A steady-state approach to implementing laser-plasma instabilities in hydrodynamics codes

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Abstract

The exciting, recent results in inertial confinement fusion (ICF) delivered by National Ignition Facility (NIF) have increased the interest in accelerating the development of high gain ICF implosions. The ability to do this depends on accurately modelling an implosion. Driving an implosion efficiently will probably require a direct drive approach where the laser energy is absorbed via inverse bremsstrahlung, which heats the coronal plasma ablating from a shell containing the deuterium-tritium fuel. High laser intensities are needed to rapidly compress the fuel while keeping it uniform and cold.[1] The efficiency of coupling the laser into the corona and resulting implosion velocity is reduced by the presence of laser-plasma instabilities (LPI). These instabilities excite electromagnetic and electrostatic waves in the plasma that scatter the laser energy and accelerate hot electrons, these processes risk impairing the drive symmetry and preheating the cold fuel.[2]

Implosion dynamics are typically modelled using radiation hydrodynamics codes, but these codes do not include the wave physics needed to describe LPI and instead use multipliers on the laser power to account for these processes. To address this we are creating a computationally fast model for the following LPI processes[3] that include (i) stimulated Raman scattering, (ii) stimulated Brillouin scattering and (iii) two plasmon decay. Computational speed is essential, consequently the model assumes steady-state conditions where the instability levels are calculated at their saturated level. To enable this the LPI descriptions employ linear theory for the growth rates combined with non-linear saturation mechanisms that include pump depletion.

The LPI model will run in-line with three-dimensional laser ray-tracing routines as part of a much larger radiation-hydrodynamics code. The LPI calculations are included on each ray, which will number many many thousands, to enable the code to calculate the LPI-driven energy losses which pass to scattered light and hot electrons. Outputs such as location, energy and temperature of laser depletion, plasma heating and hot electron generation, are passed back to the radiation-hydrodynamics code with routines that model, for example, the transport of hot electrons. The aim is to develop computationally efficient and physics-based codes for predictive laser-plasma simulations that can robustly check designs of new experiments.

References

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