Framed X-Ray Imaging of Cryogenic Target Implosion Cores on OMEGA

KBFRAMED optic assembly

KBFRAMED core image
OMEGA cryogenic DT target implosion shot 77064

100 × 100-\(\mu\text{m}\) image regions

Relative x-ray intensity

0
Max

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Summary

Time-resolved x-ray imaging of cryogenic target-core emission provides improved estimates of bang time, burnwidth, and peak core pressure

• Cryogenic DT target-implosion cores are imaged on OMEGA by a combination of a high-speed framing camera coupled to a pinhole array and a 16-image framed x-ray microscope (KBFRAMED)

• The time history of the core x-ray emission, determined by the high-speed framing-camera pinhole array, gives absolute values of the bang time and burnwidth (with ~5-ps accuracy)

• The core pressure is inferred from the measured core size, ion temperature, neutron yield, and burnwidth
Collaborators

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*Related talks:
V. N. Goncharov et al., U04.00005, this conference;
S. P. Regan, CI3.00005, this conference (invited).
KBFRAMED is a 16-channel Kirkpatrick–Baez (KB) x-ray microscope that provides time-resolved images of the core around stagnation.

Gate width: ~30 ps
Image to image: 15 to 60 ps
Spatial resolution: ~6 μm
Energy range: 2 to 8 keV

KBFRAMED optic magnification and framed resolution have been measured using an x-ray backlit grid on OMEGA.

Image 10

KBFRAMED OMEGA shot 76806

$M = 12$ with 6-\(\mu\)m resolution

Resolution (FWHM* of the PSF**) \(\approx 6\ \mu\)m varies from image to image

*FWHM: full width at half maximum
**PSF: point spread function
KBFRAMED records an image ($\Delta t = 30$ ps) of the stagnating core every $\sim 15$ ps in the 4- to 8-keV photon-energy range.
The detailed cryogenic core hot-spot evolution is seen every ~15 ps with KBFRAMED OMEGA shot 77064.

KBFRAMED x-ray images

Image 3: -23 ps
Image 14: -3 ps
Image 7: +2 ps
Image 11: +22 ps

100 × 100-μm image regions

Relative x-ray intensity

0 Max

Image-to-image timing is precisely determined from position and the use of measured cables (±2 ps).
The cryogenic target implosion’s hot-spot size is determined from an elliptical super-Gaussian fit.

**OMEGA shot 77064 KBFRAMED core image near peak compression**

\[
I = I_0 \times \exp \left[ -\frac{(x - x_c)^2}{a^2} - \frac{(y - y_c)^2}{b^2} \right]^{n/2}
\]

\[I^n = I \otimes \text{PSF}(x, y)\]

\[R_{1/e} = \sqrt{ab}\]

\[R_{17} = (1.77)^{1/n} \times R_{1/e}\]

- Fit is to super-Gaussian convolved with PSF \((I^*)\)
- For KBFRAMED: PSF \(\approx 6 \, \mu m\) FWHM Gaussian

![Image](black)

![Image](red)

**Lineout indicated by dotted line**

**100 \times 100-\mu m regions**
The x-ray “bang time” is independently determined by measuring the time from the first picket peak to the stagnation peak.
The pinhole-array framing-camera images determine the absolute x-ray bang time and burnwidth of the cryogenic target implosion.

Core x-ray emission, OMEGA shot 77339

Integrated x-ray flux (arbitrary units)

Time (ns)

SFC3 with 46-pinhole array

$\Delta t = 2.5\text{ ns}$
$\Delta t = 2.3\text{ ns}$
$\Delta t = 2.1\text{ ns}$
$\Delta t = 0\text{ ns}$

Flat fielded by framing constant-emission x rays.

Best fit:
$I_0 = 1710$
$t_{\text{bang (exp)}} = 2.393 \pm 0.005\text{ ns}$
$t_{\text{bang (1-D)}} = 2.38\text{ ns}$
$\Delta t_{\text{burn (exp)}} = 64 \pm 5\text{ ps}$
$\Delta t_{\text{burn (1-D)}} = 64\text{ ps}$

From first picket
The hot-spot pressure and volume are inferred from the neutron yield, burnwidth, ion temperature, and core size.

\[
\langle P_{hs}\rangle^* \simeq \left[8Y\sqrt{\ln 2/\pi} / \Delta t_{\text{burn}} \int_{V_{hs}} dV \langle \sigma v \rangle / T^2 \right]^{1/2} \quad \text{and} \quad V_{hs} \approx \frac{4\pi}{3} R_{17}^3
\]

**OMEGA cryogenic target shot 77066**

- \( R_{17} = 22.0\pm0.4 \mu\text{m} \) (KBFRAMED + framed pinholes)
- \( Y_n = 4.0 \times 10^{13} \)
- \( \Delta t_{\text{burn}} = 63\pm5 \) ps (x rays), 67\pm5 ps (neutrons), 66 ps (1-D)
- \( T_i = 3.2\pm0.4 \) keV
- \( \langle P_{hs}\rangle_{\text{exp}} = 56\pm7 \) Gbar
- \( \langle P_{hs}\rangle_{1-D} = 90 \) Gbar

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