Nonlinear frequency transduction of nanomechanical Brownian motion

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Fluctuations in nanomechanical systems are of primary interest since they address both applied and fundamental issues. On one hand, an electromechanical function (e.g. transducing force into voltage) will have its characteristics impacted if amplitude and/or phase noise are present. On the other hand, a nanomechanical system is a model anharmonic resonator dissipatively coupled to a thermal bath, hence experiencing thermal fluctuations in position as well as nonlinear dispersive coupling between modes. Here we will discuss experiments realized with simple beam-based nonlinear NEMS devices where a controlled injected force noise mimics the thermal bath. Through the nonlinear interaction, position fluctuations of an out-of-equilibrium mode of the structure create phase diffusion of another. We highlight two limit behaviors, analogous to motional narrowing and inhomogeneous broadening in NMR. Their onset is determined by the correlation time of the nonlinearly induced frequency fluctuations. The results[1] are in very good agreement with a theoretical model encompassing both limits, based on a path integral method of averaging over the frequency fluctuations[2]. Evidence of back action on the fluctuations through strong driving is also addressed. We finally discuss quantitatively the ultimate limit on frequency resolution set by this intrinsic transduction mechanism, which is not marginal for bottom-up type devices.

[1]O. Maillet et al. (ArXiv)
[2]Y. Zhang and M. I. Dykman, Phys. Rev. B 92, 165419 (2015)