Microscopic dynamical Casimir effect

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Using a quantum-optical approach, we study the radiation emitted by a ground state atom undergoing a non-relativistic oscillation in free space. This problem can be seen as the microscopic analogue of a dynamical Casimir effect (DCE) [1]. This effect is usually treated by means of constitutive equations for the field operators complemented by boundary conditions on macroscopic bodies set in motion. In the same spirit of the Ewald-Oseen microscopic approach [2] to classical electrodynamics, our main purpose is to gain insight into the physics of the DCE at the more fundamental atomic level and identify possible universal features of this effect.

We show that the interaction of the ground-state oscillating atom with the electromagnetic quantum vacuum induces two effects to leading order in perturbation theory. When the mechanical frequency is larger than the atomic transition frequency, the dominant effect is the motion-induced transition to an excited state with the emission of a photon carrying the excess energy. We obtain the angular distribution of the emitted photons as well as the excitation rate. On the other hand, when the mechanical frequency is smaller than the transition frequency, the leading-order effect is the parametric emission of photon pairs, which constitutes the microscopic counterpart of the dynamical Casimir effect. This process is similar to the parametric downconversion used in nonlinear crystals. We discuss the properties of this microscopic dynamical Casimir effect and build a connection with the photon production by an oscillating macroscopic metallic mirror.