Q 70: Quantum Optics

Time: Friday 14:30–16:15 Location: HS 3118

Q 70.1 Fri 14:30 HS 3118

Bose-Einstein Condensation of Photons in a Four-Site Quantum Ring — •Andreas Redmann, Christian Kurtscheid, Niels Wolf, Frank Vewinger, Julian Schmitt, and Martin Weitz — Institut für Angewandte Physik, Universität Bonn, Germany

Bose-Einstein condensation can be observed with e.g. ultracold atomic gases, polaritons and since about a decade ago also with low-dimensional photon gases [1]. In recent work with photon gases direct condensation into a coherently split state of light has been realized [2]. Here we report on experimental work directed at realizing thermalized photon gases in periodic potentials of increased complexity, i.e. beyond a double well.

Our experiments use a controlled mirror surface delamination technique to imprint four micro-wells arranged in a ring giving rise to a hybridized ground state for the photon gas [3]. This ring of micro-wells is enclosed by a spherically curved potential providing a manifold of harmonically spaced oscillator levels.

We observe macroscopic accumulation of photons in the ground state when reaching the condensation threshold and the measured spectral photon distribution closely follows a room temperature Bose-Einstein distribution. Using an optical interferometer we probe for the relative phase relation of the emission of the microsites, revealing the relative coherence between the four wells.

[1] J. Klaers et al., Nature 468, 545-548 (2010)
[2] C. Kurtscheid et al., Science 366, 894-897 (2019)
[3] C. Kurtscheid et al., EPL 130, 54001 (2020)

Q 70.2 Fri 14:45 HS 3118

Degenerate Cavity for Dispersive Imaging of Ultracold Atoms — •Oliver Lueghamer[1], Thomas Juffmann[2,3], and Maximilian Prüfer[1] — [1]Vienna Center for Quantum Science and Technology, Atominstitut, TU Wien — [2]University of Vienna, Faculty of Physics, VCQ — [3]University of Vienna, Max Perutz Laboratories, Department of Structural and Computational Biology

Dispersive imaging is routinely used in cold atom experiments. However the quantum limited operation is still a challenge. We present an approach using a degenerate cavity, which allows the probe beam to pass the sample multiple times. Degenerate cavities were already used in quantum microscopy to surpass the shot noise limit without the use of delicate quantum states. For this mostly biological investigations, a pulsed laser operation was employed. Only recently continuous wave applications were implemented experimentally.

We develop and test such a degenerate cavity setup for the potential use in a consisting atom chip experiment. We are able to show a signal to noise ratio (SNR) enhancement for large biological samples (e.g. epithelial cells of a human cheek). We investigate the possibility of quickly driving the input mirror over the free spectral range to have enhancement without stabilizing the cavity. We conclude by giving an outlook on the possibility to use this technique for ultracold atom experiments.

Q 70.3 Fri 15:00 HS 3118

Rb-Xe Magnetometer - Quantum Memory Based on Rare Gases — •Denis Uhland[1], Luisa Esguerra[2,4], Norman Vincenz Ewald[2,3], Tianhao Liu[3], Wolfgang Kilian[3], Jens Voigt[3], Janik Wolters[2,4], and Ilja Gerhardt[1] — [1]Leibniz University Hannover, Institute of Solid State Physics, Light and Matter Group, Hannover — [2]German Aerospace Center (DLR), Institute of Optical Sensor Systems, Berlin — [3]Physikalisch-Technische Bundesanstalt, FB 8.2 Biosignale, Berlin — [4]Technische Universität Berlin, Institut für Optik und Atomare Physik, Berlin

Optical quantum memories allow for the storage and retrieval of quantum information. A common approach to establish such memories is to map the photonic state onto optically accessible matter states. Even longer storage can be realized with rare gases, but unfortunately, they lack convenient optical access, which seemingly can be overcome [1]. Due to spin-exchange collisions arising from a polarized ensemble of alkali atoms, it is possible to transfer photonic states onto optical inaccessible spin states of the nucleus of rare gases. That results in an increase of the memory time from milliseconds seen in alkali vapors to several minutes or even hours [2]. A recent achievement uses ^{133}Cs as an optical interface for photons stored in collective spin excitation via EIT [3]. Here, we present our first steps toward quantum memories based on an Rb-^{129}Xe mixture in a magnetically shielded environment.

[1] O. Katz et al., Phys. Rev. A (2022) 105, 042606
[2] C. Gemmel et al., Eur. Phys. J. D (2010) 57, 303
[3] L. Esguerra et al., Phys. Rev. A (2023) 107, 042607

Q 70.4 Fri 15:15 HS 3118

Proposal for an experimental demonstration of unforgeable quantum tokens in a room-temperature atomic memory — •Luisa Esguerra[1,2], Elizabeth Robertson[1,2], Helen Chrzanowski[1], Inna Kviatkovski[3,1], Leon Messner[1], Norman Vincenz Ewald[1,4], Mathieu Bozzio[5], and Janik Wolters[1,2] — [1]German Aerospace Center (DLR), Institute of Optical Sensor Systems, Berlin — [2]TU Berlin, Institut für Optik und Atomare Physik — [3]TU Berlin, Institut für Luft und Raumfahrt — [4]Physikalisch-Technische Bundesanstalt, FB 8.2 Biosignale, Berlin — [5]University of Vienna, Faculty of Physics, Vienna Center for Quantum Science and Technology (VCQ)

Alkali vapor cell quantum memories offer a simple platform for a plethora of applications in quantum information technologies. In this context, the efficient and low-noise storage of quantum tokens for authentication purposes remains an outstanding challenge. Inspired by a proposal for quantum money [1,2], we develop a quantum-token protocol based on a time-bin encoding, and use the memory system presented in [3] as a test platform for secure storage of the quantum token. This constitutes an important first step towards the realisation of authentification tokens secured by quantum mechanics.

[1] M. Bozzio et al., npj Quantum Inf 4, 5 (2018).
[2] M. Bozzio et al., Phys. Rev. A 99, 022336 (2019).
[3] L. Esguerra et al., Phys. Rev. A 107, 042607 (2023).

Q 70.5 Fri 15:30 HS 3118

Analytic Expressions of a closed-loop excitation scheme for phase-sensitive RF E-field sensing using Rydberg atom-based sensors — •Matthias Schmidt[1,2], Stephanie Bohaichuk[1], Vijin Venu[1], Florian Christaller[1], Chang Liu[1], Harald Kübler[1,2], and James P. Shaffer[1] — [1]Quantum Valley Ideas Laboratories, 485 Wes Graham Way, Waterloo, ON N2L 0A7, Canada — [2]5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

In this talk, we present theoretical work aimed at understanding radio frequency phase measurement using all-optical, atom-based electric field sensors. Atom-based radio frequency field sensors have a number of applications in communications, radar and test measurements. All of these applications benefit from being able to detect phase, which remains illusive for Rydberg atom-based sensors in the steady-state. To obtain an analytic expression for phase detection, we investigate closed-loop excitations in cesium that preserve phase information in a probe laser signal transmission coupled to one transition of the loop. Insight into the mechanisms that enable phase determination is gained by analyzing the close-loop processes. We find the highest sensitivity region by looking at the absorption contrast. The sensitivity maximizes when the atomic vapor is weakly probed. By applying the weak probe approximation to the Lindblad-master equation, we find an analytic expression for the absorption coefficient. With this expression, we gain a deeper understanding of the multi-photon interference and how this applies to phase readout in atom-based radio frequency sensors.

Q 70.6 Fri 15:45 HS 3118

Chiral Orbital States with Rydberg Atoms — •Stefan Aull[1], Steffen Giesen[2], Peter Zahariev[1,3], Robert Berger[2], and Kilian Singer[1] — [1]Experimentalphysik 1, Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany — [2]Fachbereich Chemie, Philipps-Universität Marburg, Hans-Meerwein-Str. 4. 35032 Marburg — [3]Institute of Solid State Physics, Bulgarian Academy of Sciences, 72, Tzarigradsko Chaussee, 1784 Sofia, Bulgaria

A protocol for the preparation of chiral orbital Rydberg states in atoms is presented. It has been shown theoretically that using a suitable superposition of hydrogen wave functions, it is possible to construct an electron density and probability current distribution that has chiral nature [1]. Circular Rydberg states can be generated and subsequently manipulated with tailored RF pulses under the influence of electric and magnetic fields, so that the desired chiral superposition of hydrogen-like states with corresponding phases can be prepared. A method to produce such Rydberg states is outlined and their properties including time evolution are discussed. Necessary conditions for quantum numbers of superposition states have been derived analytically. The results are aimed to be used for chiral discrimination [2] of molecules.

[1] A. F. Ordonez and O. Smirnova, Propensity rules in photoelectron circular dichroism in chiral molecules. I. Chiral hydrogen, Phys. Rev. A, vol. 99, no. 4, p. 43416 (2019)

[2] S. Y. Buhmann et al., Quantum sensing protocol for motionally chiral Rydberg atoms, New Journal of Physics, vol. 23, no. 8, Art. no. 8, (2021)

Q 70.7 Fri 16:00 HS 3118

Chiral sensing with nanophotonics — •Diana Shakirova, Adrià Canós Valero, and Thomas Weiss — Institute of Physics, University of Graz, Universitaetsplatz 5, 8010 Graz, Austria

Chirality is a geometrical property whereby the mirror image of an object does not coincide with the object itself. The handedness (left or right orientation in space) of chiral molecules can define its action on living organisms, making chiral sensing a crucial task in biology, chemistry and medicine. The difference in transmission (DT) between left- and right-handed circularly polarized incident light is used as a sensing measure, but this signal is extremely small. Nanophotonics provides a great potential for enhancing DT using resonances maintained by nanostructures in optical frequency range. In the work we discuss a theory of chiral light-matter interaction, general approaches to enhance DT,and present particular nanostructures for chiral sensing that support high-Q modes.