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High-Speed, High-DQE Detectors For Electron Microscopy

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In this presentation we will discuss novel detectors for electron microscopy currently being developed at Lawrence Berkeley National Laboratory (LBNL). Both monolithic detectors – CMOS Integrated Circuits designed as pixilated, direct detection imaging detectors – and improved classical detectors – high-speed CCDs – will be discussed.

Monolithic Active Pixel Sensors (APS), first described in 1967[1,2] have enjoyed a significant re-birth as cheap digital cameras and rivals to CCDs. This same technology is potentially interesting for electron microscopy, as APS offer excellent point-spread function, direct detection and high readout speed. An Active Pixel Sensor is a CMOS integrated circuit, with an imaging region divided into pixels, and a signal processing region. The pixels are "active" as they contain transistors used for buffering the charge collected and steering it.

Active Pixel Sensors for charged particle tracking are being explored by the high energy physics community as a next generation, low mass, tracking device. The feasibility of APS for electron microscopy has been explored by several authors,[3] and in this presentation we will report on the first designs specifically targeted to electron microscopy. Figure 1 shows an APS that was submitted for fabrication in February 2005. Each 19 µm pixel contains two storage capacitors, one which holds the "reset" level, and one which holds the "signal" level. When read out, switches in each pixel subtract the reset level from the signal level (correlated double sampling). In addition, each pixel has an electronic shutter. At the bottom of each pixel column is a 10-bit analog-to-digital converter (ADC). The bank ADCs convert one row of pixels in parallel, with a conversion time of 2-5 µs. That row of data is then shifted off-chip, and the next row is digitized. A second APS, which consists of "simple" 6 µm pixels and anti-blooming 19 µm pixels will also be described.

For these Active Pixel Sensors, we have employed radiation hardening techniques developed for high energy physics. These techniques are slightly at odds with obtaining ultimate detector performance, so certain compromises are necessary. Nonetheless, APS offer an exciting new possibility – not only for greatly improved speed, but also for the ability to "custom tune" the detector to a class of experiments.

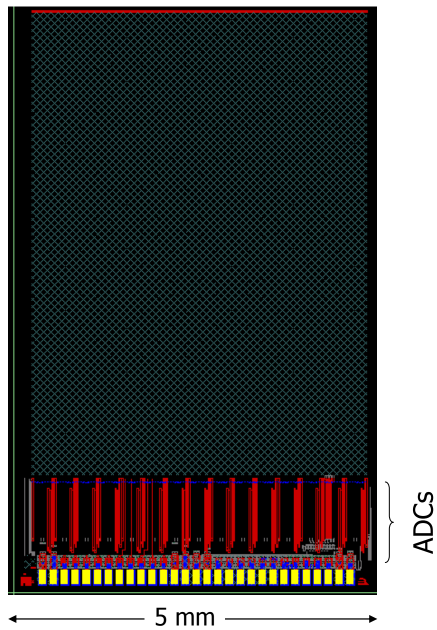

Figure 1 APS with 19 µm pixels

[1] G. Wecklers, .”Operation of p-n junction photodetectors in a photon flux integrating mode”., IEEE J. Solid-State Circuits, Vol. SC-2, p. 65, 1967.
[2] P. Noble, .”Self-scanned image detector arrays”., IEEE Trans. Electron Devices,vol. ED-15, p. 202, 1968.
[3] For example, NH Xuong, et al. “First use of a high-sensitivity active pixel sensor array as a detector for electron microscopy”, Proc. SPIE, Vol. 5301 (2004) 242.