Simulation and Analysis of Backlit Images of Cryogenic Implosions on OMEGA

Shot 54395: 10.1-μm shell, 95-μm cryo D₂, 866-μm diam

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Radiographs of cryogenic implosions have been obtained on OMEGA with an OMEGA EP driven Al backlighter.

- Analysis of the first OMEGA/OMEGA EP backlit cryogenic shots provides useful results at times well in advance of peak compression.

- The analysis is based on the Abel inversion of radiographs circularly averaged from the entire image.

- Detailed 1-D simulation of the implosions and their radiographs provides input parameters for the analysis, takes into account instrumental effects, and anticipates potential complications.
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Backlit images of imploding cryogenic targets are captured by a soft x-ray framing camera.

- Ir-coated mirrors significantly reduce the hard x-ray background by reflecting x rays below 2 keV.
X-ray radiography is used to infer target areal density during a cryogenic implosion.

- The backlit image was Abel inverted.
- A $\rho^2 R$ of $\sim 0.097 \, g^2/cm^5$ was inferred from the optical depth.
- A $\rho R$ of $\sim 33 \, mg/cm^2$ was inferred using the radius of the measured image of $\Delta R \sim 110 \, \mu m$ and an ice-block model.
- A $\rho R$ of $\sim 33 \, mg/cm^2$ is consistent with the simulated imploded mass within the inner and outer shadow radii.
The radius of the shell radiograph and the inferred $\rho R$ are consistent with simulated values at a time well before peak compression.

- Measured shell radius = 140 $\mu$m
- Experimentally inferred $\rho R = 33$ mg/cm$^2$
The analysis of cryogenic implosion radiographs is guided by hydrodynamic and radiation simulations

- LILAC simulates the hydrodynamics of the implosions
  - the simulated imploded shell mass is a useful input parameter\(^1\)
  - the simulated shell temperature is needed to infer density from opacity, but the results are only weakly sensitive to it

\[ \kappa_{\text{free-free}} \sim \frac{\rho/(kT)^{1/4}}{(h\nu)^3} \]

- Implosion radiographs are simulated by Spect3D\(^2\)
  - the backlighter spectrum, the instrumental spectral response, and the space and time resolutions are taken into account
  - the appropriate spectrum-averaged opacity is applied to the radiograph analyses


\(^2\) Prism Computational Sciences, Inc., Madison, WI.
Backlighter profile information obtained from exposed views can be applied to radiographs where the backlighter is obscured.

Another view ~40 ps later, backlighter obscured.

Intensity (arbitrary units) vs. Distance (pixels) for Shot 54395.
Simulation results are closer to measured radiographs and inferred mass density profiles with thinner CD shells.

- From the shell mass (33.5 $\mu$g, LILAC) and the density profile: $\rho R = 20$ mg/cm$^2$
- From the inferred opacity profile alone: $\rho R = 56$ mg/cm$^2$
- Much of the observed absorption is not yet accounted for.
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Simulated radiograph shows significant absorption due to an unablated trace of shell CD

- From the shell mass (34.8 µg, LILAC) and the density profile: $\rho R = 19 \text{ mg/cm}^2$
- From the inferred opacity profile alone: $\rho R = 47 \text{ mg/cm}^2$
- CD absorption complicates the analysis based on free-free D$_2$ opacity
Abel inversion recovers the shell opacity profile from its radiograph

- The optical thickness $\tau(x)$ of the shell is the measured quantity
- Abel inversion recovers the radial opacity distribution $\kappa(x)$

$$\kappa(r) = -\frac{1}{\pi} \int_r^\infty \frac{d\tau(x)}{dx} \frac{dx}{\sqrt{x^2-r^2}} \quad \text{or} \quad \int_{r_0}^\infty \kappa(r) \, dr = \frac{r_0}{\pi} \int_{r_0}^\infty \frac{\tau(x)}{x\sqrt{x^2-r_0^2}} \, dx$$