SLAC-PUB-15287

CSPAD-140k – Experimental Applications at LCLS

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***Abstract*– With the successful operation of three 2.3 megapixel, 120Hz readout rate, hybrid pixel array detectors at the Linac Coherent Light Source (LCLS), the SLAC detector group is now exploring further applications based on the same detector platform. These megapixel cameras are based on the Cornell-SLAC hybrid Pixel Array Detector (CSPAD).**

The next detector variant based on the proven CSPAD platform is the CSPAD-140k: a 140 kilopixel detector, with an active area of ca. 4x4cm2, in a small, cheap and easy-to-deploy package.

The small and modular design allows for easy adaptation to already existing experimental setups which often have tight space constraints. A further advantage of the modular design is the capability to deploy multiple detectors in various mechanical arrangements.

I. Introduction

With the successful operation of three 2.3 megapixel, 120Hz readout rate, hybrid pixel array detectors at the Linac Coherent Light Source (LCLS), the SLAC National Accelerator Laboratory detector group is now exploring additional applications based on the same detector platform. These megapixel cameras are based on the Cornell-SLAC hybrid Pixel Array Detector (CSPAD).

The CSPAD platform is developed around the CSPAD ASIC [ref], a 36 kilopixel device, each pixel at 110x110μm^2. The CSPAD can be operated at room temperature, offers 14bit on chip digitization with a purely digital data interface, and scaling modularity. These important characteristics make it an effective choice for designing detector variants that are optimized for a range of experiments and applications.

One of the first spin-off detectors based on this proven CSPAD platform is the CSPAD-140k: a 140 kilopixel detector, with an active area of approximately 4x4cm^2 and four ASICs, bundled in a small, inexpensive and easy-to-deploy package (see Fig. 1). Due to its versatility it has already been used successfully in several experiments at the CXI, XPP and XCS instruments at LCLS as well as at the Stanford Synchrotron Radiation Lightsource (SSRL) and at the Argonne Advanced Photon Source (APS), and will soon be used for an experiment at the Spring-8 Angstrom Compact free electron LAser (SACLA). In this paper we report applications at LCLS only.

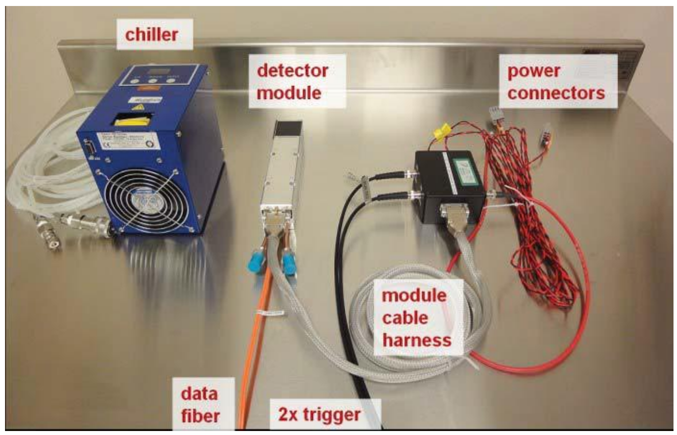

Fig. 1 The full CSpad-140k kit consists of the detector module with 140kpixels, data fiber, power cable, interface box and a chiller for water cooling.

II. 140k Camera Description

The central component of the CSPAD platform is the hybrid pixel detector ASIC with 194x185 pixels of 110x110um^2 size. Two ASICs are bumped to a single monolithic silicon pixel array, resulting in a 2x1 module of 388x185 pixels. This module is the building block of all CSPAD cameras. The CSPAD-140k uses two of those glued to a carrier, building up a 2x2 module with a total of ca. 140 kilopixels.

The hybrid pixel design enables electronic shuttering. At LCLS beamlines integration time of CSPAD can be as short as a microsecond and therefore the detector can operate at room temperature without performance degradation from leakage current. For operation in vacuum, the temperature is stabilised by water-cooling. The design also supports utilisation of a Peltier element to cool the detector in applications which need longer integration times like experiments at synchrotrons.

The 140k-module uses a fiber-optical interface to transfer data to the data acquisition system. Power and triggering use a

Manuscript received November 16, 2012. SLAC-PUB-15287

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Presented at IEEE NSS-MIC 2012
Anaheim, CA, October 29 thru November 3, 2012

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

26pin DSUB connector. These features make a small but robust interface facilitating the deployment of the detector in an experimental chamber.

III. CSPAD 140K APPLICATIONS AT LCLS

An application where the CSPAD-140k has proven its versatility is as detector in a spectrometer configuration. Figure 2 shows the detector installed in this configuration into the CXI instrument at LCLS [4]. In particular the picture shows the setup just before the installation of the wavelength diffractive elements into the vacuum chamber.

Another example of spectrometer setup is depicted in Figure 3. The drawing shows how the CSPAD-140k will be integrated into a Thomson scattering spectrometer to be used at the MEC instrument of LCLS. In this experiment the CSPAD-140k, capable of 120Hz readout rate, will replace a slow CCD camera. These examples show how the compact design of this camera allows its integration in space-challenging setup, such as in tight and crowded vacuum chambers.

Another case, different from the previous ones, where this characteristic of the detector has been relevant is shown in Figure 4. The camera is mounted on the robotic arm at the XPP instrument of LCLS, therefore can be conveniently positioned in front of various viewports of the sample chamber despite multiple obstructions from other elements of the setup such as the pump laser.

A major advantage of the small and modular design of the CSPAD-140k is the capability to deploy multiple detectors in various mechanical arrangements. An interesting application of multiple CSPAD-140k modules is to tile them into an arc-like configuration to cover a larger angle from an interaction point. Figure 5 shows the concept which has been recently used in an experiment at the CXI instrument at LCLS. From the data acquisition system point of view the multiple single detector units are managed as a compound detector.

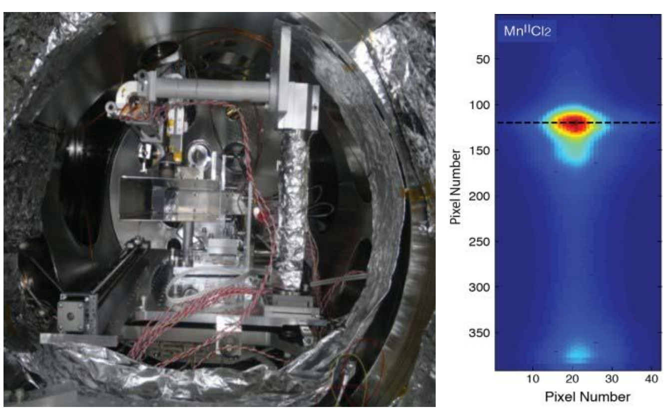

Fig. 2 The CSPAD-140k is used as a detector in a wavelength-dispersive x-ray spectroscopy setup for fluorescence signal analysis during a protein nanocrystallography experiment

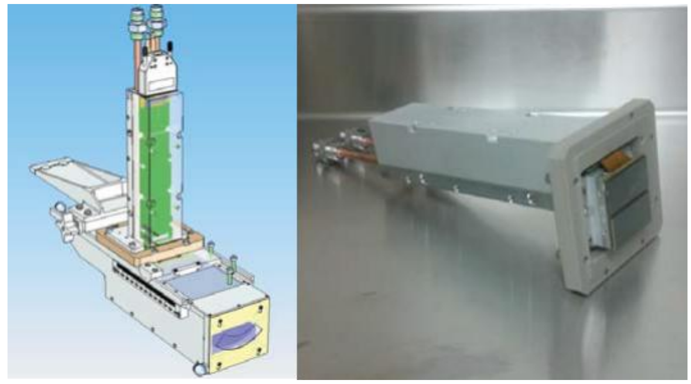

Fig. 3 The CSPAD-140k can be used in a x-ray Thomson scattering spectrometer to substitute a low frame rate CCD with a 120Hz capable detector.

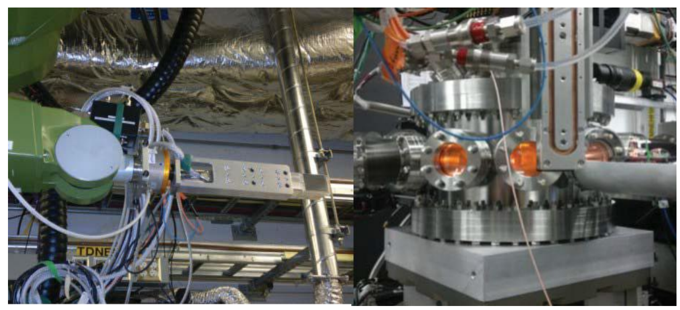

Fig. 4 The compact CSPAD-140k on a robotic arm can be used to measure peak signals in a pump-probe experiment at various positions around the sample chamber. (XPP instrument at LCLS)

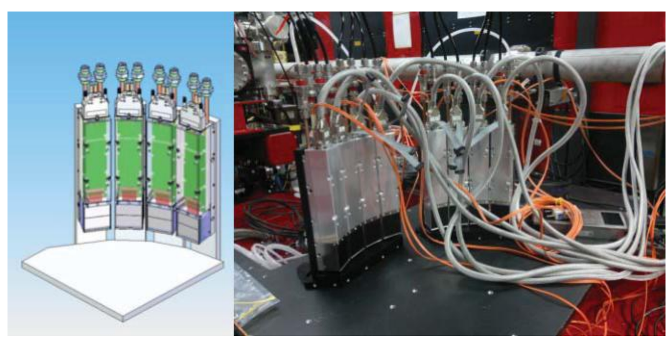

Fig. 5 Multiple CSPAD140k units are combined in an arc like configuration to cover a large angle around the sample.

IV. CSPAD-140K PERFORMANCE

A complete set of measurements has been carried out to characterize the performance of the CSPAD-140k camera; the results are summarized in Figures 6 and 7. In particular the detector has a dynamic range of 350 8keV photons in high gain and around 2700 photons in low gain mode. Noise performance in high gain mode results in a single photon signal to noise ratio of 7 for 8keV photons. Figure 7 shows a single pixel spectrum measured with an x-ray tube and a copper target. Gain homogeneity for single photons across the ASIC is around 20%.

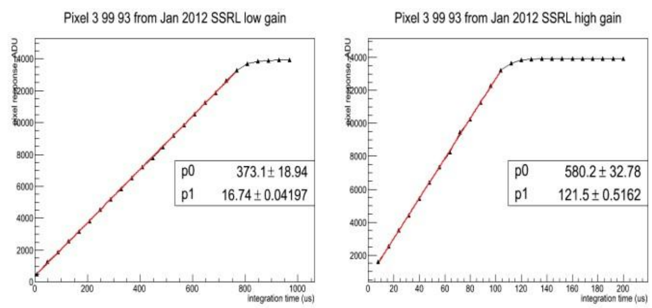

Fig. 6 Linear transfer curve of CSPAD140k measured in low (left) and high (right) gain mode. Different amounts of photons are generated by increasing the integration time with constant illumination conditions.

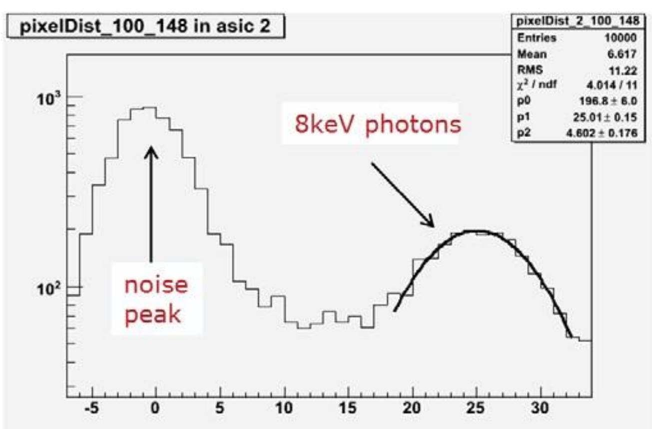

Fig. 7 Measured histogram of a CSPAD-140k pixel illuminated with copper fluorescence in high gain mode

V. CONCLUSIONS

A small versatile x-ray camera based on the CSPAD platform has been built at SLAC. This compact system helped to characterize and improve the performance of all CSPAD cameras. In addition the CSPAD-140k has already been used for several experiments at LCLS and SSRL and many more applications for this detector at synchrotrons and FELs are expected.

ACKNOWLEDGMENTS

This work is supported by the Department of Energy, Laboratory Directed Research and Development funding, under contract DE-AC02-76SF00515. Portions of this research were carried out at the Linac Coherent Light Source and the Stanford Synchrotron Radiation Lightsource, , two National User Facilities operated by Stanford University on behalf of the U.S. Department of Energy (DOE), Office of Basic Energy Sciences (BES).

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