Q 28: Quantum information: Atoms and ions IV

Time: Tuesday 14:00–15:45 Location: UDL HS3038

Q 28.1 Tue 14:00 UDL HS3038

Rydberg spectroscopy using optical and electrical read out in thermal vapor cells — •Renate Daschner, Daniel Barredo, Robert Löw, Harald Kübler, and Tilman Pfau — 5. Physikalisches Institut, Universität Stuttgart, Germany

Rydberg atoms in a thermal vapor are discussed as promising candidates for the realisation of quantum devices such as single photon sources or single photon subtractors. We present a very sensitive and scalable method to measure the population of highly excited Rydberg states in a thermal vapor cell of rubidium atoms. For this application a cell with structured electrodes and a sealing method based on anodic bonding was invented. The large DC Stark shift of Rydberg atoms provides a possibility to induce transmission or absorption in the medium. Rydberg spectroscopy can be done either by measuring the optical transmission [1] or the Rydberg ionization current [2]. This technique is compatible with state of the art fabrication methods of thin film electronics offering both scalability and miniaturization. Future prospects are arrays of individually addressable sites with integrated electronics e.g. for signal amplification. Modern materials like graphene or doped diamond can improve the properties of the electrodes e.g. transmission and conductivity.

[1] Daschner, R., et al., "Fabrication and characterization of an electrically contacted vapor cell", *Opt. Lett.* **37**, 2271 (2012)

[2] Barredo, D.,et al., "Electrical read out for coherent phenomena involving Rydberg atoms in thermal vapor cells" *Phys. Rev. Lett.* **110**, 123002 (2013)

Q 28.2 Tue 14:15 UDL HS3038

Interacting Rydberg atoms in arrays of optical tweezers — •Henning Labuhn, Sylvain Ravets, Lucas Béguin, Florence Nogrette, Daniel Barredo, Thierry Lahaye, and Antoine Browaeys — Institut d'Optique, Palaiseau, France

Controlling single neutral atoms in arrays of optical tweezers is a promising avenue for quantum science and technology [1,2]. Using a spatial light modulator (SLM), we demonstrate our ability to create traps separated by a few microns in controllable 2D geometries. We work in a regime where each trap contains only either zero or one atom. Using a two-photon excitation scheme, we coherently excite systems of two or three atoms into Rydberg states. The strong interaction between Rydberg atoms results in the observation of the characteristic Rydberg blockade effect. When the Rydberg excitation linewidth becomes comparable to the interaction, we observe a partial Rydberg blockade, where the populations in the excited states vary in time with different frequency components. Comparing the experimental measurements with a model based on the optical Bloch equations, we can determine the dipole-dipole interaction energy between the atoms [3]. We measure the evolution of the C_6 coefficient of the van der Waals interaction for different quantum numbers, as a function of the distance and the angle between the atoms.

[1] E. Urban et al., Nat. Phys. **5**, 110-114 (2009)

[2] A. Gaëtan et al., Nat. Phys. **5**, 115-118 (2009)

[3] L. Béguin et al., Phys. Rev. Lett. **110**, 263201 (2013)

Q 28.3 Tue 14:30 UDL HS3038

Effect of interparticle interaction in a free-oscillation atomic interferometer — •Thomás Fogarty[1,2], Anthony Kiely[1], Steve Campbell[1,2], and Thomas Busch[1,2] — [1]Physics Department, University College Cork, Cork, Ireland — [2]Quantum Systems Unit, Okinawa Institute of Science and Technology Graduate University, Okinawa, Japan

We investigate the dynamics of two interacting bosons repeatedly scattering off a beam-splitter in a free oscillation atom interferometer. Using the interparticle scattering length and the beam-splitter probabilites as our control parameters, we show that even in a simple setup like this a wide range of strongly correlated quantum states can be created. To quantify the usefullness of the states which are created we calculate the quantum Fisher information and we also explore the reduced state of the gas. We also show that we can dynamically create a strongly correlated state known as the NOON state, which maximizes the quantum Fisher information and is a foremost state in quantum metrology.

Q 28.4 Tue 14:45 UDL HS3038

A reversible quantum memory for OAM qubits — •Dominik Maxein, Adrien Nicolas, Lucile Veissier, Lambert Giner, Elisabeth Giacobino, and Julien Laurat — Laboratoire Kastler Brossel, Université Pierre et Marie Curie, École Normale Supérieure, and CNRS, 4 place Jussieu, 75252 Paris Cedex 05, France

Quantum communication and information processing with orbital angular momentum states of light (OAM states) promises a capacity increase by employing high-dimensional information encoding [G. Molina-Terriza et al., Nature Phys. **3**, 305 (2007)]. We report on the first implementation and characterization of a quantum memory for quantum bits encoded in this optical degree of freedom. This is an important step towards future quantum networks [H.J. Kimble, Nature **453**, 1023 (2008)] exploiting the potential of OAM of photons for quantum information applications.

Specifically, we prepare weak light pulses in Laguerre-Gaussian modes with $p = 0$ and $l = \pm 1$ and superpositions thereof. They are stored in an ensemble of cold Cs atoms using dynamical electromagnetically induced transparency. A complete tomography of the states retrieved from the memory is performed using a setup of forked holograms, an interferometer and single-photon counters, yielding fidelities above 90%. Comparing the obtained fidelities with the classically possible limit [H.P. Specht et al., Nature **473**, 190 (2011)] for a varying mean photon number per pulse (between 0.3 and 50), we show that our system is indeed a quantum memory for OAM encoded qubits [A. Nicolas et al., Nature Photon. (accepted), arXiv 1308.0238 (2013)].

Q 28.5 Tue 15:00 UDL HS3038

Demonstration of a single photon optical Kerr nonlinearity — •Jürgen Volz, Michael Scheucher, Christian Junge, and Arno Rauschenbeutel — Vienna Center for Quantum Science and Technology, TU Wien – Atominstitut, Vienna, Austria

The possibility to generate a controlled interaction between individual photons is one of the the key ingredients of future photon-based quantum applications. Since photons do not interact directly, this interaction can be facilitated by a medium with a high optical nonlinearity. Here we demonstrate the experimental realization of such an optical Kerr nonlinearity on the single photon level. Our system is based on a bottle-microresonator [1] – a novel type of whispering-gallery-mode resonator – interfaced by an optical nanofiber. The presence of a single ^{85}Rb-atom in the evanescent field of the resonator [2] in the overcoupled regime results in a strong nonlinear response of the resonator to the photon number in the incident light field. As a consequence, this imprints a photon number dependent phase shift on the light passing the resonator. Analyzing the transmitted light, we observe a phase shift close to the maximum value of π between the case where one or two photons pass the resonator. This nonlinear phase shift results in large entanglement between the two previously independent fiber guided photons, which we verify by performing a full quantum state tomography of the transmitted two-photon state.

[1] Pöllinger et al., PRL 103, 053901 (2009)

[2] Junge et al., PRL 110, 213604 (2013)

Q 28.6 Tue 15:15 UDL HS3038

Observation of the quantum speed-limit: light-cone-like spreading of quantum correlations and beyond — •Petar Jurcevic[1,2], Ben P. Lanyon[1,2], Cornelius Hempel[1,2], Philipp Hauke[1], Rainer Blatt[1,2], and Christian F. Roos[1,2] — [1]IQOQI, Technikerstrasse 21a, 6020 Innsbruck, Austria — [2]Uni Innsbruck, Technikerstrasse 25, 6020 Innsbruck, Austria

In many-body quantum systems with finite range interactions, the maximum speed at which quantum correlations can propagate in such systems is bounded by the maximal group velocity. This bounded maximal speed predicts a light-cone for quantum correlations spread in space-time. Using a linear chain of trapped ionic qubits, we are able to implement a laser-driven Ising-type Hamiltionian with tunable interaction ranges. Quenching the system locally, we observe for the first time a light-cone like ejection of entangled quasi-particles for short range interaction, where we also proof the entanglement by measuring the tangle between pairs. Furthermore, going to long range interactions we are able to enter regimes where the light-cone like picture starts break down.

Q 28.7 Tue 15:30 UDL HS3038

Optimal control for quantum simulations — •Lukasz Rudnicki[1,2], Albert Verdeny[1], Cord Muller[4,5], and Florian Mintert[1,3] — [1]Freiburg Institute for Advanced Studies, Albert-Ludwigs University of Freiburg, Albertstrasse 19, 79104 Freiburg, Germany — [2]Center for Theoretical Physics, Polish Academy of Sciences, Aleja Lotników 32/46, PL-02-668 Warsaw, Poland — [3]Department of Physics, Imperial College London, London SW7 2AZ, United Kingdom — [4]Department of Physics, University of Konstanz, 78457 Konstanz, Germany — [5]Centre for Quantum Technologies, National University of Singapore, Singapore 117543, Singapore

We present schemes for the optimization of quantum simulations, which rely on pulse shaping techniques. They apply to exact unitary evolution as well as driving-induced effective dynamics. For polychromatic driving we provide analytic solutions which significantly improve the simulation of Raman transitions in the Lambda system and bring a promising perspective for optimal implementations of multiport devices.