Self-Radiography of Imploded Shells on OMEGA Based on Additive-Free Multi-Monochromatic Continuum Spectral Analysis

Three images at $h\nu = 2.2$, 2.4, and 2.6 keV yield a shell radiograph.

Inferred optical thickness $h \nu = 2.6$ keV

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61st Annual Meeting of the American Physical Society
Division of Plasma Physics
Fort Lauderdale, FL
21–25 October 2019

$\log_{10} (\text{intensity})$ arbitrary units

Inferred optical thickness

0.1 1.0 10.0
0.00 0.60 1.25

100 $\mu$m

100 $\mu$m
Summary

The imploded cold shell structure can be radiographed using spatially resolved continuum spectroscopy of the hot core emission

- Core self-emission is the backlighter in self-radiography, unlike externally backlit radiography, where self-emission is the limiting background.
- Continuum self-radiography applies to pure cryo implosions without relying on the spectral K edges or spectral lines of additives*.
- This radiography technique has been demonstrated using multi-monochromatic imaging (MMI) of a warm CH shell implosion on OMEGA.

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Collaborators

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Core self-emission is the limiting background in externally backlit radiography, but in self-radiography, core self-emission is the backlighter.

- Three intensities \( I_1, I_2, I_3 \) determine the parameters \( A, T, \tau \) at each pixel.
- \( T \) is a chord-averaged, emission-weighted harmonic mean of a highly variable temperature profile.

We rely on the simple spectral form of continuum opacity and emissivity; no additives are needed.
With multi-monochromatic images, the emission and absorption contributions to the total image can be separated

- An inhomogeneous core and shell test the simplicity of the three-parameter continuum model
- 2-D geometry tests the simplifying assumption that absorption follows emission

Shot 81590, DRACO/Spect3D,*

\[ \alpha = 2.5, \text{IFAR} = 10 \]

Three images at \( \hbar = 1.6, 1.8, \text{and} 2.0 \text{ keV} \)

Inferred optical thickness

\[ 0 \quad 1 \quad 2 \]

Intensity \( (\times 10^{18} \text{ erg/cm}^2/\text{s/ster/eV}) \)

\( \tau \) polar lineout

\[ h\nu = 2.0 \text{ keV} \]

Optical thickness

\[ 0 \quad 0.5 \quad 1.0 \quad 1.5 \quad 2.0 \]

IFAR: in-flight aspect ratio

* Prism Computational Sciences, Inc., Madison, WI.
Simulated self-radiographs of a less-stable implosion indicate that features attributable to imprint will be visible

Shot 82717 is a less-stable ($\alpha = 1.9$, IFAR = 14) version of shot 81590 ($\alpha = 2.5$, IFAR = 10)

**log$_{10}$ (intensity) arbitrary units**

<table>
<thead>
<tr>
<th>$h\nu$ (keV)</th>
<th>2.2</th>
<th>2.4</th>
<th>2.6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inferred optical thickness</td>
<td>0.00</td>
<td>0.60</td>
<td>1.25</td>
</tr>
</tbody>
</table>

**Inferred optical thickness**

*Prism Computational Sciences, Inc., Madison, WI.*
The timing of three MCP strips on the MMI* image plane provided three simultaneous monochromatic images of a warm CH shell implosion on OMEGA

Pinhole image data from strip #2 of XRFC3 of the multi-monochromatic X-ray imager (MMI)

1.95 ns 3.5 keV
2.06 ns 4.6 keV
2.15 ns 5.5 keV

Time-spectral location of the three simultaneous images

Averaged image $h\nu = 4.5$ to 4.7 keV

Shot 94374

*H. Azechi et al., Appl. Phys. Lett. 37, 998 (1980); D. T. Cliche and R. C. Mancini, Appl. Opt. 58, 4753 (2019); UO7:00006, this meeting
MCP: microchannel plate
XRFC: x-ray framing camera
Shot 94374 has been radiographed by space-resolved continuum spectroscopy using three simultaneous MMI images.

- Inferred central optical thickness is roughly consistent with LILAC/Spect3D simulation values.
- Diagnostic development, implosion symmetry, etc., have yet to be fully explored.
- Radiographic symmetry corroborates the symmetry of other images of this implosion earlier in time.

**MMI averaged images**

- $h\nu = 3.6\ \text{keV}$
- $h\nu = 4.6\ \text{keV}$
- $h\nu = 5.4\ \text{keV}$

**Projected optical thickness**

- Intensity (arbitrary units)

**Lineout**

- Average source temperature (keV)

**Optical thickness**

- Lineout, measured
- Simulated, -100 ps
- Simulated, instantaneous
Imploded cold shell structure can be radiographed using spatially resolved continuum spectroscopy of hot core emission

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- Continuum self-radiography applies to pure cryo implosions without relying on the spectral K-edges or spectral lines of additives.*
- This radiography technique has been demonstrated using multi-monochromatic imaging (MMI) of a warm CH shell implosion on OMEGA.