increased mode numbers.

We implement EIT cooling in a segmented trap showing its effect on ion crystals of varying size in a harmonic trapping potential. The application of EIT cooling for anharmonic potentials is investigated.

Q 5.5 Mon 11:45 UDL HS3038

Ion traps based on photonic crystal fibre technology — •Frieder Lindenfelser[1], Daniel Kienzler[1], Ben Keitch[1], Patrick Uebel[2], Markus Schmidt[3], Philip St.J. Russell[2], and Jonathan Home[1] — [1]ETH, Zürich, Schweiz — [2]MPL, Erlangen, Deutschland — [3]IPHT, Jena, Deutschland

We are exploring novel ion traps using fabrication methods based on those used to create photonic crystal fibres (PCF). We fill the regular hole pattern of a pre-drawn PCF "cane" with gold wires that extend beyond the fused silica structure. The wire tips are used as the electrodes that form the ion trap. The production method used should allow fabrication of ion traps at various sizes, from 5 to 150 microns electrode diameter, and provide access to a number of different trap electrode patterns. This type of fabrication opens up new possibilities for realizing 2-dimensional arrays of ions for quantum simulations, and also results in a trap with high optical access which is suitable for combining with high-finesse cavities. I will describe our progress on trapping ions in a trap with a 130 micron electrode diameter.

Q 5.6 Mon 12:00 UDL HS3038

Structure, Dynamics and Bifurcations of Discrete Solitons in Trapped Ion Crystals — •Jonathan Brox[1], Haggai Landa[2], Philip Kiefer[1], Manuel Mielenz[1], Benni Reznik[2], and Tobias Schaetz[1] — [1]Atom-, Molekül- und optische Physik, Physikalisches Institut, Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg — [2]School of Physics and Astronomy, Raymond and Beverly Sackler Faculty of Exact Sciences, Tel-Aviv University, Tel-Aviv 69978, Israel

We study discrete solitons (kinks) accessible in state-of-the-art trapped ion experiments [1], considering zigzag crystals and quasi-3D configurations, both theoretically and experimentally[2]. We extend the theoretical understanding of different phenomena predicted and recently experimentally observed in the structure and dynamics of these topological excitations. Employing tools from topological degree theory, we analyze bifurcations of crystal configurations in dependence on the trapping parameters, and investigate the formation of kink configurations and the transformations of kinks between different structures. We present configurations of pairs of interacting kinks stable for long times, offering the perspective for exploring and exploiting complex collective nonlinear excitations, controllable on the quantum level.

[1] M. Mielenz et al., Phys. Rev. Lett. **110**, 133004 (2013)
[2] H. Landa et al., New J. Phys. **15**, 093003 (2013)
[3] H. Landa et al., arXiv:1308.2943

Q 5.7 Mon 12:15 UDL HS3038

Trennen von Ionenkristallen zur skalierbaren Quanteninformationsverarbeitung — •Thomas Ruster, Claudia Warschburger, Henning Kaufmann, Christian Schmiegelow, Vidyut Kaushal, Ferdinand Schmidt-Kaler und Ulrich Poschinger — QUANTUM, Institut für Physik, Universität Mainz, Staudingerweg 7, 55128 Mainz

Segmentierte Mikro-Ionenfallen ermöglichen skalierbare Experimente mit gefangenen, lasergekühlten Ionen. Grundlegende Operationen zum Betrieb [1] sind unter anderem der Transport [2,3] von Ionen zwischen Speicher- und Prozessorregionen sowie das Zusammenführen bzw. das Auftrennen von Ionenkristallen. Während des Trennprozesses geht das harmonische axiale Fallenpotential zeitweise in ein rein quartisches Potential über, was die Empfindlichkeit des Bewegungszustandes der Ionen gegenüber anomalem Heizen und Schwingungsanregung enorm erhöht. Wir stellen Verfahren vor, mit denen Trennoperationen mit geringer Anregung des Bewegungszustandes in typischen Mikro-Ionenfallen realisiert werden können und präsentieren unsere experimentellen Ergebnisse. Wir erreichen eine mittlere Anregung von $\bar{n} \approx 5$ Phononen pro Ion nach einer Trenndauer von 80μs, was eine Verkettung von Trenn- und quantenlogischen Operationen ermöglicht, z.B. zur Realisierung von Quantenteleportation oder Verschränkungsaustausch innerhalb einer Ionenfalle.

[1] J. P. Home et al., Science **325**, 1227-1230 (2009)
[2] A. Walther et al., PRL **109**, 080501 (2012)
[3] R. Bowler et al., PRL **109**, 080502 (2012)