Q 26: Quantum Information: Atoms and Ions 2

Time: Wednesday 10:30–13:00 Location: HÜL 386

Q 26.1 Wed 10:30 HÜL 386

Scalable architecture for quantum information processing with neutral atoms — •Malte Schlosser, Sascha Tichelmann, Jens Kruse, and Gerhard Birkl — Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt

Optical dipole potentials such as arrays of focused laser beams provide flexible geometries for the synchronous investigation of multiple atomic quantum systems, as studied e.g. in the fields of quantum degenerate gases, quantum information processing, and quantum simulation with neutral atoms.

In our work, we focus on the implementation of trapping geometries based on microfabricated optical elements. This approach allows us to develop flexible and integrable configurations for quantum state storage and manipulation, simultaneously targeting the important issues of single-site addressing and scalability.

We report on the investigation of ^{85}Rb atoms in two-dimensional arrays of individually addressable dipole traps featuring trap sizes and a tunable site-separation in the single micrometer regime. Advanced schemes for atom number resolved detection with high efficiency and reliability allow us to probe small ensembles and even single atoms stored in the microtrap array. For single atom preparation we utilize light assisted collisions to improve loading efficiencies while eliminating multi-atom events. Spatial light modulators and techniques for coherent quantum state transport complement our two-dimensional architecture of highly controllable atomic quantum systems.

Q 26.2 Wed 11:00 HÜL 386

Coherent Shaping of Photons using Electromagnetically Induced Transparency — •Andreas Neuzner, Eden Figueroa, and Gerhard Rempe — Max-Planck-Institute of Quantum Optics, Hans-Kopfermann-Str. 1, 85748 Garching

Over the last decade the effect of light-storage using electromagnetically induced transparency (EIT) has received extensive attention as a potential candidate for the realization of optical quantum memories. Towards this goal several milestones have been reached, for example, the storage and retrieval of single photons [1]. A key addition to these developments towards the implementation of future hybrid quantum networks is the full control over the temporal shape of the retrieved photon. We have set up an EIT-experiment based on a ^{87}Rb vapour cell, capable of storing weak classical pulses. In addition, a protocol to arbitrarily shape the envelope of the read-out light has been implemented [2]. We will also discuss the possibilities of this setup as a storage device for single photons generated from a cavity QED based source [3].

[1] M.D. Eisaman, et al., Nature 438, 837 (2005).
[2] I. Novikova, et al., Phys. Rev. Lett. 98, 243602 (2007).
[3] M. Hijlkema, et al., Nature Physics 3, 253 (2007).

Q 26.3 Wed 11:15 HÜL 386

Charge states of the nitrogen-vacancy center in diamond unraveled by single shot NMR — •Gerald Waldherr, Johannes Beck, Matthias Steiner, Philipp Neumann, Fedor Jelezko, and Jörg Wrachtrup — 3. Physikalisches Institut, Universität Stuttgart, 70550 Stuttgart, Deutschland

Nitrogen-vacany (NV) defects in diamond can be used for important applications such as quantum information processing at room temperature and magnetometry with atomic-scale resolution. The associated nitrogen nuclear spin is very robust even during laser illumination and ionization of the NV center and allows projective quantum nondemolition measurement of its state. Therefore, the nuclear spin can act as a probe for different electronic charge and spin states, due to their different hyperfine and quadrupole interactions. It turns out that under typical measurement conditions, the NV exists in two different charge states. Charge and spin state initialization can be achieved by optical pumping.

Q 26.4 Wed 11:30 HÜL 386

Heisenberg limited phase estimation of the electron spin of the the nitrogen-vacancy center in diamond — Ressa Said[1], Johannes Beck[2], Gerald Waldherr[2], •Philipp Neumann[2], Fedor Jelezko[2], Jason Twamley[1], and Jörg Wrachtrup[2] — [1]Macquarie University Sydney, Australia — [2]Universität Stuttgart

The exact determination of a quantum phase yields information about the corresponding Hamiltonian which is vital for quantum information processing or for metrology to name only two applications. Recently adaptive and non-adaptive quantum phase estimation sequencences have been introduced that scale like the Heisenberg limit and therefore beat the standard quantum limit. We show how these techniques can be implemented for quantum phase measurement of a single electron spin associated with the nitrogen-vacancy center in diamond. This system is a promising candidate for room temperature quantum information processing and magnetic field sensing with atomic resolution. Both applications greatly benefit from increased phase measurement speed.

Q 26.5 Wed 11:45 HÜL 386

Towards a single-atom quantum memory — •Christian Nölleke, Holger Specht, Andreas Reiserer, Manuel Uphoff, Eden Figueroa, Stephan Ritter, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching

The implementation of quantum networks composed of stationary nodes and photonic channels requires the development of quantum interconnects, featuring the coherent and reversible mapping of quantum information between light and matter. So far, these interfaces have largely been based upon the engineered exchange of information between photons and collective atomic excitations. A promising alternative is the development of an interface between a single quantum of light and a single particle of matter (e.g. single atoms). This approach has fundamental advantages as it allows for the individual manipulation of the atomic qubit and opens possibilities for in situ processing of stored qubits. We report on the current status of our experiment towards the most fundamental implementation of a quantum memory, based on a single neutral atom trapped inside a high-finesse optical cavity. This experiment is a major step in the development of a universal node of a quantum network, capable of fully controlled photon generation, qubit storage and with intriguing perspectives towards the development of quantum gates.

Q 26.6 Wed 12:00 HÜL 386

Kernspins kalter Ionen als Quantenregister — •Michael Johanning[1], Kunling Wang[2], Mang Feng[2] und Christof Wunderlich[1] — [1]Fachbereich Physik, Universität Siegen, 57068 Siegen — [2]State Key Laboratory of Magnetic Resonance and Atomic and Molecular Physics, Wuhan Institute of Physics and Mathematics, Chinese Academy of Sciences, Wuhan 430071, China

Wir schlagen einen neuen Implementierungsansatz zur Quanteninformationsverarbeitung vor, bei dem Qubits in Kern- und Elektronenspins einer kalten gespeicherten Ionenkette kodiert sind. Im Paschen-Back-Regime lassen sich in der Hochfeldnäherung die Kernspins gut vom dephasierenden Einfluss der Umgebung abschirmen und erlauben so lange Kohärenzzeiten, während man über die Manipulation der Elektronenspins eine hohe Güte bei Gatteroperationen und bei der Zustandsbestimmung erhält. Wir diskutieren effiziente Gatter und realistisch erreichbare Kopplungskonstanten, Gatterzeiten und -güten und stellen mögliche experimentelle Umsetzungen zur Erzeugung der nötigen hohen Magnetfelder und Gradienten vor.

Q 26.7 Wed 12:15 HÜL 386

Quantum computing with magnetic field insensitive dressed states — •I. Baumgart[1], N. Timoney[1], A. Retzker[2], A.F. Varón[1], M. Johanning[1], M. Plenio[2], and C. Wunderlich[1] — [1]Fachbereich Physik, Universität Siegen, 57068 Siegen — [2]Institute of Theoretical Physics, Universität Ulm, 89069 Ulm

Ion trap quantum computing or quantum simulations with easy to control and stable microwave sources instead of complex laser systems, require the use of Zeeman sub levels. Here, dephasing between magnetic field sensitive states, due to ambient magnetic field noise, shortens the coherence. By dressing magnetic field sensitive states with microwave fields we demonstrate theoretically and experimentally that the dressed states are long-lived and that fast universal quantum logic is possible with this approach. Experimentally we achieved, depending on the particular dressed state, an extension in coherence times between a factor of 4 and two orders of magnitude compare to bare states.

Using rf coupling, a dressed state and a magnetic field insensitive bare state can be used as a qubit. Multi-qubit gates can be very fast, since the carrier transition cancels by interference when tuning to a motional sideband. The advantage over the regular quantum computing scheme is that fast gates are possible even when the Lamb Dicke parameter is small.

Q 26.8 Wed 12:30 HÜL 386

Pulsed coherent Rydberg excitation in a thermal gas of Rb — •Bernhard Huber, Thomas Baluktsian, Andreas Kölle, Harald Kübler, Michael Schlagmüller, Renate Daschner, Alban Urvoy, Robert Löw, and Tilman Pfau — 5. Physikalisches Institut, Universität Stuttgart

The Rydberg blockade effect is a promising candidate for the realization of quantum devices. For this, fully coherent dynamics in the atom-light-system is required. Our approach utilizes thermal atomic vapor in a small glass cell which offers multiple advantages in terms of scalability and ease of use compared to ultracold atomic systems. However, the limited coherence time of a thermal gas requires excitation on the nanosecond timescale, corresponding to Rabi frequencies of up to 1 GHz.

In our setup a two-photon-excitation is used to address the Rydberg level via an intermediate state. In order to produce fast enough dynamics between the ground and Rydberg state the upper transition is driven by a bandwidth-limited pulsed laser amplifier.

We present time-resolved measurements of Rabi oscillations involving a Rydberg state in a thermal gas of Rb. This implies the feasibility of coherent control of thermal atomic systems including Rydberg levels.

Q 26.9 Wed 12:45 HÜL 386

Optimal Controlled Phasegates for Trapped Neutral Atoms at the Quantum Speed Limit — •Michael Goerz[1], Tommaso Calarco[2], and Christiane P. Koch[1,3] — [1]Institut für Theoretische Physik, Freie Universität Berlin, Germany — [2]Institut für Quanteninformationsverarbeitung, Universität Ulm, Germany — [3]Institut für Physik, Universität Kassel, Germany

We study controlled phasegates for ultracold atoms in an optical lattice. A shaped laser pulse drives transitions between the ground and electronically excited states where the atoms are subject to a long-range $1/R^3$ interaction. We fully account for this interaction and use optimal control theory to calculate the pulses. This allows us to determine the minimum pulse duration, respectively, gate time T that is required to obtain high fidelity. We find the gate time to be limited either by the interaction strength in the excited state or by the ground state vibrational motion in the trap. The latter needs to be resolved in order to fully restore the motional state of the atoms at the end of the gate.