Dynamical Casimir Effect in Optomechanical systems: Fully Quantum and Non-Perturbative Description

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This talk will provide a summary of some recent developments on the theory of the Dynamical Casimir Effect [1-4]. We studied this effect in optomechanical systems by using a fully quantum-mechanical and non-perturbative description of both the cavity field and the oscillating mirror [1]. Within this approach, we showed that the resonant generation of photons from the vacuum is determined by a ladder of mirror-field vacuum Rabi splittings. Moreover, we showed that vacuum emission can originate from the free evolution of an initial pure mechanical excited state, in analogy with the spontaneous emission from excited atoms [1,2]. This study also shows that a resonant production of photons out of the vacuum can be observed even for mechanical frequencies lower than the cavity-mode frequency [1]. We will also present results on the quantification of the entanglement between the oscillating mirror and the radiation produced by its motion in the vacuum field.

We also explored the dynamical Casimir effect under incoherent excitation of the mirror [2], and in the presence of a squeezed vacuum [4].

Finally, we will show how virtual photon pairs can mediate the coherent interaction of mechanical oscillators [3]. This process shows that the electromagnetic quantum vacuum can transfer mechanical energy somewhat like an ordinary fluid. Moreover, we showed that this system can also operate as a mechanical parametric down-converter even at very weak excitations.

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