Modeling Ultra-high Frequency Radiation Emission in PIC Codes

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From the mysterious γ ray bursts, which can be studied through the spatiotemporal structure of the radiation we receive, to the creation of sources of x-rays capable of probing nanoscale structures, radiation emission by relativistic charges is a key research field in plasma physics.

The processes behind radiation emission in plasmas result from many body interactions, are strongly non-linear, and involve relativistic effects, so they are best modeled through Particle-In-Cell (PIC) simulations. However, describing this radiation directly in PIC simulations is very challenging given the large disparity between the temporal and spatial scales associated with such phenomena. Additionally, the spatiotemporal features of the emitted radiation cannot be fully captured by current algorithms that describe radiation emission in the Fourier space (see e.g. [1]). Understanding and describing the spatiotemporal properties of the radiation, however, is crucial to many fields, such as super-resolution microscopy [2] and astrophysics [3].

Here we develop a diagnostic that is able to capture the unexplored spatiotemporal structure of the emitted radiation from simulated trajectories of particles, using the Liénard-Wiechert potentials. The diagnostic can work as post-processing tool, using the trajectories from PIC codes. On Figure 1 we display the results of a run with 256 particles which undergo a helical-like motion. We have also incorporated the diagnostic directly into the PIC loop, which allows us to capture the radiation from a significant fraction of the particles in the plasma. We describe the code integration into OSIRIS [4], a massively parallel, fully relativistic PIC code. This approach gives direct access to the spatiotemporal radiation emission properties as the PIC simulation progresses.

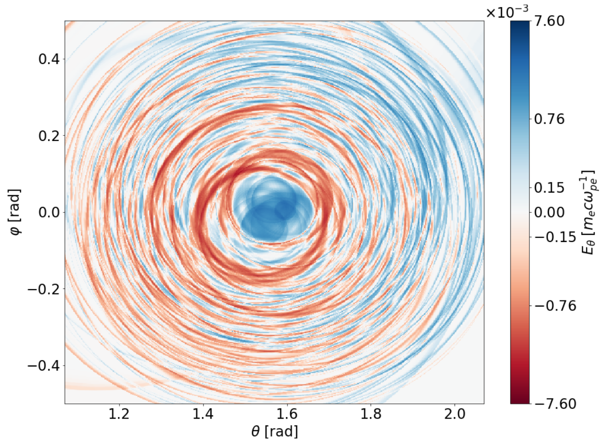

Figure 1: *Transverse electric field in a spherical surface placed far from the particles.*

References

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