High-Areal-Density Cryogenic D$_2$ Implosions on OMEGA

T. C. Sangster
University of Rochester
Laboratory for Laser Energetics
and Fusion Science Center

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Summary

High areal density $(\langle \rho R \rangle_n > 200 \text{ mg/cm}^2)$ at an ignition-relevant adiabat has been achieved on OMEGA*

- $\rho R$ degradation relative to 1-D is a combination of shock heating, hot-electron preheating, and burn-weighted sampling of the $\rho R$ distribution.
- High areal densities are achieved by using a nonlocal thermal-transport model for the target design and by mitigating hot-electron preheat.
- 1-D simulations using a nonlocal thermal-transport model agree with the measured fuel compression in low-adiabat cryogenic implosions.

The implied adiabat control with the measured 1-D areal densities is important for ignition target design.

*Additional details in the following talks:
Collaborators


University of Rochester
Laboratory for Laser Energetics

*also at Fusion Science Center for Extreme States of Matter and Fast-Ignition Physics
University of Rochester

**also: Nuclear Research Center, Negev, Israel

†also at Mechanical Engineering and Physics Department
University of Rochester

J. A. Frenje, C. K. Li, R. D. Petrasso, and F. H. Séguin

Plasma Science and Fusion Center
MIT
Significant $\langle \rho R \rangle_n$ degradation has been inferred at ignition-relevant drive intensities ($\sim 10^{15} \text{ W/cm}^2$)

Degradation suggests that the fuel adiabat is not as designed

\[ \rho R \sim E_L^{1/3}/\alpha^{0.54} \]

There are several possible sources for adiabat degradation

- Hydrostability of the imploded shell
  - mid-\(\alpha\)/high-\(I\) and low-\(\alpha\)/mid-\(I\) implosions are predicted to be stable

- Shock mistiming due to absorption discrepancies and nonlocal thermal transport
  - degradation depends on design and can be significant (>50%)

- Radiation preheating
  - \(D_2\) is almost transparent to thermal x rays so \(\Delta T < \text{few eV}\)

- Hot electrons from plasma instabilities (two plasmon and SRS)
  - hard-x-ray signal suggests \(f_{\text{hot}} \sim 0.1\%\) and \(T_{\text{hot}} \sim 100\ \text{keV}\)

- Nonlocal thermal electrons and fast electrons from resonance absorption
  - \(T_e \sim 2\) to 5 keV so penetration is < 25 \(\mu\text{m} \ll \Delta R(D_2)\)

Shock timing and hot electrons from two-plasmon decay are the most likely sources.

W. Seka (GI1.00003), V. N. Goncharov (GI1.00001), and J. A. Delettrez (JO3.00003)
1-D predictions of past shots using a new nonlocal model* are within ~80% of the experimental $\langle \rho R \rangle_n$

The remaining ~20% degradation is likely a combination of preheating and burn-weighted sampling of the $\rho R$ distribution.

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*V. N. Goncharov (Gl1.00001).
Warm CH implosions suggest that preheat is minimized with a thick CD ablator at $\sim 5 \times 10^{14} \text{ W/cm}^2$

For a thick (10-$\mu$m) CD ablator, the preheat is negligible at drive intensities of $5 \times 10^{14} \text{ W/cm}^2$
Using an optimal pulse shape*, the thick ablator-fuel assembly proceeded according to the 1-D simulations.

\[ \alpha \sim 2 \]
\[ 18 \text{ kJ} \]

*V. N. Goncharov (GI1.00001)
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Changing the timing of the picket by 200 ps reduced the areal density in the measurements and simulations.

Using an optimal pulse shape*, the thick ablator fuel assembly proceeded according to the 1-D simulations.

These are the highest fuel areal densities yet measured in ignition-relevant laboratory implosions.

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*V. N. Goncharov (GI1.00001)
Targets designed with the nonlocal model gave approximately 80% of the 1-D prediction.
Burn-weighted sampling brings the predicted areal density to within 5% of the experimental value.
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The next stage* is to develop techniques to mitigate preheat at $I \sim 1 \times 10^{15} \text{ W/cm}^2$ and achieve $V_{\text{imp}} \sim 3 \text{ to } 4 \times 10^7 \text{ cm/s}$.

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*P. B. Radha (JO3.00002), and J. P. Knauer (PO6.00010)
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