Hybrid Particle-in-Cell Simulations of MeV Electron Transport in Fast-Ignition Targets



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Three-dimensional LSP¹ simulations of MeV electron transport predict a \gtrsim 10% efficiency for a 20 μ m radius core at a propagation distance of 40 μ m

- The efficiency η_T = (energy reaching core/energy in fast electrons) and does not include stopping.
- From the beginning of fast ignition, it has been recognized that the transport distance needs to be made as small as possible leading to the concepts of hole boring and cone-focused implosions.
- Transport efficiency has been investigated using OMEGA profiles for two propagation distances.
- A standoff of 40 μm implies either hole boring or cone focused implosion.
- If electrons are generated near the critical surface the efficiency is reduced to $\sim 1\%.$
- The efficiency is observed to be a weak function of the source temperature for the electrons.

¹D. R. Welch et al., Nucl. Instrum. Methods Phys. Res. A <u>464</u>, 134 (2001).

The simulations take into account the self-generated EM fields and the charge/current neutralization by the background plasma

- MeV "beam" electrons are treated as kinetic particles.
 - generated by "promotion from background" in a prescribed source region for a duration of 10 ps.
 - The electron beam is given a directed momentum ~ 1 MeV/c and a thermal spread (beam temperature) that is varied (either 10 keV or 200 keV).
- Fluid response for the background plasma (both electrons and ions)
 - provides charge and magnetic neutralization (return current)
 - corresponds to OMEGA cryo implosion.
- Full Maxwell equations are solved.

The MeV electrons are either generated in the near critical density region or closer to the core as is appropriate for cone-focused ignition



The fractional energy flux through the core is investigated as a function of initial beam temperature for a fixed beam current

- From geometric considerations, a cold beam is better.
- Simulations show the opposite.



Snapshots of the 10 keV beam show that the poor efficiency is due to the rapid onset of beam spraying



Emittance growth is connected with the filamentation of current for the 10 keV beam and with beam focusing for the 200 keV case



Small scale filamentation is suppressed if the beam temperature is large enough



Halving the propagation distance has a large impact on the transport efficiency

- The cold beam sees an order of magnitude improvement in efficiency.
- Geometric losses are smaller.
- The beam is weaker, (n_b/n_p) smaller.



Homogeneous simulations show that beam filamentation depends on the plasma density



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