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Direct charge sharing observation in single-photon-counting pixel detector

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Abstract

In photon-counting imaging devices, charge sharing can limit the detector spatial resolution and contrast, as multiple counts can be induced in adjacent pixels as a result of the spread of the charge cloud generated from a single X-ray photon of high energy in the detector bulk. Although debated for a long time, the full impact of charge sharing has not been completely assessed. In this work, the importance of charge sharing in pixellated CdTe and silicon detectors is studied by exposing imaging devices to different low activity sources. These devices are made of Si and CdTe pixel detector bump-bonded to Medipix2 single-photon-counting chips with a 55 μm pixel pitch. We will show how charge sharing affects the spatial detector resolution depending on incident particle type (alpha, beta and gamma), detector bias voltage and read-out chip threshold. This study will give an insight on the impact on the design and operation of pixel detectors coupled to photon-counting devices for imaging applications.

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Keywords: Pixel detectors; Medical imaging; Charge sharing

1. Introduction

Dear-Mama (Detection of Early Markers in Mammography; EU contract number QLK3-2001-01318), is a scientific collaboration developing a low-dose X-ray system based on Cd(Zn)Te detectors coupled to photon-counting electronics for mammography and osteoporosis based in the read-out chip Medipix2 [1].

Silicon is the standard material for radiation detectors due to its low cost and wide spread availability; however, in the last years, CdTe has become the reference material for X-ray applications due to its high Quantum Efficiency (QE). For instance, for 20 keV photons, the QE is about 25% in a silicon detector 300 μm thick, whereas for Cd(Zn)Te is about 97%.

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Medipix2 [2] is a single photon-counting pixel read-out chip with pixel pitch of 55 μm, the ideal spatial resolution for a medical imaging device, and has 256 × 256 pixels. The chip is manufactured using IBM 0.25 μm, six metals, technology. Dear-Mama project has developed a complete high speed read-out system for the test and full control of the Medipix2 chips and the software package for the test, full control and use of Medipix2 chip through the Dear-Mama read-out systems. This system allows wafer probing, assembly characterization, single-chip image acquisitions and read-out of the Charge Sharing Test (CST) Medipix2 circuitry.

The aim of DearMama mammography system is the use of low energy X-ray sources. Nevertheless there are many other imaging applications using different incident particles as alpha, beta and gamma sources, such as autoradiography and nuclear medicine. In previous work [3], we have already shown the effect of charge sharing of 20 keV photons in 55 μm pixel detectors.

In this paper, we present the results of the of the image quality and spatial resolution loss due to multi-pixel counting of silicon and CdTe detectors tested with alpha particles from ^{241}Am, beta from ^{90}Sr and gamma from ^{57}Co.

2. Experimental setup

In order to measure the quality of the image of the Medipix2 assembly, different radioactive sources have been used. The radioactive sources used are ^{241}Am for alpha particles with an energy of 5.5 MeV, ^{90}Sr for beta particles with an average energy of 0.546 MeV and ^{57}Co for gamma-ray photons with an energy of 122 keV.^{241}Am is also a gamma emitter with a main energy of 60 keV.

Fig. 1 shows the experimental setup used to illuminate the pixel detectors. The Si and CdTe detectors are 800 μm thick. The silicon detectors were biased at full depletion voltage (100 V), whereas the CdTe was measured at different biasing voltages (50, 100, 150 and 200 V). CdTe was supplied by Acrorad (Japan), silicon detectors were fabricated at IMB-CNM (Spain), and all of them bump bonded at Ajat (Finland). The sources were held in position on a aluminum support with a hole. The detectors were illuminated thorough the backside electrode. The Medipix2 assemblies were hosted on a suitable PCB that allows the full control of the chip functions. Further details of the setup and the detectors used to perform the measurement described here have already been discussed in previous work [4].

3. Measurements

Since Medipix2 chip is a single photon-counting device, in the case of ideal imaging one expects to have one single pixel counting for any incoming radiation particle. However, due to different effects such as charge spreading or k-shell effect, the pixels involved in one event are usually more than one if the pixel is too small. The higher the number of pixels involved in one event the worse is the image quality. In fact, if the shower generated by an incoming particle hits more than one pixel, the image generated by the event will be a blurred spot instead of a single point, thus reducing the spatial resolution of the detector.

Fig. 2 shows a series of different images taken with the three radioactive sources. It is possible to notice that the images differ highly in sharpness with respect to the illuminating source, the image taken with the beta source being the worse and the image taken with the gamma source the best.

Fig. 3 shows in detail single interactions of the particles from the three radioactive sources. ^{57}Co features the smallest number of pixels involved per event. The single gamma photon entering the detector generates a charged shower that spreads over a few pixels. For any of these pixels where the charge accumulated is higher than the preset threshold value, a count is generated. By increasing the threshold it is possible to limit the photon detection to a single pixel. However, by increasing the threshold one also reduce the number of detected photons [4].

The effect of alpha particles in single-photon-counting devices is similar to the gamma rays. However since the alpha particles interact on the surface of the back-side electrode and their energy is much higher than

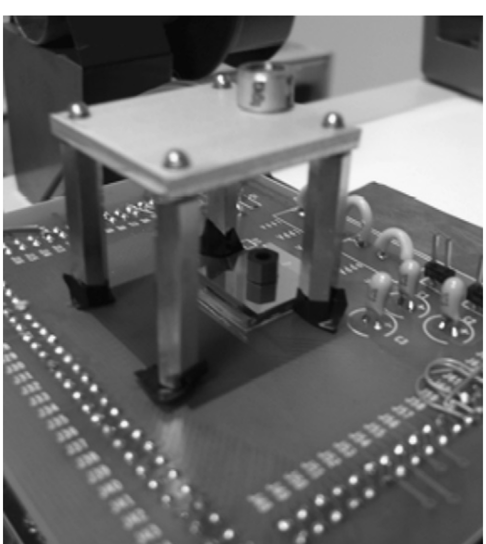

Fig. 1. The setup used to illuminate the pixel detectors with different radioactive sources.

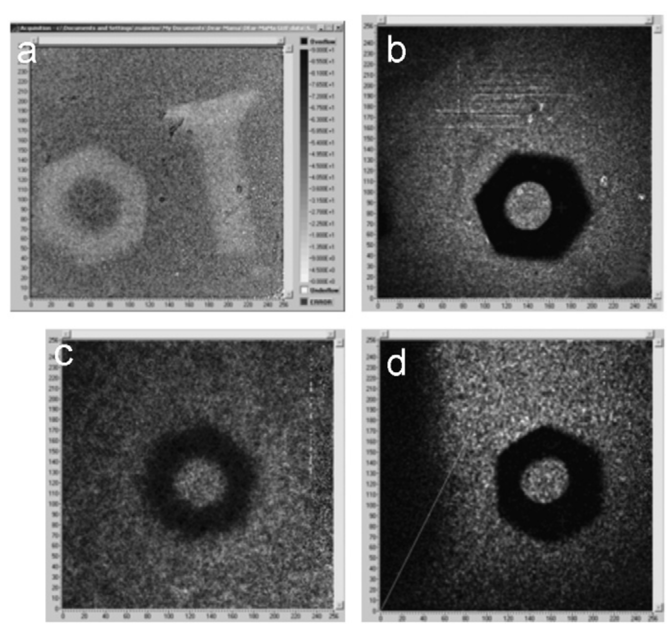

Fig. 2. Images taken with different radioactive sources using CdTe (a and b) and silicon (c and d) detectors. (a) The image of a metal nut and a screw illuminated with a ^{57}Co source. (b) and (d) The images of a plastic nut illuminated with an ^{241}Am source. (c) The image of a plastic nut illuminated with a ^{90}Sr source.