Strong and controllable dipole-dipole interaction between optically levitated nanoparticles

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Arrays of coupled mechanical oscillators have been proposed for exploring collective optomechanical effects, quantum many-body dynamics, topological phonon transport, (quantum) synchronization etc. So far, the experimental strategy has been to mediate interaction between two clamped oscillators via an optical cavity, thus limiting the scalability of such systems and confining the interaction toolbox to available cavity interaction techniques. Engineering a direct interaction between an array of oscillators would allow us to create macroscopic entangled states in order to probe the quantum-to-classical transition and explore weak forces between two isolated nanoscale objects.

Optically levitated particles smaller than laser wavelength – effectively induced dipoles – scatter light in phase with the trapping field. This coherent scattering of light by the particles has recently been used to achieve motional ground state cooling (Science 367, 892-895 (2020)). We realize a trap array of levitated nanoparticles, thus providing a fully scalable architecture to generate an optomechanical array in the quantum regime. We engineer direct interactions between motional degrees of freedom via dipole-dipole interactions ("optical binding") and Coulomb force, thus allowing for a much richer dynamics in a combination with an optical cavity in the future. I will present first results on strong and tunable interaction between nanoparticles in parallel optical tweezers, a novel platform in the context of optical binding studies as well, which paves the way for studying quantum many-body physics with massive solid-state objects.

Fig. 1: Camera image of two silica nanoparticles (diameter of 210 nm) trapped at a distance of around 5 μm.

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