First Results From A Penumbral Imaging System Design Tool

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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

- Penumbral/pinhole
- Aperture (succession of layers)
- Source
- PSF
- Coded image

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

\[ M = \frac{L}{\ell} \]
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.

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%.
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).

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

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

A source position off center by 100 µm for an aperture 26 cm from the source is equivalent to a 0.392 mrad aperture rotation.
The quality of the reconstructed image also deteriorates with the errors in the aperture fabrication.

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

• 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.