Nanooptomechanical sensing of carbon nanotube-based resonators

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Carbon nanotubes have recently been shown to be the most sensitive nanomechanical transducers. Their extremely low mass make them an exceptionally good sensor allowing the detection of forces at the 10 zN level[1] and single-proton resolution mass spectroscopy[2]. However, these performances remain confined to cryogenic temperatures, where their exquisite nanomechanical properties are typically 4 to 5 orders of magnitude better than in ambient conditions. In this paper we present our first experimental results towards the exploration of nano-optomechanical detection in the limit of a weak optical coupling at room temperature.

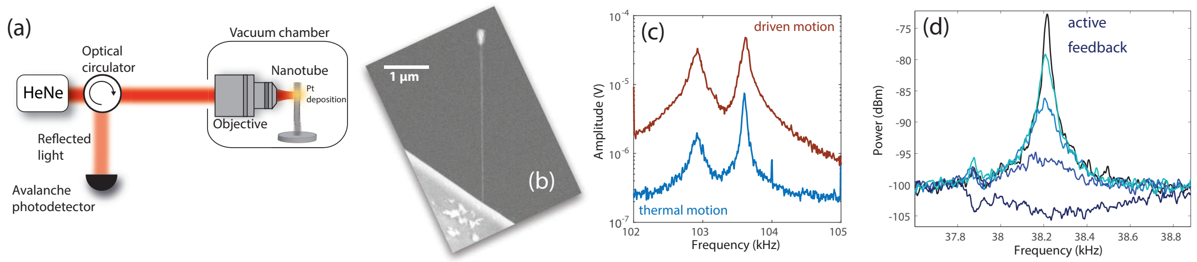

Fig. 1 – **Measuring carbon nanotube-based resonators :** (a) SEM picure of a Pt nanoparticle deposited on the edge of a carbon nanotube. (d) Experimental setup. (c) The in-plane, out-of-plane fundamental vibrational modes (blue) and their mechanical response (red). (d) Using active-feedback to damp the mechanical motion.

The detection of nanometer-scale object using optical means represents an experimental challenge because the overlap with the laser beam is limited by the diffraction limit. Our optical experimental setup is based on a non-invasive, ultra-sensitive nano-optomechanical detection method[3] (see Fig. 1(a)). We approached the problem of the very low photon scattering rate by depositing, in a controlled way, a good scatterer on its edge. We have used a Scanning Electron Microscope (SEM) equipped with a gas injection system and deposited a Pt nanoparticle on a 3.8-μm long carbon nanotube (see Fig. 1(b)). We provide a full mechanical characterization and calibration of the resonator (Fig. 1(c)) while light-induced dynamical back-action effects are measured. Furthermore, active control of the nanoresonator motion is assured by a combination of analog and digital feedback electronics ; active feedback cooling has been achieved by means of a piezoactuator mechanically coupled to the nanoresonator (Fig. 1(d)) while

This work can pave the way towards ultra-sensitive force measurements, observation of quantum back-action effects while Magnetic Resonance Force Microscopy (MRFM) can also be envisioned.

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1. J. Moser et al, Nature nanotechnology 8, 493-496 (2013)
2. J. Chaste et al, Nature nanotechnology 7, 301-304 (2012)
3. A. Gloppe et al, Nature nanotechnology 9 (2014)