Can Sheared Surfaces Emit Light?

Kirk T. McDonald
Joseph Henry Laboratories, Princeton University, Princeton, NJ 08544
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1 Problem

In an article [1] with the above title,[1] it is claimed that the answer is yes. Can this be so?

2 Solution

Two colliding charged particles, such as electrons, can emit a Bremsstrahlung photon,

$$ee \to ee\gamma. \tag{1}$$

Here we consider two (neutral) macroscopic objects that pass very close to one another. This interaction perturbs the vacuum fluctuations of the electromagnetic field in their vicinity, and might result in the realization of one or more virtual photons. The perturbed vacuum fluctuations could also result in either or both of the colliding objects being excited (by, say, surface polarons), where the energy of these excitations comes from the initial kinetic energy of the system, with the result that the kinetic energies, and hence relative velocities, of the colliding objects are reduced, which effect has been called "quantum friction" [3]. Can instead the two objects remain in their ground states (in their respective rest frames) and their close passage result in a real photon in the final state?

We analyze this "collision" in the center of mass/energy frame of the system, where the center of mass/energy is defined to be at the origin. Then, the center of mass/energy of the final state must also be at the origin.

During the brief "collision" the velocities, but not the positions, of the centers of mass/energy of the two objects can change. Hence, the center of mass/energy of the system of two objects in the final state is also at the origin. There is, of course, an uncertainty of order $\hbar/M_{\rm total}c$ ($\approx 10^{-41}$ cm for $M_{\rm total} = 1$ g) in the position of this center of mass/energy. If a photon of energy $E_\gamma = \hbar\omega$ is emitted at position x_γ, then the center of mass/energy of the system of the two objects plus the photon is

$$x_{\rm CM} \approx \frac{x_\gamma E_\gamma/c^2}{M_{\rm total}} = \frac{x_\gamma \hbar\omega}{M_{\rm total}c^2} \approx \frac{x_\gamma}{\lambda}\frac{\hbar}{M_{\rm total}c} \tag{2}$$

Thus, the center of mass/energy of the final state is zero, to within the uncertainty $\hbar/M_{\rm total}c$, so long as the photon is emitted within one wavelength of the origin.

The length scale of the perturbations of the vacuum fluctuations by the passing objects is of order of the transverse distance $D_\perp$ between them. This sets the scale of the wavelength λ of possible final-state photons. In principle, optical photons could be emitted when neutral objects pass within ≈ 1 μm of each other.

[1]See also [2, 3]. Early works on this theme include [4, 5].

However, for this to happen, the photon must be emitted very close to the center of mass/energy of the "colliding" objects. How could the photon "know" where is this origin/center of mass/energy. The photon interacts electromagnetically, but the location of the center of mass/energy of the "colliding" objects is a property of their mass distribution, which couples to gravity, but not to electromagnetism.[2] Thus, we might wish to consider possible emission of gravitons rather than photons. Of course, the coupling of gravitons, and hence the possible rate of their emission, is very small.

Thus, it appears to this author that the electromagnetic interaction responsible for the possible emission of a real photon when two neutral objects pass one another does not couple to the information needed for that emission to take place. At the very least, the rate of emission of photons would be suppressed by a (phase space) factor of order $\lambda/L_{\rm object} \approx 10^{-4}$ for objects of lengths ≈ 1 cm that pass within 1 μm of each other.

In sum, the emission of optical photons when neutral, macroscopic objects (in their ground states) pass close to one another is heavily suppressed by a "phase space" factor associated with the requirement that the center of mass/energy of the final state be the same as that of the initial state.

If the objects were not in their ground states, but at, say, a nonzero temperature T, then emission of a photon might be associated with a reduction of the kinetic energy of a single (charged) lattice ion (and the point of emission of that photon localized to within ≈ 1 Å). Of course, there is a nonzero probability that such emission (a kind of Bremsstrahlung, which contributes to the "1/f" noise in resistors) takes place in a single object at "rest". Hence, the emission of photons by the realization of vacuum fluctuations near two passing, excited objects is only a small addition to a more "ordinary" phenomenon.[3]

References

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[2]Objects of the same chemical composition, but with different isotopes in their "left" and "right" halves would have the same electromagnetic properties, but differing centers of mass/energy.

[3]For another skeptical comment on this issue, see [6]. argumens in favor of the existence of "Casimir friction" are given in [7, 8].

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