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CSPAD upgrades and CSPAD V1.5 at LCLS

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Abstract. After improving the PCB level electronics the next step in our continuing upgrade program of LCLS Cornell-SLAC Pixel Array Detector (CSPAD) cameras is the use of a new improved ASIC named CSPAD V1.5. 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. The upgrade included modifications of the gain latches and the per pixel comparators. Results from the upgraded cameras used at LCLS will be presented and discussed.

1. Introduction

The Cornell-SLAC Pixel Array Detector (CSPAD) [1 - 5] 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 performance 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. The upgrades produced first a new version defined as CSPAD V1.2, which implements new electronics, firmware and mechanics, and then, with the addition of a new ASIC, the CSPAD V1.5, which will be the last of this family. Second generation cameras will be built on a new SLAC platform, the ePix family [6]. The evolution of the cameras and their use it is shown in Fig. 1. The basic characteristics of the CSPAD are summarized in Table 1. Upgrades and experimental results are discussed in the following paragraphs.

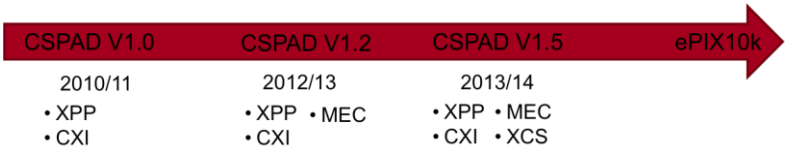

Figure 1. CSPAD cameras: upgrades and use at LCLS.

2. Design upgrades

The first set of upgrades targeted electronics, firmware and some mechanical components. We designed a set of new PCBs with modified power supply and improved bias and ramp generation circuits. These PCBs were swapped in during instrument maintenance at CXI and XPP. The new

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electronics have helped mitigate the nonlinearity and crosstalk problems observed with the first version of the cameras [5]. The cameras with the improved electronics are labeled as version 1.2. Another important upgrade involved power supplies and cable harness. Besides a significantly improved operational reliability, the new power supply units can support one 2.3Mpixel together with up to four 140kpixel cameras for experiment with concurrent techniques using multiple detectors. Alternatively up to eight CSPAD-140k detectors can be operated (this variant is deployed at the MEC instrument).

Mechanics upgrades were implemented to improve the thermal stability and enable a more compact camera housing for the 2.3Mpixel XPP detector. A new compact solid cooling plate replaced the original CXI-style design. This is especially important because this camera is mounted in a robotic arm and the very compact housing is a premium for placing the detector in critical positions around the sample.

Firmware and Software are continuously improved. The camera front-end firmware has seen improvements for debug-ability and slight performance increases. It now also includes the option to integrate for a full 8ms cycle, enabling the use of the camera at synchrotron with less than 1% dead time. The data acquisition software used for configuring and reading out the CSPAD has been made more fault-tolerant and efficient. Support has also been added for compressing CSPAD data. Many features have been added to improve analysis of the CSPAD image in real time, including: a hit finder that can also do thresholding and pixel sums, image averaging for binned and unbinned images, certain geometry corrections, improvements in common mode calculation, center of mass calculation, calculation of mean and variance of image, and the ability to suppress or enable pedestals at the click of a button. The software is highly configurable for specific experimental conditions and more responsive to user input.

Table 1. CSPAD properties

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

Finally the CSPAD ASIC was modified to overcome some of the limitations experienced with the first version of the chip. Without significant changes in the architecture, the upgraded ASIC includes on chip DACs to set the bias currents of all amplifiers. The new chip also supports power cycling by design. 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. The improved ASIC homogeneity across the full chip is shown in Figure 2.

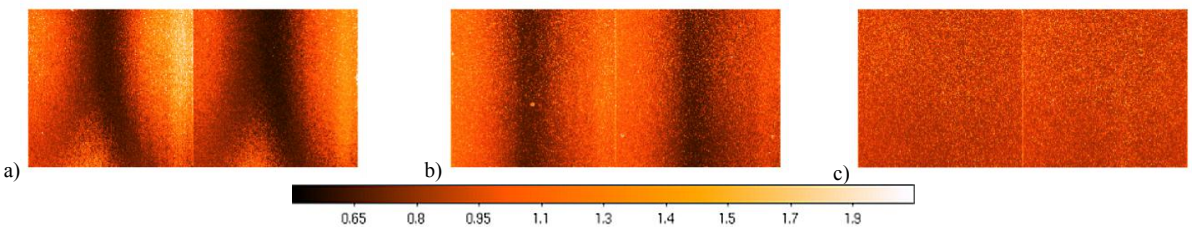
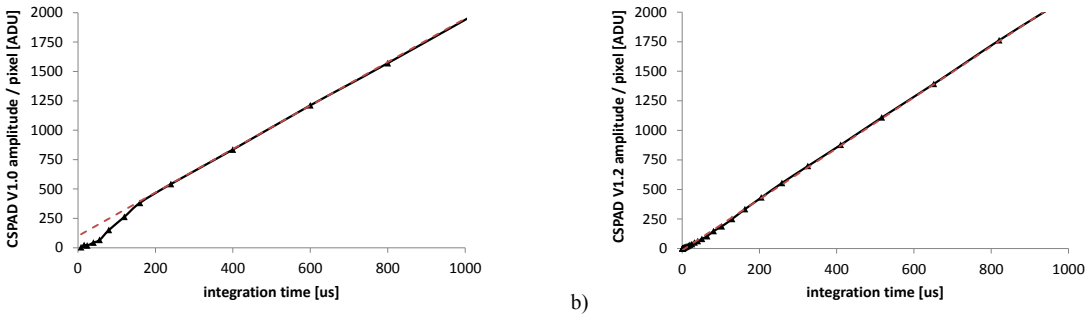


Figure 2. Series showing the improvements in homogeneity of different CSPAD versions. a) V1.0, b) V1.2 and c) V1.5. The images show the noise distribution of a CSPAD building block consisting of two ASICs bump bonded to one sensor element. The images (in arbitrary units) are normalized to show the same average noise level (set to 1.0). The scale includes the range from 50% to 200% of the average noise level of the module.

3. Measurements and camera deployment

All these upgrades made the CSPAD detectors easier to use and to adjust to the needs of very different experiments with requirements within the limit of these cameras. Performance improvement has been systematically investigated and validated with x-rays at synchrotrons and at LCLS [7]. For example figure 3 shows the improvement on the linearity of the 2.3Mpixel camera. The measurements were carried out at the Stanford Synchrotron Radiation Lightsource (SSRL) BL 2-2 with 9keV monochromatic beam by increasing the integration time under constant illumination.

The improved homogeneity of the CSPAD V1.5 ASIC can be also be observed in the spectroscopic measurements shown in figure 4. The measurements were taken at SSRL BL 7-2. The histogram shows the CSPAD response to five monochromatic energies. All pixels of the four ASICs comprised in the 140kpixel camera are included in this histogram without any pixel gain-correction applied. All the measurements were performed at room temperature.



a) b)

Figure 3. Linearity response of CSPAD in high gain mode. Measurements carried out at SSRL BL 2-2. To achieve a linear input signal the integration time of the camera was changed under constant illumination conditions. The early version of the 2.3Mpixel CSPAD detector (a) shows a distinct nonlinearity at low signal levels caused by pixels crosstalk. The improved camera version 1.2 delivers better linearity response (b).

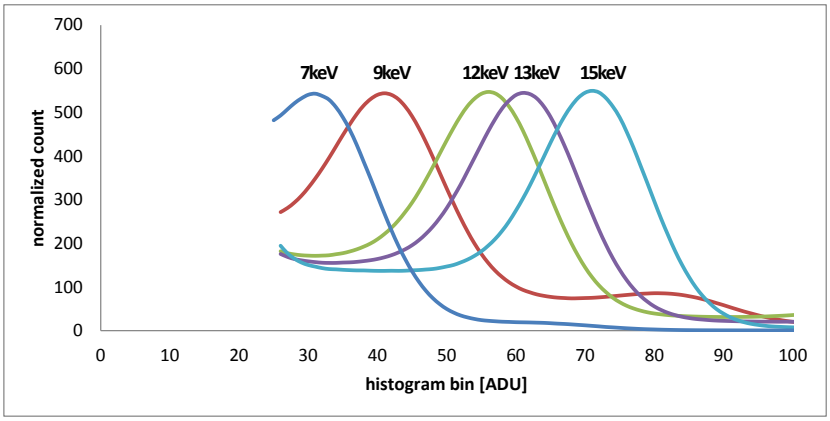


Figure 4. CSPAD-140k V1.5: histograms of all the pixels for five different monochromatic energies. Measurements performed at SSRL BL 7-2. The histograms only include entries with measured amplitudes higher than 25 ADU. Counts have been scaled on the y-axis for normalisation to show the same peak height for comparison. No pixel gain correction has been applied.

As result of this continuous effort to improve CSPAD detectors and user interface, these cameras have been used in all the hard x-rays instruments at LCLS in a variety of experiments. Thanks to a better control of the detector settings, challenging measurements at the limit of the detector capability, e.g.

low noise, low signal, low energy (as low as 2.2keV) and very high maximum signal over large areas, were successfully performed. In addition CSPAD-140ks have been used at SSRL, SACLA and at the Advanced Photon Source (APS). Examples of setup are shown in figures 5 and 6.

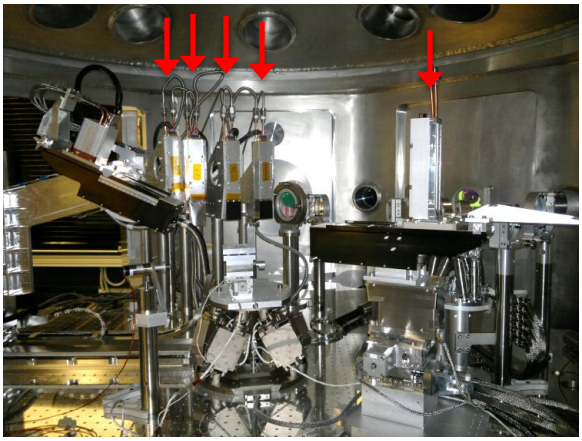


Figure 5. Arrangement of multiple CSPAD-140k cameras (left) including one used in a Thomson spectrometer (right) at the MEC instrument of LCLS.

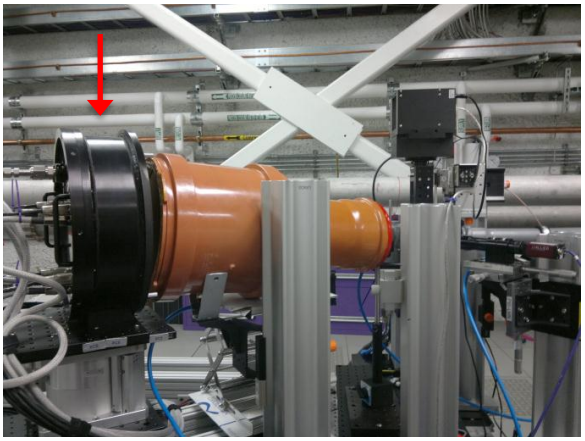


Figure 6. The 2.3Mpixel CSPAD V1.2 used for an experiment at XCS: the large area and fast readout were crucial for a delicate alignment.

References

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