Arbitrarily non-paraxial electromagnetic wave-packets in particle-in-cell codes

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Standard laser injection algorithms in particle-in-cell (PIC) codes are based on the analytical solutions of the paraxial wave equation under the slowly varying envelope approximation. These algorithms are very computationally efficient as they rely on purely analytical solutions. In addition, they are ideally suited to describe lasers where the transverse spot size and temporal duration are much larger than its wavelength and period respectively. However, they fail to accurately describe the correct field structure of ultra short (e.g., single cycled) or ultra tightly focused laser pulses which are very important to physics at ultra high intensity. For example, probing non linear quantum electrodynamics processes in the lab will necessarily require such extreme pulses.

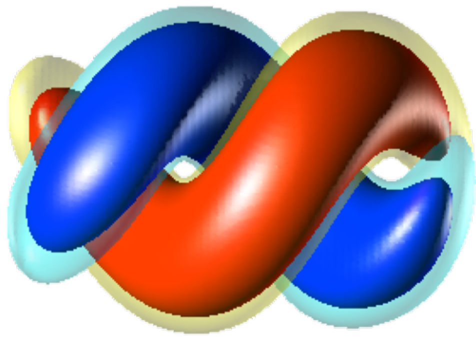

Figure 1: Isosurfaces of the transverse electric field of a λ^3 pulse carrying orbital angular momentum. The blue surfaces correspond to negative values and red to positive values of the electric field.

Up until now, there have been little to no problem in using these methods. Here, we develop a new algorithm that is capable of accounting for these extreme laser setups, allowing us to explore laser matter interaction in fundamentally novel regimes. Our new and simple method, which can be implemented on any PIC code, is based on the superposition of plane waves, which exactly satisfy Maxwell's Equations by construction. Such an algorithm was implemented in OSIRIS [1]. We show the generality of this algorithm through examples of simulations with pulses with Lorentz boosts in arbitrary directions, λ^3 regimes (ie, where the laser energy is contained within a volume corresponding to the laser wavelength cubed) and with spatiotemporal control of its profile, mainly with the development of a new flying focus description of a pulse.

References

[1] Fonseca, R. A., Silva, L. O., Tsung, F. S., Decyk, V. K., Lu, W., Ren, C., Mori, W. B., Deng, S., Lee, S., Katsouleas, T., 38; Adam, J. C. (2002). OSIRIS: A three-dimensional, fully relativistic particle in cell code for modeling plasma based accelerators.