Quantum optomechanics with levitated nanoscale oscillators

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Nanoscale oscillators levitated by optical, electric or magnetic fields in high vacuum offer a completely new arena for studies of foundational science. The drastic suppression of decoherence potentially allows observation of non-classical states of motion, while the creation of long-lived macroscopic quantum states may enable demonstrations of quantum behaviour on very large mass scales. This includes the possibility of creating large macroscopic superpositions, as well as tests of proposed mechanisms of wavefunction collapse at large length scales.

An important enabling requirement for these studies is the development of methods to manipulate and cool the centre-of-mass motion of these oscillators. In addition, the internal temperature must often be maintained at or below 300 K. In this talk I will describe our work which has demonstrated cavity cooling of levitated silica spheres (r = 200 nm) to milliKelvin temperatures in a hybrid electro-optical trap [1-2]. I will also outline more recent work that has shown internal cooling of optically levitated ytterbium-doped yttrium lithium fluoride (Yb+3: YLF) nanocrystals using anti-stokes laser refrigeration from room temperature to 130 K [2]. I will also discuss future foundational experiments which will use these developments.

[1] J. Millen, P. Z. G. Fonseca, T. Mavrogordatos, T. S. Monteiro, and P. F. Barker
Phys. Rev. Lett. 114, 123602 (2015)
[2] P. Z. G. Fonseca, E. B. Aranas, J. Millen, T. S. Monteiro, and P. F. Barker, Phys. Rev. Lett. 117, 173602 (2016).
[2] A. T. M. Anishur Rahman, P. F. Barker, arXiv:1703.07155v1 (2017)