Contribution ID: **85** Type: **Invited**

Classical and Quantum Descriptions of Radiation from Relativistic Electrons in External Fields

Monday 16 September 2019 10:10 (30 minutes)

We review the process of photon emission by a relativistic electron moving along a classical trajectory in an external field.
In a first part we assume that the emitted photon energy is much smaller than the electron energy. This case can be treated in classical electrodynamics. We briefly review the main radiation characteristics: spontaneous or stimulated emission, dipolar or non-dipolar regime, polarization, spectral sum rules, infrared divergence, coherence length effects (e.g., LPM effect), enhancement in oriented crystals. We end up this part with some considerations on photon impact parameter, radiation damping and the side-slipping effect.
In a second part we consider the case where the photon takes a non-negligible part of the electron energy. This can happen when, in the electron frame, the external field is higher than the critical electric field $1.32\tilde{\ }10^{18}$ volt/m or varies significantly in a time scale $\lambda_{Compton}/(2\pi c) = 1.2910^{-21}$ s. Then the recoil and spin effects become important and are approximately taken into account by the semi-classical formula of Baïer and Katkov (BK). We show that this formula almost coincides with an exact one when the external field is a plane wave. We state the conditions of validity of the BK formula and review its applications in high-energy coherent and incoherent electromagnetic processes in oriented crystals. Concerning the incoherent processes, we discuss whether the electron trajectory must be calculated with the classical or with the quantum scattering theory.

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Session Classification: General Properties of Radiation from Relativistic Particles

Track Classification: General radiation properties from relativistic particles