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Co-trapping an ion and a nanoparticle in a two-frequency Paul trap

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Coupling a spin qubit to a mechanical system provides a route to prepare the mechanical system's motion in nonclassical states, such as a Fock state or an entangled state. Such quantum states have already been realized with superconducting qubits coupled to clamped mechanical oscillators. We are interested in achieving an analogous coupling between a spin and a levitated oscillator — namely, a silica nanoparticle in a linear Paul trap — in order to take advantage of a levitated system's extreme isolation from its environment. In this case, we envision an atomic ion as the spin qubit.

I will present recent steps in this direction: First, we have adapted techniques originally developed for trapped atomic ions, including detection via self-interference and sympathetic cooling, for the domain of nanoparticles [1,2]. Second, we have confined a nanoparticle oscillator in ultra-high vacuum and obtained quality factors above 10¹⁰, evidence of the particle's extreme isolation from its environment [3]. Finally, we have trapped a calcium ion and a nanoparticle together in a linear Paul trap, taking advantage of a dual-frequency trapping scheme.

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

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