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

University of Rochester, Laboratory for Laser Energetics

Summary
Increasing the ratio of the atomic mass to the atomic number (A/Z) of the ablator increases the velocity of direct-drive implosions

- Accurate measurements of the trajectory of imploding shells are made for different ablators
- The hydrodynamic efficiency is calculated to increase with A/Z
- A 20% increase in shell velocity was measured for Be ablators compared to C and CH ablators when maintaining a constant shell mass
- LAC simulations that include CBET and nonlocal heat transport accurately reproduce the measurements

A simple model shows that increasing A/Z increases the mass ablation rate and the ablation pressure

At the initial laser pulse

\[ m_s = \rho_s V_s \]

Ablation pressure

\[ P_a = \frac{\rho_s V_s}{V_s} \]

Shell ablation rate

\[ \frac{dA}{dt} = \rho_s V_s \]

Accurate measurements of the shell trajectories were obtained for the three ablators

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The position of the gradient in the XRFC images is measured with an accuracy better than 0.5 μm

The XRFC interstrip timing is known to within ~5 ps, allowing for a 4% accuracy in the 200-ps-averaged shell velocity

The XRFC was used to measure the trajectory of the imploding shell

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The absolute timing requires cross-calibrating the XRFC with the pulse shape of the laser

The absolute timing has been measured on multiple absolute timing shots and an accuracy of ~30 ps was obtained

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The steep gradient in the x-ray emission is created by the combination of the limb effect and the absorption of the coronal x-rays in the cold dense shell

The diagnostic analysis has a very weak dependence on the modeling of the plasma conditions

The hydrodynamic modeling shows that the increase in A/Z results in an increase in hydrodynamic efficiency

Simulations that include CBET and nonlocal heat flow reproduce the amount of laser energy coupled to the plasma

Simulations show that the hydrodynamic efficiency is increased by 30% in Be and 7% in C.

The absorption was the same for all three materials, suggesting increased hydroefficiency

The good match between simulation and experiment indicate that transfer of the absorbed laser energy to the motion of the shell is well modeled

The increase in A/Z results in the increased shell acceleration could be caused by increased absorption or hydroefficiency

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Increasing the ratio of the atomic mass to the atomic number ($A/Z$) of the ablator increases the velocity of direct-drive implosions

- Accurate measurements of the trajectory of imploding shells are made for different ablators
- The hydrodynamic efficiency is calculated to increase with $A/Z$
- A 20% increase in shell velocity was measured for Be ablators compared to C and CH ablators when maintaining a constant shell mass
- *LILAC* simulations that include CBET and nonlocal heat transport accurately reproduce the measurements
Collaborators

V. N. Goncharov, I. V. Igumenshchev, P. B. Radha, S. X. Hu, and D. H. Froula

University of Rochester
Laboratory for Laser Energetics
A simple model shows that increasing $A/Z$ increases the mass ablation rate and the ablation pressure.*

At the end of laser pulse

<table>
<thead>
<tr>
<th>A/Z</th>
<th>CH</th>
<th>C</th>
<th>Be</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>52</td>
<td>54</td>
<td>58</td>
</tr>
<tr>
<td></td>
<td>56</td>
<td>58</td>
<td>60</td>
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</tbody>
</table>

Increasing $A/Z$ by changing the ablator from CH to Be is predicted to increase the implosion velocity.

An experiment was designed to compare the implosion velocity for different ablator materials. To determine the effect of $A/Z$ on the target performance, the velocity must be accurately measured.

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

X-ray framing camera (XFRC)

Streak camera

Scattered-light power

Trjectory/velocity

Scattered-light energy

5 calorimeters

16-$\mu$m Be

27-$\mu$m CH

8-$\mu$m C

$P (\text{TW})$

$0 \quad 1000 \quad 2000$

$0 \quad 5 \quad 10 \quad 15 \quad 20$

To determine the effect of $A/Z$ on the target performance, the velocity must be accurately measured.
The steep gradient in the x-ray emission is created by the combination of the limb effect and the absorption of the coronal x-rays in the cold dense shell.

The diagnostic analysis has a very weak dependence on the modeling of the plasma conditions.
The position of the gradient in the XRFC images is measured with an accuracy better than 0.5 μm.

\[ \delta R = \left( \frac{MTF}{2} \right) \left( \frac{1}{S/N} \right) \sim 2 \mu m \]

\[ R_{av} = \frac{1}{N_\theta} \sum_\theta R(\theta) = 195 \mu m \]

\[ \delta R_{av} = \frac{\sigma_R}{\sqrt{N_\theta}} \frac{\delta R}{10} < 0.5 \mu m \]

\[ **N_\theta = \frac{2\pi R}{MTF} \]

*Modulation transfer function*
The XRFC interstrip timing is known to within $\sim 5$ ps, allowing for a 4% accuracy in the 200-ps-averaged shell velocity.

\[
\frac{\delta v}{v} = \frac{\delta(\Delta R)}{\Delta R} + \frac{\delta(\Delta t)}{\Delta t} \sim 0.5 \, \mu\text{m} + \frac{5 \text{ ps}}{200 \text{ ps}} \sim 4\%^* 
\]

The absolute timing has been measured on multiple absolute timing shots and an accuracy of $\sim \pm 30$ ps was inferred.

* A 200 km/s shell velocity is assumed
The absolute timing requires cross calibrating the XRFC with the pulse shape of the laser.
The XRFC was used to measure the trajectory of the imploding shell.

To determine the effect of $A/Z$ on the target performance, the velocity must accurately measured.
Accurate measurements of the shell trajectories were obtained for the three ablators.

The good match between simulation and experiment indicate that transfer of the absorbed laser energy to the motion of the shell is well modeled.
A 20% increase in the velocity of the shell is observed for Be compared to CH and C ablators.

The increase in $A/Z$ results in the increased shell acceleration could be caused by increased absorption or hydroefficiency.
The absorption was the same for all three materials, suggesting increased hydroefficiency.

Simulations that include CBET and nonlocal heat flux reproduce the amount of laser energy coupled to the plasma.
The hydrodynamic modeling shows that the increase in $A/Z$ results in an increase in hydrodynamic efficiency.

Simulations show that the hydrodynamic efficiency is increased by 18% in Be and 7% in C.
Increasing the ratio of the atomic mass to the atomic number \((A/Z)\) of the ablator increases the velocity of direct-drive implosions

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