Towards strain-coupled optomechanics with rare-earth doped crystals

S. Seidelin[a,e*], N. Galland[a], N. Lucic[b], S. Piccolomo[b], H. Alvarez-Martinez[b], R. Le Targat[b], A. Ferrier[c,d], J.-F. Motte[a], B. Fang[b], P. Goldner[c], Y. Le Coq[b,]

a. Université Grenoble Alpes and CNRS, Institut NEEL, F-38042 Grenoble,
b. LNE-SYRTE, Observatoire de Paris, Université PSL, CNRS, Sorbonne Université, 61 avenue de l'Observatoire 75014 Paris
c. Université PSL, Chimie ParisTech, CNRS, Institut de Recherche de Chimie Paris, 75005, Paris,
d. Sorbonne Université, 75005, Paris, France
e. Institut Universitaire de France, 103 Boulevard Saint-Michel, F-75005 Paris, France

* signe.seidelin@neel.cnrs.fr

An exciting challenge of modern physics is to investigate the quantum behavior of a bulk "material" object - for instance a mechanical oscillator - placed in a non-classical state. One major difficulty relies in interacting with the mechanical object without perturbing with its quantum behavior. An approach consists of exploiting a hybrid quantum system consisting of a mechanical oscillator coupled to an atom-like object, and interact via the atom-like object. A particularly appealing coupling mechanism between resonator and "atom" is based on material strain. Here, the oscillator is a bulk object containing an embedded artificial atom (dopant, quantum dot, ...) which is sensitive to mechanical strain of the surrounding material. Vibrations of the oscillator result in a time-varying strain field that modulates the energy levels of the embedded structure. We have recently suggested to use rare-earth doped crystals for strain-coupled systems [1]. More concretely, we are currently studying an yttrium silicate (Y2SiO5) crystal containing a triply charged europium ion (Eu3+), which is optically active. The reason behind this choice stems from the extraordinary coherence properties of this dopant, combined with its high strain-sensitivity: the Eu3+ in an Y2SiO5 matrix has an optical transition with the narrowest linewidth known for a solid-state emitter [2], and the transition is directly sensitive to strain [3]. We have successfully fabricated mechanical resonators (see figure1), designed and set up the experiment, and achieved a signal-to-noise ratio compatible with the planned measurements [4]. We have recently obtained measurements of the frequency sensitivity the europium ions of uniaxial stress applied to the bulk crystal, and are currently starting to investigate the resonator shown in figure 1.

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[3] M. J. Thorpe et al., Frequency stabilization to 6 x10-16 via spectral-hole burning, Nature Photonics, 5, 688 (2011)

[4] O. Gobron et al, Optics Express, 15539, 25 (2017)