

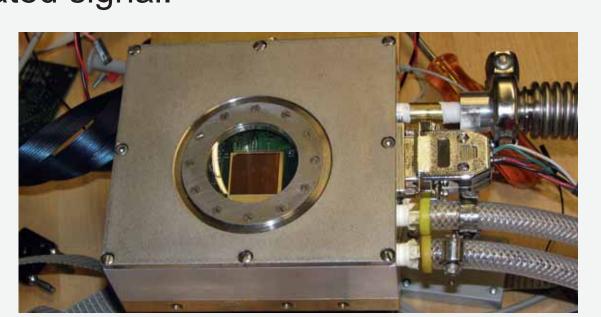
# PIXEL ARRAY DETECTOR DEVELOPMENT

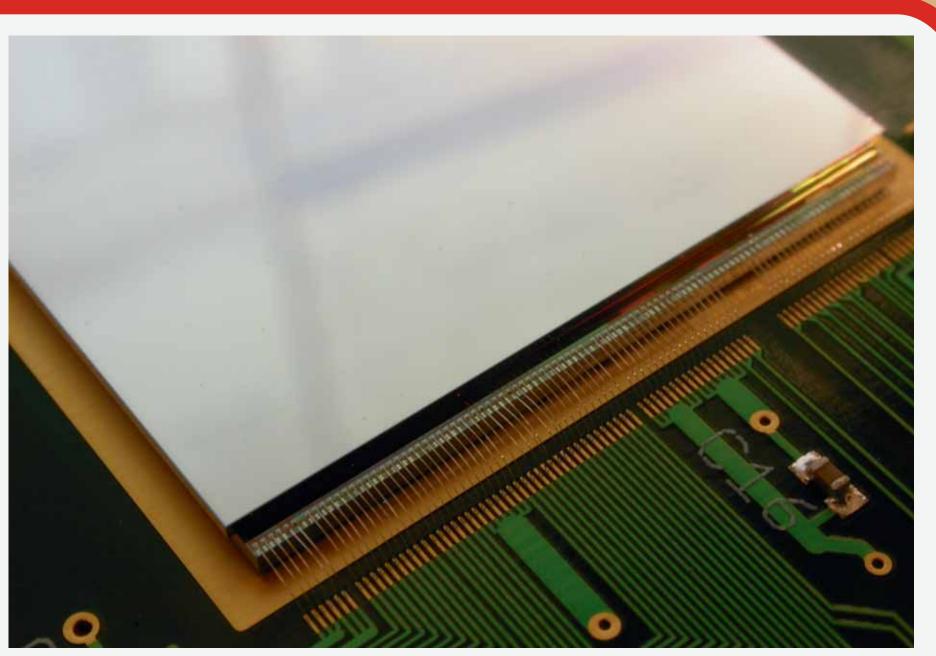
# AT CORNELL

Hugh T. Philipp<sup>a</sup>, Marianne Hromalik<sup>c</sup>, Katherine S. Green<sup>a</sup>, Darol Chamberlain<sup>b</sup>, Mark W. Tate<sup>a</sup>, and Sol M. Gruner<sup>a,b</sup>. <sup>a</sup>Laboratory of Atomic and Solid State Physics, Physics Department, Cornell University, Ithaca, NY. <sup>b</sup>Cornell High Energy Synchrotron Source (CHESS), Cornell University, Ithaca, NY. <sup>c</sup> Computer Science Department, SUNY-Oswego, Oswego, NY

#### Introduction

This poster shows some of the work done at Cornell to develop pixel array detectors (PADs) that will meet and anticipate the needs of the x-ray science community. PADs allow for a highly flexible detector that is made by coupling commercially fabricated CMOS with high-quality, pixelated silicon diode sensors. Direct conversion of absorbed x-rays to charge carriers in silicon provides high-fidelity measurements of total absorbed x-ray energy, and high-resolution spatial data. Using commercial CMOS processes allows for efficient and custom processing of x-ray generated signal.

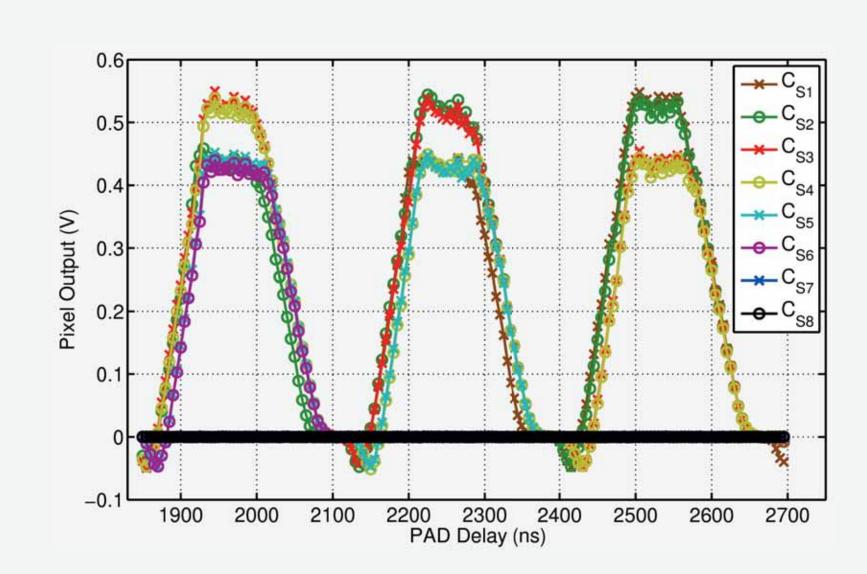




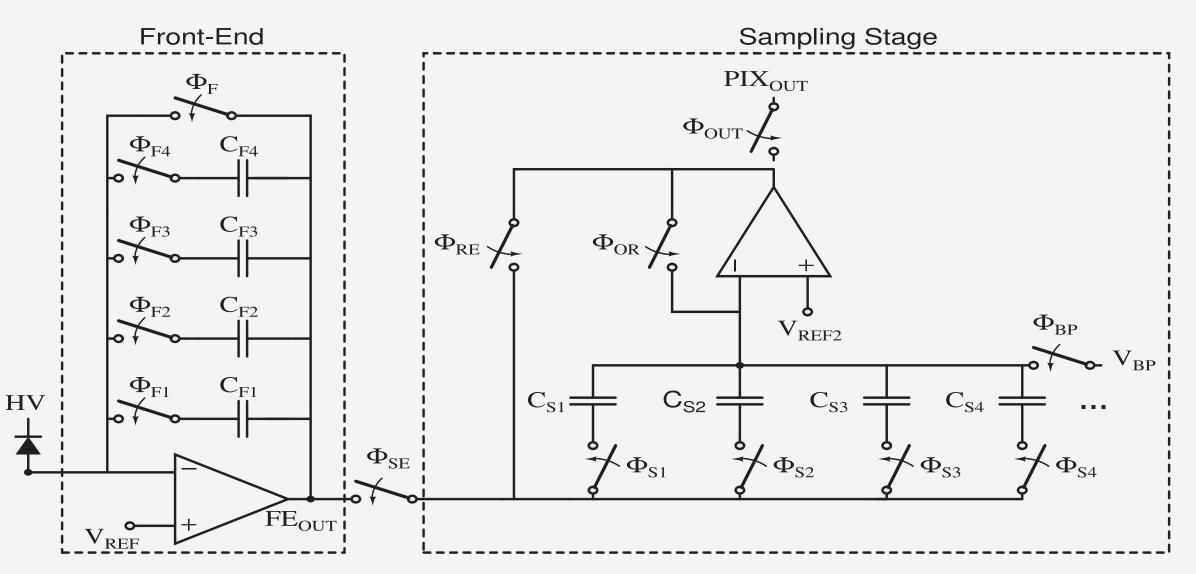
Above: Wire bonds coming off one side of a pixel array detector module. The top face is the alumunized side of a silicon diode array. The wirebonds are connected to a CMOS ASIC that is underneath and mated at the pixel level to the silicon

## KECK PAD

Parameter	Target Value		
Noise	<0.5 x-ray/pixel/accumulation		
Minimum exposure time	<150 ns for 12-bit imaging		
Capacitor well-depth	2000-4000 x-rays		
Nonlinearity (% of full well)	<0.2%		
Diode conversion layer	500 μm thick Si		
Number of capacitor wells/pix	8		
Full chip frame time	1 ms/frame e.g. 8 ms for 8 capacitors		
Radiation lifetime	>50 Mrad at detector face (8-keV x-rays)		
Pixel size	150 μm x 150 μm 128 x 128 pixels per IC		
Detector format	2x4 chips = 256x512 pixels		
Dark current	2 x-rays/pix/sec		
Data Rate for 256x512 PAD	0.25 GB/s		



Single Synchron Bunch Imaging: X-rays at CHESS are generated by electrons and positrons circulating the CESR ring in trains of 5 or 6 bunches. The train-to-train separation is 280 ns; bunches within a train are separated by 14 ns. The inpixel frame storage capacitors ( $C_{S1}$  -  $C_{S4}$  in the pixel schematic below) allow capture of 8 successive frames before detector readout. This feature was used at G3 to isolate images from successive bunch trains. In the plot of integrated signal versus PAD delay with respect to the synchrotron timing, the 5- and 6-bunch trains are clearly distinguishable from one another.

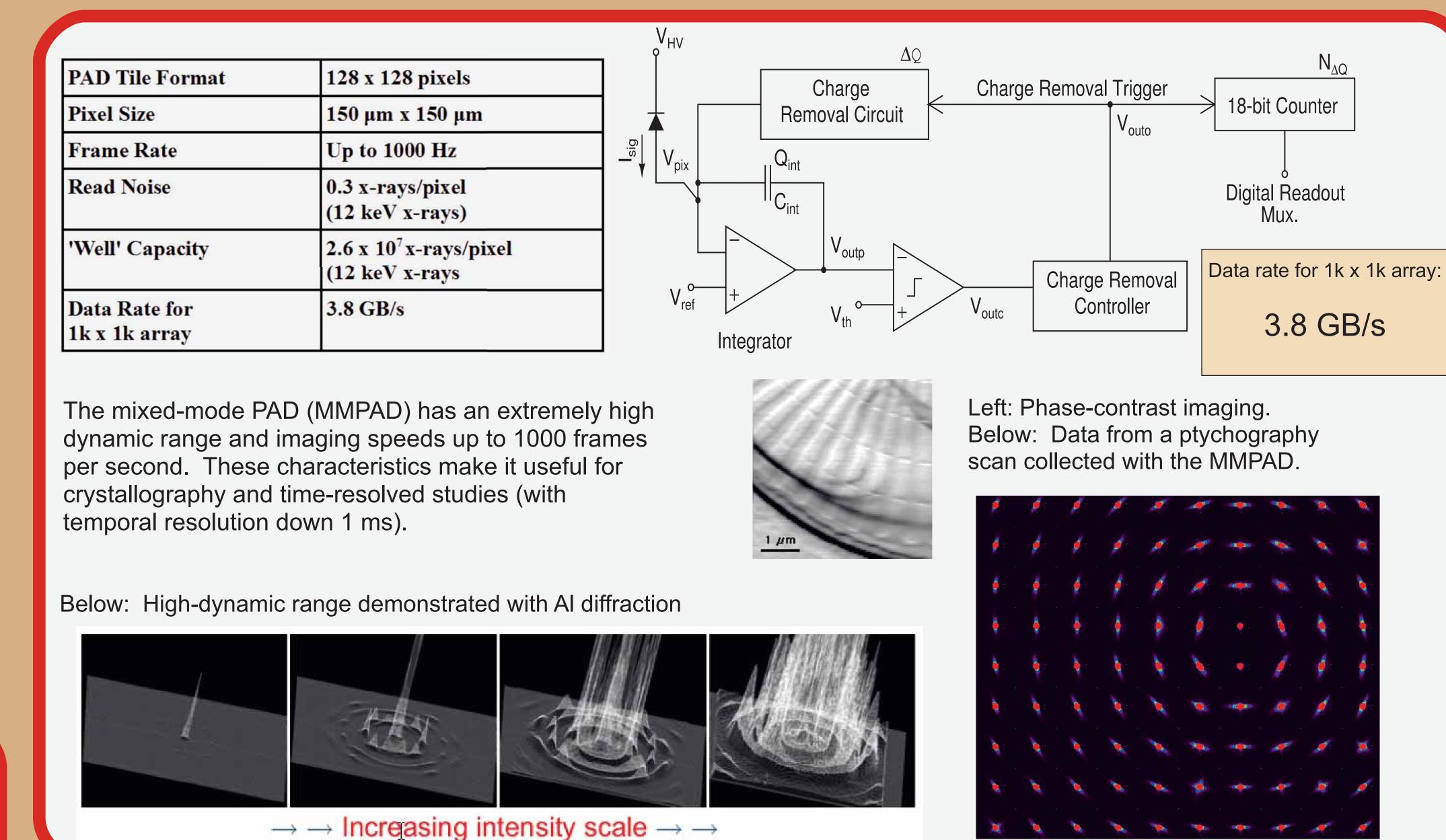


ref. [1,2]

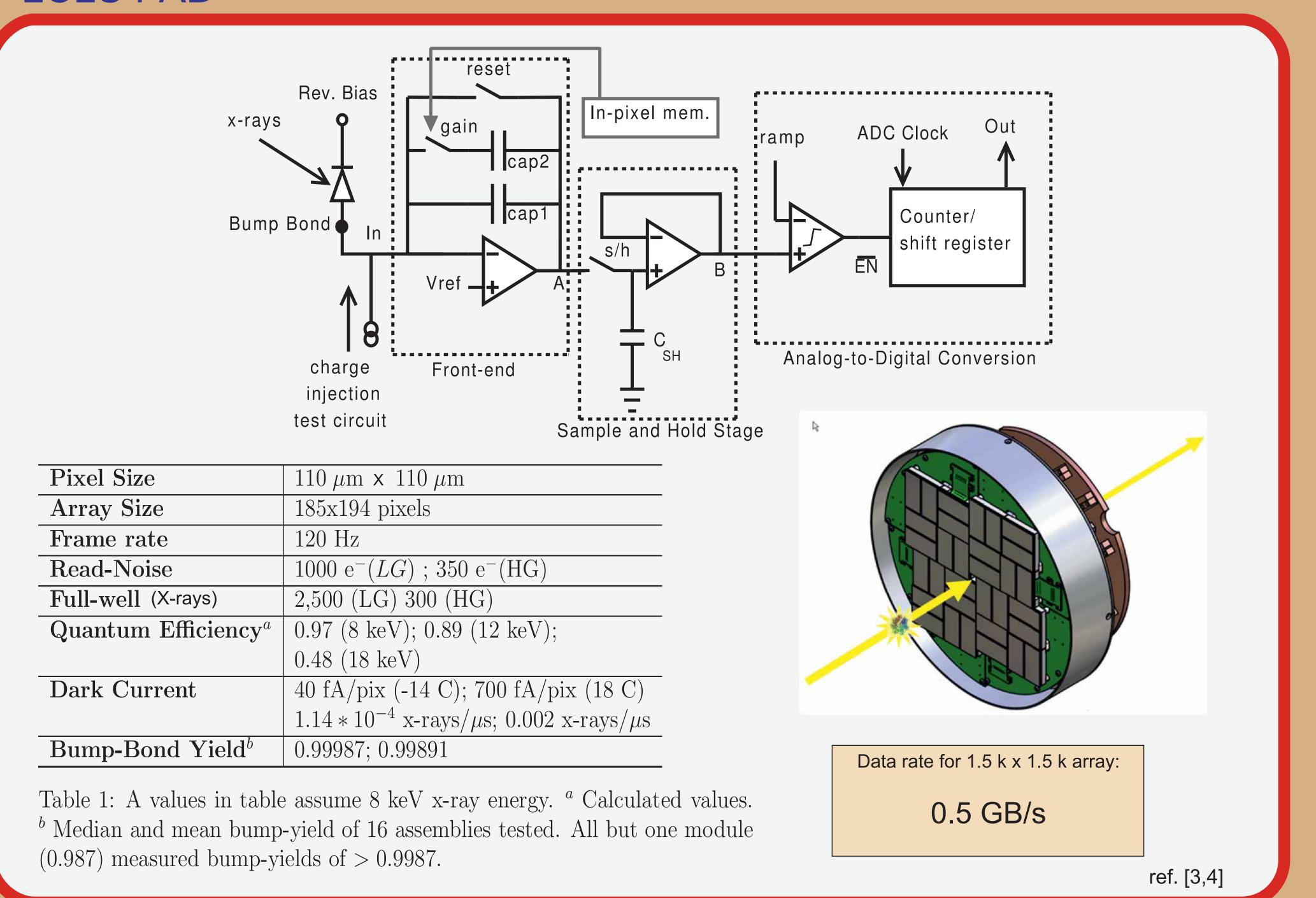
Data rate for 256x 512 PAD:

0.25 GB/s

#### Mixed Mode PAD



### LCLS PAD

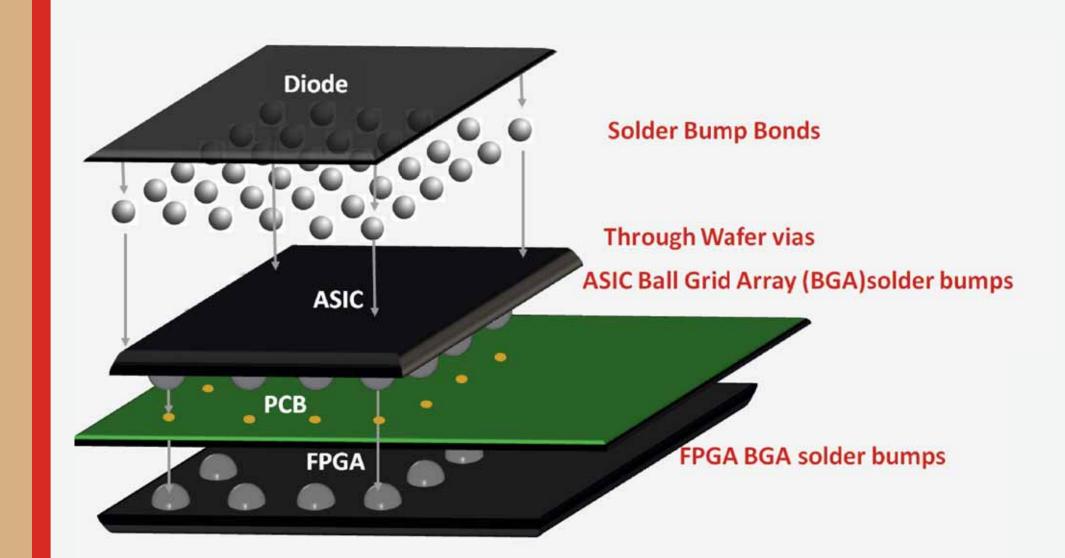


# Smart Pixel Array Detectors

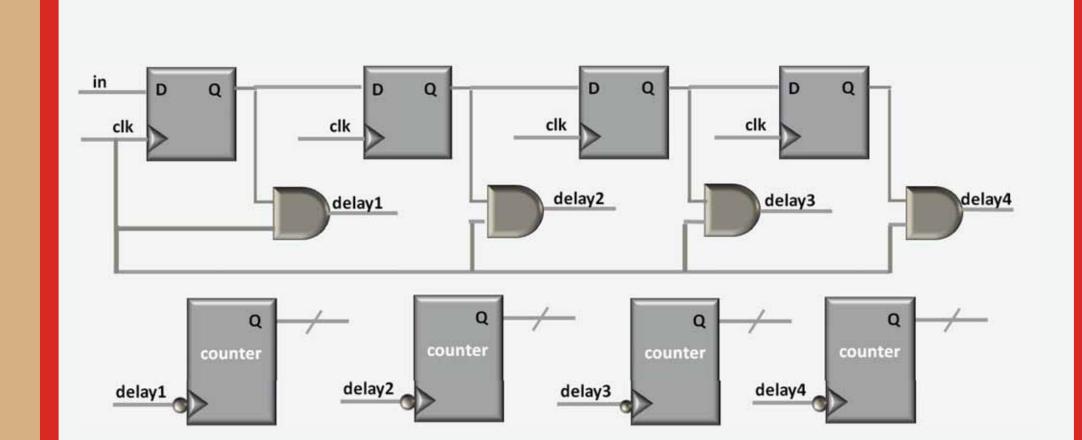
Under DOE-BES support, we are addressing the problems of massive data flows from these and future PADs. The volume of data produced by advancing detector technology means two technical problems must be addressed. In simple terms, these are:

- Getting the data off the detector and into
- Processing enormous amounts of data and extracting meaningful results.

Real-time processing of data with a low-level connection between the pixel array detector and programmable logic can address both of these.



Above: Conceptual (and possible physical) connection between Detector and Programmable logic.

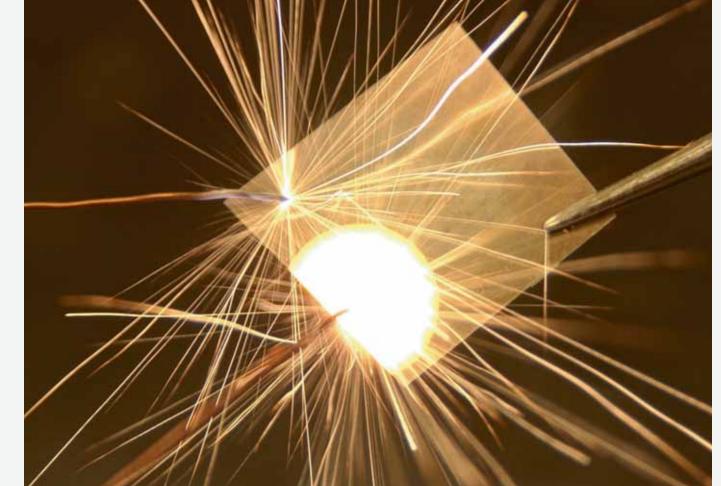


Above: Calculating the autocorrelation function of pixels in real-time is one possible application of programmable logic coupled closely to pixel readout. It serves as a test application with direct relevance to speckle experiments.

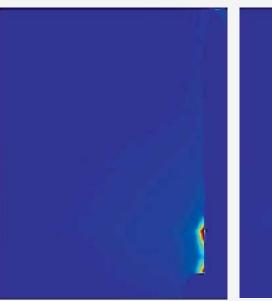
Device Family	Logic Cells	Maximum Block RAM	DSP slices	PCI Express interfaces	Maximum User IO	Ultra-fast IO
Virtex 4 (2004)	142,00	6 Mbits	512	0	960	24
Virtex 5 (2006)	330000	18 Mbits	1056	4 (2 soft)	1000	48
Virtex 6 (2009)	549,888	38 Mbits	2000	4	1200	48
Virtex 7 (2010)	1,954,560	56 Mbits	3900	4	1200	72

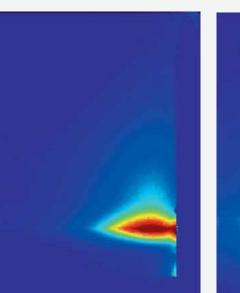
Above: The processing capability and I/O of FPGAs are increasing at an astonishing rate.

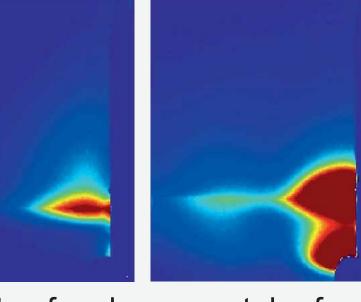
# Time-Resolved Studies Using PADs



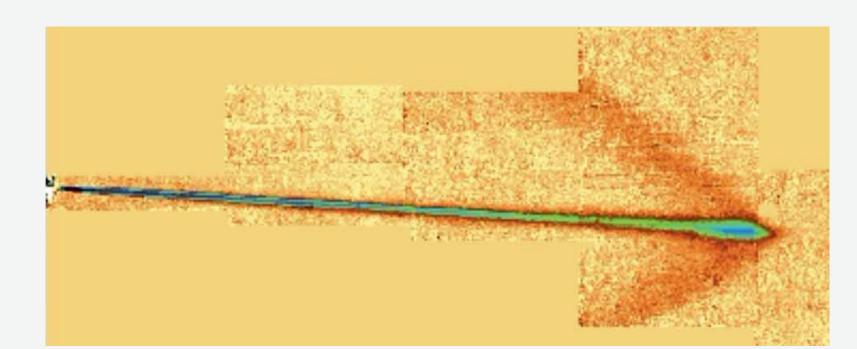
intermediaries using predecessor to the KECK PAD. Time resolution in microsecond [5].







Real-time measurements of carbon nanotube forest nucleation, growth and termination. (LCLS PAD) Frame rate: 100 Hz [6,7].



Supersonic diesel fuel jet imaged with predecessor of the KECK PAD [8,9].

Contact: Sol Gruner, smg26@cornell.edu

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Work of past and present members of the detector group is presented. Present group members include:

Sol Gruner, Mark Tate, Hugh Philipp, Darol Chmberlain, Prafull Purohit, Kate Green, Marianne Hromalik and Martin Novak

We would also acknowledge past group members: Lucas Koerner, Tom Caswell, Guiseppi Rossi, Sandor Barna, Bob Wixted, Eric Eikenberry, Dan Schuette, Alper Ercan, Matt

# References and Selected Publications

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