The Design and Prototype of a Detector for Protein Crystallography*

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The Digital Pixel Array Detector (DPAD), specifically designed for third-generation synchrotrons, is truly a unique photon counting detector with an extremely high throughput (up to 10^{10} photons per second for a 1000 x 1000 pixel detector). Three applications in macromolecular crystallography are as follows: (1) In standard rotation method, it can easily collect data at a rate of 1° per second, i.e., finish a data set in 90 seconds. (2) In MAD data collection procedure, one can use the fine slice method i.e., read out at 0.1° (instead of every 1˚) without losing time or adding noise due to the read out process. (3) In a time-resolved Laue experiment, DPAD can automatically store eight (or more) successive frames with an exposure of 10 ms and a switching time of a few microseconds.[1]

The room-temperature detector is a high-resistivity N-type Si with a pixel pitch of (150 x 150) microns, a thickness of 300 microns, and is bump bonded to an application-specific integrated circuit (ASIC). The detector event driven readout is based on the column architecture and allows an independent pixel hit rate above one million photons/sec/pixel over the entire detector. The device provides energy discrimination and sparse data readout which yields minimal deadtime. This type of architecture allows a continuous (frameless) data acquisition. For the targeted detector size of (1000 x 1000) pixels, average hit rates of 10 billion photons/sec for the complete detector appears achievable. The detector has almost infinite photon counting dynamic range and exhibits superior spatial resolution when compared to present crystallographic phosphor imaging plates or phosphor-coupled CCD detectors.

An 8 x 8 pixel array x-ray detector prototype has been built and tested. To characterize the analog portion of the readout and the digital characteristics of the detector, the pixel electronics contain only the analog portion of the circuit and are independent of the surrounding cells. The conversion of a photon hit into a pixel address is generated by conventional external electronics. The measured results are very encouraging. The analog electronics demonstrate the capability of processing charge pulses at a rate of 1×10^6 photon/sec/pixel, with an energy resolution of 480 eV (FWHM at 5.9 keV) at room temperature. The detector displays uniform digital behavior and has a very low point-spread function. The full width at 1/100 maximum is less than one pixel width (150 µm), which is less than 1/2 that of CCD and 1/7 that of an imaging plate.[2]

A 16 x 16 pixel array with most of the readout electronics included in the ASIC has been designed and tested. The 16 x 16 device, which includes both analog and digital circuitries on the same chip, continues to display the remarkable low point-spread functions and similar low-noise characteristics of the 8 x 8 analog-only device. More test results will be presented at this conference.

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[1]E. Beuville et. al., IEEE, Transactions of Nuclear Science, 43 (3) (1996) pp. 1243-1247.

[2]P. Datte et. al., Nuclear Instruments and Methods in Physics Research, A391 (1997) 471-480.