Title: Testing quantum mechanics and gravity with levitated optomechanicsâ€™

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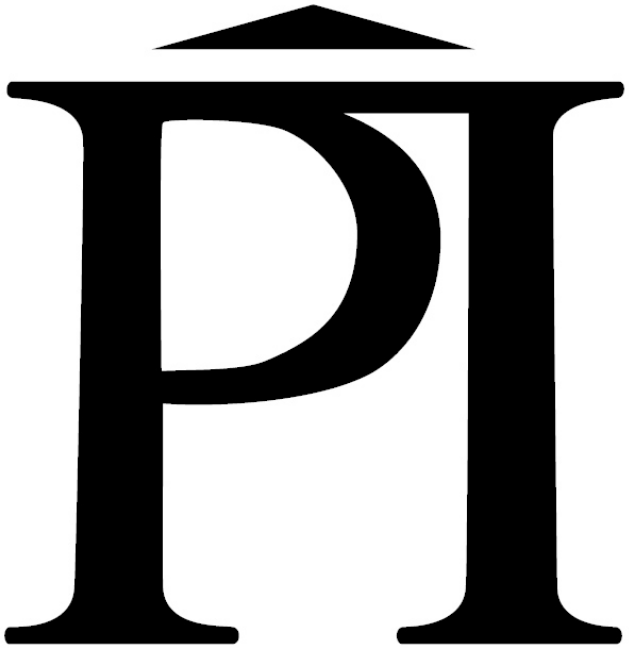
Abstract: We will discuss recent trapping and cooling experiments with optically levitated nanoparticles [1]. We will report on the cooling of all translational motional degrees of freedom of a single trapped silica particle to 1mK simultaneously at vacuum of 10⁻⁵ mbar using a parabolic mirror. We will further report on the squeezing of a thermal motional state of the trapped particle by rapid switching of the trap frequency [2].

We will further discuss ideas to experimentally test quantum mechanics by means of collapse models [3] by both matter-wave interferometry [4] and non-interferometric methods [5]. While first experimental bounds by non-interferometric tests have been achieved during the last year by a number of different experiments according to our idea [4], we at Southampton work on setting up the Nanoparticle Talbot Interferometer (NaTalI) to test the quantum superposition principle directly for one million atomic mass unit (amu) particles.

We will further discuss some ideas to probe the interplay between quantum mechanics and gravity by such levitated optomechanics experiments. One idea is to seek experimental evidence about the fundamentally quantum or classical nature of gravity by using the torsional motion of a non-spherical trapped particle [6], while a second idea is to test the effect of the gravity related shift of energy levels of the mechanical harmonic oscillator, which is predicted by semi-classical gravity (Schroedinger-Newton equation) [7] or thirdly try to pick up entanglement mediated by gravity [8].



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