Comparison of Implosion Velocities for Be, C, and CH Ablators Measured in Direct-Drive Implosions

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Summary

Increasing the ablator $A/Z$ increases the velocity of direct-drive implosions

- A 20% increase in shell velocity was measured for Be ablators compared to C and CH ablators when maintaining a constant shell mass.
- The measured absorbed laser power is similar in all three ablators.
- LILAC simulations that include cross-beam energy transfer (CBET) and nonlocal heat transport accurately reproduce the measurements.
- A further increase in ablation pressure is obtained by reducing CBET using multilayer targets.

The increase in implosion velocity is a result of the increase in the conversion of the absorbed laser energy into kinetic energy of the shell (rocket efficiency).
Collaborators

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A simple model indicates that increasing $A/Z$ increases the mass ablation rate and the ablation pressure*.

Ablation pressure:

$$P_a = 2\rho_c c_s^2 \sim \left(\frac{A}{Z}\right)^{1/3}$$

Mass ablation rate:

$$\dot{m}_a = \rho_c c_s \sim \left(\frac{A}{Z}\right)^{2/3}$$

Laser-energy deposition:

$$\rho_c c_s^3 = \frac{I}{4}$$

The increased mass density where the laser is absorbed results in a higher rocket efficiency.

An experiment was designed to measure the conversion of absorbed laser energy into the shell’s kinetic energy for different ablator materials.

To determine the effect of A/Z on target performance, the target mass and the laser pulse were kept the same.

$I = 7 \times 10^{14} \text{ W/cm}^2$ with smoothing by spectral dispersion (SSD)

Five calorimeters
Scattered-light energy

Streak camera

X-ray framing camera (XFRC)

Trajectory/velocity

$P (\text{TW})$

$0$ $5$ $10$ $15$ $20$

$0$ $1000$ $2000$

Incident
Scattered
Self-emission x-ray images are used to measure the trajectory and velocity of the implosions.

\[
\delta v = \frac{\delta (\Delta R)}{\Delta R} + \frac{\delta (\Delta t)}{\Delta t} = \frac{0.5 \mu m}{40 \mu m} + \frac{5 \text{ ps}}{200 \text{ ps}} = 5%*
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The simulated trajectories and absorbed laser energy for all three ablators are in good agreement with the measurements.

The good agreement between simulations and experiments indicates that the absorbed laser energy and its transfer to the motion of the shell is well modeled.
A 20% increase in the shell velocity is observed for Be compared to CH and C ablators*

Simulations show that the 20% increase in implosion velocity is a result of the 28% increase of the rocket efficiency.

To further enhance the ablation pressure, multilayer targets were designed to reduce CBET by increasing the coronal electron temperature.

Simulations show that the ablation pressure is increased by 17% in a multiple-ablator compared to a mass-equivalent Be target.
Shell velocities measured on multilayer targets agree well with simulations.

The multilayer ablator increases the electron temperature around a quarter-critical density by ~15%.

*R. J. Henchen et al., JO5.00010, this conference.
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