Electron distribution in nonlinear Compton scattering
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Synopsis Our calculation of the final electron distribution in nonlinear Compton scattering with very energetic electrons is performed for an electromagnetic pulse with finite duration. In contrast to the monochromatic case, this gives access to the the asymptotically free electrons and not to those dressed by the laser field.

The electron distribution in nonlinear Compton scattering was less studied than the radiation distribution, although it was implied in the experimental detection of the process [1].

Modeling the electromagnetic flux by a plane wave with a fixed direction of propagation and a finite duration allows the use of the same formalism as for the calculation of the emitted radiation [2], in which the electron interacting with the laser field is described by a Volkov solution of the Dirac equation and the interaction with the quantized field, responsible for the spontaneous emission of the photon, is treated in first order perturbation theory. From our previous results for the probability density corresponding to the emission of the photon, is treated in first order perturbation theory. From our previous results for the probability density corresponding to the simultaneous detection of the final electron and the emitted photon, we obtain the electron distribution \( \frac{d^2\sigma}{dE_\text{e}d\Omega_\text{e}} \), and then from it, by numerical integration, the energy and angular distributions \( \frac{d\sigma}{dE_\text{e}} \) and, respectively, \( \frac{d\sigma}{d\Omega_\text{e}} \).

In the case of a monochromatic laser field conservation rules imply the dressed electron initial and final momenta and, consequently, the electron distribution is usually written [3] in terms of these momenta; for an electromagnetic pulse, modified conservation laws are valid and they allow us to express the probability distribution in terms of the direction and energy of the final free electron, its attributes after the radiation pulse has gone.

We revisit first the monochromatic case; from the equations expressing the conservation rules we calculate numerically the asymptotically free electron momentum. For given initial conditions, one obtains an infinity of solutions \( p_2^{(N)} \), \( N \geq 1 \), each of them corresponding to the absorption of a fixed number \( N \) of laser photons. At fixed propagation direction, the electron energy spectrum consists in an infinite series of lines.

Then we focus on the case of a finite laser pulse, where the double differential probability distribution \( \frac{d^2\sigma}{dE_\text{e}d\Omega_\text{e}} \) becomes continuous. At relatively small intensity of the laser (1 of the order of atomic unit) and for a central frequency of the laser pulse in the optical range, the distribution presents a series of maxima, whose positions coincide to the positions of the lines in the monochromatic case, and whose shape depends on the shape and length of the laser pulse. At larger intensities, the maxima in the electron spectrum acquire a rich structure and also become larger, such that they start to overlap. A comparison between the results valid in the monochromatic case and those for a finite pulse reveals the influence of the singularities present in the angular distributions in the first case and which disappear in the second case.

In the case of ultrarelativistic electrons and moderate intensity our results show that the final electron is scattered in a very small cone around its initial direction and its energy spectrum spreads between very low values and up to the initial energy. When the laser intensity increases the electron energy distribution has the tendency to concentrate near the initial value; we connect this behaviour with the "dressing" of the electron during the laser pulse, the increase of the dressed mass leading to a very small recoil of the electron.

Finally, we calculate separately the energy and angular distributions of the electron. By the numerical integration leading to these distributions, the very sharp structures in spectra are smoothed, such that the obtained results are practically independent of the shape or length of the laser pulse.

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References

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