CSPAD Geometry and Alignment

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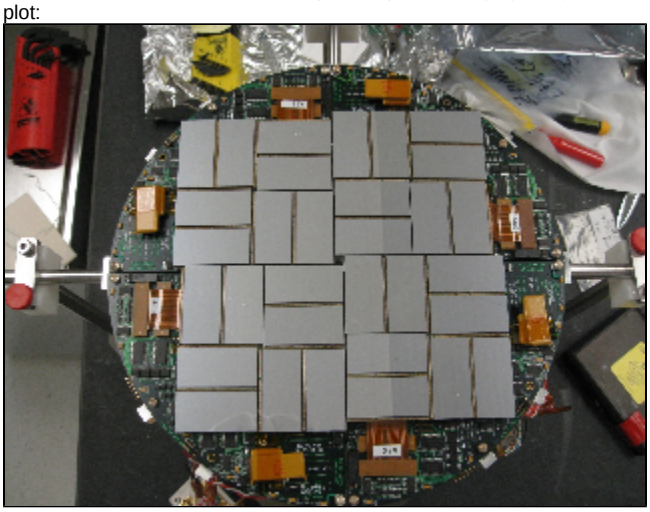
Introduction

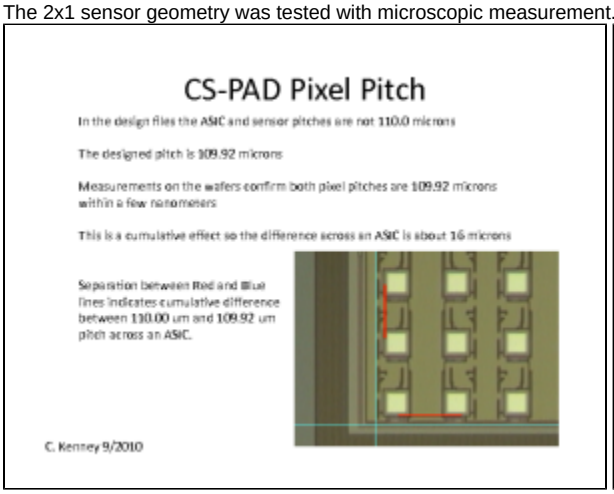
Cornell SLAC Pixel Array Detector (CSPAD) is an imaging X-ray detector made of silicon sensors (2x1) covering about 20x20cm² surface, as shown in the plot:

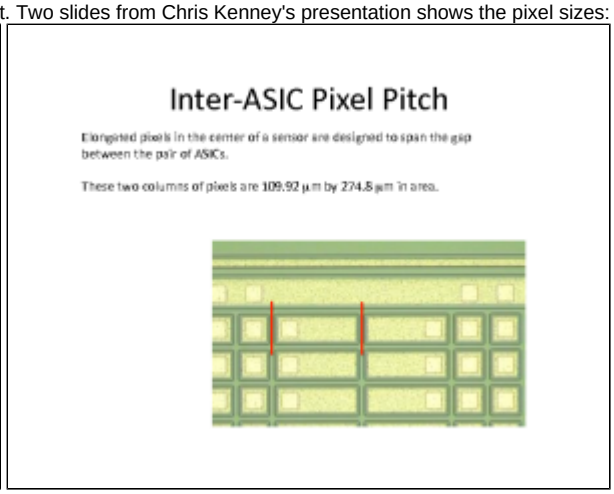


Pixel coordinates in 2x1 sensor chip are known with sub-micrometer precision. Construction of the detector allows significant freedom in relative positions of 2x1 sensors. To get precise pixel positions in the detector the 2x1 sensor coordinates needs to be calibrated. In this note we describe geometry of the CSPAD detector, optical and quad alignment procedure, parameters, and software providing access to precise geometry information.

2x1 Sensor Geometry

The 2x1 sensor geometry was tested with microscopic measurement. Two slides from Chris Kenney's presentation shows the pixel sizes:





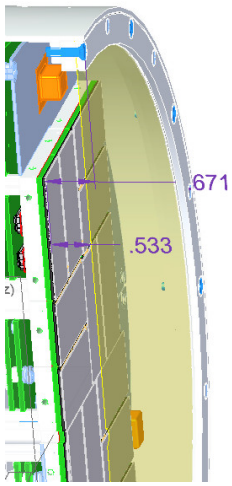
The same slides in PDF format.

Important 2x1 features:

- Number of rows x columns = 185 x 388. (In DAQ notation of rows and columns is interchanged...)
- Most of pixels have size 109.92 x 109.92 um².
- Gap between two ASICS is covered by the two rows of elongated pixels with size 109.92 x 274.8 um².
- Two versions of sensors have different dimensions between corners, so it is reasonable to define pixel coordinates w.r.t. the sensor center.

Shield to sensor distance

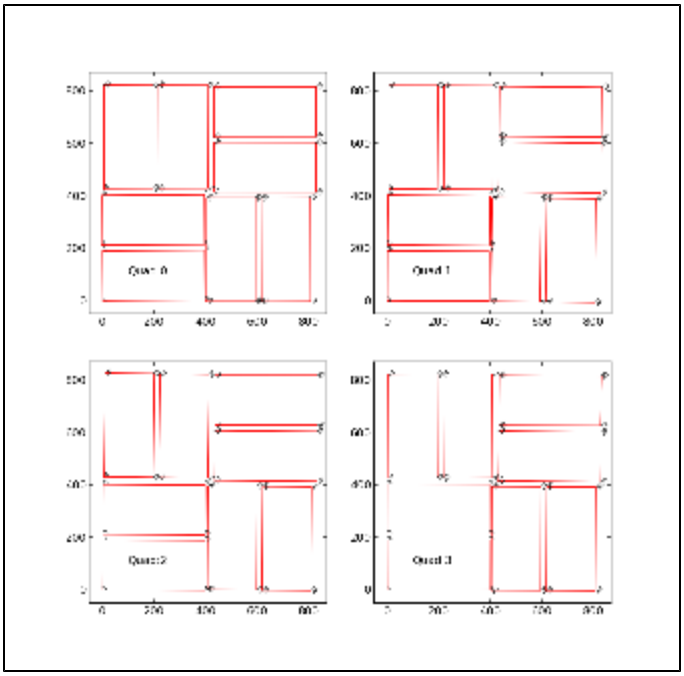
Chart of CXI Camera1 provided by Serge Guillet on 2017-06-12.

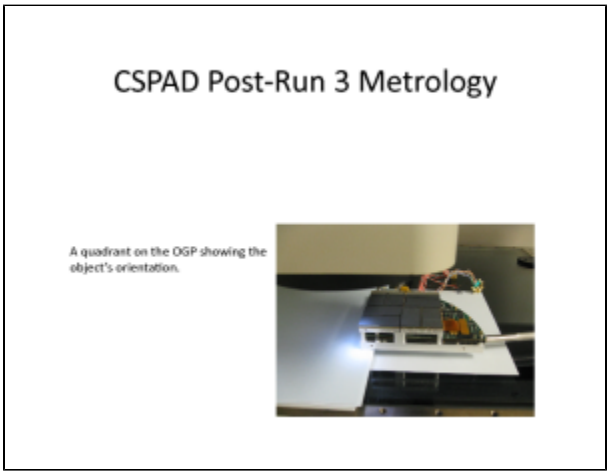


Optical measurement

Optical measurement is conducted by Gabriel Blaj. Detector or its quad is installed on microscope table and 3-d coordinates of all 2x1 sensor corners are measured with precision about 8um (RMS) in x-y plane. All corners in the measurement are numerated in arbitrary order. It is expected that numeration order should be the same for different measurements. This procedure depends on CSPAD construction;

- For CSPAD with movable quads (i.e. for CXI) optical measurement is done separately for each quad. The numeration of corners is shown in the plot:

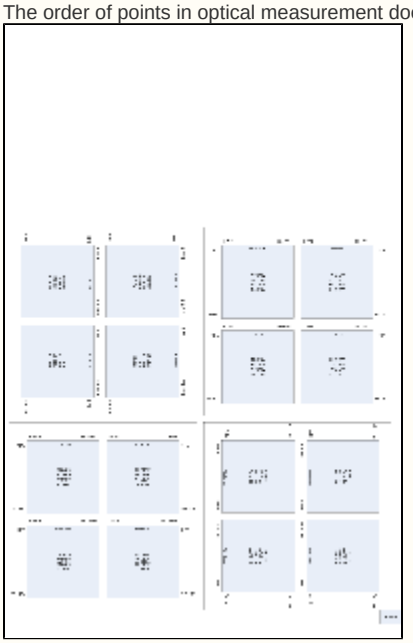




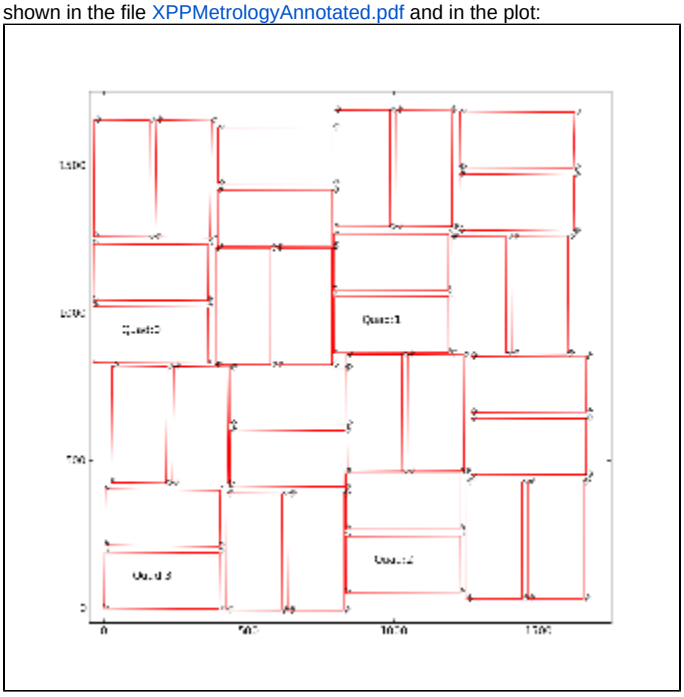
The same plots in PDF format: CSPAD quad metrology and CSPAD pixel layout in quads.

For each quad measurement is started from the point #1 which in assembled detector is closest to the beam. The 1-st point (x,y,z) coordinates are re-set to (0,0,0) in the beginning of measurements. At the end, it is checked that the 1-st point coordinates are reproduced within precision of measurement.

The order of points in optical measurement does not coincide with numeration of 2x1 in DAQ, as shown in the plot (and in PDF file):



- For CSPAD with fixed quad geometry (i.e. for XPP) optical measurement is done for entire detector. The numeration of corners in this case is shown in the file XPPMetrologyAnnotated.pdf and in the plot:



The 1-st corner of the 3-rd quad (x,y,z) coordinates are re-set to (0,0,0) in the beginning of measurements. At the end, it is checked that the 1-st point coordinates are reproduced within precision of measurement.

Corner coordinates are measured in micrometers (um) and are saved in the xlsx format table, also containing numeration of quads and points. Then, xlsx format table is converted to the text file format in order to use it in python script.

Example of tables for CXI:

- Metrology in XLSX
- Metrology in TXT

Example of tables for XPP:

- Metrology in XLSX
- Metrology in TXT Python script converts this table to the table with standard numeration of points in quads:
- Metrology in standard TXT

Then, text table with "standard" numeration of points in quads is feed to the python script which provides quality check of optical measurement and evaluates the alignment parameters for quads. In the beginning, this script changes the numeration of points adopted in optical measurement to numeration of 2x1 used in DAQ. Further, all calibration parameters are associated with numeration of 2x1 sensors and quads in DAQ.

Quality Check Procedure

For quality check of optical measurement we calculate
S1 - 1st short side length of 2x1
S2 - 2nd short side length of 2x1
L1 - 1st long side length of 2x1
L2 - 2nd long side length of 2x1
D1 - 1st diagonal of 2x1 between corners 1 and 3
D2 - 2nd diagonal of 2x1 between corners 2 and 4
dS and dL are the deviations of the 1st and 2nd corner along the short and long sides, respectively. The sign of all dS are chosen in order to provide correct sign for the tilt angle (the same direction for all 2x1 sensors).
<dS/L> - the tilt angle of 2x1 averaged over two sides in radians.
angle(deg) - the same angle in degrees.
dD = D1 - D2
d(dS) = dS1 - dS2
d(dL) = dL1 - dL2
dz3(um) - signed distance from 2x1 sensor plane and corner 3, where the 2x1 sensor plane contains the corner points p1, p2, and p4. This plane is defined by the vectors v21=p2-p1, v41=p4-p1, and their orthogonal vector

```
vort = [v21 x v41].
```

Scalar product with normalization defines the distance from point 3 to the 2x1 plane containing 3 other points:

```
dz3 = (v31 * vort) / |vort|.
```

Quality check parameters expected for perfect geometry:

S1=S2, L1=L2 - the 2x1 sides should have equal length and width,
D1=D2 - the 2x1 diagonals should be equal,
dS1 = dS2 ? (388/185)*dL1 = (388/185)*dL2 - tilt angle should provide consistent deviation for all corners,
dD=0, d(dS)=0, and d(dL)=0 - within precision of measurement.
dz3(um) = 0

Everything, excluding <dS/L> and angle(deg), are in micrometers.

Example of the table with quality check results:

```
pair:        S1      S2     dS1     dS2        L1      L2     dL1     dL2    <dS/L>  angle(deg)      D1
D2      dD   d(dS)   d(dL)    dz3(um)

Quad  0
pair: 0   20891   20913     200     222     43539   43541    -102    -100    0.00485    0.27766   48298
48297       1     -22      -2      2.981
pair: 1   20910   20894     293     277     43540   43535    -127    -132    0.00655    0.37506   48302
48289      13      16       5    -23.986
pair: 2   20890   20906      99      83     43536   43536      42      42    0.00209    0.11976   48290
48293      -3      16       0     -3.034
pair: 3   20897   20895     131     133     43545   43543      65      63    0.00303    0.17369   48299
48297       2      -2       2      6.003
pair: 4   20911   20896     -30     -45     43549   43547      17      15   -0.00086   -0.04934   48303
48306      -3      15       2     -5.994
pair: 5   20901   20898      10       7     43540   43544      -8      -4    0.00020    0.01119   48296
48299      -3       3      -4      9.993
pair: 6   20904   20903     104     105     43536   43540      55      59    0.00240    0.13752   48302
48290      12      -1      -4     52.002
pair: 7   20901   20901      -7      -7     43545   43543      -3      -5   -0.00016   -0.00921   48299
48301      -2       0       2     14.001

Quad  1
pair: 0   20913   20914    -343    -342     43540   43550     165     175   -0.00787   -0.45066   48313
48303      10      -1     -10    -24.002
pair: 1   20898   20901    -145    -142     43548   43551      62      65   -0.00330   -0.18880   48300
48309      -9      -3      -3    -23.005
pair: 2   20895   20903    -151    -159     43535   43532     -74     -77   -0.00356   -0.20400   48289
48291      -2       8       3    -17.995
```

```
pair: 3   20872   20909    -235    -272     43341   43354     -37     -24   -0.00585   -0.33507   48201
48036     165      37     -13    -13.010
pair: 4   20940   20904    -455    -491     43527   43554     214     241   -0.01086   -0.62242   48309
48309       0      36     -27     1.101
pair: 5   20910   20903    -302    -309     43546   43546     145     145   -0.00702   -0.40196   48304
48307      -3       7       0     6.016
pair: 6   20901   20919    -421    -439     43529   43539    -213    -203   -0.00988   -0.56593   48296
48298      -2      18     -10     -8.026
pair: 7   20907   20907    -452    -452     43548   43539    -201    -210   -0.01038   -0.59475   48315
48294      21       0       9     -8.982

Quad  2
pair: 0   20914   20914     -25     -25     43536   43540      10      14   -0.00057   -0.03290   48300
48300       0       0      -4    -11.013
pair: 1   20901   20897       7       3     43546   43536      -1     -11    0.00011    0.00658   48293
48300      -7       4      10      4.036
pair: 2   20899   20903    -256    -260     43533   43539    -127    -121   -0.00593   -0.33954   48293
48294      -1       4      -6     -1.023
pair: 3   20912   20904    -210    -202     43540   43547    -106     -99   -0.00473   -0.27106   48300
48306      -6      -8      -7     24.004
pair: 4   20910   20903    -543    -550     43535   43536     261     262   -0.01255   -0.71923   48298
48299      -1       7      -1      0.004
pair: 5   20904   20905    -241    -240     43538   43544     111     117   -0.00552   -0.31647   48298
48301      -3      -1      -6     -6.024
pair: 6   20903   20902      21      22     43539   43543       8      12    0.00049    0.02829   48298
48298       0      -1      -4      8.999
pair: 7   20902   20903      82      81     43546   43547      35      36    0.00187    0.10723   48300
48306      -6       1      -1      9.995

Quad  3
pair: 0   20902   20898     -82     -86     43536   43543      30      37   -0.00193   -0.11054   48289
48302     -13       4      -7      1.994
pair: 1   20900   20904      79      83     43548   43541     -35     -42    0.00186    0.10658   48301
48301       0      -4       7    -17.993
pair: 2   20912   20894     181     199     43536   43535      97      96    0.00436    0.25005   48298
48289       9     -18       1     10.011
pair: 3   20912   20905     119     126     43539   43538      57      56    0.00281    0.16121   48296
48301      -5      -7       1    -16.000
pair: 4   20894   20912    -454    -436     43534   43545     212     223   -0.01022   -0.58560   48303
48296       7     -18     -11      2.023
pair: 5   20906   20919    -336    -323     43527   43535     155     163   -0.00757   -0.43369   48295
48294       1     -13      -8      5.993
pair: 6   20902   20905    -203    -206     43537   43525     -89    -101   -0.00470   -0.26916   48293
48287       6       3      12      2.981
pair: 7   20900   20897    -140    -137     43539   43544     -68     -63   -0.00318   -0.18225   48298
48296       2      -3      -5     29.997
```

This quality check works well to catch significant typos in input table. In case of obvious typos input table can be corrected. When the quality check is passed successfully the alignment parameters are saved and deployed under the `calib`.

Detector geometry model

Since 2014 we support universal detector geometry software which is documented in the Detector Geometry page and in CSPAD-geometry-parameters.pdf.

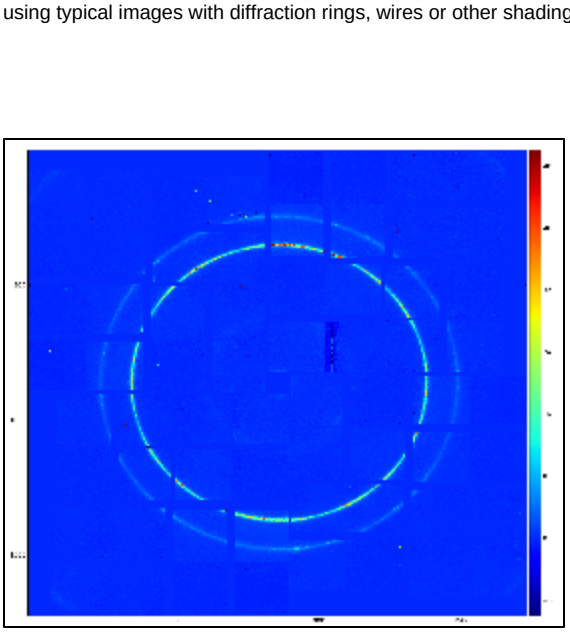
Alignment parameters from optical measurement

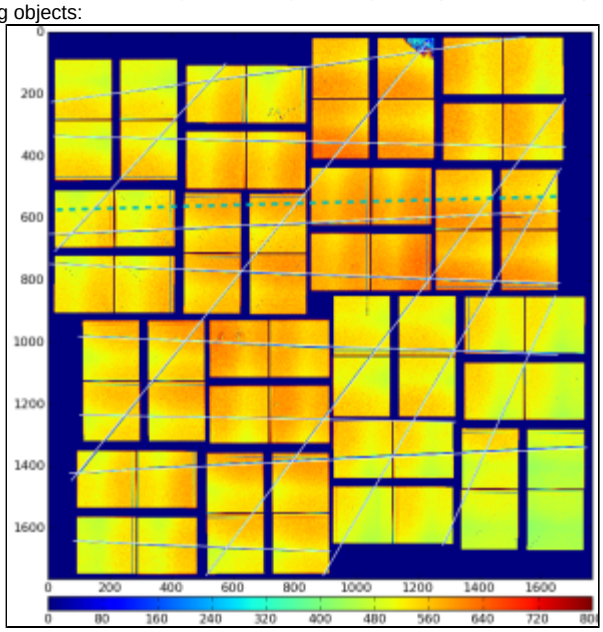
From optical measurement we extract coordinates of the center of each 2x1 sensor and its tilt angle.
The center coordinates are evaluated as an averaged over 4 corners measurements for each axis.

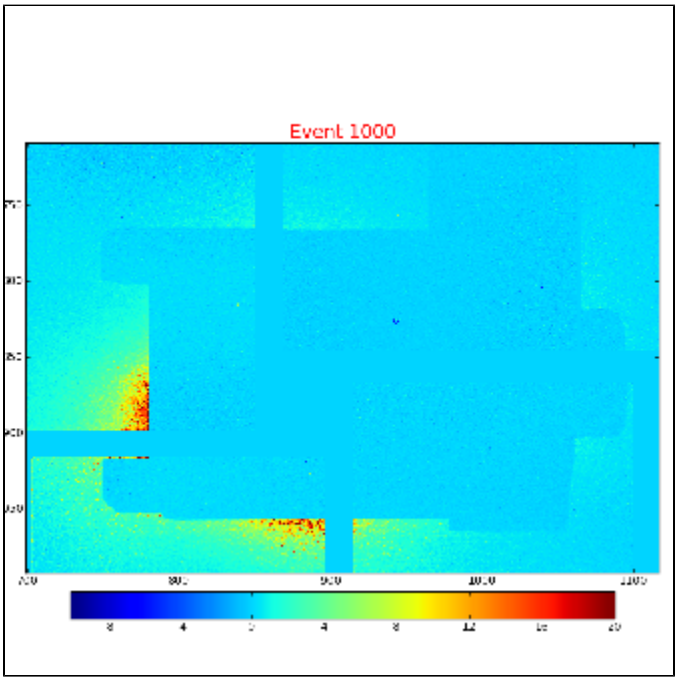
The `tilt` parameters are used along with `rotation` to completely define orientation of 2x1 in quad (for CXI) or in detector (for XPP).

Alignment of quads in the detector

For CSPad with fixed quad geometry (like in XPP) optical measurement of entire detector (should) produces complete information for geometry alignment. For CSPad with moveable quads (like in CXI) quads relative position needs to be adjusted through the alignment parameters for quads. It is usually done using typical images with diffraction rings, wires or other shading objects:







Although few algorithms of automatic quad alignment were tried, we did not find good generic way for automated quad tuning. Currently, the quad tuning parameters in `marg_gap_shift` and `offset_corr` are adjusted manually for runs with specific images.

Calibration store

The official space for CSPAD alignment parameters is
`/reg/d/psdm/<INSTRUMENT>/<experiment>/calib/CsPad::Calib<VERSION>/<CSPad-name>/<type>/<run-range>.data`
For example:

```
/reg/d/psdm/CXI/cxi80410/calib/CsPad::CalibV1/CxiDs1.0:Cspad.0/geometry/1142-end.data
```

The file name consists of the run range followed by the `.data` extension, for example, `0-end.data`, `11-end.data`, `47-52.data`, etc.

Calibration type

Detector geometry calibration information is located in a single file of type

- `geometry` - contains hierarchical description of all detector components; for example for CSPAD, sensors' location and rotation in the quads, quads - in the detector, detector - in the setup, etc.

Archive and History

Optical measurement and other alignment files can be found in

- /reg/g/psdm/detector/alignment/cspad/
- Geometry History

Detector data access software

- Detector data access software

References

- CSPAD Geometry and Alignment - Depricated - old version of this page
- Detector Geometry - confluence page
- CSPAD in DAQ - schematic description of CSPAD geometry available in DAQ.
- CSPAD quad metrology - slides for CXI type CSPAD quads
- CSPad pixel layout in quads - pdf file with numeration of ASICs in the CSPAD quads
- XPPMetrologyAnnotated.pdf - order of measurements of XPP camera.
- Geometry History - page with references to calibration files.
- Detector data access software - auto-generated documentation of the Detector package.