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Spatial Resolution of BaF_2:Y and LYSO Crystal Based Hard X-ray Imager

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***Abstract*–We report an investigation on spatial resolution for BaF_2:Y and LYSO pixelated crystal screens and monolithic plates for inorganic scintillator-based front imager for GHz hard X-ray imaging. Their spatial resolution was evaluated by using line-pair pattern and knife edge phantom by two CCD cameras. Possible improvement of spatial resolution is also discussed.**

I. Introduction

INSPIRED by the total absorption crystal calorimetry in high energy physics (HEP) a pixelated ultrafast inorganic scintillator-based front imager was proposed for GHz hard X-ray imaging [1-4]. Fig. 1 shows a schematic of the imager concept with a pixelated ultrafast scintillator screen, a pixelated ultrafast photodetector, and ultrafast readout electronics [1].

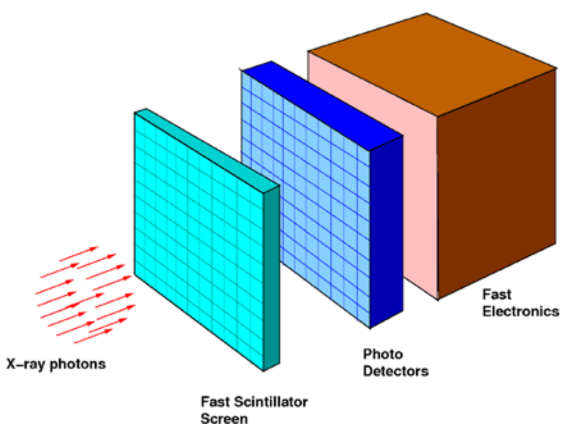

Fig. 1. A schematic showing a pixelated ultrafast inorganic scintillator-based front imager concept for GHz hard X-ray imaging.

Temporal response of a dozen ultrafast and fast inorganic scintillators was measured at the 10-ID site of the Advanced Photon Source (APS) of ANL by using hybrid X-ray beam of 30 keV consisting of both singlet bunches of 50 ps and septuplet bunches of 27 ps with 2.83 bunch spacing [3]. Both BaF_2 and Yttrium doped BaF_2 (BaF_2:Y) [5] crystals show cleanly separated X-ray pulse structure for the septuplets, while BaF_2:Y crystals show no pile-up effect because of its suppressed slow component. In this paper, we investigate spatial resolution of BaF_2 and BaF_2:Y crystal screens for ultrafast front imager, and compared to LYSO screens.

II. Samples and the Experimental Setup

Fig. 2 shows pixelated (a) and monolithic (b) LYSO, BaF_2, and BaF_2:Y crystal screens from various vendors.

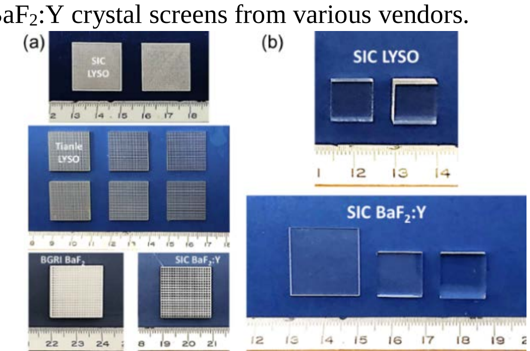

Fig. 2. (a) Two pixelated LYSO screens from SIC (top), six pixelated LYSO screens from Tianle (middle), a pixelated BaF_2 screen from BGRI and a BaF_2:Y screens from SIC (bottom). (b) Two SIC LYSO plates of 10×10×3 mm^3 and 10×10×5 mm^3 (top), and three SIC BaF_2:Y plates of 20×20×1.5 mm^3, 13×13×3 mm^3, and 13×13×5 mm^3 (bottom).

Fig. 3 is a schematic showing the setup for X-ray imaging taken by CCD cameras. Samples were placed in a light tight box with X-ray shielding. Imaging was taken through a mirror and a Φ25 mm optical lens by two CCD cameras: a PCO.edge 4.2 bi or a Princeton Kuro10208. Lead phantoms with line-pair pattern or knife edge were used to measure modulation transfer function (MTF).

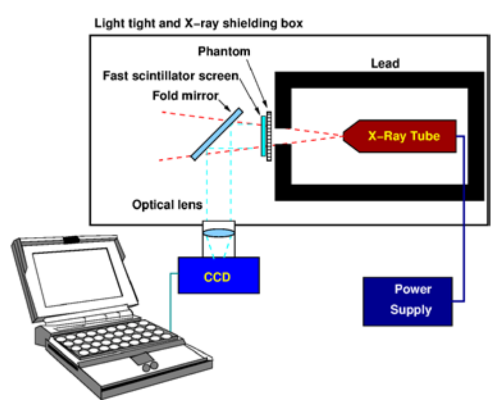

Fig. 3. A schematic for X-ray imaging setup of pixelated and monolithic crystal screens measured by PCO and Princeton CCD cameras for ~8keV X-rays from an AmpTek ECLIPSE-III tube.

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III. Results and Discussion

Fig. 4 shows X-ray imaging taken by the PCO camera for pixelated LYSO (top) and BaF_2 (bottom) screens with a stainless steel wire phantom “CIT” (right). The letters are well resolve by the pixelated LYSO screen of 400 µm pitch and the BaF_2 screen of 980 µm pitch, showing a special resolution defined by the pitch.

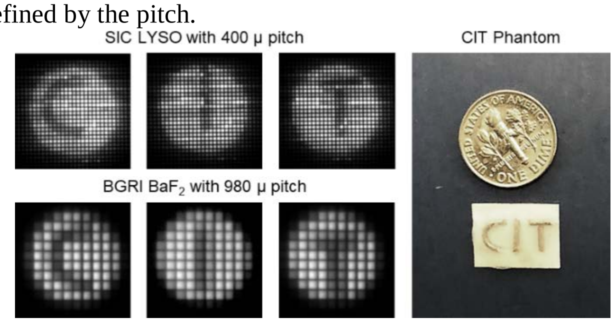

Fig. 4. X-ray imaging taken by the PCO Camera with a stainless steel wire phantom “CIT” for pixelated LYSO (top) and BaF_2 (bottom) screens.

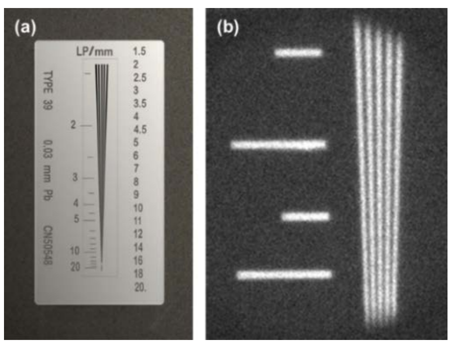

Fig. 5. Photos of line-pair pattern used as a phantom taken under visible light (a) and the corresponding X-ray (b).

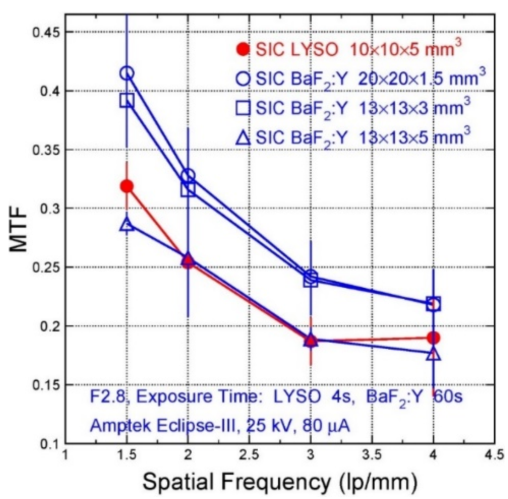

Fig. 6. MTF values obtained by using the Princeton Kuro10208 camera are shown as a function of spatial frequency for SIC BaF_2:Y crystal screens with various thickness. A 5 mm thick SIC LYSO was used as a reference.

Spatial resolution of monolithic crystal screens was also investigated for LYSO and BaF_2:Y monolithic plates by using the line-pair pattern method. Fig. 5(a) shows a standard line-pair pattern with 5 black and white line-pairs used as a phantom. Fig. 5(b) shows the corresponding X-ray imaging taken by using the Princeton Kuro10208 camera with the phantom at the front of crystal screens.

Fig. 6 shows the MTF values as a function of the spatial frequency measured for the BaF_2:Y plates of 1.5, 3 and 5 mm. Also shown in the figure is a 5 mm thick LYSO screen for a comparison. It is clear that the spatial resolution (MTF value) is poorer (lower) for thicker samples. One approach to improve spatial resolution for thick screen is to use small optical aperture. Such an approach may be taken by a front imager requiring 5 and 2 mm thick BaF_2 and LYSO screens respectively for total absorption of hard X-rays around 120 keV with a loss in both signal intensity and dynamic range.

IV. Summary

We investigated the spatial resolution of inorganic crystal based imager for hard X-rays. Pixelated BaF_2, BaF_2:Y and LYSO crystal screens with a pitch down to 400 µm was fabricated by mechanic slicing. Their optical and X-ray imaging were taken by using a PCO camera under different optical aperture. Their spatial resolution and detection efficiency for hard X-rays are defined by the pitch and thickness, respectively.

WE plan to pursue pixelated crystal screens with a pitch down to 25 µm [6] by laser slicing. Additional ultrafast inorganic scintillators, such as ZnO:Ga films [7] and all inorganic Cs Pb halide perovskite quantum dots [8, 9] etc, are also considered.

Acknowledgements

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