Q 5: Quantum information: Atoms and ions I

Time: Monday 11:00–12:30 Location: E 214

Q 5.1 Mon 11:00 E 214

Operating 2D Arrays of Addressable Ion Traps — •Muir Kumph[1], Michael Niedermayr[1], Michael Brownnutt[1], and Rainer Blatt[1,2] — [1]Institut für Experimentalphysik, Universitäts Innsbruck Technickerstr 25, 6020 Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, 6020 Innsbruck, Austria

Controlling interactions between ions in a segmented linear ion trap is becoming standard technology. Extending these methods to two dimensions, however, is not trivial. The trapping and control of 40Ca+ ions in a 4 by 4 array of addressable planar-electrode ion traps is shown. Demonstration of the micromotion minimization and estimates of the heating rates will be given.

Q 5.2 Mon 11:15 E 214

Quantum quenches of ion Coulomb crystals across structural instabilities — •Jens D. Baltrusch[1,2], Cecilia Cormick[3], and Giovanna Morigi[1] — [1]Theoretische Quantenphysik, Universität des Saarlandes — [2]Grup d'Optica, Universitat Autònoma de Barcelona — [3]Institut für Theoretische Physik, Universität Ulm

We theoretically analyze the efficiency of a protocol for creating mesoscopic superpositions of ion chains, described in [Phys. Rev. A **84**, 063821 (2011)], as a function of the temperature of the crystal. The protocol makes use of spin-dependent forces, so that a coherent superposition of the electronic states of one ion evolves into an entangled state between the chain's internal and external degrees of freedom. Ion Coulomb crystals are well isolated from the external environment, and should therefore experience a coherent, unitary evolution, which follows the quench and generates a structural Schrödinger cat-like state. The initial temperature of the chain, however, introduces a statistical uncertainty in the final state. We characterize the quantum state of the crystal by means of the visibility of Ramsey interferometry performed on one ion of the chain [Phys. Rev. A **86**, 032104 (2012)], and determine its decay as a function of the crystal's initial temperature. This analysis allows one to determine the conditions on the chain's initial state for performing the protocol.

Q 5.3 Mon 11:30 E 214

Generation of quantum discord between trapped atomic ions — Ben P. Lanyon[1,2], •Petar Jurcevic[1,2], Cornelius Hempel[1,2], Rainer Blatt[1,2], and Christian F. Roos[1,2] — [1]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Technikerstr. 21A, 6020 Innsbruck, Austria — [2]Institut für Experimentalphysik, Universität Innsbruck, Technikerstr. 25, 6020 Innsbruck, Austria

Quantum systems can be unentangled and yet correlated in a way that is not possible for classical systems. These correlations, which exist for mixed quantum states, can be quantified by the quantum discord. Like entanglement, discord is known to be useful in a range of information processing tasks.

In this work we show, experimentally, that discord can be generated by simple classical noise processes. First, starting from a state of two trapped ions with only classical correlations, we generate discord using local operations i.e. by manipulating of only one ion. Then we show that even stronger discordant correlations can be generated by collective dephasing channels.

Since entanglement cannot be generated via any of the above processes, these experiments highlight a fundamental difference between the two types of non-classical correlations. Our work contributes to the continuing research on distinguishing the quantum/classical boundary and the generated states will find application in quantum information processing tasks.

Q 5.4 Mon 11:45 E 214

Driven single-sideband geometric phase gates with trapped ions — •Andreas Lemmer, Alejandro Bermúdez, and Martin B. Plenio — Institut für Theoretische Physik, Universität Ulm, 89069 Ulm, Germany

We will present our recent work on the implementation of a two qubit quantum logic gate for trapped ions which is robust against both thermal and dephasing noise. In particular, it is simpler than previous schemes because it relies on a single red-sideband excitation for quantum logic while the robustness against thermal and dephasing noise is achieved by a strong driving from a microwave source [1]. By choosing the laser and microwave frequencies appropriately the gate can be transformed into a geometric phase gate and thus be made faster and more reliable [2].

[1] A. Bermúdez et *al.*, Phys. Rev. A **85**, 040302(R) (2012)
[2] A. Lemmer, A. Bermúdez and M. B. Plenio *in preparation*

Q 5.5 Mon 12:00 E 214

Large controllable phase shift from a single trapped ion — •Andreas Jechow[1,2], Erik Streed[2], Benjamin Norton[2], and David Kielpinski[2] — [1]Universität Potsdam, Photonik, Karl Liebknecht Str 24-25, 14476 Potsdam — [2]Centre for Quantum Dynamics, Griffith University, Brisbane, Australia

Laser cooled trapped atomic ions are effectively isolated atoms held at rest and largely free from perturbations, representing a quantum system with control over all degrees of freedom. Recently, we have demonstrated wavelength scale imaging resolution of ytterbium ions trapped in a radio frequency Paul trap utilizing a phase Fresnel lens (PFL). This high spatial resolution and the high NA of the PFL allowed us to perform absorption imaging with a single isolated atom [1].

Here we show new results obtained with the absorption imaging technique. We have induced and measured a large optical phase shift in light scattered by a single trapped atomic ytterbium ion. The phase shift in the scattered component was unraveled by performing spatial interferometry between the scattered light and unscattered illumination light. The optical phase shift of 1.3 radians reaches the maximum value allowed by atomic theory over the accessible range of laser frequencies. Single-atom phase shifts of this magnitude open up new quantum information protocols, including long-range quantum phase-shift-keying cryptography and quantum nondemolition measurement.

[1] E.W. Streed, A. Jechow, B.G. Norton, and D. Kielpinski "Absorption imaging of a single atom, " Nature Communications 3, 933 (2012)

Q 5.6 Mon 12:15 E 214

Präzise Vermessung des Kibble-Zurek Mechanismus in Ionenkristallen — •Stefan Ulm, Johannes Rossnagel, Georg Jacob, Charlotte Degünther, Sam T. Dawkins, Ulrich G. Poschinger, Ferdinand Schmidt-Kaler und Kilian Singer — QUANTUM ,Institut für Physik, Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany

Wird ein System schnell über einen Phasenübergang zweiter Ordnung in einen symmetrisch entarteten Grundzustand getrieben, dann können strukturelle Defekte entstehen, wenn in unterschiedlichen, räumlich und kausal getrennten, Regionen das System eine unabhängige und verschiedene Wahl des Zustandes trifft. Die Anzahl der strukturellen Defekte folgt dabei einem universellen Skalierungsgesetz, welches von Kibble und Zureck eingeführt wurde [1].

Kristalle aus einzelnen kalten Ionen stellen ein nahezu ideales Modellsystem dar, um die universelle Skalierung der Defektrate zu studieren. Schnelle Änderungen der Fallenkontrollspannungen und exakt einstellbare Parameter ermöglichen eine genaue Beobachtung der Defekte beim Übergang von linearen zu zickzack Kristallen [2]. Die Experimente werden mit numerischen Simulationen verglichen und wir finden eine hervorragende Bestätigung des Skalierungsgesetzes für den inhomogenen Kibble Zureck Effekt[3]. [1] T. W. B. Kibble, Jour. Phys. A 9, 1387 (1976) und W. Zurek, Nat. 317, 505 (1985). [2] H. Kaufmann et al., accepted for publication in PRL, arxiv:1208.4040 [3] A. Del Campo, et al. PRL 105, 75701 (2010) und G. De Chiara, et al. NJP 12, 115003 (2010).