Probing Non-Standard Physics with Levitated Optomechanics

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Levitated optomechanics aims to measure and control the motion of mechanical systems through light, by integrating various levitation mechanisms in traditional optomechanics, to suspend objects in air or vacuum without any mechanical clamping. This makes for a flexible platform, capable of employing optical, electric or magnetic fields to capture and control the motion of objects of various nature (dielectric, magnetic etc.) with a wide range of masses, dimensions, and eigenfrequencies [1].
The possibility to perform such experiments in ultra-high vacuum and cryogenic environments, combined with the absence of additional clamping, provides excellent environmental decoupling. This allows us to work as close as possible to the Heisenberg measurement-disturbance limit, enabling the engineering of ultra-sensitive detectors.
Such versatility has quickly brought levitated optomechanics under the spotlight as a promising candidate for probing quantum physics with macroscopic objects, to unlock new frontiers in fundamental physics and sensing.
In this talk, we will speak about the founding principles of levitated optomechanics, and illustrate the tools needed to exert quantum control on the motion of a trapped object. In particular, we will see how to use a measurement-based feedback scheme to cool a levitated silica nanoparticle from a highly populated thermal state to its motional quantum ground state [2, 3]. We will then explore how systems based on levitated optomechanics can be used as test benches for quantum gravity theories [4], and to engineer sensitive detectors capable of unveiling interactions with dark matter [5]. Finally, we will discuss how such platforms can be used to bridge the gap between classic and quantum physics, by testing collapse models and providing a viable platform for the creation quantum superposition states with macroscopic objects [6, 7].

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