Direct-Drive ICF Implosions with Picket-Fence Pulse Shapes

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Summary

Shaped pulses have been used to control the seed amplitude of the deceleration-phase instability

- First experiments showed significant increase in neutron yield with a picket pulse due to reduction of the deceleration-phase instability initial amplitude.

- Experimental yield/1-D simulation yield (YOC) increases with greater separation between the ablation and gas interfaces.

- YOC also improves when ablation interface growth is reduced.
A 120-ps FWHM picket pulse before the drive pulse showed increased fusion yields.
The Rayleigh–Taylor instability at the shell–gas interface during deceleration strongly affects fusion yield

- Deceleration interface is classically unstable.

\[ A = A_{\text{initial}} e^{\gamma t} \]

\[ A_{\text{initial}} = \sqrt{A_{\text{inner}}^2 + A_{\text{feedthrough}}^2} \]

\[ A_{\text{feedthrough}} = A_{\text{ablation}} e^{-k\Delta CH} \]

- Shaped-pulse implosions will study both \( A_{\text{ablation}} \) and \( \Delta CH \).
CH targets were imploded using laser pulse shapes with and without picket pulses.

$\delta t$ varied between 730 and 960 ps

$I_{\text{foot}}$ varied between 1 and 6 TW
Picket timing relative to the drive pulse ($\delta t$) changes the distance between the ablation and gas interfaces, $\Delta CH$.

- Large $\delta t$ – Decaying shock wave reaches rear of shell before compression wave.
- Small $\delta t$ – Compression wave catches decaying shock wave before rear of shell.

- $v_f$ is larger when the compression wave overtakes the decaying shock wave in the shell.
- $\Delta CH$ is larger and continues to grow.
Experimental yield/1-D yield (YOC) is sensitive to the timing of the picket pulse relative to the drive pulse.

\[ \Delta CH \equiv \left\langle r_{\text{ablation}} - r_{\text{gas}} \right\rangle_t \]

- 4-atm-gas-filled targets travel farther during the deceleration phase.
Both picket and non-picket pulse shapes were used to change the ablation-interface amplitude, $A_{\text{ablation}}$.

- Separation of ablation and shell–gas interfaces $= 18 \pm 2 \ \mu m$

\[
A_{\text{bubble}} = a_0 e^{\gamma t}
\]

\[
\gamma = 0.9 \sqrt{\frac{kg}{(1 + kL)}} - 1.7 \text{ kV}_a
\]
Acceleration-phase stability growth affects the ratio of the experimental yield to the 1-D simulation yield.

- Separation of ablation and shell–gas interfaces, $\Delta_{CH} = 18 \pm 2 \mu m$

- Bubble amplitude is calculated using postprocessor\(^1\) to 1-D code *LILAC*.
- Calculation includes 1-Thz, 2-D SSD and interface roughness.

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