New Detectors on the Horizon

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Detectors Group/XSD
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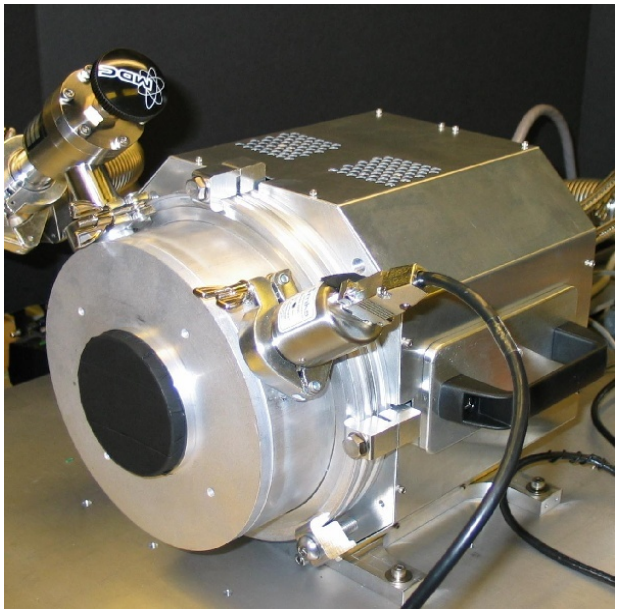
X-ray Interface Science Workshop

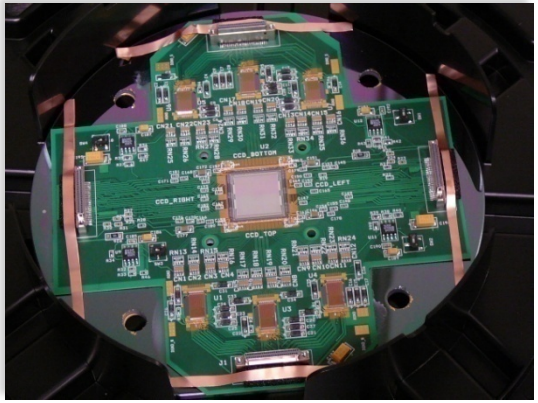
Outline

- Pixel Array Detectors
  - CCDs
  - PSI Eiger
  - Analog PADs
- Imaging
  - Scintillators

FastCCD 480 x 480 Detector Prototype

- **LBNL CCD Sensor**
  - 480 x 480 pixels, 30µm x 30 µm pixel size
  - 200µm Thick Fully Depleted (High QE)
    - Direct Detection
  - Readout Time = 5.1 msec
  - 96 Analog outputs - Almost column-parallel readout
  - fCRIC Readout ASIC
- **APS DAQ System**
  - Dalsa X64-CL Full Frame Grabber
    - Original Frame Grabber collecting raw data
    - Too Much Data! ~100 MB/sec continuous
  - Dalsa Anaconda Frame Grabber
    - User Programmable FPGA
    - Allows real time data compression
  - XPCS applications at 8-ID





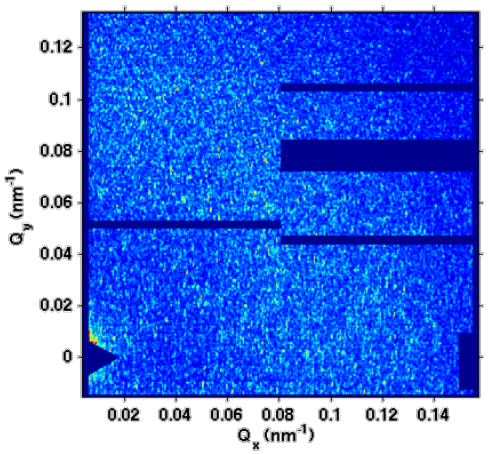
FCCD 6” wafer holder

John Weizeorick & Tim Madden

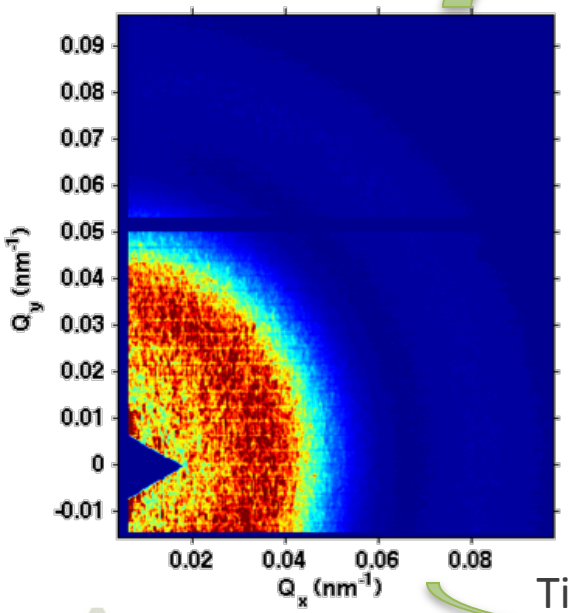
FCCD Science – Speckle & XPCS at 8-ID

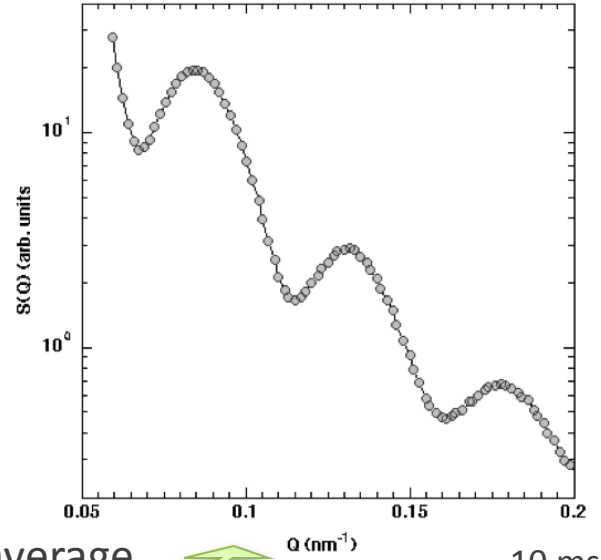
- Static and dynamic speckle measurements
  - Aerogel – static speckle
  - Dynamics of latex spheres (R=260 nm) in glycerol
    - Bread and butter XPCS experiment– performed for NX summer school – know answers

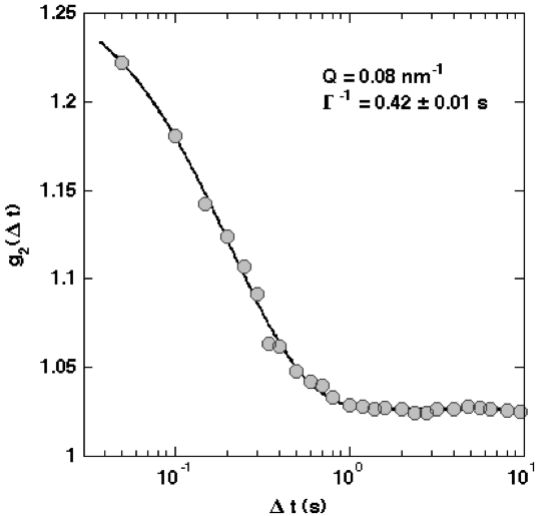
    [L. Lurio, et al., Phys. Rev. Lett. 84, 785 (2000)]
  - Fast CCD works for speckle and XPCS measurements!



Time autocorrelation







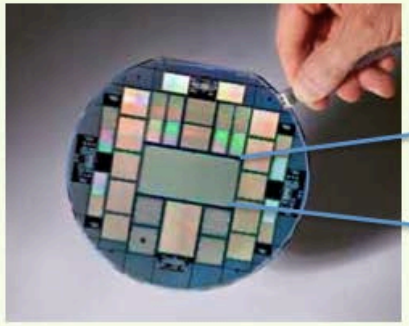
Time average

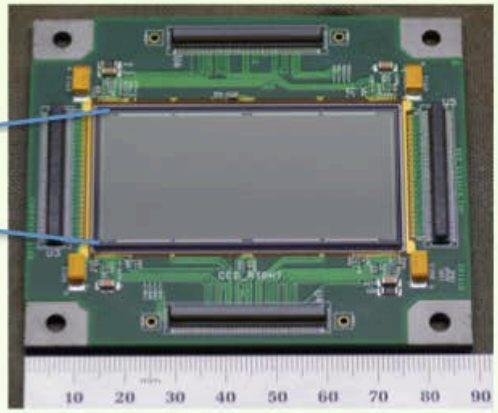
10 ms exposures

A. Sandy & L. Lurio

Next Generation FastCCD…

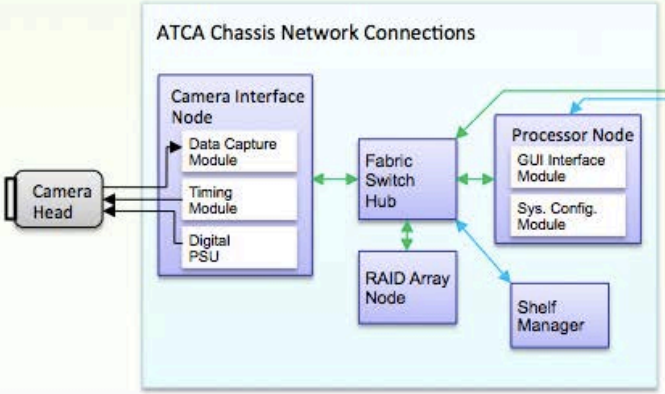
1k Frame Store FCCD





- New CCD
- Improved readout chip – fCRIC2
- New buffer chip – for higher speed

2k x 1k CCD or
1k x 1k with electronic shutter

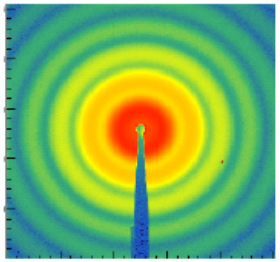


John Weizeorick

Eiger – Next Generation of Pilatus (PSI Detector Group)

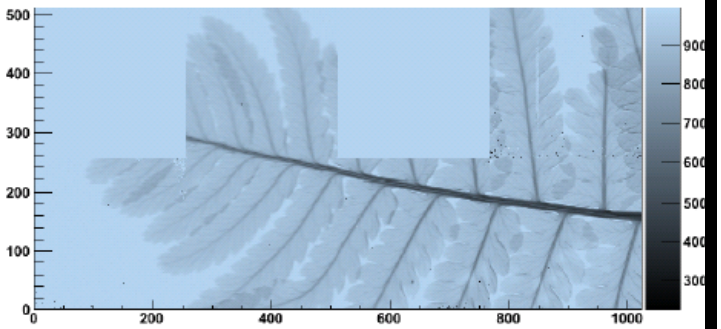
- Readout chip main features:
  - **<u>75 micron pixels</u>**
  - Frame rates:
    - 8kHz (12-bit)
    - 12kHz (8-bit)
    - 24kHz (4-bit)
  - Almost dead time free readout (<3 us)
  - One Module: 524k pixels (512x 1024)
- PSI methologically working towards 9M for cSAXS beamline.
- Dectris has signed a license agreement with PSI to commercialize the EIGER chip.
  - They plan to be on the market with a 1M (2 EIGER module) product in 2013.
  - However, Dectris version only up to 4kHz (?)

Planned Eiger Systems



Transition from the single chip system to the module

Putting the complete system together



Single module system @ cSAXS
- In the 2nd quarter 2012

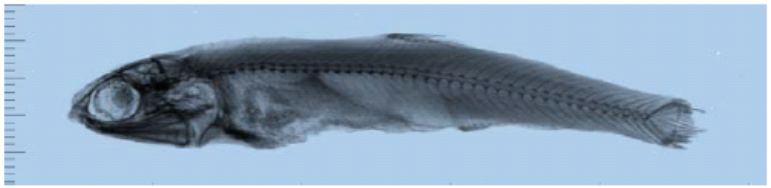
High performance 9M Eiger @ cSAXS
- On Detector memory (288 GB RAM) or 2.5 sec @ highest data rates
- 100 Hz continuous operation and data to disk
- IT infrastructure and data storage (Heiner Billich)
- Previously discussed in firmware data processing

Dectris 16M Eiger @ PX
- Collaboration between Dectris and PX beamline
- We are working closely with Dectris to develop a common data file format

Collaboration with the ESRF
- Single module systems @ ESRF

500k Single module system at the surface diffraction station (MS)

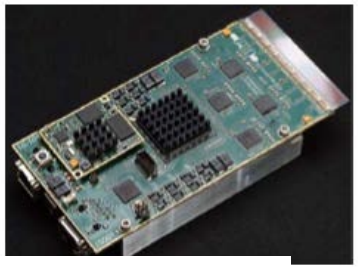
Future installations are under discussion
- We would prefer fixed single module installations rather than a detector pool.

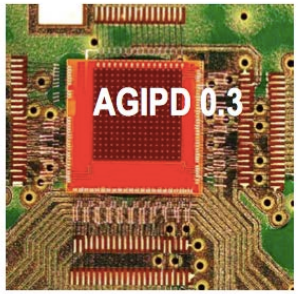


Other PSI Detector Activities

- **1D Strip Detector -- Mythen II (Photon Counting)**
  - Trying out 1mm thick Silicon and also 500 micron CdTe (Spring-8 Collaboration)
- **XFEL Detector (Collaboration with DESY)**
  - **Gotthard** -- Charge integrating silicon strip detector
    - 50 micron pitch, 1280ch/module, 14 bits
    - Solution for the bunch train problem:
      - Fast readout (>1MHz) with more than 600 bunches/train recovered
  - **AGIPD – Adaptive Gain Integrating Pixel Detector**
    - On-pixel analog storage of XFEL bunch train (~200)
    - DESY, PSI, U. Bonn and U. Hamburg
  - **"Swiss XFEL Detector"**
    - Small pixel Charge integrating detector
    - ***75 micron pixels***
    - Frame rate 100 Hz
    - First prototype multi-project wafer chip submission in 2012
    - 4M Detector late 2014

Gotthard





Cornell Detectors (Sol Gruner)

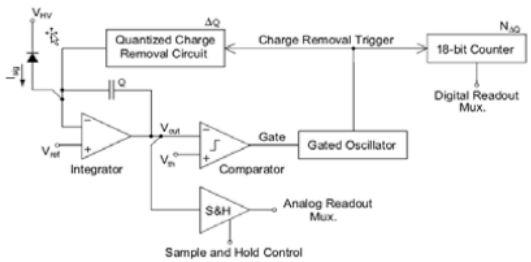
- Analog/integrating Pixel Array Detectors

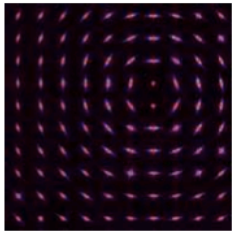
- Very high count rate performance (10^8 cps) (compared to photon counting pixels)
  - Mixed Mode PAD
    - High dynamic range
    - 1kHZ frame rate
    - Commercially available via ADSC (already at BNL?)
      - 2 modules 40 x 80 mm 131K pixels $160k
  - Keck PAD
    - Ultra Fast Frame (i.e., single bunch imaging)

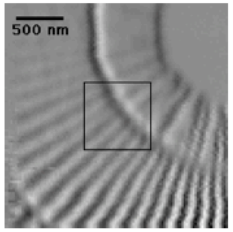
Cornell - Mixed-Mode PAD

PAD #3: Mixed-Mode PAD

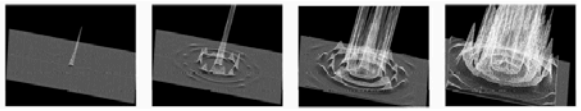
PAD Tile Format	128 x 128 pixels
Pixel Size	150 µm x 150 µm
Frame Rate	Up to 1,000 Hz
Read Noise	0.3 X-ray [12 keV] / pix
Well Capacity	2.6 x 10^7 X-ray [12 keV]/pix/frame



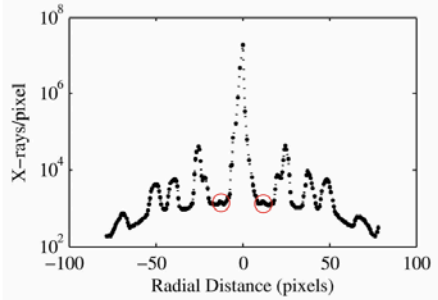




Mixed-Mode PAD has a HUGE dynamic range



MMPAD. Al @ CHESS F2. 1 sec expos. No Beamstop!



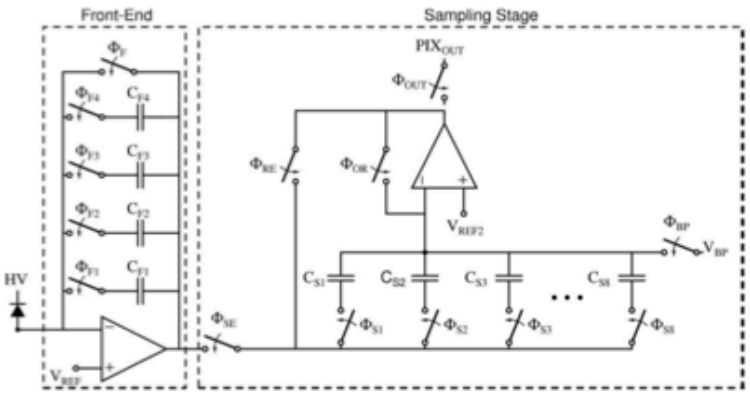
Cornell University
Physics Department & CHESS

DOE Contractors

- Cornell role: Design PAD chips, build single chip, cooled detector to spec. Completed.
- ADSC role: Build large detectors & vend. In process.
- 65 MB/ASIC/s. For a 1k x 1k this is 400 TB/day, continuously!
- Papers: see refs at tend of talk #196, 226, 265
- In process of building mosaic detectors for CXI, SAXS and other applications.

Cornell – “Keck” PAD
-- Single Shot pixels

KECK PAD	
Parameter	**Target Value**
Noise	< 0.5 x-ray/pixel/accumulation
Minimum exposure time	<150 ns for 12-bit imaging
Capacitor well depth	2000 – 4000 x-rays
Nonlinearity (% full well)	< 0.2%
Diode conversion layer	500 µm thick Si
Number of capacitor wells/pix	8
Full chip frame time	1 msec/frame, e.g., 8 msec for 8 capacitors
Radiation lifetime	> 50 Mrad at detector face @ 8 keV
Pixel size	150 µm on a side, or 128 x 128 pixels per IC
Detector chip format	2 x 4 chips = 256 x 512 pixels
Dark current	2 x-rays/pix/sec

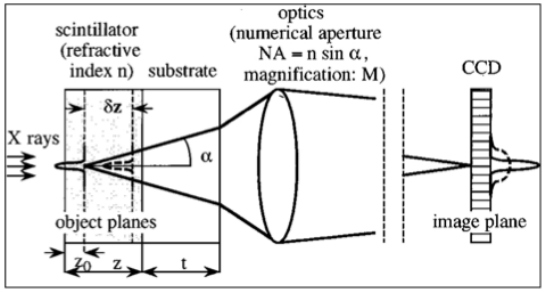


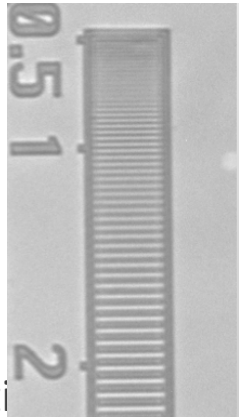
Koerner & Gruner, J. Synchro. Rad. 18 (2011) 157.

< 150 ns for 12 bit settling shown. Equivalent to ~4000 8 keV x-rays. Faster for fewer bits. A few bits in 10’s of ns should be feasible.

Imaging -- Scintillators

- Micron Imaging Applications
  - (e.g., tomography, full-field microscopy, etc)
  - Scintillators are the limiting component.
    - Light yield
    - Density (to limit thickness and thus resolution)
    - Non-glowing substrates
  - ESRF R&D Scintillator Program (T. Martin)
    - Liquid phase epitaxy facility for single crystal film scintillators
    - Welcome collaborations concerning substrates and the growth of exoti materials.





☺ **Multi-functionnality**

- YAG:Ce — Fast imaging with low dynamic (10 bit), radiation hardness
- LAG:Eu, Ce — High optical grade, radiation hardness, Low(Ce)/Moderate dynamic range
- GGG:Eu — Full Frame Transfer CCD chip, High dynamic range, λ = 715nm
- LSO:Tb — Interline and back illuminated CCD chip, Moderate dynamic range, λ = 550nm

☺ **Liquid Phase Epitaxy Facility (staff, equipment)**

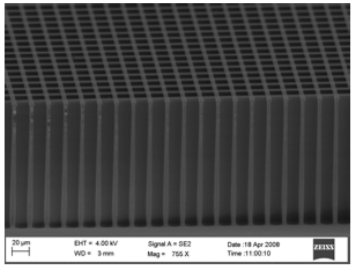
☺ *Production and stock of GGG & LSO*

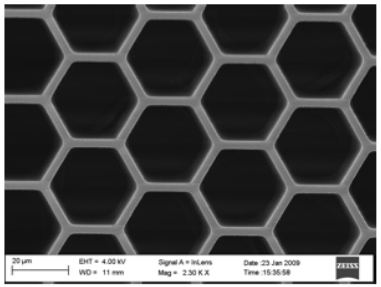
☺ *Dev. Eng. of new crystal : LuGG, GSO, LuAP*

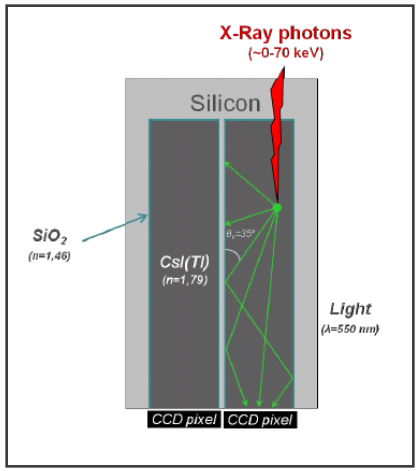
☺ *Research program:* Lu_2O_3 , $Lu_2Hf_2O_7$, $Lu_4Hf_3O_{12}$, Lu_3TaO_7 *Gain abs. 100% (/GGG)*

Imaging -- Scintillators

- High Spatial Resolution (< 50 microns) @ High Energies (> 40keV)
  - Structured scintillators
    - Commercially available (e.g., Scint-X in Sweden)
      - ~20 microns pores, 200 microns thick CsI







  - Potentially direct-detection
    - Selenium detectors from medical/dental applications
      - 3D mammography (tomosynthesis)

Conclusions

- CCDs are not dead → FCCD → Towards fully column parallel CCDs.
- PSI is methodically working away on counting & integrating PADs.
- Cornell PADs will soon be commercially available.
- Scintillators needed for high spatial resolution.