Synchrotron Radiation and Bremsstahlung – A Thought Experiment

Summary

Classical theory says that electromagnetic radiation is produced by the acceleration and deceleration of charged particles. An alternative is proposed here in which electromagnetic radiation is produced only by positive acceleration. Comparison of synchrotron radiation and bremsstahlung in a thought experiment suggests that radiation apparently produced by deceleration is caused by adventitious accelerations of some particles in a stream undergoing collisions during deceleration of the bulk.

A. Synchrotron radiation and bremsstahlung compared

Synchrotron radiation is produced by accelerating charged particles to within 1% of the speed of light in a particle accelerator using powerful magnets and radiofrequency electric fields. The radiation is intense, forward focussed and highly polarised, and has an extremely broad spectrum up to hard X-ray wavelengths.

Bremsstahlung by contrast is produced by charged particles as they are slowed down, usually by an electric field.

In both cases the classical theory is that acceleration must produce electromagnetic radiation: positive acceleration for synchrotron radiation and negative acceleration for 'braking' radiation or bremsstahlung.

The two types of radiation may be compared in a thought experiment using a particle accelerator which can be symmetrically reversed. The apparatus accelerates particles up to velocity v and then reverses to slow them down to the initial velocity again, using the identical acceleration profile in the negative sense.

When the accelerator is used to produce positive acceleration from 0 to velocity v:

electrical energy input (accelerating) = kinetic energy of particles at velocity v
+ synchrotron radiation
+ internal losses in the apparatus (wiring)

When the accelerator is used to produce negative acceleration from v to 0, then

electrical energy input (decelerating) = kinetic energy loss of particles from v to 0
+ bremstahlung
+ internal losses in the apparatus (wiring)

If the design of the apparatus is such that there are no overall losses of energy from the total system, it seems that the energy of the synchrotron radiation must be equal to the energy of the bremsstahlung.

This is not possible unless it produces exactly the same number of photons at exactly the same frequencies in both cases i.e. it needs to be not only equal but identical. Moreover it is not easy to see how the forward focussed, highly polarised radiation of synchrotron radiation could be matched by braking radiation.

The two types of radiation are either different phenomena, and if so, why, or alternatively the theory is wrong. Synchrotron radiation is so well controlled and characterised that it seems unlikely that the problem lies here. The conclusion is that the characterisation of bremsstahlung needs further consideration.

B. A proposed alternative theory

The alternative is that the classical theory is wrong. The proposal, which has been spelt out in previous papers (Ref.) is that radiation is produced by positive acceleration but not by deceleration of a particle. Furthermore, the frequency of radiation emitted increases with the velocity from which acceleration takes place. If radiation is emitted during the braking process, it is because adventitious accelerations occur during the deceleration process.

The reasoning is that observations conveniently apply not to single particles but to numbers of particles in the form of streams. The synchrotron radiation model is streamline flow in which all particles in the system accelerate smoothly together in Grand Prix fashion. Any radiation produced by a few particles which did not follow the streamlines would be buried in the rest of the spectrum.

However, for bremsstahlung, the more likely metaphor is a motorway pile-up of the sort which would occur if particles travelling in a stream at high velocity were each caused individually and simultaneously to brake. Just a few particles out of line would career off other particles and/or the walls, and produce the radiation that would accompany any temporary accelerations which occurred to a small number of particles. These are regions of turbulent particle flow, and the result would be a different spectrum.

A.C. Sturt

4 July 2007

Reference

An Electromagnetic Model of Atomic Structure by A.C. Sturt, 3 October 2003
www.churingapublishing.com/dynamat_1.html.