IMPLEMENTATION OF X-RAY ENERGY DETECTION AND PHOTON COUNTING USING A SILICON FIELD-EMISSION IMAGING ARRAY

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In our previous work [1, 2], a silicon field-emission array (FEA) was proposed for the application of X-ray energy detection. An incident X-ray photon, depending on its energy, generates a specific numbers of electron-hole pairs. The holes are subsequently collected at the p^+ doped layer, while the photo-generated electrons drift through the fully-depleted Si toward the spatially-defined field-emission tips. When the photo-generated electrons reach the field emission tips, they are field-emitted and subsequently collected at the anode (Figure 1). Our previous work modeled the response of single X-ray photon events of differing X-ray energies, showing two pulses with different widths and amplitudes. To verify the theory, a 2cm x 2cm silicon field emission array has been fabricated by subtractive etching and oxidation sharpening techniques. At 450μm cathode to anode distance and at a vacuum level of $5x10^7$ Torr, the device was biased at 1400V, field emitting at an integrated current of 32pA. When the device was excited by a 100μCi Fe55 X-ray source, an average increase of 24pA was observed.

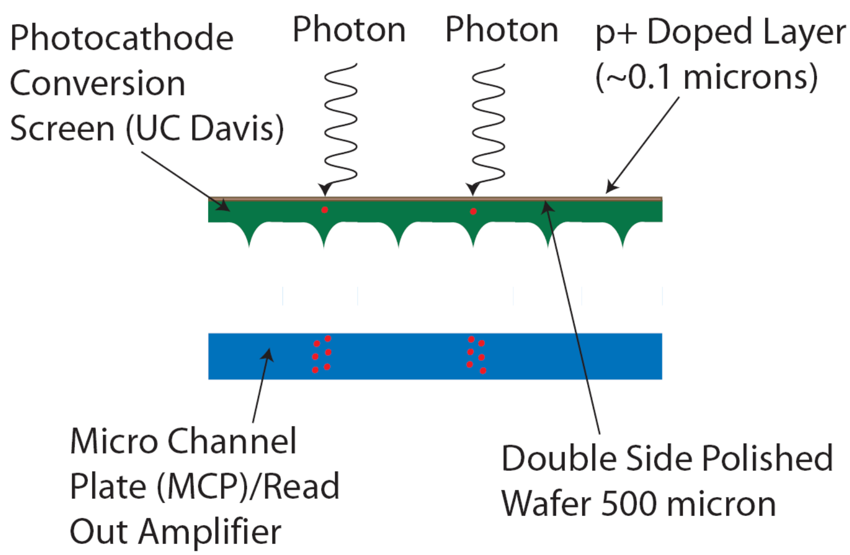

Figure 1: X-ray Imager and Energy Detector

According to our calculations, each photon event should generate approximately 1616 electron-hole pairs. Our X-ray source (at its current age) should have a flux of $1.85x10^6$ photons per second. Also, since the X-ray source is a point source, it radiates in all directions. Therefore the maximum amount of radiation subtended by the imager would be less than 50%. Given these parameters, and assuming negligible recombination of the electrons during drift across the Si, an integrated current of 240pA is expected.

In our measurements, we observed an average increase of integrated current of 24pA with the Fe-55 X-ray source (Figure 2). Several factors contribute to a higher calculated current. First, the number of photons striking the detector (assumed 50% of the flux) is likely much less than estimated. Secondly, our calculation assumes no recombination of the photo-generated electrons in the Si bulk or at the surfaces. Furthermore, although we calculate the Si is fully depleted, we have no experimental evidence to prove this.

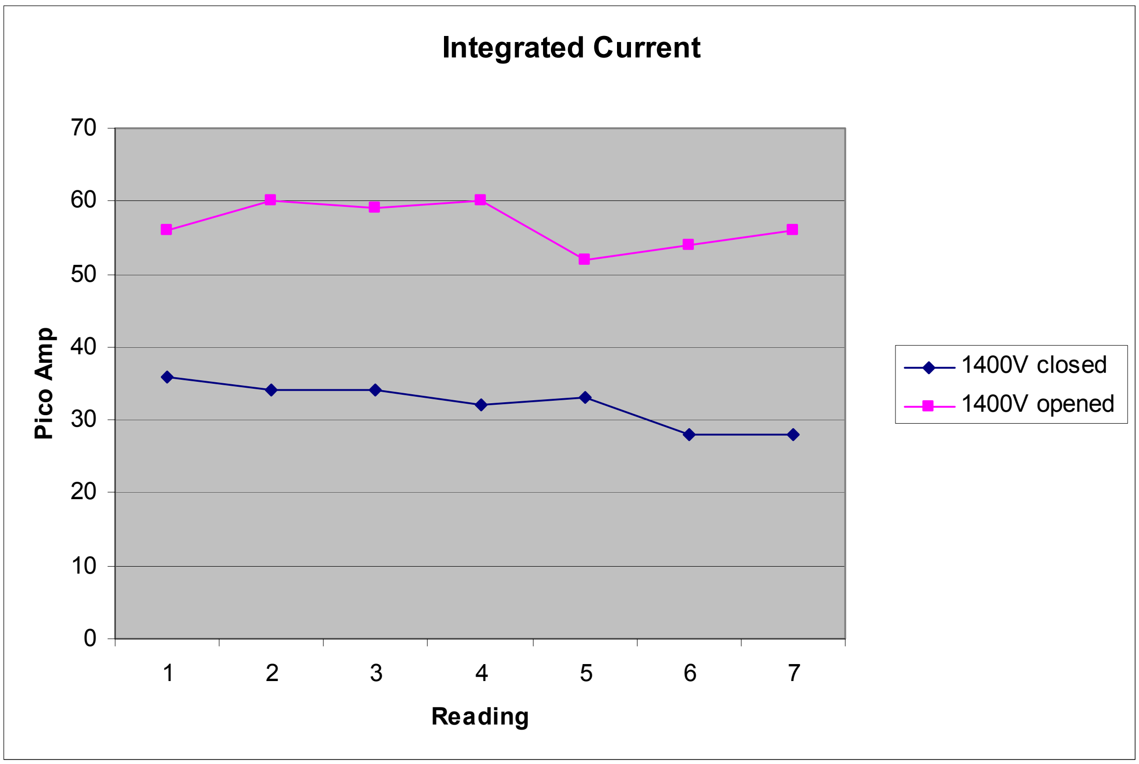

Figure 2: Integrated Current measurement with and without X-ray source.

Currently, we are working on time-resolved measurements to capture single photon events. The field-emitted current will be amplified using a Micro-Channel-Plate (MCP) by improve the sensitivity of the time-resolved measurements.

[1] Michael C. Wong, C. Hunt, Y. Diawara, "X-ray Energy Detection Using Silicon Field Emission Imaging Array," Digest of the 19th International Vacuum Nanoeletronic Conference (2006) pg 169-170.

[2] Y. Wang, C. Hunt, Y. Diawara, "X-ray Imaging Detector Using Silicon Field Emission Tip Array Energy Conversion," Digest of the 18th International Vacuum Nanoeletronic Conference (2005) pg 52-53.