Q 20: Quantum Optics III

Time: Tuesday 11:00–13:00 Location: f442

Q 20.1 Tue 11:00 f442

Towards Rydberg polariton dynamics with cold atoms in quasi 1D geometries — •Mohammad Noaman, Maria Langbecker, and Patrick Windpassinger — QUANTUM, Institut für Physik, Johannes Gutenberg-Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany

Cold atoms inside hollow-core fibers present a promising candidate to study strongly coupled light-matter systems. Combined with the long range Rydberg interaction which is controlled through an EIT process, a corresponding experimental setup should allow for the generation of a strong and tunable polariton interaction. Due to dipole blockade, polaritons are restricted to a quasi one dimensional structure. Using this scheme, novel photonic states, eg. crystallization of photons, can be observed with possible applications in quantum information and simulation. This talk will review the current status of our experimental setup where laser cooled Rubidium atoms are transported into a hollow-core fiber. We present the first measurements of Rydberg EIT of the optical molasses in front of the fiber and discuss the progress towards Rydberg physics in a quasi-one-dimensional geometry.

Q 20.2 Tue 11:15 f442

Storage of fiber-guided light in a nanofiber-trapped ensemble of cold atoms — •Bernhard Albrecht, Christoph Clausen, Clément Sayrin, Philipp Schneeweiss, and Arno Rauschenbeutel — VCQ, Atominstitut, TU Wien, Stadionallee 2, 1020 Wien, Austria

The storage of a classical optical pulse is an important capability for the realization of all-optical signal processing schemes. Simple optical buffers can be extended to work as optical quantum memories, in which quantum states of light can be stored and retrieved. They are crucial elements of a global quantum optical network. The storage of light has been achieved with several systems. However, the realization of efficient, long-lived fiber-integrated optical memories is still subject to active research.
Here, we report on the progress of a novel implementation of an integrated optical quantum memory. We use an optical-nanofiber-based experimental platform for trapping and optically interfacing laser-cooled cesium atoms. Using the effect of electromagnetically induced transparency we are able to slow down fiber-guided light pulses to only 50 m/s [1]. We also experimentally show the storage and retrieval of fiber-guided light pulses on the single-photon level. We achieve a good overall efficiency and a largely improved characteristic memory lifetime compared to previously demonstrated fiber-integrated optical memories. Our results are an important step towards fully fiber-based quantum networks.

[1] C. Sayrin *et al.*, Optica **2**, 353-356 (2015).

Q 20.3 Tue 11:30 f442

Anregung atomarer Übergänge mit einem Vortex Laserstrahl[1] — •Jonas Schulz, Christian Tomás Schmiegelow, Henning Kaufmann, Thomas Ruster, Ulrich Poschinger und Ferdinand Schmidt-Kaler — QUANTUM, Institut für Physik, Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany

Aufgrund ihres internen Spins tragen Photonen Drehimpuls, der abhängig von der Lichtpolarisation die Werte $\pm 1\hbar$ annehmen kann. Vortex-Strahlen besitzen zusätzlichen externen Bahndrehimpuls. Wir demonstrieren den Transfer von optischem Bahndrehimpuls (OAM) aus dem Vortex-Strahl auf interne, elektronische Freiheitsgrade eines Atoms. Wir platzieren dafür ein einzelnes $^{40}Ca^+$ Ion im Zentrum eines Vortex-Strahls und treiben den $S_{1/2} \leftrightarrow D_{5/2}$ Quadrupolübergang. Abhängig von der Polarisation des Lichtes ($\sigma^\pm$) und der Vortizität des Strahls (OAM=0, ±1) erhalten wir modifizierte Auswahlregeln für die Übergänge zwischen Zeeman Niveaus mit Δm=0,$\pm$1 und $\pm$2 was zeigt, dass Spin- und Bahndrehimpuls der Photonen zu einem effektiven Gesamtdrehimpuls mit den Werten $0\hbar$, $\pm 1\hbar$ und $\pm 2\hbar$ gekoppelt werden.

[1] Christian T. Schmiegelow et al., arXiv:1511.07206 (2015)

Q 20.4 Tue 11:45 f442

Phase shifting a weak coherent beam by a single ^{174}Yb$^+$ ion — •Martin Fischer[1,2], Lucas Alber[1,2], Bharath Srivathsan[1,2], Markus Weber[1,2], Markus Sondermann[1,2], and Gerd Leuchs[1,2,3] — [1]Max Planck Institute for the Science of Light, Erlangen, Germany — [2]Friedrich-Alexander University Erlangen-N ürnberg (FAU), Department of Physics, Erlangen, Germany — [3]Department of Physics, University of Ottawa, Canada

We report on the phase shift induced on a weak coherent beam of light acting on the π-transition of a single $^{174}Yb^+$ ion. The π-transition is driven by focusing a radially-polarized donut-mode with a deep parabolic mirror, covering 94% of the relevant solid angle, onto the ion. The phase shift is measured in a heterodyne configuration with a local oscillator detuned by twenty linewidths from the investigated atomic transition. Measurements with a still imperfectly corrected parabolic mirror show phase shifts of 3°, as expected for the coupling efficiency determined through saturation measurements.

The measured phase shift deviates significantly from the predicted phase shift of a two-level system [1]. We discuss the influence of coupling to a J = 1/2 to J = 1/2 transition instead of coupling to a two-level system and estimate the residual aberrations limiting the observable phase shift. Prospects of using $^{174}Yb^{2+}$ as a target for the dispersive interaction are discussed.

[1] M. Sondermann *et al.*, J. Europ. Opt. Soc. Rap. Public. **8**, 13052 (2013)

Q 20.5 Tue 12:00 f442

Towards a quantum simulator using engineered spin arrays in diamond — •Nikolas Tomek[1], Thomas Unden[1], Timo Weggler[1], Florian Frank[1], Alexandre Le Boité[2], Jianming Cai[3], Paz London[4], Alex Retzker[5], Kohei Itoh[6], Martin Bodo Plenio[2], Boris Naydenov[1], and Fedor Jelezko[1] — [1]Institute for Quantum Optics, 89081 Ulm University, Ulm, Germany — [2]Institute for Theoretical Physics, Ulm University, 89081 Ulm, Germany — [3]School of Physics, Huazhong University of Science and Technology, Wuhan 430074, China — [4]Department of Physics, Technion, Israel Institute of Technology, Haifa 32000, Israel — [5]Racah Institute of Physics, The Hebrew University of Jerusalem, Jerusalem 91904, Israel — [6]Department of Applied Physics and Physico-Informatics, Keio University, Hiyoshi, Yokohama, Japan

Numerical simulations of strongly correlated quantum many-body systems are becoming intractable for as few as <100 particles. This gave rise to the idea of quantum simulation to gain access to nonequilibrium mechanics of large systems. As solid state system for our quantum simulator experiments we use a dense layer of C13 nuclear spins inside an otherwise C12-enriched bulk diamond. Initialization, control and read-out of this spin array is accomplished with nitrogen-vacancy (NV) centers implanted in the diamond. The system stands out due to exceptional long coherence times even at room temperature. Using nuclear magnetic resonance techniques we can control the dipole-dipole interaction between the nuclear spins in the 2D ensemble. This will allow us to simulate a wide variety of strongly correlated spin models.

Q 20.6 Tue 12:15 f442

The Resonant Fluorescence of Nitrogen-Vacancy Centers — •Thai Hien Tran[1], Petr Siyushev[2], Jörg Wrachtrup[1], and Ilja Gerhardt[1,3] — [1]3. Physikalisches Institut, Universität Stuttgart — [2]Institut für Quantenoptik, Universität Ulm — [3]Max-Planck-Institut für Festkörperforschung, Stuttgart

The interaction between photons and single quantum systems is a key question and necessity for quantum information processing in means of reading, writing, and storing information. In our study we investigate the efficient optical interaction between a laser beam and a negative charged nitrogen-vacancy (NV^-) center in diamond – a promising solid state spin qubit. We are able to observe the interference and the relative phase shift between the exciting laser and the coherently emitted photons. This allows us to distinguish the coherently and the incoherently scattered photons within the narrow zero phonon line.

Q 20.7 Tue 12:30 f442

Single Molecule NMR using NV centers — •Matthias Kost[1,2], Jianming Cai[1,2,3], and Martin B. Plenio[1,2] — [1]Institut für Theoretische Physik, Albert-Einstein Allee 11, Universität Ulm, 89069 Ulm, Germany — [2]Center for Integrated Quantum Science and Technology, Universität Ulm, 89069 Ulm, Germany — [3]School of Physics, Huazhong University of Science and Technology, Wuhan 430074, China

Nuclear magnetic resonance spectroscopy (NMR) allows for the structure determination of molecules and proteins and therefore contributes fundamentally to the advancement of the biological sciences. The recent progress in the control of a single electron spin in Nitrogen-vacancy (NV) centers in diamond offers a new perspective here as it becomes possible to use optically detected magnetic resonance to read out the effect of smallest magnetic fields.

This talk presents, how to utilize the sensitivity of shallow NV centers to perform NMR-like protocols at a single molecule level, which yields information on e.g. coupling strength and spatial structure of the target molecule. Theoretical simulations demonstrate application of the protocol addressing small amino acid.

Q 20.8 Tue 12:45 f442

Robust dynamical decoupling sequences for individual-nuclear-spin addressing — Jorge Casanova, Zhenyu Wang, •Jan Haase, and Martin Plenio — Institut für Theoretische Physik and IQST, Albert-Einstein-Allee 11, Universität Ulm, D-89069 Ulm, Germany

We propose the use of non-equally-spaced decoupling pulses for high-resolution selective addressing of nuclear spins by a quantum sensor. The analytical model of the basic operating principle is supplemented by detailed numerical studies that demonstrate the high degree of selectivity and the robustness against static and dynamic control-field errors of this scheme. We exemplify our protocol with a nitrogen-vacancy-center-based sensor to demonstrate that it enables the identification of individual nuclear spins that form part of a large spin ensemble.