Experimental Investigation of Cross-Beam Energy Transfer Mitigation via Wavelength Detuning in Directly Driven Implosions at the National Ignition Facility

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We have successfully reduced energy losses from cross-beam energy transfer (CBET) via wavelength detuning in directly driven implosions at the National Ignition Facility (NIF).

- CBET is a primary energy-loss mechanism in directly driven implosions.
- $\Delta \lambda$ detuning of interacting beams is the main mitigation strategy for CBET, but the NIF’s current capabilities for its implementation are limited.
- A hemispheric $\Delta \lambda$ in polar-direct-drive (PDD) implosions was achieved by means of NIF’s wavelength capabilities between inner and outer quads.
- Enhanced energy coupling is observed by means of shell trajectory, shape, and hard x-ray emission.

First experimental demonstration of CBET mitigation by means of wavelength detuning in direct drive.
Collaborators

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Lawrence Livermore National Laboratory
CBET is a main energy-loss mechanism in direct-drive inertial confinement fusion (ICF) experiments

- CBET reduces laser drive energy by $\sim 30\%$
- Wavelength detuning shifts the resonance location sufficiently to mitigate CBET*
- CBET mitigation increases with $\Delta \lambda$

*I. V. Igumenshchev et al., Phys. Plasmas 17, 122708 (2010); J. A. Marozas et al., NO5.00009, this conference; P. B. Radha et al., NO5.00005, this conference.
The current NIF can achieve hemispheric detuning using a cone-swapped PDD beam pointing in one hemisphere*

- $\Delta \lambda_{UV} = 12 \, \text{Å} \ (\pm 6 \, \text{Å})$ is required for CBET mitigation
- The current NIF can test hemispheric detuning using a north–south asymmetric beam pointing with up to $\Delta \lambda_{UV} = 4.6 \, \text{Å} \ (\pm 2.3 \, \text{Å})$

*J. A. Marozas et al., NO5.00009, this conference.
CBET mitigation with hemispheric $\Delta \lambda$ was diagnosed in directly driven implosions by means of implosion trajectory and shape.

- Fe backlighter for face-on, x-ray radiography ($\text{Fe He}_\alpha = 6.7$ keV) driven by Q16T and Q41B
- Self-emission imaging without backlighter uses all 48 quads for CH implosion
X-ray radiography data exhibit changes to the azimuthal energy absorption and an increased shell velocity in the presence of $\Delta \lambda = 4.6 \, \text{Å}$.

**Experiment**

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Simulation</th>
<th>Experimental shell outline</th>
</tr>
</thead>
<tbody>
<tr>
<td>N160405-002 $\Delta \lambda_{\text{UV}} = 0 , \text{Å}$ 8.60 ns</td>
<td>DRACO</td>
<td>$\Delta \lambda_{\text{UV}} = 0$ $\Delta \lambda_{\text{UV}} = 4.6 , \text{Å}$</td>
</tr>
<tr>
<td>N160821-001 $\Delta \lambda_{\text{UV}} = 4.6 , \text{Å}$ 8.56 ns</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Time (ns)**

- N160405-002 $\Delta \lambda_{\text{UV}} = 0$

**Radius ($\mu$m)**

- N160821-001 $\Delta \lambda_{\text{UV}} = 4.6 \, \text{Å}$
Self-emission data also exhibit increased absorption around the target equator for $\Delta \lambda = 4.6$ Å.

Enhanced hard x-ray emission in the presence of $\Delta \lambda = 4.6 \text{ Å}$ is consistent with less laser energy lost as a result of CBET.

The hot-electron fraction inferred through hard x-ray emission increases with $\Delta \lambda = 4.6 \text{ Å}$. 

The table shows the following:

<table>
<thead>
<tr>
<th></th>
<th>N160406-001 $\Delta \lambda = 0 \text{ Å}$</th>
<th>N160821-002 $\Delta \lambda = 4.6 \text{ Å}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_{\text{hot}}$ (keV)</td>
<td>$34\pm3$</td>
<td>$42\pm2$</td>
</tr>
<tr>
<td>$E_{\text{hot}}$ (kJ)</td>
<td>$0.74\pm0.19$</td>
<td>$1.03\pm0.13$</td>
</tr>
<tr>
<td>$f_{\text{hot}}$ (%)</td>
<td>$0.13\pm0.03$</td>
<td>$0.17\pm0.02$</td>
</tr>
</tbody>
</table>
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