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BNL's Synchrotron-radiation Research Hub for Characterizing Detection Materials and Devices for the NA22 Community

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Project Overview: Why NSLS as a Research Hub?

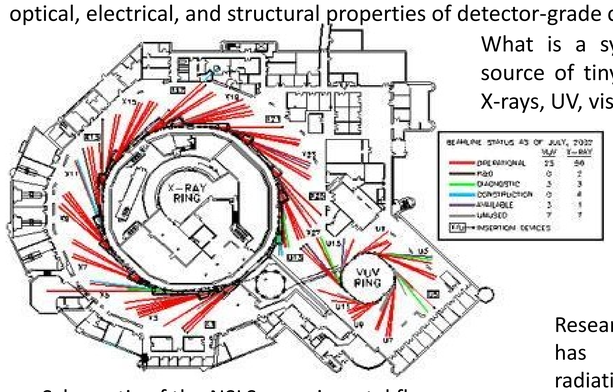
- This project is focus on providing technical service to research groups from industry and academia to offer multi-level beamline support to characterize radiation detection materials and devices.
- Many requests for support from outside R&D organizations – both as service and collaborations
- About 50% of the requests involve CZT; remaining half scattered over a wide range of semiconductor and scintillator materials
- Mono-energetic X-ray beams hold promise for accurate measurements of non-uniformity of material and device properties, particularly at lower energies
- DOE Office of Science constructed and operates the NSLS as a User Facility
- Organized to host, train and accommodate guest scientists (2500 guest scientists each year)
- Desire by Office of Science and BNL to show science impact to NNSA and other national security agencies
- Excellent match between the beam-line capabilities and material issues limiting device performance
- No synchrotron facility among NNSA labs
- NSLS II – continued leadership role and ability to resolve additional material challenges; access is highly desirable and competitive

Objectives, Approach and Deliverables

- Goal: Improve solid-state gamma-ray detectors operating at room temperature for nonproliferation applications involving spectroscopy and imaging
- Approach: Position the NSLS as a multi-purpose user facility to provide critical materials and device characterization data in support of the entire radiation-detector development community
- Metrics: Impact as measured by the number of (1) users, (2) crystals / detectors analyzed, (3) publications, (4) presentations, and (5) material advances

National Synchrotron Light Source (NSLS): User Facility

BNL's National Synchrotron Light Source (NSLS) is actively used to measure the optical, electrical, and structural properties of detector-grade crystals.



Schematic of the NSLS experimental floor

What is a synchrotron? NSLS is a source of tiny beams of very bright X-rays, UV, visible and IR light.

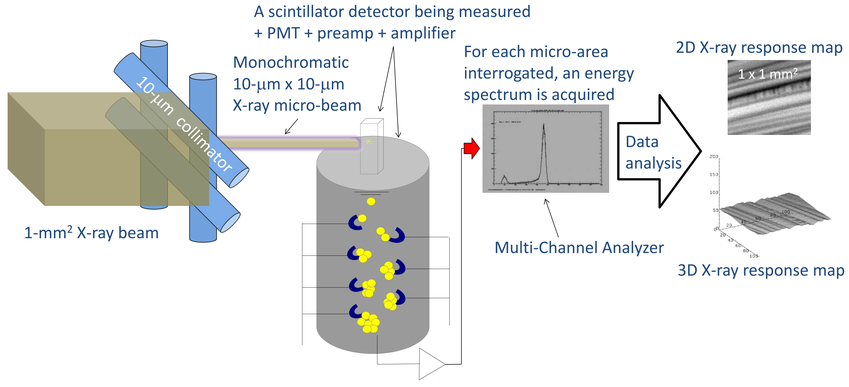
NSLS at Brookhaven National Laboratory in New York is a national user research facility founded by the U.S. Department of Energy's Office of Basic Science. Research conducted at NSLS has yielded advances in radiation-detection materials.

Research Groups, Vendors and Academia

Partial list of vendors and universities requesting our help in materials understanding:

- Lockheed Martin, CZT (~80 crystals)
- Endicott Interconnects, CZT (~40 crystals)
- Caltech, CZT (~50 crystals)
- Acrorad, CdTe (10 crystals)
- DSRI, CZT (2 very large crystals)
- Redlen Technologies, CZT (~20 detectors)
- Kromek, CZT (~20 crystals)

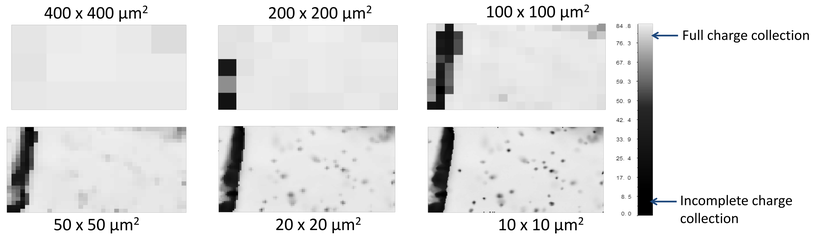
Technical Approach: Micro X-ray Response Mapping



The X-ray response mapping measurement is done at the NSLS X27B beamline. The detector response is measured across the surface of the crystal facing the X-ray beam. The beam is collimated to an area of a few square μm. For scintillators a pixel is plotted on the image with a relative brightness corresponding to how much light is produced in the irradiated area.

Why do we need high spatial-resolution raster scans?

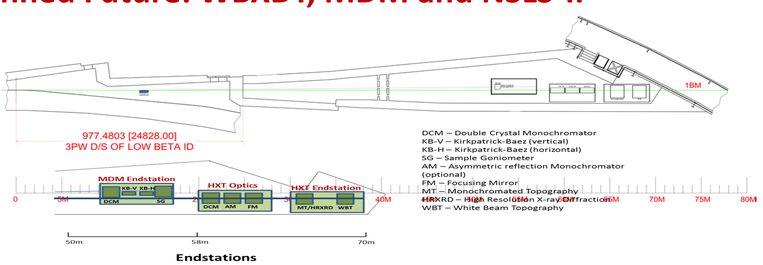
Planar detector 1.6 x 1.2 x 1 mm³; micro-beam energy = 30 keV; Bias voltage = 60 V



X-ray response maps give information on:

1. Detector polarization (hole trapping)
2. Local and global Electric field (aberration of the anode electrode geometry)
3. Extended defects (charge loss)
4. Electrode- and side-surfaces preparation (performance deterioration)
5. Electrodes design (defocusing effect)
6. Non-uniformity of material (photopeak shift)

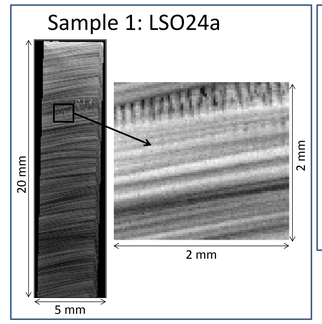
Planned Future: WBXDT, MDM and NSLS-II

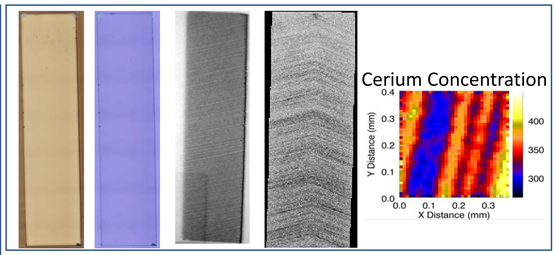


Few Examples of Recent Accomplishments

Non-uniformities for LSO Scintillators

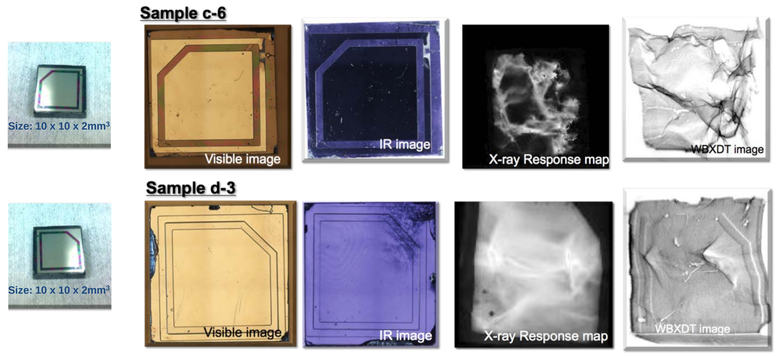
X-ray response maps show non-uniformities surprisingly arranged in striations.





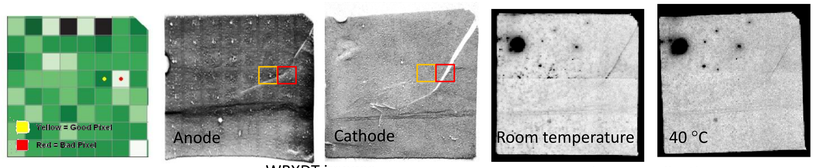
From left to right: bright field micrographs in reflection and transmission, WBXDT image, X-ray response- and Cerium-concentration- map.

Vapor Phase CZT Detector Measurements for Kromek



The WBXDT images and the X-ray response maps show a one-to-one correlation of the extended defects and the charge collection loss. Vapor phase growth method has made huge progress recently toward the production of high quality single crystal CZT.

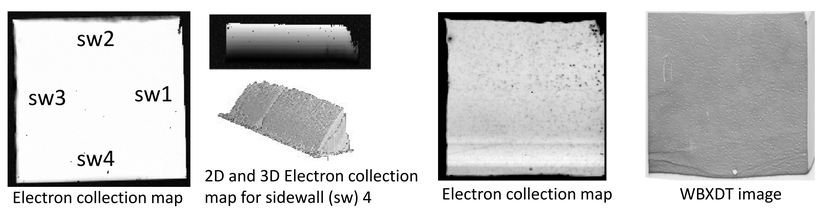
Temperature Stability of THM-grown CZT Detectors



WBXDT images — Electron collection map

These results gave insight to Redlen on the temperature instability of some of their detectors.

Edge-effect Non-uniformities vs. Fabrication Process



Electron collection map — 2D and 3D Electron collection map for sidewall (sw) 4 — Electron collection map — WBXDT image

X-ray response maps show edge-effect non-uniformities due to fabrication process.

Acknowledgments

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