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Simulation Tool Developments for Extreme Laser-Matter Interactions

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As laser intensities exceed $10^{21}\ Wcm^{-2}$ plasma dynamics become dominated by Strong-Field Quantum Electrodynamics (SFQED), which require sophisticated simulation tools to model phenomena like gamma-ray emission and quantum radiation reaction. This work presents a C++ benchmark code developed to implement the Locally Monochromatic Approximation (LMA) within the particle-in-cell framework OSIRIS. Unlike the standard Local Constant Field Approximation (LCFA), already implemented in OSIRIS, LMA accounts for the harmonic structure of the fields at lower intensities while remaining valid in the ultrarelativistic regime.
The framework supports flexible particle and field initialization and is designed with parallelisation in mind for high-performance computing environments. Validation tests against analytical solutions for cyclotron motion and laser-pulse interactions have been successfully performed up to the implementation of LCFA, and are in perfect aggreement with the theoretical predictions. This code provides a foundation for future LMA-based SFQED studies and contributes toward realistic modeling of upcoming high-intensity laser–plasma experiments, such as those at SLAC.

Field of Research/Work

Plasma and Solar Physics, Accelerators and Beams

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