Q 2: Ultracold Atoms, Ions and Molecules I (with A)

Time: Monday 11:00–13:00 Location: e001

Q 2.1 Mon 11:00 e001

3D Printed Atom Traps — •Reece Saint[1], Will Evans[1], Yijia Zhou[1], Mark Fromhold[1], Ehab Saleh[2], Christopher Tuck[2], Ricky Wildmann[2], Mark Hardy[2], Ian Maskery[2], Fedjia Oručević[1], and Peter Krüger[1] — [1]School of Physics and Astronomy, University of Nottingham, United Kingdom — [2]Additive Manufacturing,University of Nottingham, United Kingdom

Atom chip technologies have shown excellent promise as a base in order to probe the physics of quantum gases, but also for the implementation of quantum based sensors in gravitometry [e.g. EU-funded iSense project], nanoTesla sensitive magnetic devices with micrometer resolution and optical cloud based microscopy. Such chips are inherently ultra-high vacuum (UHV) compatible, necessary for long lifetime atom traps. Further these traps rely on highly power consuming and planar "under-structures", required to form and cool the magneto-optical traps (MOT) on which atom-chip based experiments depend; not to mention often cumbersome experimental baggage.

We introduce a different approach, addressing the challenges started above: additive manufacturing (3D Printing). Using an additive process where successive layers of material are laid down allows for almost arbitrary structures to be created; coupling this with modern optimization algorithms to optimize magnetic trapping in terms of power consumption, heat generation, structure robustness and size would substantially improve overall device performance. 3D Printing offers the possibility of integrating electronic, optical or vacuum components, potentially allowing the formation of a fully integrated atom chip device.

Q 2.2 Mon 11:15 e001

A 3d micro-structured trap with low axial micromotion and high field gradients — •Delia Kaufmann, Timm F. Gloger, Peter Kaufmann, Michael Johanning, and Christof Wunderlich — Department Physik, Universität Siegen, 57068 Siegen, Germany

We present the status of a second generation 3d micro-structured segmented ion trap with built in solenoids for the creation of inhomogeneous magnetic fields. The new design is based on a trap, which, among other things, was used to demonstrate rf single ion addressing [1] and fault tolerant Hahn-Ramsey-spectroscopy [2]. To overcome the present limitations in terms of finite gradient size and axial micromotion and make it better suitable for the application of MAgnetic Gradient Induced Coupling (MAGIC) [3], and the formation of tailored entangled states [4], the new trap features a redesigned middle layer for lower axial micromotion and improved connectivity for higher solenoid current damage threshold. We discuss the design, simulations and the status of the experimental setup.

[1] D. Kaufmann et al., Appl. Phys. B 107, 935 (2012); D. Kaufmann, PhD thesis, Siegen, 2011.
[2] N. Vitanov et al., Phys. Rev. A 91, 033406 (2015)
[3] Ch. Piltz et al., arXiv:1509.01478 (2015)
[4] S. Zipilli et al., Phys. Rev. A 89, 042308 (2014)

Q 2.3 Mon 11:30 e001

Investigation of hyperfine qubit dephasing in trapped ions — •Theeraphot Sriarunothai, Christian Piltz, Gouri Giri, and Christof Wunderlich — Department Physik, Universität Siegen, 57068 Siegen, Germany

Magnetic sensitive hyperfine states of trapped ions that serve as qubits can be protected against decoherence by use of continuous or pulsed dynamical decoupling (e.g., [1]). Nevertheless it is desirable to experimentally identify noise sources and characterize them to enhance the basic stability of experiments in quantum information science. We report on investigations into the dephasing of hyperfine qubits exposed to a magnetic gradient using trapped $^{171}Yb^+$ ions confined in a macroscopic linear Paul trap. Effective magnetic field noise caused by the ions' motion in varying electric fields is reduced by minimizing the ions' micromotion and by passively filtering the DC potentials applied to trap electrodes. An active magnetic field compensation system counteracts ambient magnetic noise. The dependence of the fidelity of conditional quantum gates (e.g., CNOT) is investigated as a function of the thermal excitation of the ions' motion in the range between the Doppler cooling limit and close to the motional ground state employing microwave sideband cooling [2-4].

[1] N. Timoney *et al.*, Nature **476**, 185 (2011).
[2] C. Ospelkaus *et al.*, Nature **476**, 181 (2011).
[3] A. Khromova *et al.*, Phys. Rev. Lett. **108**, 220502 (2012).
[4] S. Weidt *et al.*, Phys. Rev. Lett. **115**, 013002 (2015.)

Q 2.4 Mon 11:45 e001

Feedback-based position stabilisation of microparticles — •Saravanan Sengottuvel, Michael Johanning, and Christoph Wunderlich — University of Siegen, Germany

We report on the status of an experiment utilizing feedback for the three-dimensional position stabilization of a charged micro particle. Laser light scattered by the particle illuminates position sensitive detectors and generates an error signal upon displacement of the particle. This error signal is then used to generate a compensating field using correction electrodes. For a particle that is initially trapped in a linear segmented Paul trap, this allows to ramp down and finally switch off the trap and end up with a well localized quasi-free particle. We discuss the approach, potential applications and limitations for sensitivity, position confinement and particle size.

Q 2.5 Mon 12:00 e001

All-optical Atom Trap Trace Analysis for Rare Krypton Isotopes — •Pablo Woelk[1], Markus Kohler[1], Carsten Sieveke[1], Simon Hebel[1], Peter Sahling[1], Christoph Becker[2], and Klaus Sengstock[2] — [1]Carl Friedrich von Weizsäcker Centre for Science and Peace Research, University of Hamburg, Beim Schlump 83, 20144 Hamburg — [2]Institut für Laser-Physik, University of Hamburg, 22761 Hamburg

The isotope Krypton-85 is an excellent indicator for the detection of nuclear reprocessing activities. However, for the analysis of atmospheric air samples, sensitive measuring methods down to the single atom level are required because of the small concentrations. Furthermore, for a practical and effective detection of clandestine reprocessing, small sample sizes and a high sample throughput rate are desirable.

Established methods using Atom Trap Trace Analysis (ATTA) allow high sensitivity but have a limited throughput of about 200 samples per year, since the vacuum chambers have to be flushed for several hours after each measurement to avoid cross contamination due to the RF-driven excitation of metastable states.

Here we present an enhanced ATTA apparatus, which in contrast to the established methods, produces metastable Kr all-optically. This avoids cross contamination, therefore allowing a much higher throughput rate. The apparatus is based on a self-made VUV-lamp and a 2D-3D magneto-optical trap setup. In the 2D trap metastable krypton is produced and a beam of atoms is formed by Doppler-cooling simultaneously.

Q 2.6 Mon 12:15 e001

Quantum simulation of the dynamical Casimir effect with trapped ions — •Nils Trautmann[1] and Philipp Hauke[2,3] — [1]Institut für Angewandte Physik, Technische Universität Darmstadt — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften — [3]Institut für Theoretische Physik, Universität Innsbruck

Quantum vacuum fluctuations are a direct manifestation of Heisenberg's uncertainty principle. The dynamical Casimir effect allows for the observation of these vacuum fluctuations by turning them into real, observable photons. However, the observation of this effect in a cavity QED experiment would require the rapid variation of the length of a cavity with relativistic velocities, a daunting challenge. Here, we propose a quantum simulation of the dynamical Casimir effect using an ion chain confined in a segmented ion trap. We derive a discrete model that enables us to map the dynamics of the multimode radiation field inside a variable-length cavity to radial phonons of the ion crystal. We perform a numerical study comparing the ion-chain quantum simulation under realistic experimental parameters to an ideal Fabry–Perot cavity, demonstrating the viability of the mapping. The proposed quantum simulator, therefore, allows for probing the photon (respectively phonon) production caused by the dynamical Casimir effect on the single photon level.

Q 2.7 Mon 12:30 e001

Experimental realization of a single-ion heat eninge —

•Kilian Singer[1,2], Johannes Rossnagel[1,2], Samuel Thomas Dawkins[1,2], Ferdinand Schmidt-Kaler[1], Georg Jacob[1], and Dawid Criwelli[1,2] — [1]Quantum, Institut für Physik, Universität Mainz, D-55128 Mainz, Germany — [2]Experimentalphysik I, Universität Kassel, Heinrich-Plett-Str. 40, D-34132 Kassel, Germany

Thermodynamic machines can be reduced to the ultimate atomic limit [1], using a single ion as a working agent. The confinement in a linear Paul trap with tapered geometry allows for coupling axial and radial modes of oscillation.

The heat-engine is driven thermally by coupling it alternately to hot and cold reservoirs, using the output power of the engine to drive a harmonic oscillation [2].

From direct measurements of the ion dynamics, the thermodynamic cycles for various temperature differences of the reservoirs can be determined [3] and the efficiency compared with analytical estimates.

[1] J. Rossnagel et al., "A single-atom heat engine", arXiv:1510.03681
[2] O. Abah et al., Phys. Rev. Lett. 109, 203006 (2012).
[3] J. Rossnagel et al., New J. Phys. 17, 045004 (2015)

Q 2.8 Mon 12:45 e001

Single-ion heat pump — •Dawid Crivelli[1,2], Johannes Rossnagel[1,2], Samuel Thomas Dawkins[1,2], Ferdinand Schmidt-Kaler[1], Georg Jacob[1,2], and Kilian Singer[1,2] — [1]Quantum, Institut für Physik, Universität Mainz, D-55128 Mainz, Germany — [2]Experimentalphysik I, Universität Kassel, Heinrich-Plett-Str. 40, D-34132 Kassel, Germany

We will present new concepts of implementing a heat pump with a single atom. Analytical and numerical predictions employing realistic experimental conditions are reviewed together with a new trap design for the implementation. We include a detailed description of the experimental procedure. We build on the results of our previous implementation of a single ion heat engine [1,2,3], inverting the mechanism to realize a heat-pump, transferring heat from the cold to the hot reservoir, induced by an external electric field.

[1] J. Rossnagel et al., "A single-atom heat engine", arXiv: 1510.03681.
[2] O. Abah et al., Phys. Rev. Lett. 109, 203006 (2012).
[3] J. Rossnagel et al., New J. Phys. 17, 045004 (2015).