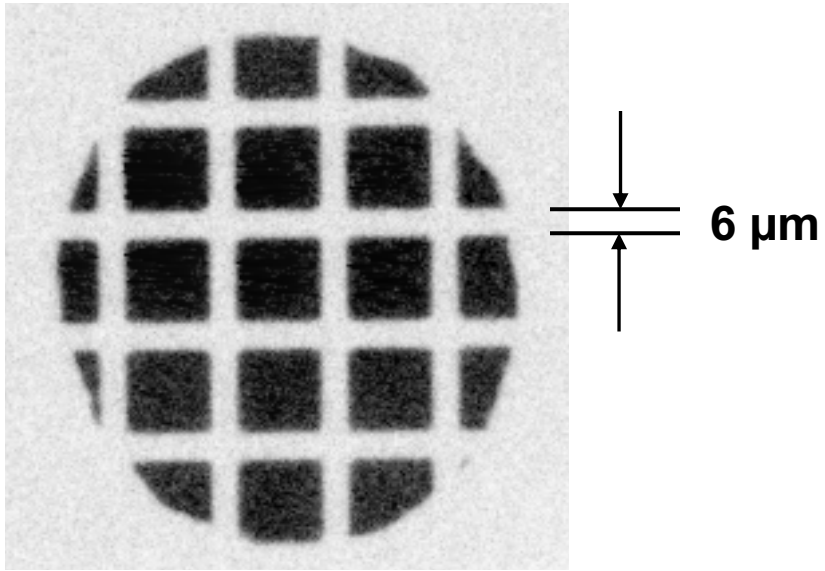
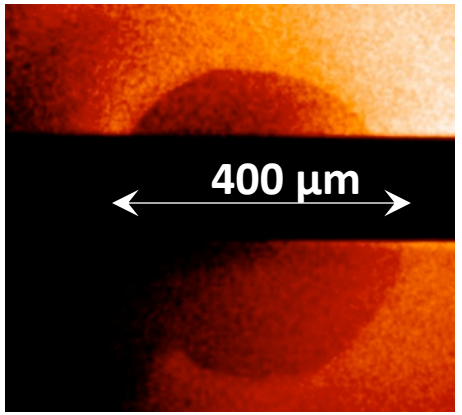
High-Resolution X-Ray Imaging with Fresnel Zone Plates on the University of Rochester's OMEGA and OMEGA EP Laser Systems

Fresnel zone plate image
OMEGA EP shot 30382
Au grid backlit with 4.75 keV x rays



Ti backlit (4.75 keV) FZP images taken with a high speed framing camera (Δt~30 ps)



LANL Revolver double shell implosion (Inner shell after collision)

F. J. Marshall
University of Rochester
Laboratory for Laser Energetics

61th Annual Meeting of the American Physical Society
Division of Plasma Physics, Fort Lauderdale, FL
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Summary

Experiments performed on the OMEGA and OMEGA EP Laser Systems have used Fresnel Zone Plates (FZP's) obtaining x-ray images with a best resolution of ~1.5 μm

FZP* resolution tests at LLE have achieved ~1.5 to 1.6 μm resolution by direct x-ray detection using CCDs and film and ~3 to 4 μm resolution using high-speed framing cameras

We have performed a number of experiments on both OMEGA and OMEGA EP using FZPs to obtain radiographs of driven foils and imploding shells as examples

X-ray imaging with single or arrays of FZPs is being implemented for a magnification of 25 in the OMEGA and OMEGA EP diagnostic inserters

***FZPs manufactured by Applied Nanotools Inc., Edmonton, AB**

Collaborators

S.T. Ivancic, C. Mileham, P.M. Nilson, and J.J. Ruby

University of Rochester, Laboratory for Laser Energetics

B.S. Schiener, M.J. Schmitt, and C.A. Wilde

Los Alamos National Laboratory

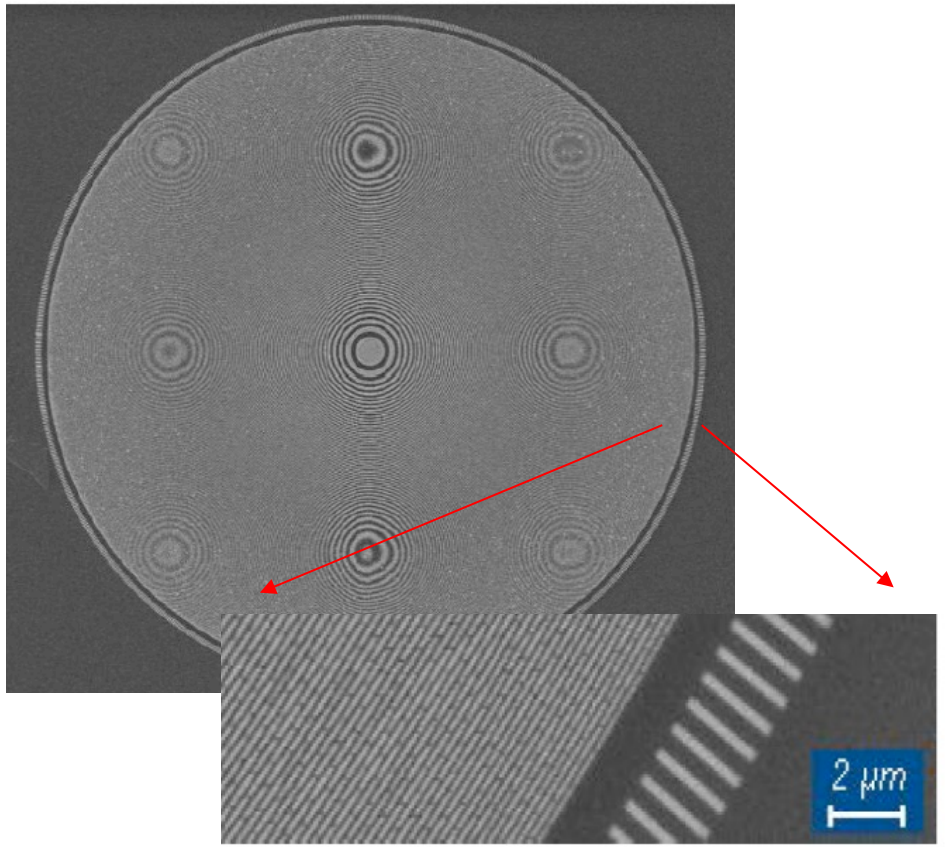
Fresnel Zone Plates obey a simple focus equation dependent on wavelength and are best used for monochromatic backlighting

FZPs obey the thin lens equation: $$\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$$

the FZP focus length is given by: $$f_{FZP} = \frac{4N(\Delta r)^2}{\lambda}$$

where
- p = object to optic distance
- q = optic to image distance
- R_{mirror} = mirror radius of curvature
- N = number of zones
- Δr = width of outermost zone of FZP
- λ = wavelength of x-rays

500 zone, 216 μm OD, 1.3 μm thick Au FZP with 108 nm outer bars, for 8 keV x rays



www.appliednt.com

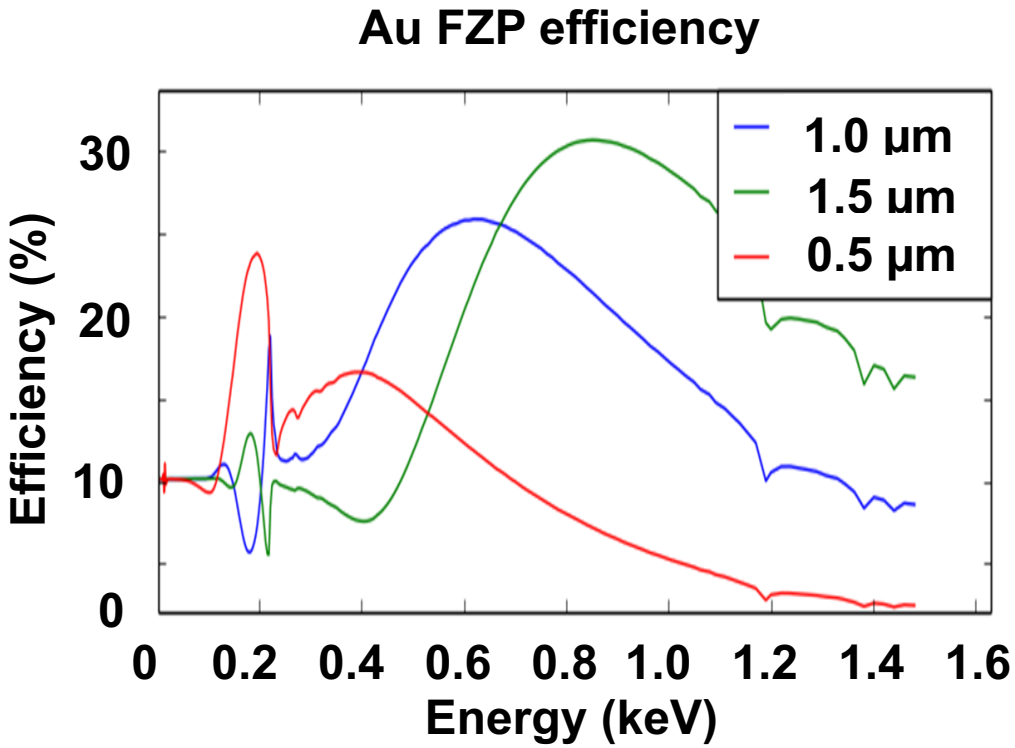
We currently have a set of FZPs that can be used over an energy range from 1.9 to 9 keV

FZP	Z	dt (μm)	N	D (μm)	ΔRn (nm)	f (mm)
Cu(8 keV)	Au	1.3	500	216	108	156.4
Ti(4.8 keV)	Au	1.3	512	281	120	151.9
P(2.1 keV)	Ni	0.9	258	300	291	151.8

Each case is not restricted to the central energy
The focal length however is linearly proportional to energy (1/λ)

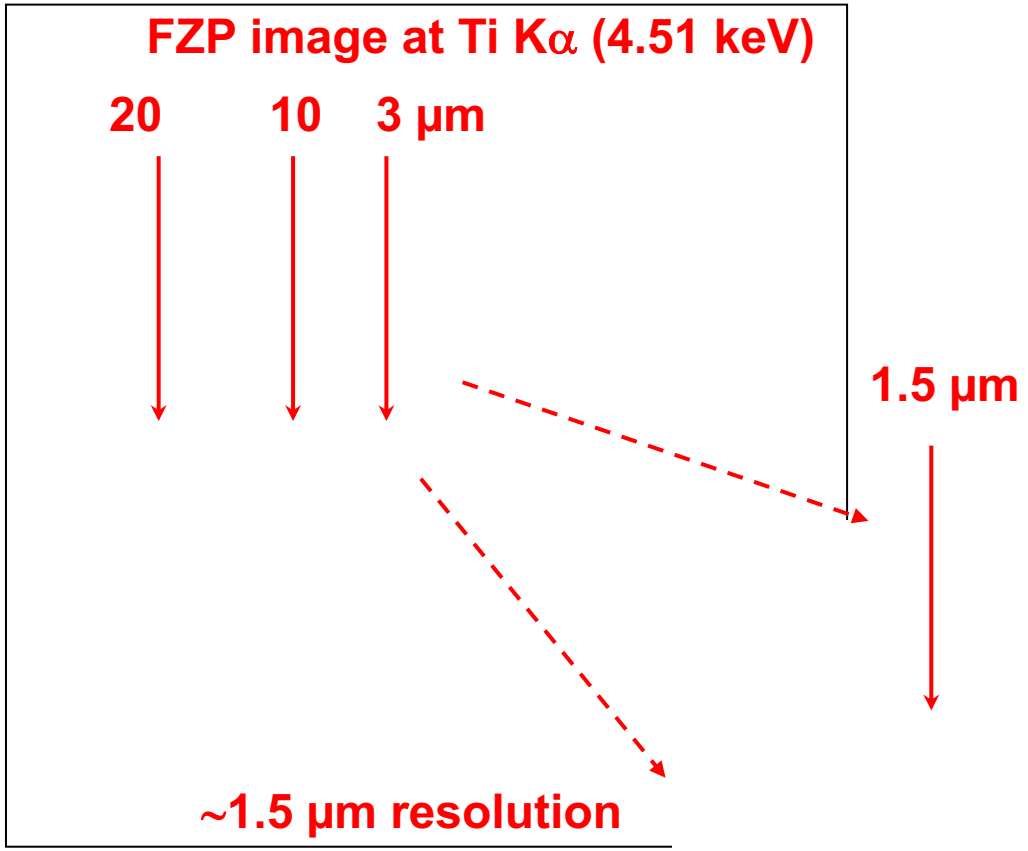
We currently have a set of FZPs that can be used over an energy range from 1.9 to 9 keV

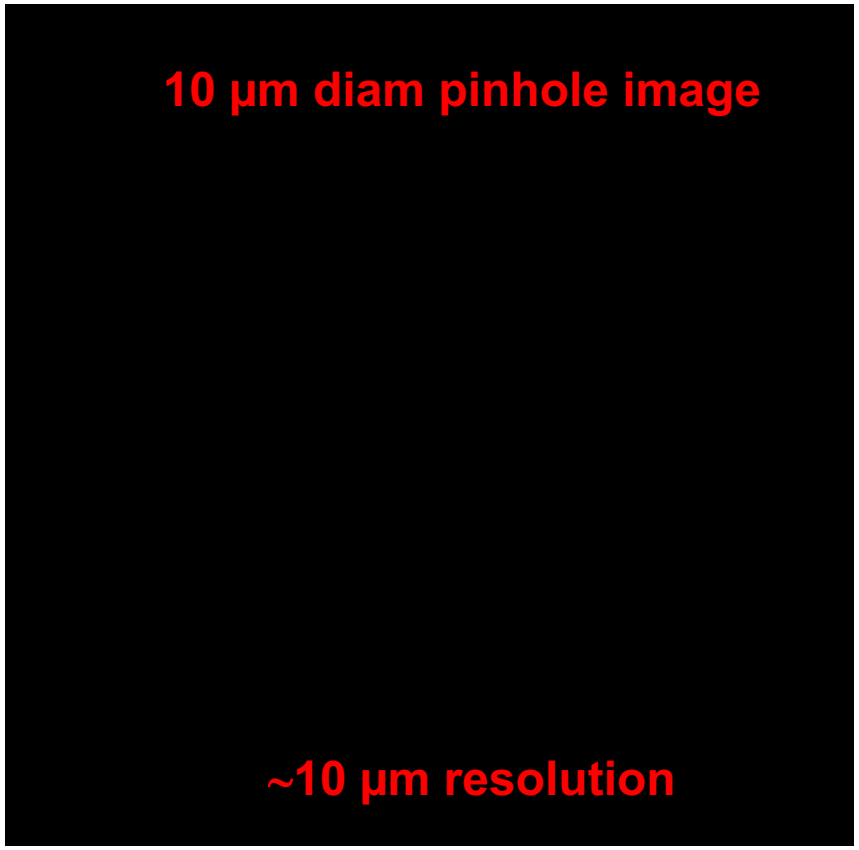
Example FZP efficiencies are shown for Au zoneplates and are accurately calculated from the atomic scattering factors



Fresnel zone plates can dramatically increase the x-ray image resolution over that obtained with a pinhole

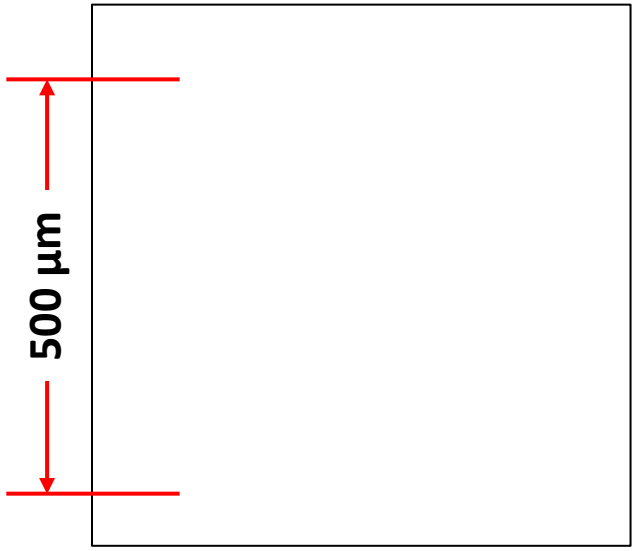
Spoke averaged star patterns (407 micron diam)
taken with an x-ray CCD in the LLE X-Ray Laboratory at M=14.4





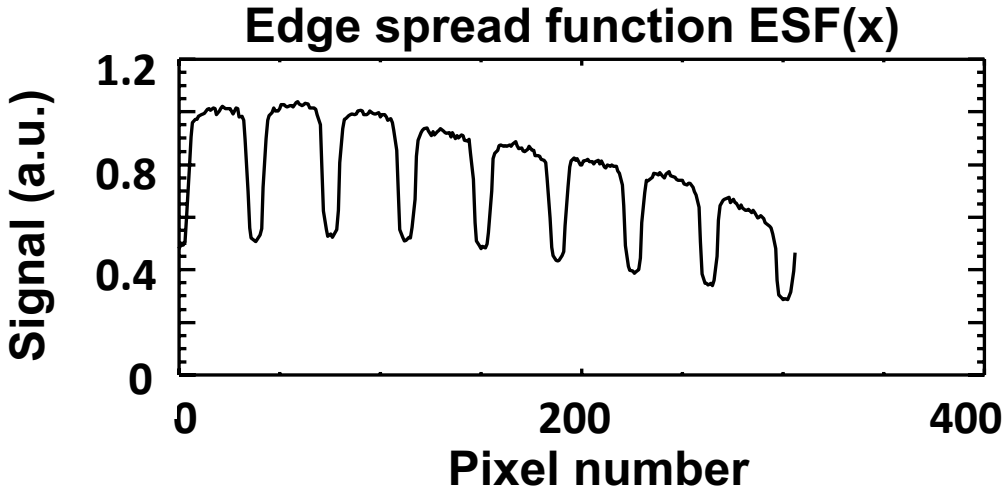
We are currently able to obtain a resolution of ~1.5 to 1.6 μm using Fresnel zone plates, limited by the choice of detector

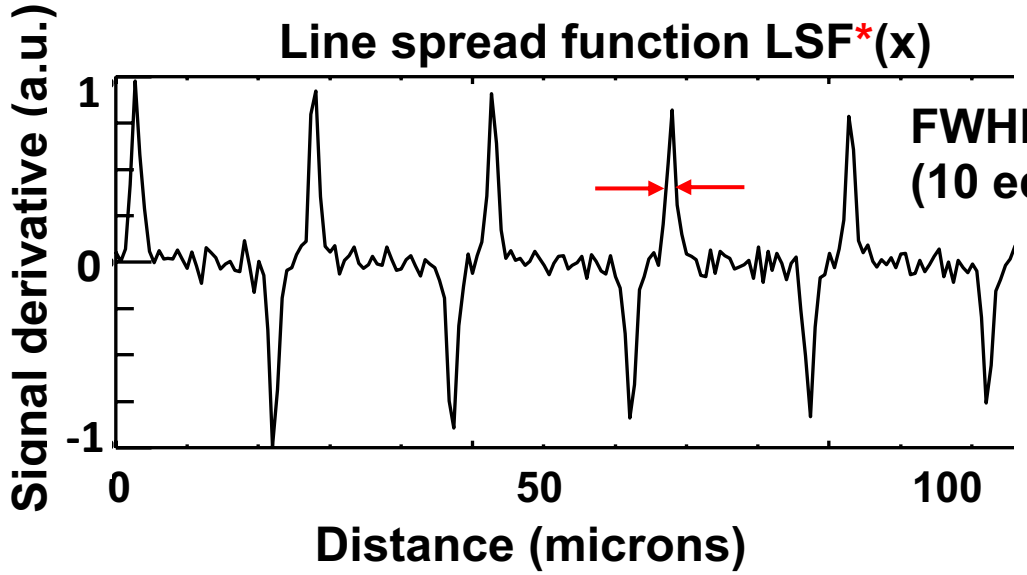
OMEGA EP shot 31019
V Heα backlighter (5.2 keV)
FZP CCD image



0.8 micron thick Au grid
(6 micron bars, 19 micron gaps)

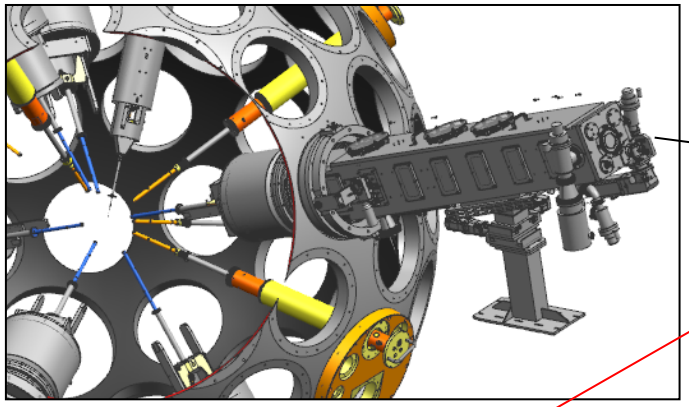
$$*LSF(x) = \frac{d}{dx}\left(ESF(x)\right)$$



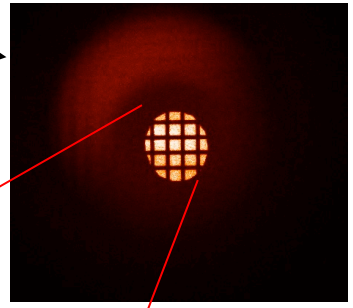


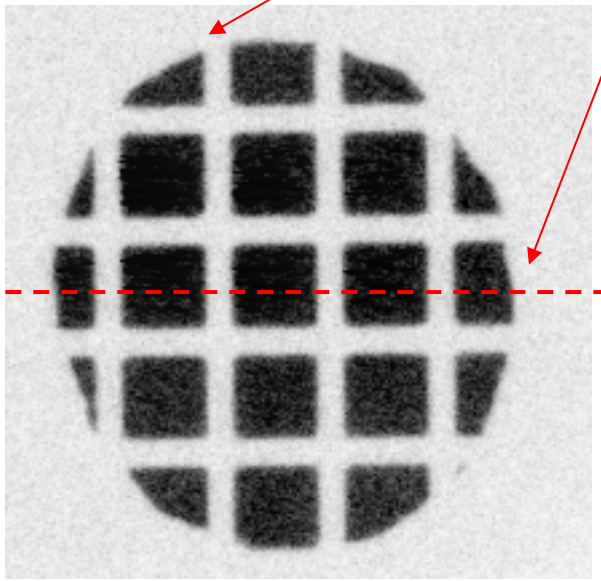
FWHM=1.54+/-0.16
(10 edge values)

We are currently able to obtain a resolution of ~1.5 to 1.6 μm using Fresnel zone plates when images are recorded with a CCD



OMEGA EP shot 30382
Ti Heα (4.75 keV) backlit grid

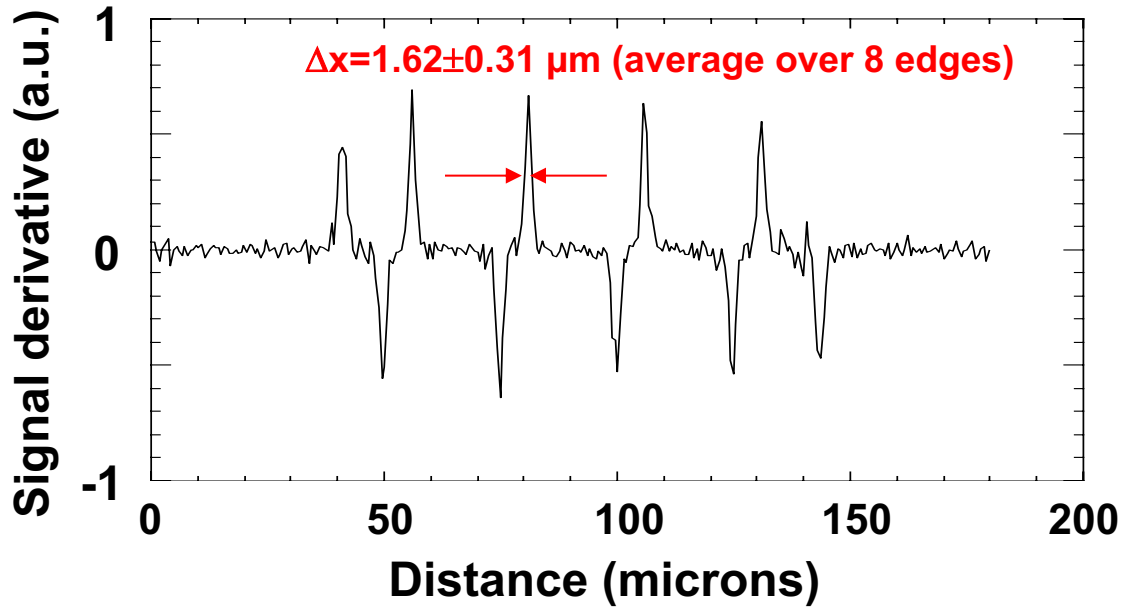




FZP CCD image
Au grid
with 6 μm bars
19 μm gaps

Full width half max (FWHM)
LSF*(FWHM)=1.62±0.31 μm

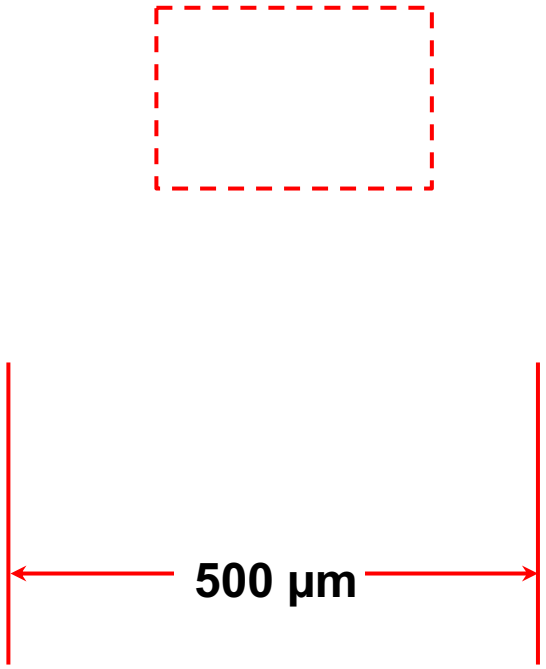
Measured over 8 grid edges



* Nyquist limit = 2 pixels = 1.21 μm

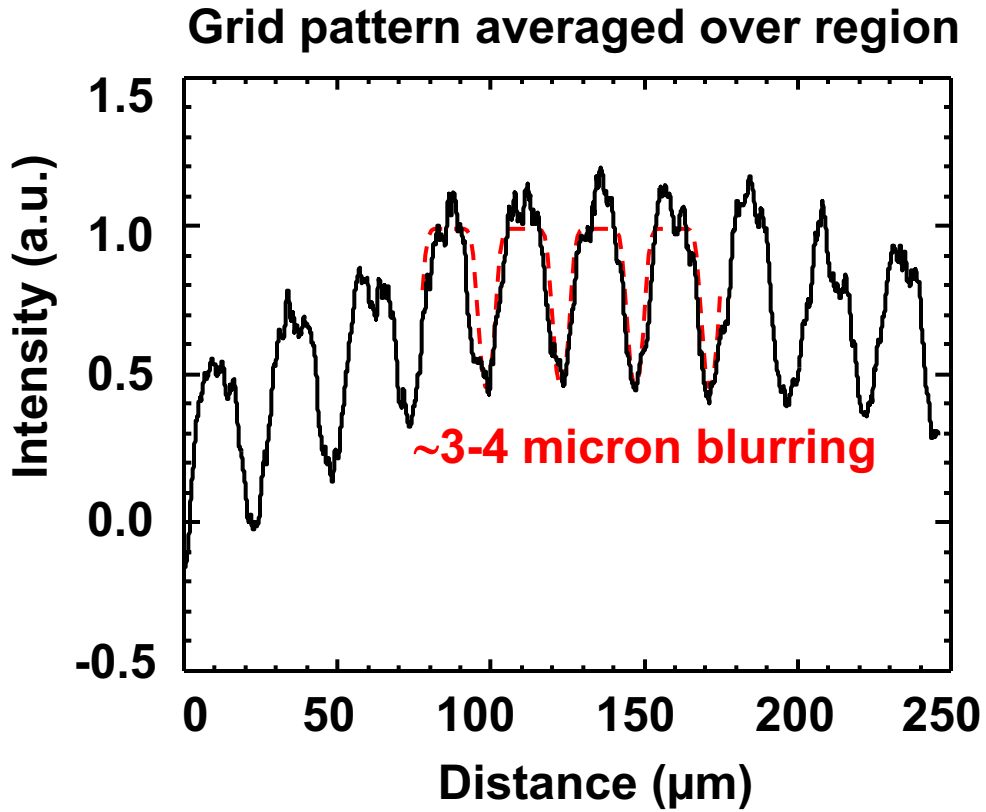
A Fresnel zone plate image of a resolution grid was obtained with a high speed framing camera (Δt~30 ps) with ~3 to 4 um resolution

XRFC1 film recording
Ti backlighter (4.75 keV)



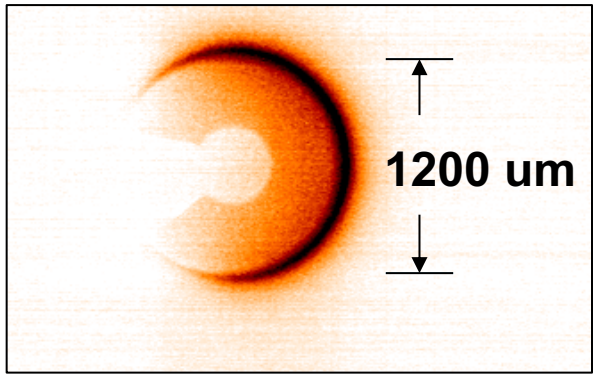
Au grid 6 μm bars, 19 μm gaps

FZP image
OMEGA shot 94697

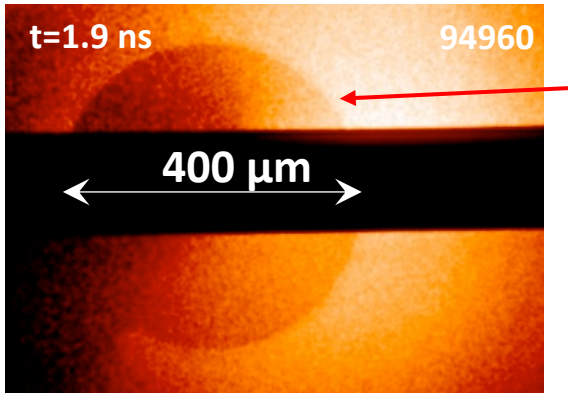


Framed FZP imaging is used to study the collision of the outer shell with the inner shell in LANL Revolver double shell implosions on OMEGA

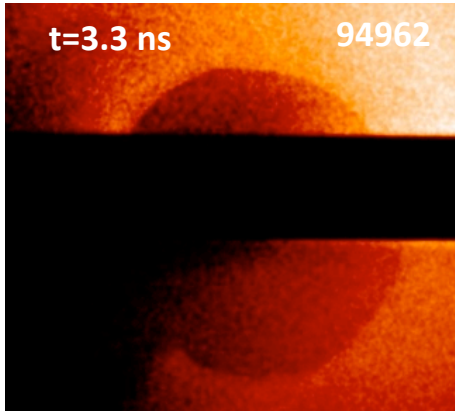
H13 XRPHC CID image

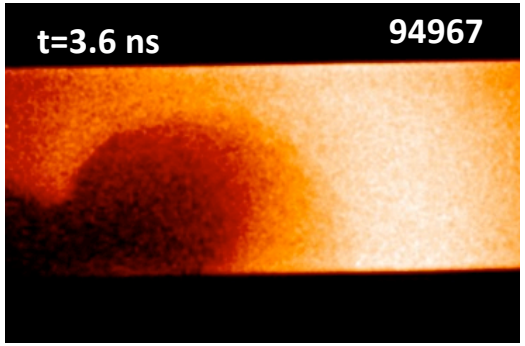


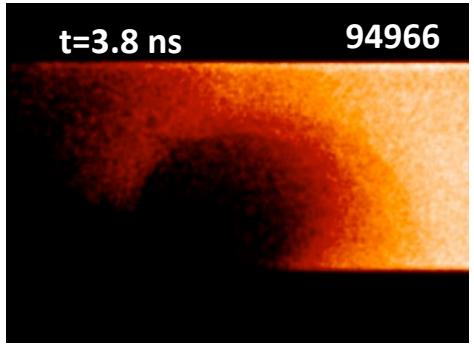
Ti backlit (4.75 keV) FZP images taken with high speed framing camera (Δt~30 ps)

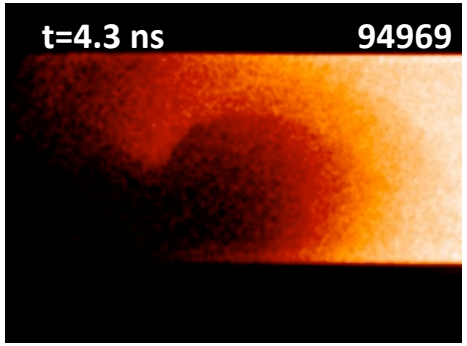


inner shell at time of collision









Mode structure evident in earlier post collision images

Revolver-19B Experiments
B. S. Scheiner, M. J. Schmitt, LANL
F. J. Marshall, P. M. Nilson, LLE

Summary/Conclusions

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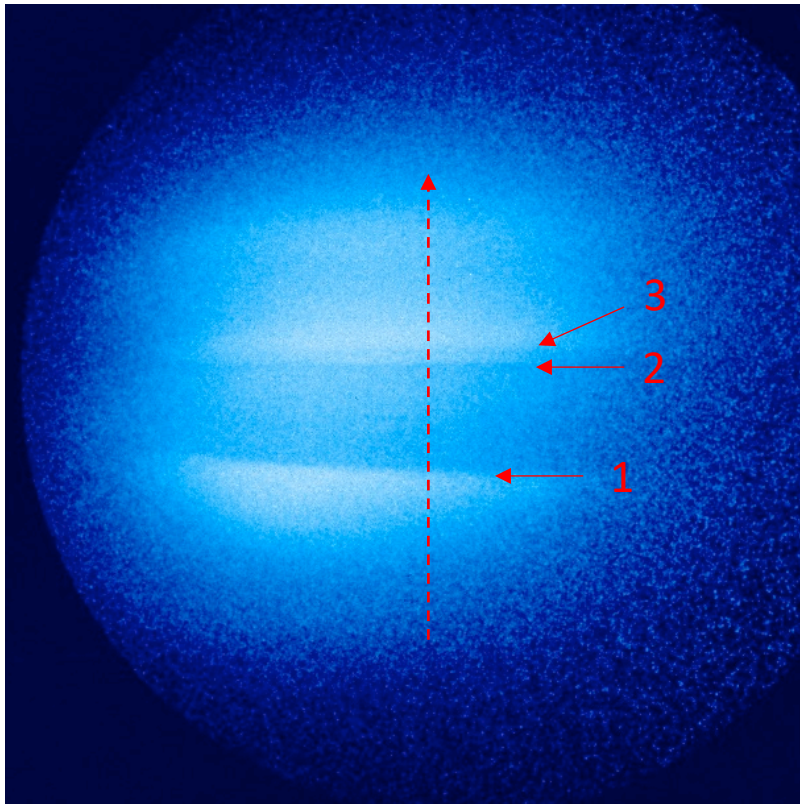
Backup slides

When imaged with a framing camera the limiting resolution of FZP images is ~2.5 to 3 μm at a magnification of ~20

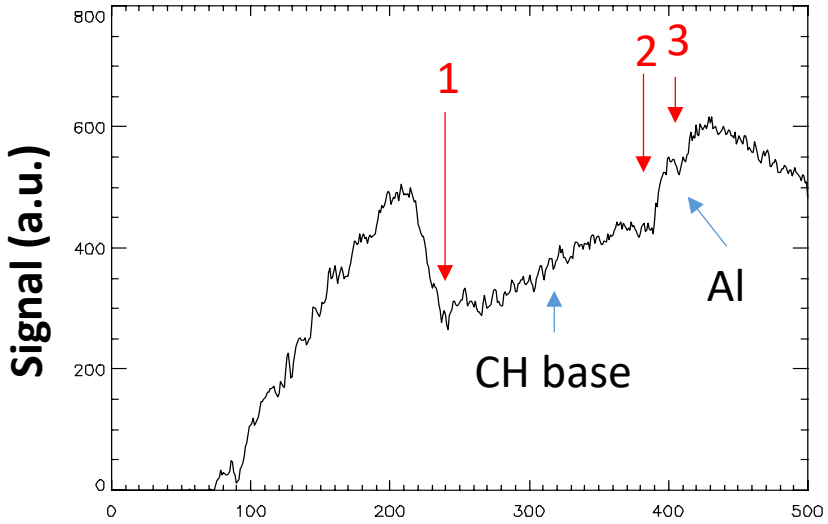
OMEGA EP shot 31027
FZP TZ23 V Heα backlighter (5.2 keV)



XRFC5 with single strip head (M=20.24)

Example foil driven on EP with Al region undergoing compression imaged with a Fresnel zone plate and a framing camera

Line out in direction of red line



Distance (microns)

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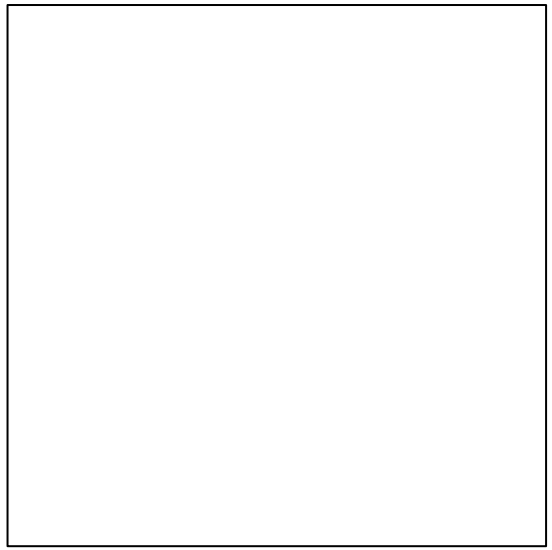
OMEGA EP shot 31019
V Heα backlighter (5.2 keV)



0.8 micron thick Au grid
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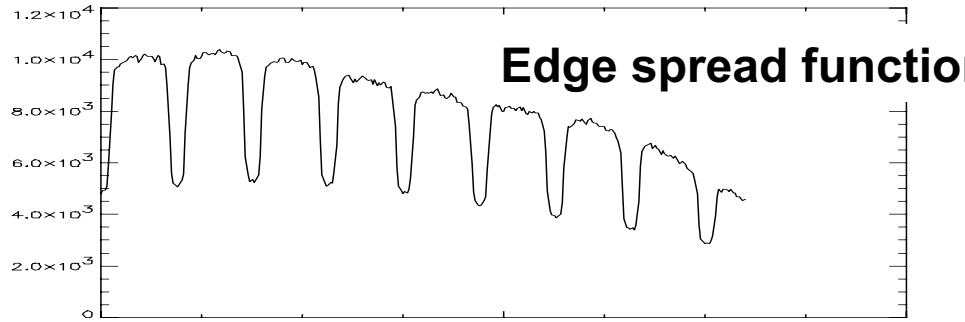
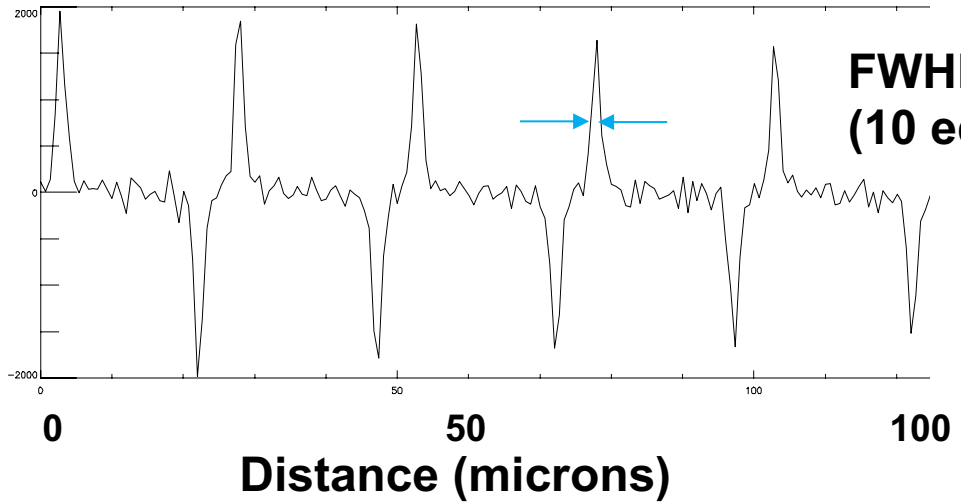


Line spread function



FWHM=1.54+/-0.16
(10 edge values)

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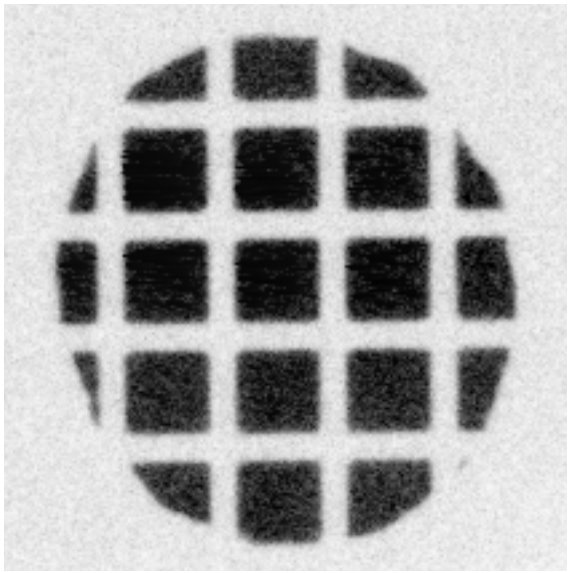
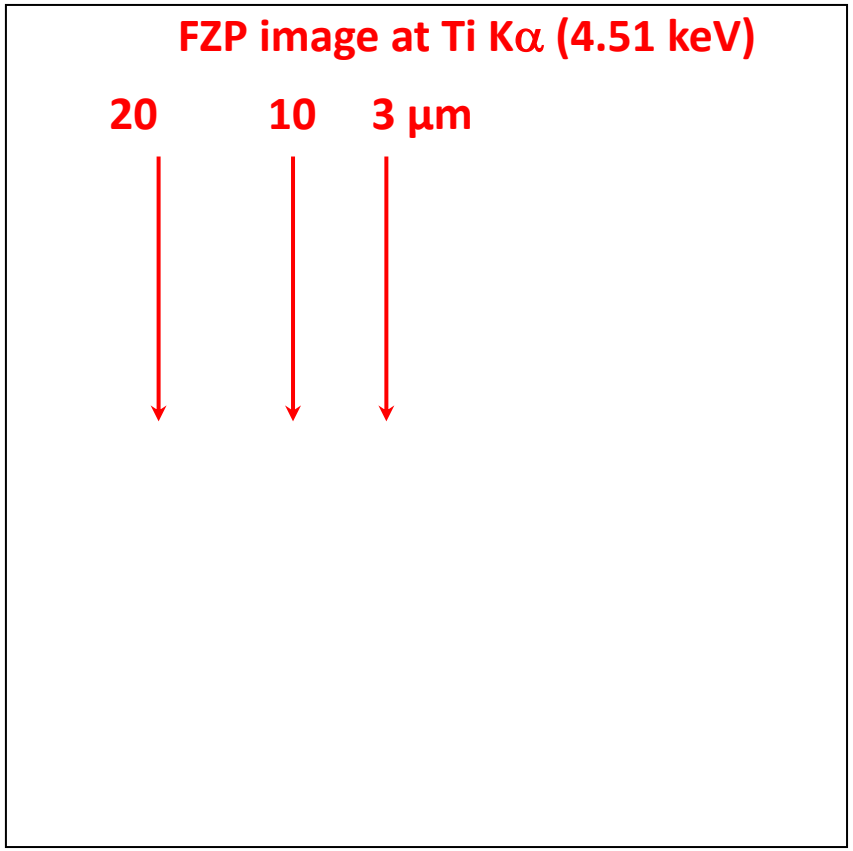
OMEGA EP shot 30382
1 kJ in 0.5 ns on Ti foil
Fresnel zone plate image
of 1000 mesh 0.8 micron thick Au grid
6 micron bars, 19 micron gaps



Spoke averaged star pattern (407 micron diam) taken with an X-ray CCD at M=14.4



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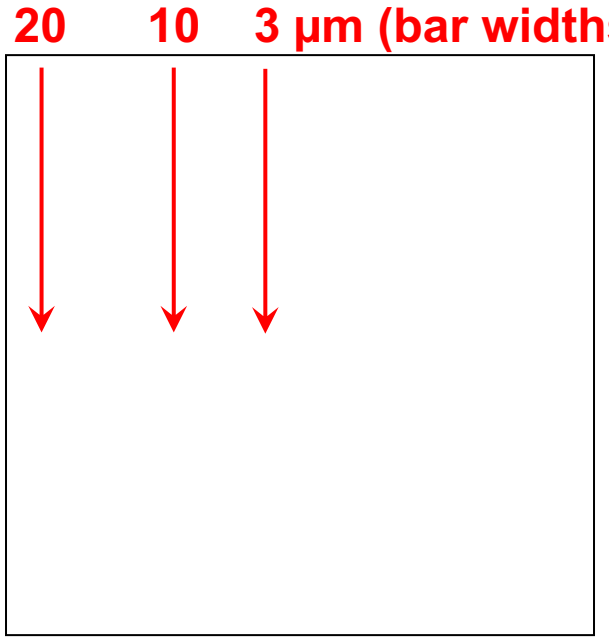
Spoke averaged star pattern (407 micron diam)
FZP X-ray CCD at M=14.4 (4.51 keV)



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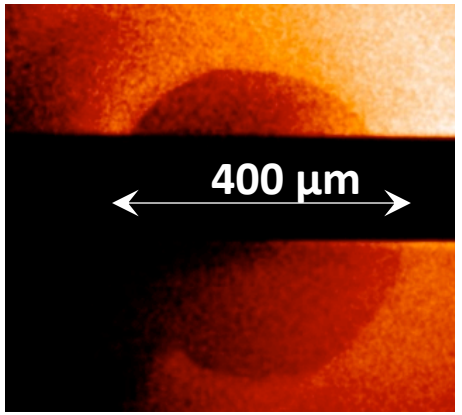

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(Inner shell after collision)

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