Q 47: Quanteninformation: Atome und Ionen 2

Time: Thursday 14:00–16:00 Location: V7.02

Q 47.1 Thu 14:00 V7.02

Robust dynamical decoupling with concatenated continuous driving — •Jianming Cai[1], Fedor Jelezko[2], Martin Plenio[1], and Alex Retzker[1] — [1]Institute of Theoretical Physics, University Ulm, Germany — [2]Institute of Quantum Optics, University Ulm, Germany

The loss of coherence is one of the main obstacles for the implementation of quantum information processing. Here we introduce the concept of concatenated continuous dynamical decoupling, which can overcome not only external noise but also fluctuations in driving fields that implement the decoupling sequences and thus holds the potential for achieving relaxation limited coherence times. The proposed scheme can be applied to a wide variety of physical systems including, trapped atoms and ions, quantum dots and nitrogen-vacancy (NV) centers in diamond, and may be combined with other quantum technologies challenges such as quantum sensing or quantum information processing.

Q 47.2 Thu 14:15 V7.02

Dynamical decoupling sequences for realizing robust quantum gates and memories with trapped ions — •Christian Piltz, Anastasiya Khromova, Benedikt Scharfenberger, Timm Florian Gloger, Michael Johanning, Andrés Varón, and Christof Wunderlich — Department Physik, Naturwissenschaftlich-Technische Fakultät, Universität Siegen, 57068 Siegen, Germany

Dynamical decoupling (DD) is a widely used technique in the framework of nuclear magnetic resonance to protect the coherence of quantum systems against a detrimental environment. DD pulse sequences can be used to enhance the coherence time of quantum memories and the fidelity of quantum gates. However, imperfections of pulses may destroy quantum information or interfere with gate dynamics. We investigate different sequences with respect to their capability to suppress decoherence while still being robust against pulse imperfections in an ion trap experiment. Our results obtained with $^{171}Yb^+$ ions demonstrate that sequences based on varying phases are self-correcting. We found sequences that allow for the implementation of a conditional quantum gate even if the gate time is more than one order of magnitude longer than the coherence time of the system. Furthermore, we show that DD sequences can be combined with selective recoupling to implement quantum memories with trapped ions.

Q 47.3 Thu 14:30 V7.02

Topological defects in ion Coulomb crystals — •Manuel Mielenz[1,2], Günther Leschhorn[1,2], Christian Schneider[1,2], Thomas Huber[1,2], Martin Enderlein[1,2], Miriam Bujak[1,2], Magnus Albert[1,2], and Tobias Schätz[1,2] — [1]Physikalisches Institut, Albert-Ludwigs Universität Freiburg — [2]MPI für Quantenoptik

Solitons are localized and topologically protected structures in a nonlinear system [1]. Classical Solitions have been studied, e.g. in waveguides [2,3]. In the context of the Frenkel-Kontorova (FK) model solitonic solutions are predicted in chains of coupled particles in a local nonlinear potential. These configurations, referred to as "Kinks", are theoretically predicted in two-dimensional ion crystals [1]. Their vibrational spectrum exhibits characteristic modes seperated by a gap from the quasi-continuous phonon band of an unperturbed crystal.

We will report on the first experimental realization of "Kinks" in ion crystals confined in a linear Paul trap [4]. Various types of topological defects have been observed and we will present systematic studies of their properties, along with a comparison to theoretical simulations. Such well controlled ensembles of ions are an interesting model system to investigate the quantum mechanical properties of solitons and might open up for applications in quantum simulation and information [1].

[1] H. Landa *et al.*, PRL **104**, 043004 (2010)
[2] H. .S. Eisenberg *et al.*, PRL **81**, 33833386 (1998)
[3] J. W. Fleischer *et al.*, Nature **422**, 6928 (2003)
[4] Ch. Schneider *et al.*, arXiv:1106.2597v1, to be published in Rep. Prog. Phys 2011

Q 47.4 Thu 14:45 V7.02

Fast transport operations in a segmented ion trap quantum computer — •Andreas Walther, Ulrich Poschinger, Konstantin Ott, Michael Schnorr, Sam Dawkins, Kilian Singer, Frank Ziesel, Max Hettrich, and Ferdinand Schmidt-Kaler — QUANTUM, Inst. für Physik, Univ. Mainz, Staudinger Weg 7, 55128 Mainz

For scalable quantum information processing in ion traps, two essential types of operations have to be performed in a combined way: i) shuttling operations of ions between different segments of the trap and ii) quantum logic operations. In addition, it is important that these operations are performed as fast as possible, such that many operations can be made before decoherence and heating effects set in. Here we experimentally demonstrate the realization of very fast shuttling of ions between segments. An ion, cooled near to its motional ground state, is transported more than 300 μm within only a few cycles of its harmonic oscillation period. With properly chosen parameters, the ion can be made to remain in the vibrational ground state after the transport. We also report on a fast cooling scheme, utilizing continuous near resonant Raman interactions for a combination of single and two photon processes that is able to cool ions close to their motional ground state. For multiple-ion crystals, this scheme represents a particular advantage, allowing for the possibility of cooling multiple motional modes at once, which yields fast cooling times in the order of 100 μs.

Q 47.5 Thu 15:00 V7.02

An individual trapped-ion pseudo-molecule with adjustable spin-spin coupling — •Andrés F. Varón, Anastasiya Khromova, Christian Piltz, Timm F. Gloger, Michael Johanning, and Christof Wunderlich — Universität Siegen, NT Fakultät, Department Physik, 57068 Siegen, Germany

Already early on during the development of quantum information science nuclear magnetic resonance (NMR) has been successfully applied to realize quantum algorithms based on J-coupling between nuclear spins in molecules. Scalability of NMR is hampered mainly by the use of ensembles of molecules. Additionally, nuclear spin resonances and J-coupling between spins are determined by the molecule structure, and thus often are not well suited for quantum computing. Here, we report on the creation and experimental investigation of an individual 3-spin pseudo-molecule that exhibits adjustable J-type coupling between spin states. This coupling has been employed to entangle consecutive spins or distant ones at demand using microwave radiation. Effective spin-1/2 systems are realized by using hyperfine states of trapped atomic ions. They are addressed with high fidelity since the resonances of individual spins are well separated due to a spatially varying magnetic field which also induces the J-type coupling mediated by the vibrational modes of this ion pseudo-molecule. The demonstration of Conditional-NOT gates between non-nearest neighbours serves as a proof-of- principle of a novel quantum bus employing a spin chain.

Q 47.6 Thu 15:15 V7.02

Laser cooling and spectroscopy of trapped Yb^+ ions at 297nm — •Hendrik-Marten Meyer, Matthias Steiner, and Michael Köhl — Department of Physics, University of Cambridge, Cavendish Laboratory, JJ Thomson Avenue, CB3 0HE, Cambridge, United Kingdom

In the last decade trapped Yb^+ ions have been used in quantum information processing, precision measurements and hybrid systems. We explore the $^2S_{1/2}$ - $^3D[3/2]_{1/2}$ transition at 297 nm in Yb^+ and provide absolute frequency measurements of this transition for even Yb^+ isotopes. Light at 297 nm is generated using sum frequency generation of light near 532 nm and 672 nm. We also show that this light can be used for laser cooling of trapped Yb^+ ions. The possibility to address the $^2S_{1/2}$ - $^3D[3/2]_{1/2}$ transition makes a new lambda-system available in Yb^+ which opens new ways of quantum state manipulation of these ions.

Q 47.7 Thu 15:30 V7.02

RF optical double resonance spectroscopy on $^{172}Yb^+$ in a segmented micro-structured ion trap — •Michael Johanning, M. Tanveer Baig, Thomas Collath, Timm F. Gloger, Delia Kaufmann, Peter Kaufmann, and Christof Wunderlich — Universität Siegen, NT Fakultät, Department Physik, 57068 Siegen, Germany

We apply rf-optical double resonance spectroscopy to laser cooled ions, stored in a micro-structured segmented trap with integrated magnetic field coils. Such a setup is a very flexible starting point for quantum information science experiments, as it allows for coherent processing of quantum information, and for the generation of tailored interaction Hamiltonians to simulate various physical systems. A $^{172}Yb^{+}$-ion is optically pumped into a dark Zeeman state of the $D_{3/2}$-manifold, and fluorescence is recovered, when a resonant rf field bridges the energy gap between the Zeeman sublevels and the ion is optical pumped back into the $S_{1/2}$-state via the $[3/2]_{1/2}$-state by light near 935 nm. Thus the resonance frequency is a sensitive measure of the magnetic field and can be used to precisely map the spatial magnetic field dependence along the trap axis. An intentional magnetic gradient lifts the degenercy of the rf resonance in a string of ions and is applied to address single ions in frequency space.

Q 47.8 Thu 15:45 V7.02

Numerische Simulationen und Vorbereitung zur experimentellen Realisierung einer Quanten-thermodynamischen Wärmekraftmaschine mit einzelnen Ionen — •Johannes Rossnagel[1], Georg Jacob[1], Ferdinand Schmidt-Kaler[1], Obinna Abah[2], Eric Lutz[3] und Kilian Singer[1] — [1]Quantum, Institut für Physik, Universität Mainz, 55128 Mainz, Germany — [2]Institut für Physik, Universität Augsburg, 86135 Augsburg, Germany — [3]Dahlem Center für komplexe Quantensysteme, Freie Universität Berlin, 14195 Berlin

Die Untersuchung von Wärmekraftmaschinen im Quanten-Regime ist ein aktuelles Forschungsfeld, in dem Thermodynamik und Quanteninformation miteinander verbunden werden. Wir präsentieren Simulationen und Vorbereitungen auf dem Weg zur experimentellen Realisierung eines Quanten-thermodynamischen-Kreisprozesses. Als aktives Medium dieser Quanten-Wärmekraftmaschine wird ein einzelnes Ca^{+}-Ion in einer neuartigen, asymmetrischen Paul-Falle eingesetzt. Das kalte und warme Wärmebad wird durch nahresonantes rot und blau verstimmtes Laserlicht realisiert, wobei das Ion durch den Doppler-Effekt abwechselnd gekühlt und aufgeheizt wird. Die Arbeit dieser Maschine wird gegen ein axial eingestrahltes Lichtfeld eines Dissipationslasers verrichtet. Ein solches System erlaubt die Kontrolle und eine unabhängige Manipulation sämtlicher äußerer Parameter in einem weiten Bereich. Wir präsentieren Simulationen aus denen die Leistung und Effizienz dieser Maschine ermittelt werden kann.