Q 32: Quantum Information: Atoms and Ions II

Time: Wednesday 14:00–16:00 Location: E 214

Q 32.1 We 14:00 E 214

Universal enhancement of the optical readout fidelity of single electron spins — •Matthias Steiner, Neumann Philipp, Beck Johannes, Jelezko Fedor, and Wrachtrup Jörg — 3. Physikalisches Institut, Universität Stuttgart, Germany

Single spins in diamond associated with a Nitrogen-Vacancy (NV) center are one of the major candidates for room temperature quantum devices. They might be applied as quantum processors or single spin based magnetometers with unprecedented spatial and magnetic field resolution. Many of the possible applications rely on nearby nuclear spins that can be coherently controlled and coupled to the electron spin. Here we demonstrate how a switchable flip-flop process among the electron spin and several nuclear spins can be used to (1.) initialize the nuclear spin register, (2.) to read out the nuclear spin states directly and (3.) greatly improve the signal-to-noise ratio for the readout of quantum information.

Q 32.2 We 14:15 E 214

Coupling of individual electron spins in a room temperature solid — •Philipp Neumann, Roman Kolesov, Boris Naydenov, Johannes Beck, Florian Rempp, Matthias Steiner, Fedor Jelezko, and Jörg Wrachtrup — 3. Physikalisches Institut, Universität Stuttgart, Germany

Building quantum information devices goes far beyond the coherent control of single quantum systems. The challenge for every physical realization of such devices lies at the coherent coupling of their individual constituents that enables generation of nonlocal quantum states. This has been demonstrated for a variety of systems one of them being the Nitrogen-Vacancy (NV) defect center in diamond.[1,2] This artificial atom represents an electron spin qubit at room temperature. Together with surrounding nuclear spins in the diamond lattice quantum registers of up to 4 spin qubits have been realized.[3] Another way of scaling up this spin system is the direct magnetic dipolar coupling of closely spaced NV centers. Here we show recent results of such coupling of two NV centers. Conditional two-qubit gates are realized and the interaction is used to determine the relative position of the two centers in the diamond lattice with an uncertainty of one unit cell.

[1] M.V.G. Dutt *et al.*, *Science* **316,** 1312 (2007)
[2] P. Neumann *et al.*, *Science* **320,** 1326 (2008)
[3] N. Mizuochi *et al.*, *PRL* **80,** 041201(R) (2009)

Q 32.3 We 14:30 E 214

Nanoscale electric field sensing via the Stark effect of a single NV^- center in diamond — •Helmut Rathgen[1], Florian Dolde[1], Tobias Nöbauer[2], Fedor Jelezko[1], and Jörg Wrachtrup[1] — [1]3. Physikalisches Institut, Uni Stuttgart — [2]Atom Chip Group, TU Wien

We measure the Stark effect of a single Nitrogen vacancy center in diamond, and demonstrate its capability as a nanoscale electric field sensor. High sensitivity towards slowly oscillating electric fields is reached through coherent refocussing of the electron spin, following Hahn-echo and Carr-Purcell-Meiboom-Gill (CPMG) scheme. Experimental data of the Stark effect is confronted with current model Hamiltonians of the NV^- center. A highly local (nm scale) electric field measurement is enabled by using NV-doped diamond nano crystals, paving the way to in situ biological field sensing applications.

Q 32.4 We 14:45 E 214

Quantum non-demolition measurement of a single nuclear spin — •Johannes Beck[1], Philipp Neumann[1], Matthias Steiner[1], Florian Rempp[1], Helmut Rathgen[1], Philip Hemmer[2], Nawid Zarrabi[1], Fedor Jelezko[1], and Jörg Wrachtrup[1] — [1]3. Physikalisches Institut, Universität Stuttgart, Germany — [2]Department of Electrical and Computer Engineering, Texas A&M University, USA

Rapidly growing quantum technologies exploit the fundamental aspects of measurement in quantum mechanics. Here we experimentally demonstrate non-demolition projective measurement of a single nuclear spin associated with a nitrogen-vacancy (NV) center in diamond under ambient conditions. This enables the detection of quantum jumps and the quantum Zeno effect and will push spin-based measurement precision beyond the standard quantum limit.

Q 32.5 We 15:00 E 214

Fast and Robust Laser Cooling of Trapped Systems — •Javier Cerrillo Moreno — Inst. for Mathematical Sciences, Imperial College, London, UK — Quantum Optics and Laser Science group, Imperial College, London, UK — Inst. für Theoretische Physik, Universität Ulm, Germany

We present a robust and fast laser cooling scheme suitable for trapped ions, atoms or cantilevers. Based on quantum interference, generated by a special laser configuration, it is able to rapidly cool the system such that the final phonon occupation vanishes to zeroth order in the Lamb-Dicke parameter in contrast to existing cooling schemes. Furthermore, it is robust under conditions of fluctuating laser intensity and frequency, thus making it a viable candidate for experimental applications.

Q 32.6 We 15:15 E 214

Interfacing Ions and Photons at the Single Quantum Level — •Matthias Keller, Anders Mortensen, Alexander Wilson, Daniel Crick, Fedja Orucevic, Hiroki Takahashi, Nicolas Seymour-Smith, Elisabeth Brama, Andrew Riley-Watson, and Wolfgang Lange — University of Sussex, Brighton, BN1 9QH, United Kingdom

The complementary benefits of trapped ions and photons as carriers of quantum information make it appealing to combine them in a joint system. Cavity-QED provides a setting in which the quantum states of ions and photons can be interfaced efficiently. The most suitable scheme to use depends on the strength of the coherent ion-field coupling and the cavity damping rate. For moderate coupling, quantum entanglement may be generated probabilistically. Multiple ions are projected to an entangled state upon detecting photons emitted from the cavity. For stronger coupling, deterministic transfer of quantum states between ions and photons is possible, linking ionic qubit states with the two orthogonal polarization modes of the cavity. Entanglement of ions in a cavity may even be generated through the exchange of virtual photons. This requires the coupling to exceed considerably the cavity damping rate. We will report on progress in the realization of these schemes at the University of Sussex.

Q 32.7 We 15:30 E 214

Quantum Optics Experiments in a Segmented Microchip Ion Trap — •Ulrich Poschinger, Gerhard Huber, Andreas Walther, Max Hettrich, Markus Deiss, Frank Ziesel, Kilian Singer, and Ferdinand Schmidt-Kaler — Institut für Quanteninfarmationsverarbeitung, Universität Ulm, Albert-Einstein-Allee 11, 89069 Ulm

We present recent results from our experiment aiming at scalable quantum simulation and information. We first show how a qubit is implemented by using the Zeeman split groundstate levels of a $^{40}Ca^+$ ion. Emphasis is put on how the challenging conditions in our microtrap [1] compared to standard traps affect readout, ground state cooling and coherent manipulations [2]. We then present first experiments based on these techniques, including coherent manipulations on two-ion crystals, implementation of spin-dependent and spin-independent light forces, creation and characterization of Schrödinger cat states and quantum state tomography.

[1] S. Schulz et al., New Journal of Physics 10, 045007(2008)
[2] U. G. Poschinger et al., J. Phys. B 42, 154013 (2009)

Q 32.8 We 15:45 E 214

Effects of Ion-Trap RF-Potential on Atom-Ion Scattering Processes — •Björn Arnold[1], Tommaso Calarco[1], and Zbigniew Idziaszek[2] — [1]Institute for Quantum Information Processing, University of Ulm, D-89069 Ulm, Germany — [2]Institute for Theoretical Physics, University of Warsaw, 00-681 Warsaw, Poland

We investigate collisions of a single ion trapped in RF potential with a single atom trapped in a static trap. Within the one- and three-dimensional models we examine the effects of the time-dependent ion trap on the collision dynamics and on the average particle energies. We first perform our calculations employing an idealized model of atom-ion interaction provided through a delta potential, later we turn to a more realistic description involving long-range $1/r^4$ atom-ion interaction supplemented by the quantum-defect boundary conditions at short range. We introduce different description methods for the wavefunction and its time evolution by applying simple expansions in different ortho-normal bases and Floquet expansion.