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Optomechanical response of rare earth ion doped hybrid systems

Description of the scientific project:

Quantum hybrid mechanical systems investigate the interactions between a quantum degree of freedom (a qubit) and macroscopic mechanical motion. The main idea behind this concept is to **create an interface between the quantum and the classical domains**, with the general perspective to experimentally extend quantum foundational principles at the macroscopic scale. Since its emergence 20 years ago, quantum hybrid optomechanical science has witnessed remarkable progress, in the microwave regime. Concurrently, only a few approaches have successfully addressed hybrid mechanical coupling in the optical domain yet with coupling strengths remaining **far below the conditions for coherent quantum-mechanical interaction.** This is mainly because of the **very short lifetime of the optical emitters used so far**, imposing coupling rates which presently appear out of reach. **Our project tackles this very issue**, by relying on the unique coherence properties of the strain-induced optomechanical coupling in rare-earth ion doped crystals (see Fig. 1(a – b)). With optical decoherence rates in the kHz range, **we notably expect strain coupling to operate deep into the strong coupling regime,** provided large enough zero-point motion levels, which we will achieve by **engineering micro and nanomechanical structures**.

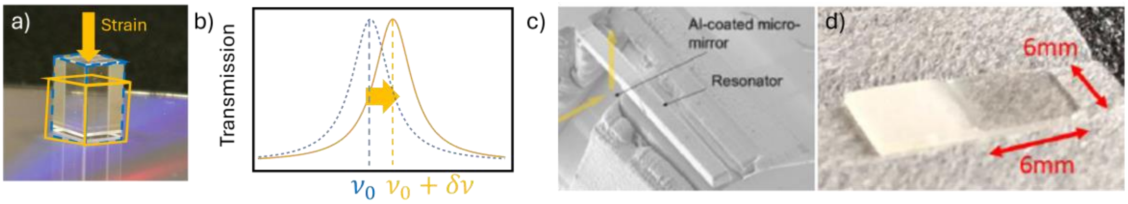

Figure 1 (a – b) Optomechanical coupling in rare-earth ion doped hybrid systems. A strain is applied to the crystal, resulting in a spectral shift of the ions transitions. (c) SEM image of a 100 µm-long Eu:YSO resonator etched by FIB in a single crystal. (d) Photograph of the 350µm-thick Eu:YSO plate.

The internship will be based in the 505 building of the LuMIn lab, and will focus on building a ultra-sensitive interferometer enabling to monitor both the acoustic and backaction response of rare earth ion based mechanical structures with various architectures (see examples in Fig. (c-d)). This work and may be continued in the frame of collaborative project jointly funded with CNRS NPSC group (Grenoble), IRCP, the SYRTE and Institut Langevin (Paris), with one of the aims being to **demonstrate coherent transfer of quantum states over mechanical degrees of freedom**.

Methods and techniques: Optomechanics; Rare-earth spectroscopy; Quantum hybrid systems

Possibility to continue as a PhD student ? YES

PhD grant available ? YES