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Comment on "Sonoluminescence as Quantum Vacuum Radiation"

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In a recent Letter [1] Eberlein proposed that the dynamical Casimir effect [2] or perhaps more properly the Unruh effect [3] could be responsible for the remarkable light emission during single-bubble sonoluminescence [4]. However, I believe that the effect proposed is far too small to account for the observation of something like a million optical photons per bubble collapse. This is supported by detailed calculations which will appear elsewhere [5]. Moreover, even the model profile given in [1], although implying supraluminal velocities, yields an energy output orders of magnitude too small. Although technical objections to [1] are given in [5], having to do with the force on a dielectric surface, I will concentrate here on the insufficiency of the energy radiated in such a model.

One would expect that the relevant time scales for a macroscopic, collapsing bubble to be much longer than the period of visible light, $t \sim 10^{-15}$ s. Indeed, the observed collapse time for sonoluminescing bubbles is $\sim 10^{-6}$ s, while the duration of the flash is $\lesssim 10^{-11}$ s. If that is the case, then an adiabatic approximation should be highly accurate. Statically, the quantum Casimir energy of electromagnetic field fluctuations in a bubble of radius $a \sim 10^{-4}$–10^{-3} cm in a liquid should be of order

$$E_c \sim \frac{\hbar c}{a} \sim 10^{-1}\text{eV}, \tag{1}$$

some 8 orders of magnitude too small to be relevant. In fact, putting in the numbers [5] reduces the energy by another 3 orders of magnitude. It should be emphasized that formally divergent results which are therefore highly sensitive to cutoffs [2,6] are not physically plausible.

A reliable estimate for the power radiated should be obtainable from the Larmor formula,

$$P = \frac{2}{3}\frac{(\ddot{d})^2}{c^3}, \tag{2}$$

where d is the dipole moment. A reasonable estimate for the latter is $d \sim ea$ (in fact, the short-wavelength limit given in [1] is equivalent to $d \approx ea\dot{a}/c$), so we would expect that the energy emitted during a flash of duration τ to be roughly

$$E \sim \alpha\hbar c\frac{a^2}{c^3\tau^3} \sim 10^{-44}\text{eVs}^3/\tau^3. \tag{3}$$

Even for τ as short as a femtosecond, only 10 eV of energy is radiated. An extraordinarily short time scale, $\tau \sim 10^{-17}$ s, is required to liberate 10^7 eV.

One would think such a time scale would imply supraluminal velocities, $a/\tau \sim 10^{13}$ cm/s. Indeed, the specific model proposed by [1] has precisely this feature, and even so yields only 10^3 eV of energy. But, it is possible to imagine that velocities could remain nonrelativistic while the acceleration, or the derivative thereof, becomes very large. Precisely such phenomena occur during the formation of a shock. Classical shock models of sonoluminescence have been proposed [7]. In this case, the radiation is supposed to be emitted by bremsstrahlung after ionization of the air in the bubble. Whether or not such a picture is viable, it is apparent that it has nothing to do with quantum radiation.

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