Q 10: Quantum Optics and Nuclear Quantum Optics I

Time: Monday 17:00–19:00 Location: AP-HS

Invited Talk Q 10.1 Mon 17:00 AP-HS

Nuclear quantum memory for hard x-ray photon wave packets — •Sven Velten[1,2], Lars Bocklage[1,2], Xiwen Zhang[3], Kai Schlage[1], Anjali Panchwanee[1], Sakshath Sadashivaiah[4,5], Ilya Sergeev[1], Olaf Leupold[1], Aleksandr I. Chumakov[6], Olga Kocharovskaya[3], and Ralf Röhlsberger[1,2,5,4,7] — [1]Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging CUI, Hamburg, Germany — [3]Department of Physics and Astronomy and Institute for Quantum Science and Engineering, Texas A&M University, College Station, USA — [4]Helmholtz-Institut Jena, Jena, Germany — [5]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany — [6]ESRF -The European Synchrotron, Grenoble, France — [7]Friedrich-Schiller Universität Jena, Institut für Optik und Quantenelektronik, Jena, Germany

Quantum optics concepts rarely extend to hard X-ray radiation due to the high field strengths needed for coherent control. However, nuclear transitions, notably the 14.41 keV transition of ^{57}Fe, enabled establishing hard X-ray quantum optics due to their ultranarrow linewidths, their high number densities found in solids, and relatively large resonant cross-sections. Aiming to extend this field to quantum information processing, we demonstrated a nuclear quantum memory. By moving multiple resonant absorbers, a Doppler frequency comb is formed capable of storing X-ray photon wave packets on the single-photon level. Conceptually analogous to atomic frequency combs, it constitutes a robust, highly flexible platform for X-ray quantum memories.

Q 10.2 Mon 17:30 AP-HS

Two-photon excitation spectroscopy of high pressure xenon-noble gas mixtures — •Eric Boltersdorf, Thilo vom Hövel, Frank Vewinger und Martin Weitz — Institut für Angewandte Physik, Bonn, Deutschland

Photons confined in a dye-filled optical microcavity can exhibit Bose-Einstein condensation upon thermalization through repeated absorption and (re-)emission processes on the dye molecules. This has been experimentally demonstrated for photons in the visible spectral regime in 2010. In the present work, an experimental approach is investigated to realize Bose-Einstein condensation of vacuum-ultraviolet (100nm-200nm; VUV) photons via repeated absorption and (re-)emission cycles between the $5p^6$ ground state and the $5p^5 6s$ ($J = 1$) excited state of xenon-noble gas excimer molecules in dense gaseous ensembles (pressure of up to 100 bar). The optical pumping via two-photon excitation from xenon's $5p^6$ electronic ground-state to higher lying states, e.g. the $5p^5 6p$ and $5p^5 6p'$ states, is investigated. We report on the measurement of excitation spectra with excitations wavelengths ranging from 220 nm to 260 nm. The emission is collected between 145nm and 180nm, which stems from the decay of the $5p^5 6s$ ($J = 1$) state that was proposedly populated by collisional deactivation from the higher lying excited states. Data will be shown for xenon-helium mixtures as well as for xenon-krypton mixtures, showing strong dependency on pressure and the atomic species.

Q 10.3 Mon 17:45 AP-HS

Quantum optical effects in three-layer thin-film x-ray cavities — •Julien Spitzlay, Fabian Richter, and Adriana Pálffy — Julius-Maximilians-Universität Würzburg

Thin-film cavities with several embedded layers of Mössbauer nuclei are an intriguing platform for the realization of quantum optical effects in the x-ray regime. Many theoretical models have been developed in the past decade to describe the resonant x-ray scattering in these nanostructures, for instance an ab-initio formalism based on the electromagnetic Green's function [1,2].

In this work, we investigate parallels between this numerically efficient description and well-known cavity QED models, which provide a better physical interpretation. Applied to a three-layer x-ray cavity, we are interested in the occurrence of electromagnetically induced transparency (EIT) and Autler-Townes-Splitting (ATS). The aim is to identify parameter regimes where thin-film x-ray cavities can exhibit a behaviour reminiscent to these phenomena and in particular the tuning parameter that controls the transition between EIT and ATS. Our analysis is based on the model of decaying dressed states [3].

[1] D. Lentrodt, K. Heeg, C. H. Keitel, J. Evers, Phys. Rev. Research 2, 023396 (2020)
[2] X. Kong, D. Chang, A. Pálffy, Phys. Rev. A 102, 033710 (2020)
[3] P. Anisimov, O. Kocharovskaya, J. Mod. Opt. 55, 3159 (2008)

Q 10.4 Mon 18:00 AP-HS

ORKA- Cavity enhanced dipole trapping of Rb87 atoms for microgravity — •Marius Prinz, Jan Eric Stiehler, Marian Woltmann, and Sven Herrmann — Center of Applied Space Technology and Microgravity (ZARM), University of Bremen, Germany

Using a dipole trap as a source for ultra-cold quantum gases comes at the cost of a high power budget of the trapping lasers. This limits the usability of all-optical trapping/cooling in power limited environments, e.g. space. To overcome this limit, the ORKA project aims to exploit the high intracavity power and crossed beam geometry of a high finesse optical bow-tie cavity. Our goal is to employ such a setup in the Bremen GraviTower to prepare Rb87 BECs as a matter wave source in microgravity. In this talk we will present the design and statud of our drop tower setup as well as first measurements of the basic properties of the cavity. The ORKA project is supported by the German Space Agency DLR with funds provided by the Federal Ministry for Economic Affairs and Climate Action under grant number DLR 50 WM 2267.

Q 10.5 Mon 18:15 AP-HS

Cryogenic Feedforward of a Photonic Quantum State — •Niklas Lamberty[1,2], Frederik Thiele[1,2], Thomas Hummel[2], Nina A. Lange[1,2], Lorenzo M. Procopio[1,2], Aishi Barua[1,2], Sebastian Lengeling[3], Viktor Quiring[2], Christof Eigner[2], Christine Silberhorn[3], and Tim J. Bartley[1,2] — [1]Department of Physics, Paderborn University, Warburger Str. 100, Paderborn, 33098, Germany — [2]Institute for Photonic Quantum Systems (PhoQS), Paderborn University, Warburger Str. 100, Paderborn, 33098, Germany — [3]Integrated Quantum Optics Group, Institute for Photonic Quantum Systems (PhoQS), Paderborn University, Warburger Str. 100, Paderborn, 33098, Germany

A wide range of quantum optical protocols require feedforward operations, entailing a partial measurement and subsequent manipulation of a quantum state. Reducing the latency between these two operations reduces the required storage time of the quantum state. By operating the measurement electronics and the modulator in the same cryogenic environment as high efficiency Superconducting Nanowire Single Photon Detectors (SNSPD), we achieve the lowest latency demonstrated so far of (23±3) ns. We use this feedforward operation to manipulate the $g^{(2)}(0)$ of a parametric down conversion source conditional on a photon-number measurement.

Q 10.6 Mon 18:30 AP-HS

Quantum dynamics of nuclear many-body systems driven by an XFEL — •Miriam Gerharz and Jörg Evers — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Mössbauer nuclei are an extreme platform for quantum optics because of their narrow transitions in the x-ray regime. These narrow transitions feature long lifetimes, but on the other hand also allowed to only study single excitations for decades. This has recently changed with first experiments at X-ray free electron lasers, where now multiple photon excitations and the subsequent dynamics can be studied. This technological progress immediately raises the question whether there are new effects expected depending on the number of resonant photons. In this project we theoretically explore quantum dynamics after multiple photon excitations.

Q 10.7 Mon 18:45 AP-HS

Upper-level spectroscopy of cold trapped ^{174}Yb atoms for their preparation in the metastable $^3P_0$ state — •Ke Li, Gabriel Dick, Saran Shaju, Dmitriy Sholokhov, and Jürgen Eschner — Universität des Saarlandes, Experimentalphysik, 66123 Saarbrücken, Germany

We trap and cool ^{174}Yb atoms in a magneto-optical trap (MOT) inside a high-finesse cavity [1] for exploring atom-cavity interaction on the $^1S_0$ – $^3P_0$ clock transition at 578 nm [2]. For populating the metastable $^3P_0$ level, we employ repumping lasers resonantly driving the $^3P_1$ – $^3S_1$ and $^3P_2$ – $^3S_1$ transitions, thereby transferring all atoms to $^3P_0$

via the $^3S_1$ level. We study the time-resolved repumping process to characterize and optimize its efficiency. The detuning-dependent population dynamics include coherent population trapping phenomena.

[1] H. Gothe et al., Phys. Rev. A, 99, 0134 15, 2019.
[2] D. Meiser et al., Phys. Rev. Lett. 102, 163601, 2009.