Q 48: Optomechanics I

Time: Thursday 14:30–15:45 Location: P 4

Q 48.1 Thu 14:30 P 4

Orientational localization in the CSL model — •Björn Schrinski, Benjamin A. Stickler, and Klaus Hornberger — Fakultät für Physik, Universität Duisburg-Essen

Recent experimental progress in the control of anisotropic levitated nano-particles [1-3] holds the promise of accessing the orientational degrees of freedom in the quantum regime and thus testing macrorealistic modifications of quantum mechanics. Here, we discuss how the model of continuous spontaneous localization (CSL) [4] affects the orientational coherence of a nano-particle. In particular, we determine the resulting spatio-orientational localization rates and examine how the angular momentum diffusion might help to improve on existing CSL tests.

[1] Kuhn et al., Nano Letters 18, 5604 (2015)
[2] Hoang et al., Phys. Rev. Lett. 117, 123604 (2016)
[3] Kuhn et al., arXiv: 1608.07315 (2016)
[4] Bassi et al., Rev. Mod. Phys. 85, 471 (2013)

Q 48.2 Thu 14:45 P 4

Orientational decoherence of nanoparticles — •Birthe Papendell, Benjamin A. Stickler, and Klaus Hornberger — Fakultät für Physik, Universität Duisburg-Essen

Motivated by trapping and cooling experiments with nonspherical nanoparticles [1-4] we discuss how their rotational quantum dynamics is affected by photon scattering or the interaction with a gaseous environment. We present the localization rate for gas collisions off a van der Waals-type potential and for Rayleigh scattering off a symmetric or an asymmetric dielectric nanoparticle. Finally we show in what sense the associated master equation describes angular momentum diffusion [5].

[1] S. Kuhn, P. Asenbaum, A. Kosloff, M. Sclafani, B. A. Stickler, S. Nimmrichter, K. Hornberger, O. Cheshnovsky, F. Patolsky, and M. Arndt, Nano Lett. 15, 5604 (2015).
[2] B. A. Stickler, S. Nimmrichter, L. Martinetz, S. Kuhn, M. Arndt, and K. Hornberger, Phys. Rev. A 94, 033818 (2016).
[3] T. M. Hoang, Y. Ma, J. Ahn, J. Bang, F. Robicheaux, Z.-Q. Yin, and T. Li, Phy. Rev. Lett. 117, 123604 (2016).
[4] S. Kuhn, A. Kosloff, B. A. Stickler, F. Patolsky, K. Hornberger, M. Arndt, and J. Millen, arxiv: 1608.07315 (2016).
[5] B. A. Stickler, B. Papendell, and K. Hornberger, Phys. Rev. A 94, 033828 (2016).

Q 48.3 Thu 15:00 P 4

Rotational optomechanics with levitated nanorods — •Stefan Kuhn[1], Benjamin A. Stickler[2], Alon Kosloff[3], Fernando Patolsky[3], Klaus Hornberger[2], Markus Arndt[1], and James Millen[1] — [1]University of Vienna, Faculty of Physics, VCQ, Boltzmanngasse 5, 1090 Vienna, Austria — [2]University of Duisburg-Essen, Lotharstraße 1, 47048 Duisburg, Germany — [3]School of Chemistry, Tel-Aviv University, Ramat-Aviv 69978, Israel

Optical control over nano-mechanical structures has become invaluable for force sensing applications and tests of fundamental quantum physics. To achieve the optimal performance of such devices, their coupling to the environment needs to be minimized. This can for instance be achieved by levitating nanoparticles in external fields which has led to a growing interest in the field of levitated optomechanics. Here we extend this work to the rotational motion of optically trapped silicon nanorods[1]. We track and manipulate both their linear and rotational motion in the field of two counter-propagating, focussed laser beams via the light polarization. In this way we gain full control over the ro-translational dynamics of the rod. We will discuss the prospects of our levitated systems for realising rotational optomechanics[2,3], single particle thermodynamics and as a novel source for high-mass matter-wave interferometry experiments.

[1] S. Kuhn et al., arXiv:1608.07315 (2016)
[2] S. Kuhn et al., Nano Lett., 15(8), 5604-5608 (2015)
[3] B. A. Stickler et al., Phys. Rev. A, 94, 033818 (2016)

Q 48.4 Thu 15:15 P 4

Cavity optomechanics with levitated nanospheres at low pressures — •Uros Delic, David Grass, Nikolai Kiesel, and Markus Aspelmeyer — Faculty of Physics, University of Vienna, Vienna, Austria

In recent years cavity cooling of levitated nanospheres has been demonstrated in multiple experiments [1, 2]. However, regime of high cooperativity $C > 1$ is yet to be reached, leading to ground state cooling of nanosphere center-of-mass motion and full quantum control of nanosphere motion. A common obstacle in many experiments is stable levitation of nanospheres at low pressures, which has so far been shown in hybrid electro-optical systems [2] and in optical tweezers [3, 4].

We report on progress of combining stable optical levitation in optical tweezers with an optical cavity to reach a regime of high cooperativity at low pressures. We will present first results on coupling a nanosphere levitated by tweezers to the optical cavity. We will discuss further improvements to the experiment necessary to reach quantum control of nanosphere motion.

[1] Kiesel et al., PNAS 110: 14180-14185 (2013) [2] Millen et al., Phys. Rev. Lett. 114, 123602 (2015); Millen et al., Phys. Rev. Lett. 117, 173602 (2016) [3] Jain et al., Phys. Rev. Lett. 116, 243601 (2016) [4] Mestres et al., Appl. Phys. Lett. 107, 151102 (2015)

Q 48.5 Thu 15:30 P 4

Nonlinear Quantum Optics in Nanophotonic Waveguides — •Hashem Zoubi and Klemens Hammerer — Leibniz University Hannover, Germany

We develop a systematic method for deriving a quantum optical multimode Hamiltonian for the interaction of photons and phonons in nanophotonic dielectric materials by applying perturbation theory to the electromagnetic Hamiltonian [1]. The Hamiltonian covers radiation pressure and electrostrictive interactions on equal footing. As a paradigmatic example, we apply our method to a cylindrical nanoscale waveguide, and derive a Hamiltonian description of Brillouin quantum optomechanics. We show analytically that in nanoscale waveguides radiation pressure dominates over electrostriction, in agreement with recent experiments. We explore the possibility of achieving a significant nonlinear phase shift among photons propagating in nanoscale waveguides exploiting interactions among photons that are mediated by vibrational modes and induced through Stimulated Brillouin Scattering (SBS) [2]. We introduce a configuration that allows slowing down the photons by several orders of magnitude via SBS involving sound waves and two pump fields. We extract the conditions for maintaining vanishing amplitude gain or loss for slowly propagating photons while keeping the influence of thermal phonons to the minimum. The nonlinear phase among two counter-propagating photons can be used to realize a deterministic phase gate.

[1] H Zoubi, K Hammerer, arXiv:1604.07081 (Phys. Rev. A, in press). [2] H Zoubi, K Hammerer, arXiv:1610.03355.