Comment on “Intense Superradiant X Rays from a Compact Source Using a Nanocathode Array and Emittance Exchange”

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In Ref. [1] the authors proposed a novel and promising idea for generation of x-rays using microbunches produced by a nanocathode field-emission array. These microbunches are accelerated to relativistic energies and transported through an emittance-exchange unit which converts transverse density modulation into a longitudinal one. The beam is then collided with an infra-red laser pulse, where the microbunches radiate coherently thus considerably increasing the x-ray output from the system. Unfortunately, we found that the estimate in [1] of the number of photons radiated by the modulated electron beam has an error.

Radiation of a beam due to the inverse Compton scattering can be treated as undulator radiation with the number of periods N_u in the undulator equal to the number of periods in the laser pulse. Radiation intensity depends on the beam transverse size σ (σ is the rms beam size in each transverse direction). If σ is larger than the transverse coherence length $d = \sqrt{\lambda_x L_u/4\pi}$ (L_u is the undulator length and λ_x is the radiation wavelength), one has to use a 1D model. In this model the number of radiated photons is given by [2]

$$N_{\rm ph} = \alpha \frac{K^2}{1+K^2} b^2 N_e^2 \frac{N_u}{N_b} \frac{d^2}{\sigma^2}, \qquad (1)$$

where K is the undulator parameter, N_b is the number of the microbunches (equal to the bunch length divided by the radiation wavelength), b is the bunching factor, N_e is the total number of the electrons, and $\alpha = 1/137$ is the fine structure constant. Eq (1) is derived assuming $N_b \gg N_u$, which is approximately satisfied for the case considered in [1].

We now substitute in (1) parameters from [1]: $N_u = 190$, $N_b = 400$, $N_e = 10^7$, $b = 0.2$, $\lambda = 13$ nm, $K = 0.3$. For σ we use 3 microns (assuming that the source size in Table 1 of [1] is the rms transverse size of the beam matching the 6 microns laser waist for the laser with the wavelength $\lambda_L = 0.7$ microns). Eq. (1) then gives

$$N_{ph} = 1.7 \times 10^7, \qquad (2)$$

which is about 50 times smaller than the number $N_{ph} = 8.5 \times 10^8$ quoted in [1]. Note that the ratio σ/d for the used set of parameters is approximately equal to 8 and hence using the 1D model is justifiable.

We find that the error in [1] originates from a wrong estimate of the emission angle as $\Delta\theta = 1/(\gamma\sqrt{N_u + N_b})$. First, the number of microbunches N_b should not be involved in this estimate. For a bunch with a small transverse size, $\sigma \ll d$, this estimate should be $\Delta\theta = 1/(\gamma\sqrt{N_u})$. However, as mentioned above, for the parameters of [1], the opposite approximation is valid, $\sigma \gg d$. In this limit the emission angle is $\Delta\theta \sim \lambda_x/4\pi\sigma$. Using this angle with the estimate for the spectrum width $\Delta\omega/\omega \sim 1/N_b$ in Eq. (5) of [1] leads to the result which within a numerical factor would agree with our Eq. (1).

[1] W. S. Graves, F. X. Kärtner, D. E. Moncton, and P. Piot, Phys. Rev. Lett. **108**, 263904 (2012).
[2] E. Saldin, E. Schneidmiller, and M. Yurkov, Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment **539**, 499 (2005).

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