Contribution ID: **72** Type: **Invited talk**

Spectral Characteristics of Radiation from Thomson and Compton Scattering of an Intense Laser Field by Relativistic Electrons

Thursday, 9 October 2014 09:00 (30 minutes)

The mechanisms of Thomson and Compton scattering under linear and nonlinear interactions between relativistic electrons and counter propagated intense laser wave are considered. The quantum consideration of the Compton scattering process allows to calculate a probability of a few successive collisions k of an electron with laser photons accompanying by absorption of n photons (nonlinear regime for n more than unit) when the number of collisions and the number of absorbed photons are random quantities. The cross-section of the nonlinear Thomson scattering process was obtained from the classical formula for intensity using the Planck's law. An electron interacts with a few laser photons subsequently, emitting a "hard photon"in each collision if a laser pulse intensity is high enough (multiple Compton scattering process, MCS) [1]. A mean number of emitted photons κ is determined by a luminosity of the MCS process and its cross-section. We have showed that spectra of emitted photons can be described by the classical Thomson formula if the condition $4\kappa\gamma\hbar\omega/E \ll 1$ (γ is Lorentz-factor, $\hbar\omega$ is energy of laser photon, E is electron rest energy) is fulfilled. In opposite case one has to use the Compton cross-section formula.

We developed an approach based on Monte-Carlo technique allowing to simulate spectral distributions of photons emitted into a narrow aperture for both linear and nonlinear MCS processes. In contrast with other models we took into account a multiplicity of collisions of an electron with laser photons and showed that monochromaticity of radiation is worsening due to such a reason. In each collision an electron loses an energy during emission process and a subsequent photon will have an energy less than the first one (in the average). For modern projects (such as the ELI-NP [2, 3]) the average number of emitted photons by each electron can enhance the value $\kappa \geq 1$.

For typical parameters of the ELI-NP project ($\kappa = 1.1$, the electron energy 720 MeV ($\gamma = 1409$), acceptance angle 0.1 mrad) we have simulated the spectral line shape and found that the line has a "tail"of soft photons (about 20% from the total number of photons accepted into an aperture). Such an effect should be taken into account for design of monochromatic gamma-beam.

References

[1] A. Potylitsyn, A. Kol'chuzhkin, Nucl. Phys. and Meth. B 309 (2013) 15-19.

[2] www.extreme-light-infrastructure.en.

[3] V. Petrillo, A. Bacci, R. Ben Ali Zinati et al., Nucl. Instrum. and Methods A 693 (2012) 109.

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Session Classification: S2: Channeling & Radiation in Various Fields