Development of "DURGA" facility for prompt γ-ray spectroscopy studies using thermal neutrons

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Prompt γ-ray spectroscopic studies are important to understand the properties of the nucleus that offers an opportunity to explore a rich variety of nuclear phenomena. The γ-rays are emitted at various stages of de-excitation and provide information on the nuclear excited states. In the case of thermal neutron induced reactions, the target nucleus is excited and emits prompt γ-rays or undergoes β-decay, followed by subsequent γ-ray emission. For thermal neutron induced reactions with heavy actinide targets, nuclear fission is the dominant reaction channel and a variety of neutron-rich nuclei are produced. In nuclear fission, the excited fragment nuclei emit large number of prompt γ-rays having overlapping energies and the total energy spectrum is very complex. The prompt γ-γ coincidence technique is found to be suitable for identifying the individual fragment mass, in the presence of more than hundreds of other nuclei produced in nuclear fission [1,2].

A facility has been developed at Bhabha Atomic Research Centre, for prompt γ-ray spectroscopic studies using thermal neutrons from a radial beam line at Dhruva reactor. The facility for **D**hruva **U**tilization in **R**esearch using **G**amma **A**rray (**DURGA**) has been commissioned at R-3001 radial beam-line at Dhruva reactor, BARC. A well collimated neutron beam of 10 mm diameter has been extracted by inserting a wooden plug inside the biological shield (shown in Fig. 1). The size of the Dhruva beam hole R-3001 is 300 mm in diameter and 4040 mm in length. The beam hole starts at a distance of 252 mm from the core edge. It is required to maximize the neutron flux at the target position keeping small beam size. A wooden collimator is used to reduce the beam size. The outer diameter (OD) of the collimator is 300 mm with a central conical cavity of OD 24 mm at entry point and of OD 10 mm at the exit end. The length of the collimator is 1260 mm and is placed in the beam hole such that it extends up to the biological shield surface. At the entry point of collimator one S.S cap of thickness 6 mm having a center hole of diameter 24 mm at the center is mounted. A Cd sheet of 4 mm thick and a Pb block of 50 mm thick is mounted at the entry-side of the wooden block. To further reduce the γ-background at the detector position, a cylindrical bismuth crystal plug (diameter = 70 mm, length = 50 mm) was placed inside the wooden block along the beam line. Another Pb block of 250 mm thickness and having a hole of 16 mm OD is mounted just after the Bi-plug at the exit point of the collimator.

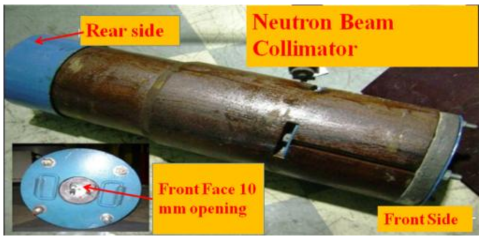

Fig.1: Neutron beam collimator

The shielding calculation of the setup was carried out by using the Monte Carlo 2-

dimensional transport Code "DORT". The "DORT" code solves the Boltzmann transport equation in two dimensional geometry using the method of discrete ordinates. The setup is covered by shielding materials as shown in Fig.2, on both the sides of total 140 mm thickness [where 10 mm (MS) + 80 mm paraffin wax +40 mm (Pb) + 10 mm (MS)]. These shielding are used for stopping the scattered neutrons and γ-rays inside the shielding material. The target was mounted at a distance of 1635 mm from the outer edge of the reactor wall. For the capture of the direct neutron beam, a beam-catcher of size150 x 150 x 150 mm^3 was placed at a distance of 3400 mm from outer edge of the reactor hall.

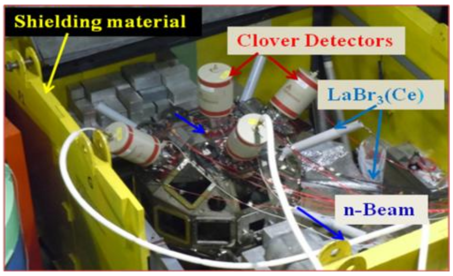

Fig.2: Experimental setup of the DURGA facility showing the Clover germanium and $LaBr_3$(Ce) detectors.

The beam profile at the target position was determined by using a neutron radiography setup having LiF + ZnS(Ag) material as a neutron scintillator and a charged coupled device(CCD) camera as shown in Fig.3. The neutron imaging system was interfaced to a personal computer with a frame grabber card. It was placed in such a way, that the back side of scintillator plate touched the surface of the shielding wall containing the beam hole. The beam was almost circular with a diameter of 10 mm at the target position. It was further collimated by introducing a cylindrical Pb piece of diameter 5 mm and length 100 mm. The image of the beam spot and the intensity of neutron beam profile is shown in Fig.3.

The neutron flux measurement at the target position was carried out by irradiating ^{197}Au target foils and measuring the activity by using the 4πβ-γ coincidence measurement of the activated foil that was used to obtain the thermal neutron flux. The measured flux as obtained from this measurement was ~ 10^8 neutrons/cm^2/sec.

To carry out on-line prompt γ-spectroscopy experiments, four clover germanium detectors and six $LaBr_3$(Ce) were mounted in the Array as shown in Fig.3. The mechanical design and fabrication of the detector mounting assembly was reported earlier [3]. Using this facility, experiments are carried out for prompt γ-spectroscopy studies using ^{113}Cd(n_{th}, γ) reaction.

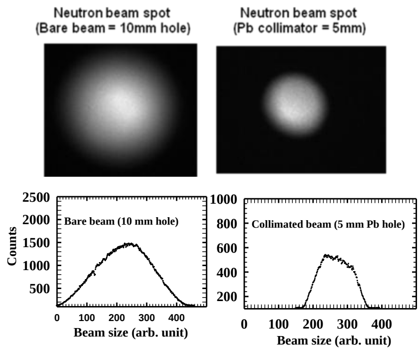

Fig.3: Beam spot taken by CCD camera and the intensity of beam profile for collimators having diameter 10 mm (left) and 5 mm (right).

The DURGA facility will be utilized to for nuclear structure studies employing prompt (n,γ) reactions and Fission Fragment Spectroscopy to investigate the properties (shape and structure) of the neutron-rich fragment nuclei.

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References:

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