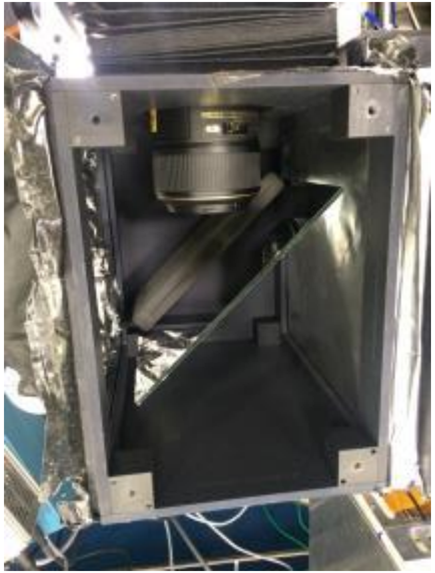
PHOTONIS
Scientific Detectors

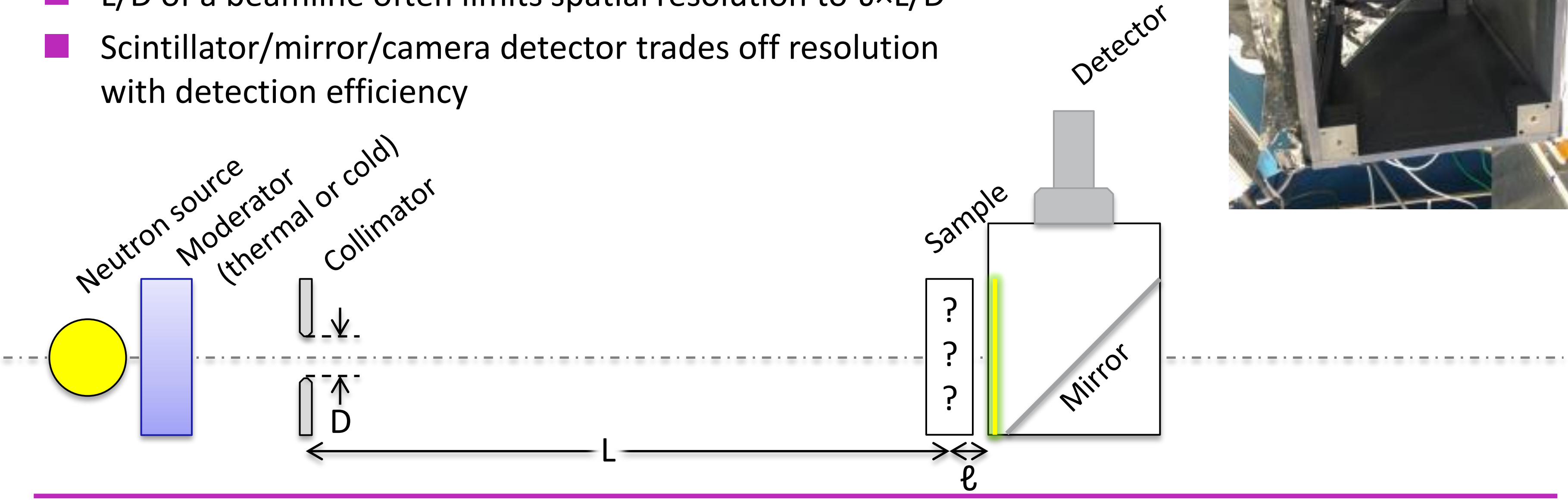
Neutron Imaging and Tomography with MCPs

Serge Duarte Pinto
4 July 2017
iWoRiD - Krakow

Neutron Imaging simplified setup

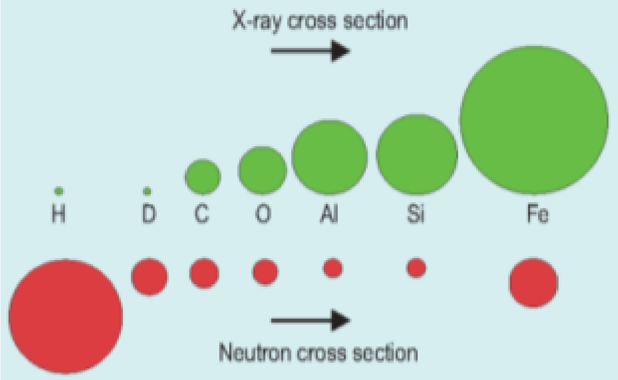
- Bright field imaging most conventional
- Tomography possible with a rotating sample stage
- L/D of a beamline often limits spatial resolution to ℓ×L/D
- Scintillator/mirror/camera detector trades off resolution with detection efficiency

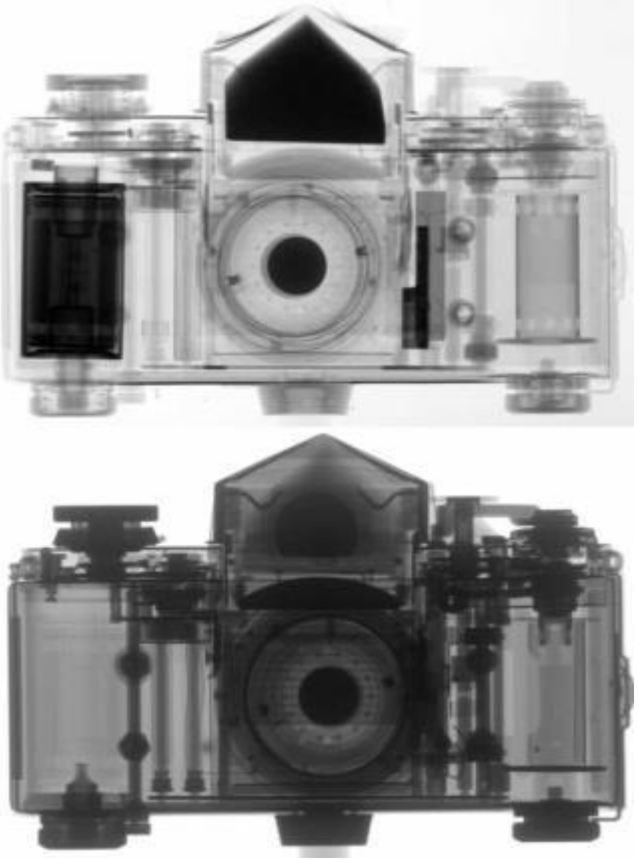




Neutron Imaging vs X-ray imaging

- Difference in contrast: X-rays interact with electrons, neutrons with nuclei
- X-ray cross-section increases steeply with Z, neutron cross-section less predictable, and depends on isotope

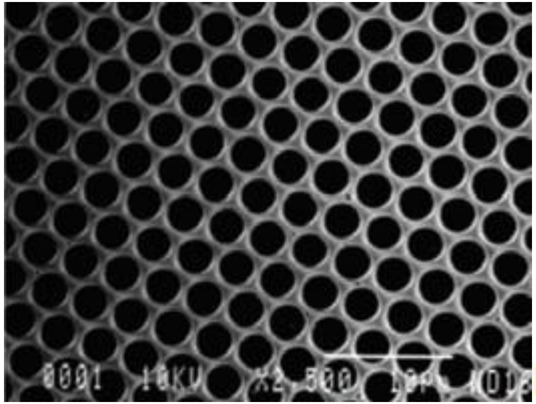


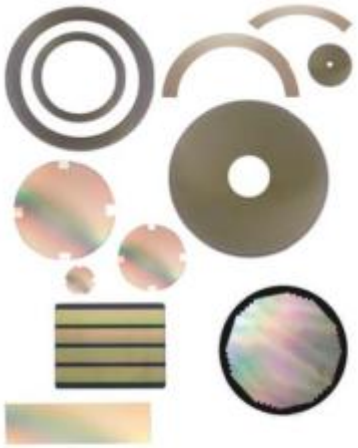


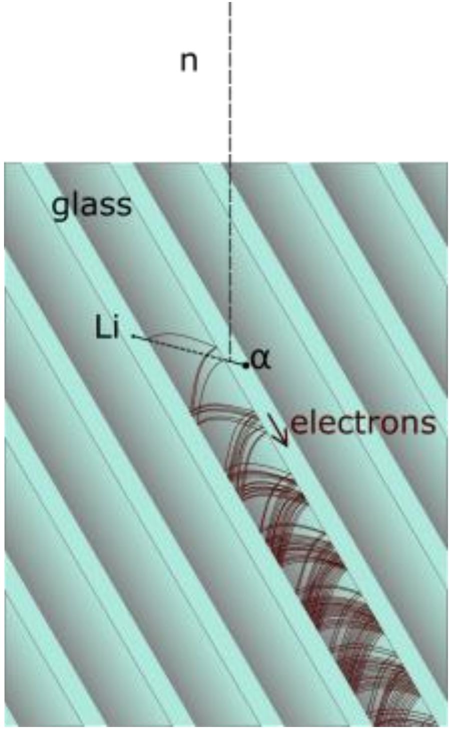
Source: PSI

Microchannel Plates loaded with ^{10}B and Gd

- Glass capillary structures with millions of microscopic pores, each of which acts as an electron multiplier
- Can be made in almost any size and shape
- If the glass is doped with ^{10}B and Gd, it becomes neutron sensitive
- Detection efficiency ~50% for thermal neutrons (~70% cold)

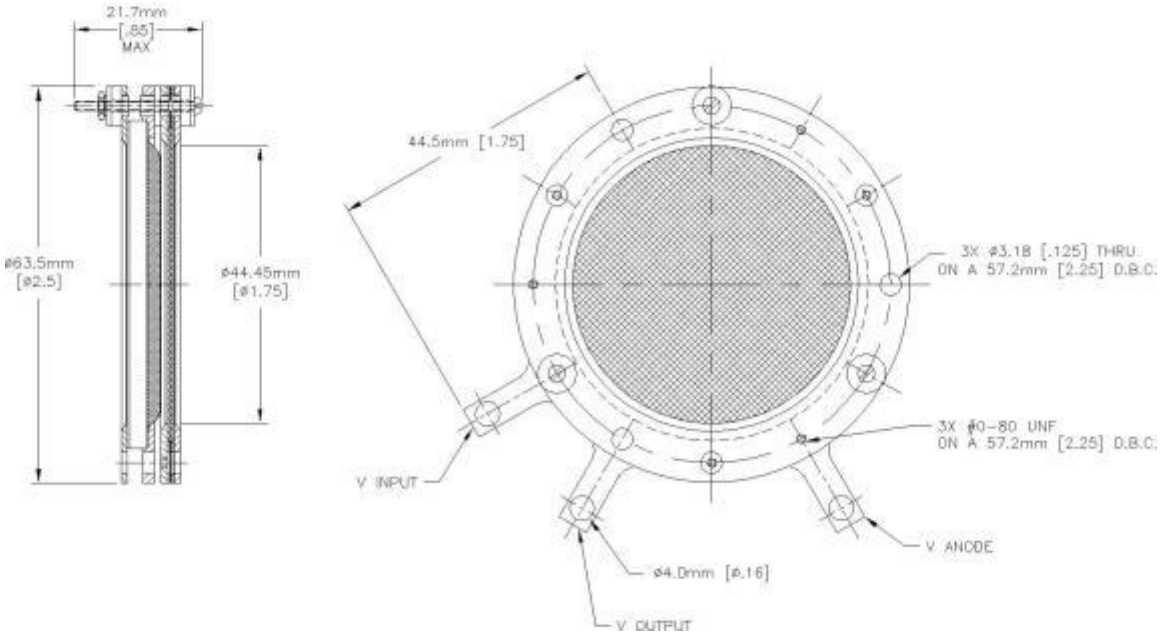




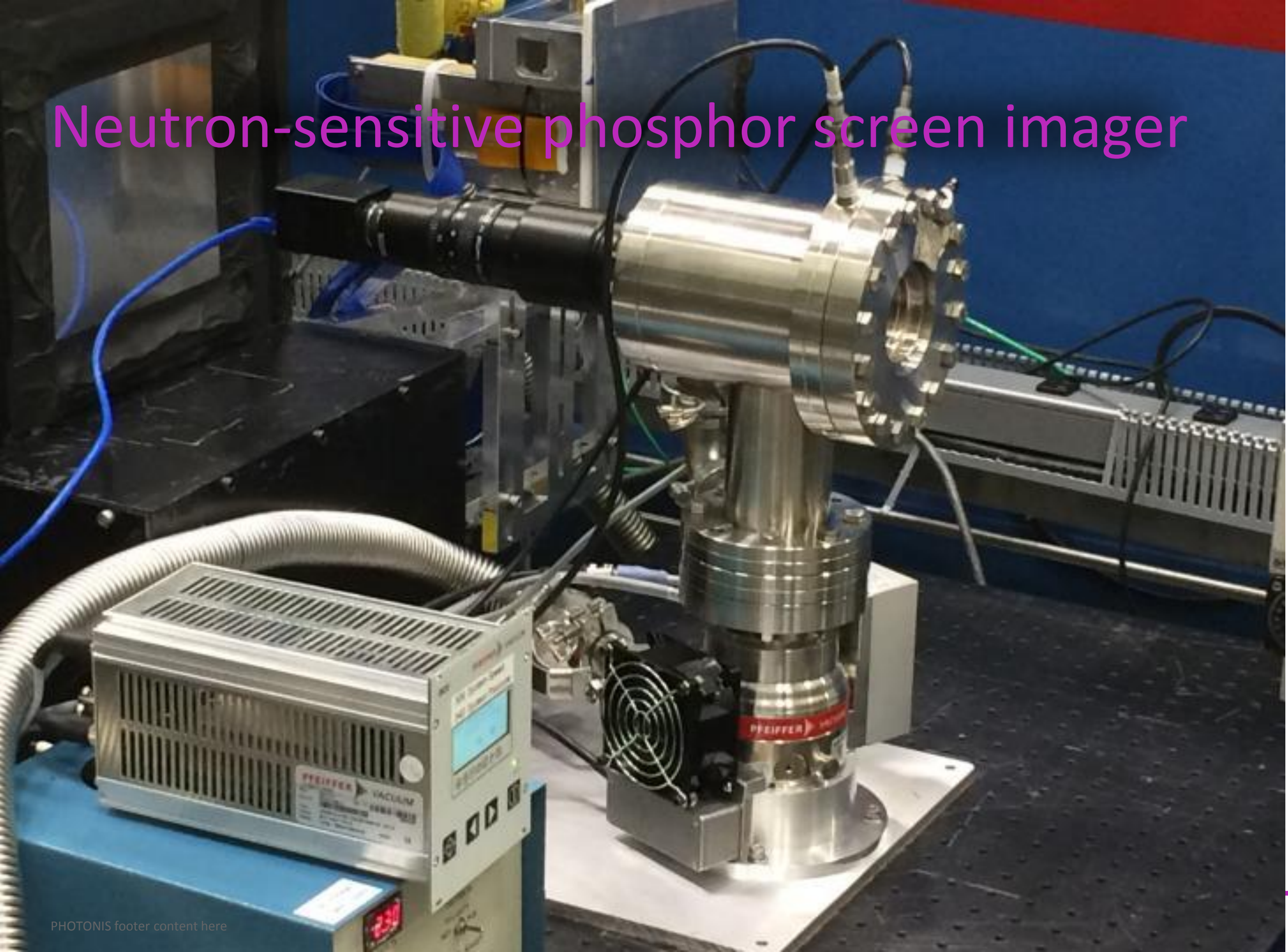


Neutron-sensitive phosphor screen imager

- An assembly of one or more MCPs with a phosphor screen
- Mounted in a vacuum enclosure, screen observed through a viewport by a camera
- 2 MCPs high gain, wider PSF
- 1 MCP lower gain
- First tests with 40 mm round FoV
- 100x100 mm^2 unit in progress



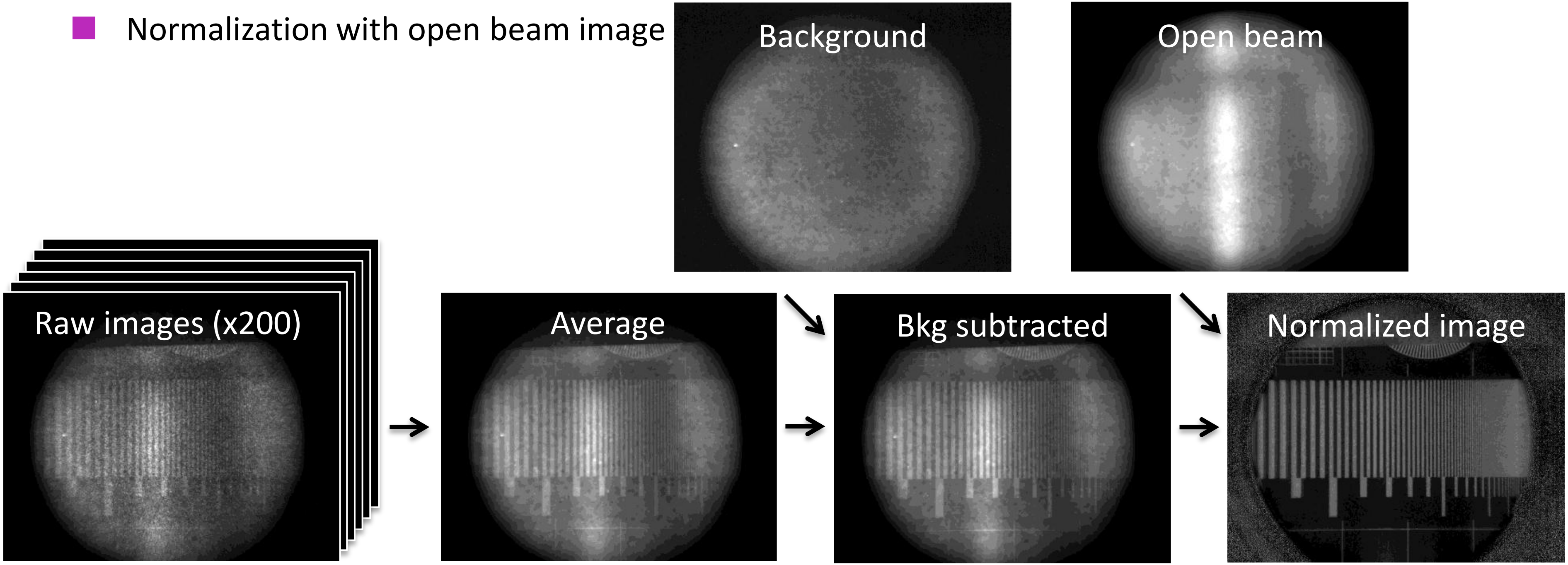
Neutron-sensitive phosphor screen imager



Tested in February at the Reactor Institute Delft (NL) with thermal neutrons, and in March at HFIR, Oak Ridge National Lab with cold neutrons.

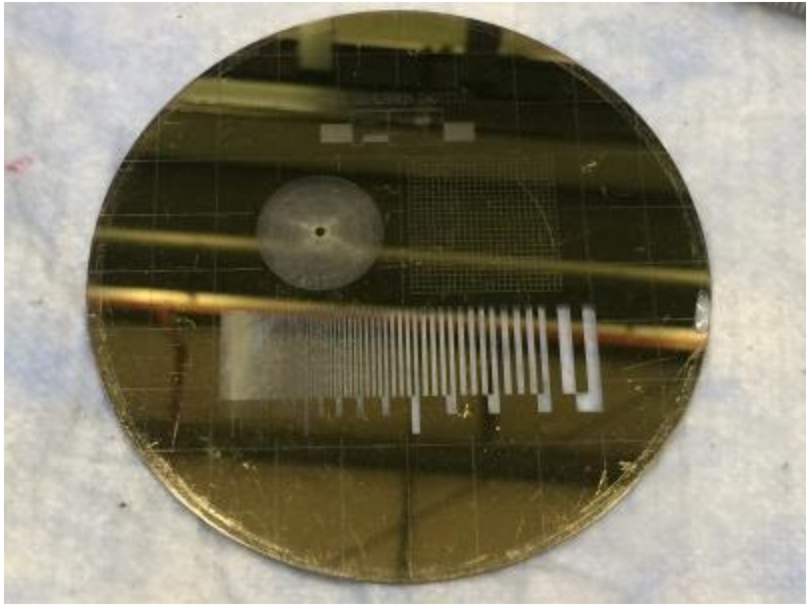
Taking Images and processing them

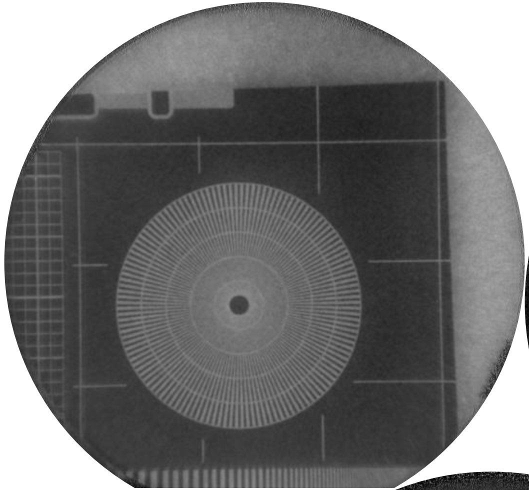
- Raw images are taken until sufficient exposure
- Background subtracted from the average raw image
- Normalization with open beam image

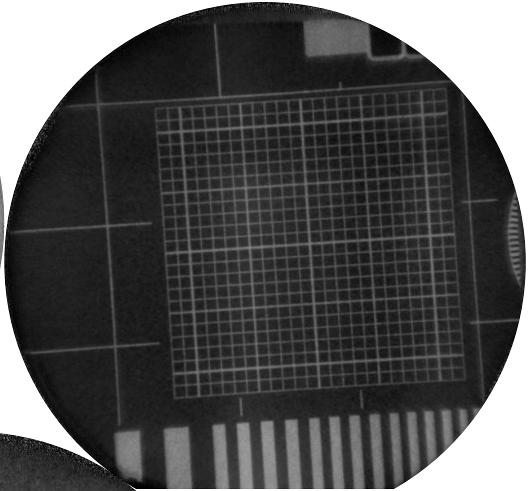


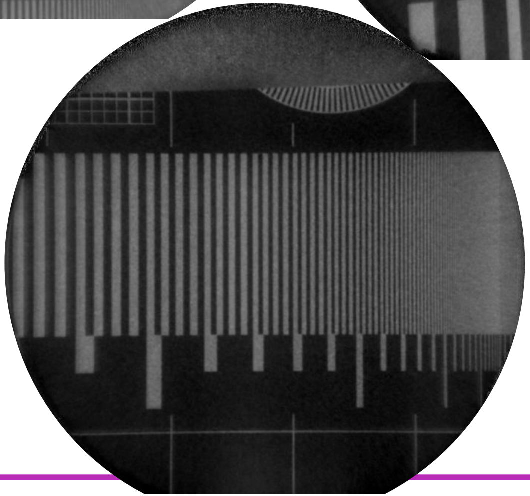
Gadolinium test mask

Made at PSI: C. Grünzweig et al., *Rev. Sci. Instrum.*, vol. 78, no. 5, p. 53708, May 2007.



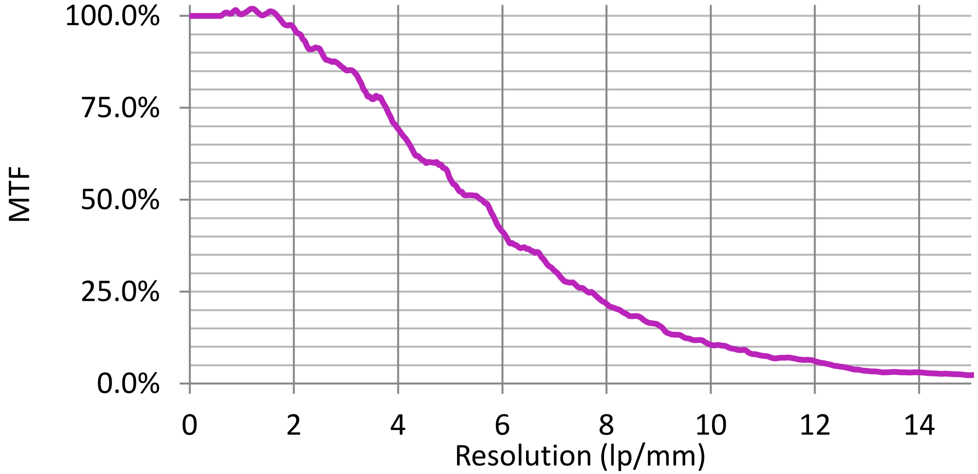


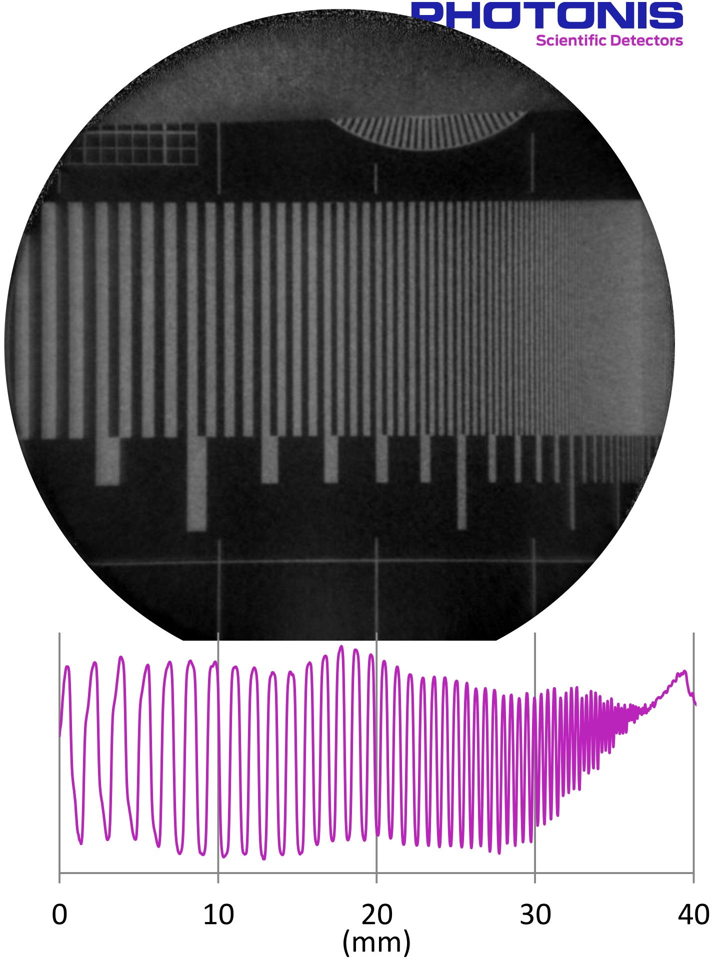




Gadolinium test mask

- Resolution line grid can be used to calculate *modulation transfer function* (MTF) curve
- *Limiting resolution* is often defined @ 10% or 5% MTF
- This means 10-12 lp/mm, or 80-100 µm for our imager

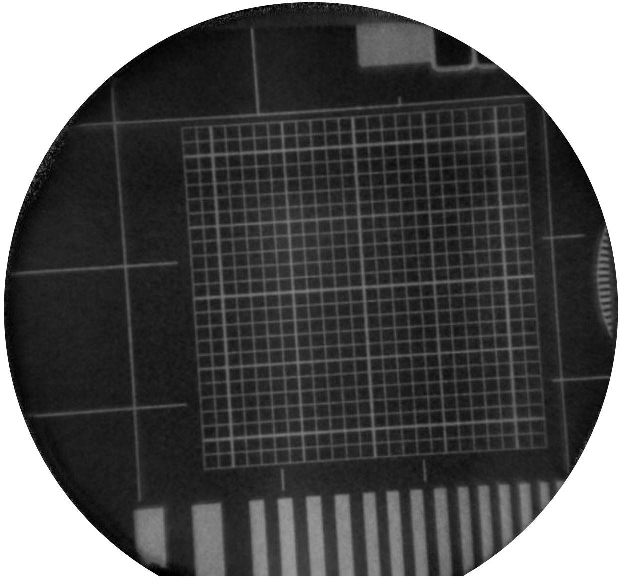




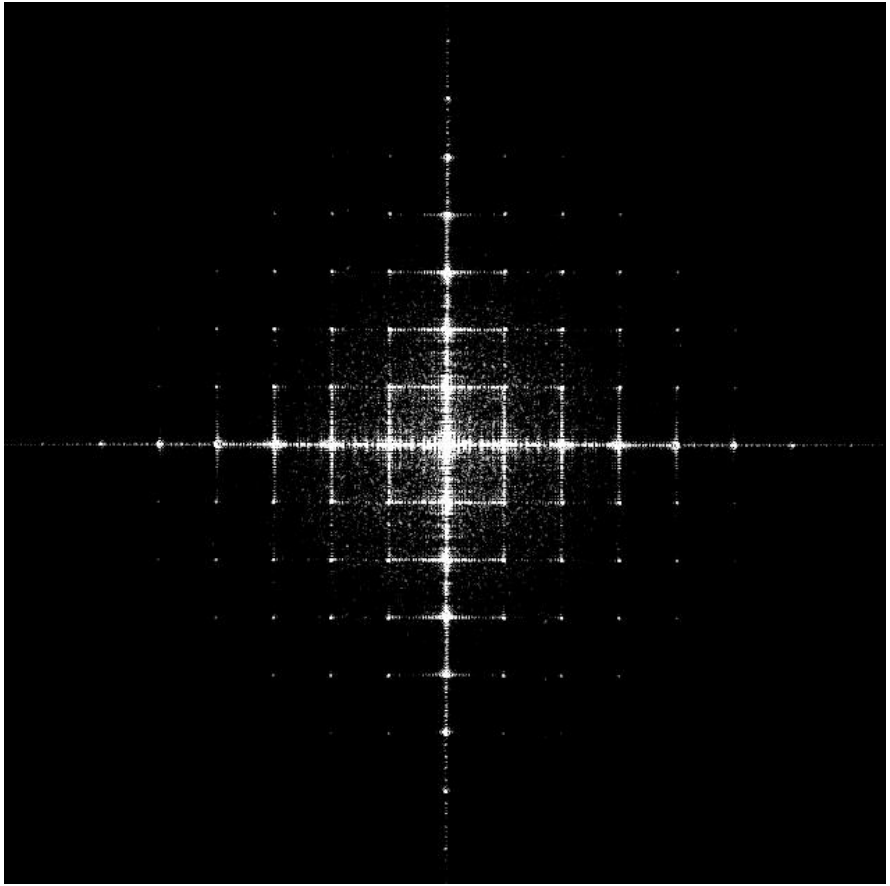
PHOTONIS
Scientific Detectors

Gadolinium test mask

The square line grid can reveal pincushion or barrel distortions. A 2D Fourier transform is particularly sensitive to such distortion.

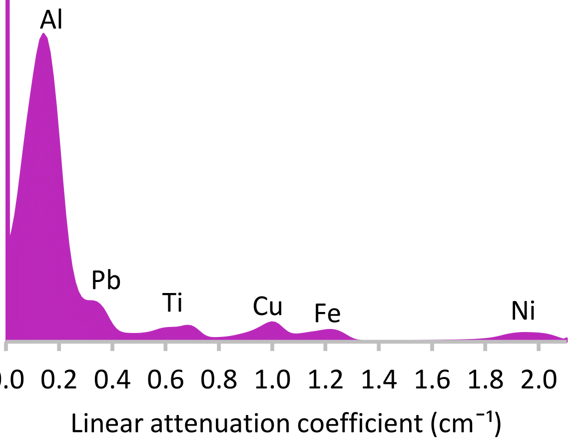


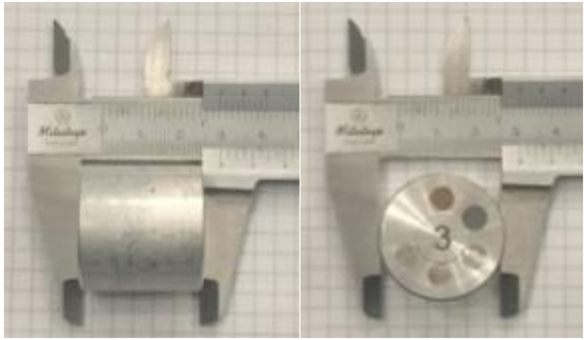
2D FFT



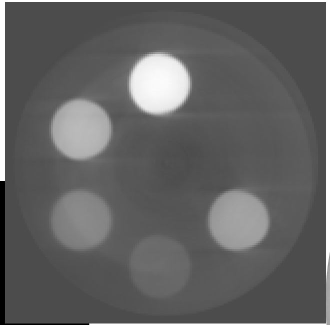
Tomography

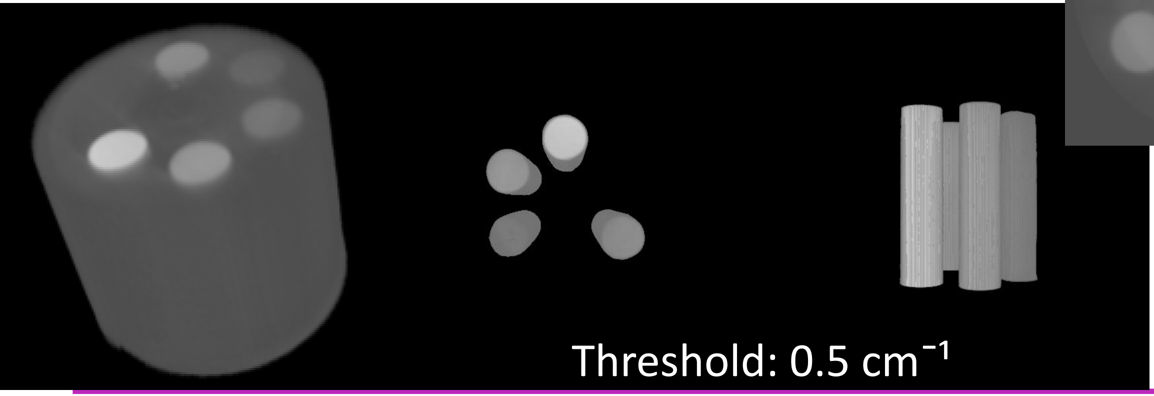
Test sample from: A.P. Kaestner et al., *Phys. Proc.* 43 (2013) 128–137.

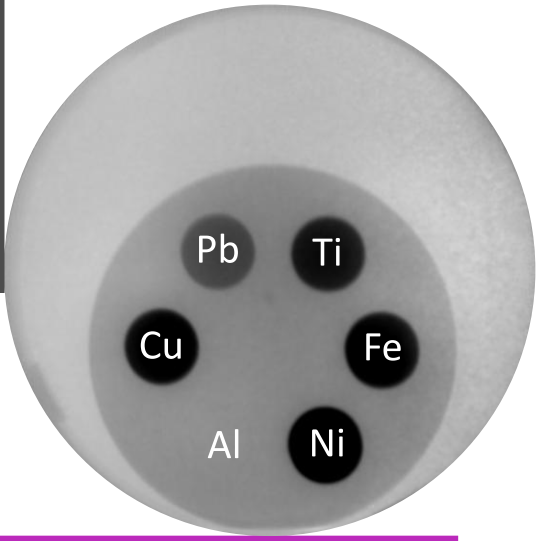




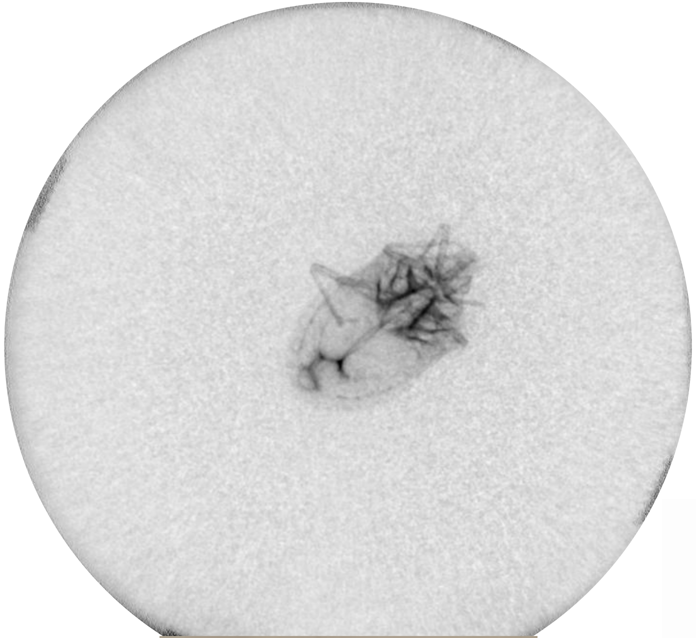
- Tomography of multimetal sample
- 900 projections in <2 hours
- Shadows due to uncorrected beam hardening →
- By adjusting the attenuation coefficient threshold metals can be in- or excluded

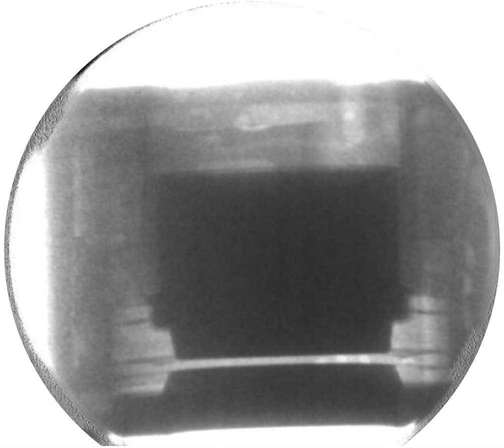






Some more images



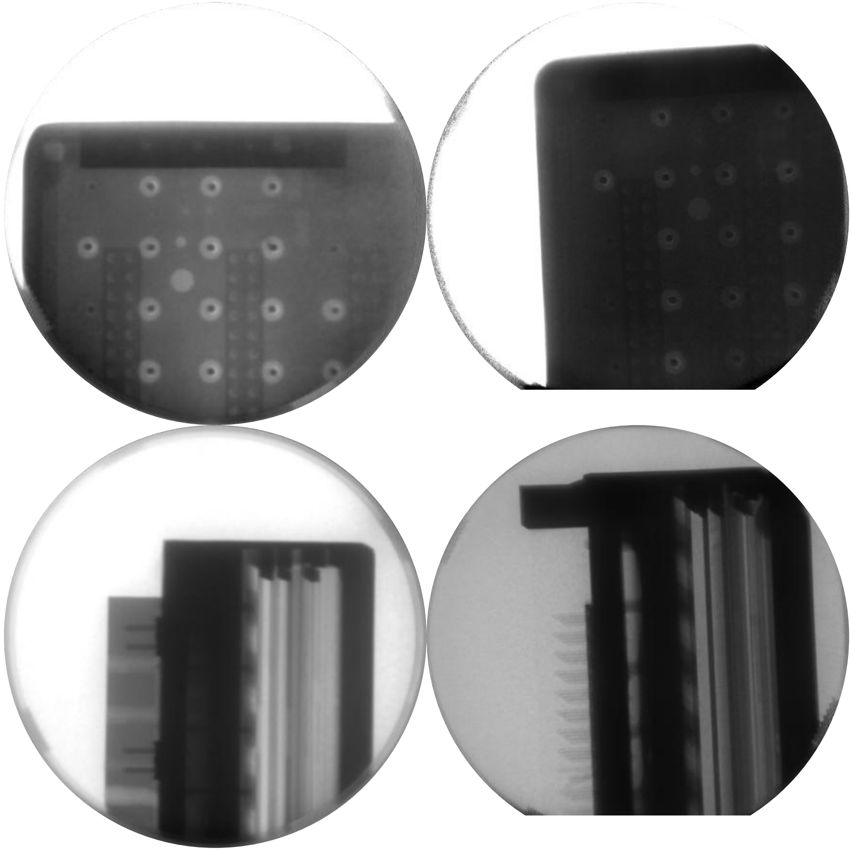


Thermal vs cold neutrons

- Thermal neutrons: more penetration
- Cold neutrons: more contrast

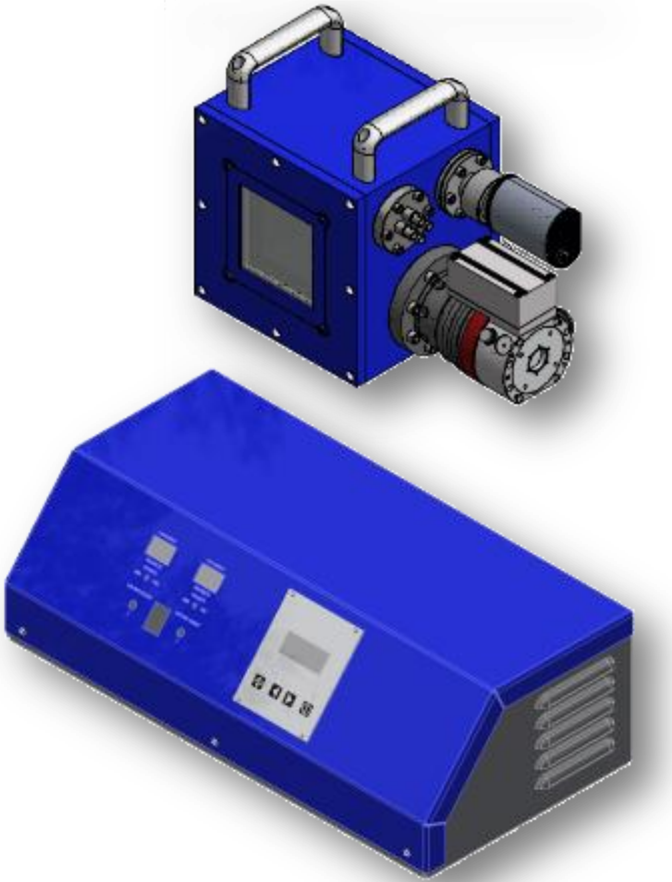
Images of a Planacon MCP-PMT made in Delft (thermal) and ORNL (cold).

Thermal Cold



Improved design

- $100x100\ mm^2$ active area
- A single MCP for better resolution
- MCP electroding and spacing to phosphor better optimized for resolution
- Services (pumps, gauges, high voltage etc.) integrated in one control box
- All aluminum housing (low activation)
- Square active area means cylindrical FoV for tomography
- Need a hi-res camera to reach a better resolution
- Beam time scheduled at HFIR (ORNL) in September



Conclusions & outlook

- A neutron imaging detector that does not trade off resolution with detection efficiency
- Resolution so far: ~100 µm, we know how to improve to <50 µm
- Detection efficiency ~2 orders of magnitude better than scintillators of comparable resolution
- Strongly reduces exposure time for low-contrast samples, and especially for tomography
- Time resolution limited by the camera
- Imaging with portable sources within reach

PHOTONIS
Scientific Detectors

PHOTONIS Technologies S.A.S.
18 Avenue de Pythagore
CS 70019
33693 MERIGNAC Cedex
France

T +33 (0)556 16 40 50
F +33 (0)556 16 40 62
www.photonis.com