A Polar-Drive Alpha-Heating Platform for the National Ignition Facility

V_{imp} (\mu m/ns)

Time (ns)

- No CBET, \( f = 0.06 \) (shifted 1 ns)
- No wavelength detuning
- Tricolor detuning

CBET, nonlocal heat transport

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Summary

Three-color detuning cross-beam energy transfer (CBET) mitigation achieves ignition-relevant implosion velocities

• Tricolor detuning restores over half the drive energy lost to CBET

• Nonlocal electron transport increases the hydrodynamic efficiency, offsetting the decrease in drive energy caused by CBET

• A polar-drive target design, with an implosion velocity of 370 μm/ns, is predicted to demonstrate alpha heating with a neutron yield of $2 \times 10^{16}$
Collaborators

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The majority of CBET* occurs over the equatorial region in polar drive

- CBET reduces the laser drive by as much as 30%, making CBET mitigation the most-important design issue.

- Laser wavelength detuning is used for power balance in indirect-drive experiments; for direct drive it is used for CBET mitigation.

- Detuning the laser wavelength in each hemisphere changes the location of the CBET resonance region; the interaction region vanishes only in the large detuning limit.

*J. A. Marozas et al., NO4.00014, this conference; P. W. McKenty et al., NO4.00015, this conference.
Three wavelength detuning strategies were explored for CBET mitigation

- Banded and tricolor detuning have less scattered light at the equator because of reduced intrahemispherical CBET and less scattering of the polar beams.
- Tricolor detuning has less scattered light at the poles because of reduced interhemispherical CBET and less scattering of the equatorial beams.
- The sign $\Delta \lambda$ determines whether the interaction region moves radially in or out; this introduces a north-south asymmetry and a significant $\ell = 1$ perturbation.
Tricolor detuning restores over half of the absorbed energy lost to CBET

- Tricolor detuning not only reduces interhemispherical CBET but also reduces CBET within each hemisphere

This design uses phase plates relevant to polar-drive ignition
The loss of absorbed energy is offset by the increase in hydrodynamic efficiency caused by nonlocal heat transport.

- Nonlocal electron transport is modeled with the implicit Schurtz–Nicolaï–Busquet (iSNB) model.*
- Tricolor detuning achieves an implosion velocity comparable to that of the original point design as simulated without CBET or nonlocal heat transport.

![Graph](image)


A robust target design has been developed that is predicted to demonstrate alpha heating

- The hot-spot temperature and uniformity are sufficient to generate significant alpha-deposition yield
- This design operates on an adiabat of $\sim 3$ to reduce hydrodynamic instability
- This lowers the growth factor for mode $\ell = 100$ by 82%

<table>
<thead>
<tr>
<th>Design properties</th>
<th>Alpha-burning design</th>
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</thead>
<tbody>
<tr>
<td>$V_{\text{imp}}$ ($\mu$m/ns)</td>
<td>370</td>
</tr>
<tr>
<td>$E_{\text{laser}}$ (MJ)</td>
<td>1.5</td>
</tr>
<tr>
<td>Peak power (TW)</td>
<td>433</td>
</tr>
<tr>
<td>In-flight aspect ratio (IFAR)</td>
<td>23</td>
</tr>
<tr>
<td>In-flight $\alpha$</td>
<td>3</td>
</tr>
<tr>
<td>Peak $\rho R$ (g/cm$^2$)</td>
<td>1.6</td>
</tr>
<tr>
<td>Peak $T_i$ (keV)</td>
<td>6.3</td>
</tr>
<tr>
<td>Neutron yield</td>
<td>$2.4 \times 10^{16}$</td>
</tr>
</tbody>
</table>

Simulated with CBET, nonlocal heat transport, and long-wavelength nonuniformities
A high-gain, low-adiabat design is being developed based on the robust alpha-burning design.

The ion temperatures achieved are sufficient to demonstrate “bootstrap” heating.

- The areal density and peak ion temperature, while insufficient to produce a sustained burn wave, do generate alpha-deposition neutron yield comparable to the neutron yield generated by compression alone.

- \( E_\alpha / E_{\text{tot}} \sim 0.5, \ Y_\alpha / Y_{\text{no }\alpha} \sim 1.7 \)

- The target implosion speed can be further increased by
  - increasing incident laser energy from 1.5 MJ to 1.8 MJ*
  - reducing the spot size to 85% of the target radius, increasing the absorbed laser energy by 6%
  - increasing the coronal electron temperature using moderate-Z ablators**

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*J. A. Marozas et al., 44th Anomalous Absorption Conference, Estes Park, CO (2014).

**M. Lafon et al., JO4.00011, this conference.
Summary/Conclusions

Three-color detuning cross-beam energy transfer (CBET) mitigation achieves ignition-relevant implosion velocities

- Tricolor detuning restores over half the drive energy lost to CBET
- Nonlocal electron transport increases the hydrodynamic efficiency, offsetting the decrease in drive energy caused by CBET
- A polar-drive target design, with an implosion velocity of $370 \, \mu m/ns$, is predicted to demonstrate alpha heating with a neutron yield of $2 \times 10^{16}$
- A second design with a low adiabat is being toned for ignition