Argonne NATIONAL LABORATORY

… for a brighter future

U.S. Department of Energy

UChicago ▶ Argonne LLC

Office of Science U.S. DEPARTMENT OF ENERGY

A U.S. Department of Energy laboratory managed by UChicago Argonne, LLC

The XSD-BTS Group Detector Program

P. Fernandez

Beamline Technical Support Group

Advanced Photon Source, X-ray Science Division

Argonne National Laboratory

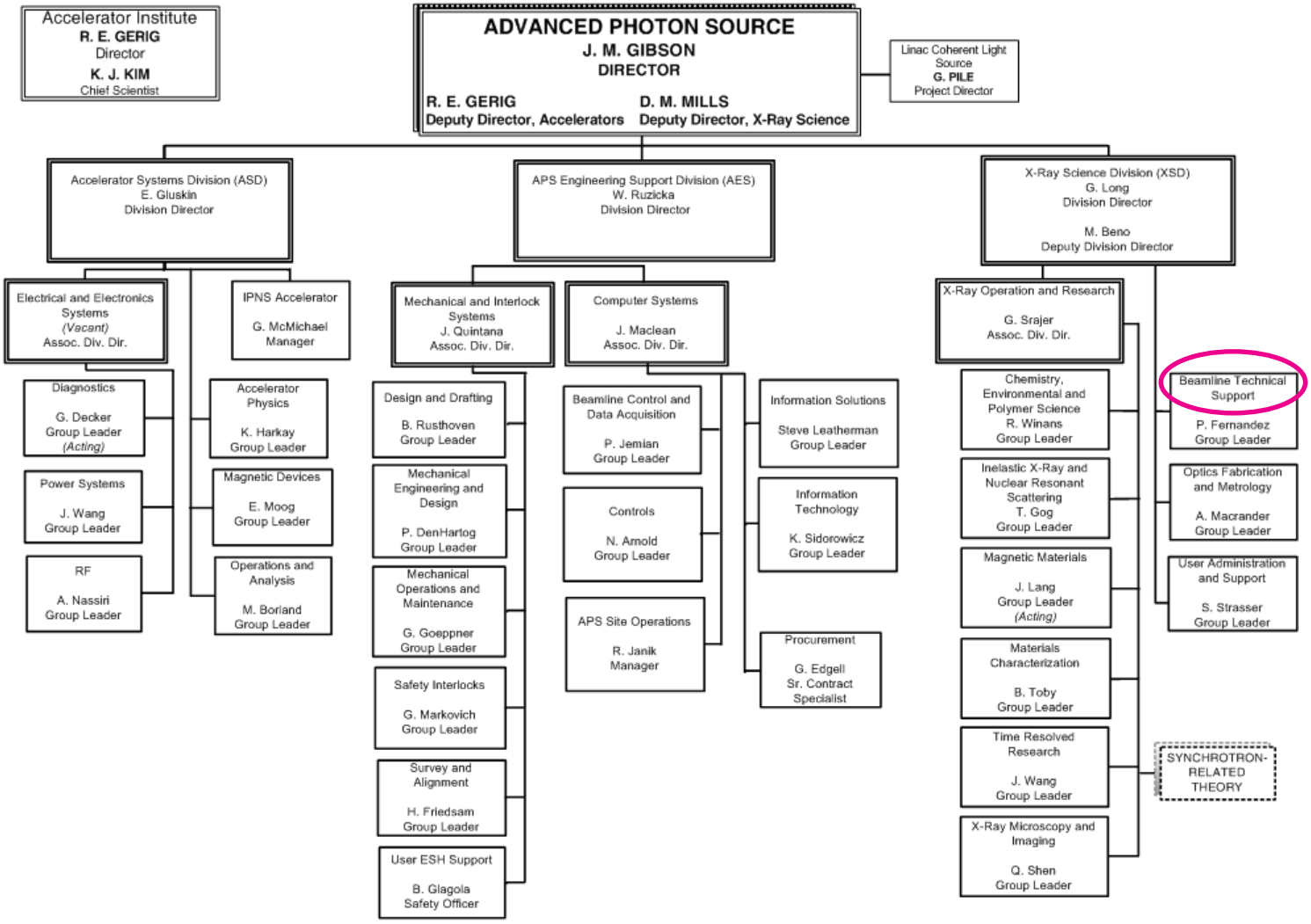
ESRF, SPring-8, APS Three-way Meeting

March 18, 2008

Outline

- Who we are: The XSD Beamline Technical Support Group
- What we do – Focus on:
  - The APS Detector Pool
  - X-ray detector activities
- Future plans

Advanced Photon Source Organization Chart



The XSD Beamline Technical Support Group

- The BTS group was conceived as a means to provide efficient centralized technical support to APS scientists as the number of beamlines operated by the APS increased.

- The mission of the XSD Beamline Technical Support group is to facilitate the efficient and productive use and operation of APS beamline-based research facilities.

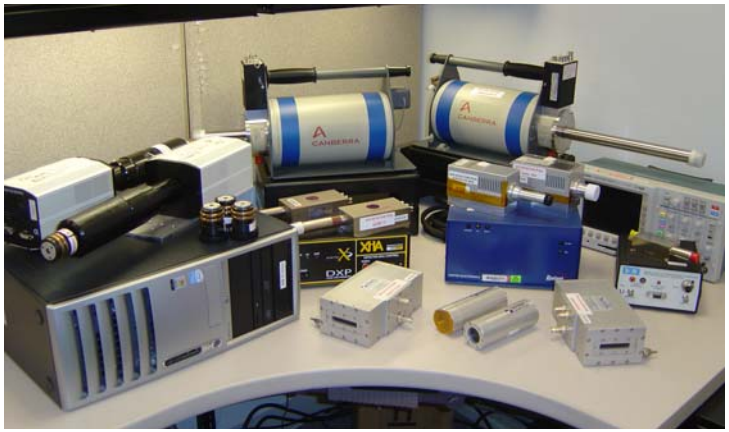
- Core functions:
  - Operate the APS Detector Pool and the APS Equipment Pool.
  - Provide detector support: integrate existing sensors; develop new detectors.
  - Provide beamline electronics support.
  - Provide beamline support: manage user storage; support limited-scale upgrade projects (design, fabrication, management).

- Personnel: 3 engineers, 2 physicists, 4 support staff, 2 electronics technicians

The APS Detector Pool

The goals of the Detector Pool are:

- To provide a range of detectors suitable for the research interests of the APS community.
- To facilitate access to expensive detectors and increase the efficiency of detector use through time-sharing.
- To provide expertise and guidance on x-ray detector capabilities.
- To identify and assess upcoming commercial technologies.



APS Detector Pool – Contact: A. Miceli

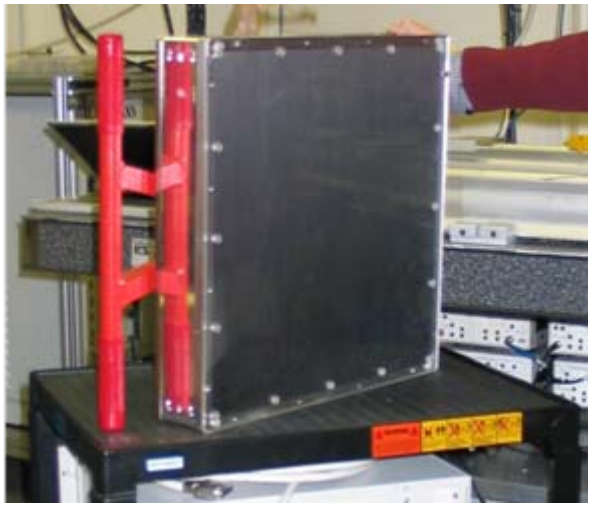
- Began operations in April 2003.
- Capital equipment to date: $ 1.9M; 42 detectors.
- Approximately 75% of APS beamlines have borrowed equipment from the Detector Pool.
- Our services include assistance with detector installation and troubleshooting.
- Arrange inter-beamline loans.
- Operate visible light and x-ray detector test stands, available to APS scientists.

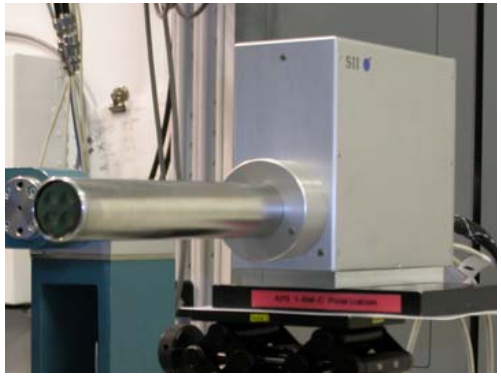
The APS Detector Pool – Recent Additions

- Pilatus 100K digital Si pixel array detector developed at the Swiss Light Source/PSI (http://pilatus.web.psi.ch/pilatus.htm)
- a-Si flat panel detector (GE Healthcare)
- 4-element Si drift detector array (SII NanoTechnology)

Pilatus 100K digital Si pixel array detector (SLS/PSI; XSD-BTS contact: A. Miceli)

a-Si flat panel detector (GE Healthcare; XSD-BTS contact: J. Lee)





4-element Si drift detector array (SII NanoTechnology; XSD-BTS contact: A. Miceli)

XSD-BTS X-ray Detector Strategy

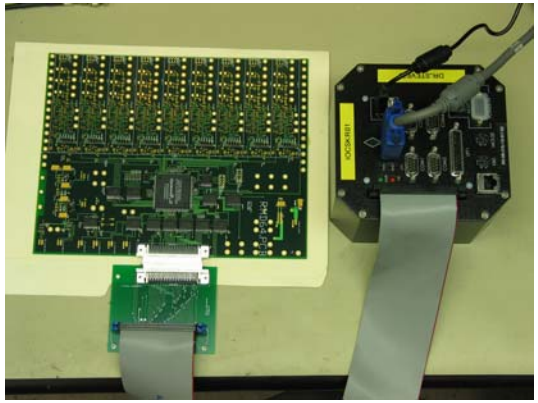
- The X-ray Science Division held a workshop in July 2006 to identify the detector needs at the APS.
- Twelve speakers presented detector requirements for different research areas pursued at the APS.
- P. Denes (Advanced Light Source) and G. Drake (Argonne High Energy Physics) discussed detector projects in their areas.

Workshop recommendations included:

- Continue and expand support for existing detector development activities at the APS.
- Collaborate with other institutions and industry in the development of Si avalanche photodiode arrays, Si pixel array detectors (analog and digital), and large-area energy-dispersive detector arrays (Si drift detector arrays).
- Investigate new technologies: transition edge sensors (TES) and/or superconducting tunnel junction detectors for very high energy resolution applications; column-parallel CCDs for micro-diffraction, XPCS, time-resolved imaging.

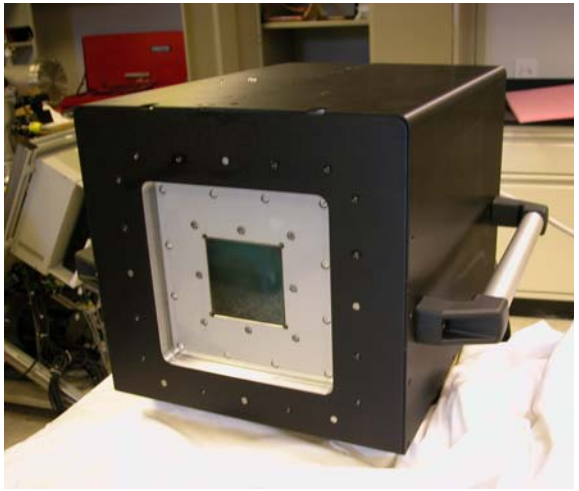
XSD-BTS X-ray Detector R&D Activities

- Build detectors using existing silicon chips
  - Custom single element Si avalanche photo diode (APD) detectors (S. Ross)
  - APD array electronics for EXAFS (Sector 20 – S. Ross)
  - Tiled CCD detector for protein powder diffraction; uses Kodak KAF-4320E CCD (T. Madden)
  - 4-element fiber-optic-coupled CCD camera for small angle x-ray scattering; uses Kodak KAF-4320E CCD (T. Madden, J. Lee)



PCB electronics for testing commercial 3x3 Si APD array (contact: S. Ross)

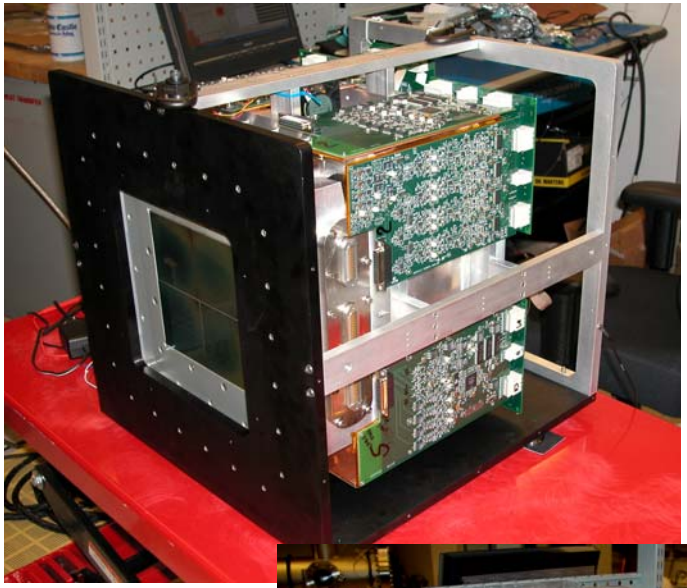
Single element fiber-optic-coupled CCD camera built by XSD-BTS (contact: T. Madden)



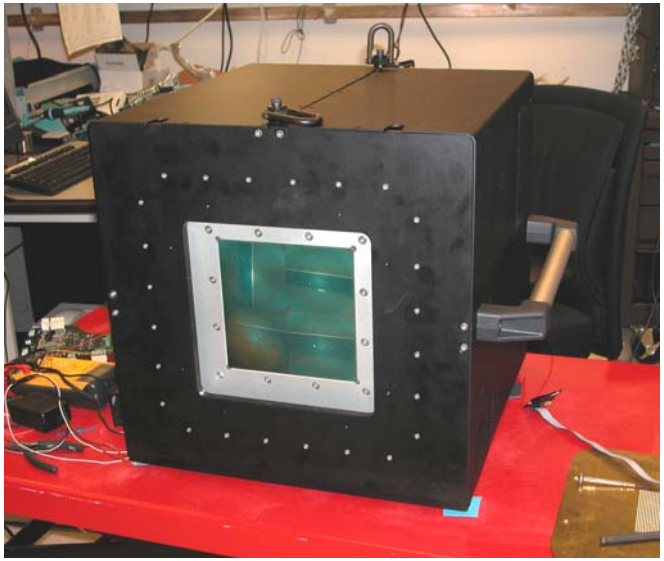
XSD-BTS X-ray Detector R&D Activities – continued

4-element fiber-optic-coupled CCD camera for small angle x-ray scattering – T. Madden, J. Lee

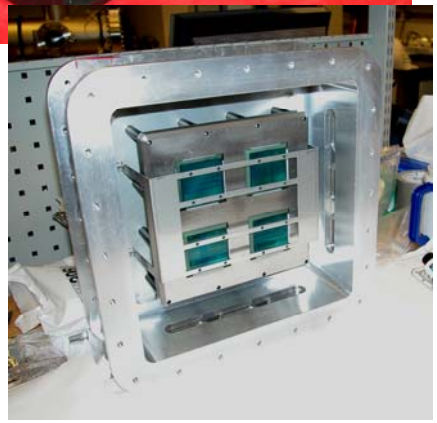
- 2x2 mosaic of CCDs, $(170\ mm)^2$ active area
- 1.74 demagnification fiber-optic tapers
- Kodak KAF-4320E CCDs, front illuminated
  - *2084 x 2084, 24 µm pixels*
  - *QE of .65*
- Readout: 5 fps for 4x4 binning, 2 fps for 2x2 binning
- Commissioning: starting October 2007



View of the electronics in the 4-element CCD camera.



4-element fiber-optic-coupled CCD camera built by XSD-BTS (contact: T. Madden)



4-element fiber-optic taper 2x2 array.

XSD-BTS X-ray Detector R&D Activities – continued

- Explore path to IC design capabilities
  - Collaboration with Northern Illinois University Department of Electrical Engineering to gain experience with IC design codes and fabrication processes.
  - Establish collaboration with Argonne HEP and Fermi National Laboratory on digital Si PADs.

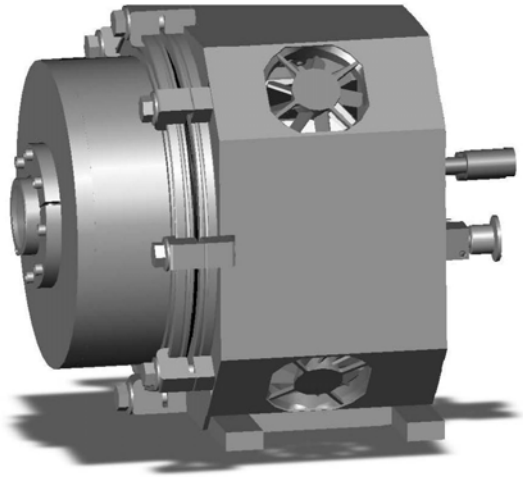
- Collaborate on detector development projects
  - Collaborations on Si APD arrays, with Voxtel, Inc., and RMD, and on multilayer fluorescence detectors with HD Technologies, Inc.
    - *DOE Small Business Innovation Research grants program*
  - Fast CCD detector collaboration with P. Denes and H. Padmore, Advanced Light Source, LBNL:
    - *use quasi-column parallel CCD and fast readout chip designed by LBNL; XSD-BTS designs and fabricates detector back-end electronics.*

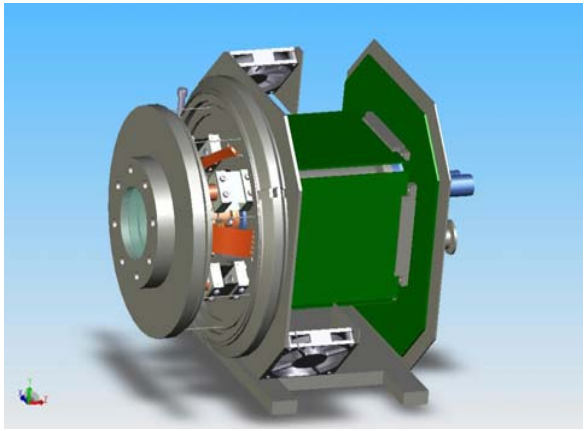
XSD-BTS X-ray Detector R&D Activities – continued

ALS/APS Collaboration on fast CCD detectors

P. Denes, H. Padmore, ALS; J. Weizeorick, APS/XSD-BTS

- Produce two CCD x-ray detectors using prototype 480x480 pixels CCD chip
- Frame rates up to 400 fps
- Expected completion in 2008
- If prototype is successful, pursue larger CCD: 1k x 1k (or larger?)
- At the APS, strong interest from the XPCS community





XSD-BTS X-ray Detector R&D Activities – continued

ALS/APS Collaboration on fast CCD detectors

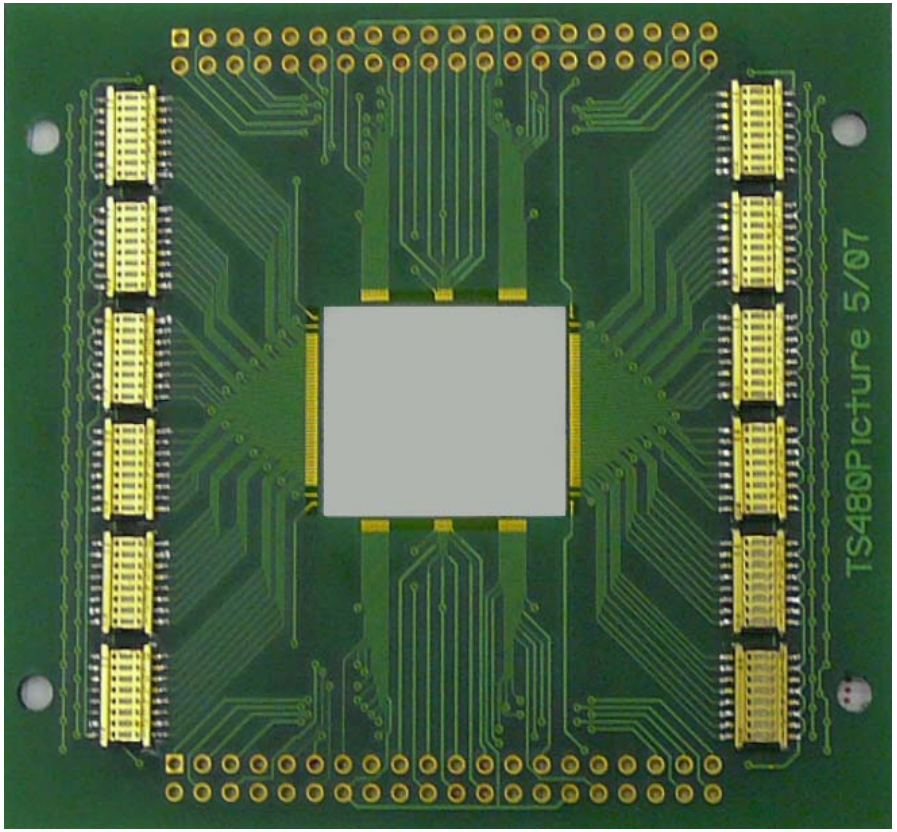
LBNL provides overall project management and the following:

- Custom chips based on SNAP (SuperNova/Acceleration Probe) ICs
  - *Custom CCD*
    - *480 x 480, 30 µm pixels*
    - *Back-illuminated CCD: Good QE for phosphor coupled x-ray cameras*
    - *Fully depleted 300 µm silicon: Direct detection of x rays*
    - *Almost Column-Parallel Readout*
      - Split top/bottom of CCD with one output/10 columns: 96 analog outputs
      - Readout time of 2.4 msec / frame = max of 416 frames/sec
      - 192 Mbytes/sec
  - *16-channel Fast Custom Readout IC (fCRIC): performs analog-to-digital conversion*
    - *Low power, large dynamic range (14+ bits) pipeline ADCs*
    - *1 µsec/pixel conversion rate*
    - *Low noise (~ 10 e- read noise)*
- CCD assembly design and fabrication
- Mechanical housing design and fabrication

XSD-BTS X-ray Detector R&D Activities – continued

ALS – Picture frame board for testing 480 x 480, 96 port CCD

February 2008

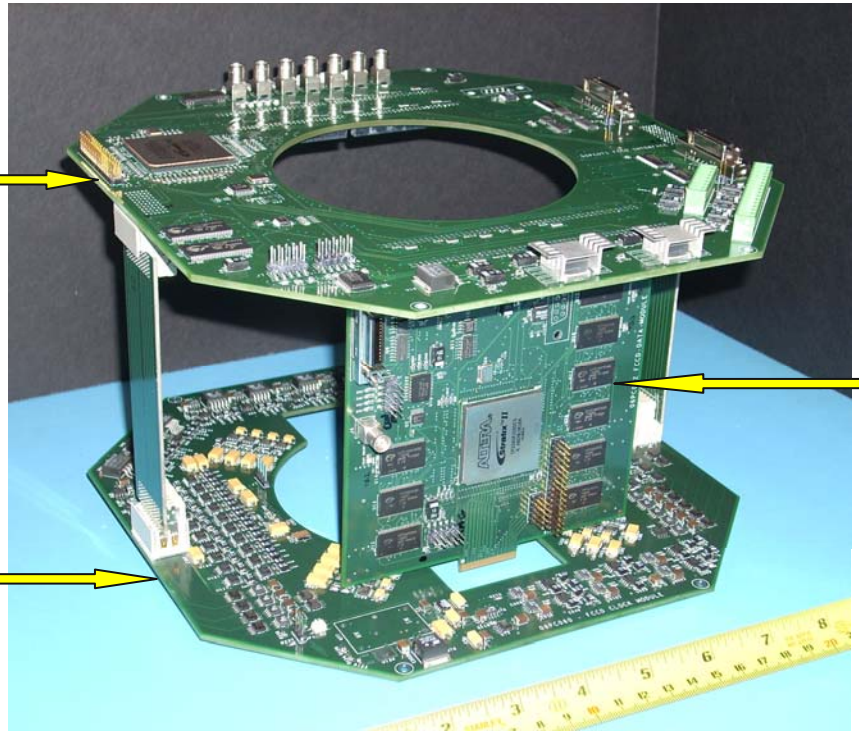


XSD-BTS X-ray Detector R&D Activities – continued

ALS/APS Collaboration on fast CCD detectors

APS/XSD-BTS provides the following:

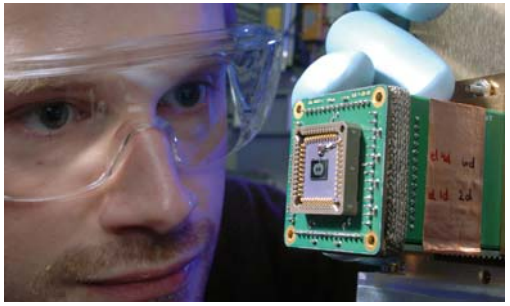
- Design and fabrication of readout electronics: interface, data, and clock driver modules
- Computer with commercial frame grabber
- Development of DAQ and control software



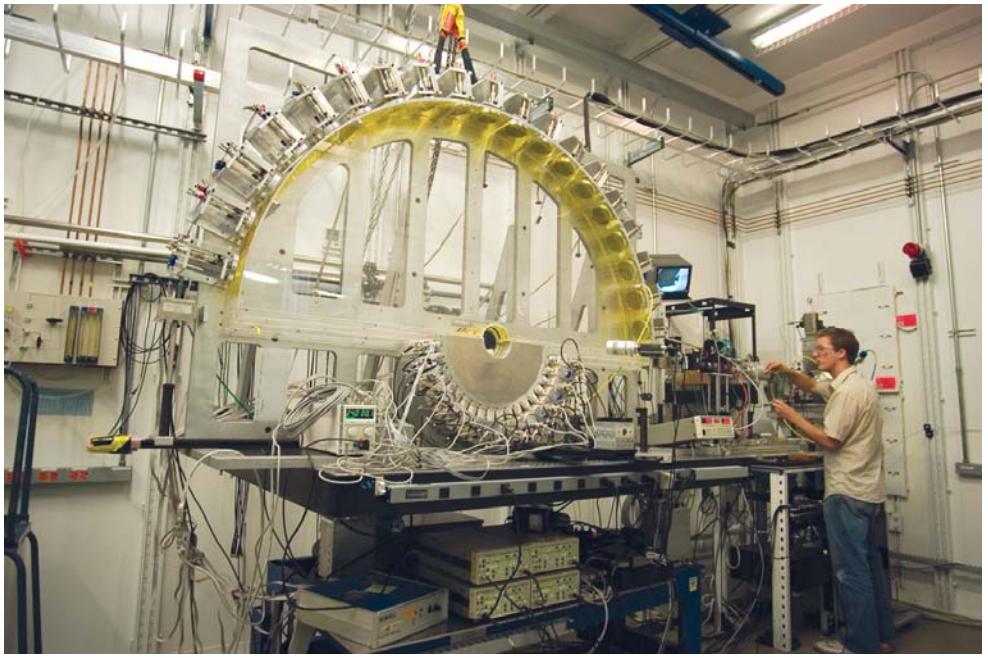
Detector Efforts at the APS

- Detector efforts within XSD-BTS represent a fraction of all detector-related work being carried out at the APS. Several groups integrate and develop detectors for specific applications. Some examples:

Time-resolved small angle x-ray scattering detector (contact: S. Seifert, Sector 12), developed by Argonne CHM and HEP divisions (J.Hessler, P. De Lurgio).



Detector for differential phase contrast imaging (S. Vogt, Sector 2), collaboration between APS-XSD X-ray Microscopy and Imaging Group and SUNY-SB/BNL.

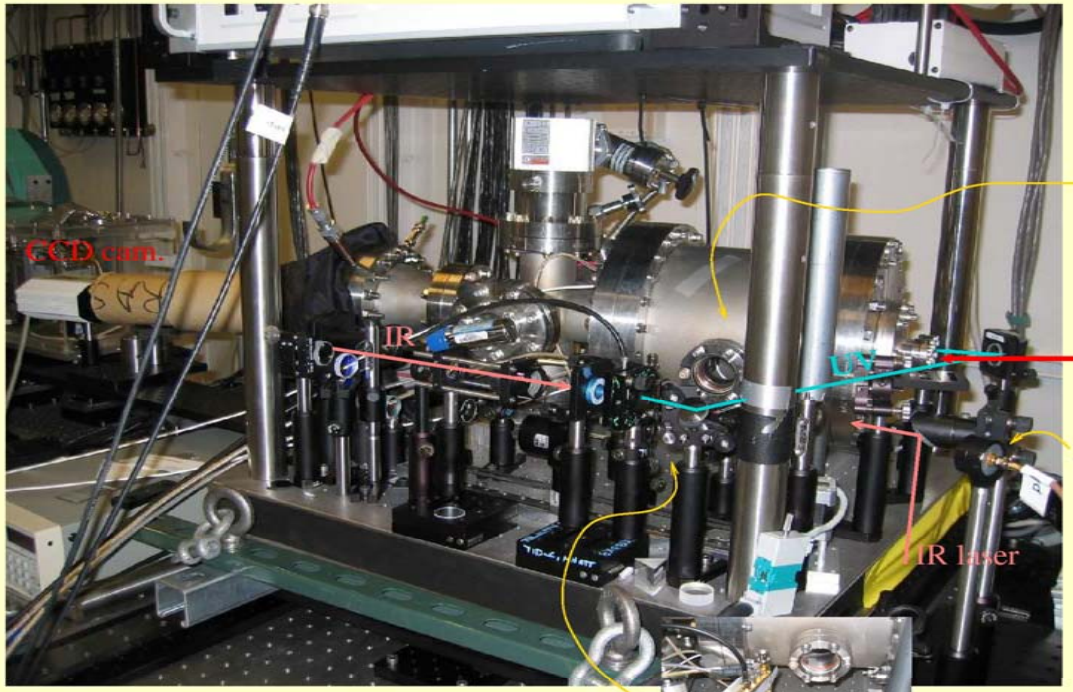


LERIX x-ray Raman scattering spectrometer at 20-ID, developed by G. Seidler and collaborators (T.T. Fister et al., "Multielement spectrometer for efficient measurement of the momentum transfer dependence of inelastic x-ray scattering," Rev. Sci. Instrum. **77**, 063901 (2006)).

Detector Efforts at the APS – continued

- X-ray streak camera work at 7-ID – Contact: B. Adams

APS X-Ray Streak Camera



deflection, focusing

x–ray

photodiode for timing to 100 ps

photoconductive switch for laser–triggerred rapid deflection

CsI photocathode for x-ray & UV

UV double pulse (10 ps) for time scale

XSD-BTS Group – Future Plans

- Continue to seek the most effective routes to bring cutting-edge detector technology to our scientists, pursuing collaborations within and without the x-ray science community.
- Continue growing as a resource for the APS community on detector-related matters, e.g. new technologies; technique development; etc.
- Keep improving the operation, inventory, and services of the APS Detector Pool, including improvements to our detector test stands.

- Future detector development projects
  - Real-time data processing for XPCS.
  - Ge strip detector for inelastic scattering (Sector 30).
  - Explore TES for x-ray detection (collaboration with Argonne Materials Science Division).