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Characteristics and Properties of Synchrotron Radiation

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There is ample historical evidence that a basic knowledge of the essential properties of synchrotron radiation enhances the effectiveness of users in exploiting this wonderful resource. Unfortunately, this fact clashes with the difficulties in dealing with complete theoretical descriptions, which are rather complicated and rely on a complex mathematical formalism. This problem is becoming increasingly acute because of the evolution of the general population of synchrotron radiation users. Which for a long time has not been dominated by physicist and includes a majority of scientists and technologists from other areas.

Fortunately, a solution for this problem does exist and has been developed over the years, reaching an excellent level of effectiveness. The key point is that the emission of synchrotron radiation for practical uses exploit relativistic electrons. The standard theories threat in the first place the general case and then deal with relativistic particles. This unnecessarily complicates the treatment making it difficult to understand for non-physicists.

We shall see instead that the extreme relativistic case by itself can be much simpler. The description of fundamental radiation properties does not require complicated mathematical formalism. On the contrary, it can be handled without differential equations, derivatives or integrals. Furthermore, this approach brings immediately to light the essential physics. And It makes it easy for all to understand the direct link between relativity and synchrotron radiation features.

We shall specifically use six basic relativity features to derive the most important synchrotron radiation properties. The six features are Einstein's gamma factor, two reference frames (the electron and the laboratory frames) and three effects, the Lorentz contraction, the Doppler effect and time expansion. The radiation properties that will be explained include the emission of short wavelengths, the very high emitter power, the strong angular collimation, the high brightness, polarization, spatial and time coherence and the emitted spectra of undulators, wigglers and bending magnets.

We shall then use the same extreme relativistic strategy to treat the basic properties of x-ray free electron lasers. These properties include the optical amplification by electron microbunching., the short duration of the radiation pulses, the small transverse cross section and the corresponding ultrahigh brightness, plus coherence -- including the use of seeding.

The lectures will include a few selected examples of applications of the basic properties derived with the above approach. In particular, we shall present the impact of coherence on x-ray imaging.