DETECTOR DEVELOPMENT AT APS

"Make no little plans; they have no magic to stir men's blood and probably themselves will not be realized."
- Daniel Burnham

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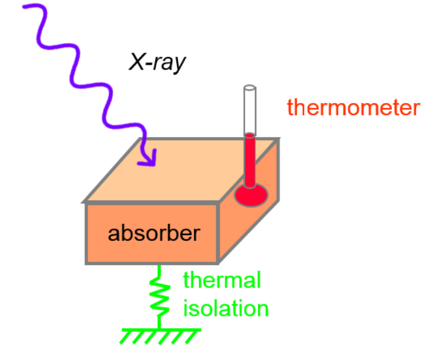
DETECTORS AT THE APS

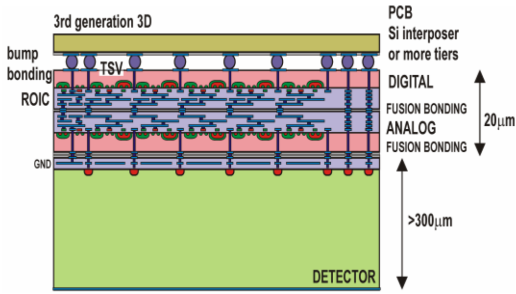
Resources aligned to prioritize

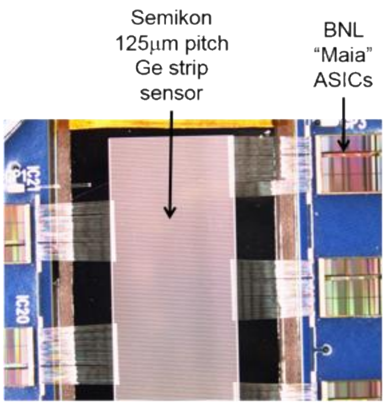
- Detector Pool: Introduce new, cutting-edge commercial detectors
- **Detector R&D**: Projects compelling to APS-U science.

▪ Detector R&D plan

- **Transition Edge Sensors (TESs)** for emission spectroscopy (E > 1 keV)
  - Enable new science – APS-U: ISN, Ptycho, Polar (APS, NIST, SLAC)
- **VIPIC** for XPCS (Vertically Integrated Photon Imaging Chip)
  - Enhanced coherence of APS-U: WA- & SA-XPCS, CHEX, CSSI (NSLS-II, APS, Fermilab)
- **Germanium** for high-energy applications (NSLS-II, APS)
  - APS is a high-energy light source → efficient sensors
- **High-Energy, High Dynamic Range Area Detectors**
  - High-energy MM-PAD v2.0 (Cornell, APS)







X-ray Transition Edge Sensors (TESs)

E/ΔE > 1,000 can be achieved in high-efficiency energy dispersive detectors

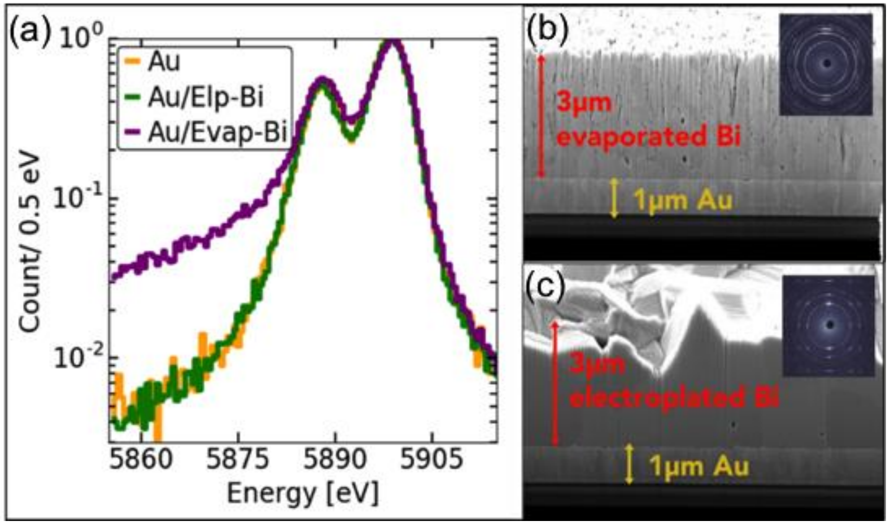
Energy spectra measured over entire energy range simultaneously using transition-edge sensors (TES)

Expands application of X-ray spectroscopy

e.g., time-resolved & nanoscale imaging of dilute, radiation-sensitive samples

Challenge: tension between sensor resolution, speed, collecting area

Improved theoretical understanding of superconducting transition guiding sensor design



(a) Comparison of the Mn Kα spectrum measured by the three TES devices, normalized at the peak maxima. A low-energy (LE) tail is observed only in the Au/evaporated-Bi absorber devices (b) Scanning electron micrograph of the Au/evaporated-Bi absorber. Inset: X-ray diffraction pattern of electroplated-Bi. (c) Scanning electron micrograph of the Au/electroplated-Bi absorber cross-sections. Inset: X-ray diffraction pattern of electroplated-Bi.

D. Yan, *et al*, Appl. Phys. Lett. **111**, 192602 (2017), doi: 10.1063/1.5001198

R&D Accomplishments

– Microwave SQUID readout with high bandwidth (2 MHz/pixel); Room-temperature electronics built on LCLS ATCA platform
– Soft X-ray sensors achieved 1.0 eV and 80 μs response time
– Hard X-ray sensors achieved with Gaussian response

Science-grade Spectrometers

– APS XAFS/XES funded
– LCLS-II SXR funded

High-energy X-ray Germanium Detectors

Hard X-ray energy-resolving applications

High-quality Ge sensors efficient at high energies (E > 20 keV) for spectroscopic applications

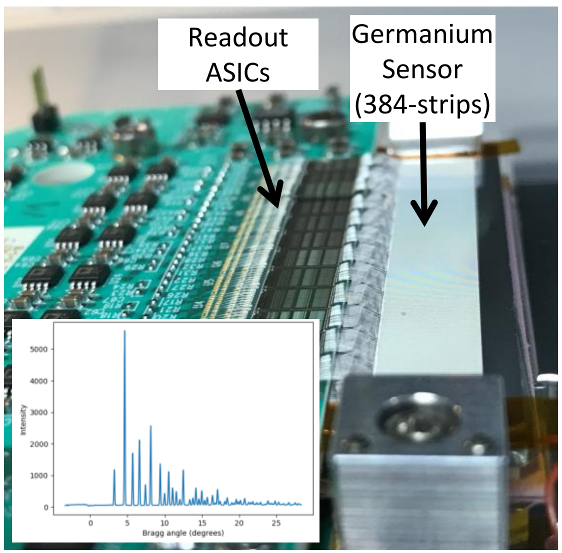
Improve efficiency of high-energy applications

Parallel collection of spatially-resolved, energy-dispersive diffraction

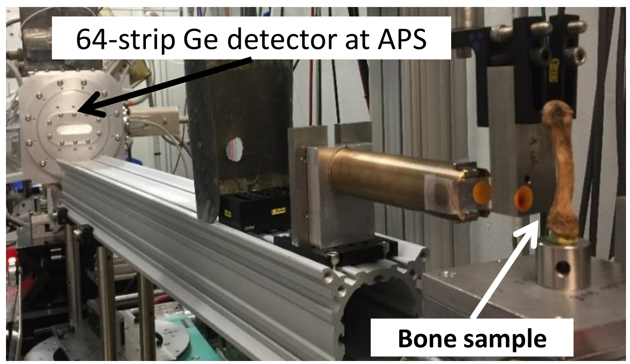
Suppression of unwanted fluorescence background in powder diffraction experiments

Lack of high-quality high-energy sensors

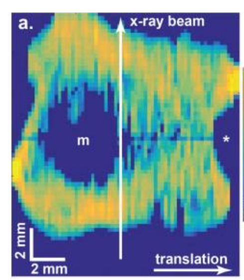
Combines BNL's low-noise readout integrated circuits with 1D germanium sensors arrays



A 384-strip germanium sensor is wire bonded to twelve low noise ASICs. This sensor assembly is cooled to 100 K. (Insert) $BaTiO_3$ diffraction spectrum taken at NSLS-2 with the 384-strip germanium detector.

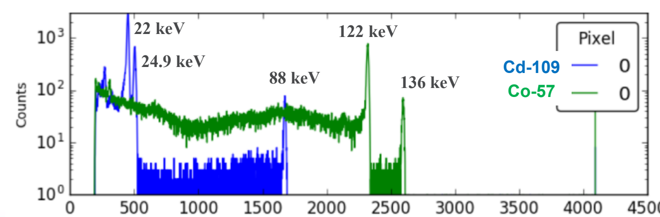


(Above) 64-strip Ge detector at APS 6-BM located in far left and a human second metacarpal bone, from the Roman-era cemetery in the UK, in the near right of the photograph. (Right) EDD reconstruction.



R&D Accomplishments

- 384-strip detector with a 125 μm pitch with ΔE < 500 eV at 60 keV at NSLS-2 XPD beamline
- 192-strip detector with 0.25 mm pitch with ΔE < 500 eV at 60 keV at APS EDD beamline (6-BM-A)



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TES

- Ullom *et al* (NIST), Irwin *et al* (SLAC)

Germanium

- Siddons *et al* (BNL)

VIPIC

- Siddons *et al* (BNL)
- Deptuch *et al* (FNAL)

MM-PAD v2.0

- Gruner *et al* (Cornell)