Detector Development and Support at the Advanced Photon Source

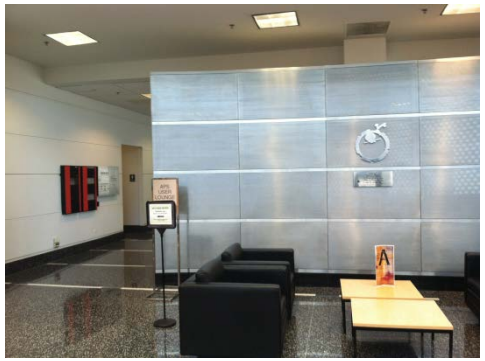
Robert Bradford, *for the APS Detectors Group*

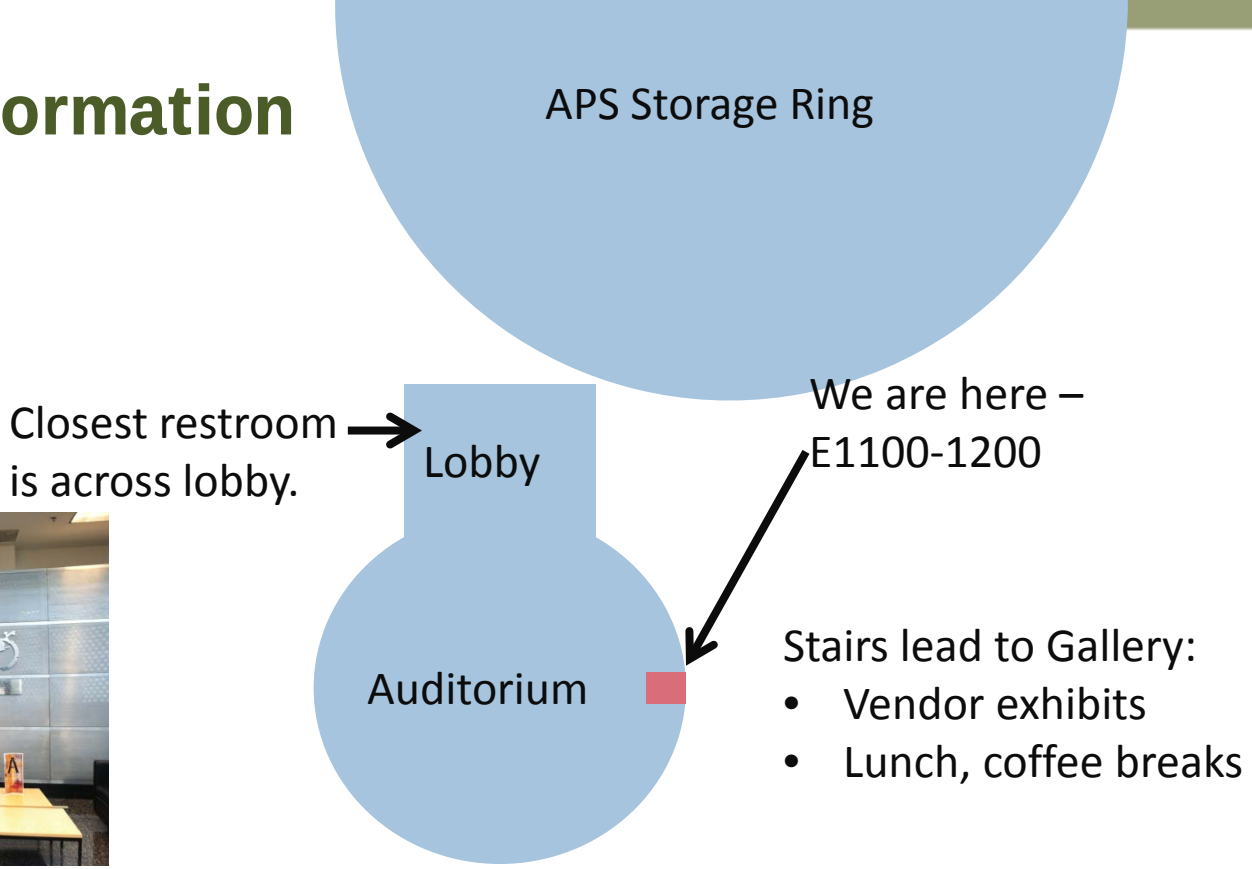
Detectors Workshop
ESRF/PETRA-III/Spring-8/APS 3-Way Meeting
31 July, 2013

Welcome to APS!

- First detectors workshop at a 3-Way Meeting!

Useful Information

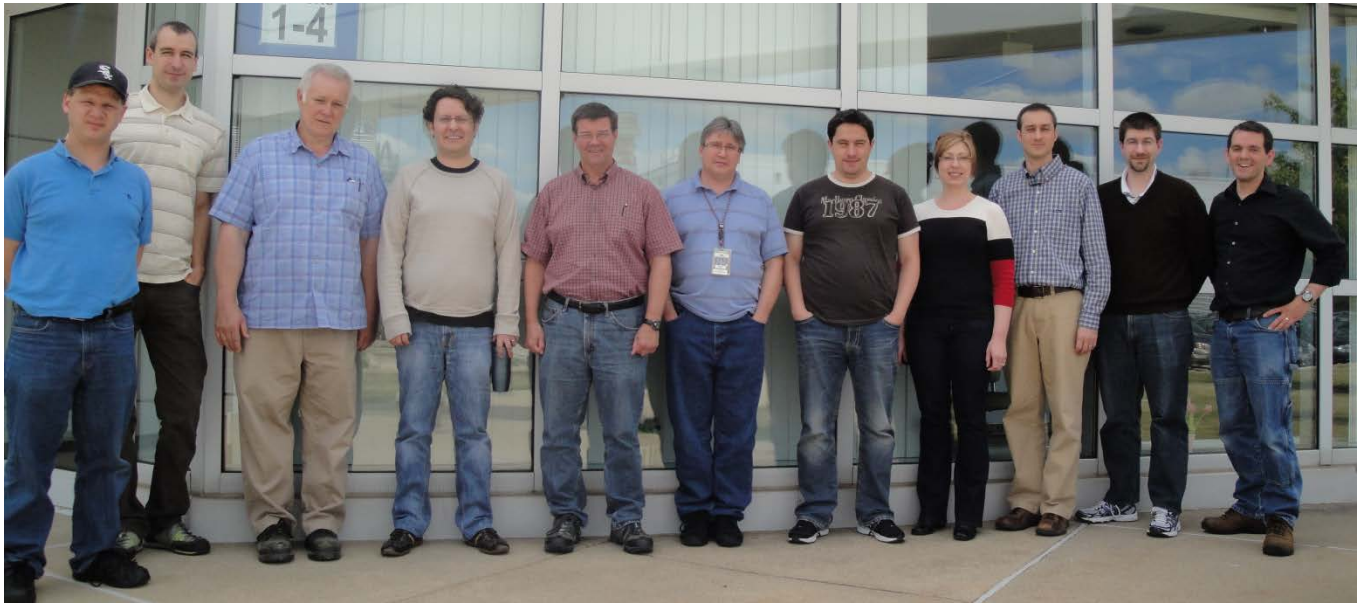




Wireless: Please use “APS Guest” network!

Questions?
- Registration Desk
- Any APS attendee

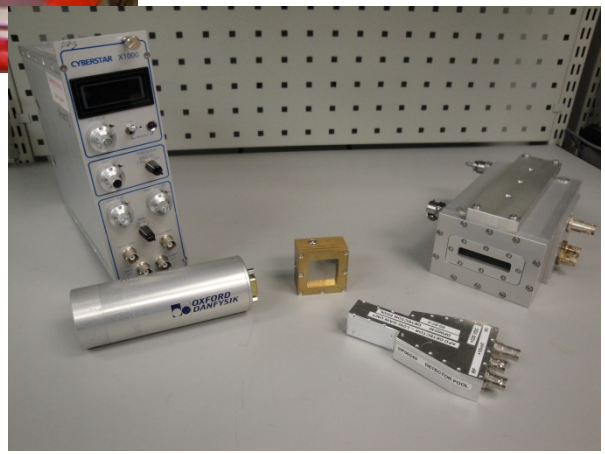
So…APS Detectors Group



- Vital Statistics:
  - 13 full-time members: 3 scientists, 5 engineers (mainly EE), 1 post-doc, and 4 technical/support staff
  - Interim Group Leader: Chris Jacobsen
    - Open search
  - Activities: Beamline support and detector development

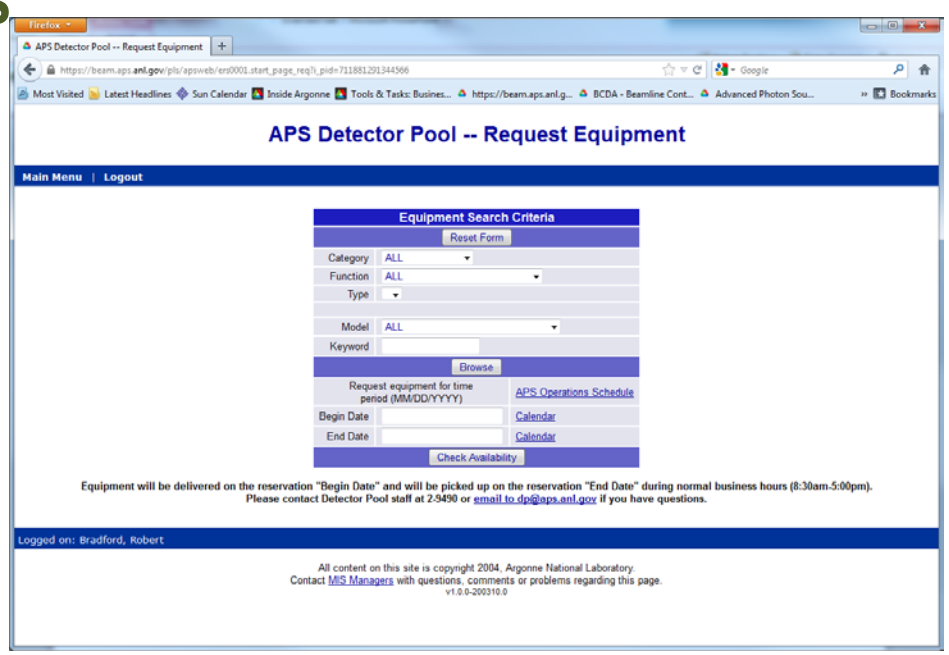
Detector Pool: Equipment and technical support

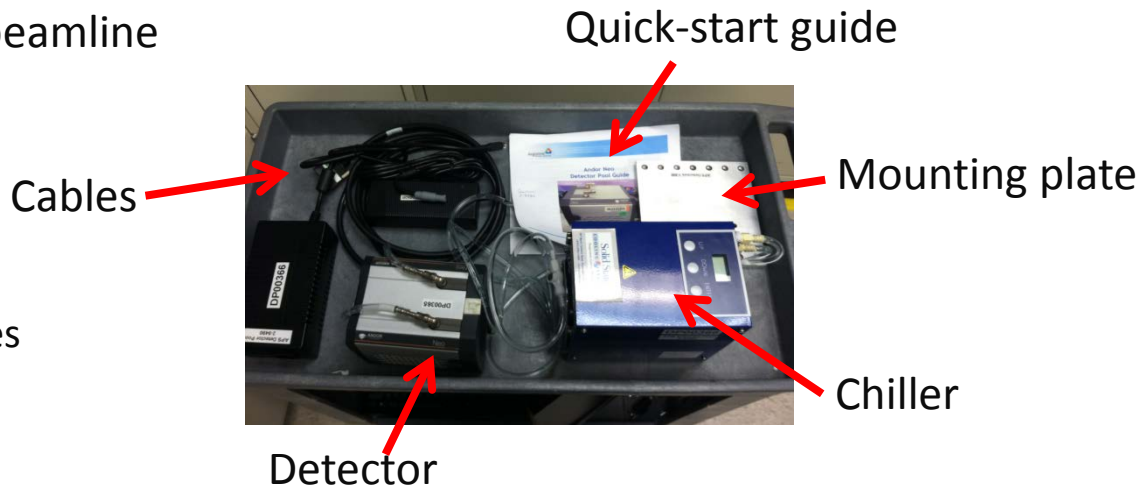
- Equipment loan service made available to all beamlines:
  - 50+ detector systems
  - Sample environments
  - Electronics
- …and so much more
  - On-call technical support
  - Set-up of new detectors
  - Characterization and testing
  - Advice
  - Help with special applications
  - Emergency equipment needs
- 3 FTE + support from all group members
  - 1/3 of group resources
  - Matt Moore, Russell Woods, Chris Piatak, Lisa Gades
  - Everyone contributes



Detector Pool Operations

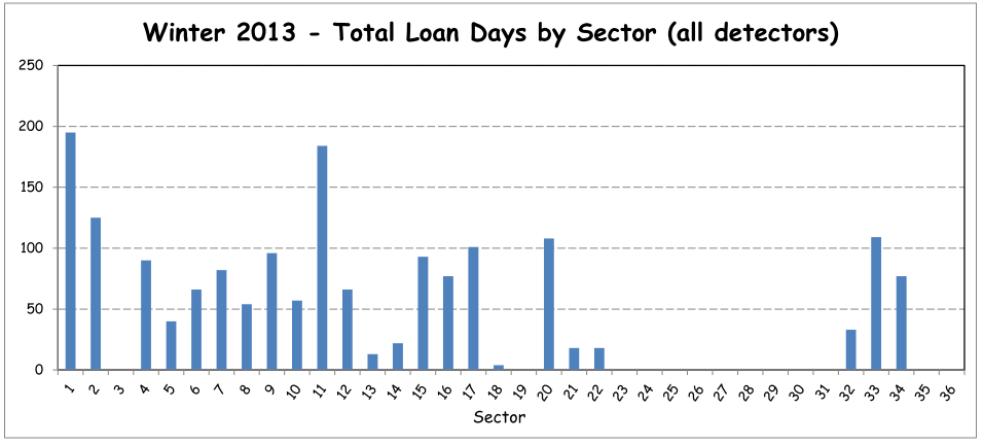
- Beamline staff or users request equipment before run starts
  - Online form
- Oracle database key to scheduling and tracking equipment
  - Broker loans between beamlines
- On-call person:
  - Carries Pager for support calls
  - Responsible for equipment moves
- Equipment delivered to beamline on date of request
  - Detector
  - Control PC
  - Quick-start guide
  - Any required accessories

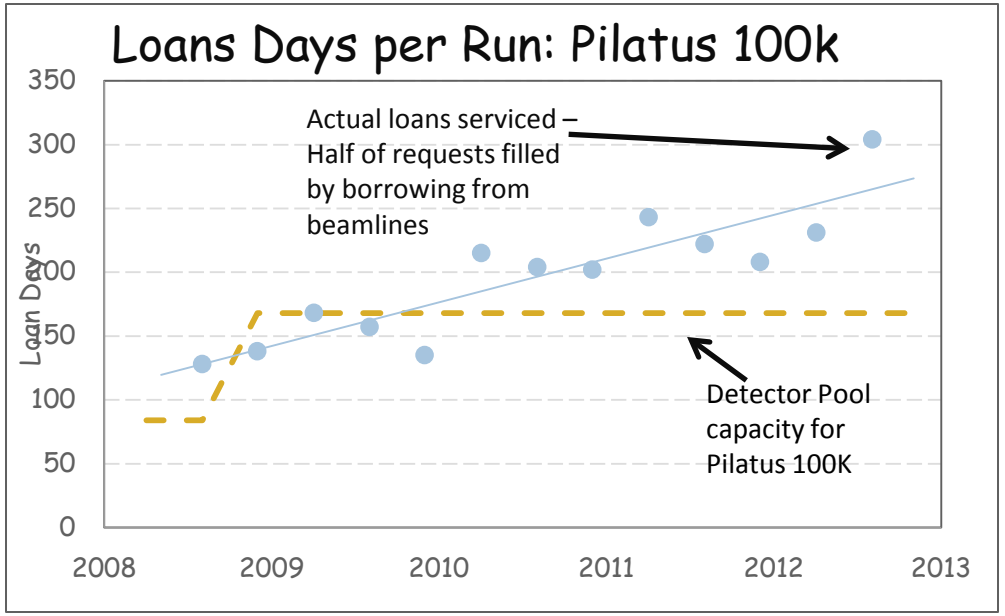




Detector Pool Operations

- 24/7 support:
  - Help line forwarded to pager or cell phone
  - Service both Detector Pool and beamline equipment
  - Typical week sees ~10 calls, with standard deviation of ~5
  - Wide breadth of problems
- Served ~550 equipment loans in 2012
- Most popular equipment over last few years:
  - Pilatus 100K
  - 4-element Vortex SDD
  - Mar 165 CCD





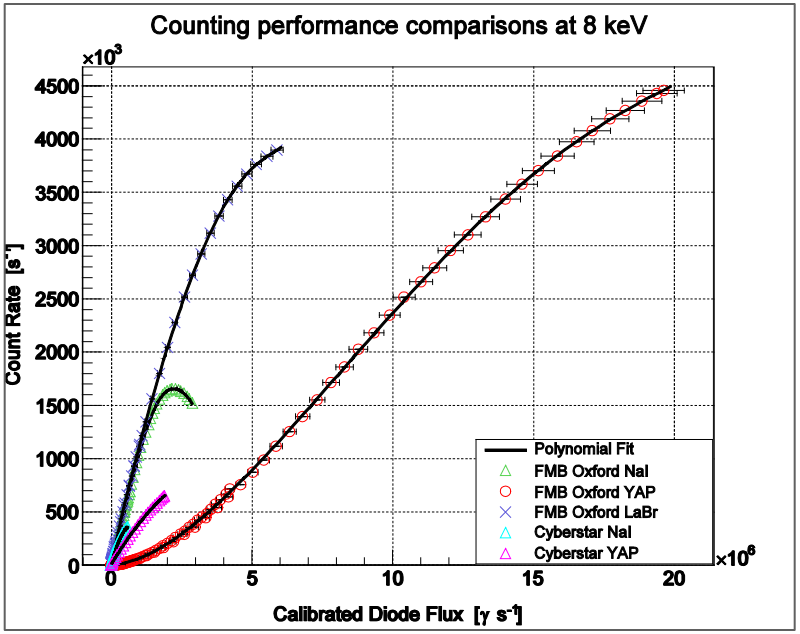
Characterization: Test beamline

- Optics and detectors testing program at 1-BM commissioned in 2012
  - Bending magnet line
  - Beamline retrofit – summer 2012
- Facilities:
  - White or mono beam, up to 30 KeV
  - Two experimental hutches
  - Flux: 9 x 10^{11} γ/s @ 10 keV
- Shared resource – detectors, optics, and HEDM at Sector 1
  - 25% of beamtime each run + possibility of rapid access
  - See Al Macrander's talk today at 1:25 in Optics Workshop

R. Bradford, APS Detectors Group

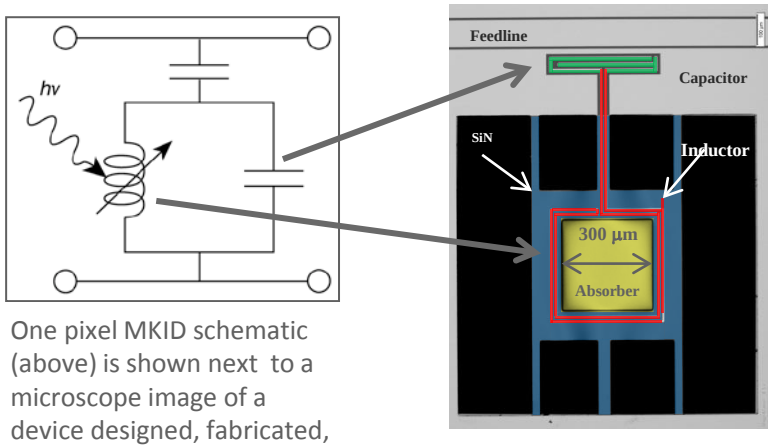
1-BM Detectors Testing

- Purposes:
  - Calibrate existing equipment
  - Evaluation of commercial detectors prior to purchase
  - Complement group's development effort
- Planned capabilities:
  - Counting detectors (flux calibration, linearity, dead time)
  - Scintillator (temporal response, light output, etc)
  - Area Detectors (Gain uniformity, linearity, etc).
- Past year
  - PyEpics/PyRoot scripts for control of data acquisition and analysis
  - Evaluation of new Oxford scintillation counters

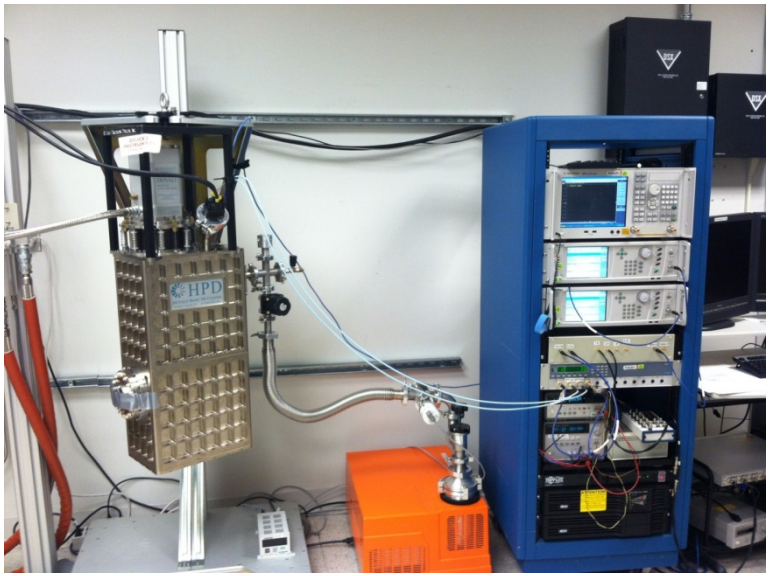


Detector Development: Microwave Kinetic Inductance Detectors (MKIDS)

- High resolution energy dispersive detectors based on superconducting resonators
  - Targeted Resolution: <5 eV at 10 keV
  - Straightforward to multiplex with microwave readout
    - Pixelated detectors for high count rates and large solid angle
- DOE Early Career Award to Nino Miceli
  - Tom Cecil, Orlando Quaranta, Lisa Gades, Tim Madden
  - Complete simulation, fabrication, and test facilities at APS
- Nino Miceli's talk later today

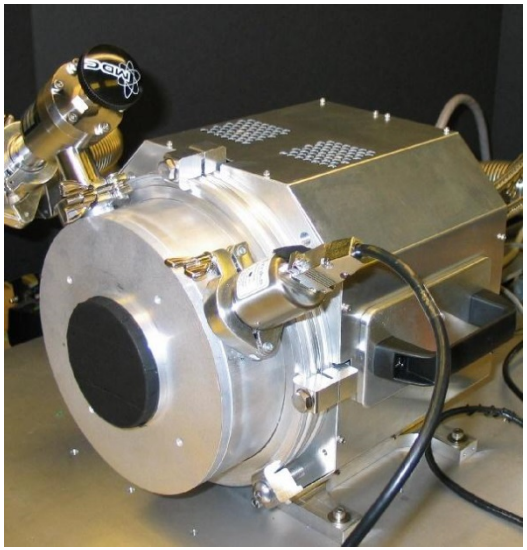


One pixel MKID schematic (above) is shown next to a microscope image of a device designed, fabricated, and tested at APS.

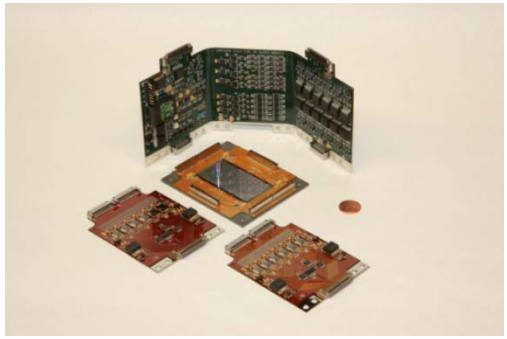


Detector Development: Fast CCD

- High frame rate direct-detection CCD
  - Chip: 250-350 μm thick back-illuminated direct detection CCD; 30 μm pixels
  - Near column-parallel readout
  - Full well: ~900k e^-/pixel
  - Custom 13-bit ADC
- Collaboration with LBNL
  - APS: clock boards, data acquisition, software
  - John Weizeorick and Tim Madden

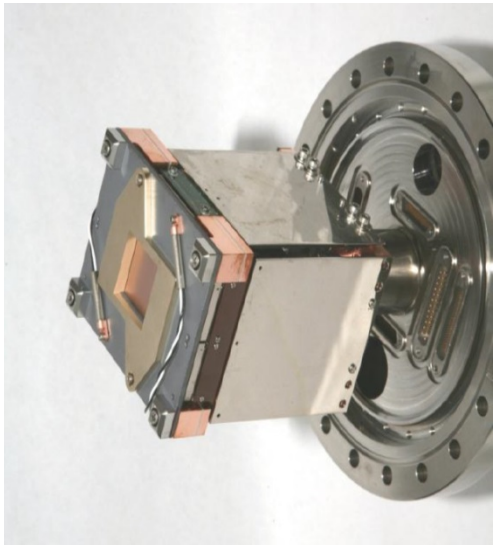


1st generation: 480 X 480 pixels capable of reading out at 125 Hz used at Sector 8 of APS.



2nd generation: 1K Frame Store Fast CCD (1KFSFCCD):

- 2K X 1K pixels
- frame-store capability to increase frame rate to 200 Hz



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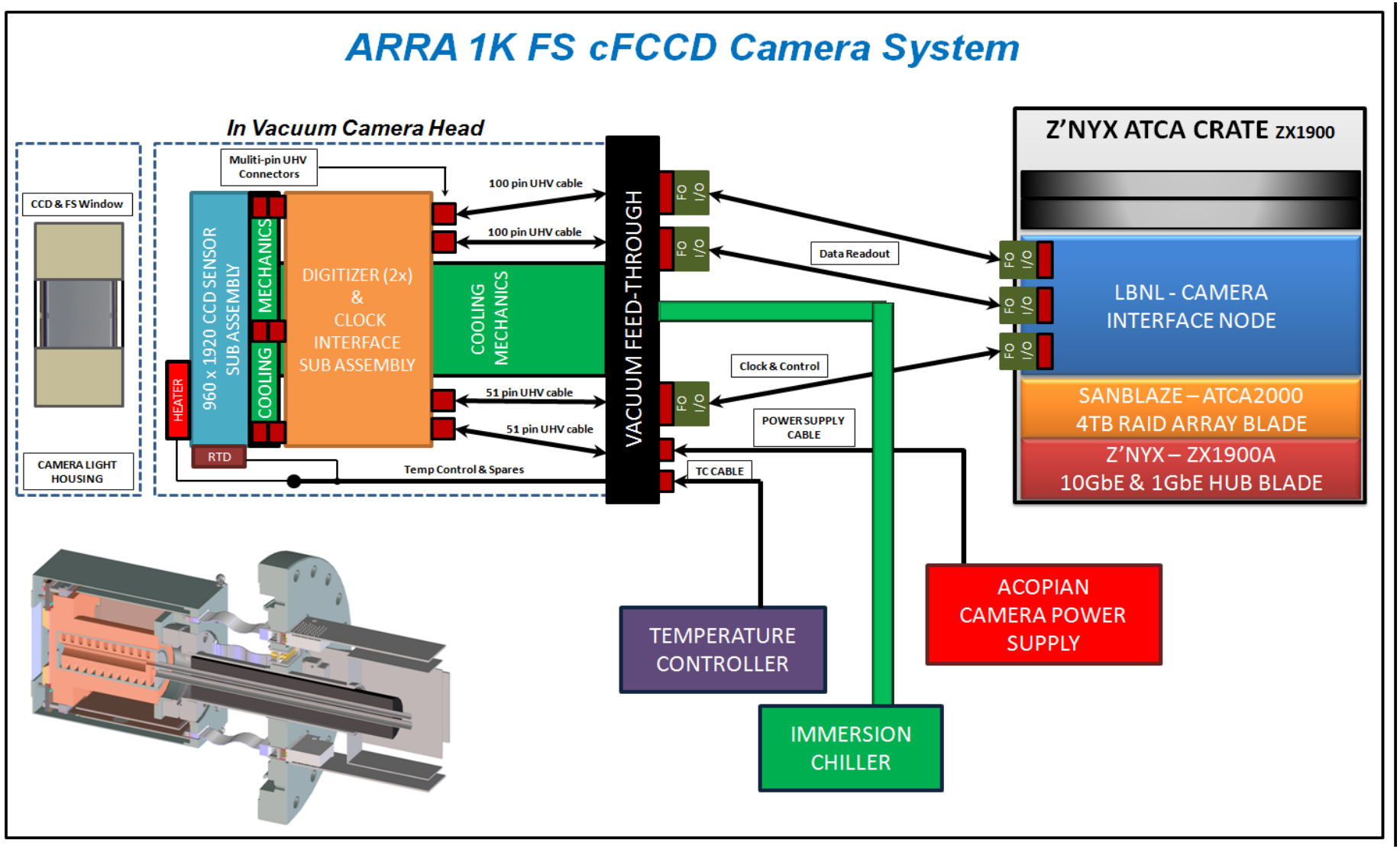
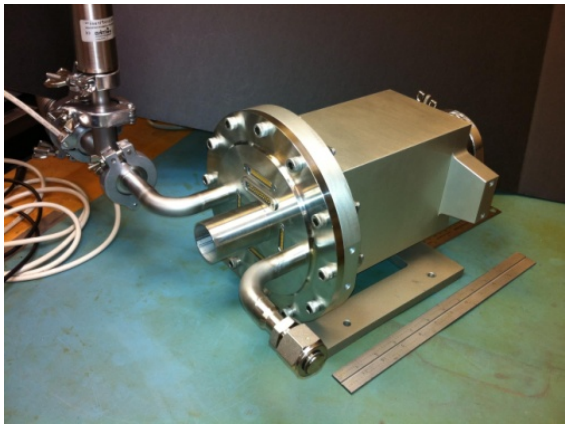
Fast CCD: 1kFSCCD – System Block Diagram

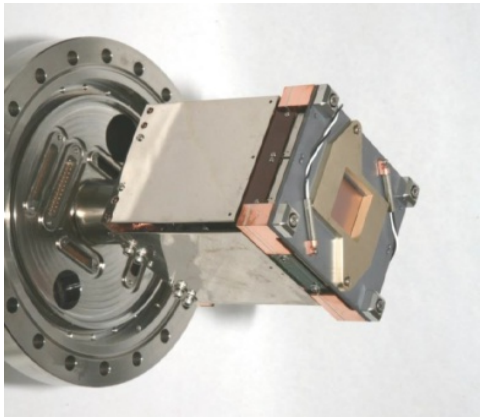


Slides courtesy of J. Weizeorick

Fast CCD



Detector Head



Detector Assembly in Vacuum

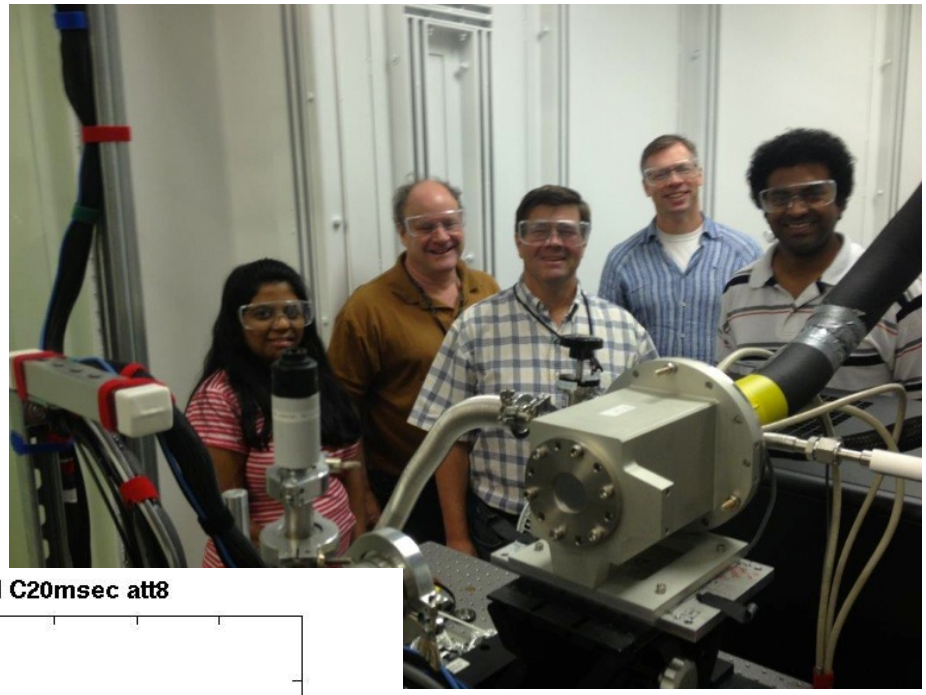
ATCA Crate

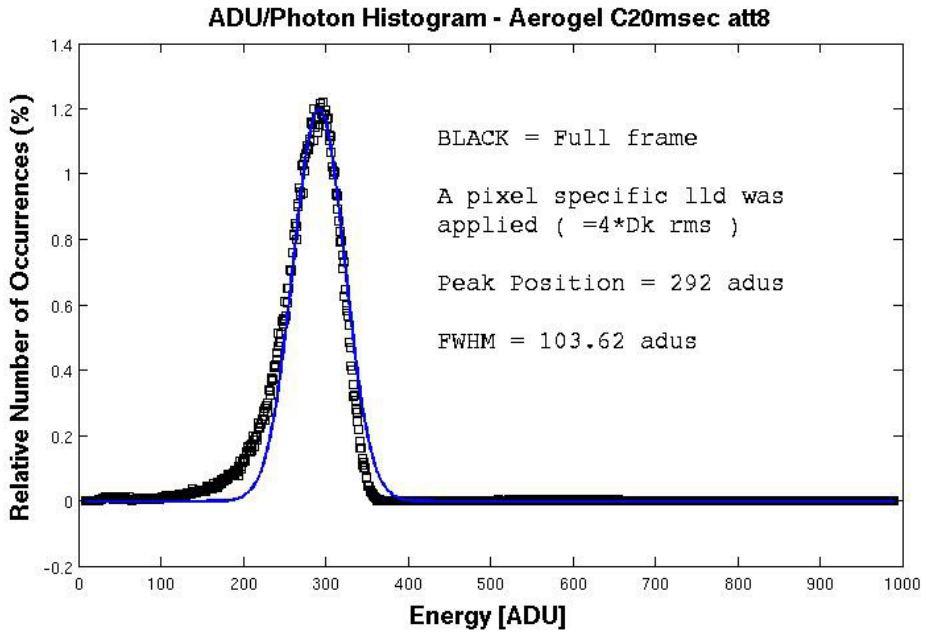
- APS applications and status:
  - APS now has one of two 1kFSCCD which will be used at 8id for XPCS
  - Detector has been in commissioning for most of 2013, but first run was in July 2013
- At ALS it has been used at the Nanosurveyor for **Ptychography**
- There are plans for the detectors to also be used at LCLS and NSLS II

Slide courtesy of J. Weizeorick

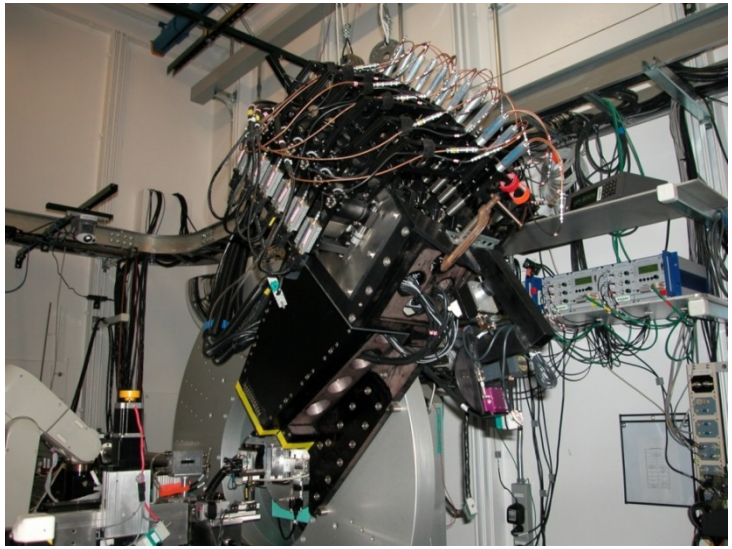
Fast CCD: 1KFSFCCD First run, July 2013

Pictured from left to right:
Preeti Vodnala[1], Larry Lurio[1], John Weizeorick[2], Alec Sandy[2], Nuwan Karunaratne[1]
1- Northern Illinois University, 2- Argonne National Lab





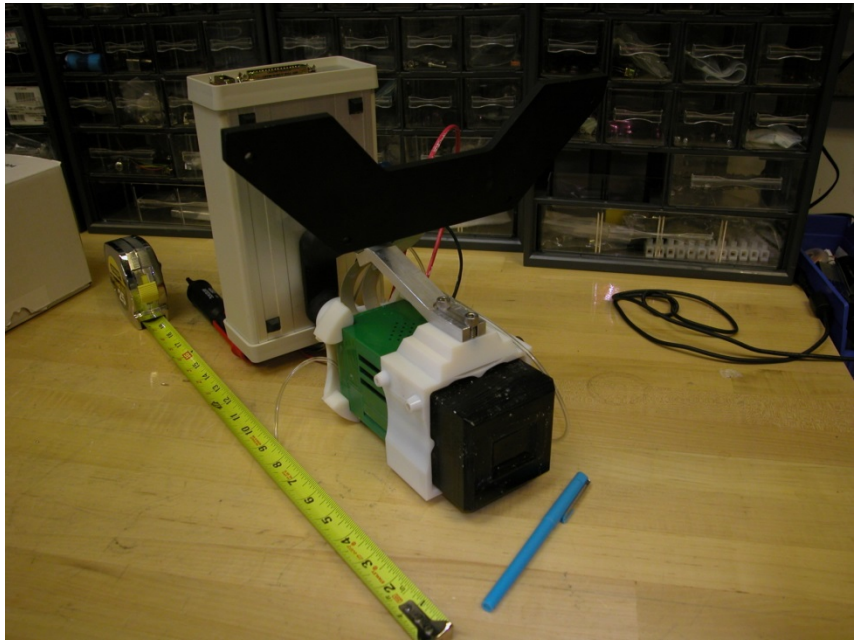
Detector Development: Powder Diffraction CCD



Currently at 11-BM:

- Crystal analyzers with scintillation counters
- ~$1M
- ~1 hour to scan

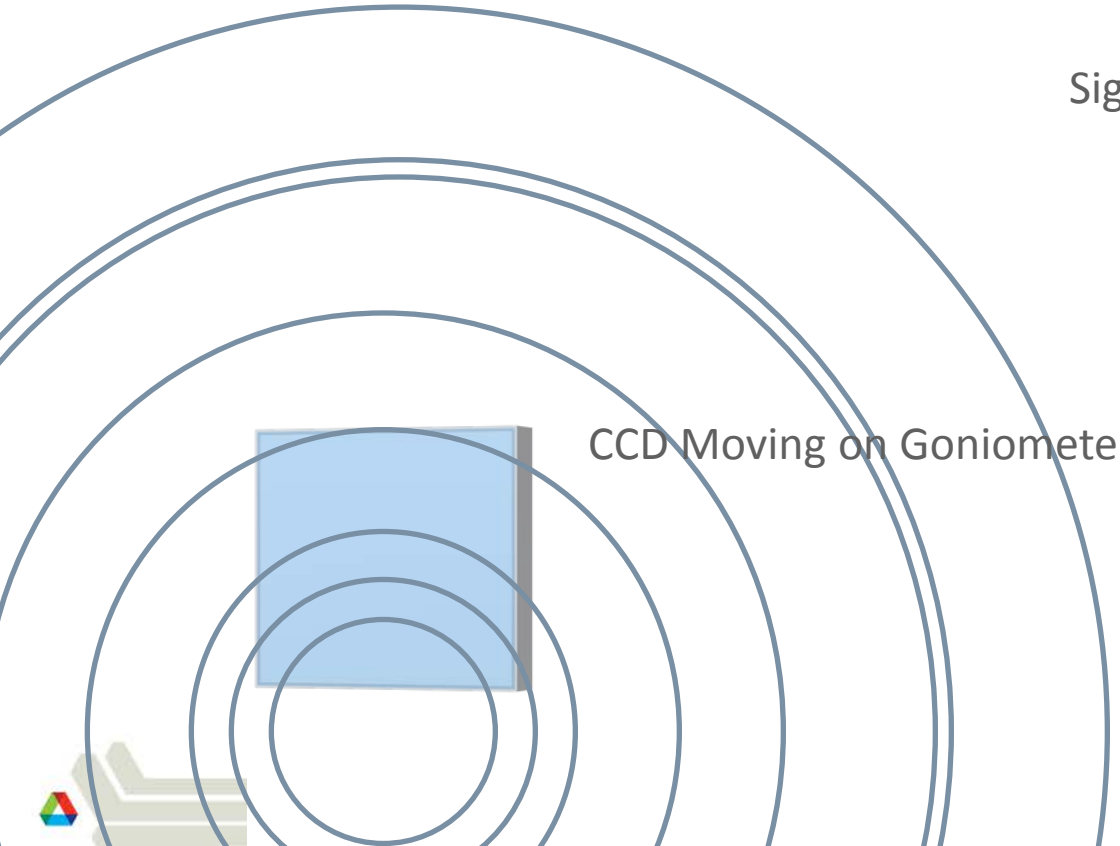
- Small CCD for acquisition of powder diffraction data
  - Mounts on diffractometer arm
  - Kodak KAF-16801 CCD
    - 9μm x 9μm pixel
    - 4096 x 4096 pixels
  - 1:1 Fiber Optic Faceplate
  - Scint-X Structured Phosphor
- Tim Madden



Synchronizing CCD Readout with Movement

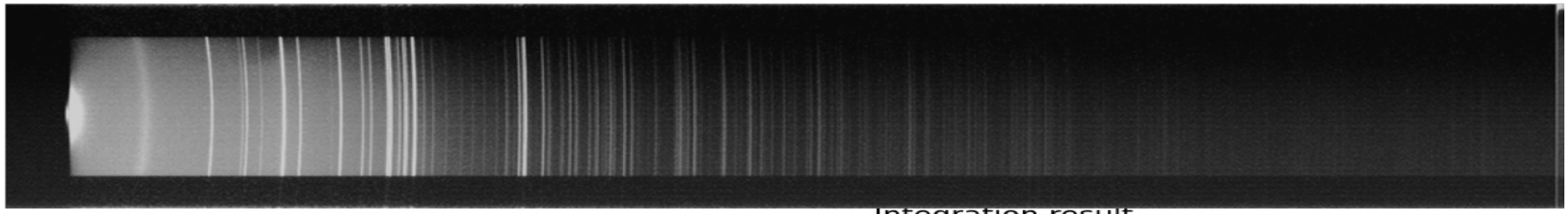
- CCD moves through diffraction rings projected in space
- CCD readout sync’ ed with movement.
- Area of CCD allows integration of signal as it moves through projected diffraction rings.

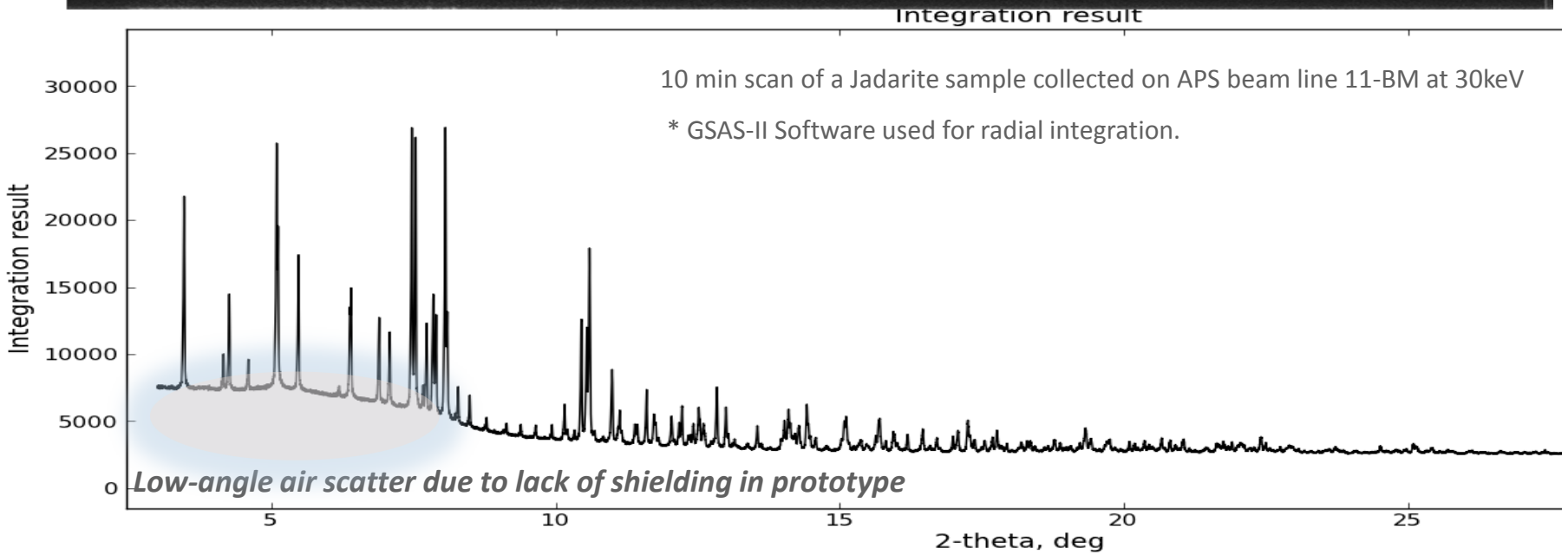
Signal on CCD



Testing of Scan CCD at APS 11-BM

- Detector returns a series of 4k x 4k pixel images, 16 bit data. 32MB images.
  - Separate images out of convenience.
  - Data are actually single 40k x 4k pixel image.
- Images are then stitched into a Debye-Scherrer filmstrip replica.
  - Below, 10 images stitched. Images can be stitched without any fancy math.

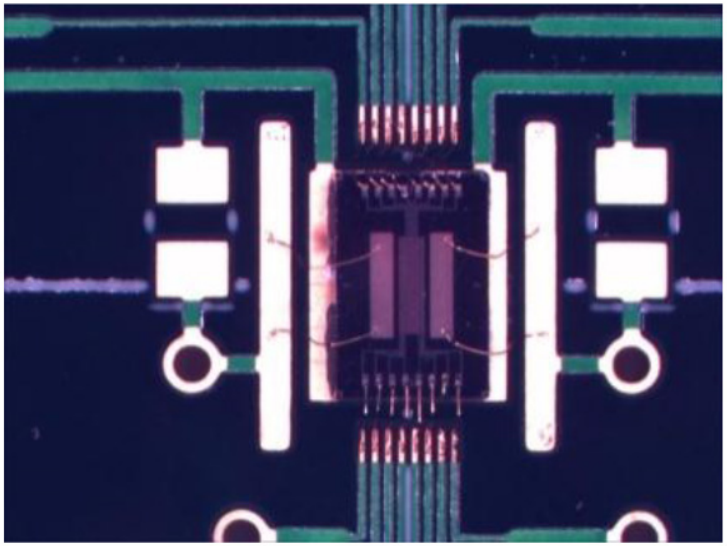




Slide courtesy of T. Madden

Other initiatives

- Fuel Spray Detector:
  - Steve Ross, Dave Kline
  - Integrating silicon strip detector
  - 25 µm x 1500 µm pixels, 0.5mm thick
  - 6.5 MHz frame rate
- Control electronics:
  - Dave Kline
  - FPGA with microcontroller
    - User has some control over parameters in FPGA logic
    - Flexible architecture
  - Applications: Detector trigger, device synchronization, scalar and other beamline devices
- Steve Ross with industry:
  - Hi-Z scintillator, diamond beam position monitors



Future initiatives: APS Upgrade

- APS working towards major facility upgrade:
  - Storage ring upgrade:
    - 100 milli-Amps to 150 milli-Amps
  - Short Pulse X-ray Facility:
    - RF cavity will vertically deflect electron bunch
    - Slit can then control temporal width of x-ray pulses
  - Suite of new and upgraded beamlines
- See George Srajer's talk tomorrow at 11:50.
- Detector development:
  - Not initially included
  - My job: Develop plans for complementary initiatives
    - Have looked at fast hybrid pixel area detetors

AGIPD

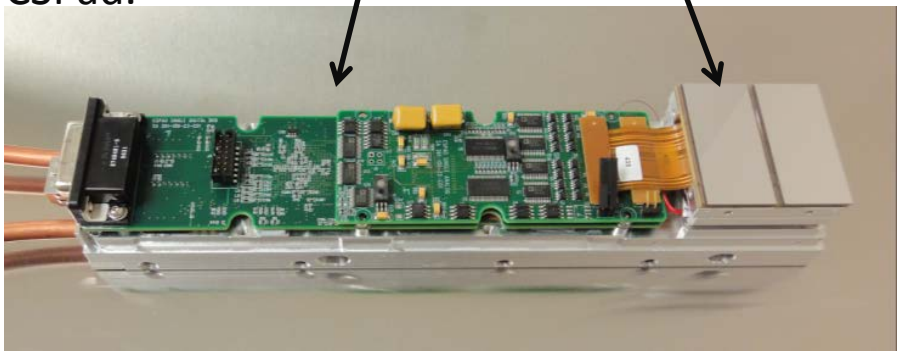
Backstory: Had considered joining AGIPD ~one year ago, but DOE preferred domestic initiatives.

CPix2: Unique capabilities for pump-probe experiments

- Dual Gating: Two counters per pixel that can be independently gated
- Upper and lower discriminators in each pixel separate scattered, Compton, and fluorescent signals.

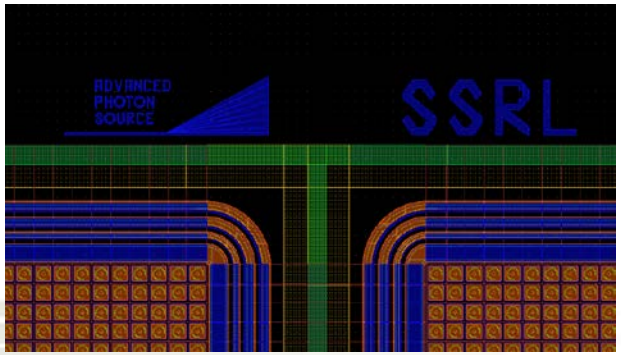
Detector Properties	
Counting rate	6.5 MHz
Processing time	96 ns
Counter length	14 bits
Readout dead time	< 3 ms
Pixel size	100 μm
Minimum energy	5 keV

Developed with SLAC:
Mechanics and software adapted to APS, but does leverage electronics and sensor from CSPad.



Potential applications:

- Scattering and emission spectroscopy at SPX
- Pump-probe experiments at Sectors 7 and 11

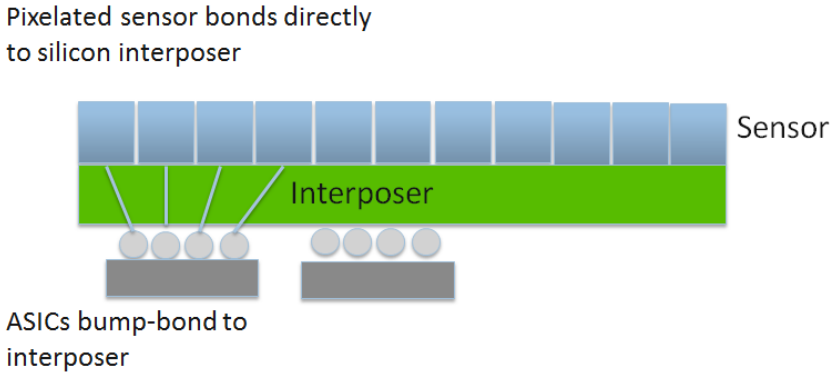


APS and SSRL logos on a sensor layout drawing.

FASPAX: Fermi-Argonne Semi-conducting Pixel Array X-ray detector

- Verastile, fast integrating detector:
  - Stores 48 images in 100 μm pixel
  - Novel passive integrators based on current splitters perrmits 10^5 photons/pixel/pulse
  - Edgeless sensor
- Possible applications:
  - Dynamic Compression Sector
  - High Flux Pump Probe
- Collaborative development with Fermilab and ANL HEP
- Two funding proposals:
  - UChicago seed grant just funded
  - ANL Laboratory Directed Research and Development

Edgeless sensor:



Detector Properties	
Charge handling	Integration
Max photons/pixel/pulse	10^5
Burst image rate	48 images at 6.5 MHz
Sensor type	Pixelated silicon
Pixel size	100 μm

Conclusion

- APS Detectors Group has strong emphasis on beamline support
  - Detector Pool
  - Test beamline program at 1-BM
  - 1/3 of Group effort
- Detector Development:
  - New effort in MKIDS
  - Historical expertise in CCDS
    - Fast CCD
    - Novel CCDs for specific applications
  - Fuel-spray detector
  - Beamline electronics
- Immediate future concerned with complementing the scientific program of the APS Upgrade
  - Collaborative efforts in hybrid pixel detectors
    - CPix2 with SLAC
    - FASPAX with FNAL and ANL HEP