Simulation of Polar-Direct-Drive Saturn Implosions on OMEGA

Saturn target

Simulated density distribution, $t = 1$ ns

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Summary

Simulations of OMEGA Saturn PDD implosions are in good agreement with experimental data

- An Eulerian hydro option has been developed and implemented into DRACO.
- Laser ray refraction in the target corona has been accurately calculated using DRACO full 3-D ray trace.
- Different optimization techniques for PDD implosions have been examined using Eulerian DRACO simulations.
- Simulation results have been compared and show good agreement with experimental neutron yields and observed x-ray images of OMEGA PDD implosions.
Collaborators


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In the polar-direct-drive designs, laser beams are repointed toward the equator.

**Beam profile:** \( I(r) \propto \exp \left[ -(r/\delta)^n \right] \), \( n = 2.2 \sim 4.0 \)

**PDD concepts are being tested on OMEGA.**
Eulerian hydro is required to simulate plasma flow between ring and target

- The complexity of the flow makes it difficult to use ALE hydrodynamics.
- An Eulerian hydro option has been developed and integrated into *DRACO*.
  - Godunov-type hydro scheme
  - piecewise parabolic interpolation
  - moving spherical numerical grid

**OMEGA Saturn design**

- 40-beam 15-kJ drive
- 1-ns square pulse
Full 3-D laser ray trace has been used in simulations to accurately calculate the effects of ray refraction on laser deposition uniformity.

- Beam pointing and ray refraction provide nearly uniform irradiation of Saturn target.
- Caustics in the laser field near the equator are the result of the refraction of beam 3 (59°, 180 μm).
- Influence of caustics is insignificant in this implosion.

Plasma self-emission effects were self-consistently included using DRACO radiation transport.
Simulations show in detail the formation of bow shock during Saturn target implosion.
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Comparison of PDD implosion simulations with and without the ring show improvement in target uniformity.

Beginning formation of hot spot, $t = 1.85$ ns
DRACO simulations recover the observed relative degradation of neutron yield between PDD implosions with and without the ring.

PDD neutron yield ($Y_N$) relative to symmetric implosions

<table>
<thead>
<tr>
<th>Target type</th>
<th>Observed range</th>
<th>Simulation</th>
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</thead>
<tbody>
<tr>
<td>Saturn</td>
<td>0.64 to 0.76</td>
<td>0.59</td>
</tr>
<tr>
<td>Saturn pointing without ring</td>
<td>0.31 to 0.41</td>
<td>0.34</td>
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</tbody>
</table>
DRACO/SPECT3D images clearly reproduce the target shape and size when compared with OMEGA images.

Saturn pointing without ring
Shot 38502

Saturn
Shot 39281

Reduction of the equatorial perturbation

OMEGA

DRACO/SPECT 3-D

$t = 1.68 \text{ ns}$

$t = 1.7 \text{ ns}$

$t = 1.71 \text{ ns}$

$t = 1.7 \text{ ns}$

$200 \mu\text{m}$
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