Ignition and Burn in Inhomogeneous Inertial Confinement Fusion Hotspots

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The formation and resultant shape of Inertial Confinement Fusion (ICF) hotspots is heavily influenced by perturbations, which in turn affect the power balance of the hotspot. The heat flow from the hotspot conversely also changes the evolution of these perturbations. Understanding these two phenomena and how they interact is crucial to understanding the requirements for achieving ignition.

We present simulations using the 3D radiation hydrodynamics code Chimera developed at Imperial College London, upgraded with a Monte-Carlo Particle-in-Cell (PIC) alpha-transport model. The heat flow out of the hotspot via processes of alpha-transport, radiation transport and thermal conduction is investigated, first in a 1D spherically symmetric simulation of the high-foot radiation drive shot N130927, chosen due to the significant contribution to the yield from alpha-heating. This is used to illustrate the influence of burn physics on the energetics of a homogeneous, unperturbed hotspot.

The ignition process and propagation of burn are observable in 1D, resulting in a significantly extended burn pulse and a reduction in areal density over time. The alpha-heating causes maintains fusion temperatures in the expanding hotspot, with the raised plasma temperature (compared to the burn-off scenario) greatly increasing hotspot pressure and rate of expansion.

Significant ablation of shell material due to direct heating from the alpha-particles via coulomb collisions is observable, although heat transport due to electron thermal conduction and radiation also remain significant throughout the burn phase of the implosion. Radiative heat flow penetrates deeper into the shell than that due to either alpha-particles or electron thermal conduction.

This platform is then used to further investigate the heat flow in inhomogeneous configurations in multi-dimensional simulations, investigating how the inhomogeneity inhibits ignition and affects the propagation of burn, in addition to the growth and fire-polishing of perturbation structures. We look to explore how interactions between inhomogeneity and the effects of alpha-heating can cause phenomena such as burn truncation and loss of confinement, in contrast to the observations in 1D.