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Arbitrary Electromagnetic Wave Packets in Particle in Cell Codes

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Particle-in-Cell (PIC) codes commonly employ laser injection algorithms rooted in analytical solutions of the paraxial wave equation under the slowly-varying envelope approximation. These algorithms, while computationally efficient, are tailored to lasers with transverse spot sizes and temporal durations significantly larger than their respective wavelengths and periods. Consequently, they encounter limitations when representing the field structure of ultra-short or ultra-tightly focused laser pulses, crucial for applications in ultra-high intensity physics.

Here, we introduce a groundbreaking algorithm for the injection of electromagnetic wave packets in PIC codes that precisely satisfies Maxwell's Equations without resorting to any approximations. The algorithm, applicable to 2D and 3D full-scale simulations, as well as cylindrical coordinates simulations with Fourier decomposition along the azimuthal direction, has been successfully implemented in OSIRIS and is readily adaptable to any other PIC code.

An inherent feature of this algorithm is its capability for the continuous injection of laser fields from any simulation boundary, enabling the usage of smaller simulation domains. Furthermore, we provide illustrative examples of its practical applications, such as leveraging lasers with spatiotemporal couplings to excite plasma wake fields with controllable phase velocity and the accurate modelling of wave packets with realistic spectra.

Available for oral presentation in a session

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