Comment on “Enhancing Acceleration Radiation from Ground-State Atoms via Cavity Quantum Electrodynamics”

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Scully et al. [Phys. Rev. Lett. 91, 243004 (2003)] have recently proposed a scheme to enhance the radiation emitted when ground-state atoms are accelerated through a high Q cavity. There are a few basic points which are not so well expounded and concepts not so well differentiated in this paper, which may mislead readers into believing that this proposed scheme will improve the chance of detecting Unruh effect (Ref. [1] in Scully et al.). One simple fact to bear in mind is that Unruh effect is not about radiation emitted by an accelerated detector (e.g., a two-level atom) and the key issue to recognize is that there is a basic difference between the thermal distribution in the cavity when injecting a large number of atoms at random times (as claimed by Scully et al.), and the thermal bath experienced by an atom undergoing uniform acceleration (as in Unruh effect).

1) There is no radiation emitted by a uniformly accelerated detector/atom. Unruh effect attests to the fact that a uniformly accelerated detector perceives the quantum fluctuations of the vacuum in Minkowski spacetime as a thermal bath. No direct reference is made to radiation emitted by the detector. In fact, when a detector is uniformly accelerated in free space for a sufficiently long time and the field-detector interaction is adiabatically switched on and then adiabatically switched off after a given period of time, there is no energy flux emitted by the detector during that period, just a modification of the vacuum polarization. (At least when the quantization of the translational motion and recoil effect are neglected, as done by Scully et al.).

2) When the atoms are accelerated inside the cavity, they no longer perceive the vacuum fluctuations as a thermal bath. In the presence of a cavity, the mode spectrum of the electromagnetic field inside the cavity is no longer Lorentz invariant. Stationarity of the vacuum fluctuations perceived by the uniformly accelerated atom in Unruh effect requires Lorentz invariance of the vacuum state. Therefore, the vacuum fluctuations experienced by an accelerated atom inside a cavity is not stationary and the motional effect therein does not correspond to that of a thermal bath.

3) The thermal distribution of photons in the cavity is not in one-to-one correspondence with that of the Unruh effect. In the scheme of Scully et al. there is some probability for the cavity mode to become excited when an atom is accelerated inside the cavity. If the atom-field interaction is somehow switched on adiabatically, the ratio of the emission and absorption coefficients is exponentially suppressed by the Boltzmann factor for a temperature $T = h\alpha/(2\pi k_B)$, which coincides with the temperature of the thermal bath perceived by a uniformly accelerated atom in free space with the same acceleration. The reason for such a coincidence can be understood qualitatively as follows: in the “golden rule” limit (large $T$ with finite $g^2T$) one can show that the ratio of excitation and de-excitation of a two-level atom with characteristic frequency $\omega$ induced by each inertial mode in free space is given by the same Boltzmann factor $\exp(-2\pi\omega/\alpha)$. Nevertheless, this is not the same thermal distribution as in the Unruh effect. For one reason, the atoms accelerated inside the cavity are not in thermal equilibrium. For another, the thermal population of photons in the cavity results from statistically independent events as a result of injecting a sufficient number of atoms at random times.

4) The great enhancement in the emission-absorption ratio appears in a regime dominated by a phenomenon unrelated to the accelerated motion of the atoms. Injecting the atoms into the cavity at some initial time is effectively equivalent to a sudden switch-on of the atom-field interaction. In that case, the emission-absorption ratio is enhanced. In particular, in the regime $\nu \gg \omega \gg \alpha$, it is given by $R_2/R_1 \simeq \alpha/(2\pi\omega)$. As recognized by Scully et al., this is entirely due to the nonadiabatic switch-on of the interaction. However, when the emission is dominated by the non-adiabatic switch-on, the acceleration no longer plays a crucial role. Indeed, in that regime the emission rate is $\lambda^2|I_2|^2 \simeq \lambda^2/\nu^2$ and is, thus, independent of the acceleration. It is true that the absorption coefficient still depends on the acceleration, but this is not essential. This point can be seen by considering the case in which the atoms are injected with constant velocity into the cavity. (Use the equation in Footnote [18] of Scully et al.). The essential features are then recovered without any need for an accelerated motion of the atoms.

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