Three-Dimensional Modeling of X-Ray Self-Emission Images on NIF Polar-Drive Implosions

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Experimental image N130703, $t_{\text{NIF}} = 6.0$ ns

Calculated image SAGE run 6343, $t_{\text{NIF}} = 5.9$ ns

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Summary

X-ray self-emission imaging* was used on National Ignition Facility (NIF) polar-drive experiments to observe 3-D target nonuniformities during the implosion.

- A 3-D postprocessor was created to calculate self-emission images using 3-D profiles obtained from SAGE hydrodynamic simulations.
- Modeling reproduces the target shape when two NIF quads were dropped.
- Predicted deviations of $\sim 10 \, \mu m$ resulting from beam-energy variations are observed with the self-emission diagnostic.

Collaborators

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X-ray framing-camera images of the target self-emission provide information on the symmetry of the target outer radius.

Self-emission imaging provides 3-μm accurate measurement of the radius perpendicular to the diagnostic plane.
The 3-D postprocessor calculates self-emission images by integrating the radiation transfer equation through a 3-D model of the target.

\[ \frac{dI_{\nu}}{ds} = \kappa'_{\nu} (B_{\nu} - I_{\nu}) \]

- \( I_{\nu} \) = Specific intensity
- \( B_{\nu} \) = Blackbody term
- \( \kappa'_{\nu} \) = Opacity

The total intensity calculation incorporates a wide range of frequencies using multigroup methods.
The calculated intensity is filtered and convolved to accurately compare with the experiment.

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**SAGE run 6349**

**Equatorial plane**

- Green line: $T_e$
- Blue line: $n_i$

Ablation surface

**Diagnostic plane**

- Blue line: Filtered
- Black line: Data
- Purple line: Filtered and convolved

$t_{\text{NIF}} = 6.5 \text{ ns}$

$t_{\text{NIF}} = 6.0 \text{ ns}$

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The effects of power balance are observed in the polar self-emission images for a uniform shot. 10-μm variations caused by beam-energy imbalance can be measured.
Two quads were dropped on a NIF polar-drive experiment, creating large nonuniformities observed in the self-emission images.
For $R \approx 600 \, \mu m$, deviations in the target radius resulting from the missing quads are well-reproduced by the model.

The equatorial radius on the correctly driven side is underestimated by the model.
Calculated self-emission images agree well with experimental images taken from the polar direction.

Measured, $t_{\text{NIF}} = 5.9$ ns

Calculated, $t_{\text{NIF}} = 5.9$ ns

Polar view

$I = 4 \times 10^{14}$ W/cm$^2$

Weak drive at $135^\circ$

Missing quads

SAGE (shifted 53 $\mu$m)

Data

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**Summary/Conclusions**

X-ray self-emission imaging* was used on National Ignition Facility (NIF) polar-drive experiments to observe 3-D target nonuniformities during the implosion.

- A 3-D postprocessor was created to calculate self-emission images using 3-D profiles obtained from SAGE hydrodynamic simulations.
- Modeling reproduces the target shape when two NIF quads were dropped.
- Predicted deviations of ~10 μm resulting from beam-energy variations are observed with the self-emission diagnostic.

*D. T. Michel et al., Rev. Sci. Instr. 83, 10E530 (2012).*