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Teaming with Brookhaven National Laboratory

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Introduction

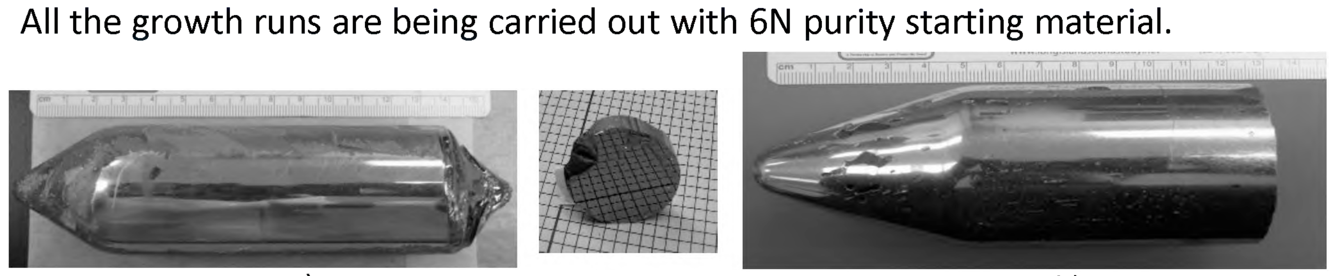
BNL has started growing CdZnTeSe crystals for room-temperature radiation detector applications. The addition of Se to CdTe reduces the concentration of secondary phases and sub-grain boundary networks. The addition of Zn increases the energy band gap.

Material characterization to understand the limiting factors of radiation detection material and to improve the properties continues to be a core element of an extensive R&D program at the LBNL's ALS and BNL's NSLS-II synchrotron facilities. ALS's Beamline 3.3.2 is available for 60% of its beamtime and allows us to perform both White Beam X-ray Diffraction Topography and Micron Scale X-ray Detector Mapping. The latter technique is extremely useful when measuring scintillators because it allows us to subtract contributions from the variability in the counting statistics, and also the fluctuations due to delta electrons, and non-proportionality.

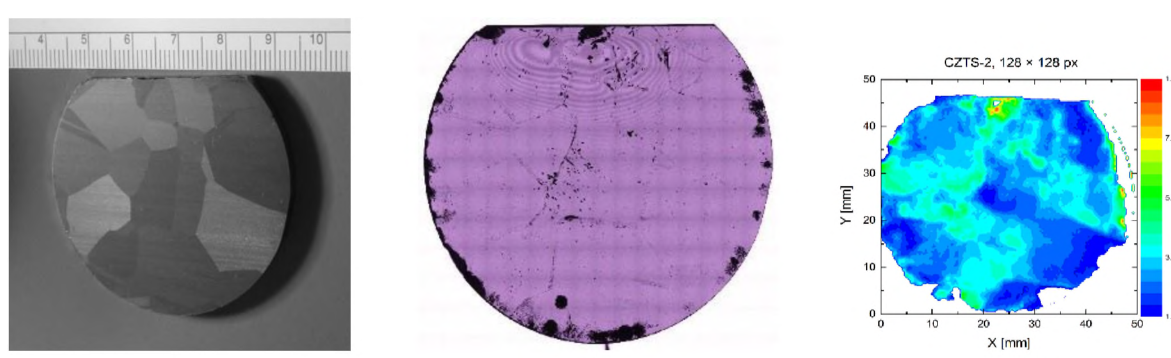
BNL has recently developed a new type of thermal neutron detector using pad technology in combination with ^{3}He gas operated in ionization mode. The new detector is used for coded aperture thermal neutron imaging.

CdZnTeSe Crystal Growth

CdZnSeTe crystals are grown by the
i) Vertical Bridgman technique as well as ii) Traveling Heater Method (THM).
All the growth runs are being carried out with 6N purity starting material.

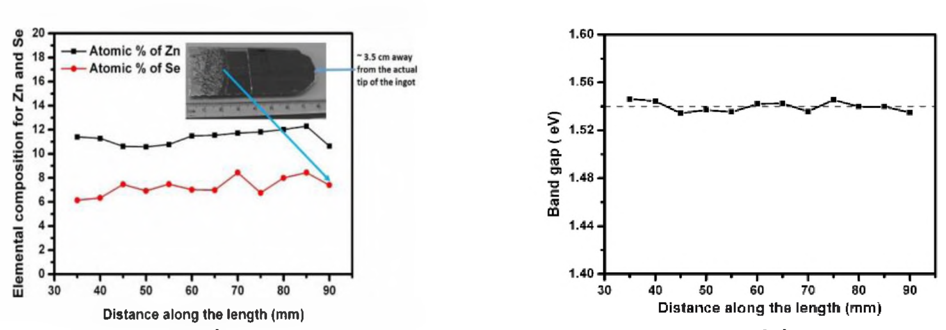


$Cd_{0.9}Zn_{0.1}Te_{0.93}Se_{0.07}$ ingot a) 40-mm diameter, grown by the Bridgman technique (undoped), b) In-doped 52-mm diameter grown by THM technique.



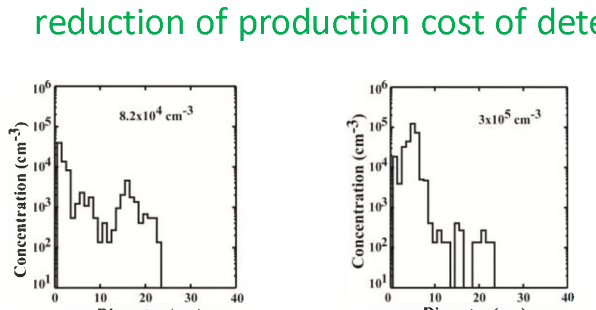
Picture of the cross-sectional THM grown $Cd_{0.9}Zn_{0.1}Te_{0.93}Se_{0.07}$ two inch wafer and the resistivity map, a) lapped, b) IR transmission of the whole wafer and c) resistivity map.

Compositional analysis of the THM grown $Cd_{0.9}Zn_{0.1}Te_{0.93}Se_{0.07}$ ingot:



a) Variation of Zn and Se composition and b) the band gap along the length of the THM grown $Cd_{0.9}Zn_{0.1}Te_{0.93}Se_{0.07}$ ingot

Composition is fairly constant along the entire length of the ingot as opposed to CdZnTe ingot. This is very encouraging and has tremendous potential for drastic reduction of production cost of detectors.



Concentration and size distribution of secondary phases over the volume of 1.1x1.5x6 mm^3 of Bridgman (a) and THM (b) grown CZTS.
Total average concentration is $1x10^5$ cm^{-3} and $2.5 x10^5$ cm^{-3} for Bridgman and THM grown CZTS, respectively.

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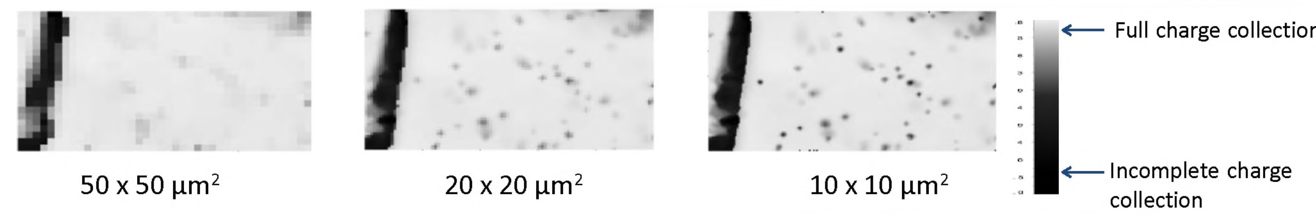
Material Characterization at User Facilities

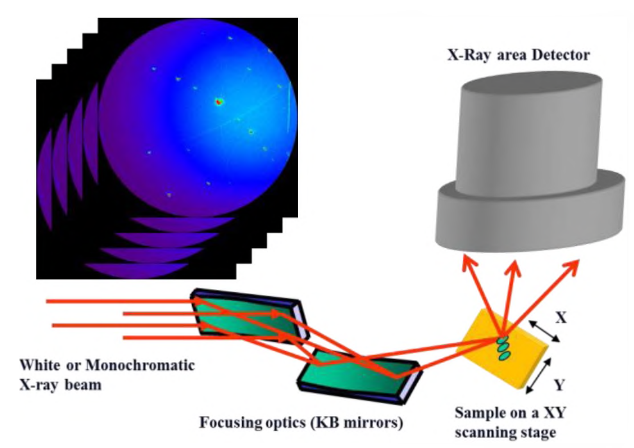
To maintain continuity of our radiation detector R&D research program beyond the shut-down of the NSLS at the end of FY14, we are using BNL's NSLS-II and Lawrence Berkeley National Laboratory's Advanced Light Source (ALS) Beamline BL 3.3.2, which is available to us for 60% of its operational beamtime. The main techniques utilized at these facilities are Micron-scale Detector Mapping, Micro and Nano X-ray Fluorescence (XRF), Micro X-ray Diffraction (XRD) and White Beam X-ray Diffraction Topography (WBXDT).

Why do we need high spatial resolution raster scans?

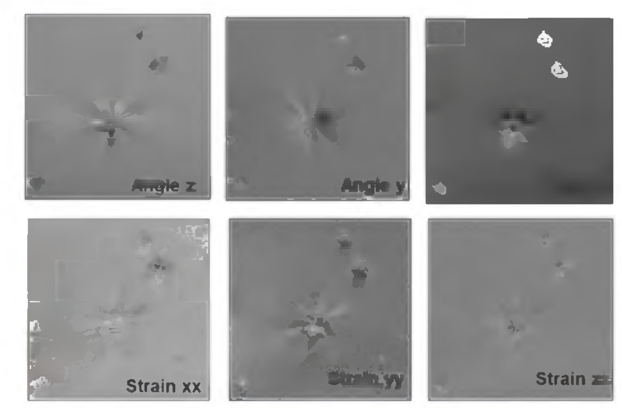
Planar detector 1.6 x 1.2 x 1 mm^3; micro-beam energy = 30 keV; Bias voltage = 60 V



Micro-X ray Diffraction (XRD)



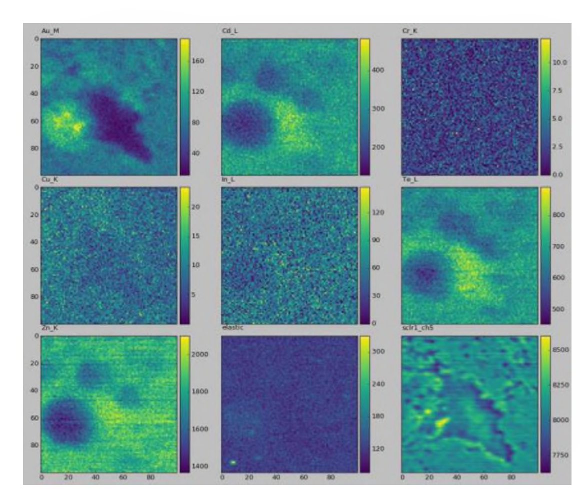
Micro-diffraction X-ray (XRD) Setup



Micro-diffraction maps
(area measured: 0.5 x 0.5 mm^2)

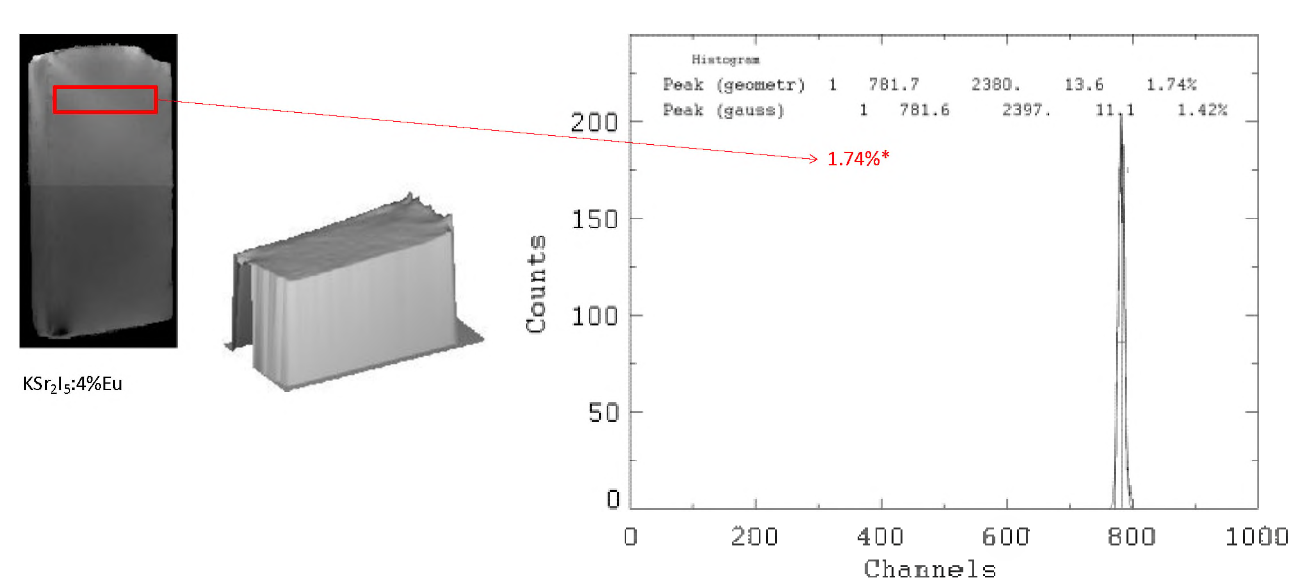
Precise structures of punching defects and strains around them were revealed at different angles and coordinates.

Nano X-ray Beam Induced Current (XBIC) and X-ray Fluorescence (XRF)



The first 7 sub-figures represent the fluorescence maps of different elements and the last sub-figure of 'sclr1 Ch5' represents the current mapping result.

X-ray Response Maps of Scintillators

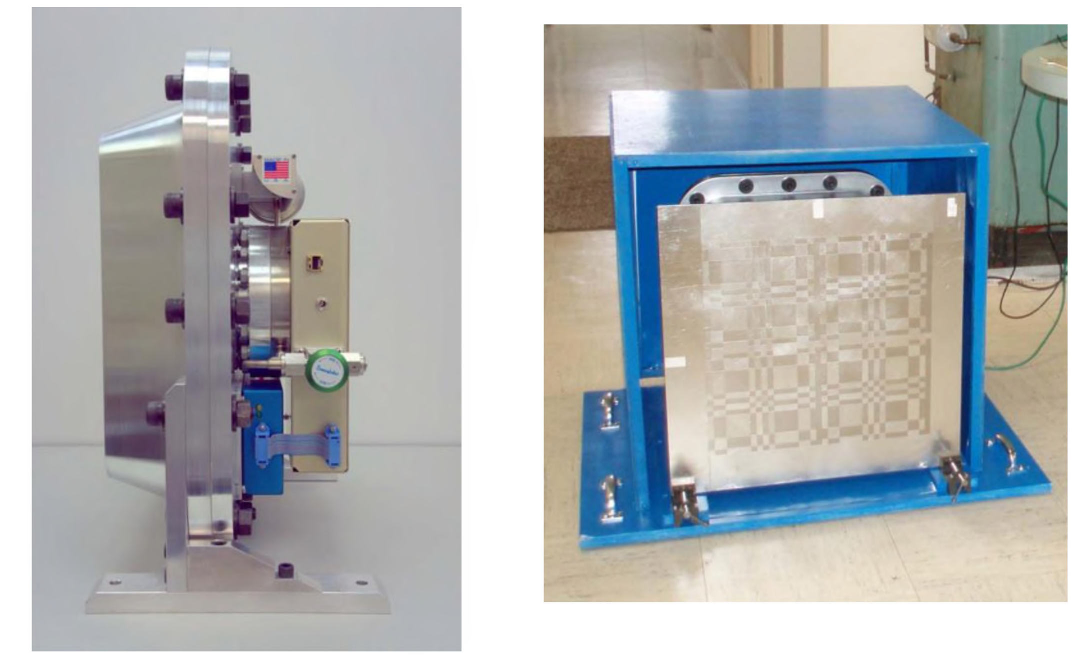


X-ray response map of a 5 x 5 x 10 mm^3 KSr_2I_5:4%Eu (grown in the Scintillation Materials Research Center, University of Tennessee) measured with a 25-µm raster scan and histogram of the photopeak's position for the X-ray response map within the small area inside the red box. The fluctuation of the photopeak is ~1.74%, indicating that this material could achieve a much better resolution with the rectification of material issues.

*This method allows us to subtract contributions from the variability in the counting statistics, and also the fluctuations due to delta electrons, and non-proportionality

Neutron Detectors

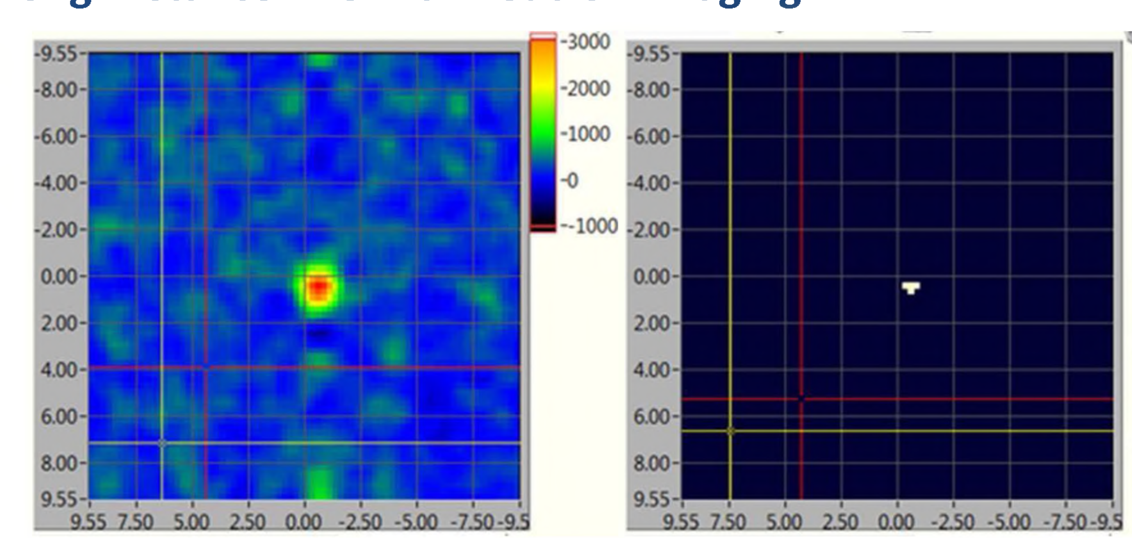
Coded Aperture Neutron Imaging



Pad based neutron detector (left) and coded aperture thermal neutron imager (right)

The Instrumentation Division at BNL has recently developed a new type of thermal neutron detector using pad technology in combination with a converter gas operated in ionization mode. In the novel ^{3}He filled device there are no thin-wire grids, resistor chains, or high electric fields, rather just a converter region bounded by the entrance window on one side and an anode pad plane on the other. Each of the 2304 pixels is connected to a preamplifier, shaper, ADC and multiplexer, realized in 36 new 64 channel application specific integrated circuits (ASICs) developed specifically for this detector.

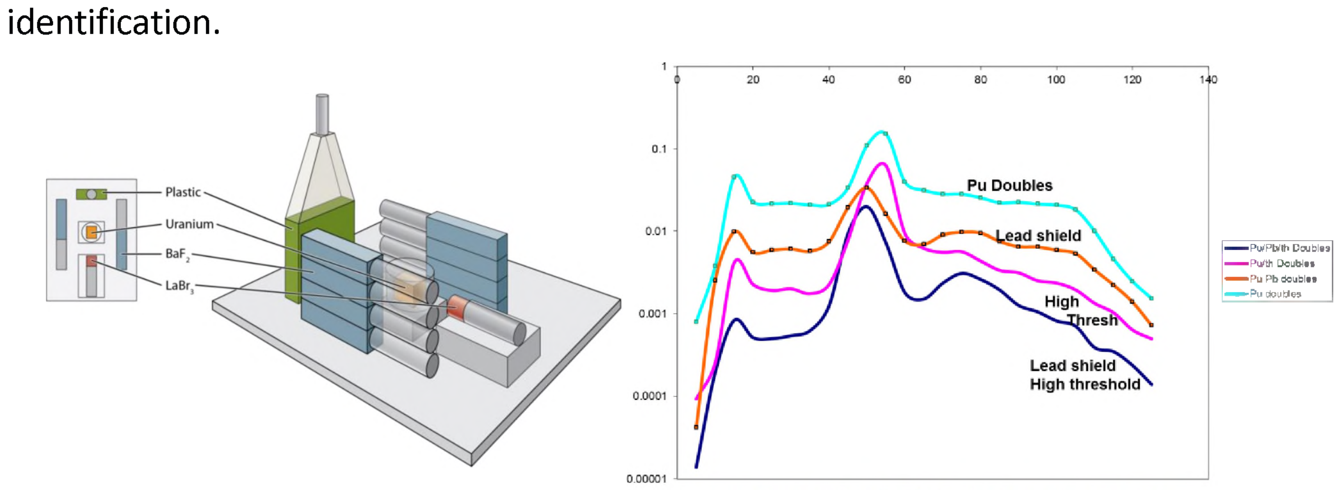
Long Distance Thermal Neutron Imaging



Thermal neutron image of a moderated ^{252}Cf source. The source was placed at 30 m distance. The left panel shows the reconstructed coded aperture image, the right panel was created using a threshold cut to eliminate background. The camera is capable of imaging multiple or extended sources, and could be used in warhead counting for treaty verification.

Neutron and gamma-ray coincidence measurements

Neutron and gamma detector arrays are used for special nuclear material identification.



1g Weapon Grade Plutonium measurements

Conclusions

BNL welcomes expanded collaboration with Universities and Industry.

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