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Spontaneous emission, superradiance and subradiance of atoms in dynamical environments

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It is well known that a structured environment such as a cavity, a mirror or a photonic crystal, can strongly affect radiative properties of atomic systems, for example the spontaneous emission process by single atoms or the cooperative spontaneous emission (superradiance or subradiance) by multi-atom systems. Recently, much interest has been devoted in investigating the effects of a dynamical (i.e. time-dependent) environment (for example oscillating cavities, dynamical mirrors or dynamical photonic crystals, that is photonic crystals whose dielectric properties change on time) on radiative properties of atoms or molecules placed nearby. These investigations are also related to the so-called Dynamical Casimir effect. In this talk, we discuss how the adiabatic motion of a perfectly conducting plate can affect the spontaneous emission of an atom nearby, or the cooperative spontaneous emission of two identical atoms, prepared in a correlated (symmetric or antisymmetric) state, placed near the oscillating mirror.

We first consider one atom, prepared in an excited state, and interacting with the quantum electromagnetic field in the vacuum state, in the presence of an oscillating perfectly reflecting mirror. We suppose that the perfectly reflecting plate oscillates adiabatically. Using perturbation theory, we evaluate the transition rate to the ground-state and the emitted spectrum. We show that the presence of the oscillating mirror changes the physical features of the spontaneous emission by the atom, in particular the emitted spectrum. In particular, we find the appearance of two lateral peaks in the spectrum separated from the central peak by the modulation frequency, not present in the case of a static mirror, due to the presence of the modulated environment [1]. Also, we briefly discuss the spontaneous emission of an excited atom placed inside a photonic crystal with time-dependent properties (dynamical photonic crystal) [2]. We finally consider two identical atoms, one in the ground state and the other in the excited state, prepared in a correlated (symmetric or antisymmetric) *Bell-type* state, and placed near an oscillating mirror. We evaluate the transition rate to the collective ground state of the two-atom system in both cases of the superradiant (symmetric) and subradiant (antisymmetric) state. We show that the presence of the oscillating mirror significantly affects the physical features of the superradiant and subradiant emission by the two correlated atoms, that can be enhanced or inhibited compared to the case of atoms in vacuum space or near a static boundary [3].

These results indicate that dynamical environments can be exploited to manipulate and control the radiative properties of atoms or molecules embedded in.

References

[1] A. Ferreri, M. Domina, L. Rizzuto, R. Passante, Symmetry, **11** 1384 (2019)
[2] G. Calajò, L. Rizzuto, R. Passante, Phys. Rev. A, **96** 023802 (2017)
[3] M. Reina, A. Ferreri, M. Domina, A. Noto, G. Fiscelli, L. Rizzuto, R. Passante, Phys. Rev. A **103**, 033710 (2021)