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Comment on Lasetron

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Abstract

In a recent paper [1] Kaplan and Shkolnikov propose to generate intense ultra-short pulses of electromagnetic radiation in the range $\sim 10^{-21}$ s (zeptosecond) and large magnetic fields by using a petawatt electron laser irradiating a small solid particle or a piece of wire of a submicron size. In this comment we would like to point out that the method proposed in Ref. [1] will not achieve the desired results.

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In a recent paper [1] Kaplan and Shkolnikov propose to generate intense ultrashort pulses of electromagnetic radiation in the range $\sim 10^{-21}$ s (zeptosecond) and large magnetic fields by using a petawatt electron laser irradiating a small solid particle or a piece of wire of a submicron size. In this comment we would like to point out that the method proposed in Ref. [1] will not achieve the desired results.

It is assumed in Ref. [1] that under the influence of the circularly polarized laser field a microbunch of electrons will be formed with dimensions of order of the size of the solid particle. In a numerical example given in the paper, electrons are accelerated to the energy of ≈ 30 MeV rotating in a circular orbit of radius $r = 0.1$ μm and emitting synchrotron radiation with characteristic wavelength $\lambda \sim r/\gamma^3$ ($\lambda \equiv c/\omega$). The physics of radiation is the same as for an electron bunch in a synchrotron, the only difference being a minuscule scale of the orbit.

The authors claim that the duration of the pulse of the radiation will be given by their Eq. (1),

$$\tau_{pl} \sim 1/(2\omega_L \gamma^3), \tag{1}$$

where ω_L is the frequency of the laser. This however, is only true for the radiation of a *single electron*; for an electron cloud of size $\sigma > \lambda$ the superposition of radiated pulses from different electrons would result in the duration of the radiation pulse equal to

$$\tau_{pl} \sim \sigma/c. \tag{2}$$

For σ not much smaller than r, this is about 5 orders of magnitude larger than given by Eq. (1).

In another statement made in Ref. [1] it is claimed that the radiation of such bunch will be coherent and is given by Eq. (6), $P_{\text{rad}} = N_e^2 P_e$. Again, for the parameters of the electron bunch quoted in the paper this statement is not correct. Indeed, it is well known [2, 3] that a bunch radiates coherently at frequency ω only if it is confined within a coherence volume of the radiation $V_{\rm coh} = l_\perp \times l_\perp \times l_\parallel$. The transverse size of this volume is $l_\perp = \lambda/\theta$, where θ is the angular spread of the radiation, and the longitudinal size is $l_\parallel = \lambda$ (we assume a broadband radiation with $\Delta\omega \sim \omega$). For the synchrotron radiation $\theta \sim 1/\gamma$ and for 3 MeV photons with $\lambda = 5 \cdot 10^{-12}$ cm one finds for the coherence volume

$$V_{\rm coh} \sim 10^{-30}\ {\rm cm}^3. \tag{3}$$

Even assuming the electron density $n_e = 10^{24}$ cm^{-3}, we obtain that the average number of electrons in the coherence volume is equal to 10^{-6} which means that a microbunch of density n_e will have a volume many orders of magnitude larger than $V_{\rm coh}$. Hence, the radiation of such microbunch is *incoherent* and its power scales linearly with the number of electrons in the bunch, $P_{\rm rad} = N_e P_e$. This makes the discussion in the paper of the effects of coherent radiation force on the bunch dynamics irrelevant.

Finally, we would like to point out an important effect of the self field of the bunch on the electron motion. In the case when the bunch size is smaller, but comparable to the orbit radius, there is *no cancellation* between electric and magnetic forces of an ultrarelativistic beam which would otherwise result in the suppression of the Lorentz force by a well-known factor of γ^{-2}. Hence, if the self field of the beam exceeds the laser field, which keeps the electrons in the circular orbit, one can expect a strong perturbation of the electron motion, instability, and possible destruction of the beam. The authors, in the numerical example at the end of their paper, ignore this likely beam disruption and compute a magnetic field of $10^8 - 10^9$ G (which is an order of magnitude larger than the applied laser field).

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[3] Hung-Chi Lihn, SLAC Report SLAC-R-480, Section 1.1, unpublished, 1996.