Comment on "Nonlinear Compton scattering in ultrashort laser pulses"

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(Received 8 August 2011; published 13 April 2012)

In a recent paper [Phys. Rev. A **83**, 032106 (2011)], Mackenroth and Di Piazza studied photoemission spectra of an electron driven by intense ultrashort laser pulses. Using kinematic principles, they argued that an electron experiences no mass dressing in an ultrashort pulse. They also proposed a method by which one might experimentally verify their claim. We argue that the scattering kinematics do not imply this conclusion nor do they justify the proposed experiment.

DOI: 10.1103/PhysRevA.85.046101 PACS number(s): 12.20.Ds, 42.65.Re

Mackenroth and Di Piazza [1], working in the Furry picture of quantum electrodynamics, recently studied the photoemission spectra of an electron in an intense ultrashort laser pulse. We comment on one aspect of their conclusions. At the onset of their calculation, they find that the scattering matrix element has the form

$$S_{fi} = (2\pi)^3 \delta^{(2)}(\mathbf{p}'_\perp + \mathbf{k}'_\perp - \mathbf{p}_\perp) \times \delta(\epsilon' + \omega' - \epsilon - (p'_3 + k'_3 - p_3)) M_{fi}, \tag{1}$$

where the electron energy is denoted by the symbol ϵ [2]. Primed quantities represent the final measured state. Noting that the kinematic δ functions depend only on the asymptotic electron momenta (rather than the dressed momenta), the authors conclude that the electron experiences no "mass shift" in an ultrashort pulse.

The authors then propose that adherence to the relation

$$\omega' = \frac{\epsilon - p_3 - (\epsilon' - p'_3)}{1 - \cos\theta} \tag{2}$$

signifies an absence of mass dressing (where θ is the polar angle at which the scattered photon is detected). Equation (2) is enforced by the second kinematic δ function of Eq. (1). To experimentally verify Eq. (2), one must measure the energy momentum of both the scattered photon and the scattered electron.

The above conclusion does not hold because Eq. (1) and therefore Eq. (2) apply equally well to monochromatic fields, where the well-known mass dressing is contained entirely in M_{fi}. It is significant that all dependence on $A(k \cdot x)$ is contained in the expression for M_{fi}. Starting from Eq. (1), the authors produce the full kinematics for the special case of a monochromatic wave [3]:

$$\delta^{(4)}(q'_\mu + k'_\mu - q_\mu - s k_\mu), \tag{3}$$

where s is an integer, and q_μ is the dressed momentum defined by

$$q_\mu \equiv p_\mu + \frac{e^2 \mathcal{A}^2}{4k \cdot p} k_\mu. \tag{4}$$

The consistency between Eqs. (3) and (1) can be better appreciated by solving for the quantity

$$\Delta k = s\omega + \frac{e^2 \mathcal{A}^2}{4} \left(\frac{1}{k \cdot p} - \frac{1}{k \cdot p'} \right) \omega \tag{5}$$

in one of the δ functions, and then substituting into the remaining δ functions. After doing this, Eq. (3) takes a form identical to Eq. (1):

$$\delta^{(2)}(\mathbf{p}'_\perp + \mathbf{k}'_\perp - \mathbf{p}_\perp)\, \delta(\epsilon' + \omega' - \epsilon - (p'_3 + k'_3 - p_3)) \times \delta(q'_3 + k'_3 - q_3 - s\omega). \tag{6}$$

This demonstrates that the dressing of an electron's energy momentum is determined entirely by the factor M_{fi}, as the explicit constraints enforced by Eq. (1) are satisfied *irrespective* of the dressing. It follows that Eq. (2) and any experimental test thereof are unrelated to the question of a mass shift. Since the authors did not investigate the detailed structure of M_{fi} in their analysis, they cannot infer the absence of a mass dressing.

[1] F. Mackenroth and A. Di Piazza, Phys. Rev. A **83**, 032106 (2011).
[2] We write the kinematics in terms of arbitrary initial momentum (p_1, p_2, p_3).
[3] M. Boca and V. Florescu, Phys. Rev. A **80**, 053403 (2009).

