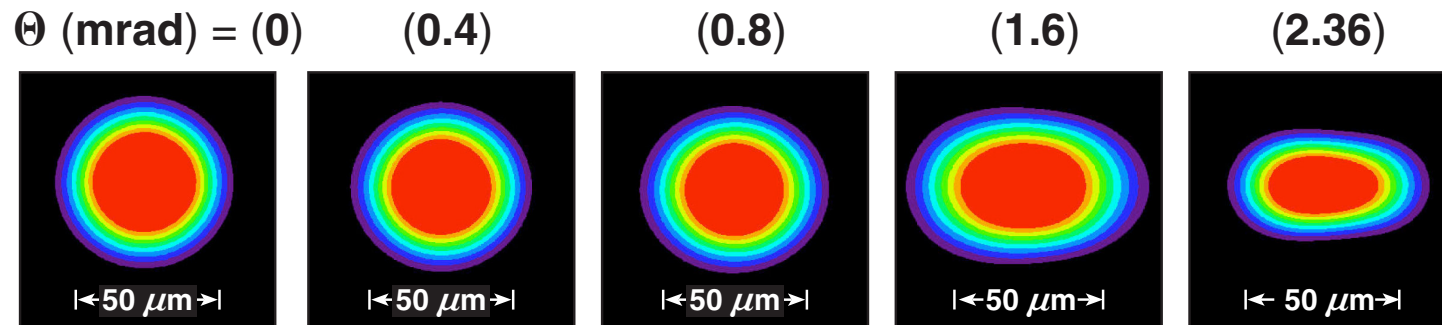


Neutron Detection With Bubble Chambers



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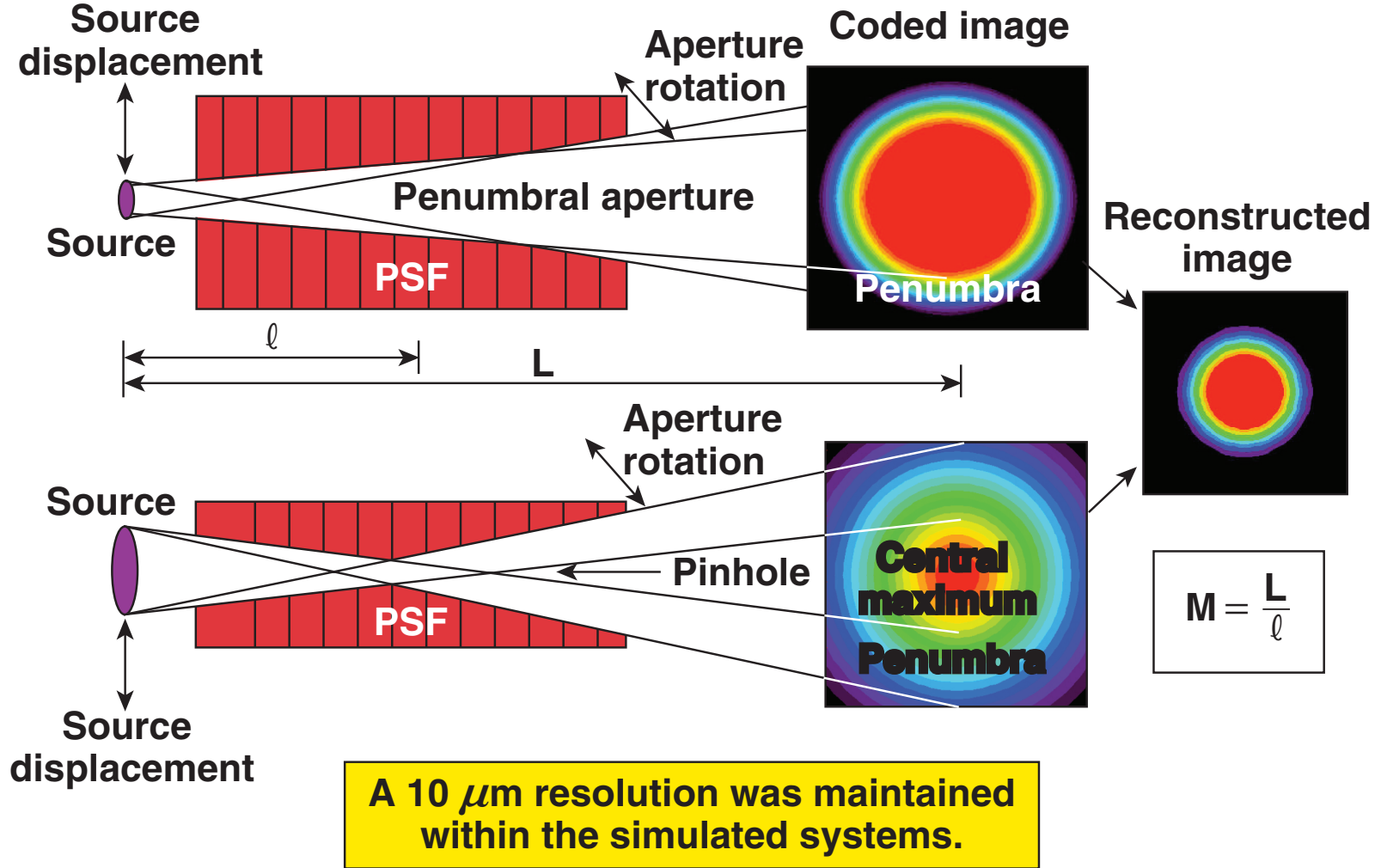
Summary

A neutron imaging (NI) design tool has been used to quantify the effects of aperture fabrication and alignment on reconstructed images



- **Alignment tolerances of less than 1 mrad (current precision at OMEGA) introduce measurable features in a reconstructed image.**
- **Penumbral apertures are several times less sensitive to fabrication errors than pinhole apertures.**
- **A NI bubble chamber is being assembled at LLE and will be operational in the coming year.**

With a design tool we can control the source, aperture, and detector parameters



Penumbra Apertures

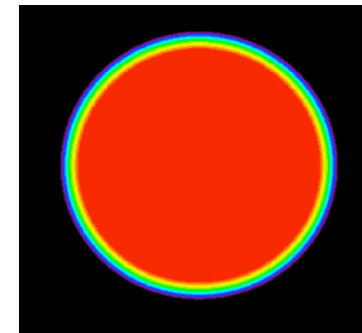
The accuracy of the reconstructed images deteriorates with aperture misalignment



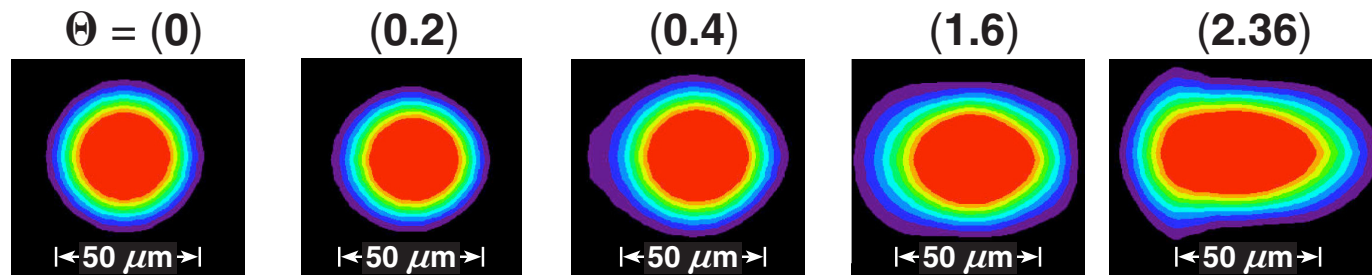
System characteristics

- Flat source image ($50 \mu\text{m}$)
- Biconic aperture, FOV $\sim 200 \mu\text{m}$
 $\ell = 26 \text{ cm}$, $L = 800 \text{ cm}$, $M = 30.76$
- Central diameter = 2 mm
- Thickness = 10 cm

Raw image



Reconstructed images and misalignment angle (mrad)



A source position off center by $100 \mu\text{m}$ (edge of the FOV) for an aperture 26 cm from the source is equivalent to a 0.392 mrad aperture rotation.

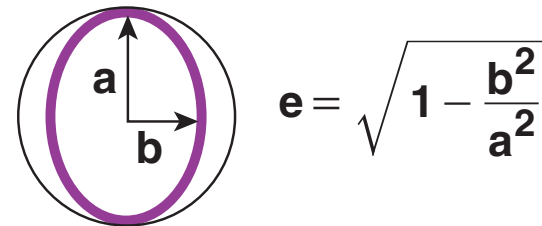
Pinhole Apertures

The accuracy of the reconstructed image deteriorates with aperture fabrication errors

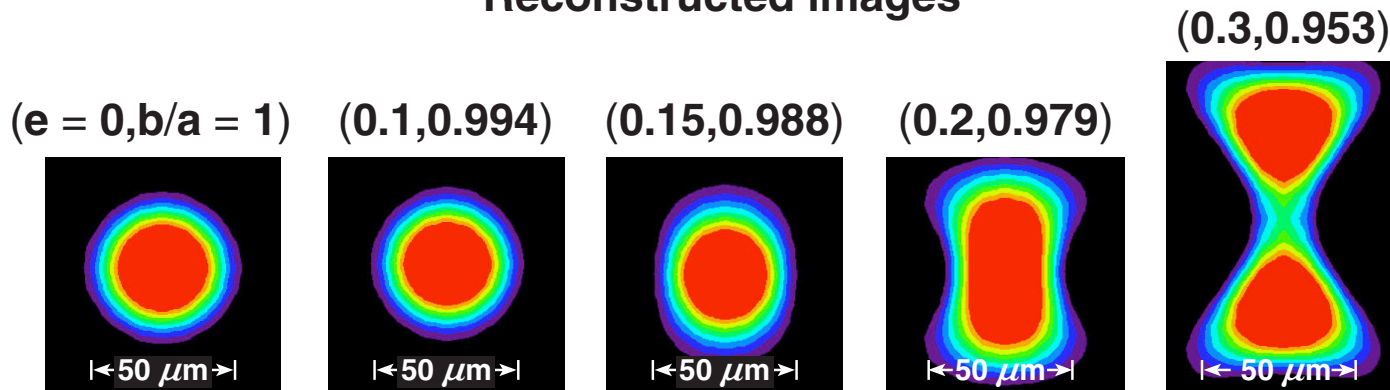
System characteristics

- Flat source image ($50 \mu\text{m}$)
- Biconic aperture, FOV $\sim 200 \mu\text{m}$
 $\ell = 26 \text{ cm}$, $L = 800 \text{ cm}$, $M = 30.76$
- Central diameter = 2 mm
- Thickness = 10 cm

Aperture cross section



Reconstructed images



Aperture defects appear to be as important as alignment errors for the accurate reconstruction of an image.

Pinhole Apertures

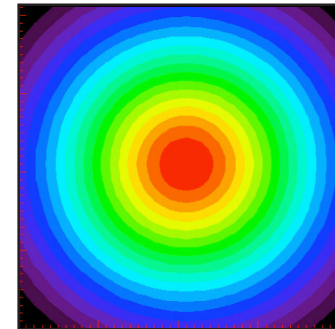
The accuracy of the reconstructed image deteriorates with aperture misalignment



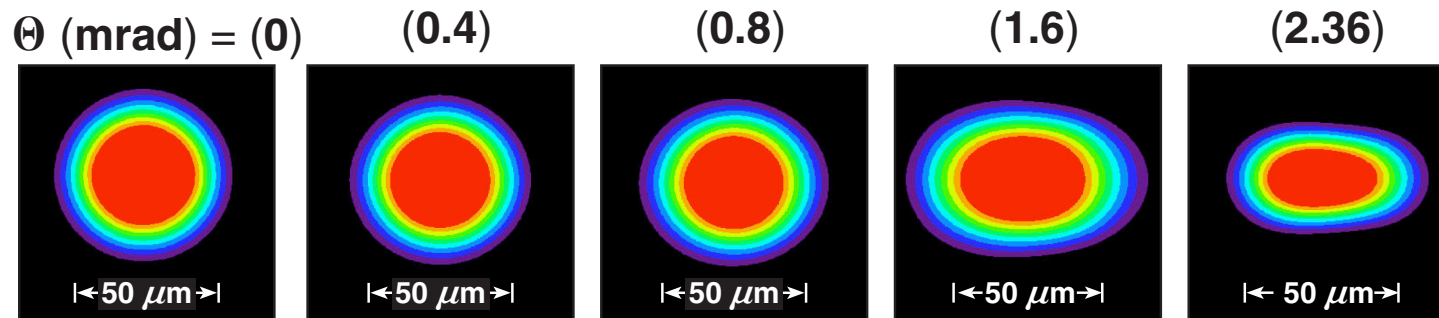
System characteristics

- Flat source image ($50 \mu\text{m}$)
- Pinhole, FOV $\sim 200 \mu\text{m}$
 $\ell = 26 \text{ cm}$, $L = 800 \text{ cm}$, $M = 30.76$
- Central diameter = $10 \mu\text{m}$
- Thickness = 10 cm

Raw image



Reconstructed images



A source position off center by $100 \mu\text{m}$ (edge of the FOV) for an aperture 26 cm from the source is equivalent to a 0.392-mrad aperture rotation

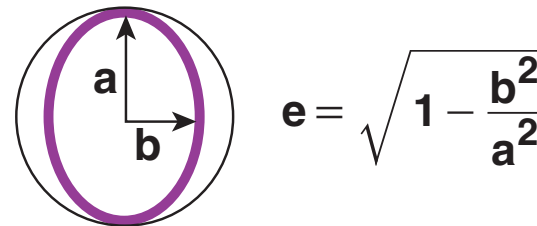
Pinhole Apertures

The accuracy of the reconstructed image is less sensitive to pinhole fabrication errors than to misalignment

System characteristics

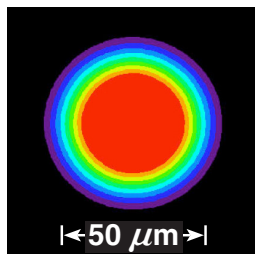
- Flat source image ($50 \mu\text{m}$)
- Pinhole, FOV $\sim 200 \mu\text{m}$
 $\ell = 26 \text{ cm}$, $L = 800 \text{ cm}$, $M = 30.76$
- Central diameter = $10 \mu\text{m}$
- Thickness = 10 cm

Pinhole cross section

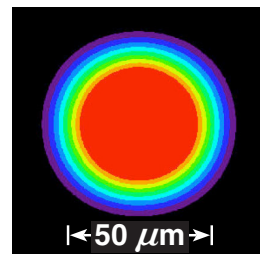


Reconstructed images

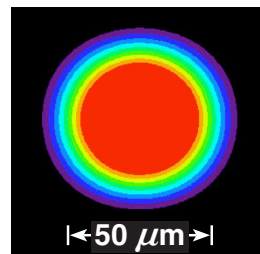
($e = 0$, $b/a = 1$)



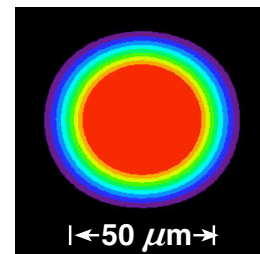
(0.2, 0.979)



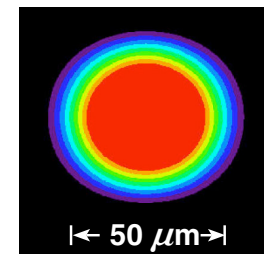
(0.3, 0.953)



(0.4, 0.916)



(0.5, 0.866)



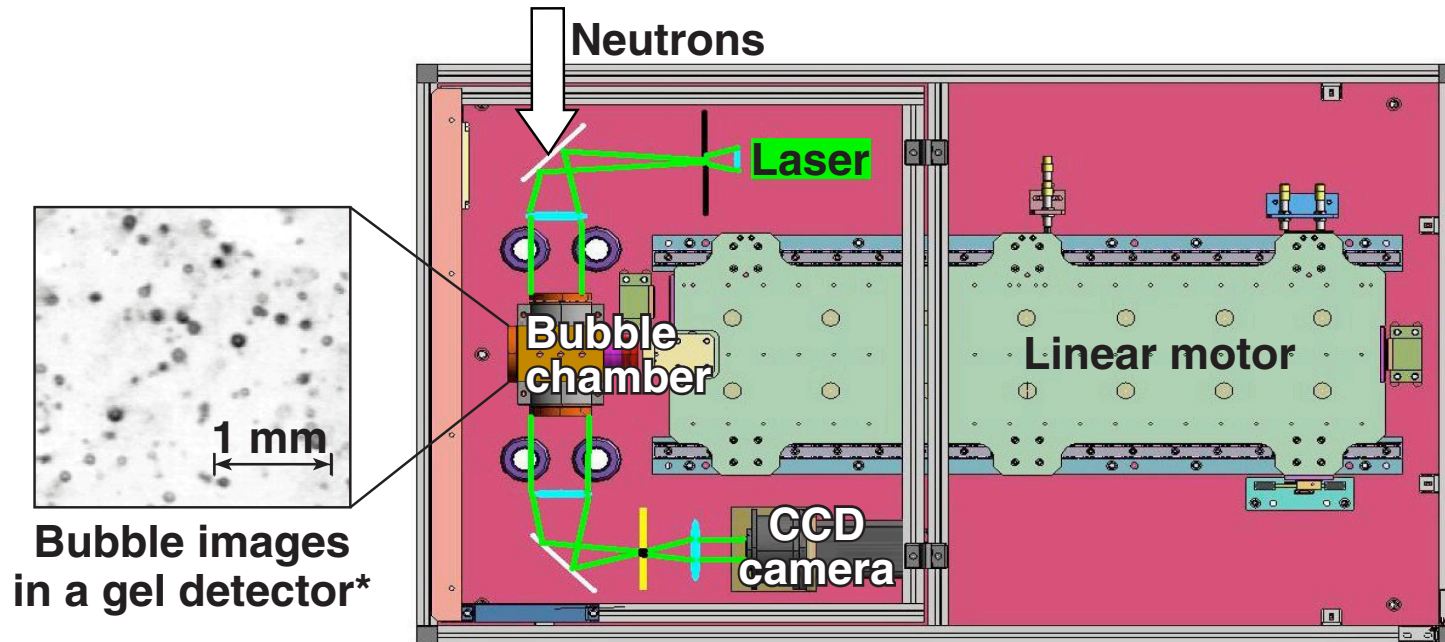
Aperture defects appear to be detectable at $b/a = 0.87$.

The alignment and fabrication tolerances to observe 10- μm features have been determined



Penumbral apertures	Pinhole apertures
<ul style="list-style-type: none">• Misalignments of 0.4 mrad• Source position off-center by 100 μm• Fabrication eccentricity of 0.15 (i.e., a 1.2% difference between the ellipse axes) or an absolute fabrication error of 24 μm	<ul style="list-style-type: none">• Misalignments of 0.8 mrad• Source position off-center by 200 μm• Fabrication eccentricity of 0.5 (i.e., an ~14% difference between the ellipse axes) or an absolute fabrication error of 1.4 μm

The LLE bubble chamber has been designed to measure the column density of bubbles rather than to count individual bubbles as in the original Fisher experiment*



Schlieren technique will be used for bubble detection

Expect to field on OMEGA within a year

Summary/Conclusions

A neutron imaging (NI) design tool has been used to quantify the effects of aperture fabrication and alignment on reconstructed images



- **Alignment tolerances of less than 1 mrad (current precision at OMEGA) introduce measurable features in a reconstructed image.**
- **Penumbral apertures are several times less sensitive to fabrication errors than pinhole apertures.**
- **A NI bubble chamber is being assembled at LLE and will be operational in the coming year.**