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CODED APERTURE IMAGING OF REACTOR ILLUMINATED LMFBR FUEL PINS*

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As a part of Sandia Laboratories program to study simulated core disruptive accidents in reactor safety research, a fuel motion detection system based on coded aperture imaging[1,2] is being developed.[3,4,5] Although fuel motion has been observed at the TREAT by the fast neutron hodoscope[6] and with a Vidicon pinhole camera technique[7], the coded aperture system offers a potential for lower cost, higher spatial resolution, three dimensional imaging and higher frame rates at lower fluences than either of the other techniques. At earlier conferences the imaging of fuel pin shaped fission γ-ray sources has been reported, but until the experiments which will be reported here were conducted it was not known whether either of two important questions could be properly answered. First, could an actual fuel pin illuminated by a reactor be imaged with a coded aperture and an active detector system with acceptable frame rates and spatial resolution? Second, could collimator and shield structures be fabricated for the Annular Core Pulsed Reactor (ACPR), for which the system is being built, that would provide acceptable signal to background ratios?

Both of these questions can now be answered in the affirmative because of the favorable experiments recently conducted at the Sandia Pulsed Reactor (SPR II) and at the ACPR.

At the SPR II, 20 percent enriched and 93 percent enriched fuel pins were positioned just outside the core and were observed at a right angle by a coded aperture and collimator mounted in the reactor

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shield wall. The detectors were x-ray films and two types of active systems. The first was an x-ray image intensifier optically coupled to a still camera, or a framing camera, and the second was a thin NaI scintillator plate observed with an optical image intensifier and cameras. Although the fuel pin pseudohologram was visible in all three detector arrangements, only the x-ray film and x-ray intensifier shadowgrams provided reconstructable pseudoholograms. The spatial resolution provided by the NaI proved to be too poor. (Thinner and more carefully constructed scintillators are being investigated.)

The laser reconstructions obtained from the x-ray intensifier recorded shadowgrams are shown in Figure 1. The spatial resolution achieved in the direction across the fuel pins is approximately 2 mm and along the pins the resolution is about 1 cm. Computer reconstructions have also been obtained. The rings in Figure 1 are from diffraction in the apparatus and do not appear in the computer reconstruction.

Careful neutron dosimetry measurements taken after the imaging tests revealed that due to an error, two polyethylene blocks placed on each side of the pin to increase the thermal neutron flux were borated instead of being normal polyethylene. Therefore, the thermal fluence at the pin was an order of magnitude lower than would have been the case without the boron. Thus, the experiment has shown that the system has significantly more capability for imaging than was anticipated. The pins were imaged with a much poorer signal to background ratio than would be possible at SPR II, and at a total dose on the detector which would accumulate during only about 10 μsec of an ACPR burst. The implication is therefore that high speed imaging of fuel motion is possible with an active recording system and the coded aperture technique if acceptable signal to background ratios can be obtained at ACPR.

The Collimation Test Module (CTM) experiment has provided the answer to the second question -- can a fuel pin be seen over background in the central test chamber of ACPR? ACPR fuel rods were removed to form a slot through which a fuel pin in the central test chamber could be viewed by the coded aperture and collimator penetrating a lead, water and steel shield. This shield structure was very limited in thickness and size because it had to be compatible with the present neutron radiography tube. There was also not room for an active detector system in the very small detector region available at this time. However, through this structure, we obtained very clear pseudoholograms of a fuel pin placed in front of a 3 cm thick lead plate background. (The lead attenuated the γ-ray flux from the reactor wall behind the pin.) A pinhole camera image was also obtained of the fuel pin. Reconstructions both by computer methods and by the laser techniques are now being carried out. Both digital and laser reconstructions have been obtained, but they are not yet ready for inclusion in this summary and have not been optimized.

This second experiment has demonstrated that the required information about the fuel pin is available outside the slot in the reactor core. We feel that the final success of the system development now depends on the success achieved in the engineering and in the optimization of data reduction and methods of analysis.

References

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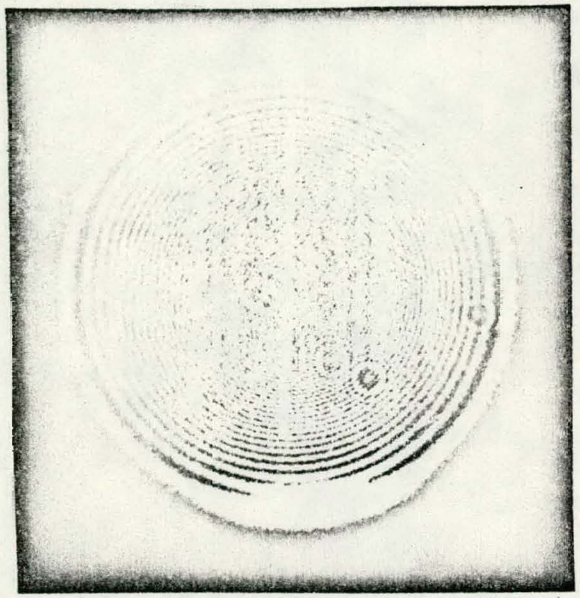
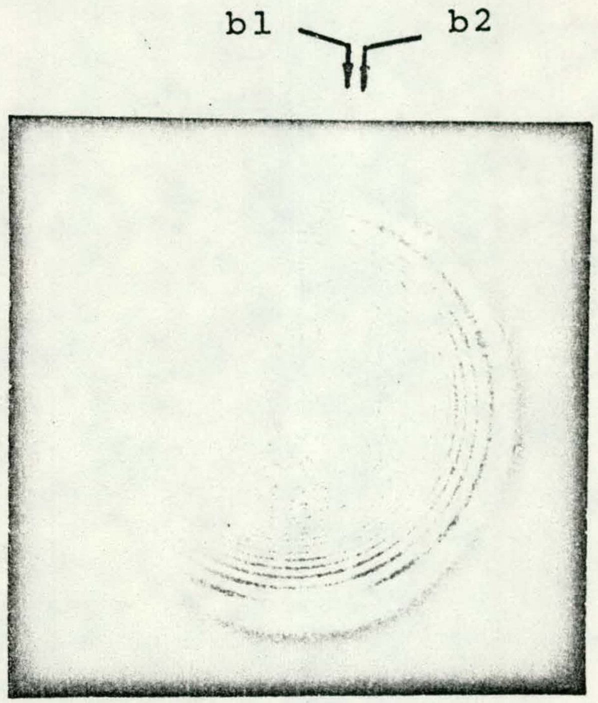


(a) Single Pin



(b) Two Pins

(b1) 93% enriched

(b2) 20% enriched

Laser Reconstructions of LMFBR Fuel Pins Illuminated by Neutrons from the Sandia Pulsed Reactor. Recorded with an X-ray Image Intensifier.