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Investigation of the output power spectrum of a driven Fabry-Perot cavity for the description of one-dimensional blackbody radiation

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Abstract
In this article, we want to describe the phenomenon of one-dimensional blackbody radiation by using the theory of quantum electrodynamics and the theory of open quantum systems in Heisenberg's picture. For this purpose, we consider a Fabry-Perot cavity, which is in thermal equilibrium with its environment at a certain temperature, while one of its longitudinal modes is optically pumped by an external laser. By writing the Heisenberg-Lanjevin dynamical equations for the longitudinal modes inside the cavity and solving them, we obtain the time evolution of the internal optical field in the steady state. Then, using the input-output theory in quantum optics, we obtain the optical field of the cavity output in the steady state and calculate the power spectrum of the cavity output from that. The result appears as the sum of a coherent part and an incoherent part in the output power spectrum, where the former is related to the mean field and the latter is related to the quantum fluctuations of the field inside the cavity, which is the source of thermal radiation. Finally, we show that in the continuum limit, the quantum fluctuations of the cavity output lead to the emergence of the one-dimensional Planck spectrum, which at the low-frequency limit leads to the one-dimensional form of the Rayleigh-Jeans relation. Then, by calculating the total output energy density, we obtain the Stefan-Boltzmann law for one-dimensional blackbody radiation.

Keywords: black body radiation, quantum electrodynamics, theory of quantum dissipation

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