Reply to "Comment on 'Controlling the spectral shape of nonlinear Thomson scattering with proper laser chirping'"

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We reply to Terzic and Krafft's forgoing Comment [Phys. Rev. Accel. Beams, Comment on "Controlling the spectral shape of nonlinear Thomson scattering with proper laser chirping" **19** (2016)]. We disagree with the conclusion of the Comment regarding the novelty of solutions and the citations presented in our paper.

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The foregoing Comment by Terzic and Krafft [1] offers criticisms, which include the novelty of analytic solutions for control of Thomson scattering bandwidth and the citations presented in our recent paper [2]. We address these criticisms and, in particular, we document that the original manuscript contains appropriate citation of prior work and we highlight the distinction between our paper and previous work by the Comment authors.

Our paper [2] presents analytic solutions for use of laser pulse frequency variation with time, or chirping, to compensate nonlinear broadening of the Thomson scattering spectrum produced by intense laser pulses, as well as an analytic calculation of the spectrum. Chirp compensation was first proposed by Ghebregziabher, Shadwick, and Umstadter [3] based on numerical simulations. Later numerical calculations of the spectrum based on an exact chirp prescription followed in several papers, including the paper by the Comment authors [4].

The core assertion of the Comment, the first sentence of Sec. I, is that the equations in Ref. [2] "can be found" from an equation in Ref. [4]. However, the derivation presented in the Comment is not in fact presented in Ref. [4]. In contrast to the numerical spectrum calculations presented in Refs. [3,4], our paper [2] provides analytical calculations of the nonlinear Thomson scattering spectrum for both the unchirped and properly chirped cases. The calculation of the spectrum in Ref. [4] is numerical in the sense that the integrals Eqs. (2a) and (2b), must be evaluated using a "numerical method, based on 10^5–10^6 point Simpson integration". Analytic solutions of the Thomson scattering spectrum offer considerable descriptive power, which was the motivation for the analytic presentation in Ref. [2].

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The Comment also discusses the calculation of peak number. In Ref. [2] we presented a calculation of the peak number, that is approximate, as described appropriately in the paper. It is known from the literature that such peaks will be smeared out for realistic electron beam emittances, and hence an approximate calculation is appropriate to outline the shape of the nonlinear spectrum [5]. Exact analytical expressions can be found in papers by Hartemann *et al.* [6] and Seipt *et al.* [7]. The Comment authors present an alternate exact calculation which could more productively have been published as a journal article, properly acknowledging the earlier calculations in Refs. [6,7].

Both the original paper proposing the concept of chirp compensation [3] and the later paper by the Comment authors [4] were referenced in multiple locations in our paper with the clear intent of acknowledging that work. This includes a reference in Sec. III of our paper, as the Comment requests. The Comment argues that even more citations to the same work should have been included later in Sec. III when applying the method of stationary phase. However, using the stationary phase approach is a common mathematical method for the evaluation of integrals and, specifically, nonlinear Compton scattering calculations (e.g., Ref. [8]). Such a common mathematical method does not require additional citation.

In conclusion, the citations in our paper [2] explicitly and accurately describe the previous work as presented in the literature, including the limitations of the previous work, from which our paper started. The derivations and solutions presented in the Comment are not present in the prior work of the Comment authors [4] (or others). In contrast to the numerical calculation of the spectrum presented in Ref. [4], our work (further extended in Ref. [9]) presents analytical calculations, offering considerable descriptive power.

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