Numerical Investigation of Bandwidth Reduction in NIF Direct-Drive Ignition Designs

P.W. McKenty
University of Rochester
Laboratory for Laser Energetics

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Summary

OMEGA and OMEGA EP experiments will determine effective techniques for reducing SSD bandwidth while maintaining adequate laser-beam smoothing.

- Current adiabat-shaping techniques cannot sufficiently smooth the laser-imprint nonuniformities initially present on the NIF.

- OMEGA EP experiments with a NIF PAM will examine the effects of beam-smoothing techniques on a NIF-like beam.

- OMEGA implosions will focus on determining the most efficient adiabat-shaping technique and testing our understanding of SSD in cryogenic and warm-foam target implosions.
K. Anderson, R. Betti, T. J. B. Collins, V. N. Goncharov, 
J. P. Knauer, J. A. Marozas, R. L. McCrory, 
P. B. Radha, S. Skupsky, and J. D. Zuegel
The need for laser-beam smoothing (SSD, ISI...) has been established for some time

\[ \sigma^2 = 0.06 \sigma_1^2 + 9 + \sigma_2^2 \geq 10 \]

Adiabat-shaping techniques improve the in-flight stability and increase the overall robustness of the direct-drive point design.

\[ \text{Initial shock} \rightarrow \text{Pressure} \rightarrow \text{Laser} \rightarrow \text{Decaying shock} \]

- Adiabat $\alpha_{\text{abl}}$
- $\alpha_{\text{fuel}}$

\[ \sigma (\mu m) \]

- Applied SSD bandwidth (two-color cycle – 1 THz)
- On-target power imbalance (2% rms)
- Inner-surface roughness (1-$\mu m$ rms)
- Outer-surface roughness (80 nm)

Initial beam-smoothing parameters for the NIF are substantially different than those required for DD.

Sustained transport of high levels of bandwidth may lead to unacceptable damage to the laser system.

<table>
<thead>
<tr>
<th>Direct-Drive Requirements</th>
<th>Initial NIF Specifications</th>
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<tbody>
<tr>
<td><strong>2-D SSD</strong></td>
<td><strong>1-D SSD</strong></td>
</tr>
<tr>
<td>Modulation frequencies</td>
<td>Modulation frequency</td>
</tr>
<tr>
<td>((X)) 15.4 GHz ((Y))</td>
<td>17.0 GHz</td>
</tr>
<tr>
<td>IR Bandwidth</td>
<td>IR Bandwidth</td>
</tr>
<tr>
<td>((X)) 10.8 A ((Y)) 2.0 A</td>
<td>2.3 A</td>
</tr>
<tr>
<td>Angular Divergence</td>
<td>Angular Divergence</td>
</tr>
<tr>
<td>((X)) 100 (\mu rad) ((Y)) 50 (\mu rad)</td>
<td>50 (\mu rad)</td>
</tr>
<tr>
<td>Color cycles</td>
<td>Color cycles</td>
</tr>
<tr>
<td>((X)) 2 ((Y)) 1</td>
<td>1.35</td>
</tr>
</tbody>
</table>
Current adiabat-shaping techniques cannot overcome the initial levels of beam smoothing available on the NIF.

Minimum level of smoothing appears to be 2-D 1-THz SSD with 1 × 1 color cycles.
OMEGA EP will implement 2-D SSD into a NIF PAM to test levels of laser-amplitude modulation

- Use 2-D SSD beam to drive planar-RT experiments on OMEGA EP
- Test dynamic bandwidth reduction (DBWR) within a NIF PAM
- Test the propagation of various bandwidth/color-cycle pairs

2-D SSD module subassemblies have been fabricated and are ready for testing.
Dynamic bandwidth reduction (DBWR) can minimize laser damage without seriously affecting target performance.
OMEGA will test reduced-bandwidth implosions trading bandwidth for increased color cycles

Imprint simulations
\( \lambda = 2 \) to 200, DPP + PS

Smoothing time \( \sim 1/\Delta \theta \)
\( \Delta \theta \omega = \Delta \lambda N_{cc} \)

OMEGA \( \bar{\sigma} \) scaling
OMEGA cryogenic and warm-foam implosions will examine the advantages of various adiabat-smoothing techniques.

- Imprint seed reduction
- RT growth mitigation

See J. Knauer V02.01
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