# Q 33: Quantum Optics IV

Time: Wednesday 11:00–12:30 Location: B/gHS

Q 33.1 Wed 11:00 B/gHS

**Dunkelresonanz-Thermometrie mit gefangenen Ionen** — •Johannes Rossnagel, Karl Nicolas Tolazzi, Georg Jacob, Ferdinand Schmidt-Kaler und Kilian Singer — Institut für Physik, Universität Mainz, 55128 Mainz, Germany

Wir stellen Messmethode zur Bestimmung der Temperatur von Ionenkristallen oder einzelner Ionen vor. Dazu untersuchen wir Dunkelresonanzen im Fluoreszenzspektrum der Ionen, die durch Quanten-Interferenzeffekte im 3-Niveau System entstehen. Wir zeigen, dass die Form der Resonanzen stark von der Temperatur der Ionen abhängt. Durch kurze Belichtungszeiten von $20\mu$s ist es möglich, thermische nicht-Gleichgewichtsprozesse zu untersuchen. Gleichzeitig erlauben es diese Resonanzen, die Temperatur der Ionen zwischen 0.7mK und 10mK einzustellen. Die Dunkelresonanz-Thermometrie ist zur Messung von Temperaturen in dem bisher schwer zugänglichen Bereich zwischen 0.1mK und 100mK geeignet. Diese Methode ist geeignet für die Untersuchung von Energietransport in Ionenketten [1,2], Thermometrie großer Kristalle [3,4] oder bei niedrigen Fallenfrequenzen [5], bzw. die Charakterisierung von thermodynamischen Kreisprozessen einer Einzel-Ionen Wärmekraftmaschine [6].

[1] Bermudez, A et al., Phy. Rev. Lett. 111, 040601 (2013). [2] Pruttivarasin,T et al. New J. Phys. 13, 075012 (2011). [3] Bermudez, A et al., Phys. Rev. Lett. 107, 207209 (2011). [4] Mielenz et al., Phys. Rev. Lett. 110, 133004 (2013). [5] Lemmer, A et al., arXiv:1407.1071 (2014). [6] Abah, O et al., Phys. Rev. Lett. 109, 203006 (2012).

Q 33.2 Wed 11:15 B/gHS

**Electromagnetically Induced Transparency in Interacting Entangled Media** — •Daniel Viscor[1], Weibin Li[1,2], Sebastian Hofferberth[3], and Igor Lesanovsky[1] — [1]School of Physics and Astronomy, The University of Nottingham, Nottingham NG7 2RD, United Kingdom — [2]School of Physics, Huazhong University of Science and Technology, Wuhan 430074, China — [3]5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

We theoretically investigate single-photon (SP) propagation and electromagnetically induced transparency (EIT) in one, two, and $\mathcal{N}$ one-dimensional ensembles of cold atoms, which are initially prepared with a single collective excitation, and interact via Rydberg exchange interaction (REI). For the single cloud, we conduct a detailed study of the absorptive and dispersive properties of such a medium. We show that the initial collective state, in conjunction with the REI, gives rise to a nonlocal susceptibility that produces nonlocal propagation and enhanced absorption of the SP compared to conventional Rydberg EIT. Second, we investigate the propagation of the SP entering simultaneously two spatially separated parallel clouds. We show that, under certain conditions, the SP can be partially transferred from one cloud to the other via the REI, leading to the formation of dark and bright path superpositions of the light that experience different absorption and dispersion. Finally, we generalize the analysis to the case of $\mathcal{N}$ clouds, and show that the dynamics of the propagating SP can be mapped on that of a free particle with complex mass.

Q 33.3 Wed 11:30 B/gHS

**Auger-pumped superradiance at 108.9nm in xenon** — •wen-te liao[1,2], clemens weninger[1,2], laurent mercadier[1,2], and nina rohringer[1,2] — [1]Max Planck Institute for the Physics of Complex Systems, 01187 Dresden, Germany — [2]Center for Free Electron Laser Science, 22607 Hamburg, Germany

X-ray Free Electron Lasers (XFELs) open entirely new directions for quantum optics in the x-ray domain. Superradiance is the collective spontaneous emission of photons by a group of quantum emitters. The superradiant decay rate of an ensemble of emitters can vastly exceed that of a single atom and strongly depends on the geometric shape of the active volume. Ionizing Xenon at the 4d threshold by soft x-rays, the subsequent Auger-decay of the 4d hole results in a population inversion of the 5p to 5s shell in doubly ionized Xenon, that was previously exploited to realize amplified spontaneous emission at 108.9 nm [1,2]. With XFEL sources, the necessary conditions for superradiance can be met. Changing the aspect ratio of the superradiant volume via adjusting the focus size and depth of the XFEL radiation can result in emission of transform limited pulses of high intensities, ranging from fs to ps duration. This opens the path to a photon source with a bandwidth tunable on demand within a wide range. We present numerical results of the superradiant emission based on a Maxwell-Bloch approach for parameters available at XFEL sources.

[1] H. C. Kaptey, R. W. Lee, and R. W. Falcone, Phys. Rev. Lett. 57, 2939 (1986).

[2] M.H. Sher, et al., Optics Letters 12, 891 (1987)

Q 33.4 Wed 11:45 B/gHS

**All-electromagnetic control of broadband quantum excitations using gradient photon echoes** — •wen-te liao[1,2,3], christoph h. keitel[1], and adriana pálffy[1] — [1]Max Planck Institute for Nuclear Physics, 69117 Heidelberg, Germany — [2]Max Planck Institute for the Physics of Complex Systems, 01187 Dresden, Germany — [3]Center for Free Electron Laser Science, 22607 Hamburg, Germany

To be competitive, future photonics technology is required to perform well at frequencies of few gigahertz. This is why finding ways of controlling and storing ultrashort, namely broadband, light pulses becomes crucial. In our work we present a solution for this challenge [1]. In nature, a chosen atom will only absorb photons with specific frequencies. However, the atomic absorption frequency can be shifted by another intense control laser. The key of our idea is using a control laser with longitudinally inhomogeneous intensity to alter the quantum behavior of an atomic medium [2]. Under this action, different frequency components of a broadband light pulse can be absorbed and stored over a different slice of a medium. Furthermore, our results show that one can retrieve or even manipulate the stored ultrashort pulse by changing the phase or intensity of the control laser [1]. This may pave the way towards ultrafast processing and high-performance photonic devices.

[1] W.-T. Liao, C. H. Keitel and A. Pálffy, Phys. Rev. Lett. 113, 123602 (2014).

[2] B. M. Sparkes et al., Phys. Rev. A 82, 043847 (2010).

Q 33.5 Wed 12:00 B/gHS

**Gravitational and special-relativistic effects on x-ray superradiance** — Wen-Te Liao[1,2,3] and •Sven Ahrens[1,4] — [1]Max Planck Institute for Nuclear Physics, 69117 Heidelberg, Germany — [2]Max Planck Institute for the Physics of Complex Systems, 01187 Dresden, Germany — [3]Center for Free Electron Laser Science, 22607 Hamburg, Germany — [4]Beijing Computational Science Research Center, Beijing, China

Time is running at different speed in Einstein's theory of general relativity. This property has been proven with atomic clock experiments and Mösbauer spectroscopy in the past.

A nuclear crystal forms a dense array of micro clocks, in which the inhomogeneous evolution of time can be probed. To do so, we propose to excite the two-level systems of nuclear transitions with x-ray photons. The phase fronts of absorbed photons are stored as collective nuclear excitation in the crystal. These phase fronts are subject to inhomogeneous time evolution in the gravitational field. Thus, we predict, that the reemitted superradiant photon is deflected by gravity while it is stored in the crystal. This is a general effect, which always appears in every quantum system of sufficiently low decoherence.

We consider the deflection of photons, which interact with a nuclear crystal in the earth gravitational field by analytically solving the combined quantum system of the photon and the nuclear ensemble in our contribution [1]. In order to enhance the deflection effect, we also consider a fast rotating setup with high centripetal acceleration.

[1] W.-T. Liao and S. Ahrens, arXiv:1411.7634 (2014)

Q 33.6 Wed 12:15 B/gHS

**Two-dimensional spectroscopy for the study of ion Coulomb crystals** — •Andreas Lemmer[1], Cecilia Cormick[1], Christian Tomás Schmiegelow[2], Ferdinand Schmidt-Kaler[2], and Martin Bodo Plenio[1] — [1]Institut für Theoretische Physik, Universität Ulm, Deutschland — [2]QUANTUM Institut für Physik, Universität Mainz, Deutschland

Ion Coulomb crystals are currently establishing themselves as a highly controllable test-bed for mesoscopic systems of statistical mechanics. The detailed experimental interrogation of the dynamics of these crystals however remains an experimental challenge. In this work, we show how to extend the concepts of multi-dimensional nonlinear spectroscopy to the study of the dynamics of ion Coulomb crystals. The scheme we present can be realized with state-of-the-art technology and gives direct access to the dynamics, revealing nonlinear couplings even in systems with many ions and in the presence of thermal excitations. We illustrate the advantages of our proposal showing how two-dimensional spectroscopy can be used to detect signatures of a structural phase transition of the ion crystal, as well as resonant energy exchange between modes. Furthermore, we demonstrate in these examples how different decoherence mechanisms can be identified.