Effects of Perturbed Picket Pulses in Adiabat-Shaped Direct-Drive Implosion Experiments

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Picket pulse intensity, 180 ps FWHM
30-ps-rms picket scatter

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Summary

Beam-to-beam picket mistiming within NIF specifications does not compromise performance in adiabat-shaped implosions

- Beam-to-beam picket mistiming appears as nonuniform picket broadening and power imbalance.
- NIF picket mistiming does not affect adiabat shaping within the fuel.
- Power-imbalance-imposed picket mistiming does not contribute significantly to the overall uniformity budget.
Collaborators

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The NIF direct-drive target design employs adiabat shaping* to enhance hydrodynamic stability.

- $t = 0$ Picket creates a strong shock
- $t = t_p$ Rarefaction wave (RW) launched
- $t = t_{RW}$ RW meets the shock
- $t > t_{RW}$ Shock weakens in time

Picket-timing scatter produces low-order intensity nonuniformity on target

Harmonic amplitudes
- shown for \( \cos(\ell \theta) \)
- terms of orders
  \( \ell = 1\text{–}12 \)

- Picket pulse, 180-ps FWHM
- 48 quads, \( \sigma_{\text{rms}} = 30\text{-ps}^* \) scatter
- \( \delta t_o \approx \frac{\sigma_{\text{rms}}}{\sqrt{n_{\text{beam}}/5}} \approx 10\text{ps} \)

*O. S. Jones et al., SPIE, 3492 49 (1998).*
Shell adiabat perturbations due to beam mistiming are expected to be small

- The picket width $t_p$ varies over the target surface by $\delta t_p$.

$$t_p \approx \left( t_{p0}^2 + \sigma_{rms}^2 \right)^{1/2} \pm \delta t_p$$

$$\frac{\delta t_p}{t_p} \approx \frac{1}{2(n_{beam}/5)} \left( \frac{\sigma_{rms}}{t_p} \right)^2 \approx \frac{0.8 \text{ ps}}{t_p} \approx 0.009$$

- A decaying-shock model* describes the resulting adiabat variations.

$$\frac{\delta \alpha_{abl}}{\alpha_{abl}} \approx \frac{2}{7} \frac{\delta t_p}{t_p} \approx 0.0025$$

$$\frac{\delta V_a}{V_a} \approx \frac{5}{21} \frac{\delta t_p}{t_p} \approx 0.0021$$

$$\frac{\delta \alpha_{in}}{\alpha_{in}} \approx 0.007 \frac{\delta t_p}{t_p} \approx 0$$

Ignition conditions are attained in simulated direct drive with NIF-spec 30-ps-rms* picket scatter

End of the acceleration phase
\( t = 8.8 \text{ ns} \)

Onset of ignition
\( t = 9.5 \text{ ns} \)

\( T_i \) contours in keV

*O. S. Jones et al., SPIE, 3492 49 (1998).
Scaling gain with $\bar{\sigma}$ allows the formation of a global nonuniformity budget for the direct-drive point design*

Current specifications

- On-target power imbalance (2% rms): $\bar{\sigma} = 0.85 \, \mu m$
- Inner-surface roughness (1-\mu m rms): $\bar{\sigma} = 0.61 \, \mu m$
- Applied SSD bandwidth (2 color cycle $\times$ 1THz): $\bar{\sigma} = 0.50 \, \mu m$
- Outer-surface roughness (80 nm): $\bar{\sigma} = 0.15 \, \mu m$

\[ \bar{\sigma}^2 = 0.06 \quad \sigma_{l}^2 \leq 10^+ \quad \sigma_{l}^2 > 10 \]

Power imbalance due to picket mistiming does not contribute significantly to the overall uniformity budget.

\[ \text{Gain} \]

![Graph showing sum-in-quadrature vs. } \overline{\sigma} (\mu m)\]

<table>
<thead>
<tr>
<th>Picket scatter rms (ps)</th>
<th>( \overline{\sigma} (\mu m) )</th>
<th>( \frac{\delta \overline{\sigma}}{\overline{\sigma}} )</th>
<th>Scaled gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>38</td>
</tr>
<tr>
<td>30*</td>
<td>0.43</td>
<td>6.6%</td>
<td>34</td>
</tr>
<tr>
<td>45</td>
<td>0.48</td>
<td>8.2%</td>
<td>33</td>
</tr>
</tbody>
</table>

*NIF standard specification
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