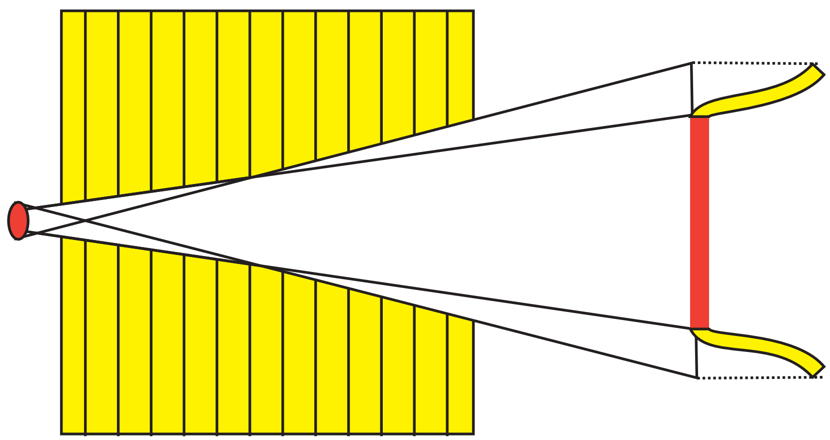
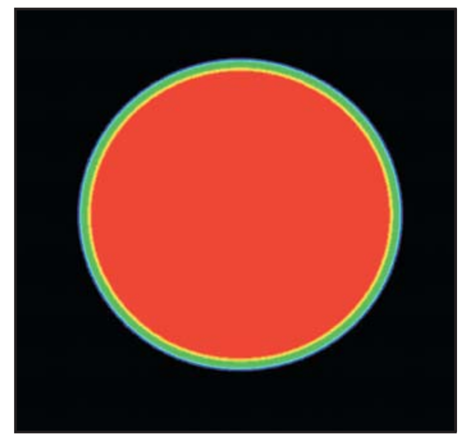
First Results From A Penumbral Imaging System Design Tool





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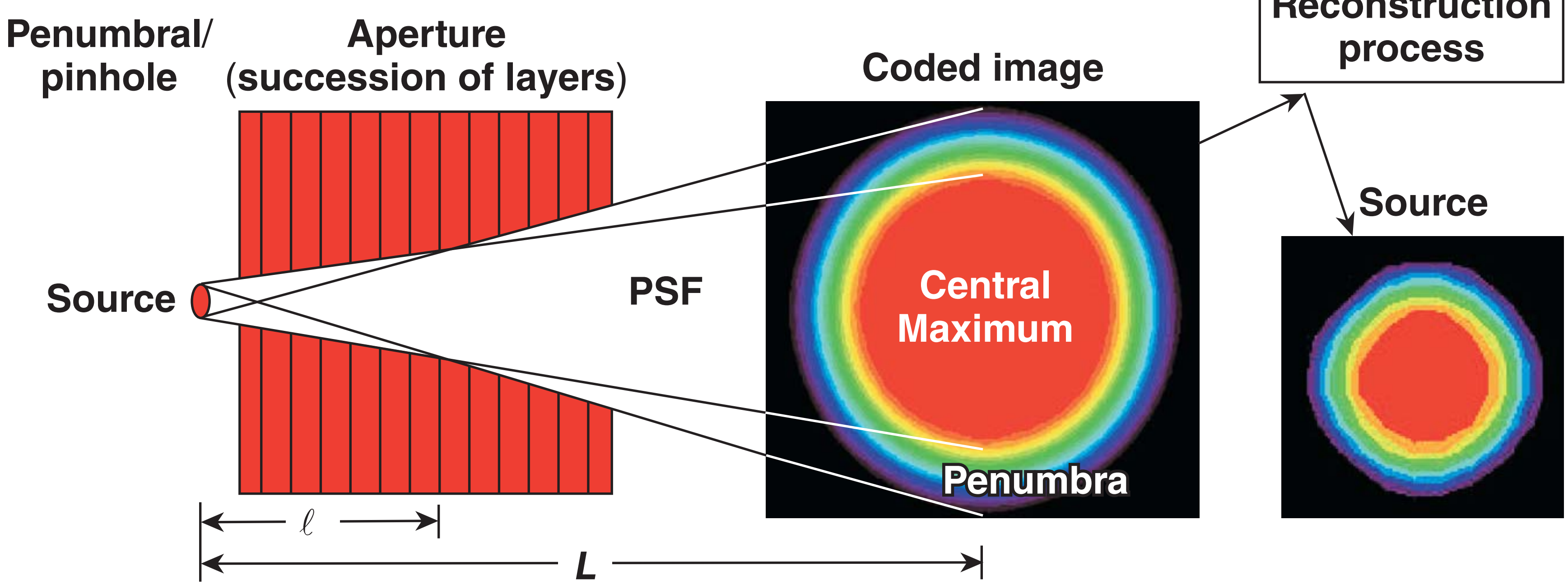
Summary

A general neutron imaging design tool is being developed for ICF/OMEGA/NIF

- The design tool is being developed to help establish the requirements of a NI system for the NIF.
- Arbitrary aperture designs and orientations can be tested and compared with arbitrary source distributions.
- Both aperture alignment and fabrication errors appear to have a significant impact on the quality of the reconstructed image.

The parameters of an imaging system can be optimized for a particular application using a design tool

Components of a NI System



$$M = \frac{L}{\ell}$$

With a design tool, we have control over the source, aperture, and detector parameters.

E13446

The design tool can generate and deconvolve penumbral/pinhole images*

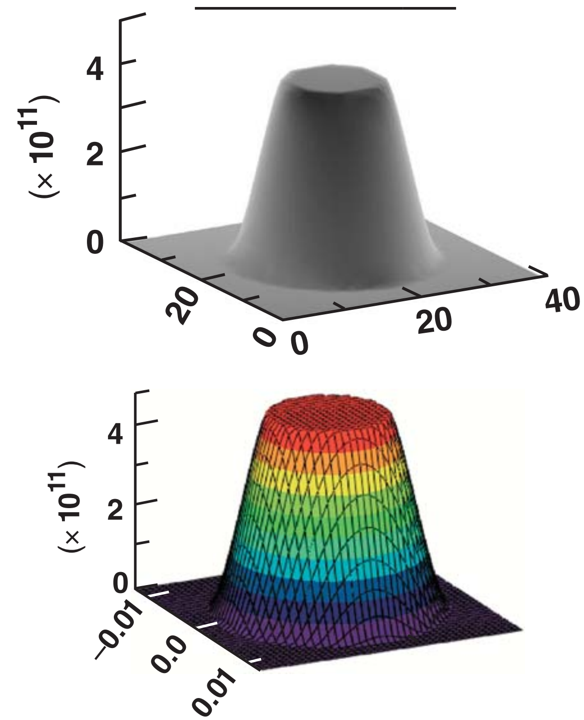
- A variety of sources (point, flat, Gaussian, irregular) can be simulated and point-spread functions are generated using ray-tracing.
- Arbitrary apertures are simulated as a stack of infinitely thin layers along the particle flux.
- A Wiener Filter (WF) and Inverse Fourier Transform (IFT) are used to deconvolve the image on the detector plane.
- The source and detector planes are described by arrays, which ultimately define the system resolution.
- Noise can be added to simulate neutron backgrounds.

*R. A. Lerche *et al.*, Laser and Part. Beams 9, 99 (1991).

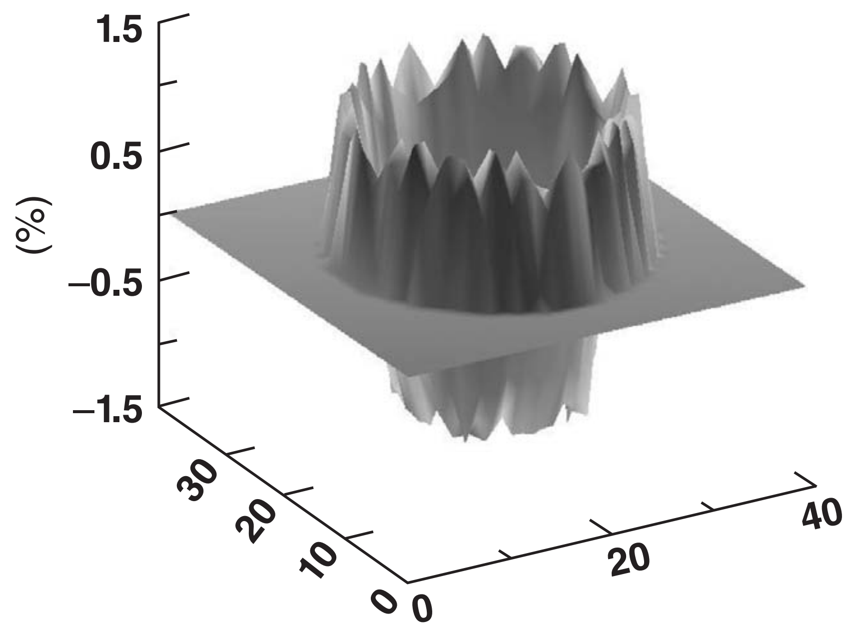
The neutron imaging design tool was tested against simple cases with analytical solutions

- For a point source, a perfect fit was obtained between the reconstructed image and the analytically calculated one.
- For a circular flat source, the relative difference between the reconstructed and the analytically calculated image was in the range of ±1%.

Flat Source



Difference



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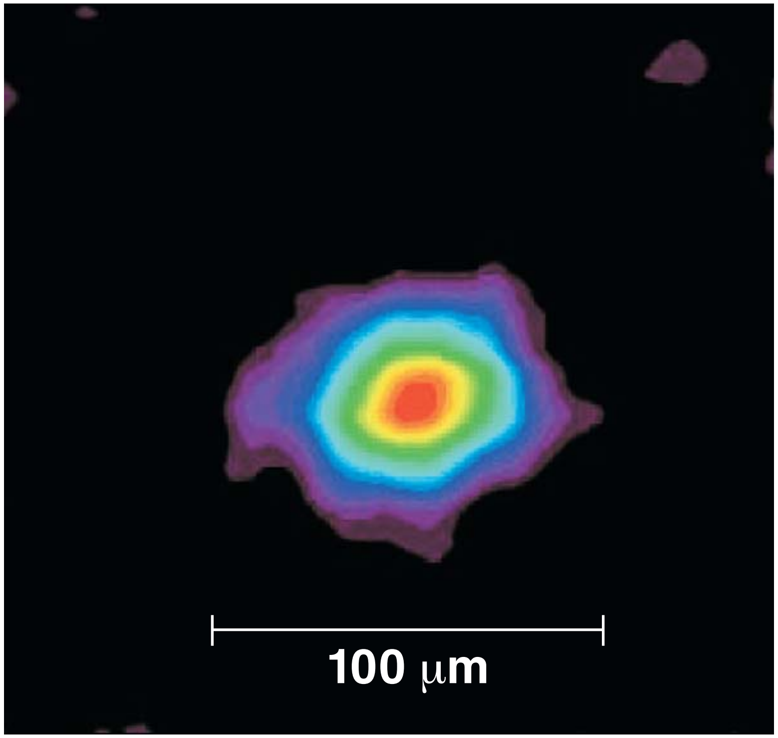
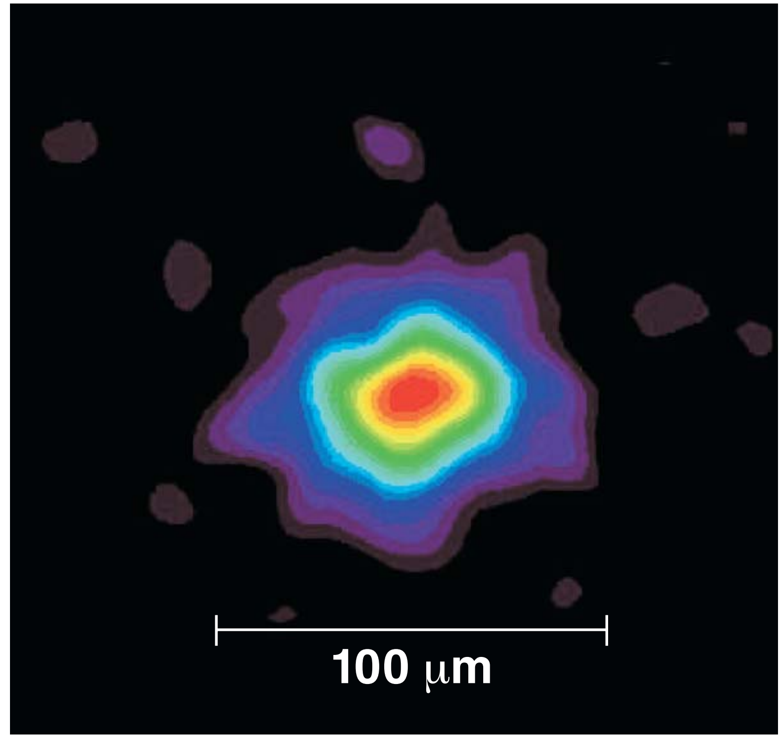
Real images from the L. Disdier group were deconvolved and compared with the results of other methods

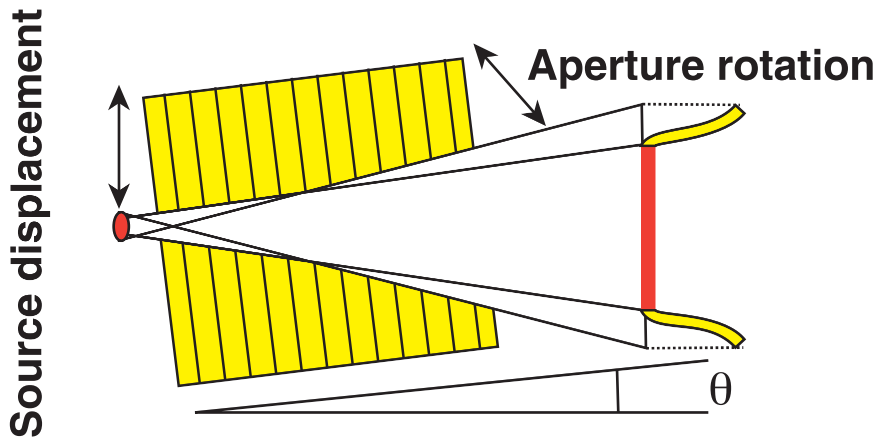




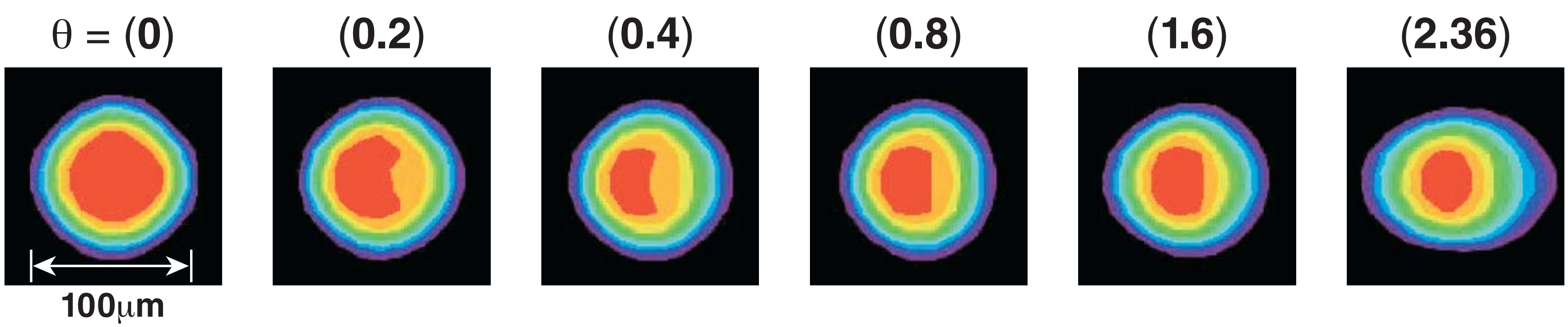
Real data (shot #35988, DT[10] CH[20], $Y_n = 8.5 \times 10^{12}$) deconvolved with our code (left) compared with reconstructed data obtained through filtered autocorrelation* (right).

*A. Rouyer, Rev. Sci. Instrum. 74, 1234 (2003).

The quality of the reconstructed image deteriorates with the misalignment of the aperture



- Flat Source Image (100 μm)
- Biconic aperture, FOV ~480μm
- Reconstructed images and misalignment angle (mrad)



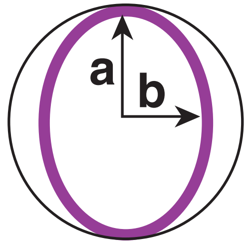
A source position off center by 100 um for an aperture 26 cm from the source is equivalent to a 0.392 mrad aperture rotation.

E13449

The quality of the reconstructed image also deteriorates with the errors in the aperture fabrication

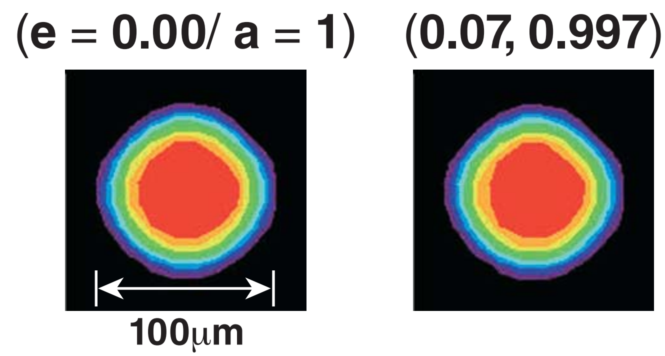
Flat Source Image (100 μm)

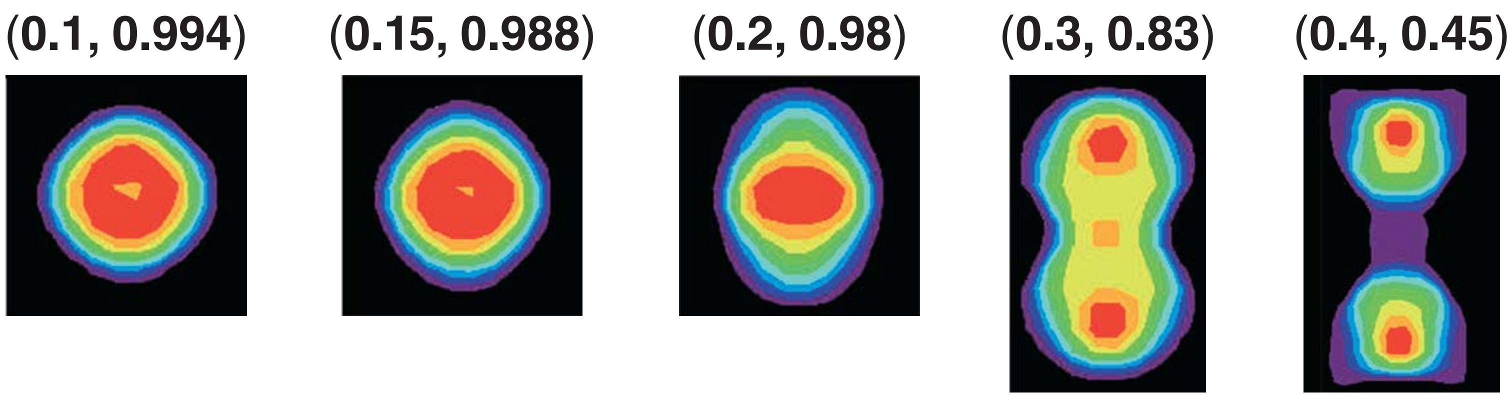
Aperture cross section



$$e = \sqrt{\left(1 - \frac{b^2}{a^2}\right)}$$

Reconstructed Images





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

E13450

A NI system sensitivity is affected by alignment and fabrication errors

- An aperture misalignment of the order less than 0.2 mrad can significantly modify the reconstructed image.
- Placing the neutron source off-center by about 50 μm can have a similar effect.
- An eccentricity of 0.1 (i.e., a 0.6% difference between the ellipse axes) can cause detectable changes in the reconstructed image.

Summary/Conclusions

NI requirements can be tested for various imaging systems with a design tool

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- The design tool is being developed to help establish requirements of a NI system for the NIF.
- Arbitrary aperture designs and orientations can be tested and compared with arbitrary source distributions.
- Both aperture alignment and fabrication errors appear to have a significant impact on the quality of the reconstructed image.