NP SBIR-STTR Exchange Meeting

Compact and Efficient
Cold and Thermal Neutron Collimators

DE-FG02-08ER86353

Program Manager: Dr. Manouchehr Farkhondeh
Office of Nuclear Physics
U.S. Department of Energy

October 25, 2011

NOVA Scientific, Inc.

STTR Project Goals

Develop a compact MCP-based 2-D neutron collimator

- Improve neutron beam parallelism and quality pre-sample; reduce beam divergence and image blur at the detector
- Reduce post-sample scattered neutrons into detector, in a very compact space (only a few mm's thick)
- Computer-controlled alignment system

Criteria: **Rocking curve sharpness**

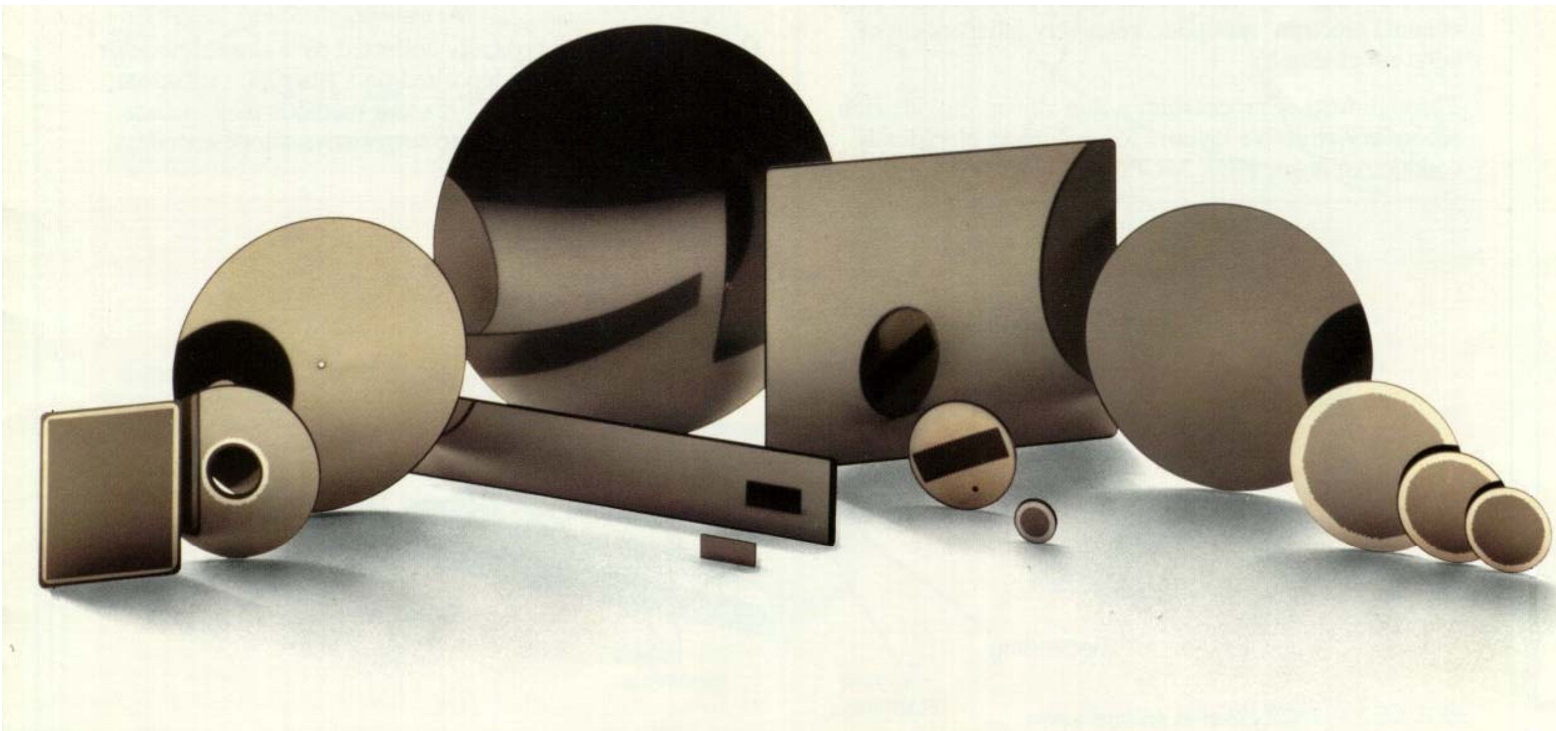
Maintain > 50 % neutron throughput, (even at extended L/D)

Improved hi-resolution neutron images

Microchannel Plate (MCP) Formats

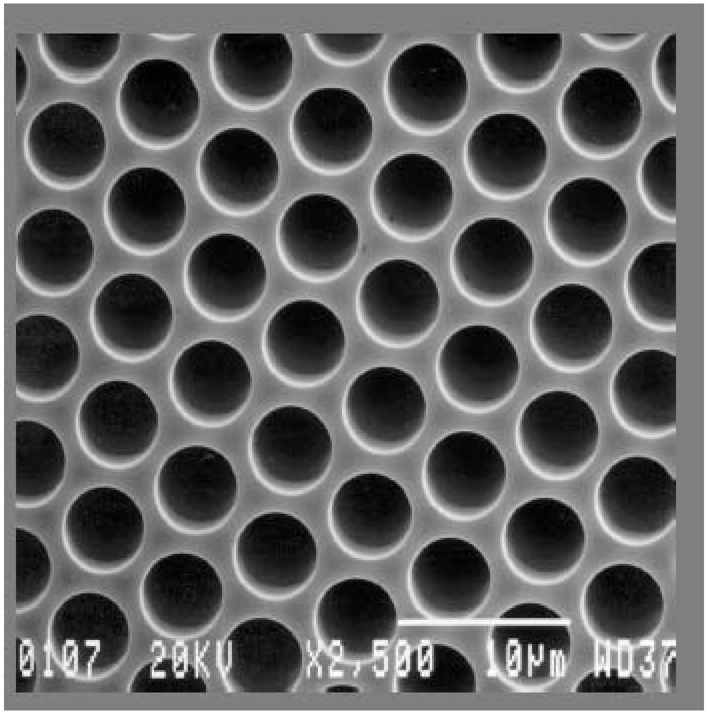
(Examples shown used for particle detection)

NOVA Scientific & the University of California-Berkeley Space Science Laboratory now adapting this technology for compact 2-D neutron collimation

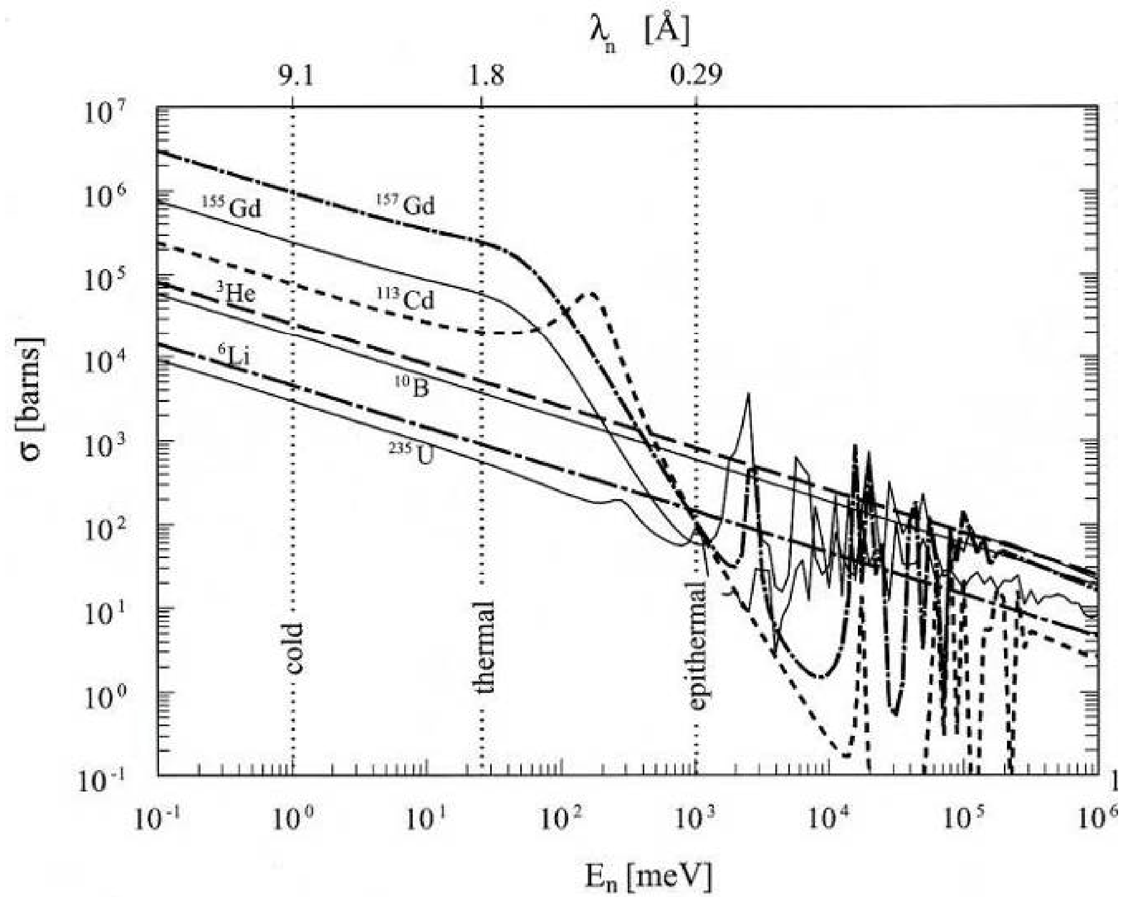


courtesy Photonis USA

MCP Structure
Typical Diameter 8µm on 10µm centers



^{10}B and Gd neutron Absorption versus Neutron Energy



Advantages of 2-D MCP-Based Collimation

- *Very compact imaging setups can be implemented with the MCP collimator devices.* Long flight paths no longer required between the aperture and the detector.
- Some beamlines, limited in space, can greatly benefit; enables high resolution tomography and radiography even in a very constrained experimental setup space.
- Collimation with compact devices substantially improves resolution for ‘large’ (few cm and larger) objects, especially in tomography where objects may be rotated and therefore placed at a distance from the detector active area.

Computer Modeling

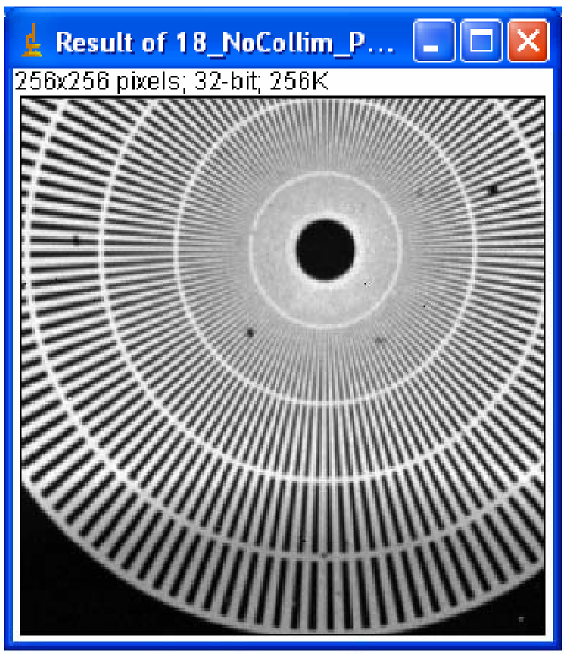
- Very powerful tool for MCP collimator design; has predicted collimator test data with very high accuracy
- Avoidance of numerous lengthy and highly expensive glass chemistry design and fabrication runs.
- Parameters in the model: glass composition (^{10}B or Gd doping levels), geometry (pore L/d and diameter)
- Output:
    - rocking curves
    - neutron transmission
    - out-of-angle rejection

Experimental Campaign

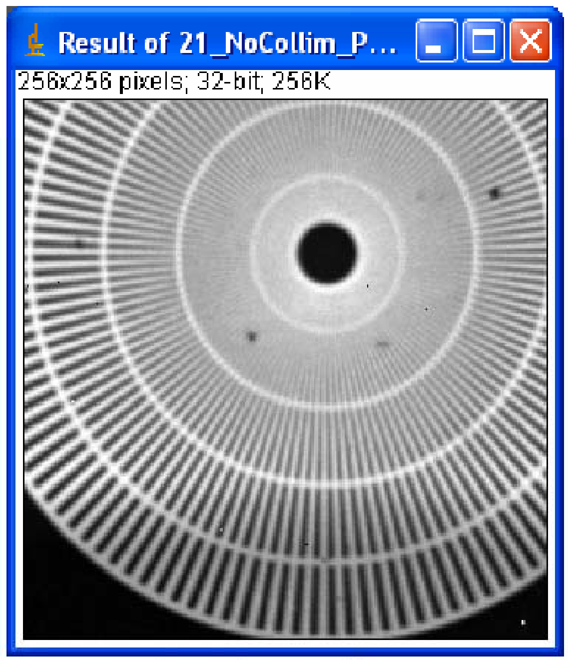
- Multiple test runs have been carried out and are continuing, using several improved MCP collimator test samples.
- Tests include both neutron beam shaping and scatter rejection.
- Tests at pulsed and continuous beamlines at:
  - ORNL SNS and HFIR(SNAP, CG-1)
  - PSI (Neutra, FunSpin)
  - ISIS (ROTAX)
  - FRM-11 (Antares)

Tests with PSI Imaging Resolution Target

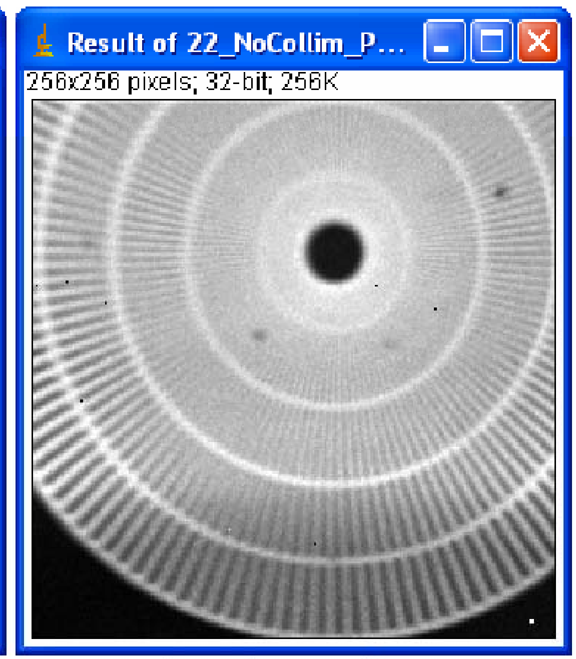
Closed position to the detector (~1 cm away from the active area)
NO COLLIMATOR



Aperture = 1cm
Flux 1e7 n/cm^2/s



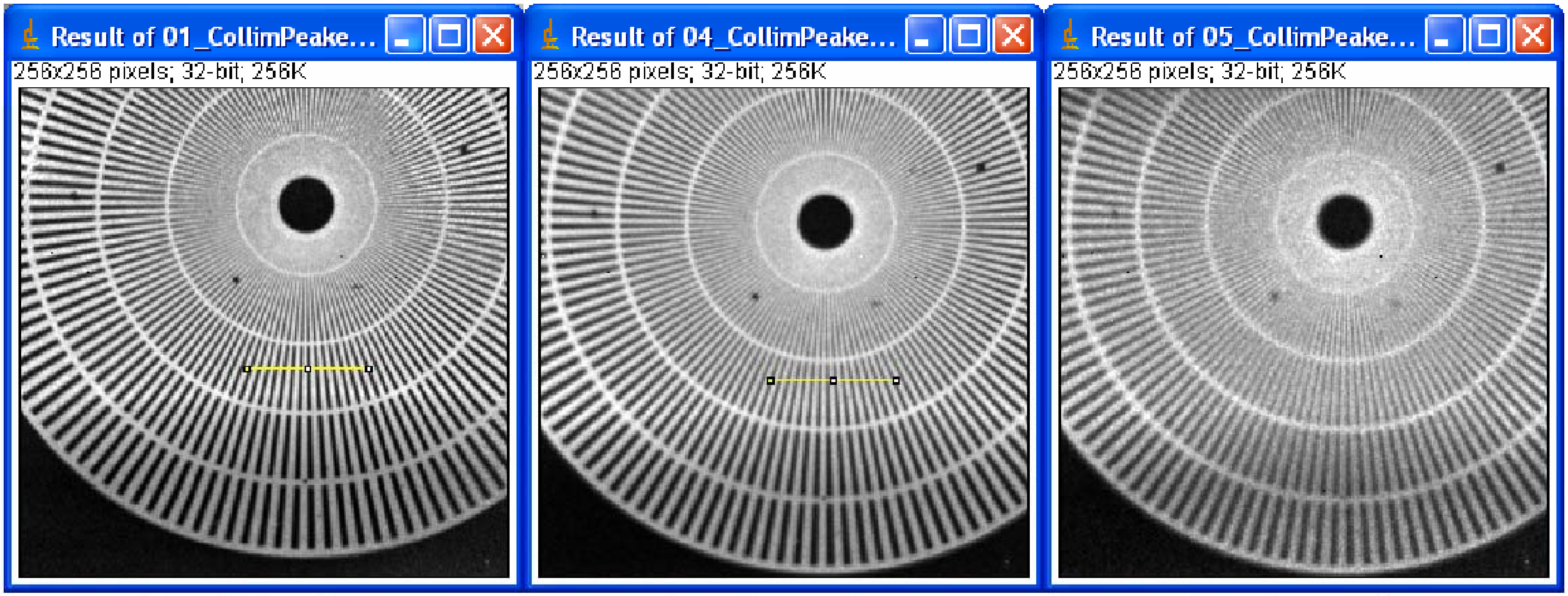
Aperture = 2cm
Flux 3.2e7 n/cm^2/s



Aperture = 42mm
Flux 4.5e7 n/cm^2/s

Image Improvement Occurs Even at Close Positioning

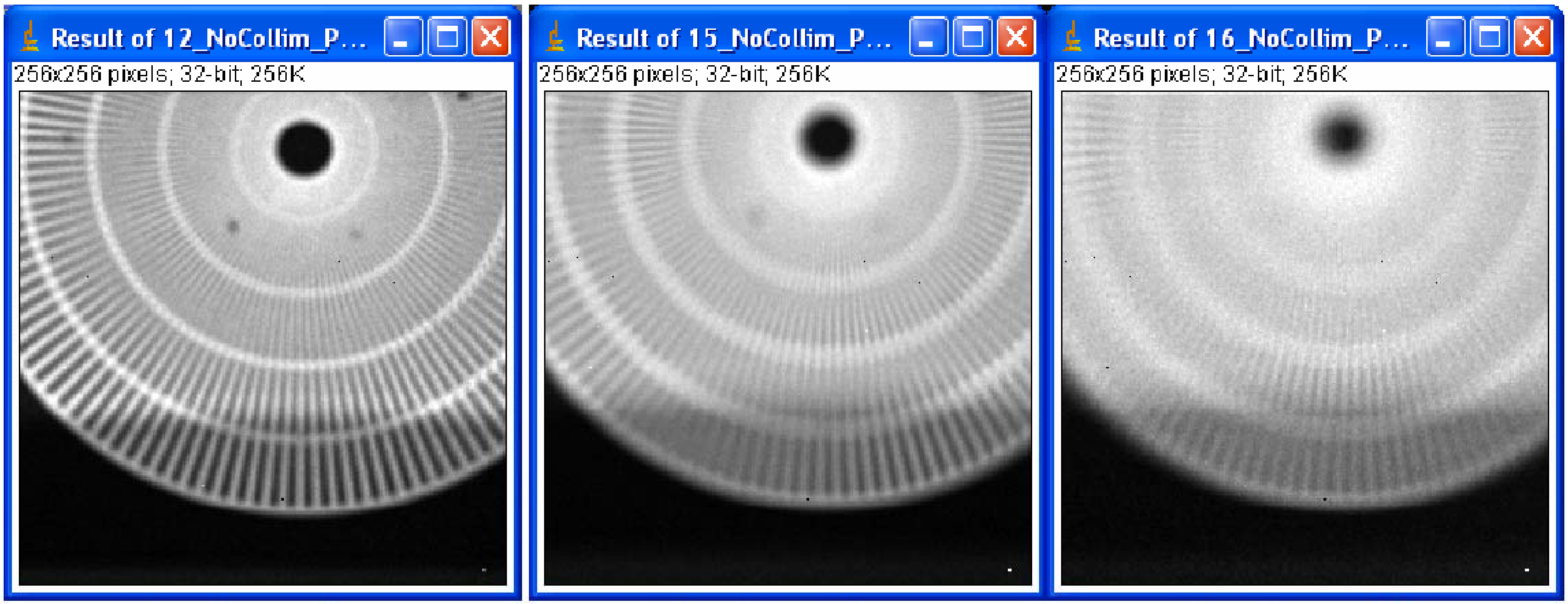
Closed position to the detector (~1 cm away from the active area)
WITH COLLIMATOR



Aperture = 1cm	Aperture = 2cm	Aperture = 42mm
Flux 5.8e5 n/cm^2/s	Flux 1.2e6 n/cm^2/s	Flux 1.72e6 n/cm^2/s

Even More Advantageous as Sample Is Placed Further from Detector

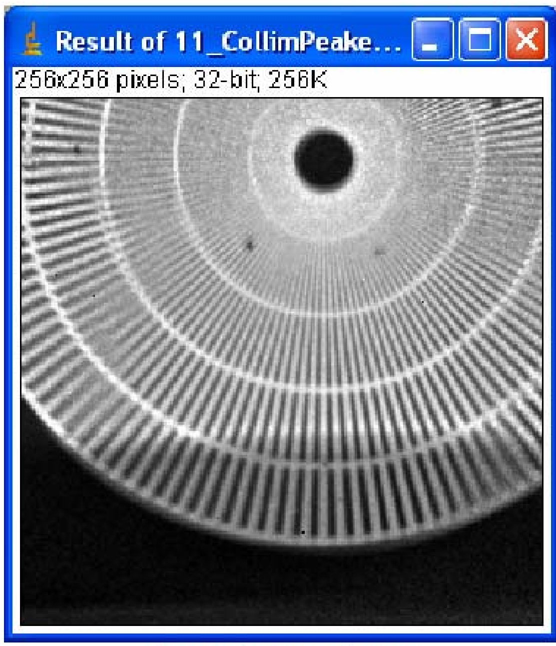
32 mm to the detector cover (~42 mm to the active area)
NO COLLIMATOR



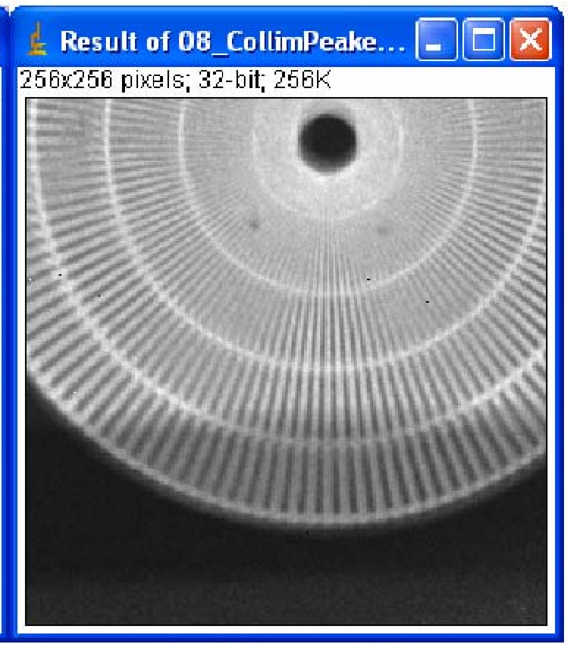
Aperture = 1cm **Flux 1e7 n/cm^2/s**	**Aperture = 2cm** **Flux 3.2e7 n/cm^2/s**	**Aperture = 42mm** **Flux 4.5e7 n/cm^2/s**

Considerable Image Improvement Observed

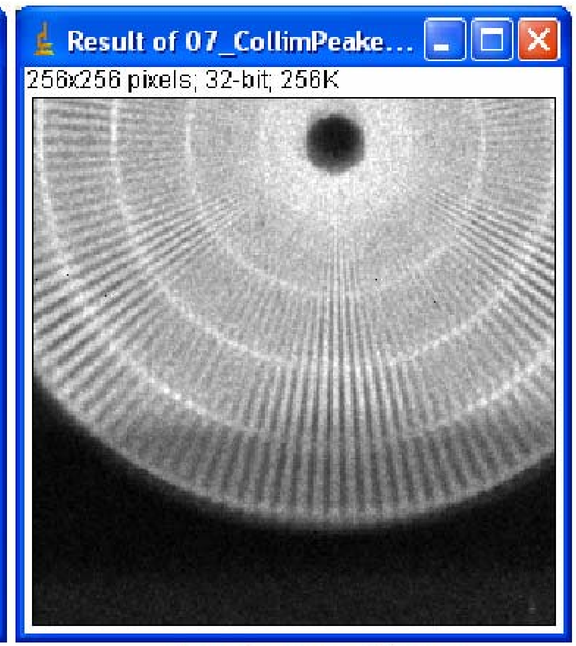
32 mm to the detector cover (~42 mm to the active area)
WITH COLLIMATOR



Aperture = 1cm
Flux 5.8e5 n/cm^2/s



Aperture = 2cm
Flux 1.2e6 n/cm^2/s



Aperture = 42mm
Flux 1.72e6 n/cm^2/s

NOVA MCP Neutron Detectors

(used in conjunction with the MCP-based collimator tests)

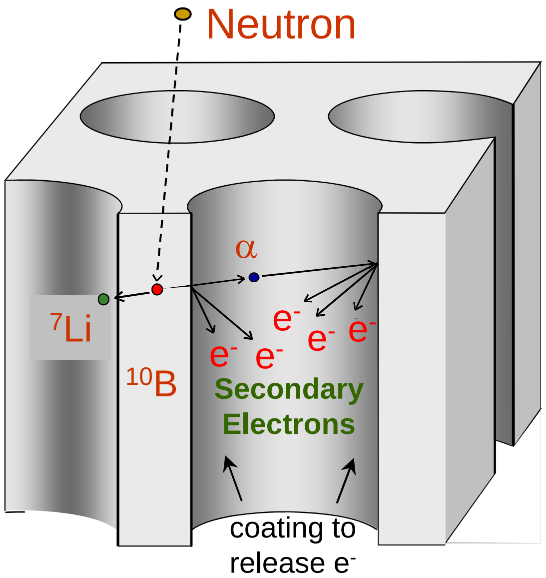
Real-time neutron imaging and TOF:

~10 µm imaging resolution)

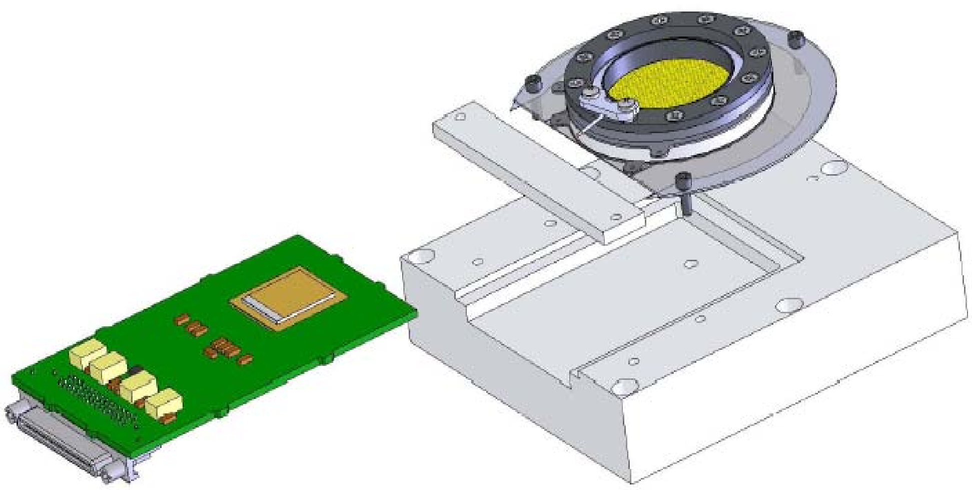
~1 µs timing resolution

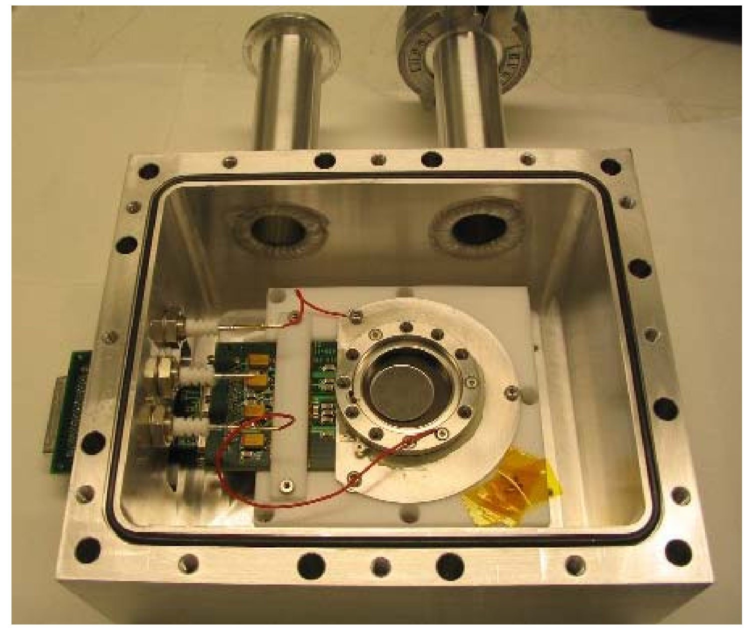
Neutron-Sensitive MCP as Detector

- ^{10}B (or Gd) incorporated into base glass material
- Reactants create secondary electrons - reactant ranges well-matched to channel wall thickness
- Secondary e-'s amplified to large ~1ns output pulses
- Spatial resolution set by pore size (5-10 µm)
- Timing resolution set by 1mm MCP thickness (~1 µs)
- Neutron efficiency ~ ^{3}He
- Neutron sensitivity/cm^{2} > ^{3}He (1.6-1.7x)



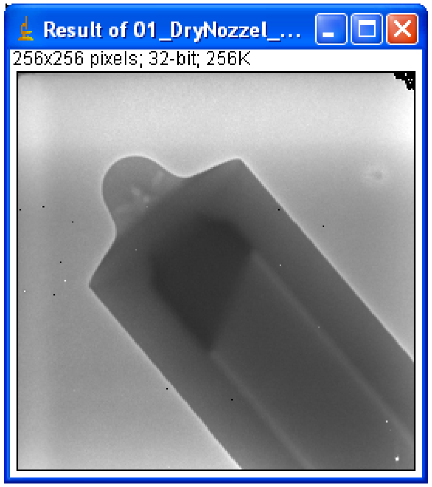
MCP Neutron Detector with Medipix/Timepix Readout
(a separate DOE Phase II STTR with UCal-Berkeley)



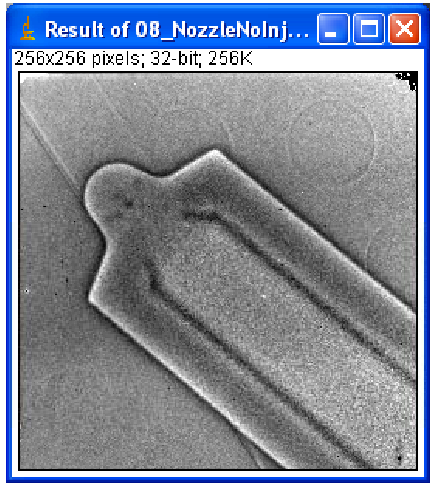


- Double MCP stack is placed ~0.5 mm above Medipix2/TimePix readout.
- Front MCP provides neutron conversion, rear MCP ‘amplifier’ further boosts output pulse to > 10^6 e^- for pulse counting.

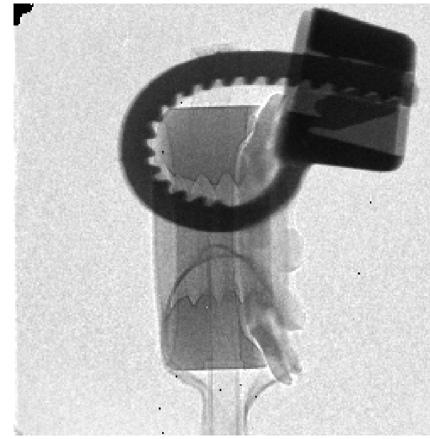
Imaging Examples of MCP Detector with Medipix



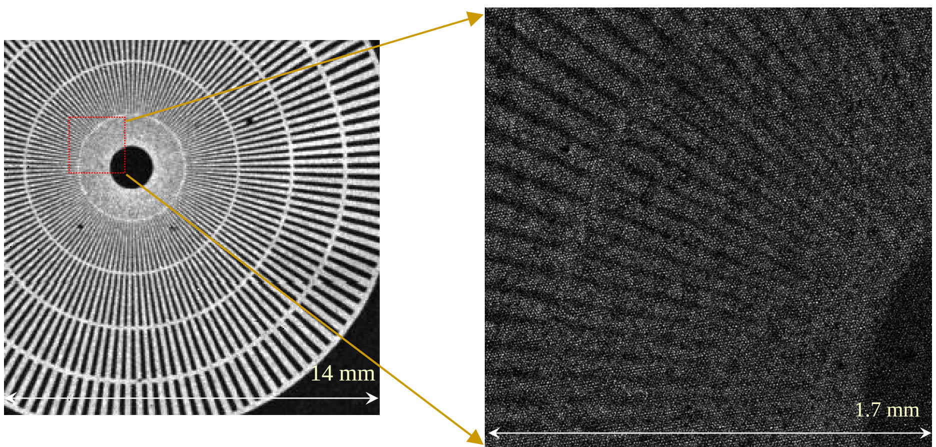
Fuel injection nozzle



Dual energy image acquisition



In collaboration with M. Muehlbauer, B. Schillinger, January 2009, FRM2, ANTARES beamline

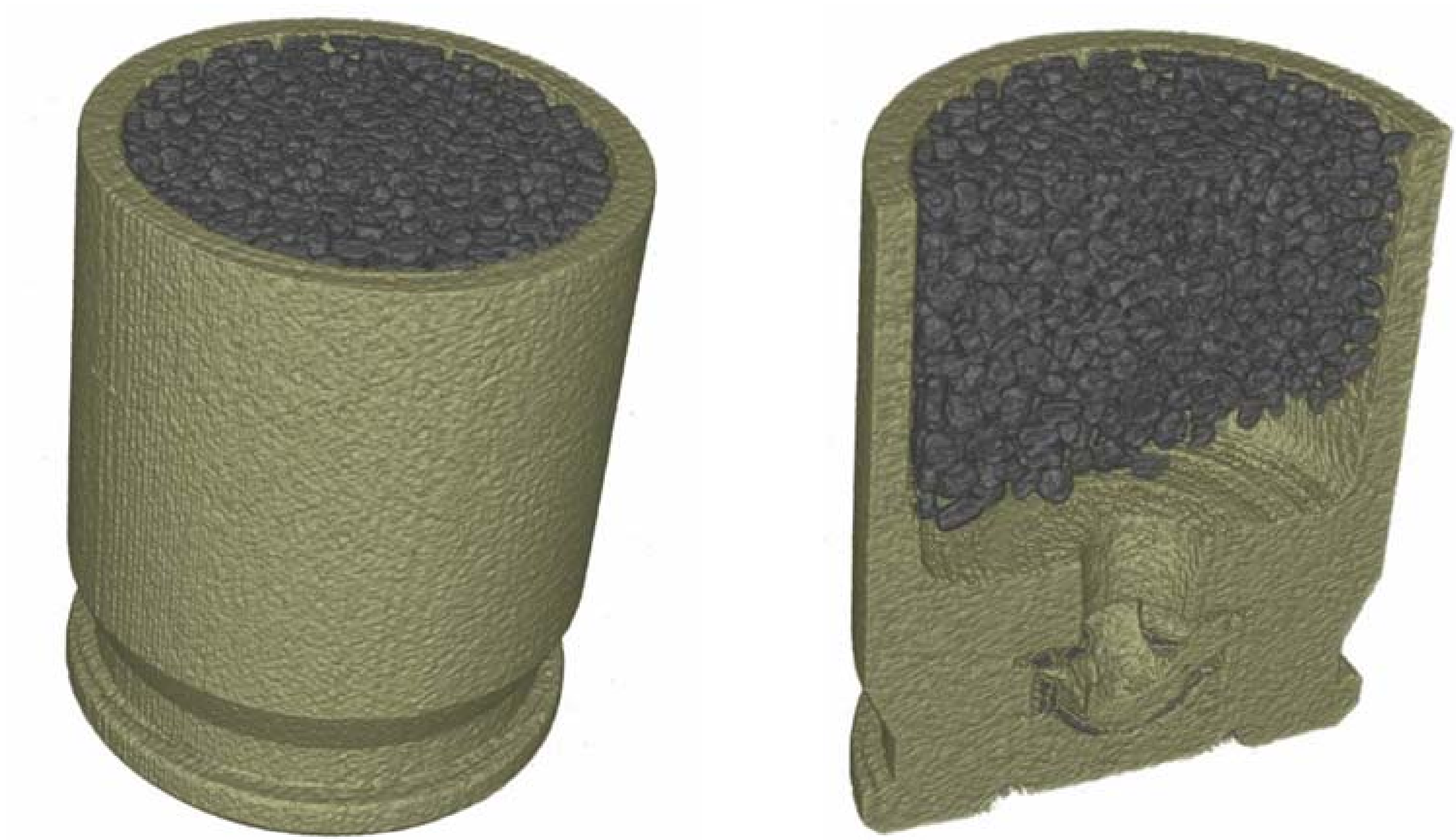


PSI Gd resolution mask

11 μm MCP pores are seen
Presently very low counting rate

Tomographic Reconstruction

MCP Neutron Imager, 1 μs timing resolution
(5 meV cold neutrons at ICON beamline, PSI)



Tomography Animations
Using MCP/Medipix Neutron Detector

Reconstructions and visualizations by M. Muehlbauer (TUM) and Anders Kaestner (PSI)

Summary

- MCP-based neutron collimators can effectively reduce the divergence of lower L/D neutron beamlines
- MCP collimators can effectively reduce scattering between the target and detector, leading to improved contrast, definition, and resolution
- *Nova Scientific's neutron-sensitive MCP and neutron collimator, together with the Medipix Collaborations's readout, offers an extremely powerful high spatial and timing resolution neutron detection system (~10 µm and ~1 µs).*
- **Nova Scientific and UCal-Berkeley appreciate the support of the DOE SBIR-STTR program!**