International Conference on Quantum Energy 2025 hosted by Dipartimento di Fisica e Astronomia Galileo Galilei an event by ICQE

Contribution ID: **95** Type: **Poster presentation**

Quantum Delocalization of a Levitated Nanoparticle - Thermodynamic aspects

Levitated objects in ultra-high vacuum offer a new paradigm for free-space optomechanics [1]. In the absence of clamping losses and background gas, an exceptional degree of isolation from the environment can be achieved, enabling quantum optomechanical cooperativities exceeding one even at ambient temperature. Combined with near-Heisenberg-limited position measurements, this has allowed the application of quantum control techniques to prepare the motional ground state of a levitated nanoparticle [2,3]. A crucial next step is to demonstrate the ability to coherently manipulate the nanoparticle's mechanical state. In this context, generating a coherent expansion of the center-of-mass wavefunction is particularly significant, as it is a prerequisite for realizing matter-wave interferometry experiments with nanoscale objects [4].

Here we present a series of experiments in which we exploit rapid optical pulse sequences to manipulate the mechanical state of a nanoparticle [5]. Our results indicate that we can delocalize the nanoparticle's wavefunction and increase its coherence length beyond the zero-point motion. We achieve more than a threefold increase in the initial coherence length with minimal added noise. Coherent squashing of position implies squeezing of the conjugate momentum. From our measurements, we infer -7.2 dB squeezing of the momentum variance below its zero-point value, a valuable resource for force-sensing applications [6].

With this contribution we aim to discuss the thermodynamic aspects of coherent state expansion with the participants of ICQE 2025. What is the entropic cost of delocalization protocols? Can increasing the spatial coherence length of a quantum system be harnessed as a thermodynamic resource?

[1] C. Gonzalez-Ballestero et al. - Science 374, 6564 (2021)
[2] L. Magrini et al. - Nature 595, 373-377 (2021)
[3] F. Tebbenjohanns et al. Nature 595, 378–382 (2021)
[4] O. Romero-Isart et al. PRL 107, 020405 (2011)
[5] M. Rossi et al. arXiv:2408.01264 (2024)
[6] S.C. Burd et al. - Science 364, 1163-1165 (2019)

Theme

Theme 1. Energy advantage and cost of quantum technology

Primary author: CARLON ZAMBON, Nicola (Photonics Laboratory & Quantum Center, ETH Zürich, Switzerland)

Co-authors: Dr ROSSI, Massimiliano (Photonics Laboratory & Quantum Center, ETH Zürich, Switzerland); Dr MILITARU, Andrei (Photonics Laboratory & Quantum Center, ETH Zürich, Switzerland); Dr RIERA-CAMPENY, Andreu (ICFO –Institut de Ciencies Fotoniques, Castelldefels, Barcelona, Spain and Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences, Innsbruck, Austria); Prof. ROMERO-ISART, Oriol (ICFO –Institut de Ciencies Fotoniques, Castelldefels, Barcelona, Spain and ICREA –Institucio Catalana de Recerca i Estudis Avancats, Barcelona, Spain); Prof. FRIMMER, Martin (Photonics Laboratory & Quantum Center, ETH Zürich, Switzerland); Prof. NOVOTNY, Lukas (Photonics Laboratory & Quantum Center, ETH Zürich, Switzerland)

Presenter: CARLON ZAMBON, Nicola (Photonics Laboratory & Quantum Center, ETH Zürich, Switzerland)

Track Classification: Theme 1. Energy advantage and cost of quantum technology