OPTIMIZATION OF STATIC POTENTIALS FOR ROBUST MACROSCOPIC QUANTUM SUPERPOSITION STATES OF LEVITATED NANOPARTICLES

Silvia Casulleras[1,2]*, Piotr T. Grochowski[1,2] and Oriol Romero-Isart[1,2,3,4]

[1]Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences, 6020 Innsbruck, Austria
[2]Institute for Theoretical Physics, University of Innsbruck, 6020 Innsbruck, Austria
[3]ICFO - Institut de Ciencies Fotoniques, The Barcelona Institute of Science and Technology, 08860 Castelldefels (Barcelona), Spain
[4]ICREA - Institucio Catalana de Recerca i Estudis Avançats, 08010 Barcelona, Spain

*Telephone number: +43 512 507 52293, E-mail address: silvia.casulleras-guardia@uibk.ac.at

Levitated nanoparticles provide a highly controllable and isolated platform for probing fundamental quantum phenomena at the macroscopic scale. Current experimental advancements include hybrid setups combining both optical and nonoptical static potentials. In our work, we introduce an efficient optimization method to determine optimal static potentials for the robust generation of macroscopic quantum states of levitated nanoparticles. Our optimization strategy accounts for position-dependent inherent noise sources within experimental setups. We provide key figures of merit that allow for fast computation and capture the main features of the dynamics, mitigating the computational demands associated with the multiscale simulation of this system. Specifically, we introduce coherence length and coherent cubicity as signatures of macroscopic quantum superposition states. We apply the optimization approach to a family of quartic potentials and show that the optimal configuration depends on the strength and nature of the noise in the system. Additionally, we benchmark our results with the full quantum dynamics simulations of the system for the optimal potentials.

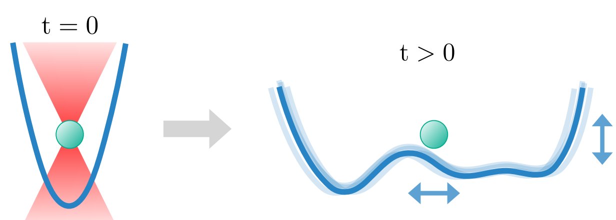

Figure 1 – Sketch of a nanoparticle trapped and ground-state cooled by an optical tweezer at t=0. For t>0, the particle evolves in a nonharmonic, static, non-optical potential. The potential features fluctuations in position and amplitude.