Cavity Optomechanics With Photonic Crystal Nanomembrane

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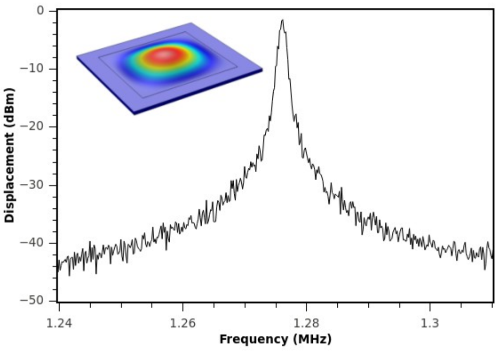
Optomechanical system have first appeared in the context of interferometric gravitational-wave detectors where quantum effects must be taken into account to reach the sensitivity required to observe such astrophysical events. From this starting point several mechanical resonators and optical cavities, involving wide range of sizes and materials, have been developed to reach the level of quantum effects. To overcome the prominent dissipation sources, mechanical quality factor and finesse of the optical cavity have been widely increased. Over the past ten years, applications spread out of the gravitational-wave field, leading to the coupling of such quantum mechanical systems to well controlled quantum systems such as atomic clouds, or Josephson circuits [1].

In this direction we have developed a suspended nanomembrane (30x30x0.26µm³) made of Indium Phosphide which exhibits a high dynamic (100 pg) with nonlinear behaviour [2], a reflectivity as high as 99.6% under normal incidence, thanks to a well designed photonic crystal [3,4], and reasonable mechanical quality factor (10000). To reach the quantum ground state our resonator needs to have its temperature under the quantum level, corresponding to 50 µK, this will be provided by the combination of cryogenic cooling and active feedback techniques [5]. To do so a feeding back loop have been settled and a efficient way of actuation of the resonator has been developed using a capacitive coupling, (see inset figure 2).



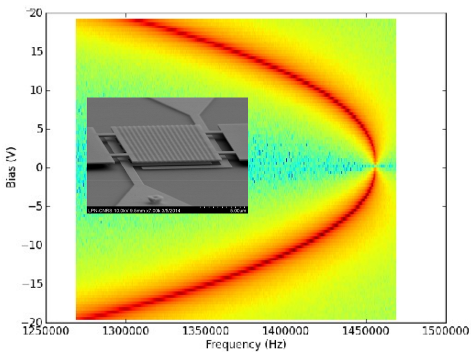


Fig. 1 a. Thermal spectrum of the nanomembrane set up in a Fabry-Perot cavity, inset : shape of the corresponding vibration mode. b. Mechanical response of the resonator under capacitive coupling for different bias values, inset : MEB view of the system.

This new actuation/sensing is based on the capacitive coupling between the dielectric membrane and inter-digitized electrodes : the motion of the membranes change the capacitance whereas the applied voltage sets the membrane in motion. We characterize for different geometries the coupling constant of this system and optimize it. We have observed the electrostatic spring effect on the membrane frequency, (see figure 2), which correspond to a quadratic bias dependency of the mechanical frequency and a widening of the response, corresponding to some dissipation introduce by the electric resistivity of the circuit. This capacitor will soon allow the coupling of our resonator to a radio-frequency circuit [6].

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