Q 53: Quantum information: Atoms and ions IV

Time: Thursday 14:00–16:00 Location: A 310

Group Report Q 53.1 Thu 14:00 A 310

Quantum technologies based on NV center in diamond — •Jianming Cai[1], Boris Naydenov[2], Liam McGuinness[2], Paz London[2], Kay Jahnke[2], Jochen Scheuer[2], Rainer Pfeiffer[2], Alex Retzker[1], Fedor Jelezko[2], and Martin Plenio[1] — [1]Institute of Theoretical Physics,Ulm University — [2]Institut für Quantenoptik, Ulm University

In this talk, I will report our recent developments on various applications of NV center in diamond. In particular, we propose a new architecture for a scalable quantum simulator, which consists of strongly-interacting nuclear spins attached to the diamond surface by its direct chemical treatment, or by means of a functionalized graphene sheet. The initialization, control and read-out of this quantum simulator can be accomplished with nitrogen-vacancy centers implanted in diamond. The system can be engineered to simulate a wide variety of interesting strongly-correlated models with long-range dipole-dipole interactions. We also explore the possibility of using NV center in diamond as a nano-scale sensor to probe the structural and dynamical processes in chemistry/biology.

Q 53.2 Thu 14:30 A 310

Trapping of Topological-Structural Defects in Coulomb Crystals — •Jonathan Brox[1], Haggai Landa[2], 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 experimentally and theoretically structural defects which are formed during the transition from a laser cooled cloud to a Coulomb crystal, consisting of tens of ions in a linear radiofrequency trap. We demonstrate the creation of predicted topological defects ('kinks') in purely two-dimensional crystals [1], and also find kinks which show novel dynamical features in a regime of parameters not considered before. The kinks are always observed at the centre of the trap, showing a large nonlinear localized excitation, and the probability of their occurrence surprisingly saturates at ~ 0.5. Simulations reveal a strong anharmonicity of the kink's internal mode of vibration, due to the kink's extension into three dimensions. As a consequence, the periodic Peierls-Nabarro potential experienced by a discrete kink becomes a globally confining potential, capable of trapping one cooled defect at the center of the crystal.

[1] H. Landa et al., Phys. Rev. Lett. **104**, 043004 (2010)

Q 53.3 Thu 14:45 A 310

Quantun non demolition measurement and entanglement of multiple nuclear spins in diamond — •Gerald Waldherr, Sebastian Zaiser, Ya Wang, Philipp Neumann, and Jörg Wrachtrup — 3. Physikalisches Institut, Uni Stuttgart

QND measurement of a nitrogen nuclear spin associated with the nitrogen vacancy (NV) defect in diamond has previously been demonstrated [1]. Here, we will show that QND measurement of certain nearby ^{13}C nuclear spins can also be performed. Additionally, we can use the interaction with the NV electron spin to entangle these nuclear spins with each other, to demonstrate basic quantum information processing tasks.

[1] P. Neumann, J. Beck, M. Steiner, F. Rempp, H. Fedder, P. R. Hemmer, J. Wrachtrup, and F. Jelezko, Science 329, 542 (2010)

Q 53.4 Thu 15:00 A 310

Quantum sensing using vacuum forces — •Christine Muschik[1], Simon Moulieras[1], Kanupriya Sinha[2], Frank Koppens[1], Maciej Lewenstein[1], and Darrick Chang[1] — [1]ICFO-Institut de Ciencies Fotoniques, Spain — [2]University of Maryland, US

We propose a scheme, which harnesses quantum vacuum forces for practical applications. Casimir Forces become extremely strong at very short distances. We use this mechanism to coupling a quantum emitter to a suspended graphene membrane. This setup allows for an instantaneous and highly sensitive read-out the position of the graphene sheet, which has important applications for mass and force sensing. Since the coupling via the Casimir force is very strong, it is also a very valuable tool for engineering the quantum state of the membrane and for investigating the damping mechanisms of moving graphene in a hitherto inaccessible regime of precision.

Q 53.5 Thu 15:15 A 310

Microwave sideband cooling of trapped ions using a static magnetic gradient — •Andrés F. Varón, Benedikt Scharfenberger, Christian Piltz, Anastasiya Khromova, and Christof Wunderlich — Universität Siegen, NT Fakultät, Department Physik, 57068 Siegen, Germany

We report on microwave sideband cooling of trapped ^{171}Yb$^+$ ions. Different to laser cooling, microwave sideband cooling requires an additional mechanism that allows to couple internal states of a trapped ion with its vibrational states. This is done in the presence of a static magnetic field gradient created by two permanent magnets. Cooling is achieved by repetitions of the following two steps: First, microwave radiation, tuned to the red sideband of the hyperfine transition F=0 $\leftrightarrow$ F=1 in the electronic ground state $S_{1/2}$ of ^{171}Yb$^+$, excites the ion reducing the phonon number by one. Second, laser light exciting the $S_{1/2}$, F=1 $\leftrightarrow$ $P_{1/2}$, F=1 dipole allowed resonance pumps the ion back to the initial F=0 state but with a phonon less. The trap is characterized by an axial trapping frequency of 121 kHz. We systematically measure the final ion temperature for different microwave and laser intensities. For the optimized set of parameters we show a reduction of more than one order of magnitude on the mean phonon occupation number from $\langle n \rangle = 176 \pm 30$ to $\langle n \rangle = 4 \pm 4$ achieving temperatures close to the ground state.

Q 53.6 Thu 15:30 A 310

Multi-site single-atom qubit manipulation in a 2D quantum register — •Sascha Tichelmann, Malte Schlosser, Moritz Hambach, and Gerhard Birkl — Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt, Germany

The ability to synchronously probe multi-component quantum systems in multi-site architectures is fostering some of the most active research in the investigation of ultra-cold atomic quantum systems for quantum information processing (QIP). For this purpose, we have introduced the application of micro-fabricated optical elements for atom optics and QIP with atoms. We present recent progress towards the realization of a scalable architecture for QIP using neutral atoms in two-dimensional (2D) arrays of optical microtraps as qubit registers. This approach is simultaneously targeting the important issues of single-site addressability and scalability, and provides versatile configurations for quantum state storage, manipulation, and retrieval. We report on the implementation of a quantum register with well over 100 sites featuring trap sizes and a tuneable site separation in the single micrometer regime. Individual ^{85}Rb atoms serve as carriers for quantum information. The atom number at each site can be initialized to 1 with sup-poissonian statistics by applying an atom number filtering process based on light assisted collisions. In each experimental realization, we prepare exactly one atom in more than 50 sites. We present single-site resolved addressing of single spins in a reconfigurable fashion and discuss the feasibility of Rydberg based two-qubit gates in our setup.

Q 53.7 Thu 15:45 A 310

Topological defect formation and dynamics of symmetry breaking in ion Coulomb crystals — •Jonas Keller[1], Karsten Pyka[1], Heather L. Partner[1], Ramil Nigmatullin[2], Tobias Burgermeister[1], Martin B. Plenio[2], Alex Retzker[3], Wojciech Zurek[4], Adolfo del Campo[4], and Tanja E. Mehlstäubler[1] — [1]Physikalisch-Technische Bundesanstalt, Braunschweig — [2]Institut für Theoretische Physik, Universität Ulm — [3]Racah Institute of Physics, The Hebrew University of Jerusalem — [4]Theoretical Division, Los Alamos National Laboratory

Structural defects in ion Coulomb crystals (kinks) have been proposed for studies of quantum-mechanical effects with solitons and as carriers of quantum information [1]. Defects form when a symmetry breaking phase transition is crossed and the finite speed of information prevents different regions from coordinating the choice of the symmetry broken state. In our case, the second-order phase transition from the linear to the zigzag configuration of a Coulomb crystal is driven by quenching the radial trapping potential. We demonstrated the creation of stable kinks and present experimental results on kink dynamics and losses. These allowed a quantitative verification of the power law scaling of kink density with the quench time as predicted by the paradigmatic Kibble-Zurek mechanism [2]. This theory applies to phase transitions in a wide range of fields, from cosmology to solid state physics and vortices in superfluids.

[1] Landa *et al.*, *Phys. Rev. Lett.* **104**, 043004 (2010)
[2] Pyka *et al.*, *arXiv*:1211.7005 (2012)