Levitated nanoparticles: the road ahead to macroscopic superpositions

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Abstract

In the century since Louis de Broglie's proposal of the matter-wave hypothesis, matter-wave interference has been observed for a range of particles, ranging from sub-atomic particles to atoms to highly complex molecules. Is there an upper limit to the particle mass for which interference can be observed? We do not know. If there is a limit, we also do not know if it is simply due to technical complexity or if it reveals a fundamental gap in our understanding of quantum mechanics.

Levitated nanoparticles are a promising experimental system with which to investigate these questions. Recently, nanoparticles levitated in optical traps have been cooled to the motional ground state. This achievement can be seen as a starting point for preparing quantum-mechanical states of a nanoparticle's motion, including macroscopic superposition states. A major hurdle, however, is the decoherence introduced in optical traps via both direct light scattering and particle heating. Here, I will present an alternate approach based on ion traps.

We have recently demonstrated a new method for precise position measurement and cooling of (charged) nanoparticles in an ion trap [1]. Furthermore, we will examine how techniques originally developed for trapped atomic ions, such as sympathetic cooling, can be transferred to the domain of nanoparticles [2]. Finally, we will see that a nanoparticle oscillator in ultra-high vacuum can obtain quality factors above 10^10 [3], evidence of its extreme isolation from its environment.

[1] L. Dania, K. Heidegger, D. S. Bykov, G. Cerchiari, G. Arenada, T. E. Northup, Phys. Rev. Lett. 129, 013601 (2022)

[2] D. S. Bykov, L. Dania, F. Goschin, T. E. Northup, Optica 10, 438 (2023)

[3] L. Dania, D. S. Bykov, F. Goschin, M. Teller, T. E. Northup, arXiv:2304.02408