Simulation of Enhanced Neutron Production for OMEGA EP Cryogenic Implosions

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Summary

Interaction of the OMEGA EP beam with an imploding cryogenic capsule significantly enhances neutron yield

• The OMEGA EP Laser will add a short-pulse (2.5 kJ in 20 ps), high-intensity beam (\(>10^{19}\) W/cm\(^2\)) to OMEGA to study the physics of fast ignition.

• The simulations were carried out with a range of realistic electron sources.

• Near stagnation, the relativistic electrons heat the cold fuel, which explodes and creates a dense and hot core that produces over \(10^{15}\) neutrons.

• Including alpha transport increases the yield by 50%.
Simulations were carried out for a 2.5-kJ, 1-\(\mu\)m-wavelength laser with a varying beam radius and FWHM.

- The electrons are transported parallel to the pole in a single time step and lose energy according to a model by C. K. Li and R. D. Petrasso.*

*To be published in Phys. Rev. E
The electron source is a one-dimensional Maxwellian distribution computed from the laser intensity and a conversion efficiency.

\[ T = 511 \, \left[ (1 + \frac{I}{1.47 \times 10^{18}})^{0.5} - 1 \right] \, \text{(keV)} \] → slope of Maxwellian (from Wilks*)

A target and pulse were designed to reach the $\rho R$ needed to stop most electrons.
The electron pulse significantly increases the neutron production in the hot core and the high density shell.
The heated shell explodes, producing a shock wave that heats the core

- Neutron yield ($\text{#/cm}^3$)
  - $	au = 0 \text{ ps}$
  - $	au = 8 \text{ ps}$

- Ion temperature (keV)

- Mass density ($\text{g/cm}^3$)

- Time with respect to the peak of the 10-ps pulse timed at 3.94 ns

Lineout at 4 $\mu$m
The neutron yield remains within a factor of two in about a 100-ps range for the pulse timing.

<table>
<thead>
<tr>
<th>Peak intensity (W/cm²)</th>
<th>Energy deposited* (kJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$1 \times 10^{19}$</td>
<td>1.00 (40%)</td>
</tr>
<tr>
<td>$2 \times 10^{19}$</td>
<td>0.79 (32%)</td>
</tr>
<tr>
<td>$8 \times 10^{19}$</td>
<td>0.30 (12%)</td>
</tr>
<tr>
<td>$2 \times 10^{19}$</td>
<td>0.32 (13%)</td>
</tr>
</tbody>
</table>

*3.94-ns case

No fast electrons

Peak intensity

Energy deposited*

%%

Time of pulse peak (ns)

Neutron yield ($\times 10^{15}$)

50% eff., 20 ps, 20 µm

50% eff., 10 ps, 20 µm

50% eff., 10 ps, 10 µm

20% eff., 10 ps, 20 µm

Percentage
The neutron yield is sensitive to the beam radius but not to the pulse duration between 5 ps and 30 ps.

2.5 kJ, 50% efficiency, 3.94 ns pulse timing
Simulations were carried out with illumination nonuniformity due to power balance.

Simulation without electron beam; $\rho R$ taken along the pole axis.
Including alpha transport in the simulation increases the yield by over 50%.

Simulations with power balance and alpha transport give the same yields as the uniform case without alpha transport.
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