Optimal Static Potentials for Robust Macroscopic Quantum State Generation of Levitated Nanoparticles

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Levitated nanoparticles offer a unique and controlled experimental platform for investigating quantum phenomena at the interface between classical and quantum mechanics. The ground-state cooling of nanoparticles in optical traps was recently achieved [1,2,3], and the current pursuit is directed towards the preparation of macroscopic quantum superposition states. Due to substantial decoherence in optical potentials, the dynamics must happen either in the absence of an optical potential [4] or within a dark potential [5]. A specific nonharmonic potential has been identified for generating these macroscopic quantum superpositions[5], yet the optimal potential shape remains unknown.

We address this question by using an optimization approach to determine the optimal static potential shape for robust generation of macroscopic quantum states. Our optimization strategy accounts for inherent noise sources within experimental setups. Given the computational demands of the multiscale simulation of this system, we provide a description of the dynamics that allows for fast computation of key figures of merit. Specifically, we use coherence length and cubicity of the state as indicators for the emergence of nonclassical features. We find that the optimal potential shape varies based on the strength and nature of the noise in the system. Our research shows that optimization can provide valuable insights for enhanced control over quantum features in levitated nanoparticle systems.

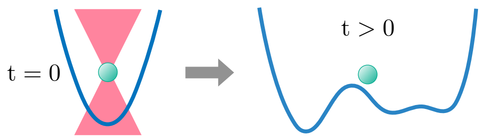

Fig. 1: Optically levitated nanoparticle evolving in a dark potential.

References

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