Fundamental physics and applications with quantum levitated optomechanics

Supervisors: Prof. Peter Barker and Prof. Tania Monteiro

UCL Lead department: Physics and Astronomy

Cold nanoscale objects levitated by optical, magnetic and electric fields in high vacuum are a new type of macroscopic quantum system, showing extraordinary sensitivity to weak forces [1]. They are currently used by our group to search for dark matter [2], while also showing great promise for probing other fundamental interactions, including the quantum nature of gravity [3].
Using these mechanical quantum systems, we are also developing real-world applications, including sensitive, low-drift, inertial sensors, as well as detectors of extremely weak electrical and magnetic forces. We also use this expertise for detailed characterization of single isolated nanoparticles [4]. Most recently we have demonstrated a miniature levitated sensor with outstanding sensitivity to low-frequency electromagnetic waves of practical use for communication through water and the ground.
A nanoparticle trapped in an optical field in high vacuum can be decoupled, almost perfectly, from its room temperature environment. We use light to damp and cool the motion of these objects [5,6], with experiments already demonstrating cooling to the quantum ground state [7,8]. Now there is significant effort worldwide to create non-classical states of motion such as a quantum superposition of a single nanoparticle [9], and entanglement in systems comparable to the size of a virus. These breakthroughs are key ingredients for understanding the classical quantum divide, and for probing the quantumness of gravity.

Our research group is working on joint theory-experiment projects which offer a range of opportunities for PhD study in theoretical, experimental and computational physics. A PhD project can be tailored for candidates that evidence aptitude and interest in one or more of the areas outlined above.

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