SIMULTANEOUS USE OF NEUTRON AND GAMMA RADIATIONS IN IMAGING APPLICATIONS

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Imaging facility

- Imaging facility, INR, uses thermal neutrons and γ radiations separately or together by transmission method. It is placed at the tangential channel of the TRIGA Arrang Core Pulling Reactor (ACPR) from INR, operable in steady state (up to 500 kW) and in pulsed mode (up to 20000 kW). For imaging experiments ACPR was operated only at 100 kW in steady state mode.
- Hanged and forward-movable detector over object holder contains:
  - Two remote controlled interchangeable scintillators: (1) 200 mm x 300 mm, Bismuth (0.3 mm) on 1.5 mm aluminum holder (a),
  - GeO2/Ge (0.12 mm) on 0.19 mm plastic holder, LAXEN type (b).
- Two remote controlled interchangeable cameras that capture scintillations 90° reflected by a mirror: (1) 305 mm X 305 mm, Hamamatsu (9100-02) camera, CD=5 mm (VImager), (2) CCID camera STARLITE EXPRESS SXV-HD (1932 pixels x 1040 pixels and 9.88 mm (H) x 6.7 mm (V) (SXV-HD), equipped with xenon 9.05/25 mm lens and exposure time (ET) on sensor from 100 μs to 10 (a), (b).

Experiments

- A kettle for water was investigated by non destructive imaging using thermal neutrons and gamma radiations, statically and dynamically, including boiling phase. Kettle has the lateral wall made in plastic (2 mm thickness) covered with a stainless steel thin sheet. The water has from 14 cm to 12 cm in diameter.
- The purpose was to establish the quality level for images obtained for such a device and to show differences on images by registering gamma radiations not only neutrons.
- Only EM=CD Hamamatsu C9100-02 camera was used with several electron multiplications (EM) factors and ET, FOV=280 mm x 280 mm. ET was established in auto exposure mode (AET) by Hamamatsu camera or manually fixed in software’s window.
- From both scintillators, EL−ZnS and Lanex, were captured static and dynamic images. EL−ZnS scintillator registers only neutrons but Lanex scintillator registers both γ and neutrons radiations.
- Thermal neutron intensity: 1.22 x 10^14 c/m^2/s, R=5.51, measured by gold foils activation method: dead dose of 740 mSv/h for γ radiations measured with a Teleprobe FH 40TG detector.

Results

- Fig. 2–Fig. 5 present the static images obtained at first series of experiments on EL−ZnS and Lanex scintillators for kettle before water boiling for EM=200, specific AET for captured image, with bismuth filter (Bi), Boral and Cd plates out of the radiations beam. All images are presented without any processing gamma image.
  - In Fig. 2, at left, it is seen the image of a device (real size and 5X), fixed on the aluminum holder of the EL−ZnS scintillator, made in gadolinium (0.1 mm thickness) for geometrical resolution assessment and image focalization.
  - In Fig. 3, at right, is seen the image of a dysprosium stripe (0.1 mm thickness), fixed on aluminum holder, produced by neutrons on Lanex scintillator. Image from Fig. 4 is similar to one obtained adding two separate images, with previous light source, EM=200, AET = 0.9 s, Cd plates. In Fig. 5 presents the obtained images simultaneously on both scintillators. Lanex scintillator being faster than EL−ZnS scintillator.
- Table 1 presents four values of the AET obtained for both scintillators for two values of the EM, 200 and 255. Four ratios for these AET are presented also. The AET ratios for every scintillator are very close, 4.576 and 4.593 respectively, indicating a reproducible dependency between chosen EM by operator and established AET by Hamamatsu camera, for images obtained over a certain detector with fixed exposure time ET for 25 units diminution of the EM. The AET ratios between scintillators at every EM are very close also, 1.445 and 1.450, respectively. This indicates that Lanex scintillator emits roughly more light than EL−ZnS scintillator in mixed beam of radiations, neutrons and gamma. Other experiment revealed that contribution of neutrons on Lanex is about 36.4% at image formation, so that only gammas on Lanex produce more lumina that neutrons on EL−ZnS scintillator.
- Fig. 7, 8, 9, 10 shows dynamic images and captures from videos made in boiling process in a second series of experiments.
  - Images from Fig. 7 and Fig. 8 were obtained as the static images. Image from Fig. 7, taken from EL−ZnS, is similar with image from Fig. 3 but with improved quality lower EM and longer AET for a better statistic of the photons not from the multiplied electrons. The same fact for images from Fig. 4 and Fig. 8 taken from Lanex scintillator. For these images was taken minimum EM that conducts to AET close to 10 s, maximum integration time on sensor. Better clarity for images from Fig. 7 and Fig. 8, than images from Fig. 3 and Fig. 4, can be seen in the magnified image in images that were applied respectively to Figs. 4 and 8, where smaller gaps are 0.1 mm, 0.05 mm, respectively.
  - To determine the neutron transmission through Bi filter were captured two images from EL−ZnS scintillator without/with light beam in obtaining images from Fig. 9 and Fig. 10 for the same EM=200 with AET=5.63 s, respectively.
  - The ratio for the two AET=1.8. This means a diminution of the neutron intensity through mono-cromatic Bi filter of 44.37%, in good agreement with theoretical supposition of 41% diminution at facility design.
  - A video film, Fig. 11, 12, with very small frame rate, EM=255, recorded with images from both scintillators. To have a quasi real time imaging must use EM=255 because of the small neutron and gamma intensity of radiations at INR facility. Tests with smaller EM failed to offer recognizable images at ET=16 s. To observe details of the kettle was a compromise between time resolution and geometrical resolution with AET=0.9 s for EM=255. In Fig. 12 is seen how the level of the water rises but no any bubbles can be observed in the thick layer of water. Image on Lanex scintillator has a better contrast between water layer and air from kettle. On EL−ZnS scintillator this boundary between water and air is very soft because of the plastic layer in the kettle’s wall that removes neutrons from beam.

Conclusion

- INR, from INR Pitesti has a beneficial possibility to use two types of penetrantradiations at non destructive investigations by imaging methods. Imaging facilities placed at neutron guides or those where y radiations are stopped by non removable filters (bismuth, saphhire, silicon) do not benefit from this advantage. This deficiency is resolved with X-ray generators at source of radiations. Some penetrans have bigger energies and so more penetrant in thick structures than X rays, even on a tangential channel like at INR facility. No gamma energy spectrum was assessed till now.
- Using Lanex scintillator, that registers thermal neutrons and gamma radiations simultaneously, it is obtained an instant sum image produced by two types of radiations (thermal neutrons and gamma). The images are resolved separately with neutrons and gamma radiations.
- For the presented experiment it is obtained a clear image through plastic structures, for screws and electrical wires. Gamma radiations create a base image on Lanex scintillator for materials discriminated by electromagnetic radiations but penetrating strong neutron absorbing or scattering materials. Objective of this experiment is to find an small contrast only with the plastic layer, the image created by neutrons with the shadow of plastic and water sensitive to neutrons, improving image created only by gammas.
- An easy operation of the facility with two operations is facilitated by use of two scintillators, changed in 5 s with a stepper motor. A unique feature for the scintillators, is the ability of the diaphragm that hangs over object’s holder and can be moved in close contact with the object to increase geometrical resolution despite low L/D of 92.8.

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