Pierre Verlot (ILM, Lyon)
Séminaire le 12/07 à 14h (Bâtiment 36 salle TD36.106)
l'Optomécanique Quantique

Quantum optomechanics at room temperature: A nanomechanical endeavour?

Optomechanics is the field investigating the reciprocal interaction between electromagnetic and mechanical degrees of freedom1.

Recently, impressive progress has been accomplished in the field, notably with the demonstration of multiple systems operating in the quantum regime of the optomechanical interaction2–4. This in great part relies on the extreme miniaturization of the mechanical devices, which enables drastic decrease of the thermal noise, at the benefit of quantum effects5,6.

So far however, the quantum regime of the optomechanical interaction has essentially been evidenced at liquid helium temperature or below and remains remote to ambient conditions. In this talk, I will present novel approaches raising the realistic perspective of operating optomechanical systems deep in the quantum regime and at room temperature. I will primarily focus on the fabrication and optomechanical characterization of a novel hybrid carbon nanotube-based approach7–9 which is found to a record low thermal force noise at room temperature, while fully preserving sensing capabilities. I will also discuss the role of non-linearities and corresponding sensing limitations for the sensitivity of those devices at ambient temperature. Last, I will introduce recent results on a novel quantum hybrid optomechanical approach, based on the use of gram-scale rare-earth ion doped crystal10,11, which appears very promising as for reaching the quantum regime at room temperature and under very robust conditions12.

References

1. Aspelmeyer, M., Kippenberg, T. J. & Marquardt, F. Cavity optomechanics. Reviews of Modern Physics 86,1391,(2014).
2. Chan, J. et al. Laser cooling of a nanomechanical oscillator into its quantum ground state. Nature 478, 89–92 (2011).
3. Purdy, T. P., Peterson, R. W. & Regal, C. A. Observation of radiation pressure shot noise on a macroscopic object. Science 339, 801–804 (2013).
4. Riedinger, R. et al. Remote quantum entanglement between two micromechanical oscillators. Nature 556, 473–477 (2018).
5. Moser, J. et al. Ultrasensitive force detection with a nanotube mechanical resonator. Nature nanotechnology 8, 493–496 (2013).
6. Moser, J., Eichler, A., Güttinger, J., Dykman, M. I. & Bachtold, A. Nanotube mechanical resonators with quality factors of up to 5 million. Nature nanotechnology 9, 1007–1011 (2014).
7. Tsioutsios, I., Tavernarakis, A., Osmond, J., Verlot, P. & Bachtold, A. Real-time measurement of nanotube resonator fluctuations in an electron microscope. Nano letters 17, 1748–1755 (2017).
8. Tavernarakis, A. et al. Optomechanics with a hybrid carbon nanotube resonator. Nature communications 9, 1–8 (2018).
9. Gruber, G. et al. Mass sensing for the advanced fabrication of nanomechanical resonators. Nano letters 19, 6987–6992 (2019).
10. Louchet-Chauvet, A., Ahlefeldt, R. & Chanelière, T. Piezospectroscopic measurement of

high-frequency vibrations in a pulse-tube cryostat. Review of Scientific Instruments 90, 034901 (2019).
11. Louchet-Chauvet, A. & Chanelière, T. Limits to the sensitivity of a rare-earth-enabled cryogenic vibration sensor. arXiv preprint arXiv:2112.03713 (2021).
12. Louchet-Chauvet, A., Verlot, P., Poizat, J.-P. & Chanelière, T. Optomechanical backaction processes in a bulk rare-earth doped crystal. arXiv preprint arXiv:2109.06577 (2021).