



X-ray Detectors for High Energy Physics Research and Diagnostics

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ABSTRACT

Sydor Technologies has a rich history of commercializing lab technologies, stemming from the cutting-edge streak cameras developed at the Laboratory for Laser Energetics (LLE). In the company's 20-year history, Sydor has fostered relationships with multiple groups at the LLE, as well as Cornell University, and Brookhaven National Laboratory. These relationships have resulted in the development and commercialization of new detectors for high energy physics and synchrotron science including burst rate and continuous framing X-ray pixel array detectors, diamond X-ray beam position monitors, and solar blind UV photodiodes. All of these developments have expanded Sydor's product offerings to include detectors for hard X-rays (>50 keV) to the deep UV (<250 nm). This suite of detectors gives researchers diagnostic options specifically designed for demanding environments like those in synchrotron X-ray science and fusion experiments, that can be customized to meet specific research needs.

DIAMOND BEAM MONITORS

Products resulting from collaborations with researchers at Brookhaven National Laboratory for measuring X-ray beam position, profile, and intensity at synchrotron beamlines.

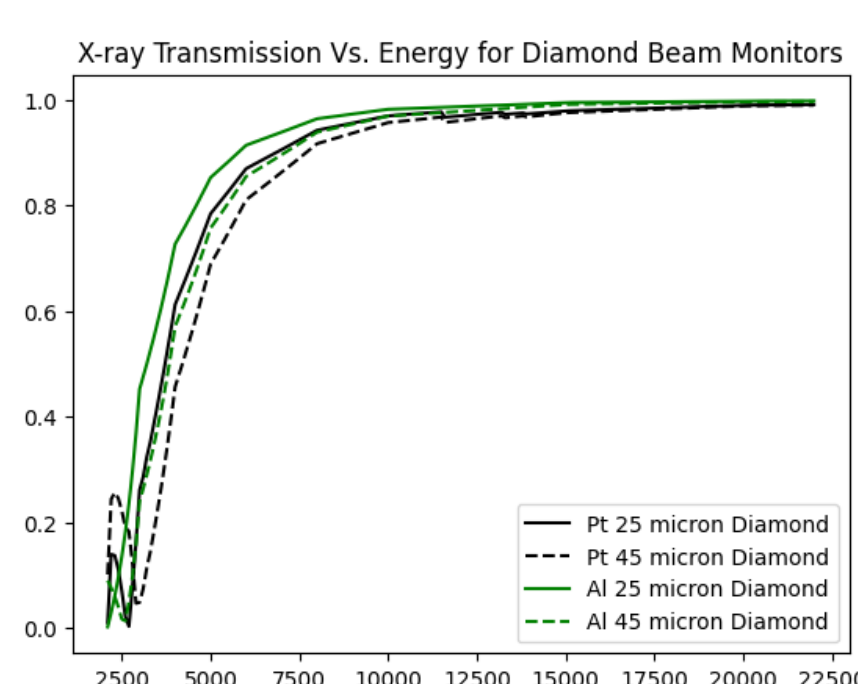


Figure 1. Calculated transmission of aluminum and platinum coated CVD diamond from 2 to 23 keV. > 90% transmission > 6 keV enables in situ measurements of: flux, position, and beam profile.

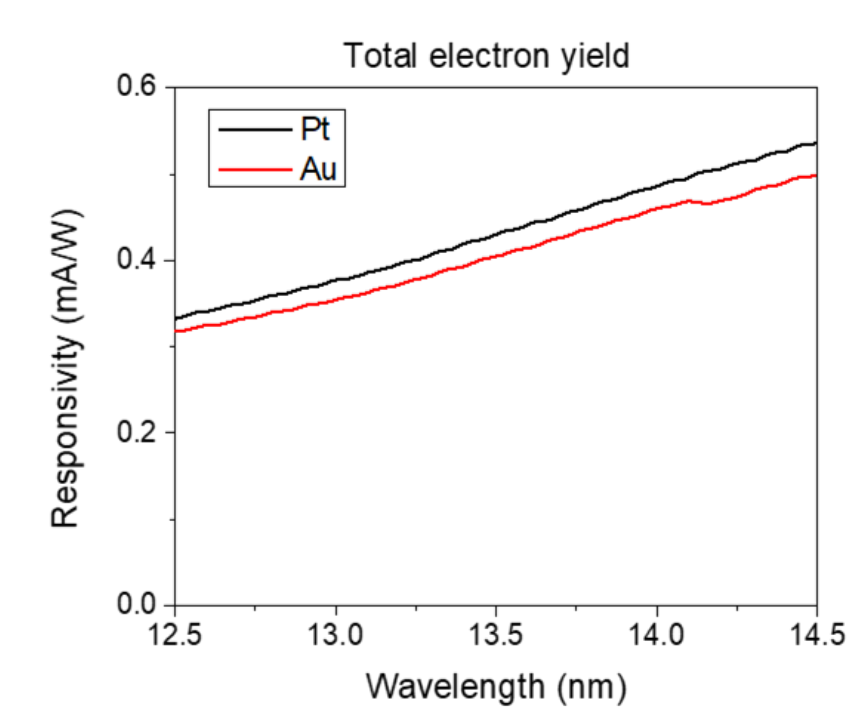


Figure 2. Deep UV response of diamond from calibrations at the Advanced Light Source for pulsed UV lithography. High thermal transport properties, ~230 nm cutoff wavelength.

Quadrant and Single Channel DBPMs

- Stage-Mounted (compact, UHV compatible)
- Flange-Mounted (CF flange, high heat load applications)
- continuous flux and position data
- 3 mm aperture
- 50 pA - 5 mA, 4 channel electrometer
- ns timing resolution configuration with pulsed bias voltage

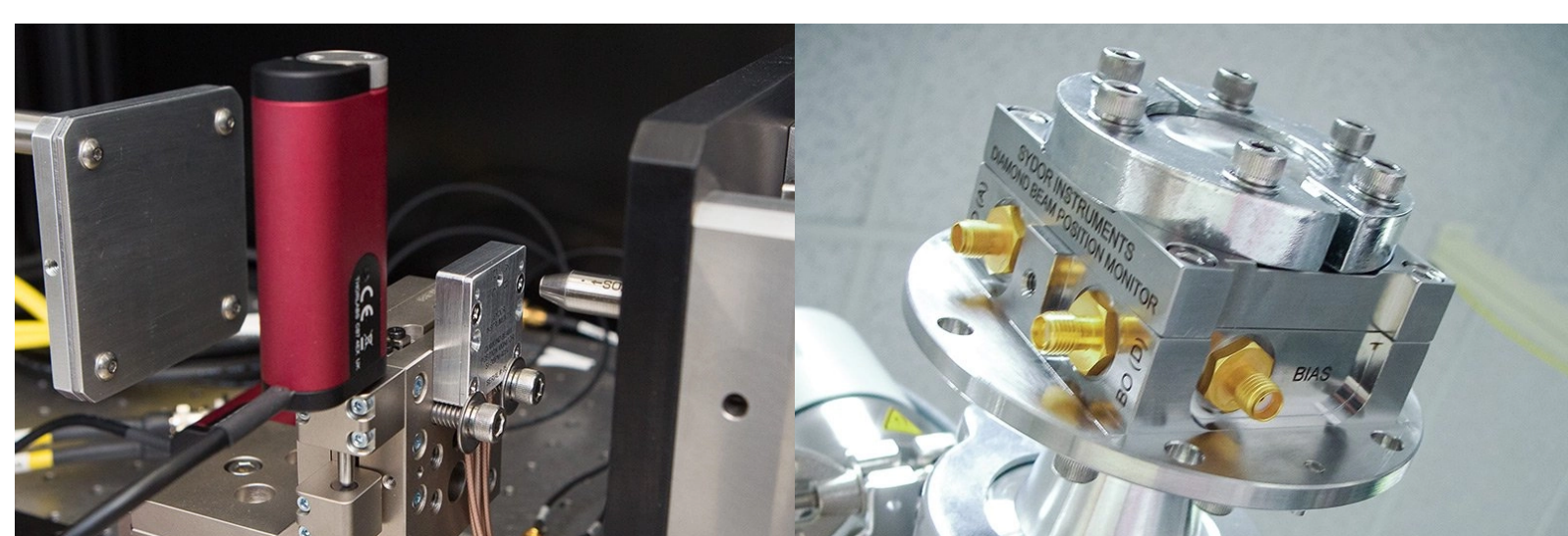


Figure 3. Left: Sydor Stage-Mounted DBPM (1.25" square stainless case). Right: Sydor Flange-Mounted DBPM (2.75" CF).

Transparent X-ray Camera (TXC)

32 x 32 pixel diamond camera enabling measurement of flux, timing, position, and beam profile while not interfering with X-ray experiments.

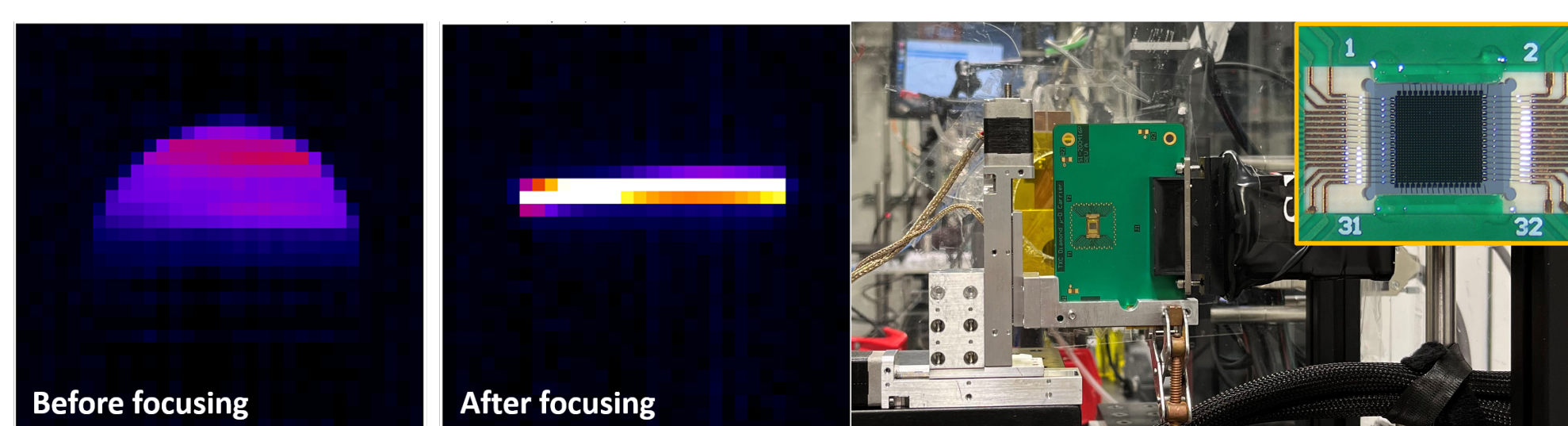


Figure 4. Left: Beam energy profile at XFP at NSLS-II (32 x 32, 80 μm pixels). Right: TXC sensor on carrier board during testing at NSLS-II. Pt coated, 45 μm thick, CVD diamond with 80 μm virtual pixels.

X-RAY DETECTOR SUITE

Hard X-ray Cameras

Products resulting from collaborations with the Detector Group at Cornell University - designed from the ROIC up for fast, high radiation environments like synchrotrons.

Specification	Mixed-Mode (MM)	Keck
Pixel pitch	150 μm	
Array size	512 x 512 pixels	
Sensor material	500 μm Si, 750 μm CdTe	
Frame rate	up to 1 kHz	6.6 MHz, 8 frames
Read noise (X-rays)*	0.17	0.45
Full well capacity (X-rays/pix)*	> 5 x 10 ⁷	> 1 x 10 ³
Instantaneous rate (X-rays/pix/s)*	> 10 ¹²	> 1 x 10 ³
Sustained rate (X-rays/pix/s)*	> 10 ⁸	n/a burst

Table 1. Specifications for the Sydor MM-PAD and Keck-PAD. *specified in units of 8 keV X-rays, and high gain for Keck-PAD

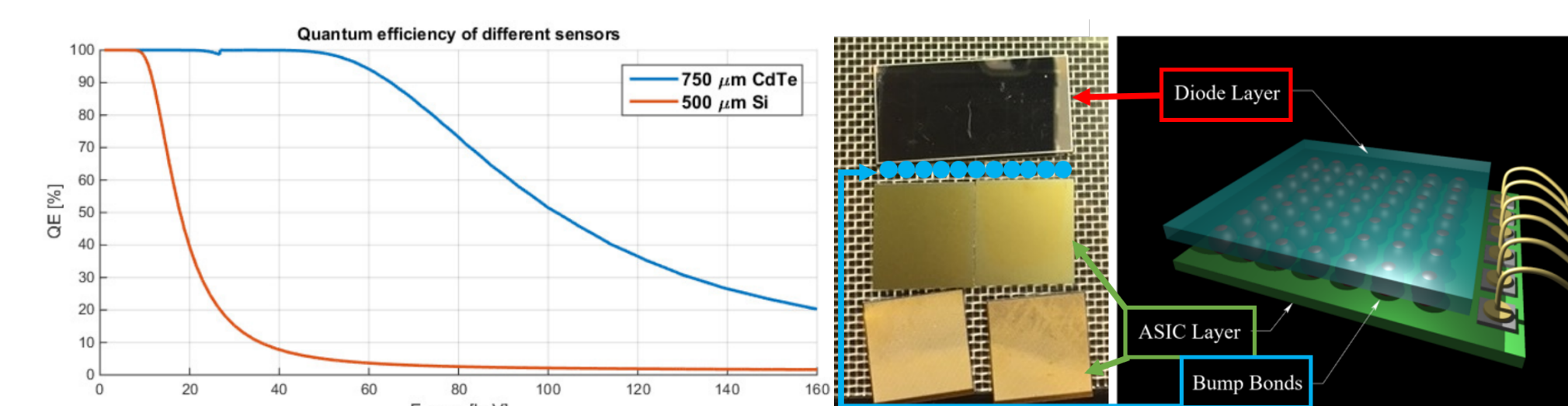


Figure 5. Left: Calculated quantum efficiency for Si and CdTe sensor material. Right: Diagram of flip chip sensor configuration. Current products use 500 μm Si and 750 μm CdTe sensors - Sydor is interested in collaborators developing thinner materials for lower X-ray energies.

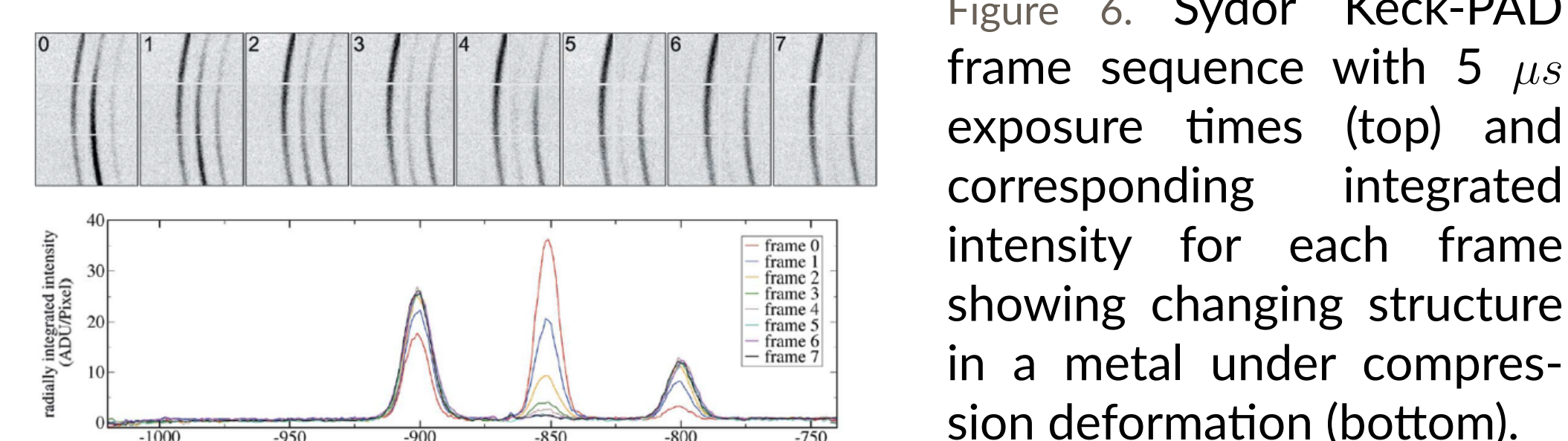


Figure 6. Sydor Keck-PAD frame sequence with 5 μs exposure times (top) and corresponding integrated intensity for each frame showing changing structure in a metal under compression deformation (bottom).

[Husted et al., Journal of Dynamic Behavior of Materials (2018)]

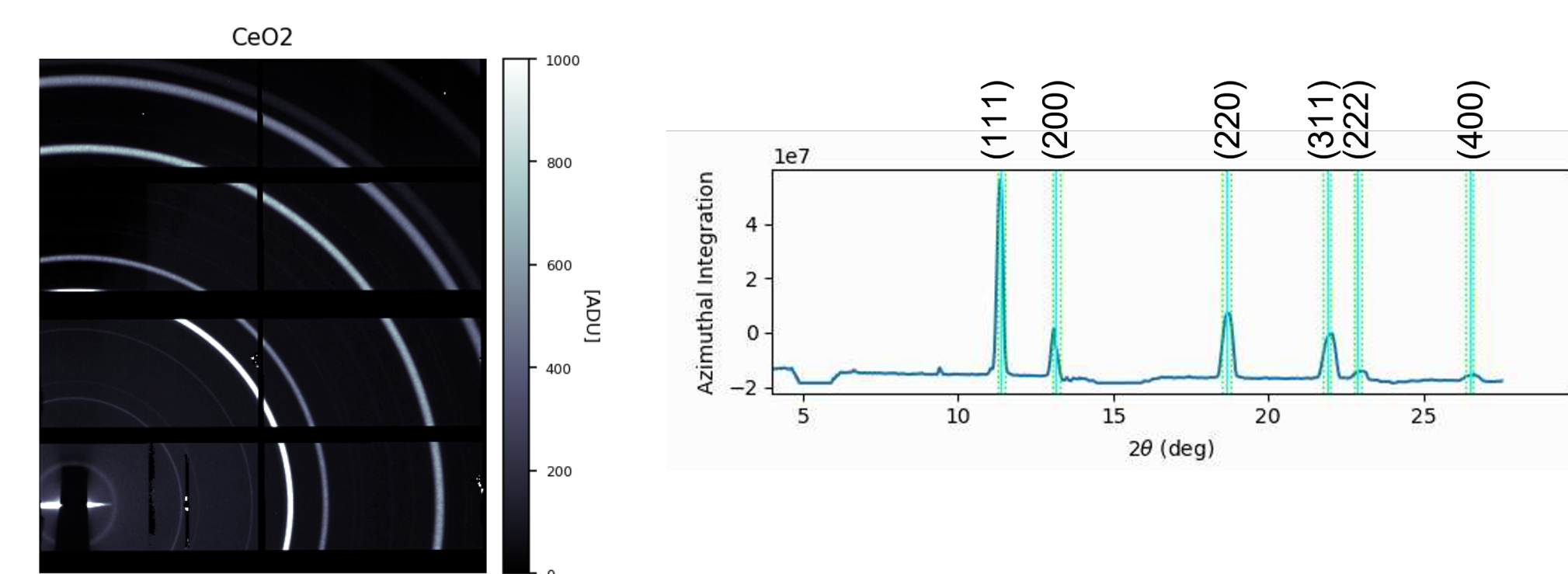


Figure 7. Left: Average of 100, 1 ms exposures of a CeO₂ powder standard measured with MM-PAD at CHESS with 19 keV X-rays. A geometric calibration is applied to account for submodule spacing in the detector array. Right: Azimuthal integration, with CeO₂ peaks labeled.

Soft X-ray CMOS Camera

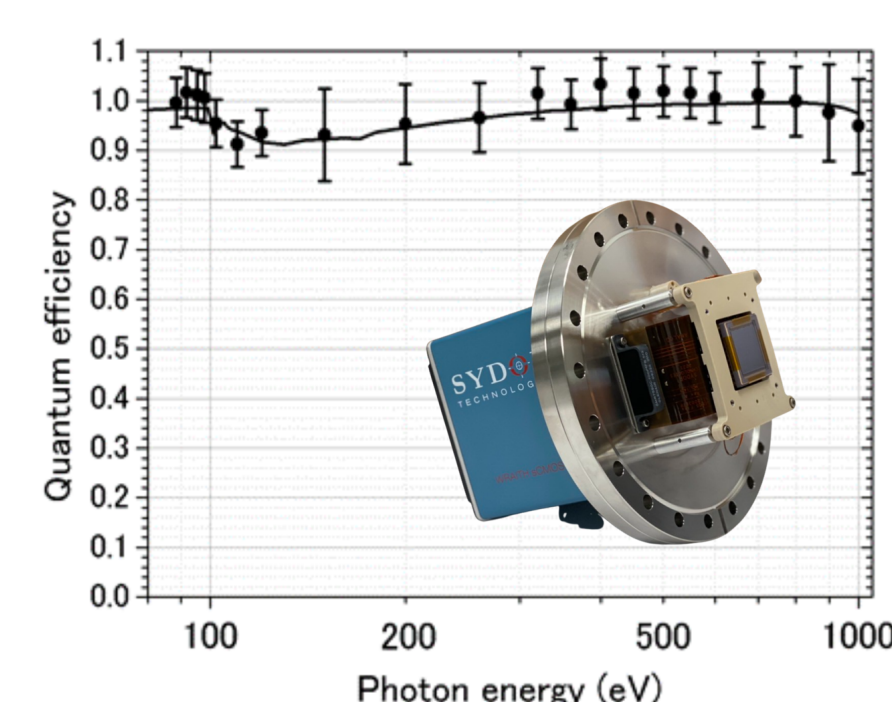


Figure 8. Quantum Efficiency of the Sydor sCMOS Si sensor.

- Sensor Format: 2048 x 2048 pix
- Pixel Pitch: 11 μm
- Full Well Capacity: 80,000 e⁻
- Full Res. Frame Rate: 48 Hz
- Min. Integ. Time: 21 μs
- Read Noise: 2.6 e⁻
- Dark Current: 0.5 e⁻/pix/s
- Spec. Range. EUV to 1 keV
- Vac. Comp.: 10e⁰ mbar

CURRENT R&D

Fast PhotoDetector - Seeking Beta-test Sites

Sydor is developing a < 50 ps rise time metal semi-conductor metal Fast PhotoDetector (FPD) with high responsivity in the extreme ultra-violet (EUV) range. Using Al_xGa_{1-x}N as a photosensitive material, cutoff wavelength and response can be tuned to suit different requirements in fast laser diagnostics like shock, plasma, and optical/UV pump-probe experiments at free electron lasers and other high energy physics facilities. This FPD technology is based on research in the Donaldson lab at the LLE.

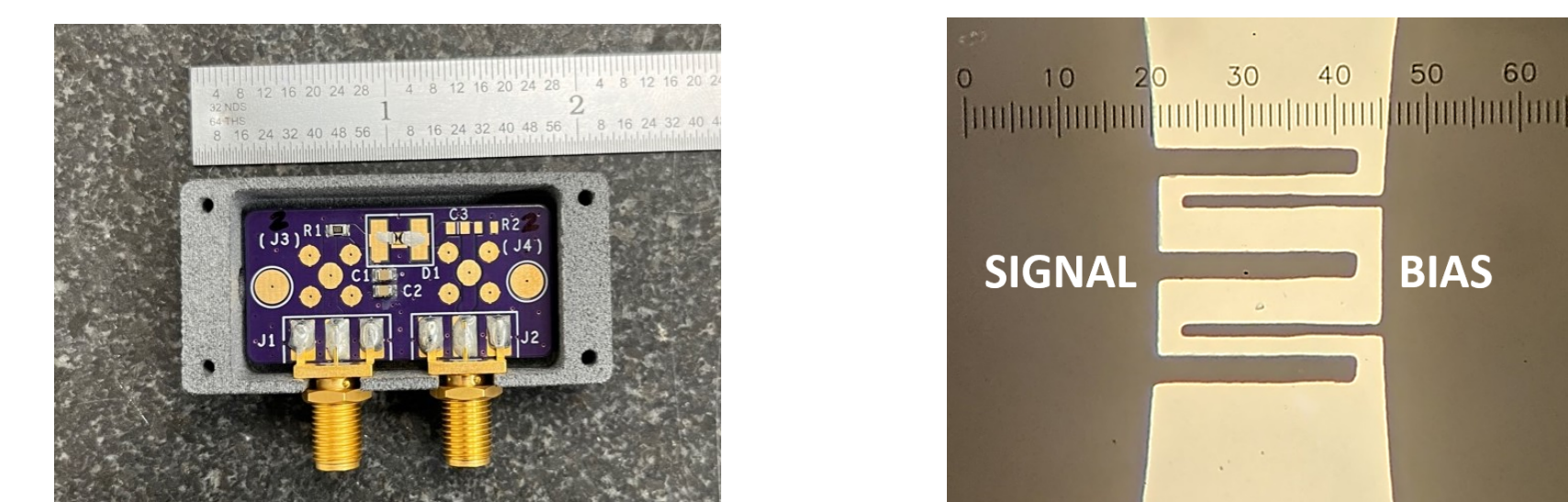


Figure 9. Left: Sydor first generation prototype FPD on printed circuit board. Right: Active area of FPD selected for early testing.

Basic properties will help screen devices for quality before fast optical testing: dark current, IV curves. Using the Donaldson lab laser system, timing and intensity response of early prototypes were investigated and all showed consistent rise time performance < 50 ps.

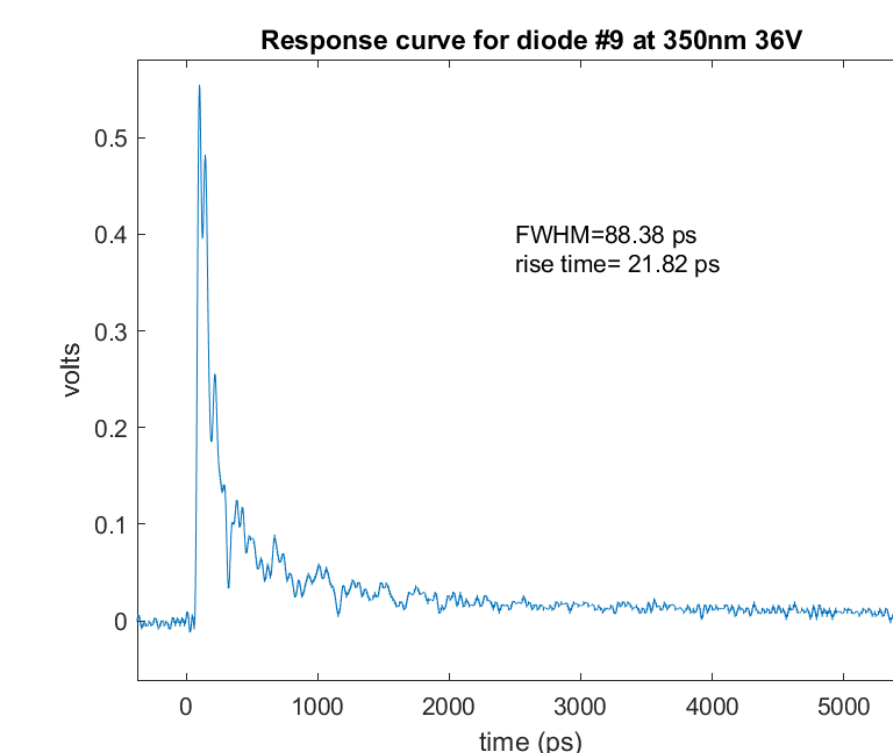


Figure 10. Results of GaN Sydor diode prototype testing at the LLE at 350 nm.

- Approximate power: 5 - 15 μW
- Effective beam size: 16 μm
- Repetition rate: 1 kHz
- Pulse duration: 30 - 100 fs

Improvements based on testing to date:

- Switching from 100 μF local bias capacitor to 0.1 μF related to improved pulse width resolution
- Case re-design with more mount points and fiber mount
- Second generation prototype is vacuum compatible

The next project phase will improve overall pulse shape resolution which involves more simulation and PCB iterations.

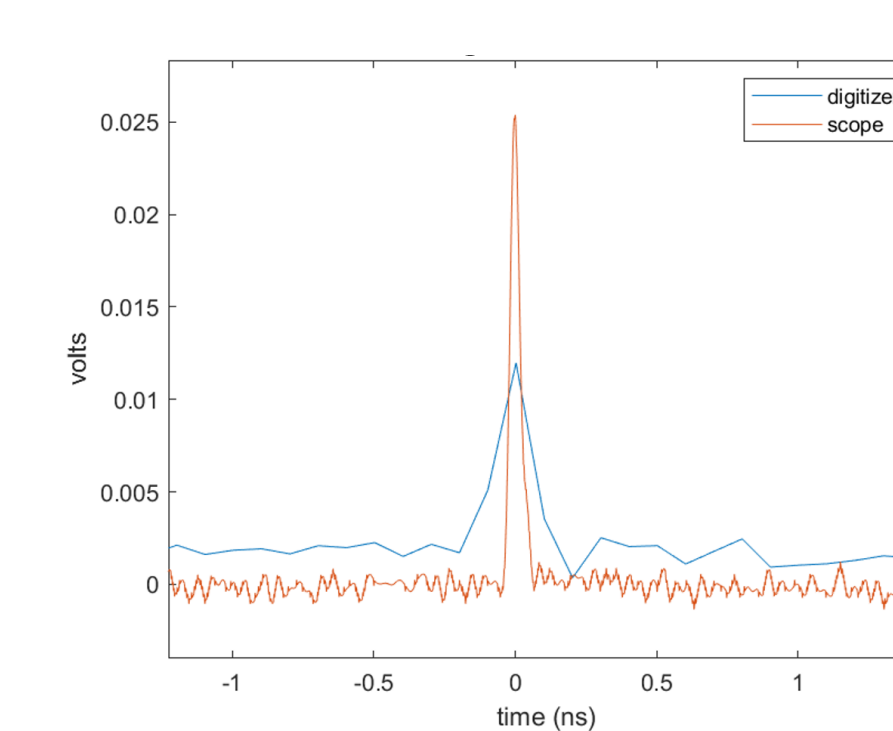


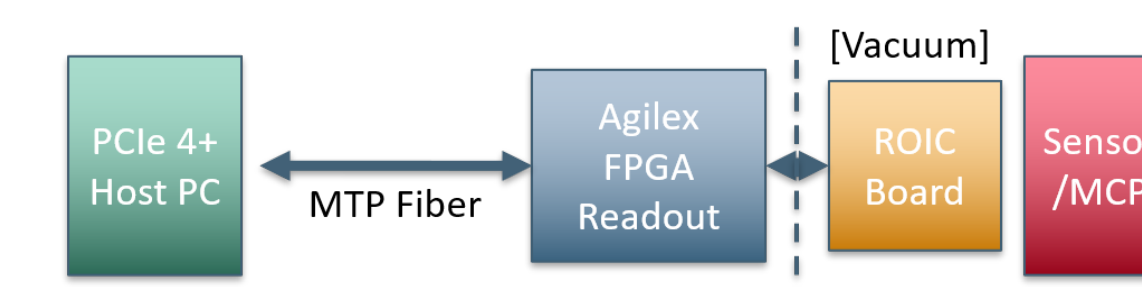
Figure 11. Results from testing a commercial off the shelf 10 GSa/s digitizer with respect to a 64 GSa/s scope using a reference diode.

- Scope: 39.3 ps FWHM, 25 mV response
- COTS digitizer: 131.4 ps FWHM, 10 mV response

Universal Camera Board - Seeking Partners and Funding Opportunities

Sydor is developing a "UCB" program for back end readout electronics that can be adapted to multiple cameras with ROIC-specific software and hardware components. The design was originally funded by development of Timepix4 camera systems and as such, has large bandwidth capability.

- 20.5 GB/s ROIC to PC host data rates (10.24 Gbps x 16)
- Sensor and Host separated by 3-10 meters over optical fiber
- Current PCIe 4.0 rated for 31.5 GB/s
- Potential ROIC implementations: Icarus/hCMOS, Gpixel Gsense soft X-ray CMOS sensors, MM-PAD and Keck-PAD in smaller form factors



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