Part II

Radiation by Particles Ensembles

The above–examined mechanisms of radiation emission relate to a single point like charged particle under prescribed conditions of its motion. The latter supposition implies that the radiation field backward influence on the emitter dynamics is negligible. In particular, decrease in the emitter energy which irreversibly goes out of the system in the form of the free field energy was supposed to be small. Actually, the statement that the radiation field backward influence on the single emitter dynamics could be negligible is justified in the overwhelming majority of cases. Only radiation emitted by an ultra-relativistic particle, the radiation losses of which are proportional to the relativistic factor squared, can turn out to be comparable with the emitter total energy during a sufficiently long-time interval, as it takes place in the case of synchrotron radiation. This is the reason why we have not estimated the total radiation power, limiting ourselves to the description of electromagnetic fields. Even being multiplied by a large number of particles simultaneously located in the region of interaction, it turns out to be far below the values that could be of interest for microwave technologies.[8]

The two examples below are sufficient to emphasize the principal difference between the radiation emission by a single particle and by ensembles.

According to the single particle theory, the energy loss in the output cavity of a 10 cm–range klystron–amplifier makes several microelectronvolts. At the same time, the 450 A–current electron beam loses the pulse power of 50 MWt in the same cavity. To generate this power, each electron of the beam transfers about 100 keV of its energy to the microwave field. This is 10^{10} times (!) higher than in the case of an individual electron.

The analogous situation takes place in the free electron maser driven by the accelerator ATA (LLNL). In this experiment, the individual electron loss for undulator radiation should be about 5 microelectronvolts. However, the radiation loss of the electron beam of the pulse current of order of 0.5 kA in the same undulator makes approximately 0.1 GWt of the microwave power. Under such conditions the energy loss of each of the beam electrons is of the order of 0.1 MeV. That is, deceleration by the collective radiation field is nine orders of magnitude larger than that of an individual particle.

Coherent summation of the radiation fields (not powers!) emitted by individual particles is essential for interpreting the effects. As regards this summation, certain mechanisms are necessary for providing the conditions for the emitter ensemble coherence and its automatic self–maintenance. These mechanisms are discussed in the part presented below. With the help of simple physical models we trace the links between coherence of radiation emitted by ensembles of charged particles and properties of emission by individual charged particles, described in Part I.

[8] Apropos, a relative smallness of the individual emitter radiation losses evidently contradicts the demand for a high efficiency, declared at the beginning of Part I.