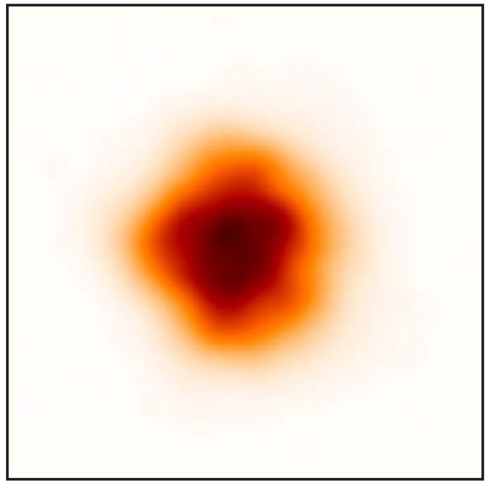
Framed X-Ray Imaging of Cryogenic Target Implosion Cores on OMEGA

KBFRAMED
optic assembly

KBFRAMED core image
OMEGA cryogenic DT target implosion
shot 77064



100 × 100-μm image regions

Relative x-ray intensity

0 Max

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Division of Plasma Physics
Savannah, GA
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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

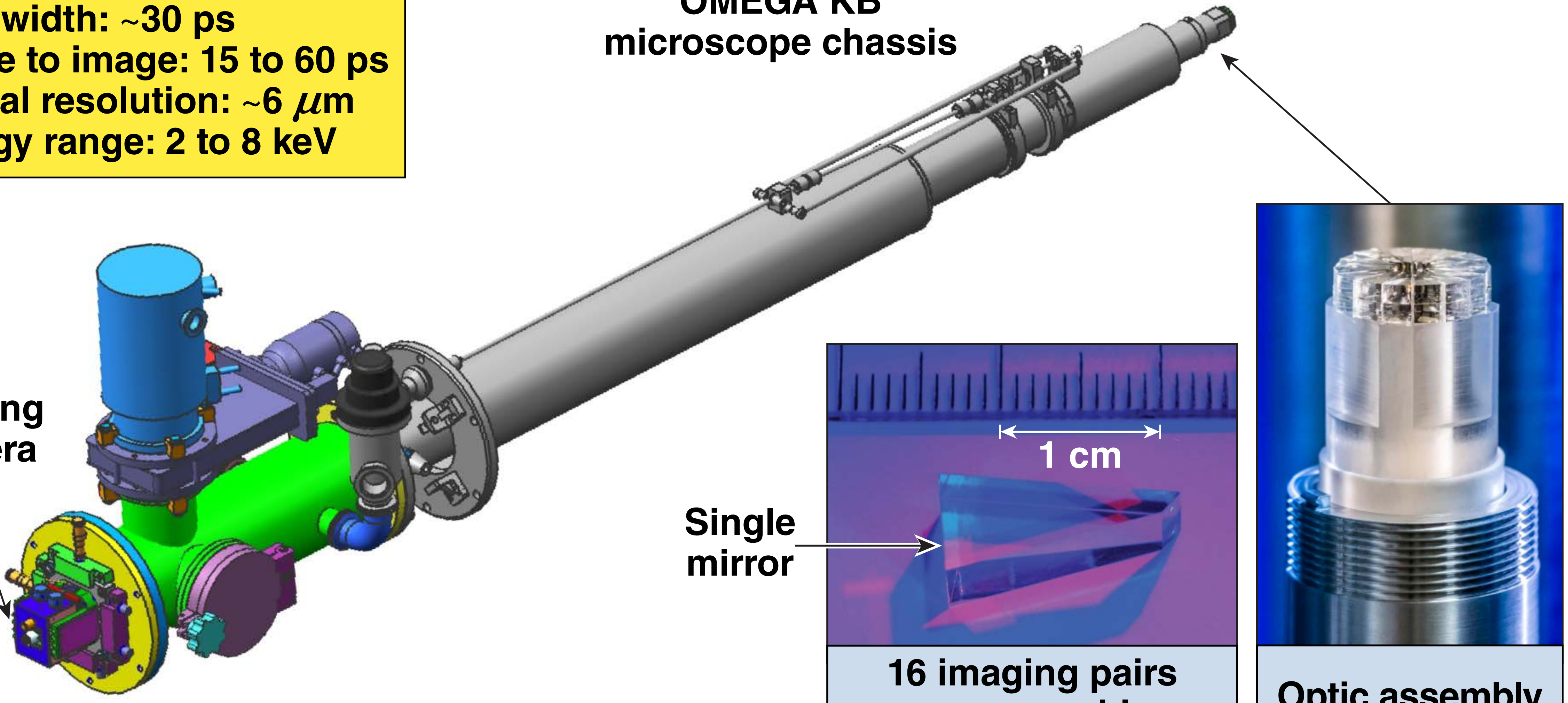
V. N. Goncharov,* V. Yu. Glebov, S. P. Regan,*
T. C. Sangster, and C. Stoeckl

University of Rochester
Laboratory for Laser Energetics

*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



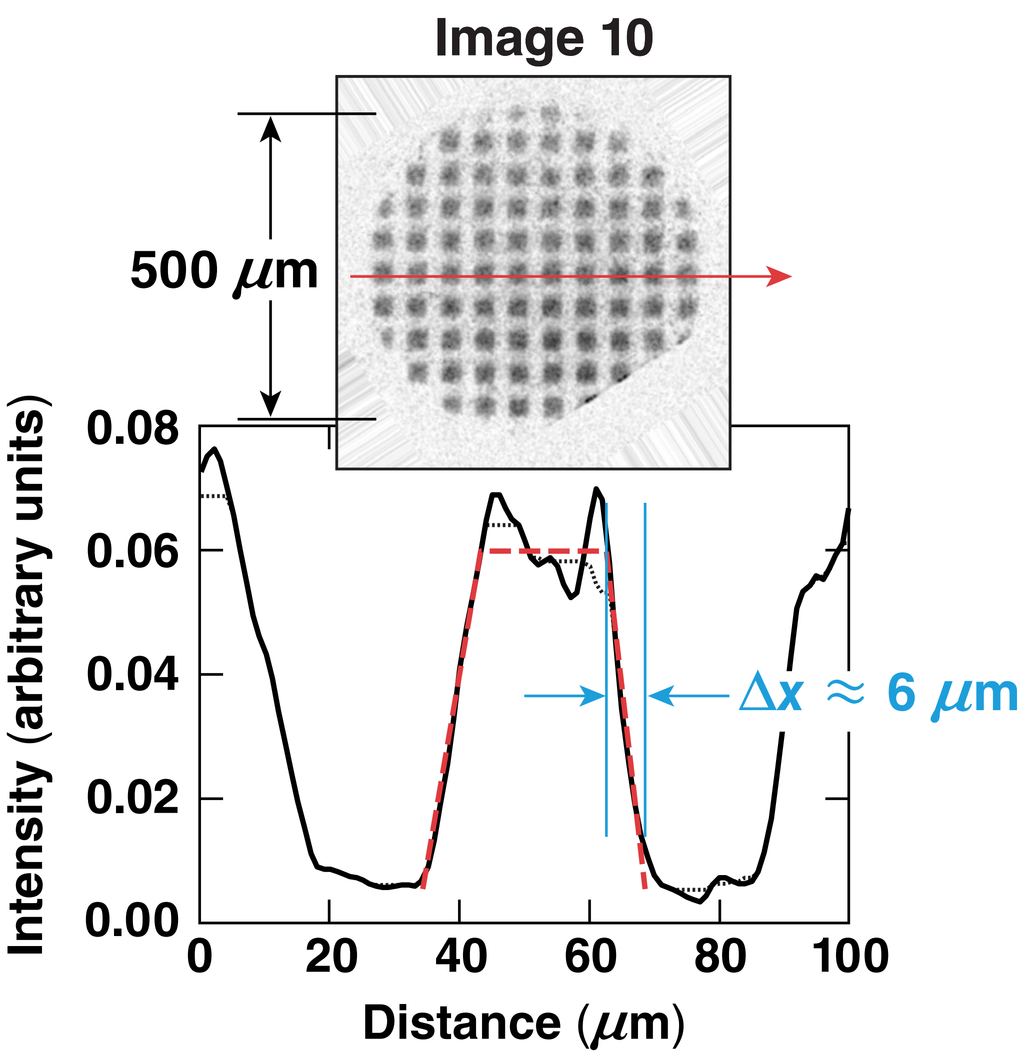
16 imaging pairs per assembly

Optic assembly

E22996e

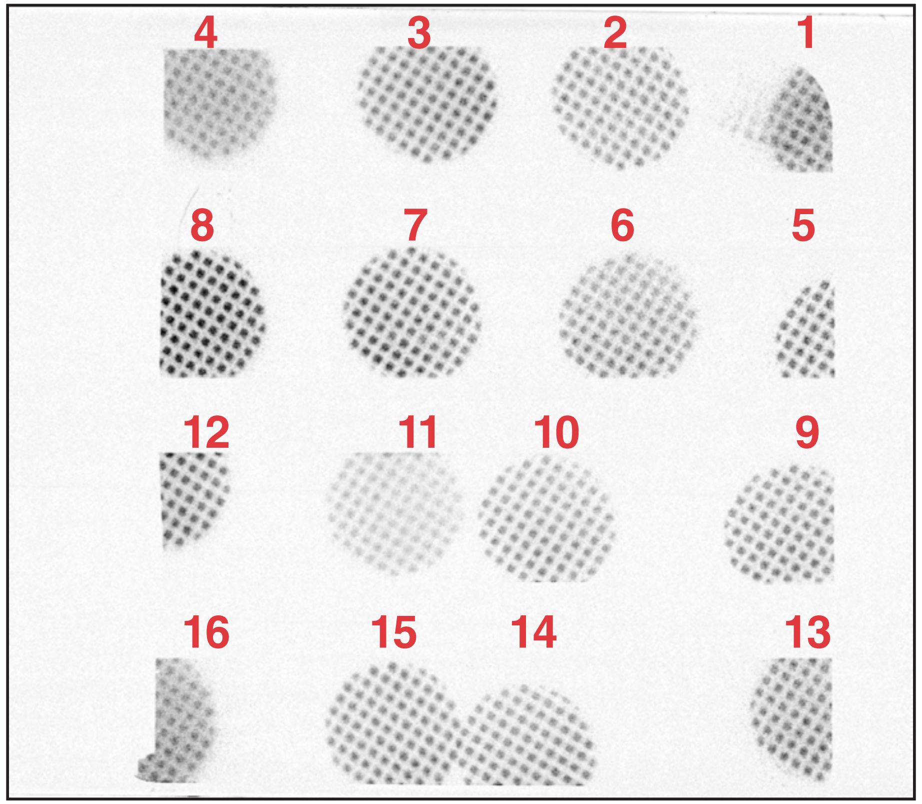
F. J. Marshall, J. A. Oertel, and P. J. Walsh, Rev. Sci. Instrum. 75, 4045 (2004).

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



M = 12 with 6-μm resolution

KBFRAMED OMEGA shot 76806



M = 12.0 within 1%
Resolution (FWHM* of the PSF) $\approx$ 6 μm varies from image to image**

*FWHM: full width at half maximum
**PSF: point spread function

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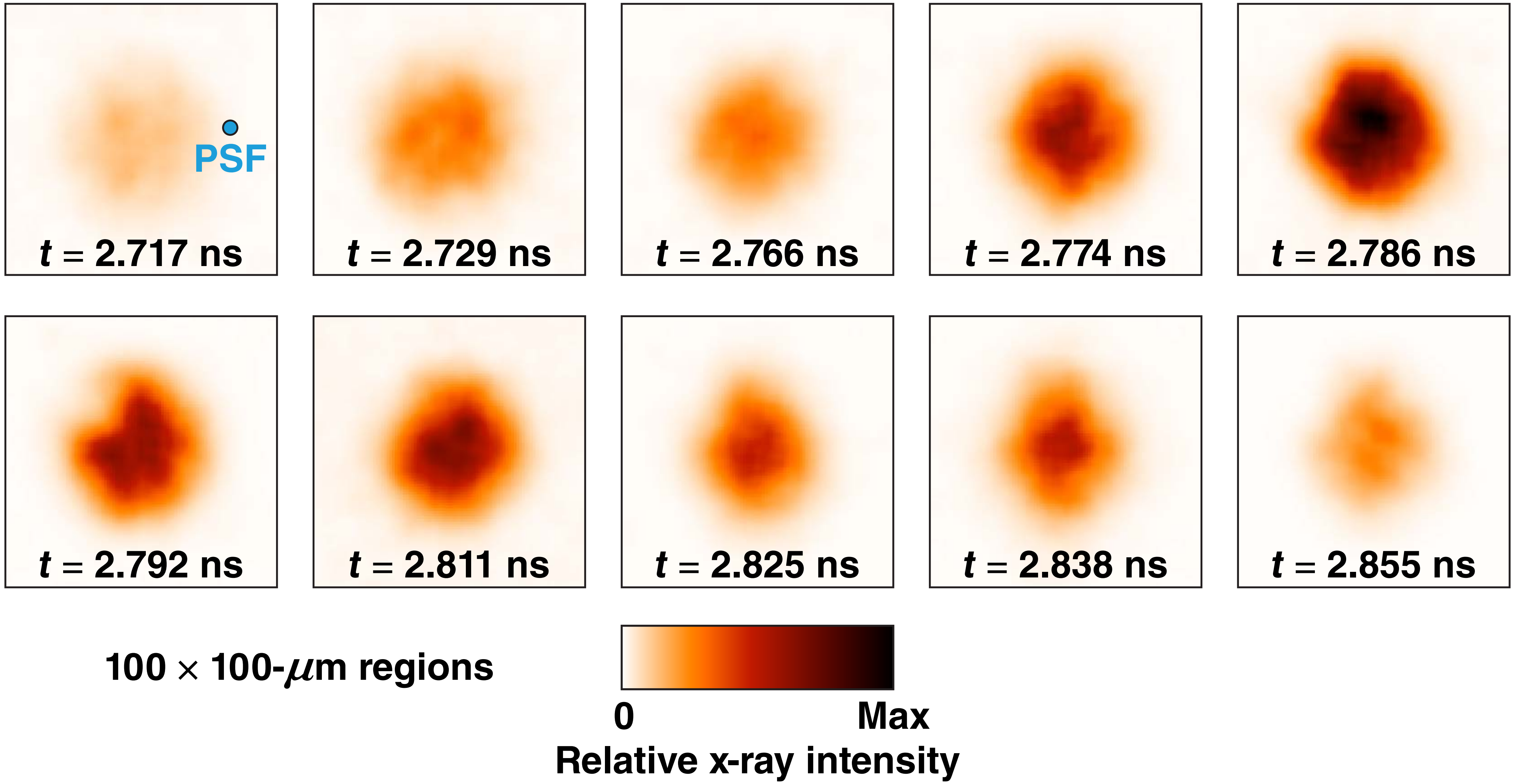
KBFRAMED records an image (Δt = 30 ps) of the stagnating core every ~15 ps in the 4- to 8-keV photon-energy range

OMEGA cryogenic DT target implosion, shot 76828



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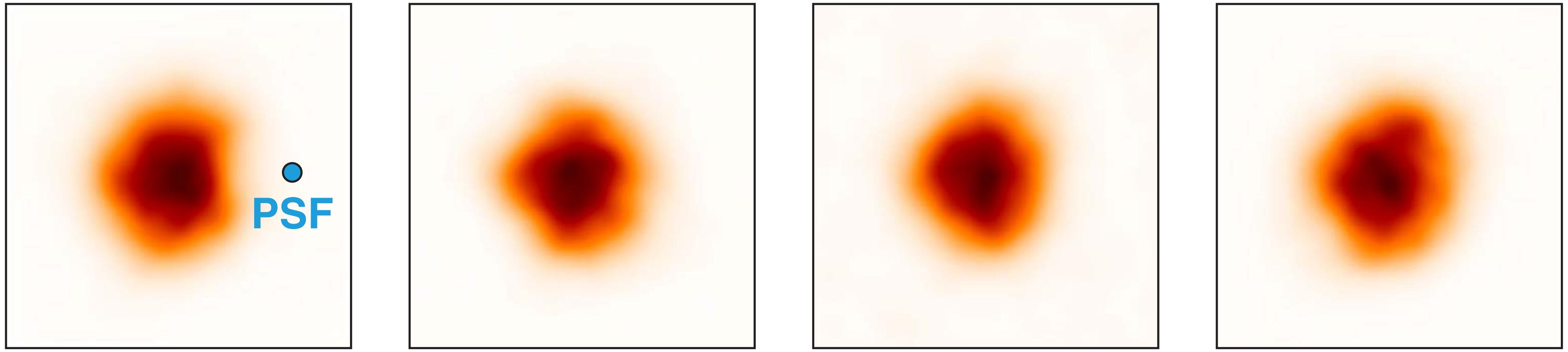
The detailed cryogenic core hot-spot evolution is seen every ~15 ps with KBFRAMED

OMEGA shot 77064
KBFRAMED x-ray images



100 × 100-μm image regions

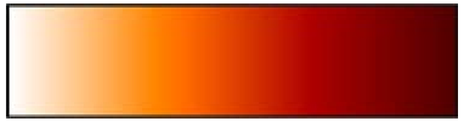


Image-to-image timing is precisely determined from position and the use of measured cables (±2 ps).

E24420a

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

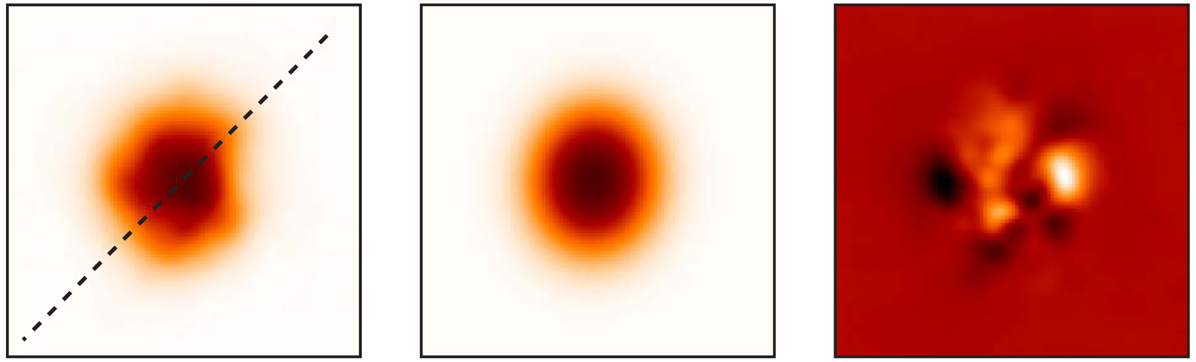
$$I = I_0 \times \exp\left[-\frac{(x - x_c)^2}{a^2} - \frac{(y - y_c)^2}{b^2}\right]^{n/2}$$

$$I^* = I \otimes PSF\,(x, y)$$

$$R_{1/e} = \sqrt{ab}$$

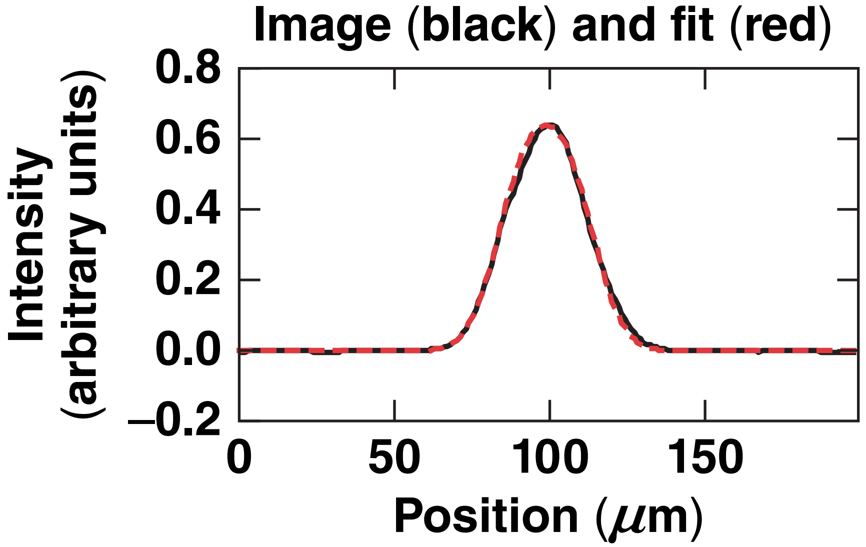
$$R_{17} = (1.77)^{1/n} \times R_{1/e}$$

Image | Super-Gaussian fit | Difference



Lineout indicated by dotted line

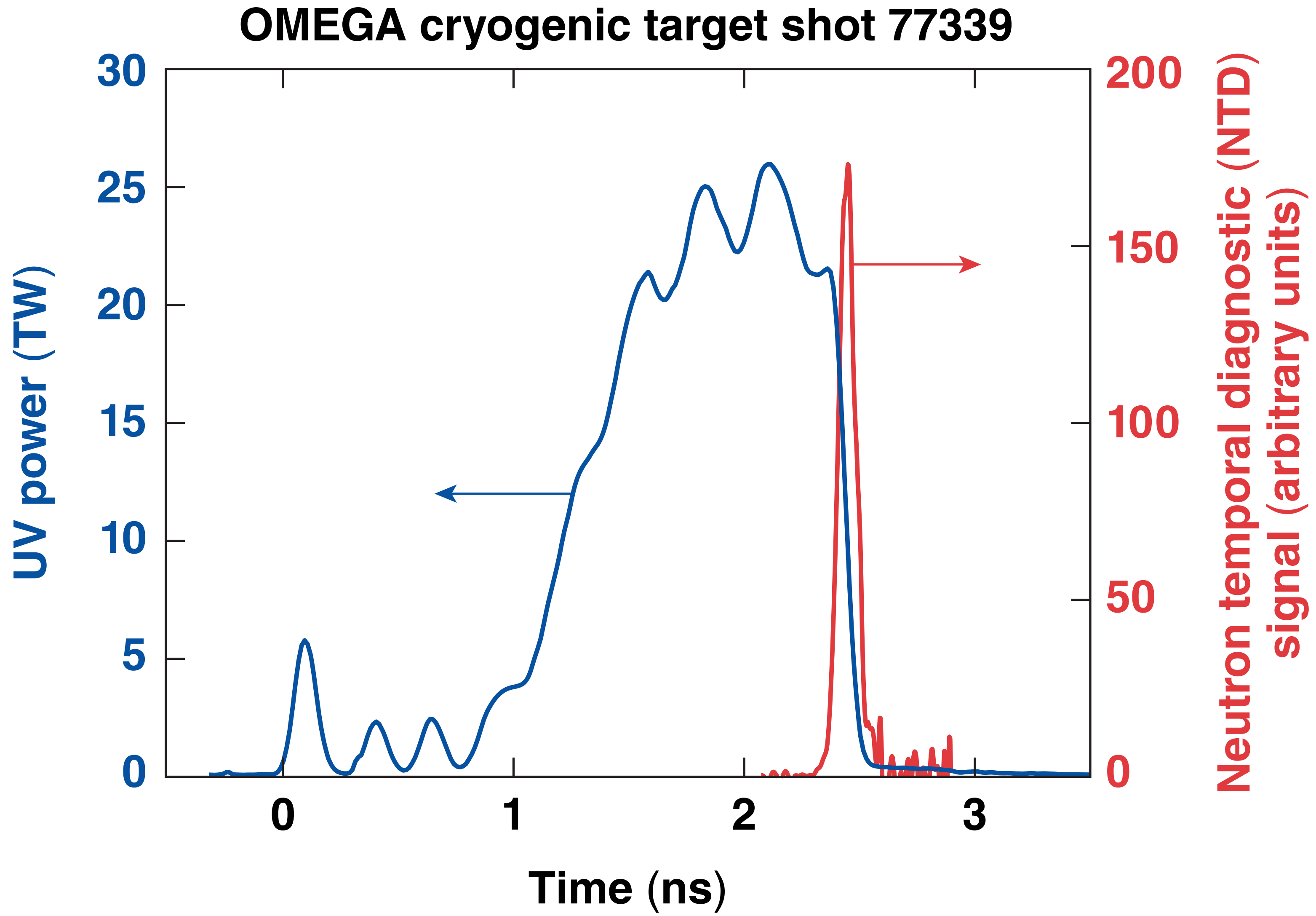
100 × 100-μm regions

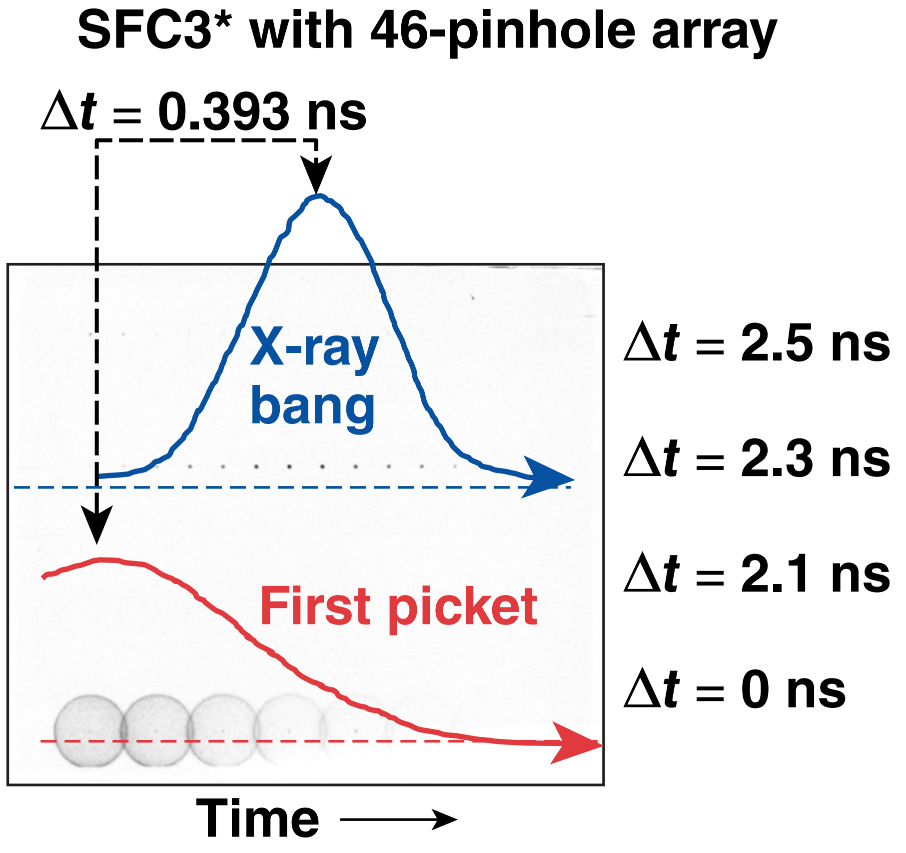


- Fit is to super-Gaussian convolved with PSF (I^*)
- For KBFRAMED: PSF ≈ 6 μm FWHM Gaussian

E24509a

The x-ray "bang time" is independently determined by measuring the time from the first picket peak to the stagnation peak



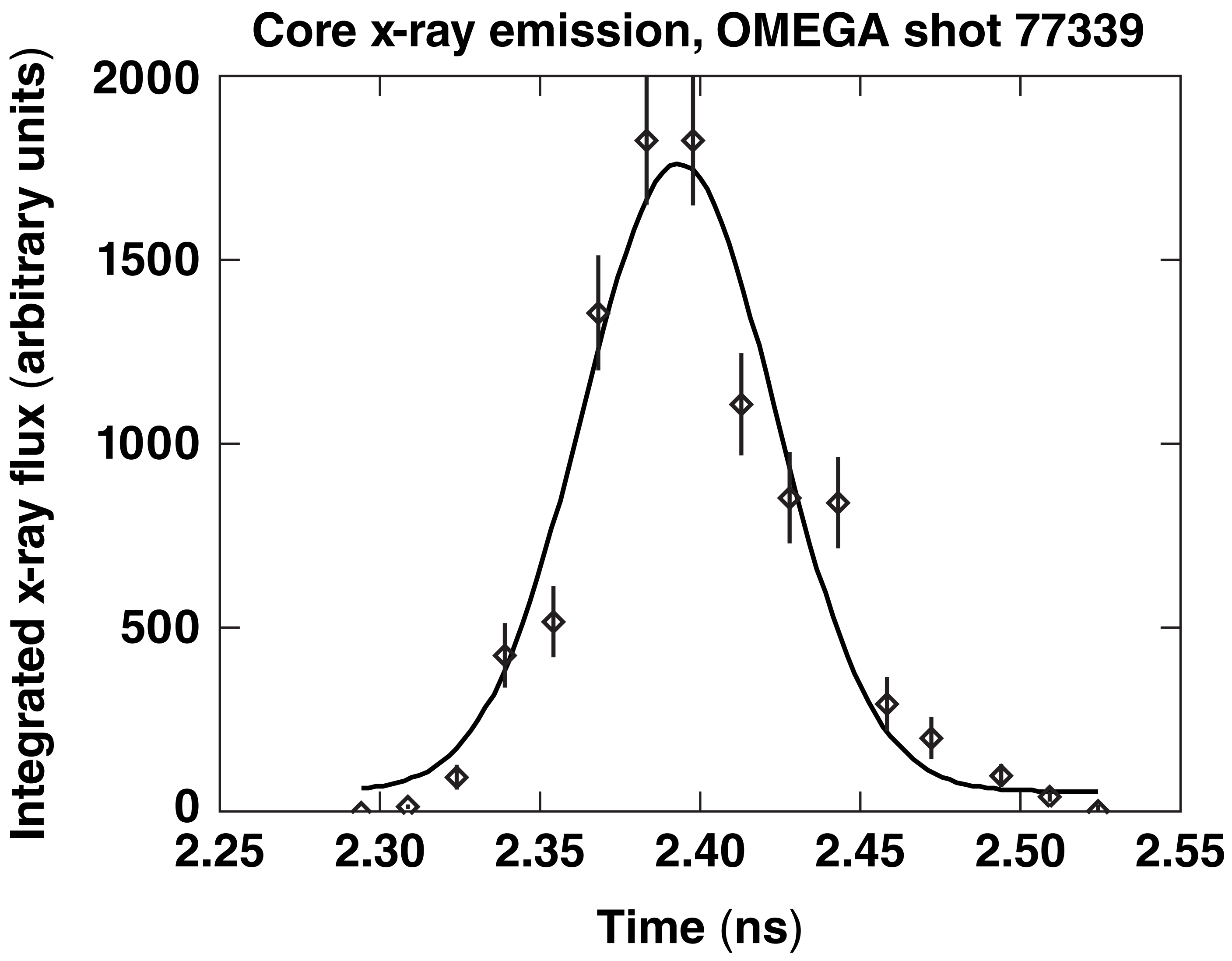


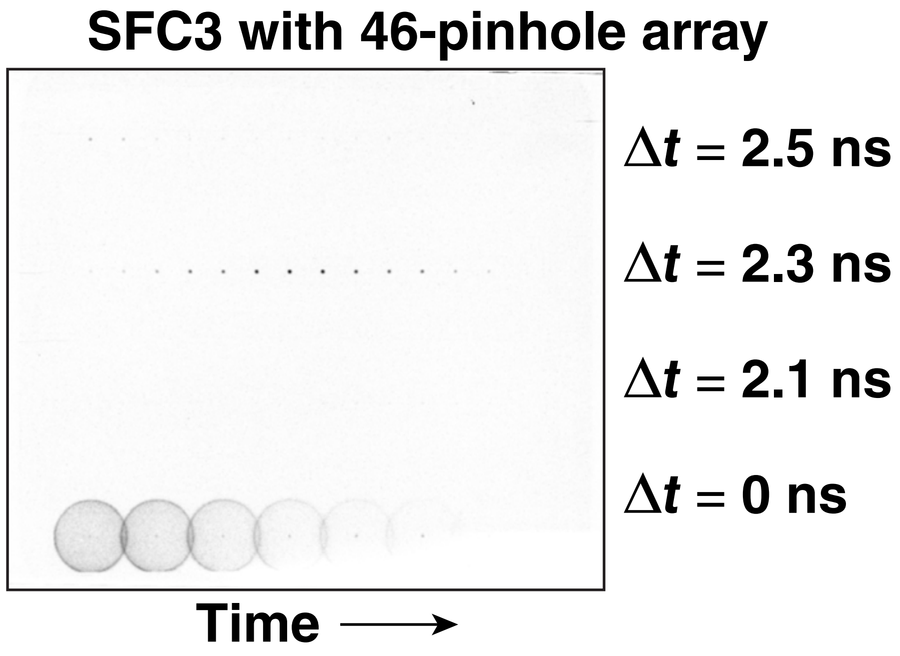
$T_{bang} = 2.3 \text{ ns} + \Delta t = 2.393 \text{ ns}$

*SFC3: Sydor framing camera

E24761

The pinhole-array framing-camera images determine the absolute x-ray bang time and burnwidth of the cryogenic target implosion





Best fit:
I_0 = 1710
t_{bang} (exp) = 2.393±0.005 ns } From first picket
t_{bang} (1-D) = 2.38 ns }
Δt_{burn} (exp) = 64±5 ps
Δt_{burn} (1-D) = 64 ps

Flat fielded by framing constant-emission x rays.

E24421a

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

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

OMEGA cryogenic target shot 77066

R_{17} = 22.0±0.4 μm (KBFRAMED + framed pinholes)

$Y_n = 4.0 \times 10^{13}$

Δt_{burn} = 63±5 ps (x rays), 67±5 ps (neutrons), 66 ps (1-D)

T_i = 3.2±0.4 keV

$\langle P_{hs} \rangle_{exp}$ = 56±7 Gbar

$\langle P_{hs} \rangle_{1\text{-}D}$ = 90 Gbar

*C. Cerjan, P. T. Springer, and S. M. Sepke, Phys. Plasmas 20, 056319 (2013);
R. Betti *et al.*, Phys. Plasmas 17, 058102 (2010).

Summary/Conclusions

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