Coupling Thermal Electron Transport and Laser Propagation in HERA

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In the context of inertial confinement fusion, laser-plasma interaction (LPI) refers mainly to the study of ponderomotively driven phenomena that affect the single laser propagation and the subsequent laser energy deposition. The most deleterious effects expected in ICF-related plasmas are the self-focusing or filamentation of the laser beam and the stimulated Raman and Brillouin scattering off electron plasma and ion acoustic waves, respectively. Other effects such as cross-beam energy transfer or more generally collective behaviors involving several laser beams add another degree of complexity but do not withdraw those primary effects.

Dealing with LPI on long-time scale (100's ps) and large-plasma volumes (mm^3) implies to solve, at least, paraxial equations for the high frequency ponderomotive coupling (laser pump wave, stimulated backscattered wave and plasma wave) and hydrodynamics equations with ponderomotive coupling (describing self-focusing for example), together with optical smoothing boundary conditions. In this case, hydrodynamics is usually limited to the density and momentum equations with a barotropic closure [1-3]. The latter is justified particularly in hot plasmas (>1 keV), where bulk temperatures vary slowly compared to the other mechanisms at play. However, such approximations do not hold when studying burn-through experiment [4,5], or when laser-speckles induce electron temperatures inhomogeneities [6] or on long-time scale simulations of colder plasmas (100's eV).

To describe the aforementioned mechanisms, we have included the electron energy equation with an implicit solver for the heat flux diffusion in our three-dimensional (3D) laser-plasma interaction code HERA [2,3]. Yet, heat flux is modeled by a Spitzer-Härm thermal conductivity, with a flux limiter accounting for nonlocal effects. Now, HERA can describe basic electron transport and plasma heating, together with laser-plasma instabilities such as the Brillouin scattering or self-focusing. This enables us to revisit the hydrodynamic evolution of a plasma driven by thermal [7] and ponderomotive effects, and to quantify their competition [8] in realistic situations, with a full nonlinear hydrodynamics. Understanding such physics may be crucial in indirect drive ICF experiments when the low intensity laser-plasma interaction heats the gas inside the hohlraum [4,5], in the first several ns of an ignition pulse.

References

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