Comment on "Experimental Characterization of Superradiance in a Single-Pass High-Gain Laser-Seeded Free-Electron Laser Amplifier"

The authors report [1] on recent experiments on a free-electron laser (FEL) amplifier injected with a short pulse high power laser seed. They claim to have experimentally characterized, for the first time, superradiance in a single-pass high-gain laser-seeded FEL. We would like to make the following comments.

(1) The authors [1] write, "The term superradiance, originally coined by Dicke [13], was used to describe this pulse shortening regime in which the radiated FEL is proportional to the square of the number of electrons in a cooperation length, $L_c = \lambda/(4\pi\rho)$," referencing their [14]. This is not the definition of superradiant emission as defined in the authors' own references of [6–13, 15, 16], although we agree with the authors' definition of L_c as previously introduced in [6]. In these references superradiant emission is correctly defined when the radiated power is proportional to the square of the number of electrons, *irrespective* of the cooperation length. Using the authors' definition, the number of electrons in a cooperation length is

$$N_c \approx \frac{IL_c}{ec},$$

where I is the peak current and $L_c \propto \rho^{-1}$, where ρ is the FEL parameter [2]. Given that $\rho \propto I^{1/3}$, then $N_c \propto I^{2/3}$, so that if the superradiant radiation power, P_{SR}, were proportional to N_c^2, as the authors claim, then it follows that $P_{\mathrm{SR}} \propto I^{4/3}$. This scaling is inconsistent with all previous definitions of superradiance in which $P_{\mathrm{SR}} \propto I^2$. In fact, the authors' scaling is consistent with that of steady-state emission [3].

(2) The scaling of the radiation power as I^2, which would be the unquestionable proof of superradiance, appears not to have been investigated experimentally by the authors.

(3) From Eq. (1) of Ref. [1] the authors give scaling of the "superradiant" radiation pulse energy, E_{SR}, σ_{SR}, and power, P_{SR}, as power laws of the undulator length, z, in accordance with their Ref. [18]. This is not the scaling reported in [8] and [12] which they cite as reporting this scaling. In fact, the scaling reported in [8] and [12] is that of their Eq. (1) but with z replaced by $z_1 \propto (z - v_z t)$, a spatiotemporal variable. This is a fundamentally different scaling which the authors appear to have overlooked and failed to explain.

While we are not stating that superradiance has not occurred in the experiments reported in [1], we do claim that due to the absence of the experimental check of the I^2 dependence of radiation power and due to the inconsistencies in the definitions and analysis noted above, we believe the authors should reexamine their analysis to see if their claims are still warranted.

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[2] R. Bonifacio, C. Pellegrini, and L. Narducci, Opt. Commun. **50**, 373 (1984).
[3] After reading our Comment, the authors submitted an erratum [Phys. Rev. Lett. **98**, 189903 (2007)] in which the phrase "in a cooperation length, $L_c = \lambda/(4\pi\rho)$" contained in the above sentence is removed, so that the sentence should read, "The term superradiance, originally coined by Dicke [13], was used to describe this pulse shortening regime in which the radiated FEL power is proportional to the square of the number of electrons." However, we still remark that pulse shortening is not specifically related to superradiance, but it may be observed also in other optical systems.

