Setup of thermal neutron detectors by employing in-house grown LiI:Eu Single crystal

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Introduction

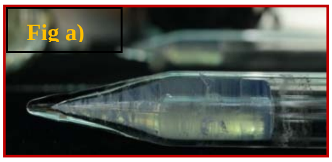
Europium activated lithium iodide is a well-known scintillator useful for thermal neutron detection. A good light yield from Eu^{2+} transitions and presence of Li^6 isotope enables it to detect thermal neutrons efficiently. The natural isotopic ratio of ^{6}Li present in europium doped lithium iodide (LiI:Eu) offers large absorption cross section (~ 940 barns) for ^{6}Li (n, α) ^{3}H reactions having 4.8 MeV of 'Q' value energy. The generated charged particles deposit energy in the crystal and generate scintillation signal. The scintillation flash falls in the blue region (~ 470 nm) and decays in few µs. The response of a Bialkali PMT matches well with this emission and the standard scintillation pulse processing chain can be used to detect the generate pulse height spectrum. However, due to the hygroscopic nature of the LiI:Eu single crystals, the detector performance and durability heavily depend on the hermetic encapsulation.

In this paper, the process employed for the hermetic sealing of an in-house grown scintillator under controlled ambient has been discussed. The fabricated detector has then been tested for its scintillation performances with gamma and thermal neutron energies.

Experiments

Synthesis

Single crystals of 0.1 % Europium doped Lithium Iodide (LiI:Eu) were grown using the Bridgman technique. Ultra-dry LiI and EuI_2 with 99.99% purity were used as the starting charge for the growth of the LiI:Eu single crystals. The starting charge was dehydrated at 300^0 C for 4 hours and sealed under argon ambient at a pressure of 5 x 10^{-4} mbar in a quartz crucible. The quartz ampoule was then loaded in a Bridgman furnace that was heated up to 510^0 C to thermalise the melt. The single crystals were grown by lowering the ampoule at a rate of 0.5 mm/hour. The grown crystals were cooled down to room temperature at a rate of 30^0 C per hour. Grown crystals were retrieved by cutting the quartz crucible under silicon oil to avoid any degradation by moisture due to hygroscopic nature of crystal.



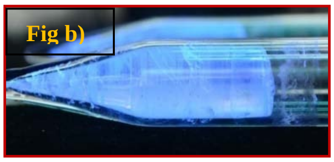


Fig 1: As grown single crystals of LiI:Eu a) Under ambient light b) Under UV light.

Characterization

As grown crystals immersed in oil were cut and then polished inside a glove box with a controlled ambient having moisture and oxygen content under 0.1 ppm. The luminescence characteristics on polished samples have been recorded using a monochromator and its compatible software (make: Princeton Instruments Acton spectra pro SP-2300). White X-ray source with Cu target at an accelerating voltage of 40kV and 30 mA of tube current was used an excitation source. Scintillators have been processed in cylindrical shape with circular cross section of 10 mm diameter and 2 mm thickness. The processed scintillators were then hermetically sealed in a cylindrical aluminium container locked on one end with a high pure quartz glass plate. The scintillator was packed with a diffused reflector (MgF_2) for efficient collection of light from the quartz glass plate.

The hermetic sealed scintillators were then couple to a 1 inch photomultiplier tube using optical grease. Scintillation measurements were performed using gamma and thermal neutron sources.

Results and Discussion

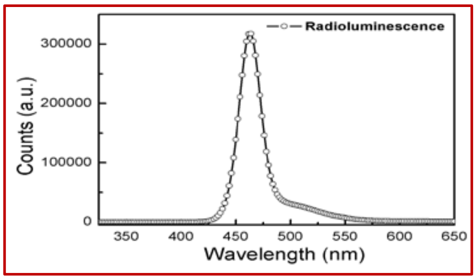


Fig. 2 Radioluminiscence spectrum of 0.1 % LiI:Eu

Fig2. shows the radio-luminescence spectrum of the 0.1 mol % LiI:Eu. It shows a strong broad emission band peaking at ~ 470 nm which is well within the high efficiency response bandwidth of the Bialkali PMT. The emission band corresponds to the transition within the Eu^{2+}energy levels in the lithium iodide matrix. It also shows the absence of Eu^{3+} energy levels whose presence could have created slow emission components.

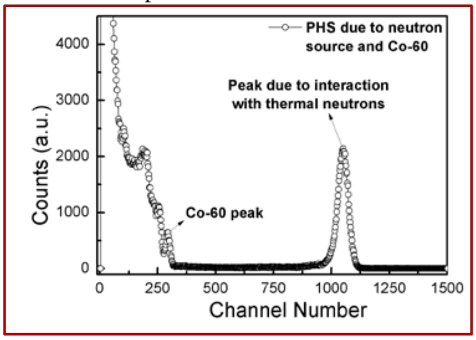


Fig. 3 Pulse height spectrum due to Co-60 & thermal neutrons from a thermalised Am-Be source recoded using LiI:Eu scintillator.

The pulse height spectrum recorded with a Co-60 gamma source kept along with the thermal neutron flux has been shown in fig 3. A distinctive peak at ~ 1050 channel no. is corresponding to the total 4.8 MeV energy of charged particles, generated from the interaction of thermal neutrons with the Li^6 present in the LiI matrix. The pulse height response due to thermal neutrons recorded at Dhruva reactor is shown in fig 4. The effect of gamma and neutron shield has also been shown in fig 4. The peak at ~ 800 channel no. could not be seen when the detector is wrapped under borated rubber. This confirmed the origin of the peak due to thermal neutrons.

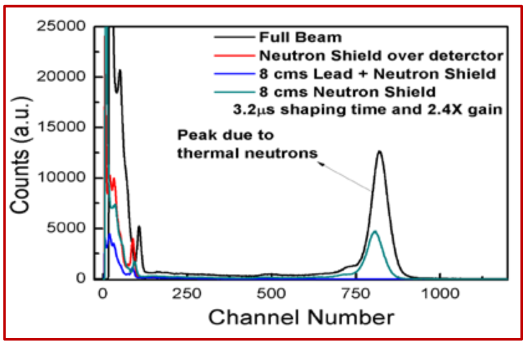


Fig. 4 Pulse height spectrum due to thermal neutrons from Dhruva reactor recoded using LiI:Eu scintillator.

Conclusion

Single crystals of 0.1 % Eu doped lithium iodide were grown using Bridgman technique. Neutron detectors have been fabricated from the as grown single crystals. Thermal neurons have been detected using the detector in the pulse mode.

Acknowledgement

The authors thank Dr S. S. Desai, SSPD, BARC for providing the thermal neutron facility at Dhruva reactor and for her help in the measurements.

References

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