A Novel Neutron Imaging Calibration System Using A Neutron Generating Accelerator Tube

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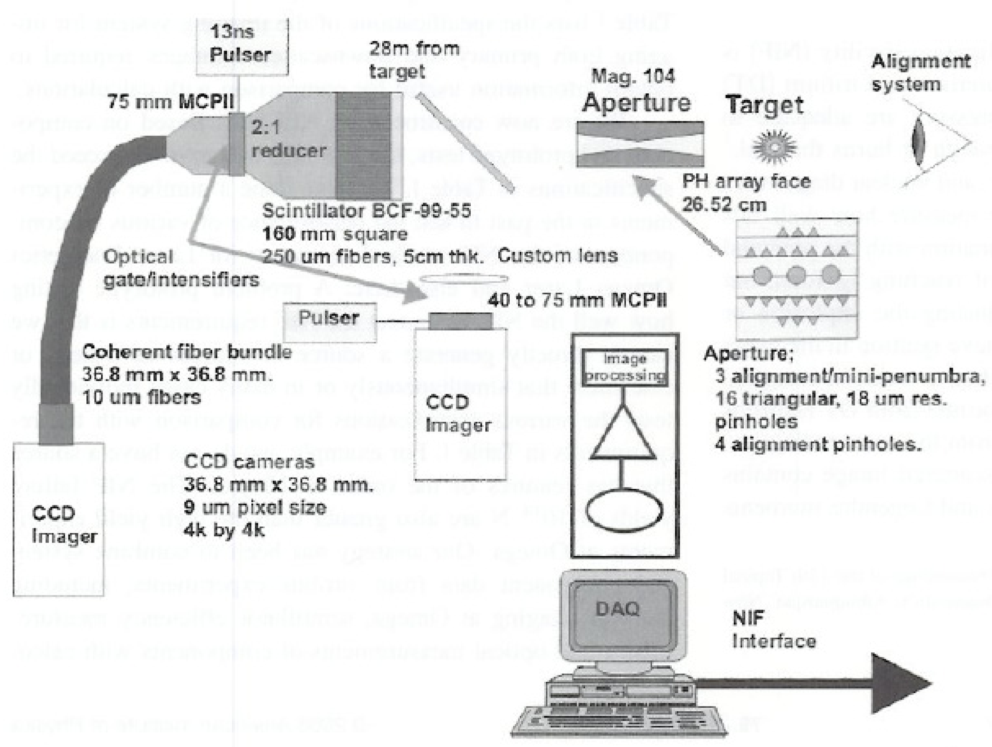
Neutron Imaging for ICF

Neutron Imaging is a key diagnostic for use in inertial confinement fusion (ICF) experiments, and has been fielded on experiments at Omega and Z. It will also be a key diagnostics at the National Ignition Facility (NIF) located at Lawrence Livermore National Laboratory (LLNL) and eventually at the Laser Megajoule in France.

Most systems are based on a neutron pinhole array placed at the target chamber while it is imaged by a scintillating fiber block. The light output of this scintillator is coupled via a reducer to a fiber bundle which transports the image to a CCD camera. Alternatively some systems use optical lens assemblies to focus the light onto a camera.

For ICF applications the neutron imaging systems will primarily look at 14.2 MeV neutrons. However, 2.2 MeV and 20+ MeV neutrons will also be present and will potentially provide key information.

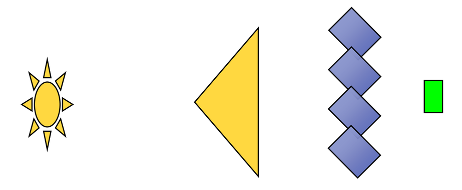
A schematic of the NIF Neutron Imaging System[1]



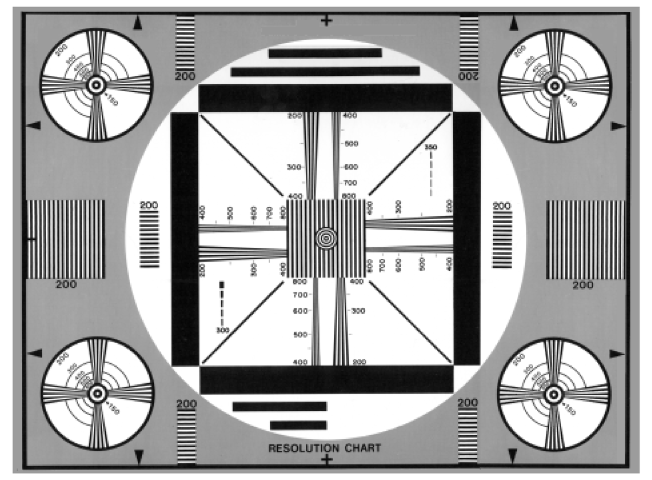
D = deuterium
T = tritium
H= hydrogen

Multiple Possible Calibration Methods

- Imagers are typically calibrated for response at certain energies and for resolution.
- Calibration methods fall into two basic categories:
  1. Resolution masks
  2. Sources that produce a pattern
- Due to the high energy of the neutrons, a resolution mask would need to be several centimeters thick and made of high Z metal.
- A source that produces a pattern on neutrons requires some sort of micro-collimation because neutrons do not interfere with each other.



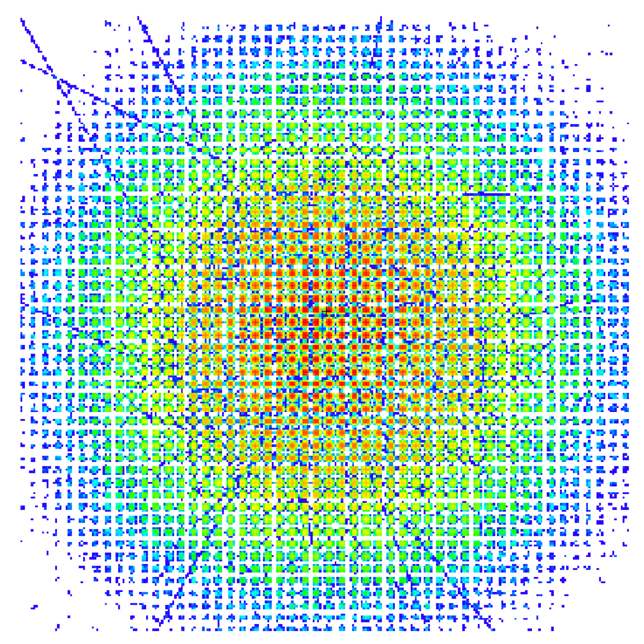
Typical resolution masks for X-rays or optical light are backlit by a source.



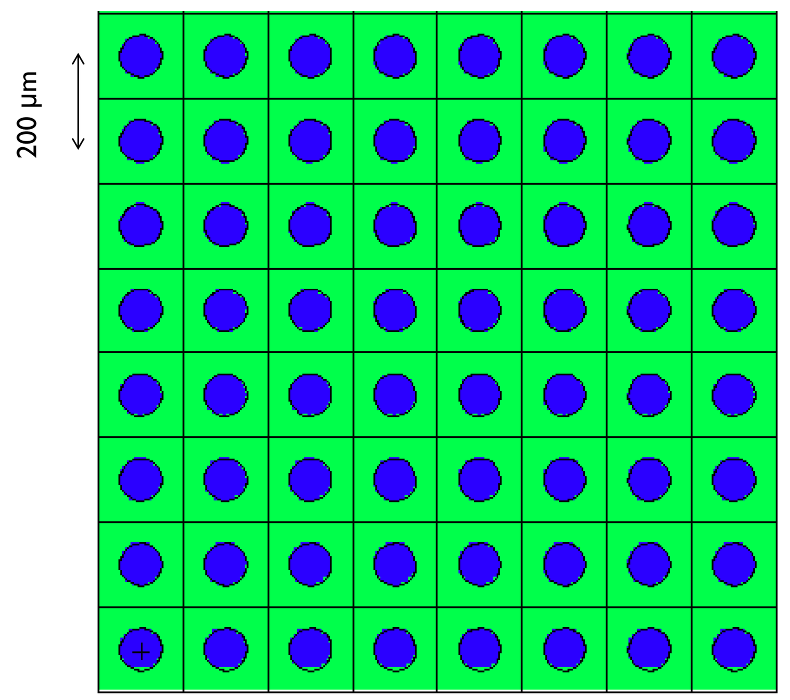
A typical optical resolution mask.

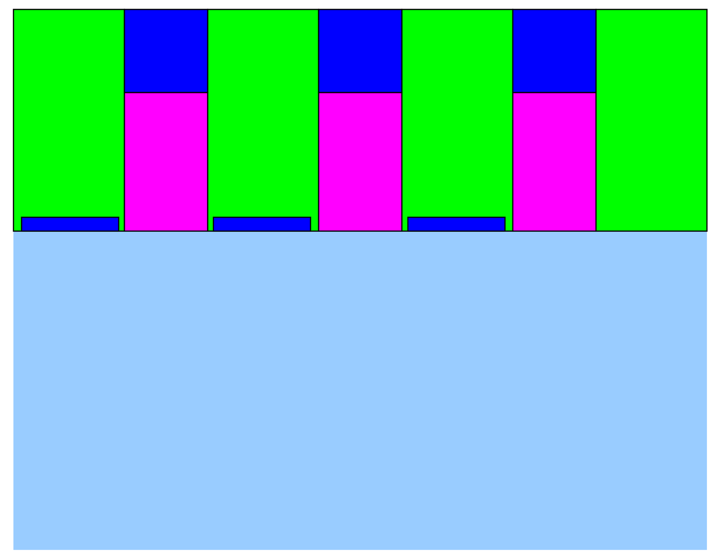
A Micro-Lithographically Arrayed Neutron Pattern Generator as a Solution

The Deuterium beam is Gaussian and creates interactions as such with the deuterated target.



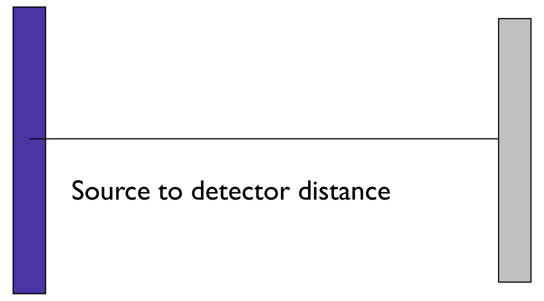
We use a neutron generator array to create a pattern at a fixed distance from the source.





Substrate: Si
Getter: Metal Hydride
Blocker: Boron
Post: SiO_x

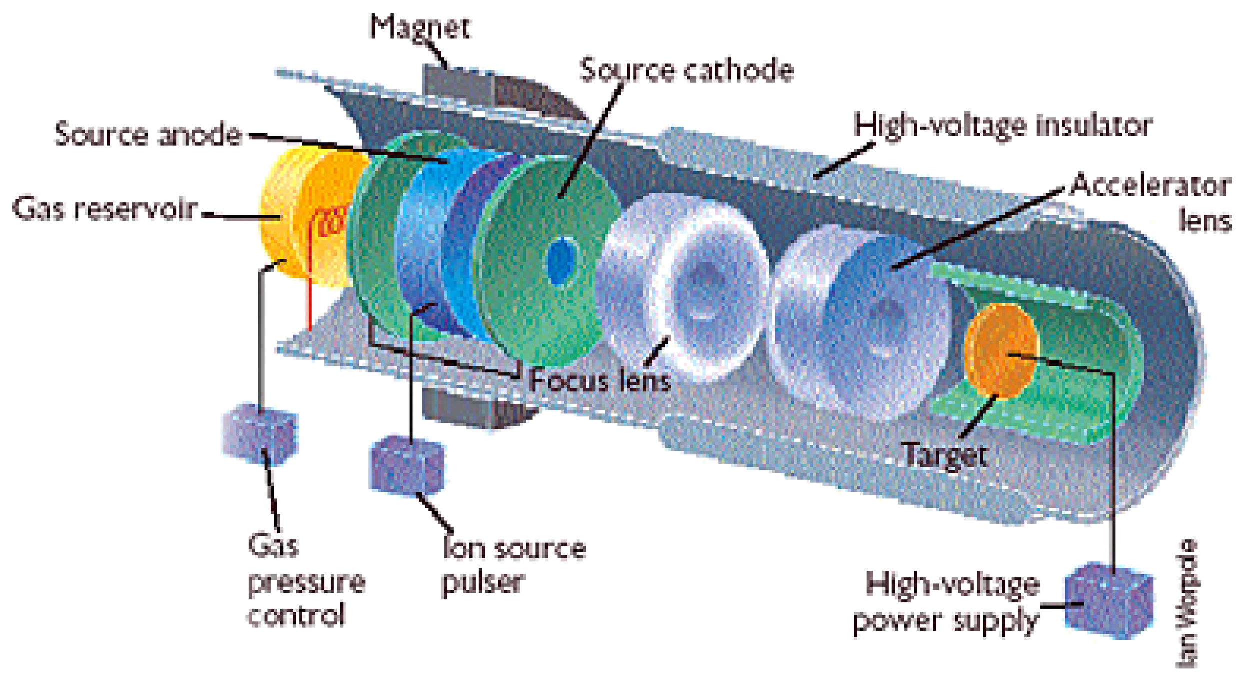
Source
1 cm x 1 cm rectangular array of
100 µm cylinders,
200 µm separation (axis to axis)
2,500 total elements



Detector
1 cm x 1 cm or
5 mm x 5 mm
250 µm resolution

Because the target is made using standard semiconductor fabrication processes, we test many different types of geometries and materials.

The Basics of a Hurley Neutron Generating Tube



•The neutron generating tube is a simple accelerator tube with a target at one end.

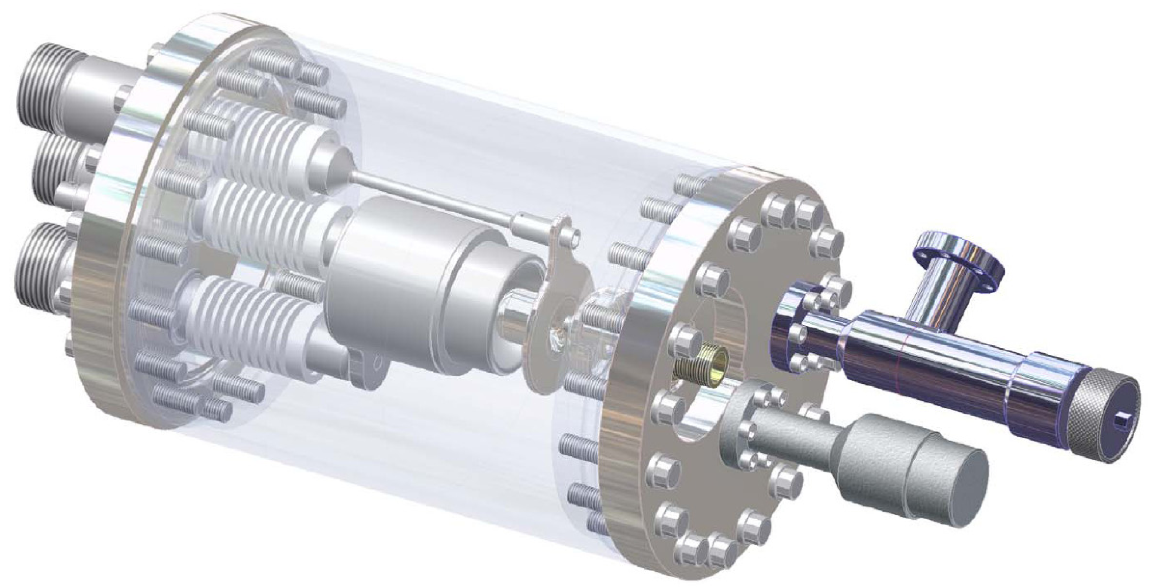
•Commercial tubes are available in D-D, D-T, and other configurations.

•The Hurley Neutron Tube is "recyclable," meaning it can be opened and have the target changed.

•The neutron imaging system calibration tube will accelerate deuterons to 100 keV into a deuterated target resulting in 2.2 MeV neutrons.

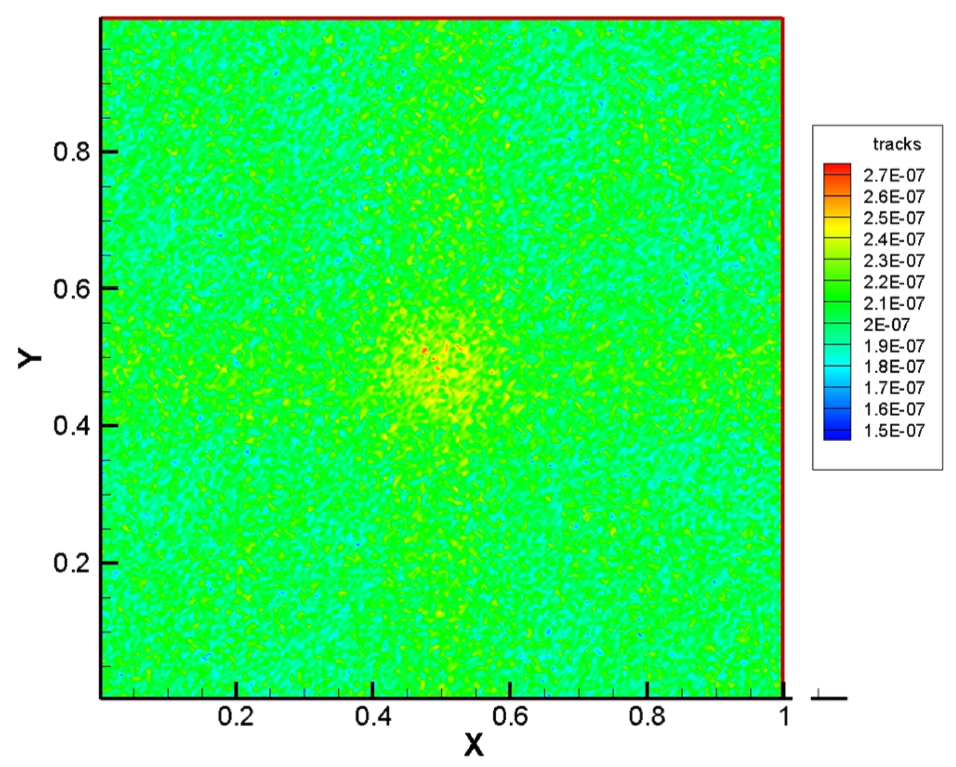
•Deuterium is a safe gas so the tube can be opened to try different targets.

•The system is small: 6" diameter and 18" long, and can generate 10^5 neutrons/s into 4Π.

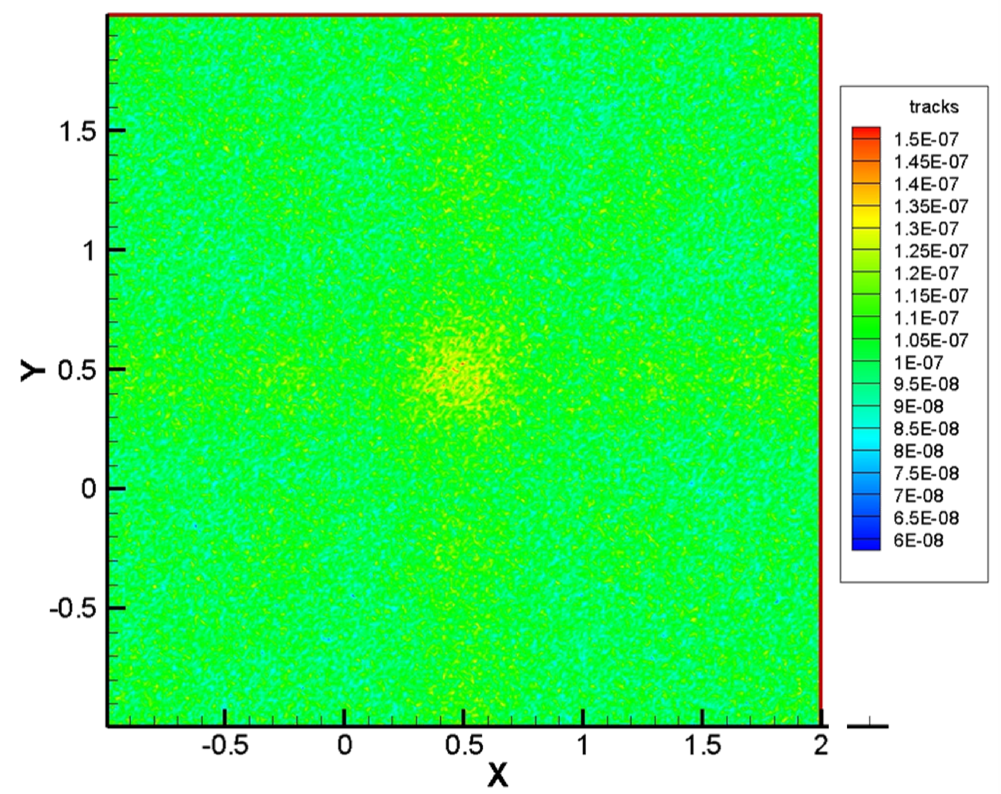


Simulations and Experiments

Array with 1mm of Boron shielding into a 1 cm^2 detector at 30 cm.



Array with 1mm of Boron shielding into a 3 cm^2 detector at 30 cm.



•These simulations were done in the most recent version of MCNP-X by the Nevada Radiological Computational Center of UNLV.

•Neutrons are generated into 4Π in each Getter element and then tracked. The neutrons interacting with a 1mm thick detector of 10% efficiency are shown above.

- Because the prototype tube needs to be recyclable, we use D-D and therefore simulate D-D reactions.
- The simulations done by the UNLV researchers show that a resolution pattern is expected with boron loading of the target.
- The tracks scale is in terms of interactions per neutron into 4Π.
- With a 10^5 n/s tube, the small interaction number implies one hour or more of data collection time for the calibration; switching to D-T tube operation would provide 10^8-10^9 n/s.
- The D-D tube is being tested by placing CR-39 (plastic particle track detecting media) at the location where the imaging system would be.
- Multiple geometric patterns are arrayed on a translatable stage which minimized tube recycling.
- Once optical geometries are established, reference images with CR-39 will be taken.
- The system will then be available for use in calibrations.

References

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Poster Information

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