Master 2 Internship

Title: Quantum imaging for sub-shot noise monitoring of optically-levitated nano-particles

Type: Experimental

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PhD funding (if any): PhD funding available

Project: **Optical levitation is a subfield of optomechanics**, in which a small particle is trapped in a vacuum chamber at the focal spot of a laser focused through a microscope objective [1]. The laser beam produces an optical force equivalent to a mechanical spring and the system can be regarded as a simple mass-spring resonator displaying pristine vibrational oscillations in the kHz regime. Because levitated systems outperform other types of mechanical resonators, they are currently exploited to achieve high-sensitivity metrology, detect gravitational waves or search for dark matter. Yet, despite their simplicity, levitated systems provide a remarkable interaction between the mechanical motion of the particle and the light field, which can be harnessed to **study and control quantum properties** of material particles.

To display such properties, the particle must be **cooled down to its motional quantum ground state**, which requires to monitor the motion of the particle with the highest precision possible. Typically, such monitoring is performed using a coherent (i.e. classical) light produced by a conventional laser. The precision one can expect from coherent states is intrinsically limited by the **shot noise**, which is inherited from the Poissonian statistics of the impinging photons. As a result, cooling levitated objects to their ground state remains a formidable task [2]. Interestingly, recent works in the field of **quantum imaging** have demonstrated that the performances of coherent light can be outperformed by quantum light. For instance, shot noise can be **suppressed using pairs of entangled photons** [3]. There, a photon of the pair (the signal) serves to image a target, while the second one (the idler) serves as a reference. As shot noise identically affects both photons, subtracting signal and idler suppresses the shot noise, while leaving the image of the target untouched.

In this internship, the candidate will experimentally harness pairs of entangled photons to monitor for **the first time the motion a levitated nano-particle below the quantum shot-noise limit**. Specifically, the student will first **develop a source of entangled-photon pairs** [4] and then **deploy it in a levitation setup** to **cool levitated nano-objects towards their motional quantum ground state**. As part of this internship, the student will visit the team of Pr. Gabriel Molina (San Sebastian, Spain) to characterize the photon source. Following the internship, the candidate will be offered a **PhD in cotutelle between the teams of Nicolas Bachelard (France) and Gabriel Molina (Spain).** Cotutelle PhDs correspond to prestigious programs, in which the student shares his or her time between both institutions and is ultimately delivered a PhD from both Universities (i.e. Bordeaux and San Sebastian).

[1] Millen *et al.*, Reports on Progress in Physics (2020).
[2] Magrini *et al.* Nature (2021).
[3] Brida *et al.* Nature Photonics (2010).
[4] Büse *et al.* Physical Review Letters (2018).