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SYRMEP: AN INNOVATIVE DETECTION SYSTEM FOR SOFT X-RAYS

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SYRMEP: an Innovative Detection System for Soft X-Rays

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In the field of digital mammography, the SYRMEP (SYnchrotron Radiation for MEdical Physics) collaboration intends to use as a source the 10-35 keV photons from a monochromatic beam at the synchrotron ELETTRA in Trieste, and as a detector a brick of silicon microstrip detectors with the beam impinging along the strip direction. In this way, the absorption efficiency is maximized and a pixel-like matrix is obtained with pixel dimensions given by the detector thickness and the strip pitch.

The digital images are obtained using a photon counting technique. We present here the results obtained with an AC-coupled FOXFET detector with 200x300 μm^2 pixels and a hybrid electronics, both with a standard X-ray tube and the monochromatic beam.

1 Introduction

The SYRMEP (SYnchrotron Radiation for MEdical Physics) collaboration is developing an innovative detection system in the field of digital mammography, based on a silicon strip detector to be used with a monochromatic beam at the synchrotron ELETTRA in Trieste [1]. In the following, after a brief description of the beam environment and the detection system, we present the results in terms of digital images obtained with a standard mammographic tube and the monochromatic beam.

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2 The beam environment

Since the beginning of 1996, the SYRMEP beam line is operating at ELETTRA in Trieste.

The primary photon beam, obtained from a bending magnet, impinges on the crystal of a monochromator positioned at ≈ 18 m from the source, giving a laminar monochromatic beam with maximum dimensions of 10×0.4 cm² and energy ranging from 8.5 keV to 33 keV.

Fig. 1a shows the flux values as a function of the energy as measured by a ionization chamber, located in the experimental hutch, ≈ 23.5 m from the source. This hutch contains also the detector and the frontend electronics, which are fixed on movable supports to permit the alignment with respect to the beam in x , y , z and θ with a precision of ≈ 10 μ m.

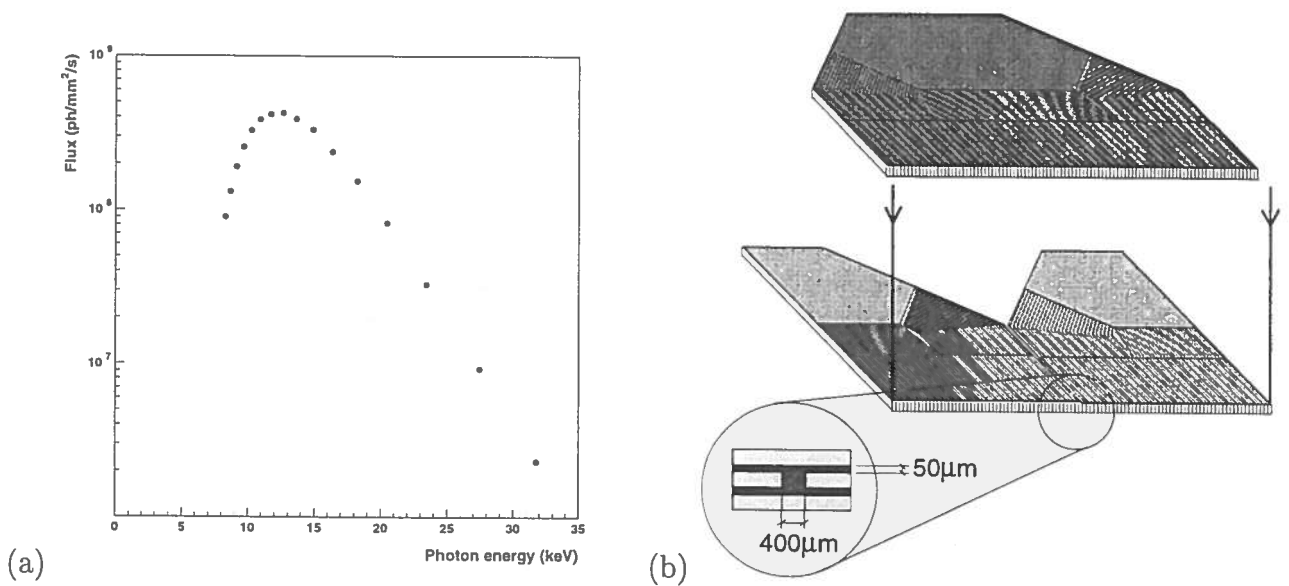


Fig. 1. (a) Flux values as a function of energy as measured by a ionization chamber at ≈ 23.5 m from the source. (b) Stacking technique example with the final detectors. The inter-layer dead region is 50 μ m; the crack between two nearby detectors is 400 μ m.

3 The detection system

3.1 The detector

The project goal is to make digital images using as a sensor for photon counting a silicon strip detector.

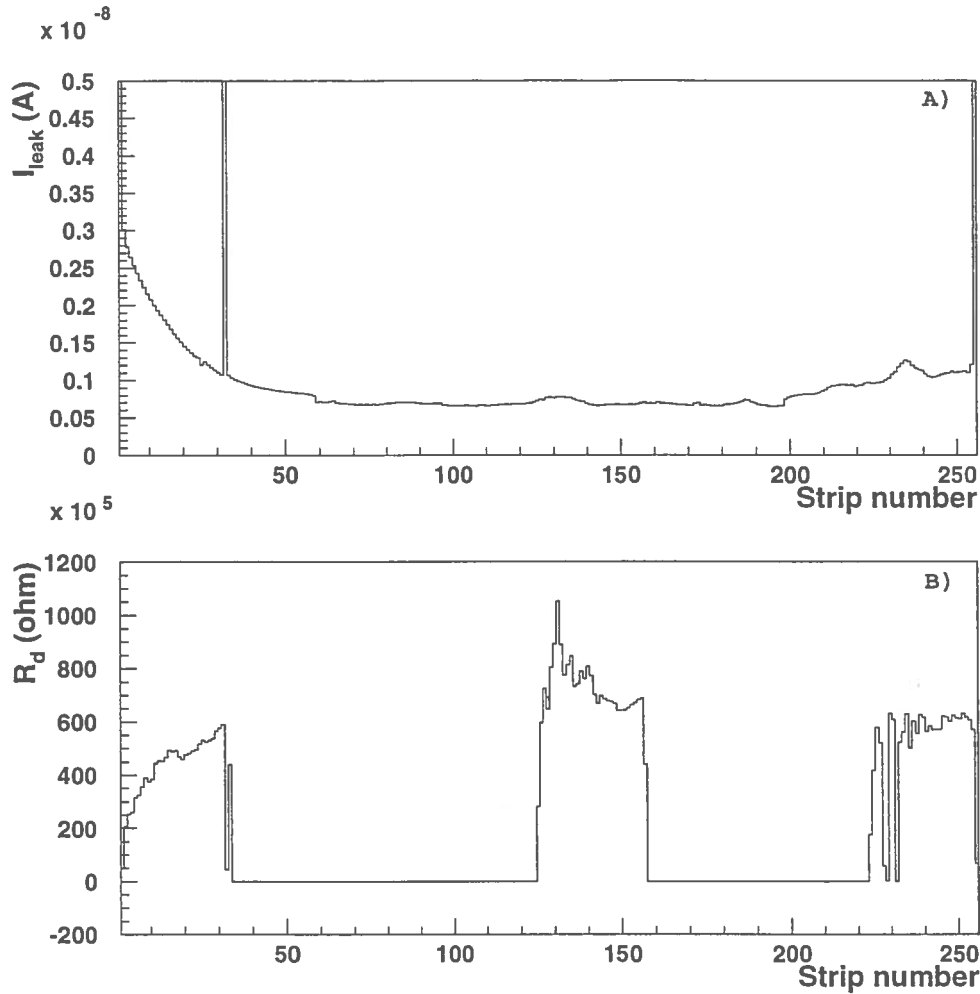


Fig. 2. a) Strip leakage current of a 256 strip detector with a bias voltage of 25 V. b) Dynamic resistance of 3 groups of 33 strips each.

20 keV photons have a rather long attenuation length in silicon. To achieve a reasonable absorption efficiency, the detector has been turned edge-on so that the beam impinges parallel to the longitudinal dimension of the strips, which becomes the effective detector thickness. A strip length of ≈ 1 cm ensures an absorption efficiency of 100% [2]. Furthermore, in this way we create a row of pixels with dimensions defined by the thickness of the device and the strip pitch. To cover the total area of the beam, several layers of detectors are stacked, minimizing the inter-layer dead region and the cross talk of superimposed pixels. Fig. 1b shows an example of the stacking technique with the final detector.

From the geometrical point of view, the final sensor has the configuration of a 'wall', where each layer is staggered with respect to the layers above and below to avoid continuous cracks in the structure. The detectors, produced by CANBERRA Semiconductors, are $300 \mu\text{m}$ thick, with a strip pitch of $200 \mu\text{m}$

and strip length of 1 cm. To build the wall, two different types have been manufactured, one with 256 strips exposing an area of $51.2 \times 0.3 \text{ mm}^2$ to the beam, and the other with 126 strips. The trapezoidal shape allowed the insertion of a fanout in the active region of the device behind the 1 cm strips, to match the $200 \mu\text{m}$ strip pitch with the $85 \mu\text{m}$ pitch of the electronics. The detector fanout is extended with a flexible upilex fanout, so that the electronics can be easily positioned and cooled.

To minimize the loss in detection efficiency caused by the presence of a blind volume in front of the detector itself due to the distance of the implanted strips from the cutting edge [3], this distance, which is usually $\approx 500 \mu\text{m}$ for a $300 \mu\text{m}$ thick detector, has been reduced to $250 \mu\text{m}$. For 20 keV photons, the final detection efficiency increases from 50% in the normal case to 80% in our device.

From the electrical point of view, the strips are AC-coupled to the readout electronics and they are biased through the FOXFET mechanism [3,4] with a p^+ structure on the junction side for the lateral depletion. Fig. 2a shows the average strip values of the leakage current of a 256 strip detector with a bias voltage of 25 V. The absence of a guard ring, in order to reduce the dead area which limits the detection efficiency, explains the high current of the 2 outermost strips. Fig 2b shows the corresponding values of the dynamic resistance R_d [3] for 3 groups of 33 strips each. Apart from the low values for strips with high dark current, R_d is $\geq 40 \text{ M}\Omega$, which fulfills our goal.

3.2 Readout electronics

For the measurements with the standard tube and the monochromatic beam, a hybrid preamplifier and a discrete readout electronics have been used with 96 and 174 channels completely equipped. Each channel is formed by a JFET-input charge preamplifier, a voltage amplifier and a discriminator whose logic signals are read by a CAMAC Lecroy scaler. The chain signal to noise ratio is $\approx 5:1$, with a gain of $\approx 70 \text{ mV/fC}$ [5]. The counting rate has been kept rather low ($\approx 10 \text{ kHz}$) to avoid double counting.

We are testing now on the beam a 32-channel analog-digital VLSI chip, CASTOR, produced by LEPSI (Strasbourg) [6], containing all the pieces from the preamplifier to a 16-bit counter; its readout chain is described in [7]. The gain has been increased to 200 mV/fC with an improvement in the signal to noise ratio up to $\approx 20:1$. The response of the analog part of the chip is linear within 1% up to 3 fC, well matched with the expected input signal of 1-2 fC. The chip has been proven fully operational up to a counting rate of 100 kHz [6]; for higher rates, studies are in progress.

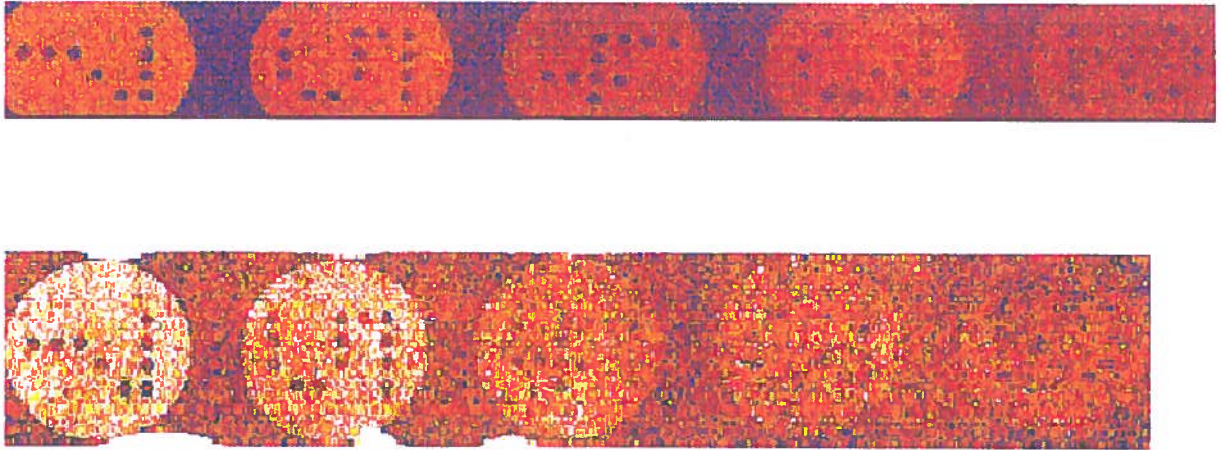


Fig. 3. Low contrast discs images of the Ackermann phantom obtained with the SYRMEP detector using a standard mammographic tube (top) and a monochromatic beam with photon energy of 20 keV (bottom).

4 Results

Both with the standard X-ray mammographic tube and the synchrotron monochromatic beam of ELETTRA, the images have been obtained scanning the whole volume of a test phantom. The data have been analyzed and compared in terms of contrast, signal to noise ratio and spatial resolution [1,5]. Fig. 3 shows the images of low contrast discs obtained in the 2 environments. In both cases, discs with a contrast of $\approx 1\%$ are visible; the use of the beam decreases the mean glandular dose of a factor of ≈ 10 .

5 Conclusions

The innovative detection system being developed by the SYRMEP collaboration is proving its possibilities both with the use of a standard mammographic tube and a monochromatic beam. Test are in progress to couple these new generation detectors to a high rate VLSI electronics. Images of a mammographic phantom have been taken in the two configurations and compared. The delivered dose has proved to be respectively ≈ 2 and ≈ 10 times lower than the standard one.

References

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