COMPUTATIONAL STUDY OF INTENSE PROTON BEAM TRANSPORT AND TARGET HEATING TO WARM DENSE MATTER STATES

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Proton-beams driven by high power short pulse lasers can rapidly heat solid-density matter to a partially-ionized warm/hot dense matter state, (intermediary between the solid and plasma states of matter) due to unique properties of the beam such as high intensity, short pulse time and localized energy deposition. These beams can isochorically heat matter that can be employed to study physics of warm dense material which exist in many aspects of the inertial confinement fusion (ICF) process such as the shocked ablator material [1], DT fuel at early times [2], and supplemental structures such as the laser-heated hohlraum [3] or beam-heated cone-tip in the fast ignition alternate ICF concept [4]. Ion transport in this regime is poorly modeled because the ion stopping power significantly changes with the local heating and ionization, which differs from cold matter or ideal fully ionized plasma, resulting in nonlinear behavior. Therefore, the main challenge to understand ion transport in this regime is self-consistently accounting for the matter's response to the ions and the ions' behavior in the matter.

To investigate this regime, we modeled proton beam transport in solid density matter using a new ion stopping power calculation module that we recently implemented into the hybrid fluid particle-in-cell (PIC) LSP code. In this module, electronic stopping power of both bound and free electrons are taken into account for the total proton stopping power. At each simulation grid and time step, the proton stopping power is dynamically updated with the varying target state variables (effective charge state, temperature, and density variation due to the beam heating) based on equation of state (EOS). The LSP simulations have been benchmarked against experimental data. Numerical modeling of proton beam heating in thin solid foils and beam dynamics after its transport designed for use in the WDM regime show that rapid, isochoric heating is achievable, but that its heated profile is intensity-dependent. We systematically investigate the dependences of proton beam transport on the beam parameters and also target materials and initial target temperatures.

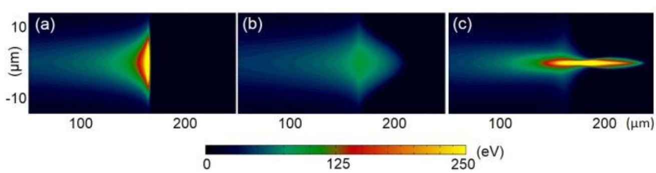

FIG. Result of LSP simulation. Temperature of an Al target heated by a proton beam showing collective effects on transport with different physics packages: (a) fixed, cold stopping, (b) updating stopping, (c) field effect with updating stopping.

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