Master 2 Internship

Title: Simultaneous cooling of degenerate optomechanical modes.

Type: Experimental

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PhD funding (if any): PhD funding available

Project: Optomechanics explores the interaction between light and mechanical vibrations [1]. As a typical example, one can consider a Fabry-Perot cavity (i.e., optical mode), in which one of the two mirrors is vibrating (i.e., mechanical mode). These devices serve as invaluable platforms for studying macroscopic quantum **phenomena** such as macroscopic quantum coherence and classical-to-quantum transition. In particular, macroscopic quantum entanglement involving two massive oscillators has recently been observed in optomechanical platforms [2]. Practically, the applicability of modern quantum technologies in optomechanical networks ultimately requires **quantum entanglement of light and many vibrations**—i.e., multiple degenerate mechanical modes (i.e., same frequency) used as nodes of the network [3].

To display quantum properties, a mechanical mode must be **cooled down close to its ground state** (i.e., down to a few quanta of vibrational energy), which is typically achieved by leveraging the optical field. Sadly, when considering multiple degenerate modes, one cannot apply conventional cooling techniques that have been devised for single modes. There, the challenge originates from the emergence of **dark modes** (i.e., hybridization of degenerate modes), which are decouple from the optical field and cannot be cooled (thus precluding any quantumness)[4].

Throughout this internship, the candidate will experimentally implement a new cooling technique intended to achieve the **first-ever cooling of degenerate mechanical modes**. Compared to former strategies, here, a spatial light modulator is used to spatially shape the wavefront of the light beam. Such a modulation enables to exert simultaneously adapted optical forces on each mode in order to reduce (i.e., cool) their individual vibrations. The student will be closely guided by the advisor and will acquire both theoretical and experimental skills on **optomechanics**, **quantum physics** and **spatial modulation techniques**. **A funding is available to continue and expand this internship through a PhD**.

[1] Aspelmeyer *et al.*, Rev Mod Phys, 2014
[2] Riedinger *et al.*, Nature, 2018
[3] Kimble, Nature, 2008
[4] Lai *et al.*, Phys Rev Letters, 2022