Sympathetic cooling of an LC-circuit in an electro-optomechanical system assisted by optical feedback

Francesco Marzioni[1,2,3], **Riccardo Natali**[1,2], **Nicola Malossi**[1,2], **David Vitali**[1,2,4], **Giovanni Di Giuseppe**[1,2], **Paolo Piergentili**[1,2]

1. *University of Camerino, School of Science and Technology, Section of Physics, Via Madonna delle Carceri 9b, 62032 Camerino (MC), Italy*
2. *INFN, Sezione di Perugia, 06123 Perugia (PG), Italy*
3. *University of Napoli "Federico II", Physics Department, 80126 Napoli (NA), Italy*
4. *CNR-INO, L.go Enrico Fermi 6, 50125 Firenze (FI), Italy*

Abstract: We present the theoretical description of an electro-optomechanical system assisted by optical feedback for the sympathetic cooling of a radio-frequency LC-circuit, even at its quantum ground state, for applications in quantum technologies.

Nano-electro-optomechanical systems play a fundamental role in quantum technologies [1-3]. In particular, electro-optomechanical devices have received significant attention in transducing radio-frequency (rf) and microwave signals to the optical domain [4,5]. Most of the electro-optomechanical systems use a gigahertz microwave resonator. However, the possibility of operating in a quantum regime at the megahertz, and even kilohertz range, with extremely low noise, can be advantageous for positioning, timing, and sensing applications, and for more fundamental science applications, such as the sensitive detection of rf signals of astrophysical nature. Unfortunately, due to the low (megahertz) resonance frequency of the rf resonator, operation in the quantum domain is difficult because the LC resonator is normally in a thermal state even at ultracryogenic temperatures.

In this talk we will present a theoretical model for sympathetic cooling of a macroscopic radio-frequency LC electrical circuit by means of an electro-optomechanical system, consisting of an optical cavity dispersively coupled to a nanomechanical oscillator, which is, in turn, capacitively coupled to the LC-circuit of interest [6]. The driven optical cavity cools the mechanical resonator, which, in turn, sympathetically cools the LC circuit. Moreover, we will discuss optical feedback assistance as a strategy to improve the cooling performance of the system, as shown in Fig. 1, allowing low occupation number for experimentally achievable parameters, which is a fundamental requirement for operating the system in the quantum regime.

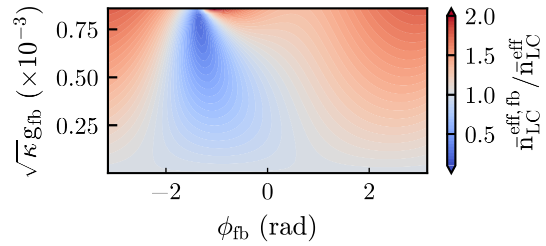

Fig. 1 Ratio between the occupation number of the LC resonator with the optical feedback and without the feedback action, represented with colors, as a function of the feedback filter gain and phase on the vertical and horizontal axis, respectively. The blue color indicates the region where the sympathetic cooling of the LC-circuit is improved.

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