Mix, Temperature, and Compression of Statistical Model Optimized Cryogenic Implosions

X-ray yield predicted on the basis of neutron yield and hot-spot temperature measurements

Measured x-ray yield

8% CD by atom in hot spot
4%
2%

X-ray yield predicted on the basis of neutron yield and hot-spot temperature measurements

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Absolute measurements of the hot-spot x-ray continuum have been used to study performance limits of presently optimized cryogenic implosions*

- Continuum hot-spot x rays are used to characterize hot-spot electron temperature and absolute x-ray yield
- The x-ray yield is not found to have a measurable enhancement (i.e., no detectable hot-spot mix)
- The x-ray yield indicates an inferred hot-spot density that is at best ~30% below 1-D as compared to a 20% reduction in the 2-D simulation
  - imprint, beam-geometry and other perturbations associated with direct drive reduce the hot-spot compression in the simulation

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Collaborators

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The absolute hot-spot x-ray yield can be used to indicate hot-spot mix*,**, 

- Yield (neutrons) $\sim \rho^2 \times <\sigma(T)> \times \tau \times V$
- Yield (x rays) $\sim \rho^2 \times e^{-\hbar v/kT} \times \tau \times V \times z^2$
- Ions and electrons are not in thermal equilibrium ($T_i \neq T_e; V_n \neq V_x$)

If the equilibration is different in the experiment, it will skew the expected ratio (and the mix inference).

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A mapping was developed to determine the expected x-ray production based on measured neutron yield, $T_i$, and $T_e$.

No-mix expected x-ray yield

$$= 2.2 \times 10^{-3} \ T_e^4 \ T_i^{-2.39} \ Y_n$$

These 2-D simulations show no hot-spot mix.
A filtered imaging array is used to obtain the x-ray data*,**

- Four channels (~10 to 20 keV, optically thin) were used to fit hot-spot model to extract $T_e$ and $Y_X$
- Images discriminate coronal emission and were used to recover the hot-spot image†

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Results

For an ensemble of the larger, high-speed targets, the measured x rays are compared to the values obtained using the equilibration mapping

• Approaches 2% by atom CD mix sensitivity
• This is a bounding sensitivity (10× decrease of mix in defect calculations* as \( \alpha \) increased from 1.7 to 3.4)

A CD mix of 2% by atom is a bounding sensitivity for the higher adiabats since mix will decrease as stability increases.

The hot-spot density is inferred using the x-ray measurements.

The hot-spot density is maximally ~70% of 1-D.

\[ \text{Yield (x rays)} \sim \rho^2 \left[ e^{-\frac{hv}{T_e}} \right] \tau R^3 Z^2 \]

\[ \text{Yield (neutrons)} \sim \rho^2 < \sigma_v(T_i) > \tau R^3 \]
The reduction of hot-spot compression in the experiment is qualitatively captured by 2-D simulation.

2-D DRACO, peak neutron production

- Imprint
- Beam geometry
- Layer roughness
- Balance, pointing
- Typical offset

- Inferred $\rho_{hs}$ 70% to 80% of uniform
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Results

Temperatures and yields were measured for an ensemble of high velocity, high-adiabat implosions

- $T_i$ is minimum of 5 detectors
- $T_e$ lower as expected (though greater drops from 1-D are expected from 2-D)
- YOCS do not suggest mix enhancement