Spontaneous Emission in 2D Arbitrary Inhomogeneous Environment

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Abstract— Control of spontaneously emitted light lies at the heart of quantum optics. It is essential for diverse applications ranging from lasers, light-emitting diodes, solar cells, and quantum information. According to the quantum electrodynamics theory, the spontaneous emission (SE) of an atom can be a weak-coupling radiation process due to the vacuum fluctuations of electromagnetic field. A suitable modification of inhomogeneous environment is required so that the vacuum fluctuations controlling the SE can be manipulated. Inhibiting unwanted SE and boosting desired ones will promote the novel optoelectronic designs tailored to industrial standard. The local density of states (LDOS) counts the number of electromagnetic modes where photons can be emitted at the specific location of the emitter, and can be interpreted as the density of vacuum fluctuations. The inhibition or enhancement of SE boils down to how the LDOS of photons is controlled.

In this work, the SE of the excited atoms in 2D arbitrary inhomogeneous environment has been systematically studied. The LDOS determines the radiation dynamics of a point source (for 3D) or a line source (for 2D). In particular, it also determines the SE rate, and the LDOS is represented by the electric dyadic Green's function. The numerical solution of the electric Green's tensor has been accurately obtained by the finite-difference frequency-domain method with the proper approximations of the monopole and dipole sources. The SE of the atoms in the photonic crystal and plasmonic metal plates has been comprehensively and comparatively investigated. For both systems, the SE strongly depends on their respective dispersion relations and could be modified or tuned by the finite-structure or finite-size effects. This work is important for the SE engineering and optimized design of optoelectronic devices.