Q 36: Optomechanics II

Time: Wednesday 14:00–15:15 Location: Q-H13

Q 36.1 Wed 14:00 Q-H13

Stationary entanglement of feedback-cooled nanoparticles — •Henning Rudolph, Klaus Hornberger, and Benjamin Stickler — Faculty of Physics, University of Duisburg-Essen, Germany

The motion of levitated nanoparticles has recently been cooled into the quantum groundstate by electric feedback [1]. In this talk we demonstrate how two interacting nanoparticles, co-levitated in adjacent tweezer traps, exhibit stationary entanglement if the individual particles can be detected and feedback cooled. We find that the stationary two-particle state can be entangled if the detection efficiency of the feedback loop exceeds the ratio of the mechanical normal mode frequencies. As an important experimental constraint, we show that the degree of entanglement decreases with increasing bandwidth of the signal-to-feedback filter.

[1] L. Magrini, P. Rosenzweig, C. Bach, A. Deutschmann-Olek, S. G. Hofer, S. Hong, N. Kiesel, A. Kugi, M. Aspelmeyer, Real-time optimal quantum control of mechanical motion at room temperature. Nature 595, 373-377 (2021).

Q 36.2 Wed 14:15 Q-H13

Testing quantum mechanics with heavy objects – using magnetically-levitated superconducting microparticles — •Gerard Higgins[1,2], Joachim Hofer[3], Philip Schmidt[1], Stefan Minniberger[3], Jannek Hansen[3], Michael Trupke[1,3], Markus Aspelmeyer[1,3], Martí Gutierrez Latorre[2], Achintya Paradkar[2], Avan Mirkhan[2], and Witlef Wieczorek[2] — [1]IQOQI, Vienna, Austria — [2]Chalmers University of Technology, Gothenburg, Sweden — [3]Vienna Centre for Quantum Science and Technology, Austria

It is unclear how our classical world emerges from the quantum world. It is also unclear how to incorporate effects of gravity into quantum mechanics. To get experimental insights into these problems, we need to prepare larger masses in quantum states.

Magnetically-levitated superconducting microparticles make promising systems for doing this. We work with a lead microsphere of $\sim 10^{18}$ amu ($\sim 1\,\mu$g) which we isolate from its surroundings using magnetic levitation. We read out the sphere's COM motion using a SQUID and cool the motion by applying additional magnetic fields. We will extend our control by coupling the sphere's motion to superconducting resonators and qubits.

Q 36.3 Wed 14:30 Q-H13

Direct loading of levitated nanoparticles into optical traps via hollow core photonic crystal fibers — •Stefan Lindner — University of Vienna, Vienna, Austria

Levitated nanoparticles have been established as a promising platform for testing quantum physics on a macroscopic scale, but as of today environmental decoherence still poses a substantial roadblock hindering the access to extended quantum experiments with these objects. Especially the coherence destroying interaction with background gas molecules has to be overcome by reducing the pressure these experiments are conducted in. The attainable pressures for most levitation experiments are directly related to the type of particle loading scheme in place. Here we present a novel method for loading nanoparticles via hollow core photonic crystal fibers, that will allow direct loading of these nanoparticles into pressures in the ultra high vacuum regime.

In this method two counter-propagating laser beams of equal wavelength are guided through the hollow core fiber to create an optical standing wave. This fiber connects the main vacuum chamber to a secondary “loading” vacuum chamber. Particles are dispersed in the loading chamber and by detuning one of the two lasers with respect to the other, these particles can be transported through the fiber. Once the fiber is aligned with respect to the target trap, the particles can be directly deposited into it. This handover of particles has been demonstrated down to pressures of 10^{-2} mbar and is currently extended to enable direct loading into ultra high vacuum environments.

Q 36.4 Wed 14:45 Q-H13

Light mediated coupling of levitated nanoparticles — •Jakob Rieser[1], Mario Ciampini[1], Henning Rudolph[2], Klaus Hornberger[2], Benjamin Stickler[2], Nikolai Kiesel[1], Markus Aspelmeyer[1], and Uros Delic[1] — [1]University of Vienna, Vienna, Austria — [2]University of Duisburg-Essen, Duisburg/Essen, Germany

Optical binding, the self organization of multiple particles in optical traps, has been studied using dielectric microparticles as well as liquid suspended metallic nanoparticles, usually trapped in a single optical potential. These particles are either comparable in size to the wavelength or plasmonic and cannot be approximated as dipoles.

In this talk, I will introduce an experiment studying light mediated interactions in the dipole regime. By using two independent optical traps to levitate two Rayleigh nanoparticles, we can study true dipole-dipole coupling effects. These arise due to interference between coherently scattered light and the trapping beams. By tuning the relative phase, amplitude, and position of the trapping light fields we can explore the interaction for a wide range of parameters, showing that we achieve strong coupling between two nanoscale dielectric objects.

Finally, we show that we can turn off the dipole-dipole interaction, which allows us to study different coupling mechanisms, such as Coulomb coupling.

Q 36.5 Wed 15:00 Q-H13

Quantum control of a nanoparticle optically levitated in cryogenic free space — •Felix Tebbenjohanns[1,2], Maria Luisa Mattana[1], Massimiliano Rossi[1], Martin Frimmer[1], and Lukas Novotny[1] — [1]Photonics Laboratory, ETH Zürich, 8093 Zürich, Switzerland — [2]Currently with the Department of Physics, Humboldt-Universität zu Berlin, 10099 Berlin

Nanospheres levitated in optical tweezers are a versatile platform and have become an indispensable tool across many disciplines ranging from biology to physics. The key ingredient, radiation pressure, couples light to mechanical motion of macroscopic objects. In an ultra-high vacuum, the system can be sufficiently decoupled from its environment, such that this optomechanical interaction becomes dominant over all other sources of heat, a prerequisite to ground-state cool the system. In my talk, I will explain how we employed a measurement-based feedback mechanism to cool the mechanical motion of a levitated nanosphere to 0.65 quanta of motion, opening the door for levitated quantum optomechanics.

[1] L. Magrini, P. Rosenzweig, C. Bach. et al. Nature 595, 373 (2021).

[2] F. Tebbenjohanns, M.L. Mattana, M. Rossi, et al. Nature 595, 378 (2021)