Development of 2D CsI:Tl Single Crystal Scintillator Array for Gamma Imaging

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Introduction

X-ray and Gamma-ray imaging are required in various applications like industrial inspections nuclear medicine imaging, and scientific research [1,2]. For imaging of a radioactive source with directional information there are various schemes like coded-aperture imaging, Compton imaging, and Directional-Sensitive Array detector. In a conventional position sensitive scintillation detector, a scintillator array coupled to a position sensitive photo-readout like position sensitive PMT (PSPMT) and Pixelated Si-PM is used. In this paper, we are reporting a cost-effective indigenous process for fabrication of scintillation detector array which realizes a spatial resolution of around 5 mm as well as a spectral resolution (~15% FWHM). In our approach, we have developed a process where pixels are fabricated with very high precision using in-house grown CsI:Tl single crystals. The developed 2D scintillator detector consisting of a 8 × 8 CsI(Tl) array coupled with a 8 × 8 array of PSPMT and a compact readout along with image processing algorithm is developed.

Experimental

Single crystals of CsI(Tl) of 50 mm diameter and 75 mm length were grown by the vertical Bridgman technique using a furnace having four separately controlled zones [3]. TlI is used as the dopant in the CsI matrix. All materials used in growth were 99.999% pure and. The TlI concentration in CsI melt was 0.15 % however actual Tl concentration in grown crystal was not assessed.

For pixel fabrication the grown crystal were processed in to the pixels as per the schematic shown in Fig.1. The 8x8 pixelated crystal was optically bonded to the H12700 Multianode PMT (MAPMT) (Fig.2). The MAPMT was then connected to a readout module for PMT signal processing.

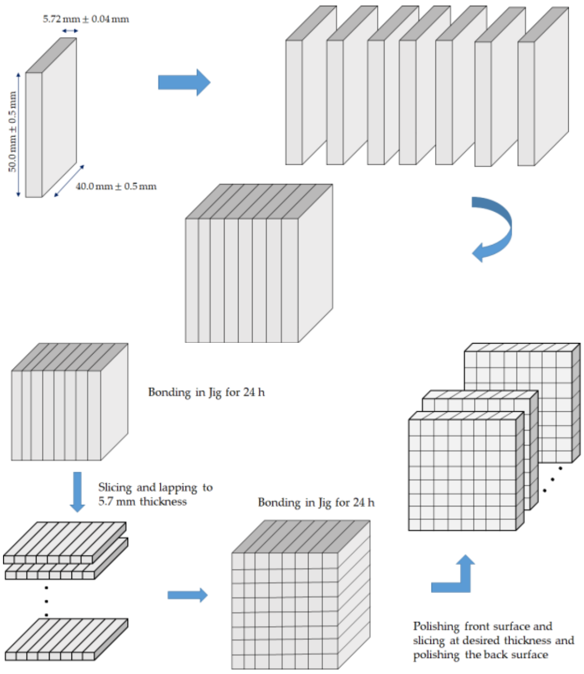

Fig. 1 Schematic of process for pixel array fabrication

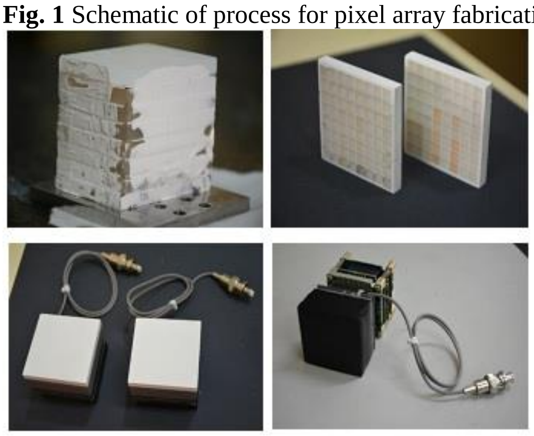

Fig. 2 2D- array of CsI:Tl (8x8) mounted on PMT.

Result and Discussion

A 8x8 pixel array of CsI:Tl is developed with individual pixel size of 5.7x5.7x6 mm^3 with a separation of 0.3 mm to match the pitch of the PSPMT. This process is also suitable to make smaller pixels down to the size of 1 mm and separation of 0.1 mm. To achieve the separation between two pixels a reflective layer based on TiO_2 and Epoxy was developed to get optical isolation as well as good adhesion to keep pixels together. Loading of TiO_2 was optimized to 70 wt% of epoxy to get best results in terms of reflectivity and mechanical stability.

To test the setup front-end control software is developed to configure and acquire data from the detector with live streaming capabilities as well as single-frame prolonged data acquisition. The individual scintillations acquired in the trigger-time mode were binned to 8x8 pixel matrix over the time of 50 milliseconds to get a frame rate of 20 fps. The frames were normalized in real-time and the live feed from the detector was obtained. The data acquisition was optimized to avoid random discontinuities in the live streaming by implementing multicore-threading to enable parallel streaming and storing of data for future use.

Various algorithms have been developed to determine individual scintillation event locations for MA-PMT based image reconstruction based on centre of gravity algorithm, truncated centre of gravity algorithm and raised to power algorithm. These algorithms make use of the light spread of individual scintillation event over multiple anodes to precisely locate the position of scintillation. In case of pixelated crystals, the same logic can be used to get sub-anode spatial resolution as the intrinsic spatial resolution of the gamma camera is limited by the crystal pixel size.

For image capture and testing ^{152}Eu 0.5mCu source was kept at a distance of 4 inches from the detector. The lead bricks in all the phantoms as well as the shielding provided around the gamma camera were 2 inches thick in order to prevent unwanted stray radiation.

Fig 3 (Top) shows gamma image of a P.S.F phantom consisting of a 4mm diameter circular slit lead phantom. Fig 3 (bottom) consists of two 4mm circular slits 3mm apart. Since the spacing between two holes was 3mm (a minimum of 25mm lead is required for significant attenuation), two holes in the image have merged as an elliptic hot-spot with a width of 14mm.

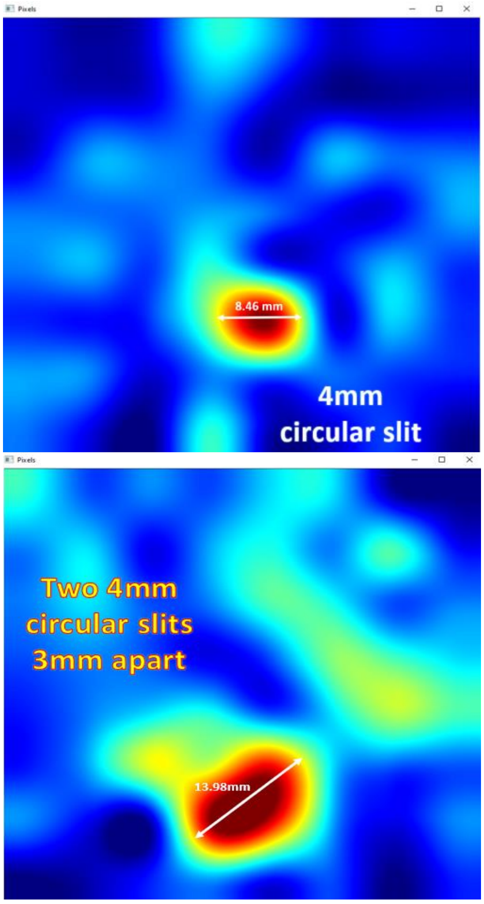

Fig. 3 Point Spread Function lead phantom (P.S.F phantom) consisting of a circular slit of 4mm diameter (Top). Two 4mm circular slits 3mm apart (bottom)

In conclusion the indigenously developed 8x8 CsI single crystal array was able to spatially resolve gamma source at approximately 5 mm distance.

References

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