Performance Study of an Amorphous-Silicon Flat Panel Detector for Fast Neutron Imaging of Nuclear Waste

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Introduction

For non destructive characterization of nuclear waste detailed information about massive and dense structural components are needed from radiography to improve analytical results.

Setup

Detector Design

- Commercial X-Ray detector (PerkinElmer)
- Active area: 40 x 40 cm²
- Segmentation: 1024 x 1024 pixels

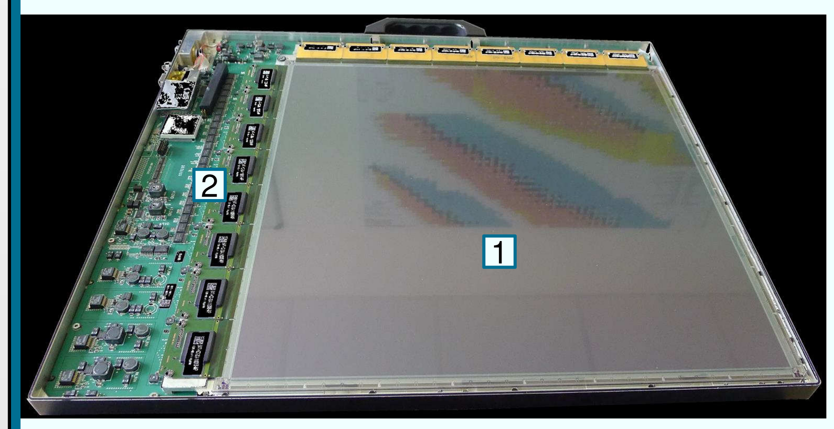


Fig. 1: Opened detector without scintillator. [1] Active area made from aSi. [2] Electronics

Scintillator

- General purpose plastic scintillator
- EJ-260 Eljen Technology
- Thickness: 3 mm

Fig. 2: General purpose plastic scintillator used for fast neutron detection via recoil protons.

Neutron generator

- Commercial generator Genie16GT (Sodern)
- D-T fusion for 14 MeV neutrons
- Flux determination with monitoring foils (Al, Au)
- Distance source to foils: 30 cm
- Activity measurement with HPGe detector
- Fast neutron source strength:

$$Q_{fast} = 15.7 \pm 2.6 \cdot 10^7 \text{ n/s}$$

Reaction	A in Bq	Φ in cm⁻²s⁻¹	Q in s⁻¹
$^{197}Au(n,\gamma)^{198}Au$	2.48	$28.1 \cdot 10^1$	$3.2 \cdot 10^6$
$^{197}Au(n,2n)^{196}Au$	0.10	$12.2 \cdot 10^3$	$1.4 \cdot 10^8$
$^{27}Al(n,\alpha)^{24}Na$	0.38	$15.5 \cdot 10^3$	$1.7 \cdot 10^8$

Tab. 1: Analysed reactions with corresponding activities, neutron fluxes and source strengths.

Experiment

- Neutron generator within 10-20 cm PE shield
- Distance source to detector: 42 cm
- Samples on lift table

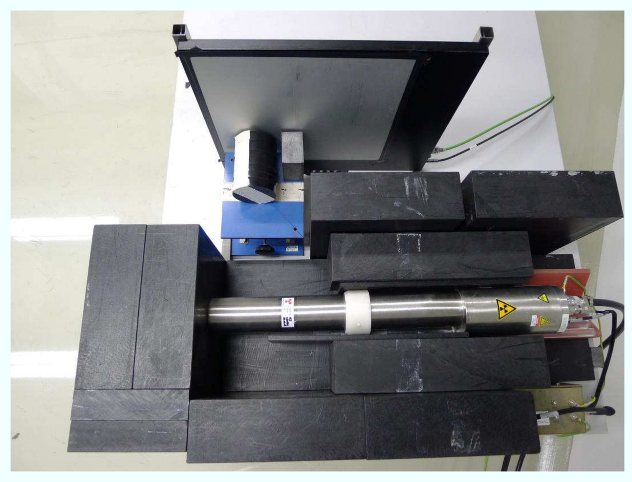


Fig. 3: Experimental setup with samples of PE and lead. Shielding lid is removed.

Image Analysis

Setup

- Pb brick and PE cylinder
- Distance source detector: 42 cm
- Average of 450 frames, each 2 s

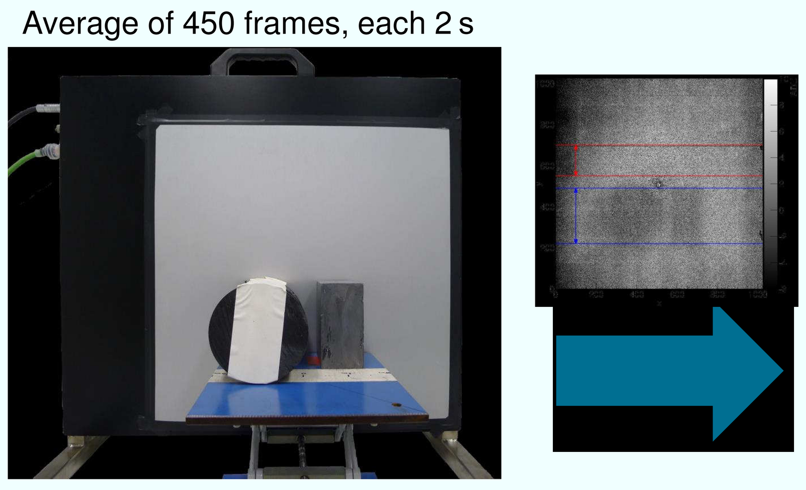


Fig. 4: Photograph of the setup for the following radiographs.

Smooth

- Profiles of areas with and without objects
- Set outliners to the average of the surrounded pixels

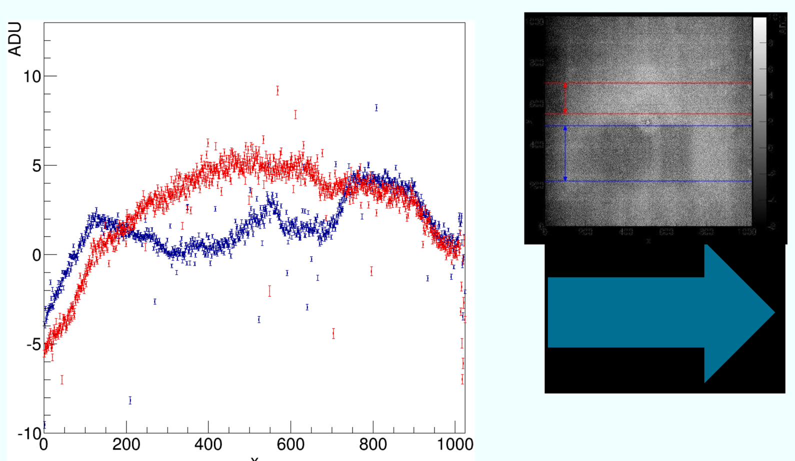


Fig. 5: Profiles of the area without object (red) and including the object (blue).

Profile Correction

- Set area without objects as background

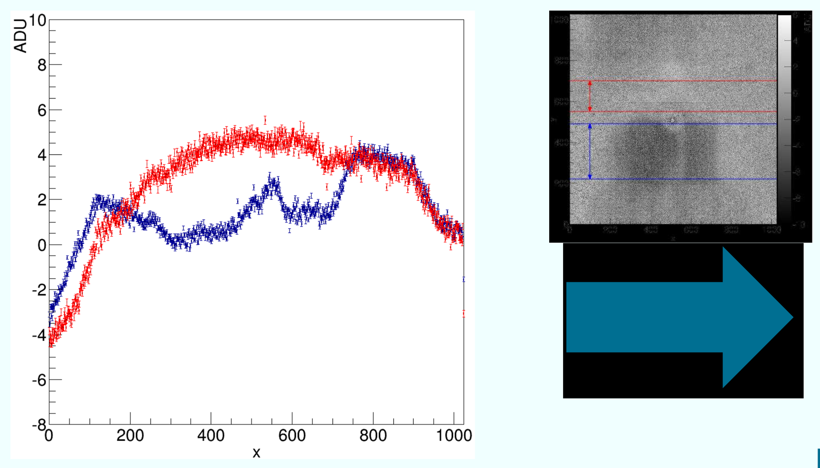
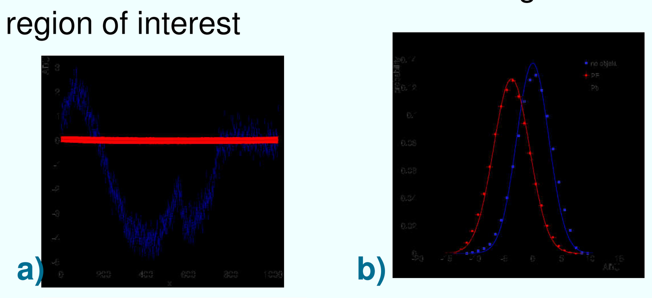
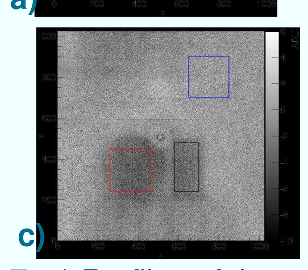


Fig. 6: Profiles of the smoothed radiograph.

Signal Analysis

- Fit Gaussian distribution to histogram from region of interest





d)

Area	μ in ADU
No obj.	-0.01(2)
PE	-3.68(2)
Pb	-3.11(2)

Fig. 7: a) Profiles of the corrected radiograph. b) histogram of the region of interest from areas seen in c). d) Mean values of the Gaussian fits.

Results

Calibration

- Radiographs of well known test samples
  - Size: 5 x 8 x 10 cm³
  - Al, C, Fe, Pb, W, concrete, PE
- PE as reference
- Combination of two samples
- Analysis as shown before

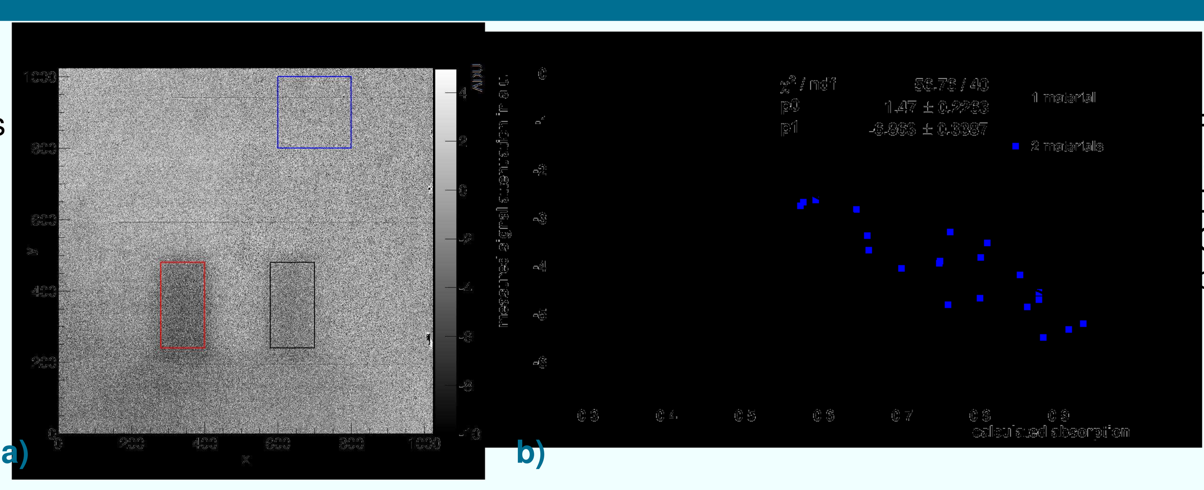
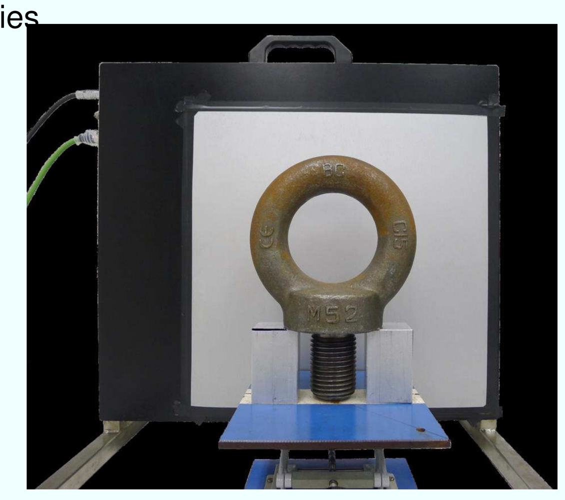


Fig. 9: a) Radiograph of Pb (red) and PE (black) sample. b) correlation between measured and calculated signal attenuation.

Fig. 8: Test samples (Al, Graphite, Fe, Pb, W, concrete, PE).

Summary

First radiography with test samples successful, despite low detector efficiency and neutron intensity
Discrimination between light and heavy objects
Correlation between detector signal and absorption properties



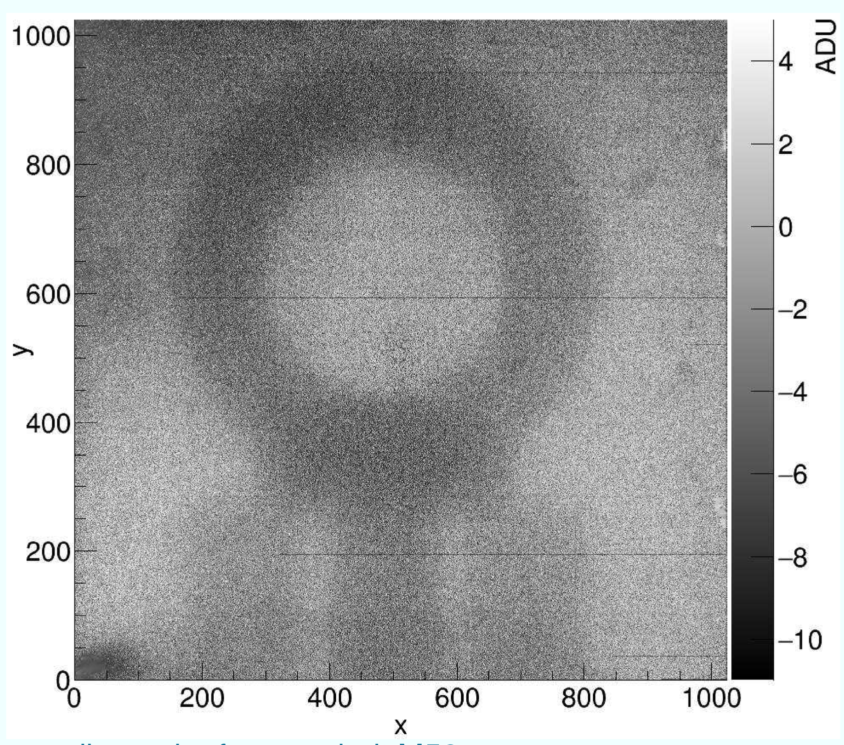
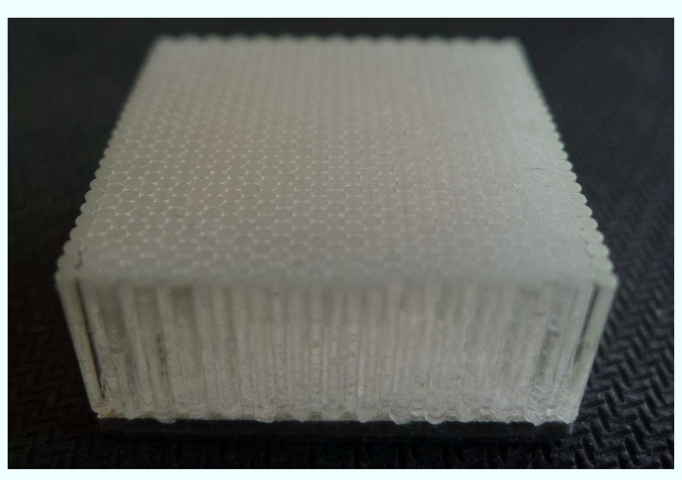


Fig. 10: Photograph of the experimental setup and corresponding radiograph of an eye bolt M52.

Outlook

New Scintillator

- Stack of scintillating fibres for increased neutron conversion efficiency
- Type: SCSF-3HF(1500)MJ from Kuraray
- Thickness: 10 mm, diameter: 1 mm



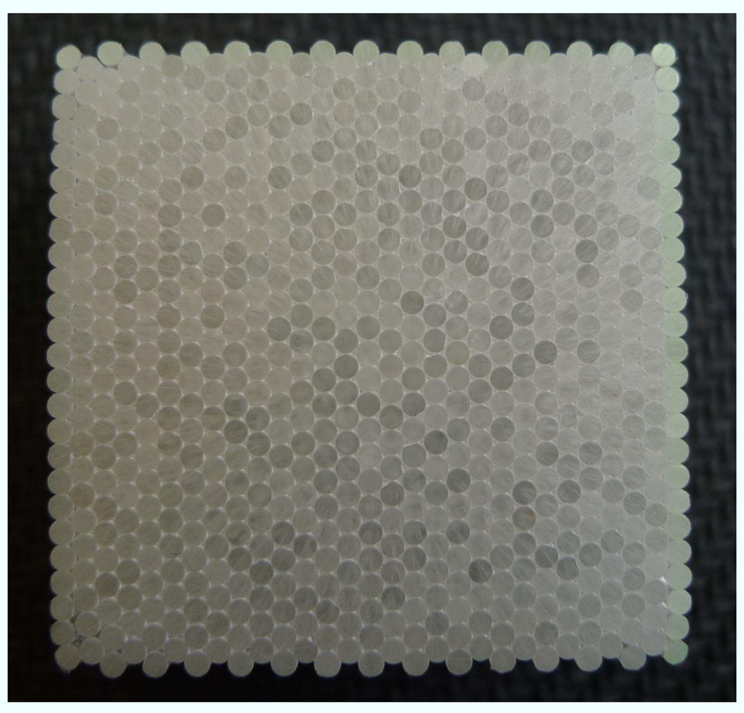
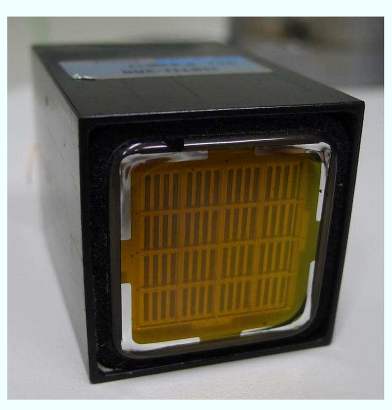
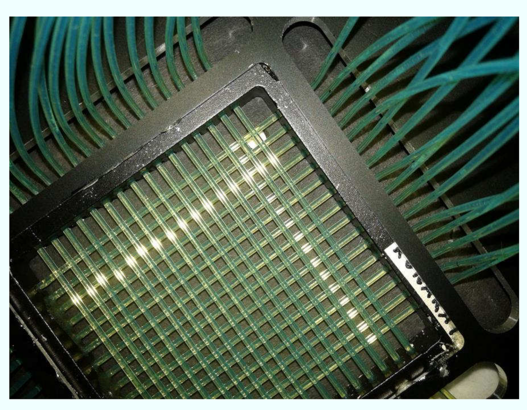


Fig. 11: First proof of concept for a scintillator as a stack made from scintillating fibres a) side view b) top down view.

Wavelength Shifting Fibres Detector

- Prototype detector
- Plastic with ZnS as scintillator
- X-Y crossed WLS fibres
- Fibre readout with PMT
- TDC coincidences for position reconstruction
- Active area: 4 x 4 cm² (16 x 16 fibres)


a)


b)

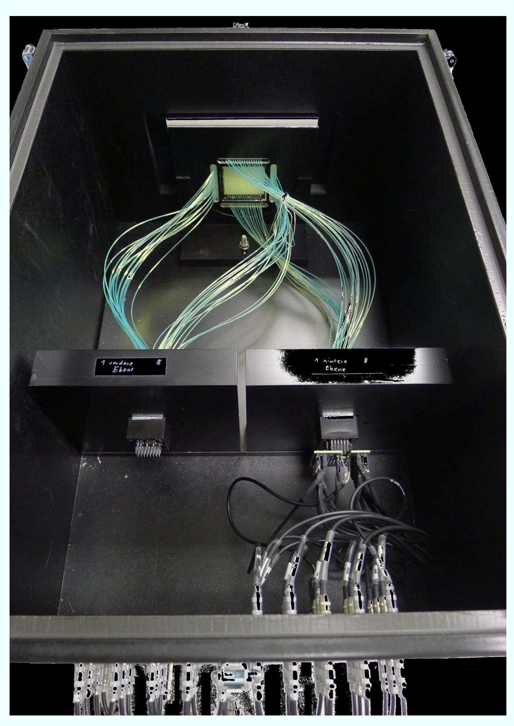

c)

Fig. 12: a) Photomultiplier used for the detector. b) Close-up from the crossed fibres. c) Detector in light tight housing.

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