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Radiation Diagnostic for OSIRIS: Applications in coherent betatron emission

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Radiation emission plasmas is often a result of collective effects associated with the dynamics of relativistic charged particles. A common numerical approach to model their motion involves the Particle-In-Cell scheme which solves the full set of Maxwell's equations and the relativistic Lorentz force for the charged particles.

The Radiation Diagnostic for OSIRIS (RaDiO) can retrieve the emitted spatiotemporal electromagnetic field structure of the emitted radiation in OSIRIS simulations, even at wavelengths smaller than the PIC resolution, by relying on the Liénard-Wiechert Potentials. These codes can run with a high level of efficiency in most of the largest CPU-based supercomputers [M. Pardal et al, submitted (2022)]. Nevertheless, GPU accelerator boards are nowadays employed in supercomputers to the point where some of the most powerful machines nowadays are GPU-based systems. Recently, the radiation algorithm has been adapted to the GPU architecture, and this adaptation was integrated into OSIRIS. This allowed for a deeper study of new radiation generation schemes in plasma accelerators.

In this work, we use RaDiO to generalize the ion channel laser concept towards superradiant betatron emission from plasma accelerated electrons in plasma channels. This is made possible by the use of generalized superradiance, which allows arbitrarily diluted beams to radiate coherently, exploiting the optical shocks coming from superluminal particle beam structures. We show that by resonantly combining betatron oscilations with the effect of a low frequency laser pulse, a plasma accelerated electron beam may acquire the modulation with a superluminal phase speed required by the onset of generalized supperadiance. The generalized ion channel laser concept can then be seeded by more traditional infra-red laser pulses, and lead to temporally coherent, broad-band radiation that can extend all the way up to x-ray frequencies. Here we show how the use of RaDiO allowed us to model radiation emission in these scenarios and determine the necessary conditions to obtain superradiant betatron emission.

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