SLAC-PUB-15843

CSPAD upgrades at LCLS

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***Abstract*– The Cornell-SLAC Pixel Array Detector (CSPAD) is the workhorse for LCLS hard x-rays experiments. After deploying three 2.3Mpixel and many 140kpixel cameras, SLAC detector group has focused in improving the detector performances and optimizing its use in experiments. This was achieved first by improving thermo-mechanical assembly, PCB level electronics and firmware. The next step consisted in upgrading the ASIC. Continuous improvements in GUI and DAQ completed the evolution of the CSPAD systems, up to the current version V1.6, and made these cameras easy to use and optimize for a given experiment. More than 85% of the hard x-ray experiments scheduled in run 7 used one or multiple CSPAD cameras.**

I. Introduction

The Cornell-SLAC Pixel Array Detector (CSPAD) [1 - 4] is the workhorse for LCLS hard x-rays experiments. Fig. 1 shows the basic pixel schematic of this hybrid pixel detector and Table 1 summarizes the basic properties of all CSPAD cameras.

After deploying three 2.3Mpixel and many 140kpixel cameras, SLAC detector group has focused in improving the detector performances and optimizing its use in experiments. Upgrading electronics, firmware and ASIC was needed to improve the performances of these detectors. In addition refining characterization, calibration and operating conditions allowed understanding fine details and finally optimizing the cameras for a given experiment.

Modifications in the PCB power supply, improved bias and ramp generation have helped to mitigate crosstalk and together with the upgraded ASIC version V1.5 provides more consistent results among all pixels. This in turn eases data visualization and analysis. The upgraded ASIC includes on chip DACs to set the bias currents of all amplifiers. The new chip also supports power cycling by design. Together this simplifies the PCB level complexity and eases the integration of many ASICs into one camera. Homogeneity across the full reticle size chip was improved by redesigning the power distribution.

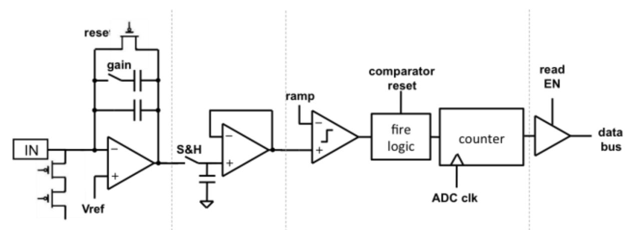

Fig. 1: Schematic of a CSPAD pixel.

TABLE I. CSPAD PROPERTIES

Pixel size	110 µm x 110 µm
Area	326 cm^2 (2.3 Mpixel)
Maximum signal	2700 8 keV photons/pixel (low gain) 350 8 keV photons/pixel (high gain)
Frame rate	120Hz
Noise	~ 3.5 keV (low gain) ~ 1 keV (high gain)

II. CSPAD Upgrades

The two CXI CSPAD-2.3M cameras have been upgraded to V1.2 status. This work included improved power supplies and power distribution and a revised cable harness. Besides a significantly increased operational reliability, the new power supply units can support one 2.3Mpixel together with up to four 140kpixel cameras: this is more often needed with the increasing number of experiments requiring multiple detectors for concurrent techniques.

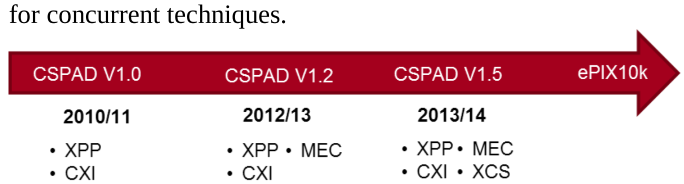

Fig. 2: Timescale of CSPAD upgrades at LCLS

The XPP/XCS CSPAD-2.3M camera was upgraded in October 2013 with the new ASICs and is currently at the V1.5 revision.

Manuscript received November 15, 2013. SLAC-PUB-15843.

Use of the SLAC National Accelerator Laboratory, was supported by the U.S. Department of Energy, Office of Science, Office of Basic Energy Sciences, under Contract No. DE-AC02-76SF00515.

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Work supported by US Department of Energy contract DE-AC02-76SF00515 and BES.

The majority of the CSPAD-140k cameras are now equipped with the new ASIC and new PCB electronics reflecting V1.5 revisions. Newer versions with improved linearity and gain homogeneity have been deployed to XPP for pump probe experiments and designated as V1.6 revision. Fig. 2 shows the basic time line of the LCLS CSPAD upgrades.

III. Camera Performance

The effect of the improved homogeneity can be also observed in the spectroscopic measurements shown in Fig. 3. The measurements were taken at SSRL beamline 7-2. The histogram shows the CSPAD response to five monochromatic energies. All pixels of four ASICs comprised in the 140kpixel camera are included in this histogram. It is worth noting that no gain-correction is applied.

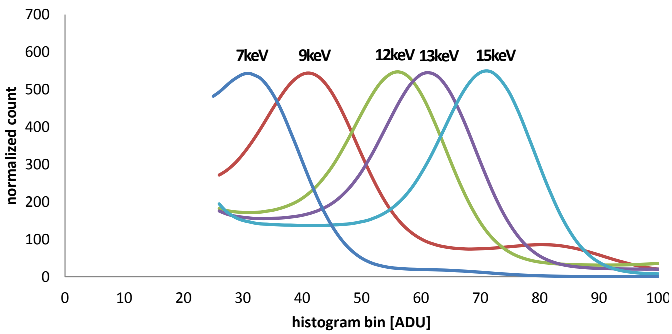

Fig. 3. CSPAD-140k V1.5: histograms of all the pixels for five different monochromatic energies. Measurements performed at SSRL BL 7-2. The histograms include only entries with amplitudes higher than 25 ADU. Counts have been scaled and normalized on the vertical axis to show the same peak height for comparison. No pixel gain correction has been applied.

The gain homogeneity of a CSPAD-140k V1.6 is quantified with the measurement in Fig. 4 where the gain of a specific pixel is plotted against the pixels dark pedestal. A flat field illumination with a Molybdenum line is measured and the single photon gain of every pixel extracted. The whole range of measured gains for the Molybdenum line is centered at ~70 ADU with 5% rms variation. A correlation of the measured gain and the pixels dark pedestal can be seen: this correlation originates from the single slope ADC comparator kickback into the ADC ramp distribution.

Further measurements with the new ASIC have been performed at LCLS specifically for linearity characterization. Fig. 5 and Fig. 6 show a linearity measurement carried out at XPP. To perform this measurement at LCLS the beam intensity has to be measured and correlated with the measured CSPAD amplitude on a pulse by pulse basis. The intensity variations after the XPP silicon (111) monochromator covered the range from 0 to 6500 ADU on the CSPAD. The measured dataset had only limited statistics for amplitudes above 3000 ADU. The known systematic non linearity of the CSPAD single slope ADCs has been corrected for this data. The resulting linearity error from 0 to 3000 ADUs is smaller than ±10 ADUs.

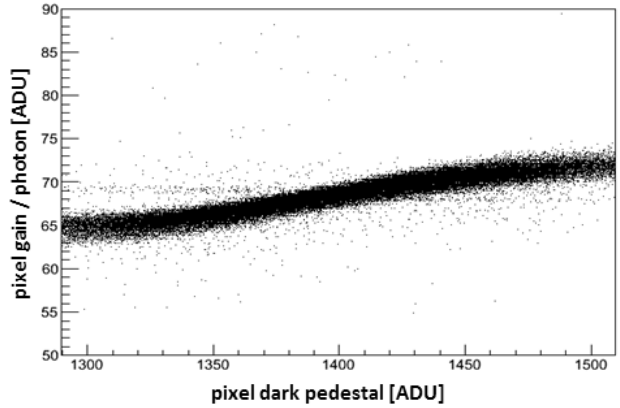

Fig. 4. Gain distribution for the Molybdenum line vs. the pixel pedestal measured with a CSPAD-140k V1.6. The gain variation is correlated with the pixel pedestal. The CSPAD 140k V1.6 shows a single photon gain dispersion of smaller than 5% rms across the chip. Older versions of the camera used at LCLS shown significantly larger gain variations from pixel to pixel.

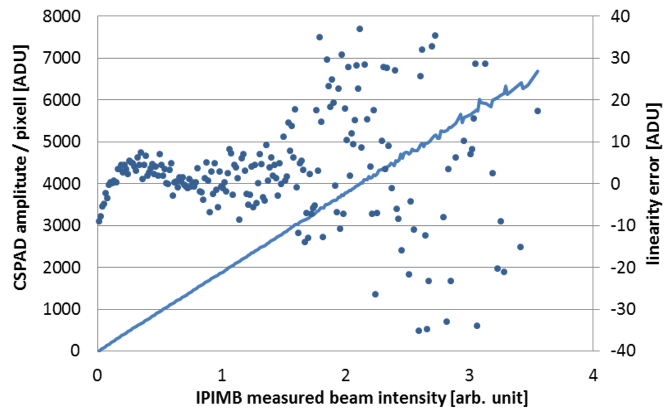

Fig. 5. CSPAD 140k V1.5 linearity measurement performed at the XPP instrument of LCLS. The plot shows the correlation between the measured CSPAD amplitude vs. the measured beam intensity from the IPM3 beam monitor. The CSPAD data is corrected for the systematic nonlinearity of the CSPAD single slope ADCs. The linearity error of the full measurement system shown by the round dots related to the second y-axis stays below ± 40 ADU in the measured signal range (6500ADU). The Measurement is limited by statistics for higher beam intensities.

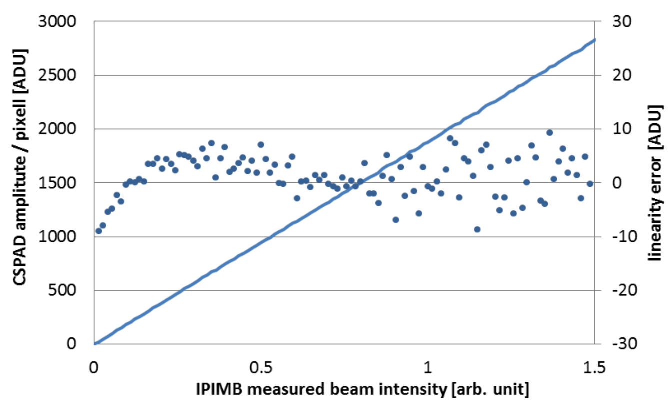

Fig. 6. Same as Fig 5, with a zoom into the region up to 3000ADU which includes better statistics. The linearity error of the measurement system shown by the round dots related to the second y-axis stays below ± 10 ADU in the signal range up to 3000 ADU

One of the first images from the upgraded XPP/XCS CSPAD-2.3M with the new V1.5 ASICs can be seen in Fig. 7. The screenshot from the online software shows a single shot speckle image from a static test sample. It illustrates the good homogeneity across the new ASIC and electronics in this very dynamic illumination condition. Despite the fact that the center ASICs are strongly illuminated there is no obvious rise in the ASIC pedestal (crosstalk)

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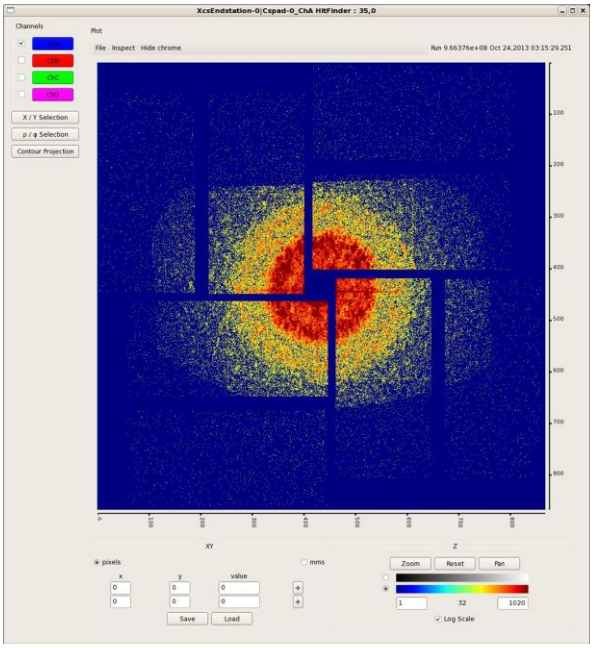

Fig. 7. Single Shot speckle image of a static sample measured at XCS with CSPAD-2.3M V1.5 measured at XCS illustrating he homogeneity of the new ASIC and electronics. The horizontal streak is a result from the beam slits.

IV. New LCLS CSPAD cameras

In addition to the already existing CSPAD-2.3M and CSPAD-140k cameras we have developed variant with 570 kilopixel. The CSPAD-570k consists of four detector assemblies and a total of sixteen ASICs. It is a very compact camera, only slightly larger than the active area front face as is shown in Fig. 8. The first camera of this type has been deployed at MEC.

Finally a modified version of the CSPAD-140k with front faced sensing area has just been recently built. This unit is particularly advantageous where the setup requires minimum obstruction around the sensitive front side (Fig. 9).

V. Conclusion

The overall performances of the CSPAD were improved. Better linearity and gain homogeneity, reduced crosstalk and continuous GUI upgrades made the new CSPAD 140k v1.5 a camera easy to use both at FELs and at synchrotrons. Similar approach is being followed for the 2.3Mpixel cameras. Currently new PCBs and firmware are implemented and work is ongoing to substitute the sensor-ASIC chips and complete the upgrades.

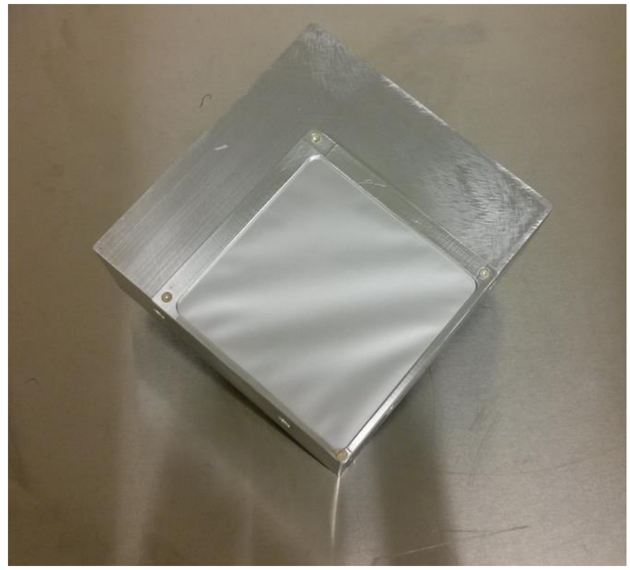

Fig. 8. The new CSPAD-570k. The four detector modules are covert under the aluminized Kapton window. The very compact camera is only slightly larger than the active area.

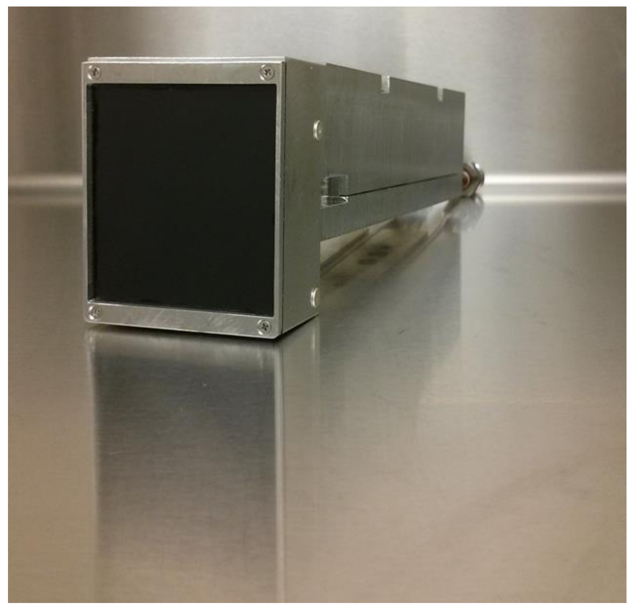

Fig. 9. Front face CSPAD 140k – this assembly variant uses the same components as the side view CSPAD 140k. Its small front side footprint is useful in experiments where minimum obstruction around the sensitive front face is wanted

Acknowledgment

Portions of this research were carried out at the Stanford Synchrotron Radiation Lightsource and at the Linac Coherent Light Source (LCLS) at the SLAC National Accelerator Laboratory. SSRL and LCLS are Office of Science User Facilities operated for the U.S. Department of Energy Office of Science by Stanford University.

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