TOWARDS STRAIN-COUPLED OPTOMECHANICS WITH RARE-EARTH DOPED CRYSTALS

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A 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 suggested to use rare-earth doped crystals for strain-coupled systems [1] and proposed a mechanism to cool down the resonator [2]. More concretely, we are currently studying an yttrium silicate (Y_2SiO_5) crystal containing a triply charged europium ion (Eu^{3+}), 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 Eu^{3+} in an Y_2SiO_5 matrix has an optical transition with the narrowest linewidth known for a solid-state emitter [3], and the transition is directly sensitive to strain [4]. We have succesfully fabricated mechanical resonators, designed and set up the experiment, and achieved a signal-to-noise ratio compatible with the planned measurements [5], as well as measured the strain sensitivity of europium ions in bulk Y_2SiO_5 crystals. Finally, the rare-earth doped crystals can also be used for laser stabilization for metrology applications, and this aspect will also be briefly discussed in the talk.

[1] K. Mølmer, Y. Le Coq and S. Seidelin, *Dispersive coupling between light and a rare-earth ion doped mechanical resonator*, Phys. Rev. A 94, 053804 (2016)

[2] S. Seidelin, Y. Le Coq and K. Mølmer, *Rapid cooling of a strain-coupled oscillator by optical phaseshift measurement*, arXiv:1905.04044 (2019)

[3] R. Yano, M. Mitsunaga, and N. Uesugi, *Ultralong optical dephasing time in* $Eu^{3+}:Y_2SiO_5$, Optics Letters, **16**, 1884 (1991)

[4] M. J. Thorpe *et al.*, *Frequency stabilization to 6 x10*$^{-16}$ *via spectral-hole burning*, Nature Photonics, **5**, 688 (2011)

[5] O. Gobron *et al.*, *Dispersive heterodyne probing method for laser frequency stabilization based on spectral hole burning in rare-earth doped crystals*, Optics Express, 25, 15539 (2017)

REMEMBER

Towards strain-coupled optomechanics with rare-earth doped crystals

Friday, 21 June 2019 – 2:30pm

Place: ICN2 Seminar Hall

Invited by: **Dr Klaas – Jan Tielrooij**