Imaging and Spectroscopic Performances For a Si Based Detection System

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Abstract

We present the imaging and spectroscopic capabilities of a system based on a single photon counting chip (PCC) bump-bonded on a Si pixel detector. The system measures the energy spectrum and the flux produced by a standard mammographic tube. We have also made some images of low contrast details, achieving good results.

I. INTRODUCTION

OUR group is working with a hybrid detection system developed in the framework of the Medipix Collaboration [1]. The system consists of a photon counting chip (PCC) bump bonded to a semiconductor detector: the hybrid approach allows to change either the thickness of the detector or the semiconductor type. So we have used GaAs detectors of 200 μm [2] and 600 μm thickness [3] for different medical applications, and now we are characterizing a 300 μm thick silicon detector both as a spectroscopic device and as an imaging system. All the mentioned detectors have the same lay-out.

II. CHARACTERISTICS OF THE DETECTION SYSTEM

The silicon detector is a matrix of 64 x 64 square pixels with a dimension of 170 μm x 170 μm. The PCC matches the geometry of the detector so it has 4096 asynchronous read-out cells, each having a low noise charge preamplifier, a leading edge comparator with 3-bits for a fine threshold adjustment and a 15-bit pseudo-random counter. The possibility of setting separately the threshold for each pixel, around a fixed threshold (Vth) value, gives a very narrow threshold distribution well fitted with a gaussian shape with a rms of 150 e^-.

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III. CALIBRATION OF THE DETECTION SYSTEM

To perform energy calibration of each PCC pixel cell, we have used a radioactive source and a standard mammographic tube. We have done a set of acquisitions decreasing the electronic chip threshold value, going from 1.600V to 1.010V with a 10mV step, then we calculated the mean counting value among the 4096 pixels for each acquisition. In this way we obtain the radioactive source integral spectrum. In fig.1 are reported the integral spectrum and the corresponding differential energy spectrum for a ^{109}Cd source. We see well the convolution of the 21.99 KeV and 22.163 KeV photons To obtain the integral spectrum we have used 59 different electronic chip threshold values, Vth(V).

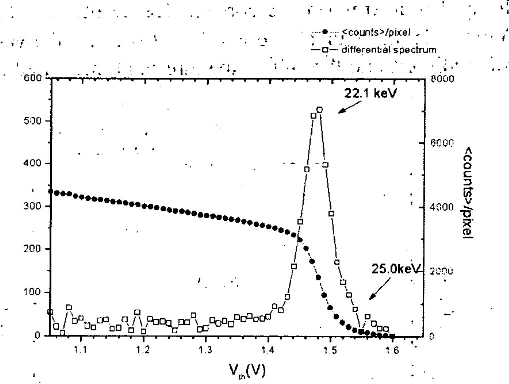

Fig.1: Integral and energy spectrum for a Cd109 source. We see well the convolution of the 21.99 KeV and 22.163 KeV photons, and, at the end of the tale, the 25.0 KeV photon.

Using the same voltage step as before, and again around 60 tube shots, we have acquired the mammographic integral energy spectrum and it is reported in fig.2, together with the corresponding differential one.

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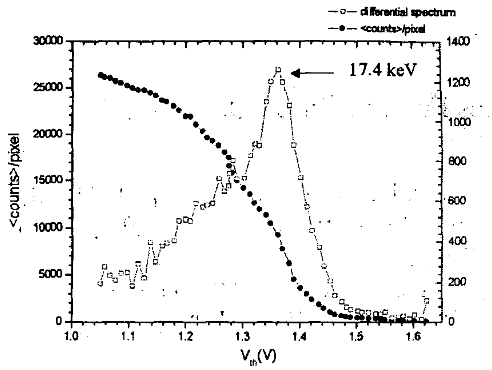


Fig.2: Integral and energy spectrum for a mammographic beam. The tube settings are: Mo anode, 28kVp, 1.0mm Be+ 0.03mm Mo, 24mAs

The peaks in the energy spectra have been fitted with a gaussian function, obtaining the mean values for the different photons energy. This kind of calibration provides only few points: the one relative to the sources used. A more detailed calibration can be obtained using the test input present in each pixel VLSI cell. For each selected PCC threshold voltage, we have sent a set of electrical signals to the input test capacitors obtaining the corresponding threshold values expressed as a function of the input signal amplitude. The data are reported in fig.3, together with the two experimental points previously calculated.

We used these experimental points to fix the scale for the electrical calibration, and we have calculated the value of the mean test capacitor for the used PCC that results 25.3 fF. We have also determined the correspondence between keV and Volt. This last equivalence is relevant because the value that we really set into the chip is the threshold, measured in Volt.

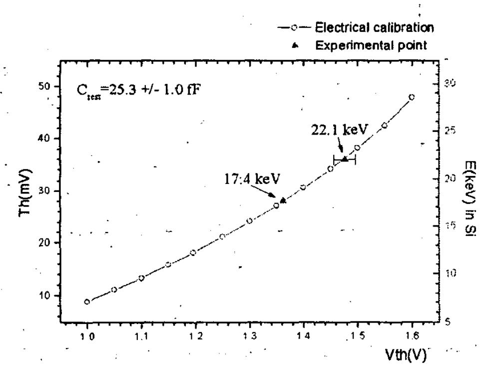


Fig.3: The equation that gives the relation between keV and V is: $E(keV)=13.7-32.1*Vth(V)+25.7*[Vth(V)]^2$

Each PCC has its own value of calibration capacitor so these routines need to be repeated for each new electronic chip.

IV. A NEW SPECTROSCOPIC SYSTEM

As shown, our detection system has a good spectroscopic performance, but requires a number too big of acquisitions to be used routinely as a spectrometer, so we decided to find a method to reduce the acquisitions number. The threshold of each pixel, as told before, can be evaluated precisely using the electrical signal calibration procedure, and performing it, we obtain a wide, flat and not pixel position correlated, threshold distribution. Choosing only four PCC threshold values, Vth (V), it is possible to cover a wide pixel threshold range, expressed as a function of the electrical signal amplitude, with a statistically significant number of pixels for each threshold value. In fig.4 are reported these four thresholds distributions.

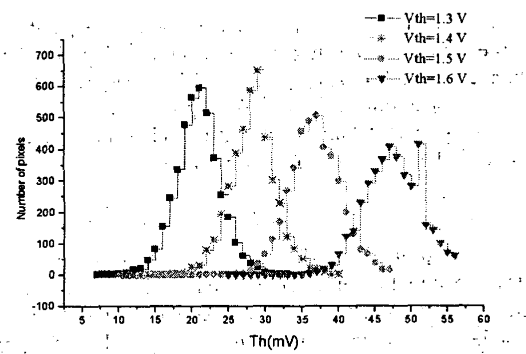


Fig.4: For each selected value of the PCC threshold value, Vth(V), we report the pixel threshold distribution as a function of the input test electrical amplitude.

We have therefore acquired the integral spectra for the ^{109}Cd source and for the mammographic tube using only four PCC threshold values. We performed only the acquisitions relative to the Vth value ranging from 1.3V to 1.6 V with 1 Volt step. We report in fig.5 the two spectra, integral and differential, for the ^{109}Cd source. The energy resolution for the 22.1 keV photons, evaluated as the FWHM/<x> is: $\Delta E/E = 8.8\%$.

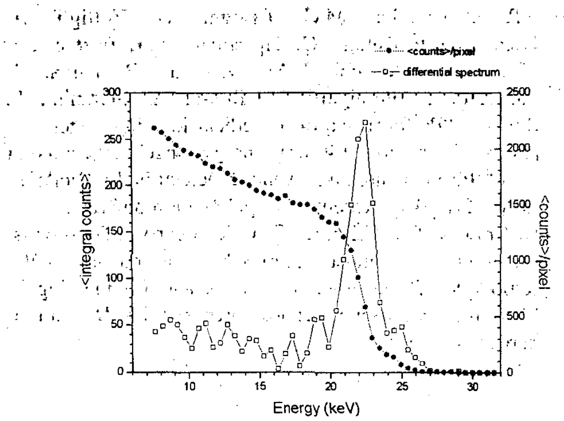


Fig.5: The integral spectrum and the differential one for the ^{109}Cd source. These spectra were obtained with only four acquisitions

For the mammographic tube we acquired the energy integral spectrum, and after differentiating it and taking into account the silicon detection efficiency, we compared the obtained energy spectrum to a simulated one [4]. The simulated spectrum and the experimental one are reported in fig.6.

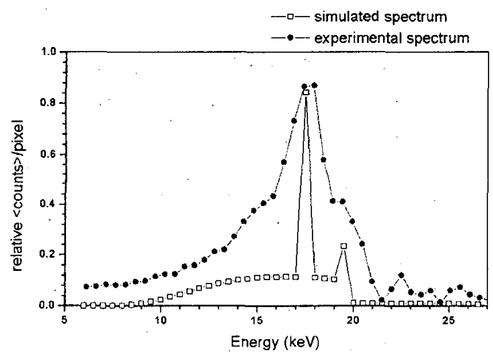


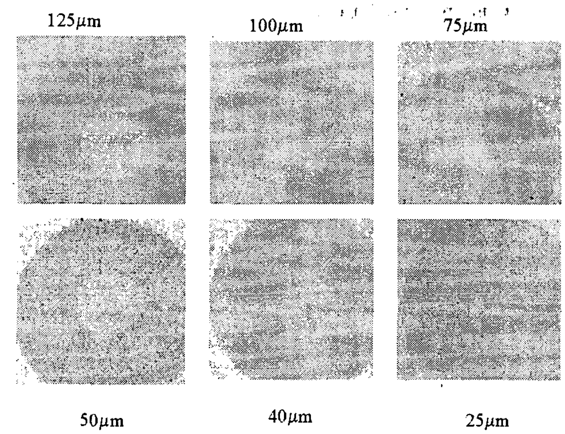
Fig.6: Energy spectrum for a mammographic beam and our experimental points. The tube settings are: Mo anode, 28 kVp, 1.0mm Be+ 0.03mm Mo, 24mAs

The experimental points follow the shape of the simulated spectrum, moreover, using the integral data we have evaluated the tube flux obtaining the value of (1.9 +/- 0.2) x 10^5 γ/(mm^2 mAs) at 75cm. Using a commercial ionization chamber, in the same experimental condition, we measured (2.1 +/- 0.1) x 10^5 γ/(mm^2 mAs).

After differentiating the acquired spectra we have performed a gaussian fit to determine the <x> and FWHM for the photons peaks. Through these values and the electrical calibration, we have estimated the value for the mean test capacitor of this new electronic chip, since that the previous one was deteriorated. The mean test capacitance results: C_{test} = 22.8 +/- 1fF. The equation that gives the relation between keV and V in this case is: E(keV)=18.9-47.4*Vth(V)+31.2*[Vth(V)]^2.

V. SYSTEM'S IMAGING CAPABILITIES

We have also checked our system imaging capabilities, and since, as a uniform response of the 4096 pixels is essential, we have performed a fine threshold adjustment. We have performed some imaging using a home made phantom. The phantom is a 40 mm thick lucite cylinder, in which are present various cylindrical holes, all 12 mm in diameter and 3 mm deep. In each hole an aluminum particular, 4 mm in diameter, of different thickness, is immersed in wax. The phantom has been placed at 75 cm from the beam focus and 1cm above the detector. The dimension of each image is 1.18cm^2; all the images have been obtained with 32 mAs and 28kVp. In fig.7 we present the images of six aluminum particular with the thickness going from 125 µm to 25 µm, and the corresponding measured contrast.



t (µm)	125	100	75
$C_{meas.}$(%)	7.89 +/- 0.23	6.39 +/- 0.23	4.24 +/- 0.28
t (µm)	50	40	25
$C_{meas.}$(%)	3.72 +/- 0.24	3.39 +/- 0.23	2.96 +/- 0.22

Fig.7: Images of six aluminum details of different thickness. All the images have been weighed, to take into account the systematic noise due to the different response of the pixels. The measured contrast, for each thickness, is reported.

Even if the mean detection efficiency for silicon, for the photons emerging from the phantom, is about 20%, the systems homogeneity and stability allows to see low contrast details.

VI. CONCLUSIONS

These results are encouraging to use this system as a fluxmeter, for spectroscopic use and also for imaging applications.

VII. REFERENCES

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