**OPTIMIZATION OF A KINETIC LASER-PLASMA INTERACTION CODE FOR MASSIVELY PARALLEL SYSTEMS**

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**Abstract**

The interaction between intense laser radiation and a fully ionized plasma can be modelled at a very microscopic level by solving a set of coupled equations: Maxwell's equations for the laser and self-generated electromagnetic fields, and Vlasov's equations for each particle species (electrons and each ion species) in the plasma. One very popular method to solve this set of equations is the so-called "Particle-In-Cell" (PIC) method [1], in which the distribution functions are sampled by large numbers of particles, and Maxwell's equations are solved on a regular cartesian grid. During one time step, the electromagnetic fields at particle positions are calculated by interpolating between values at neighboring nodes, the particles are advanced in time according to their relativistic equation of motion, their contribution to the source terms in Maxwell's equations (charge and current densities) are gathered, and the electromagnetic fields are updated [1]. Finally, a correction is applied to the electric field to ensure that Poisson's equation is verified. This model provides a very detailed account of the plasma dynamics, but at the expense of large computer ressources. The space and time-steps must at least correctly sample the laser wavelength and period, which are typically $10^{-6}m$ and $3\ 10^{-15}s$. In some cases, plasma dynamics may even impose more stringent conditions. The distribution functions must be sampled by at least 3 or 4 particles per species and per mesh cell. In 3D geometry, this translates into a computation involving $2\ 10^8$ particles, $2\ 10^7$ cells, and a few thousand time steps, to model the propagation of a short (tens of femtoseconds) laser pulse through a $100 \times 20 \times 20\ (10^{-6}m)^3$ plasma. Fortunately, efficient parallel algorithms exist to tackle this problem [2].

In our SPMD fully relativistic 3D PIC code (CALDER), the simulation domain is partitionned between the processors, and each processor is in charge of updating the field values and particle coordinates in its own subdomain. During one time step, the communication of data between processors (particles moving from one domain to the other, field values on border cells...) is handled with asynchronous MPI primitives. The communications due to the outermost cells in each subdomain are overlapped by computations associated with the inner ones. The performances of our code are also based on a cache-friendly data managment coupled with a dynamic load balancing strategy, and on the use of a parallel sparse PCG solver for the solution of the Poisson's equation.

Some illustrations obtained on the CEA Teraflops parallel computer will be presented. With hundreds of processors, we can simulate in reasonable time 3D problems with realistic laser and plasma parameters that enable a one-to-one comparison with experiments [3].

## References

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