High spatial and energy resolution gamma imaging based on LaBr\textsubscript{3}:Ce continuous crystals


I. INTRODUCTION

Over the last ten years advances in bio-medicine field have been increasing the demand of gamma imagers with even more advanced features in term of spatial and energy resolution. Gamma imagers fall into detector classes: semiconductor and scintillation devices. Recent advances are mainly related to intrinsic spatial resolution, energy resolution, detection efficiency large detection areas and low cost. Such advances are regarding both classes and in particular semiconductor imagers seem favorite for the best intrinsic spatial resolution (pixel size down to 50 micron) and energy resolution. On the other hand scintillation imagers seem favorite for larger detection area, higher detection efficiency and lower cost. Very recently scintillators with very high light yield and photodetectors with very high quantum efficiency have been opening a new way to realize gamma cameras with very high spatial and energy resolution based on continuous crystals and Anger logic. In fact pixellated imagers have a spatial resolution limited by pixel size; in contrast in continuous scintillation crystals the spatial resolution is a statistical function depending on light distribution spread and on generated photoelectrons from scintillation light flash. LaBr\textsubscript{3}:Ce, due to a light yield almost two times higher than NaI(Tl) crystal and to a lower intrinsic energy resolution, could be the best candidate to carry out a gamma imaging with sub millimetre spatial resolution and very good energy resolution.

II. EQUIPMENT AND METHODS

The LaBr\textsubscript{3}:Ce gamma cameras prototype consists of a MAPMT Hamamatsu H8500 with a continuous LaBr\textsubscript{3}:Ce scintillator, (realized by Saint Gobain). Five LaBr\textsubscript{3}:Ce scintillation crystals with different surface, optical treatment, thickness and size ranging between 5x5 cm\textsuperscript{2} and 10 x 10 cm\textsuperscript{2} were investigated. The Hamamatsu H8500 Flat Panel PSPMT is based on metal channel dynode technology and an anodic structure consists on an 8x8 matrix. It presents very compact size: the external dimensions are 52×52×14.4 mm\textsuperscript{3} for an active area of 49×49 mm\textsuperscript{2}, and 1.5 mm glass window. The Flat panel PSPMT is connected to an independent 64 channel electronic read out card READ64 developed by Southampton University, based on four RAL HX2 chips (Rutherford Appleton Laboratories 1995). The GEANT4 code was used to simulate all processing of image formation, from the gamma ray tracking to scintillation light tracking and finally applying the centroid algorithm to the light distribution detected from an anodic plane. Measurements of position resolution, linearity and energy resolution response were performed by scanning the detector with a collimated Tc\textsubscript{99}m and a Ba\textsubscript{133} sources. Finally a image performances of a LaBr\textsubscript{3}:Ce integral assembled to MAPMT were compared with a CdTe:Cl pixel detector assembled at University “Federico II” & INFN Naples, Italy, CdTe:Cl pixel detector was coupled pixel-to-pixel via bump-bonding (AJAT, Finland) to the Medipix2 readout integrated circuit for single photon counting (CMOS technology - European Medipix2 collaboration). The contact side is pixellated in a matrix array of 256x256 square pixels of 45 \mu m side and 55 \mu m pitch. The sensitive area is 14.08×14.08 mm\textsuperscript{2}.

III. RESULTS AND DISCUSSIONS

The results from MC simulation are shown in figure 1.

The results are due to only statistical contribution of the scintillation light. The resulting spatial resolution is 0.7 mm. In figure 2 the experimental data from a scanning with a 0.4 mm collimated Tc\textsubscript{99}m source at 1.5 mm step of a 5 mm LaBr\textsubscript{3}:Ce crystal integral assembled with MA-PMT H8500 is shown. In this case the intrinsic spatial resolution obtained was 0.9 mm. However the experimental spatial resolution disagree from the simulated ones mainly due to the following limitations: a sub optimal optical treatment of lateral crystal edges and a poor response in energy resolution of MAPMT, particularly due to low photocathode quantum efficiency. The most important contribution limiting intrinsic spatial resolution
is the strong reduction of scintillation light photons produced by critical angle on photocathode glass window.

The dependence of the spatial resolution on the gamma ray energy was studied by a scanning at 1.5 mm step with a Ba\(^{133}\) point source. In figure 3 the results from two LaBr\(_3\):Ce crystals in comparison with ones from an Anger Camera are shown.

We remarke that at 302 keV the best value of 0.5 mm was measured.

The comparison with CdTe detector was performed with a pinhole collimator (0.4 mm) fixing the same FoV of each detector (14 mm). Four capillaries, (0.45 mm I.D., 0.9 mm O.D.), were filled with a solution of perthecnetate \(^{99m}\)Tc with a center-to-center distance of 1.5 mm, 2.0 mm, 2.5 mm, respectively (see top, fig 4). The corresponding images from are shown in figure 4, for CdTe (middle) and LaBr camera (bottom). The system magnification (M) and the corresponding spatial resolution are indicated in figure.

IV. CONCLUSION

The lanthanum bromide shows very great potential for single photon gamma ray imaging. The experimental results seem mainly limited from the photodetector features. In the near future a possible advantage will be in using LaBr\(_3\):Ce crystals with the new SiPM better if in integral coupling.

REFERENCES