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EXTENDING LASER-PLASMA INTERACTION SIMULATIONS WITH MPP-F3D*

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Previously we have reported on our 3-D code,[1,2] F3D, to model the low frequency (filamentation and stimulated Brillouin scattering) instabilities which occur in laser-plasma interactions. In addition, we have coupled nonlinear Eulerian hydrodynamics to paraxial wave solvers and laser beam models for spatial dispersion by random phase plates (RPP) and smoothing by spectral dispersion (SSD), enabling simulations relevant to the ignition target designs for the National Ignition Facility (NIF).[3] Recently we have extended our simulation capabilities by including high frequency instabilities (stimulated Raman scattering), separation of charge (via Boltzmann electrons and Poisson's equation), and relativistic corrections to the nonlinear refraction term in the light equation and the ponderomotive force in the (fluid) momentum equation.

As we develop the F3D code, the additional capabilities and need to model interactions over larger plasma volumes bring an increase in the computational cost of a simulation. Current simulations of channeling experiments relevant to the fast-ignitor concept can require up to 2 gigabytes of memory and run for more than 100 hours on a single DEC 8400 processor. These simulations do not include the effects of SBS and SRS which dramatically increase the resource requirements. The addition of more physics capabilities and the need to simulate interactions over larger NIF-relevant plasmas are driving the need to move to massively parallel computers (MPPs).

We have begun to develop a massively parallel version of F3D. Although the SBS and SRS models are not yet included, we can run simulations of filamentation in plasma volumes approximating the size of a single NIF laser beam. We decompose the 3-D Cartesian mesh (partitioning in the directions transverse to the laser propagation) to produce rectangular subdomains. A time step is done by first advancing the light and then the hydrodynamics on each subdomain concurrently. Light propagation is handled by operator-splitting the paraxial wave equation into refraction (handled by finite differences) and diffraction and propagation (solved by a spectral method) components, the hydrodynamics step by the usual split-step 2^{nd} order Van Leer scheme, and nonlocal heat conduction via a spectral method. The finite differences are completely parallel (with the inclusion of a guard cell layer around each subdomain) and the spectral methods involve a parallel 2-D FFT. The domain decomposition technique has proved to be an efficient methodology for extending F3D.

The counterpart to computational advances is the ability to model experiments more accurately, with an eye towards developing the capability of predicting the laser-plasma interaction. While the first part of the presentation will focus on the effort to develop MPP-F3D, we will also report on the recent successes in modeling a beam deflection experiment.

Experiments have shown that an intense laser pulse propagating through a fully ionized plasma flowing in directions transverse to the propagation can be deflected downstream. This is of particular importance in hohlraum targets used in inertial confinement fusion applications where plasma flowing out of the laser entrance hole can steer the beam away from the intended path producing asymmetries in the x-ray drive. Recently, Peter Young has done an experiment with a well characterized plasma enabling quantitative comparison to theoretical predictions. The experimental results quantitatively match the F3D simulations.[4]

The experiment was performed on the Janus laser at LLNL using a 1.064 μm wavelength, 100 ps full-width at half-maximum (FWHM) Gaussian pulse interacting with an underdense plasma preformed by irradiating a 0.35 μm CH foil with a 0.532 μm wavelength, 400 μm diameter, 2×10^{13} W/cm^2 laser pulse. A 20 μm × 400 μm line focus (with peak intensity 1.5×10^{15} W/cm^2) was used to facilitate observing the phase change due to the density depression. An electron temperature of 750 eV was inferred by a Thomson scattering measurement, and the background density profile was measured using a folded-wave interferometer, showing obvious beam bending of about 10 degrees located where the flow velocity matches the inferred sound speed.

The experiment was duplicated as much as possible for the F3D simulation. We experimentally measured the phase distribution of the interaction beam and numerically propagated the beam to produce the appropriate line focus. We then scaled the electric field to match the power used experimentally. The density and velocity profiles were taken from a LASNEX simulation. Modeling a 250 μm × 500 μm region of the plasma centered on the incident laser beam in an F3D simulation (assuming a uniform $T_e = 750$ eV) produced the expected approximate 10 degree bend.

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4. *P. E. Young, et. al.*, in prep., to be submitted to Phys. Rev. Lett. (1998).