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Comparison of CsI(Tl) and CsI(Na) partially slotted crystals for high-resolution SPECT imaging

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Abstract

Dedicated systems based on Position Sensitive Photomultiplier Tubes (PSPMTs) coupled to scintillators, have been used over the past years for the construction of compact systems, suitable for applications such as small animal imaging and small organs imaging. Most of the proposed systems are based on fully pixelized scintillators. Previous studies have shown that partially slotted scintillators offer a good compromise between cost, energy resolution and spatial resolution. In this work, the performance of two sets of CsI(Tl) and CsI(Na) partially slotted crystals is compared. Initial results show that CsI(Tl) scintillators are more suitable for gamma-ray detection, since their performance in terms of sensitivity, spatial and energy resolution is superior than that of CsI(Na).

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1. Introduction

Small field of view (FOV) high-resolution γ-cameras based on Position Sensitive Photomultiplier Tubes (PSPMTs) have been used widely for studies with small animals and the development of new radiopharmaceuticals [1–5]. The main advantage of a PSPMT is that the anode provides position information, thus only a PMT is necessary in order to obtain the X–Y coordinates for each detected photon. Compact cameras can be constructed, allowing the position of the camera head in a small distance from the object to be imaged and improving its performance. In the past few years, several groups have demonstrated the ability of using such systems for the early detection of small breast lesions in clinical applications and/or in experiments with phantoms [6–9].

The main components of such γ-cameras are the PSPMT, the collimator and the crystal and their choice determines its main parameters, which are the spatial and energy resolution, the efficiency in gamma-ray detection and the cost. The advantage of PSPMTs is their ability to provide position information. Three basic types of PSPMTs have been constructed; Crossed wire Anodes, Cross Plate Anode and Multianode. Details about these PSPMTs and their readout schemes can be found in many references and they are not reported here [1–9].

The selection of scintillation crystal is based on the needs of each application. Although homogeneous crystals are

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used in most clinical systems in the case of cameras for dedicated imaging, pixelized crystals are preferred. These crystals provide a focused light spot on the anode, thus position can be calculated using simple algorithms and mostly the standard center of gravity calculation algorithm (COGA). This allows real time position calculation and image construction. However, a number of such systems based on homogeneous crystals have been introduced over the past years. In these systems, more intelligent algorithms and techniques are used for position calculation, such as; detailed crystal mapping, maximum likelihood position estimation, look-up-tables, double Gaussian fitting, etc.

In a previous work the performance of partially pixelized crystals had been assessed [10]. Studies had been carried out with a set of 7 mm thick CsI(Tl) scintillators, with varying slot depths and basic parameters such as charge distribution, spatial and energy resolution and sensitivity were measured. In this work, two sets of 4 mm thick CsI(Tl) and CsI(Na) partially slotted scintillators are studied.

2. Materials and methods

The two sets of CsI(Tl) and CsI(Na) were provided by Institute of Scintillation Materials. The size of all crystals was 50 mm in diameter and 4 mm thick, with $1.5 \times 1.5\,mm^2$ pixels size and 0.5 mm pixel septa. Slot depth varied from 0 to 3 mm in both sets. Taking into account the results of the previous studies, the crystals were placed in a way that photons hit the slotted part first.

The energy resolution of the system was measured with a 60 keV Am^{241} source and a Hamamatsu R1307 PMT. Supply voltage was 1050 V for the CsI(Tl) crystals and 950 V for the CsI(Na).

The performance of the crystals in gamma-ray imaging was measured with Tc-99 sources, using a small gamma camera, suitable for small animal imaging consisting of a PSPMT (Hamamatsu R2486) and a parallel hole collimator. The thickness of the collimator is 2.75 cm; the holes are hexagonal ~1.1 mm in diameter, with 0.25 mm septa. The 16 anode signals are preamplified through 16 preamplifiers (LeCroy TRA1000) and then transferred to a CAMAC system, which hosts an ADC (LeCroy FERA 4300B), a memory (LeCroy FERA 4302), a driver (LeCroy FERA 4301) and a controller (Jorway 73A). The digital signals are transported to a G3 Power Mac via a SCSI bus. Acquisition software is written in Kmax 6.4.5. (Sparrow Corporation) environment. Details about the system and its readout principles can be found elsewhere [11,12]. The spatial resolution of the system has been measured and found <2 mm in planar imaging and 2 mm in SPECT mode [4,11], when a CsI(Tl) fully pixelized scintillator, 4 mm thick, with $1.1 \times 1.1\,mm^2$ pixels is used.

3. Results

3.1. Sensitivity

Sensitivity has been measured using a point-like source. This initial Tc^{99} solution was 4.5 mCi/ml. In Fig. 1. sensitivity as a function of slot depth for both crystal sets is shown. Results are in good agreement with previous studies showing a fast decrease in sensitivity when slot depth is increased. Sensitivity decreased three times in both sets, when slot depth varied from 0 to 3 mm. The sensitivity of the CsI(Tl) scintillators is ~3 times greater than this of the CsI(Na). However, in the case of CsI(Na) relative sensitivity drops faster in the case of 1 and 2 mm slots.

3.2. Energy response

The energy resolution, when a Tc^{99} source is used is shown in Fig. 2.

As it can be seen energy resolution increases with slot depth. It can be observed that in gamma-ray imaging

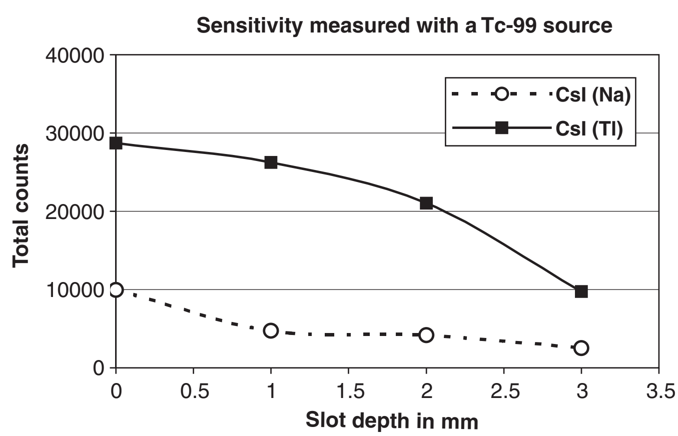

Fig. 1. Sensitivity of CsI(Tl) and CsI(Na) partially slotted scintillators as a function of slot depth.

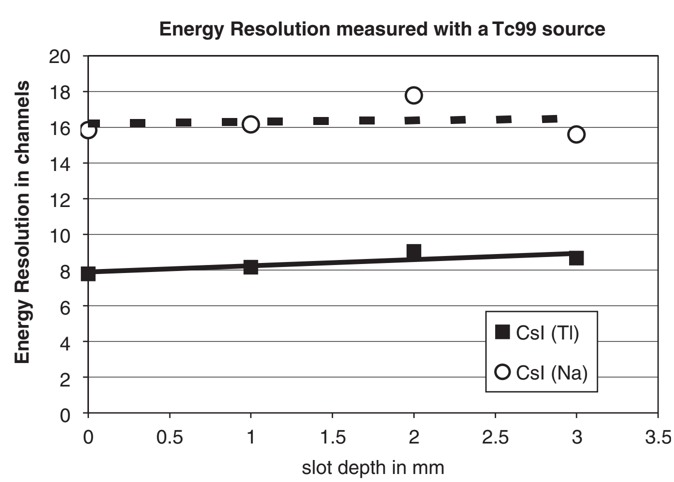

Fig. 2. Energy resolution of CsI(Tl) and CsI(Na) partially slotted scintillators as a function of slot depth, when a point like Tc^{99} source is used.

energy resolution of CsI(Tl) is two times better than that of the CsI(Na).

The energy resolution when the Am^{241} source is used is shown for comparison in Fig. 3.

When the Am^{241} source is used and with the exception of the 1 mm slot depth CsI(Na) scintillator, the energy resolution in both sets is similar (however, the supply voltage is different in the two sets) and increases with slot depth.

3.3. Spatial resolution

The spatial resolution has been measured using a thin capillary, 1.1 mm inner diameter, filled with a Tc^{99} solution. The capillary has been placed in ~5 mm distance from collimator surface. The results for both crystal sets are shown in Fig. 4.

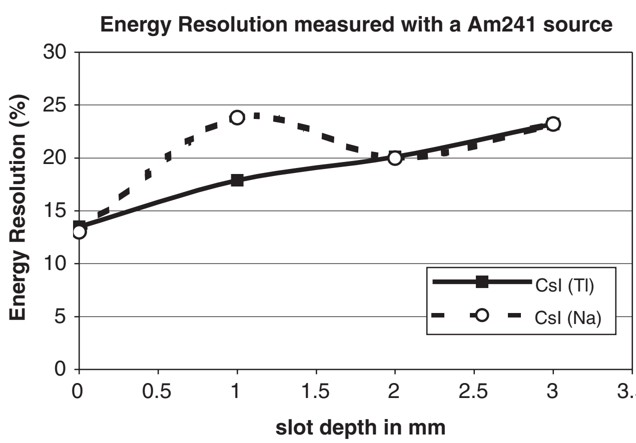

Fig. 3. Energy resolution of CsI(Tl) and CsI(Na) partially slotted scintillators as a function of slot depth, when an Am^{241} source is used.

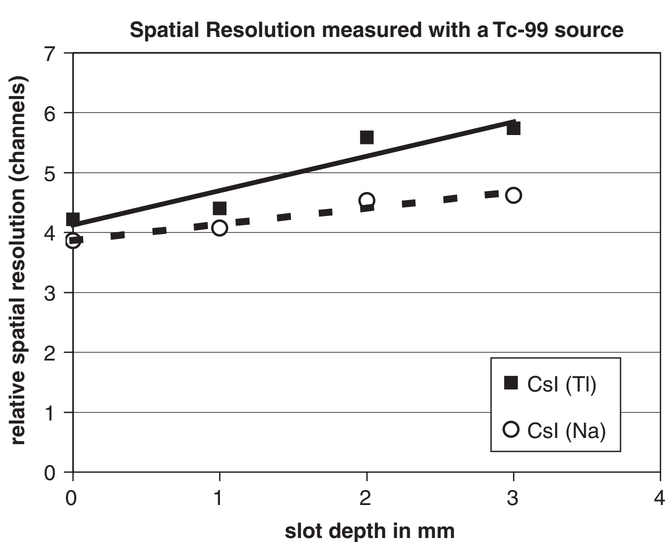

Fig. 4. Spatial resolution of CsI(Tl) and CsI(Na) partially slotted scintillators as a function of slot depth, when an capillary filled with Tc^{99} is placed in 5 mm distance from collimator surface.

4. Discussion

Although CsI(Na) seem to provide better spatial resolution, their sensitivity and energy resolution is much worse than that of the CsI(Tl). Thus CsI(Tl) is a better selection for imaging applications.

In this study, a simple Center of Gravity Algorithm has been used for position calculation. This is not the optimal choice and the techniques that have been proposed from a number of groups that use homogeneous crystals, are expected to improve spatial resolution. The proposal of using partially slotted crystals is a very interesting approach, which needs further to be explored. Simulation of optical phenomena is necessary in order to understand light transmission in the crystal, for optimization of the position calculation algorithms.

The possibility of using the relatively cheap and easy to manufacture partially slotted crystals in dedicated systems is a challenge. Such crystals could be used in probe detectors providing approximate position information without significant cost and complex data processing.

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