BNL-112162-2016--CP

Thermal Neutron Imaging Using A New Pad-Based Position Sensitive Neutron Detector

I. Dioszegi[*], P.E. Vanier*, *IEEE Member*, C. Salwen*
D. L. Chichester[†], *Senior Member, IEEE*, S. M. Watson[†], *Member, IEEE*

[*]*Brookhaven National Laboratory, Upton, New York 11973-5000, USA*
[†]*Idaho National Laboratory, 2525 Freemont Ave., Idaho Falls, ID83415, USA*

Presented at the 2016 IEEE NSS/MIC Conference
The Convention Center, Strasbourg, France
October 29, 2016 – November 6, 2016

Nonproliferation and National Security Department
Radiation Detector and Nonproliferation R&D
Brookhaven National Laboratory
Upton, NY 11973

U.S. Department of Energy
USDOE National Nuclear Security Administration (NNSA),
Office of Nonproliferation and Verification Research and Development (NA22)

Notice: This manuscript has been authored by employees of Brookhaven Science Associates, LLC under Contract No. DE-SC0012704 with the U.S. Department of Energy. The publisher by accepting the manuscript for publication acknowledges that the United States Government retains a non-exclusive, paid-up, irrevocable, world-wide license to publish or reproduce the published form of this manuscript, or allow others to do so, for United States Government purposes.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or any third party's use or the results of such use of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Thermal Neutron Imaging Using A New Pad-Based Position Sensitive Neutron Detector

I. Dioszegi*, P.E. Vanier*, *IEEE Member*, C. Salwen*
D. L. Chichester†, *Senior Member, IEEE,* S. M. Watson†, *Member, IEEE*

**Brookhaven National Laboratory, Upton, New York 11973-5000, USA*
†Idaho National Laboratory, 2525 Freemont Ave., Idaho Falls, ID83415, USA

I. INTRODUCTION

Thermal neutrons (with mean energy of 25 meV) have a scattering mean free path of about 20 m in air. Therefore it is feasible to find localized thermal neutron sources up to ~30 m standoff distance using thermal neutron imaging. Coded aperture thermal neutron imaging was developed in our laboratory in the nineties, using ^{3}He filled wire chambers. Recently a new generation of coded-aperture neutron imagers has been developed. In the new design the ionization chamber has anode and cathode planes, where the anode is composed of an array of individual pads. The charge is collected on each of the individual 5x5 mm^2 anode pads, (48x48 in total, corresponding to 24x24 cm^2 sensitive area) and read out by application specific integrated circuits (ASICs). The high sensitivity of the ASICs allows unity gain operation mode. The new design has several advantages for field deployable imaging applications, compared to the previous generation of wire-grid based neutron detectors. Among these are the rugged design, lighter weight and use of non-flammable stopping gas. For standoff localization of thermalized neutron sources a low resolution (11x11 pixel) coded aperture mask has been fabricated. Using the new larger area detector and the coarse resolution mask we performed several standoff experiments using moderated californium and plutonium sources at Idaho National Laboratory. In this paper we will report on the development and performance of the new pad-based neutron camera, and present long range coded-aperture images of various thermalized neutron sources.

II. THE NEW PAD DETCTOR

The heart of the new neutron detector is a 48x48 pad board, with 36 ASICs (64 channels each) on the back of the pad board (Figure 1). Each pad is connected to an individual ASIC channel. The ^{3}He-filled detector chamber is operated as an ionization chamber, i.e. with unity gas gain. The ~25 × 10^3 electrons created by the ^{3}He(n,p)^{3}H +764 keV conversion reaction are collected on the anode pads. From there the signals are amplified, shaped and digitized by the ASIC channels and are sent to a digital data acquisition card. The path lengths of the proton and triton can be reduced by mixing a stopping gas with the ^{3}He. Traditionally propane has been used, but more recently comparably good results were achieved using non-flammable CF_4 stopping gas.

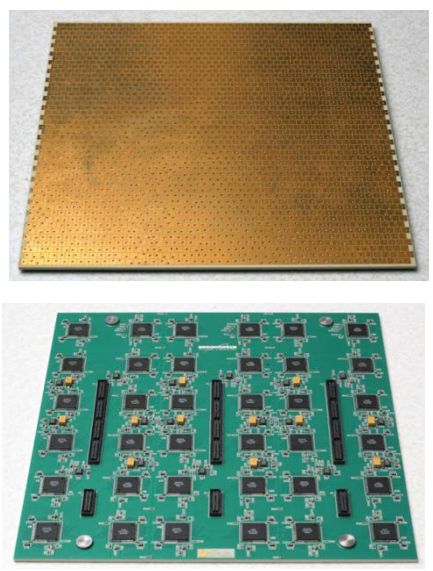

Fig. 1. Pad board (top) and 36 ASICS mounted on the back of the pad array.

A new detector with a depth of 4 cm has recently been built and tested. The long conversion depth requires only two bar ^{3}He pressure to achieve high detection efficiency. The low pressure combined with the non-flammable stopping gas increases margins of safety in a

variety of environments, and allows shipment of equipment by air.

The shape of the new detector (shown on Figure 2) is square, thus improving the active area/weight ratio. Besides the economical geometry the most important change compared to the traditional wire chambers is that the new system incorporates the high voltage power supply and a control and readout cards, so no external electronics is required.

The system takes power from a 24 V power supply and communicates to a laptop computer via Gigabit Ethernet cable. All the control functions (including high voltage control, individual ASIC channel monitoring, oscilloscope, pulse height analysis) are done through the laptop and the connected network cable.

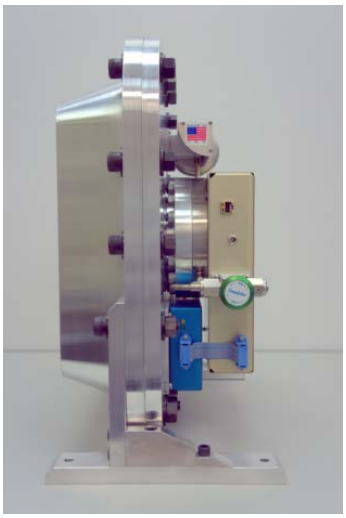

Fig. 2. Fully assembled new pad detector. The blue box behind the detector is the high voltage power supply, and the yellow metal box contains all the control electronics

III. THE NEW CODED APERTURE THERMAL NEUTRON CAMERA

In order to create a coded aperture imager the detector was placed in a cadmium shielding box, and fitted with a 11x11 pixel cadmium mask (Figure 3). The mask pixel size is 2 cm, thus a mask pixel area is sixteen times larger than the 5x5 mm^2 anode pad. The low resolution was chosen to shorten the required measurement time for standoff measurements.

A series of test experiments were performed at Idaho National Laboratory. For these experiments relatively weak californium and plutonium neutron sources were used. The data were taken and analyzed by LabVIEW-based software. Several measurements were performed, using various source/shielding configurations. As an example a long distance (9-m) measurement using a californium source is shown in Figure 4.

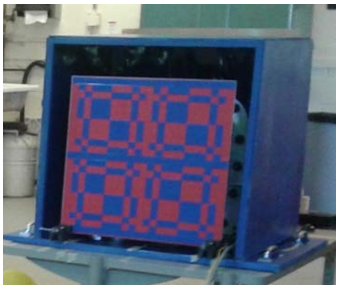

Fig. 3. The new coded aperture thermal neutron camera with 11x11 pixel four-fold coded aperture mask.

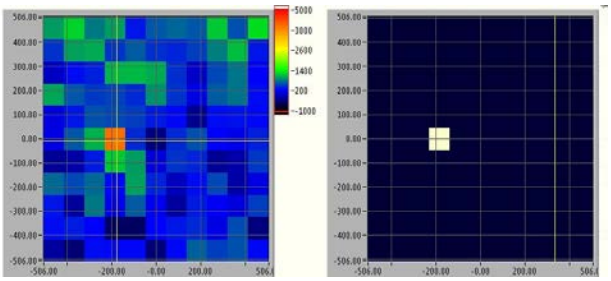

Fig. 4. Image of a moderated ^{252}Cf source. Left: reconstructed image. Right: image with threshold cut.

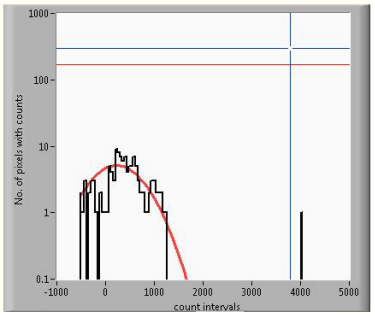

Fig. 5. Statistical analysis of the measurement above. The horizontal axis is the pixel brightness, the vertical axis shows the number of pixels with a given brightness. The background is fitted by a Gaussian. The bright image pixel is the single count on the right. The vertical cursor position marks the 7 σ statistical deviation, where the cut was made to create the cut image in Fig. 4.

IV. CONCLUSION

We have developed a new pad-based camera, which is superior to traditional wire chambers for coded aperture applications. We performed various imaging experiments and showed that the source can be located with very high statistical confidence.

REFERENCES

1. Yu, B.; Schaknowski, N. A.; Smith, G. C.; et al: Thermal Neutron Detectors with Discrete Anode Pad Readout. 2008 IEEE NUCLEAR SCIENCE SYMPOSIUM AND MEDICAL IMAGING CONFERENCE (2008 NSS/MIC), VOLS 1-9 Book Series: IEEE NUCLEAR SCIENCE SYMPOSIUM - CONFERENCE RECORD Pages: 1153-1156 Published: 2009.