Materials Science & Applications Group

VANDERBILT UNIVERSITY

Institute of Imaging Science

RADIATION DETECTORS FOR SPACE APPLICATIONS: DETECTOR DESIGN, FABRICATION AND CHARACTERIZATION

Presentation at

NASA HBCU/MSI Technology Infusion Road Tour

University Capabilities

September 29, 2016

Emmanuel Rowe, Ph.D.

Materials Science and Applications Group

FISK-VANDERBILT Master's-to-Ph.D. BRIDGE PROGRAM

Collaborators:

- Thomas Prettyman, Naoyuki Yamashita, Planetary Science Institute (PSI), Tucson, AZ
- James Lambert, Carol Raymond, Jet Propulsion Laboratory (JPL), Pasadena, CA
- Julia Bodnarik & colleagues, Lunar & Planetary Laboratory, University of Arizona, Tucson, AZ
- Ashley Stowe, Y-12 National Security Complex Oak Ridge, TN
- Nerine Cherepy & Stephen Payne, LLNL, Livermore, CA
- Sebastien Kerisit, Pacific Northwest National Lab, Richland, WA
- Lynn Boatner, ORNL, Oak Ridge, TN
- Kanai Shah and Josh Tower, Radiation Monitoring Devices, Watertown, MA

Fisk's Materials Science and Applications Group (MSAG):

- Emmanuel Rowe, Liviu Matei, Brandon Goodwin, Pijush Bhattacharyia, Kristal Morales, Vlad Buliga, Mike Groza, Jeremiah Afolabi, Maggie Zlibut
- **UGs**: Stephanie Morris, Lance Richards, Samuel Uba, Zachary Dickerson, Nati Carigano
- **Grads:** Dave Caudel, Rose Perea, John McGrew, Hugo Espejel, Jodie Hawk, Joseph Bell, Ardelia Clarke, Anna Egner, Crystal Cardenas , Jarrhett Butler, George Cooper and LaNell Williams

Fisk-Vanderbilt Master's-to-PhD Bridge Program:

Support: NSF, DOE/NNSA, DHS/DNDO, DOD/DTRA, NIH/NMBIB/R23, Vanderbilt/Discovery Grant, Cal Tech/JPL

Materials Science and Applications Group

Science & Technology

Field requirements / needs

Materials Discovery (semi-empirical) ⇄ Understanding Improving Crystal Growth Limitations ⇄ Design & Fabrication Of Gamma & Neutron Sensors ⇄ SNM Detection

Summer Research Experience ⇄ Workshops, Seminars, Lectures ⇄ Master's Degree ⇄ Internships @ National Labs ⇄ you can Reach for the Ph.D. tú puedes

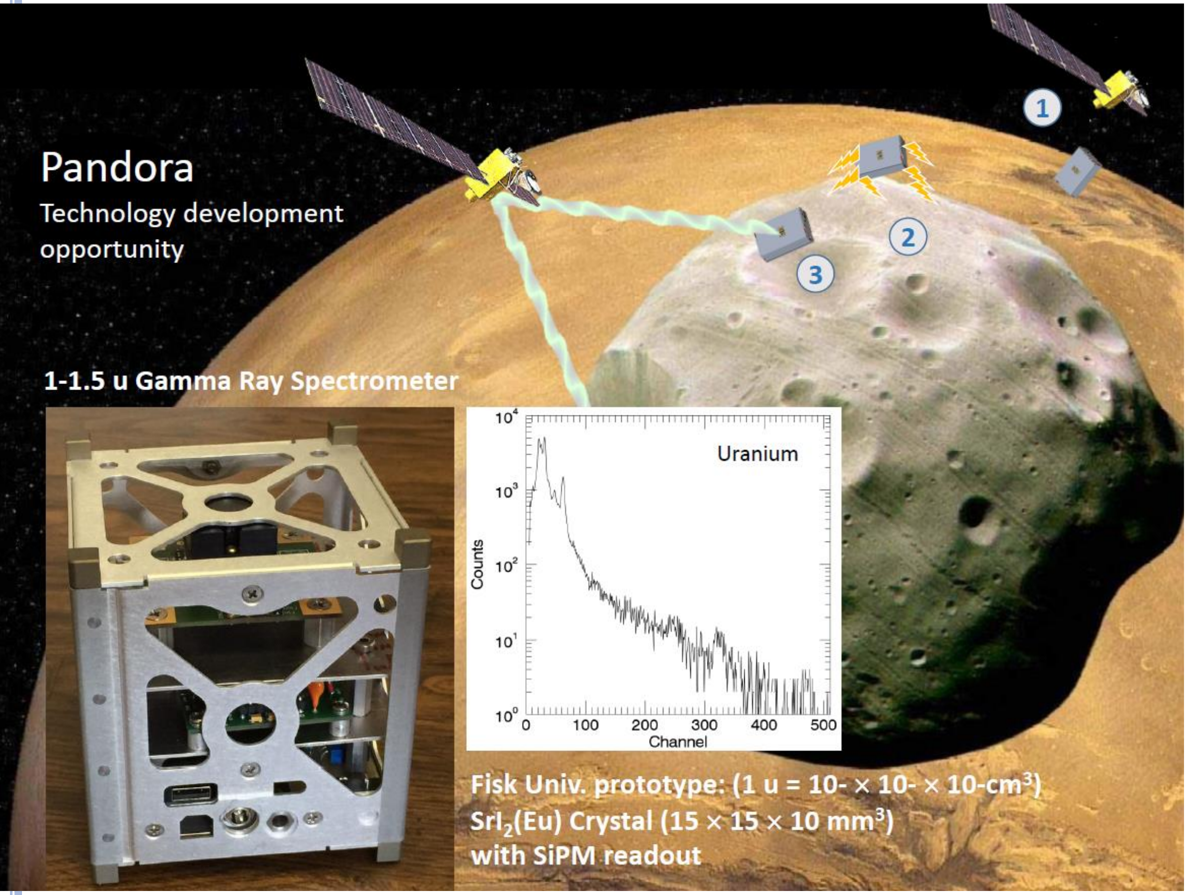
Improved understanding / new devices

Education & Training

Crystal growth is the critical enabling

Gamma Ray Spectrometer (GRS)

- Pandora: Unlocking the mysteries of the moons of Mars
- Chemical composition of planetary surfaces provides clues about their origins and evolution



Tom Prettyman, et al, 2015 SPIE Optics and Photonics, International Conference on Hard X-Ray, Gamma Ray and Neutron Detector Physics

- Power < 3 W
- Potential for commercial-off-the-shelf components

SrI_2 scintillators for planetary gamma-ray spectroscopy

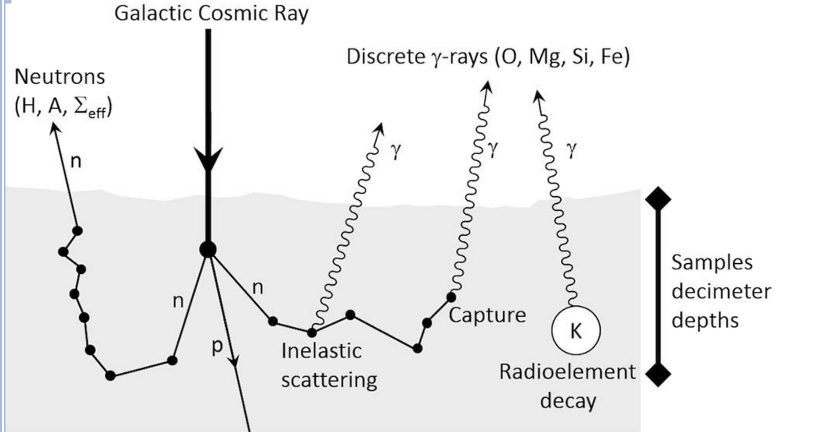


Figure 1. Cartoon of gamma-ray production processes in the surface of planetary bodies. Galactic cosmic rays

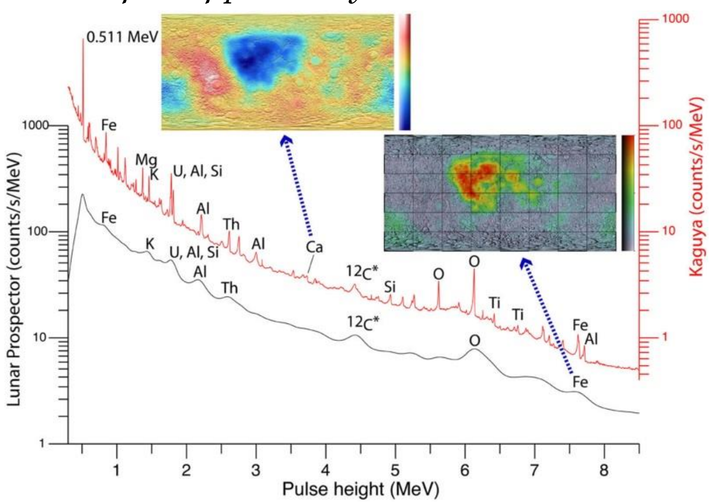


Figure 2. Comparison of the average lunar gamma-ray spectrum, as acquired during the Lunar Prospector (black) and Kaguya (red) missions.

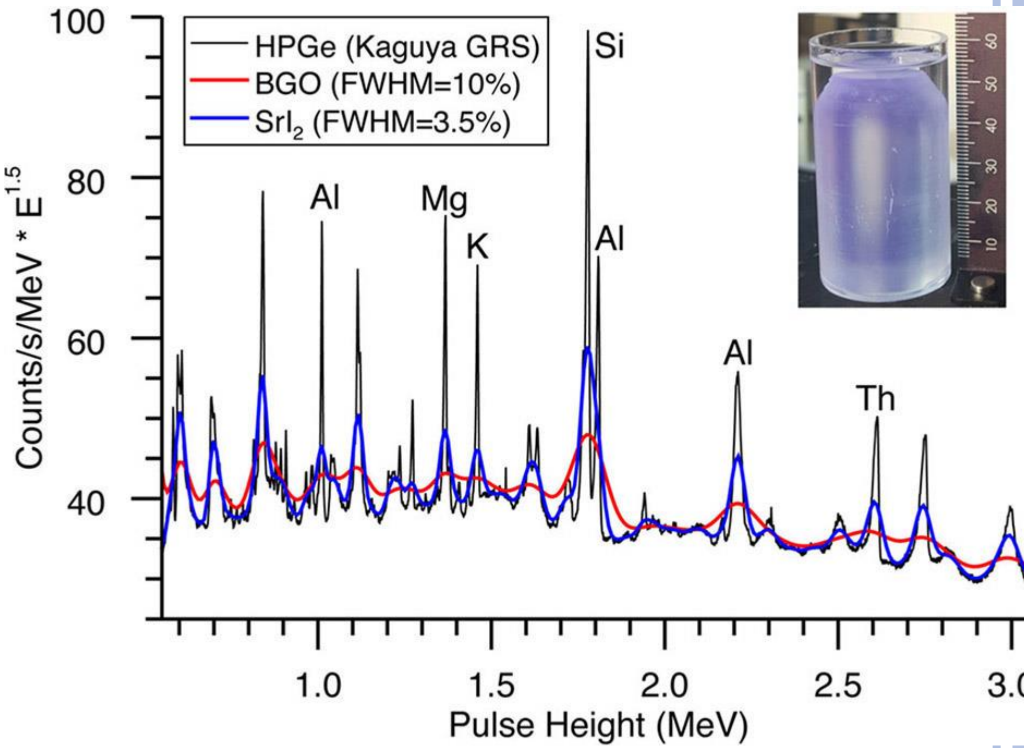
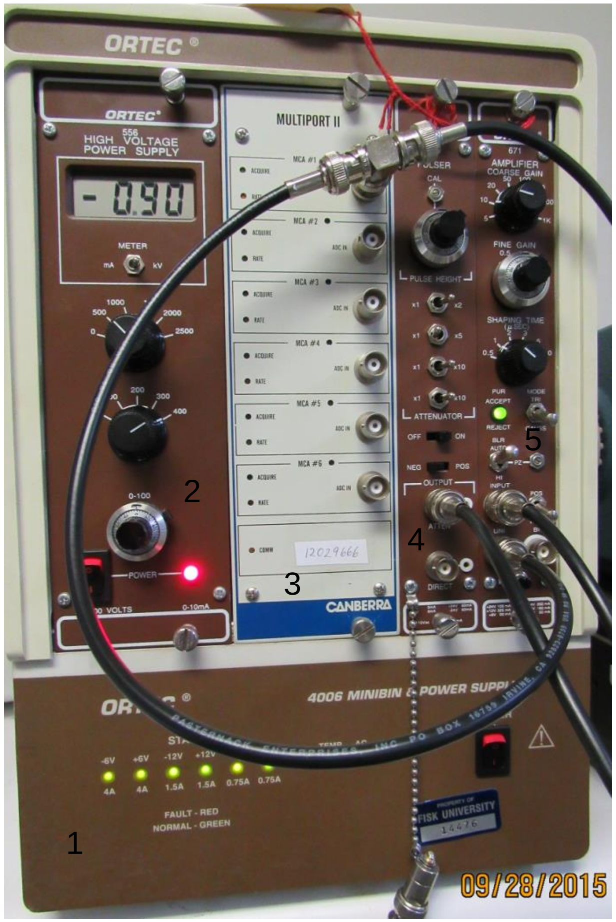


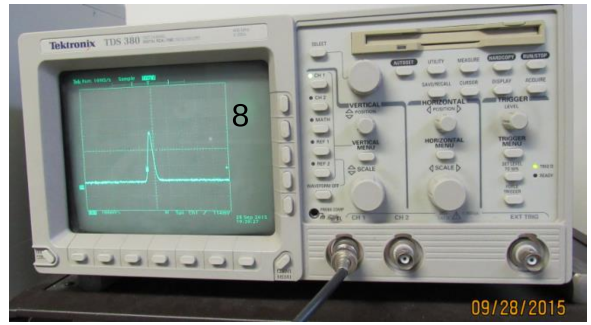
Figure 3. Illustration showing how energy resolution affects the ability to extract chemical information from a lunar gamma-ray spectrum.

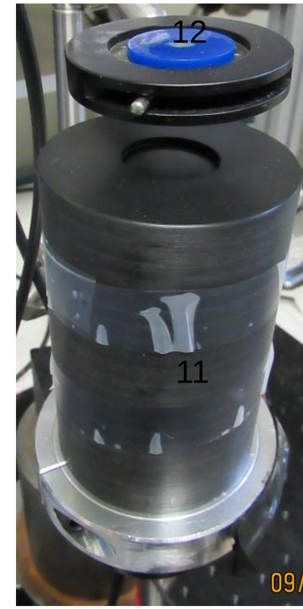
Thomas Prettyman, Arnold Burger, Naoyuki Yamashita, James Lambert, Keivan Stassun and Carol Raymond, 23 October 2015, SPIE Newsroom
http://spie.org/x115974.xml

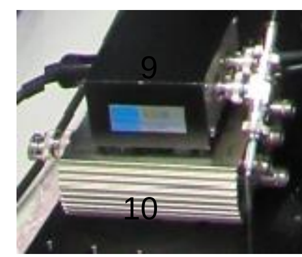
SrI2 technology may find uses on future manned missions, and their robotic precursors, to nearby asteroids

Basic Equipment Used in Radiation Detection



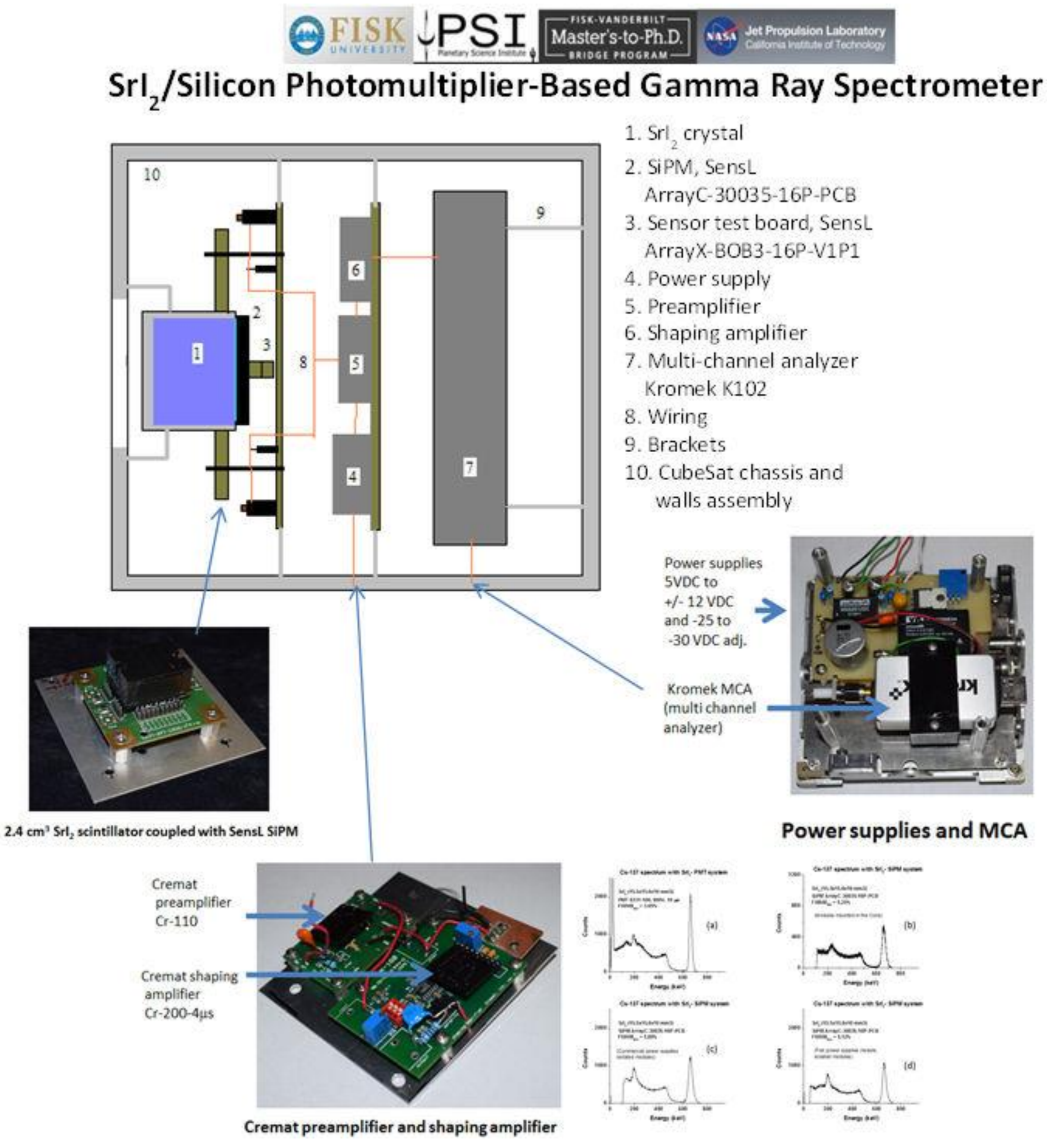


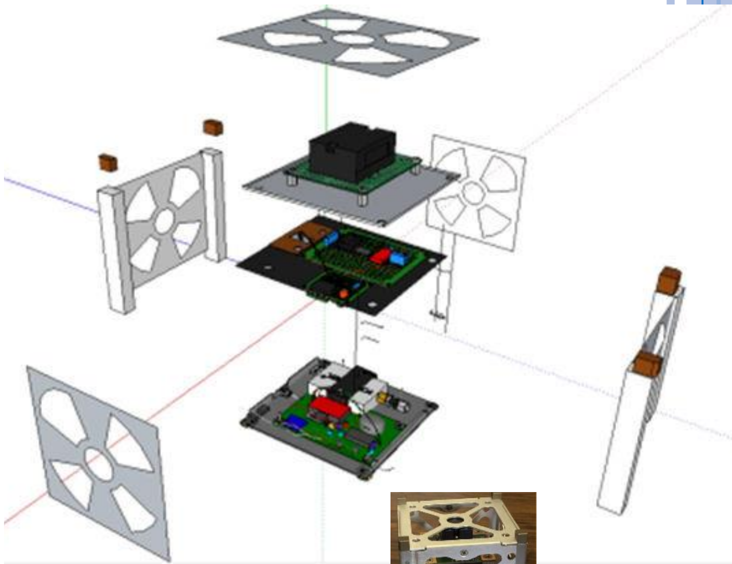




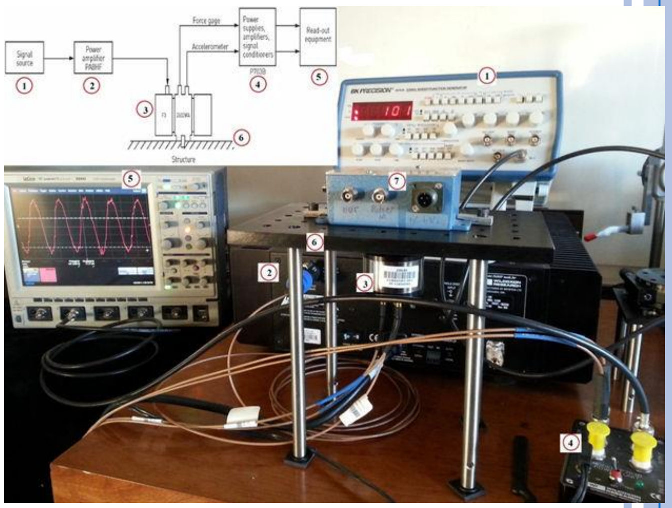
Legend: 1-NIM Minibin, 2-High Voltage Power Supply, 3-Multichannel Analyzer, 4- Pulser, 5- Shaping amplifier 6-Low Voltage Power Supply, 7-Digital oscilloscope, 8- Analog Oscilloscope, 9-Fast preamplifier C6438 (for scintillators), 10-Charge sensitive preamplifier (A250CF), 11-PMT(R6231-100), 12-Radiation source

Design

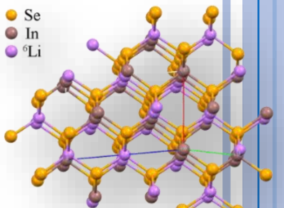




Vibration testing at Fisk



LITHIUM INDIUM DISELENIDE ($^{6}LiInSe_2$)



APPLIED PHYSICS LETTERS **101**, 202101 (2012)

Single crystal of $LiInSe_2$ semiconductor for neutron detector

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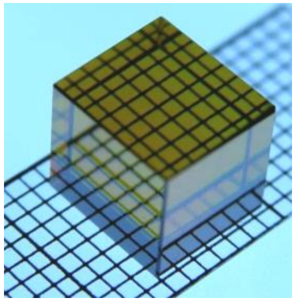
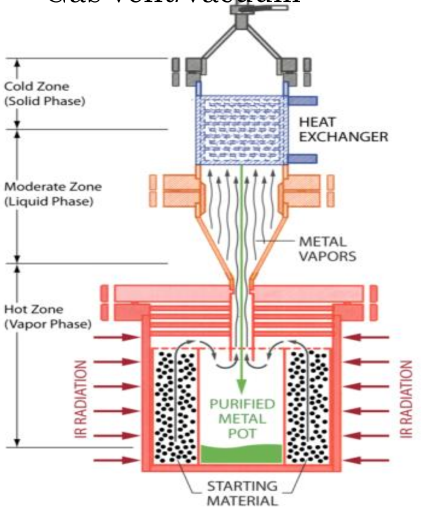
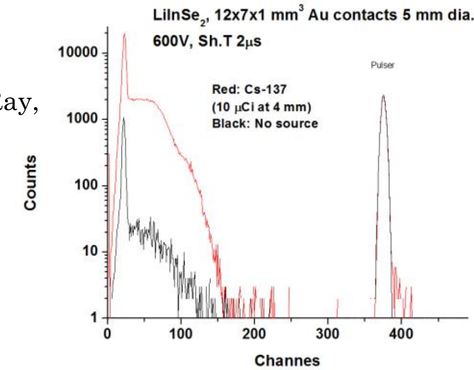
Single crystals of semiconductor-grade lithium indium selenide ($LiInSe_2$) were grown using the vertical Bridgman method. The orthorhombic structure of the materials was verified using powder x-ray diffraction. The room temperature band gap of the crystal was found to be 2.85 eV using optical absorption measurements. Resistivity of $LiInSe_2$, obtained using current-voltage measurements, has semiconducting nature (decreases with increasing temperature) and is in order of 10^{10} Ω·cm. Photoconductivity measurement showed the photocurrent peak at 445 nm. Nuclear radiation devices were fabricated, and alpha particle detection was observed, suggesting that this material could be a candidate for neutron detection applications. © *2012 American Institute of Physics*. [http://dx.doi.org/10.1063/1.4762002]



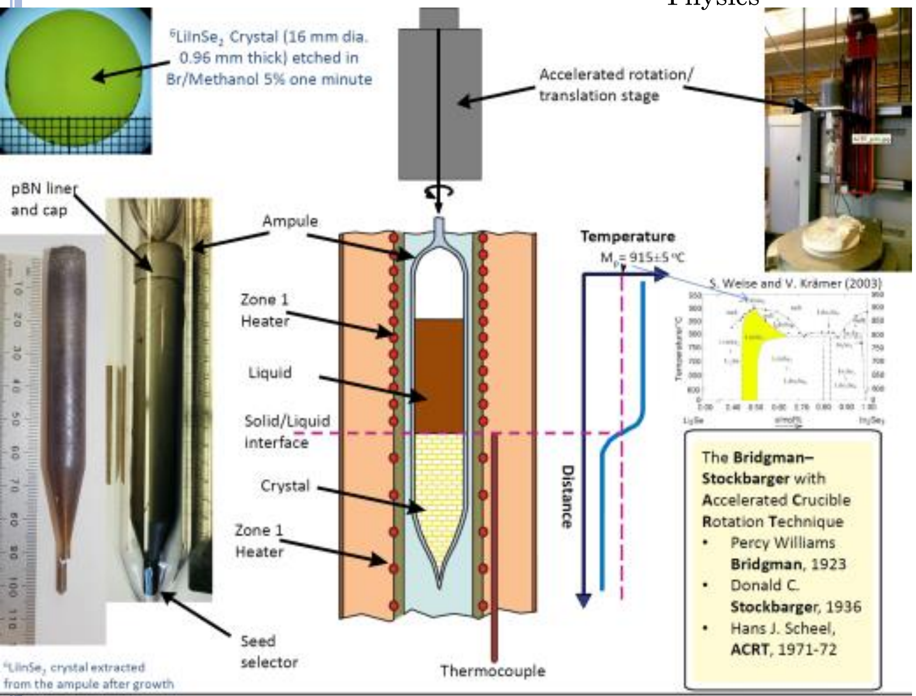
Lithium Distillation - Scale up

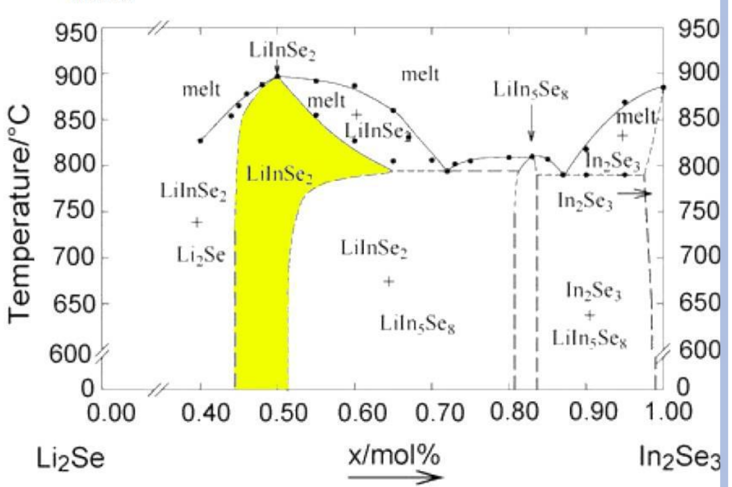


$LiInSe_2$ Detection response



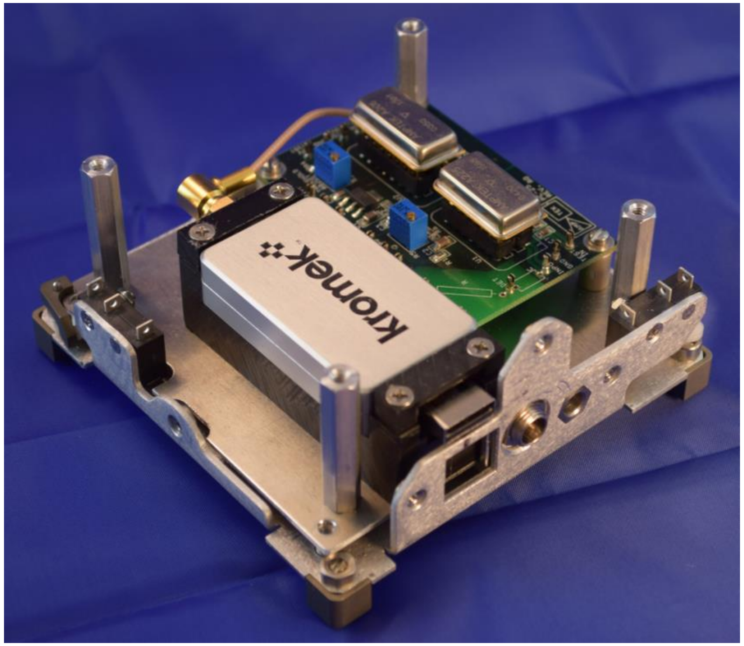
Z. Bell et al,
2015 SPIE Optics and Photonics,
International Conference on Hard X-Ray, Gamma Ray and Neutron Detector Physics





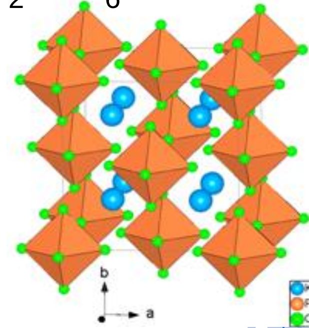
LiInSe$_2$ prototype, CubeSat 2U

- Collaboration funded by Vanderbilt – Discovery grant
- Space is sufficient to add a Raspberry Pi computer (Linux)
- LiInSe2 operates in scintillator mode with a single APD readout. Plan to test it for neutron detection at LPL – University of Arizona



APPLIED PHYSICS LETTERS **107**, 000000 (2015)

K$_2$PtCl$_6$ structure



Cesium hafnium chloride: A high light yield, non-hygroscopic cubic crystal scintillator for gamma spectroscopy

Arnold Burger,[1,2,a)] Emmanuel Rowe,[1] Michael Groza,[1] Kristle Morales Figueroa,[1] Nerine J. Cherepy,[3] Patrick R. Beck,[3] Steven Hunter,[3] and Stephen A. Payne[3]

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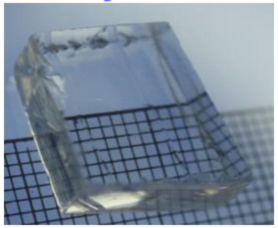


- Published in APL Vol 107, on the web at http://dx.doi.org/10.1063/1.4932570

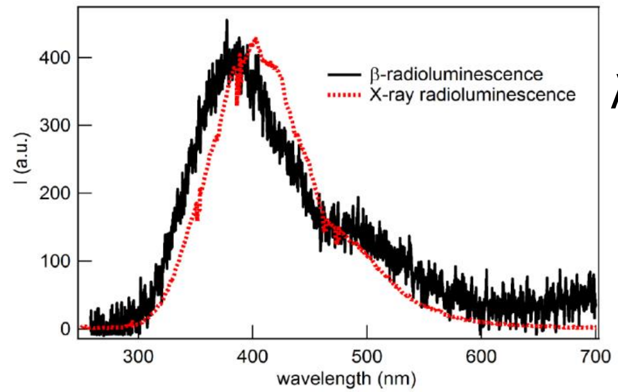


FIG. 1. Cs_2HfCl_6 radioluminescence acquired with a Sr-90 beta source is in good agreement with x-ray excited radioluminescence acquired with < 30 keV x-rays with Silicon CCD readout. Light yield is estimated to be 54,000 Ph/MeV by comparison to a standard BGO crystal. The slight shift between spectra is due to differences in spectral sensitivity between the two spectrometers used for the measurements.

λ_{max}=400 nm

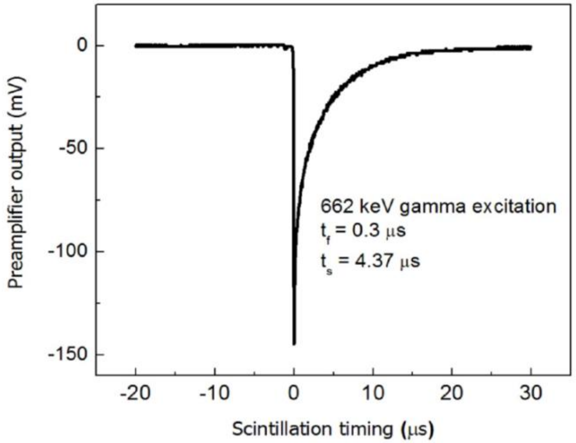


FIG.2. Digital oscilloscope traces for timing measurements of the CHC scintillation response to 662 keV gammas. The decay time has a fast component (5% of energy) of 0.3 µs and a slow component (95% of energy) of 4.37 µs. The size of the CHC sample was 8.5 mm^3.

principal decay time is 4.37 µs

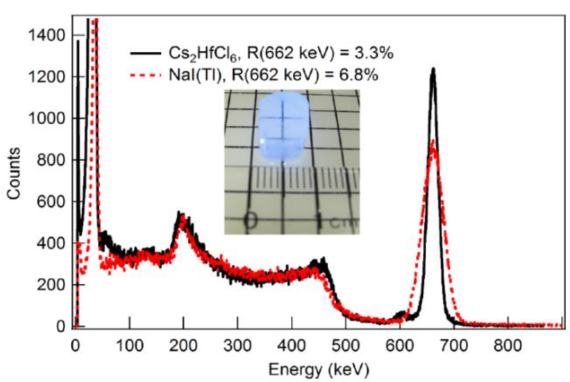


FIG.3. Pulse height spectra acquired with a Cs-137 source of a Cs_2HfCl_6 crystal 0.65 cm3 in size, compared to a standard 1" x 1" NaI(Tl) crystal, both measured with 12 µs shaping time. The gamma light yield of Cs2HfCl6, compared to NaI(Tl) is estimated to be 33,000 Photons/MeV, with super bialkali PMT readout. The small peak in the CHC spectrum at 607 keV is due to the escape of Kα fluorescence x-ray, typical of small volume detectors. The inset is a photo of the Cs_2HfCl_6 crystal on a paper background (0.5 cm squares), under 254 nm excitation, exhibiting its characteristic blue emission.

FWHM=3.3% @ 662 keV

LY of 54,000 ph/MeV with silicon CCD photodetector

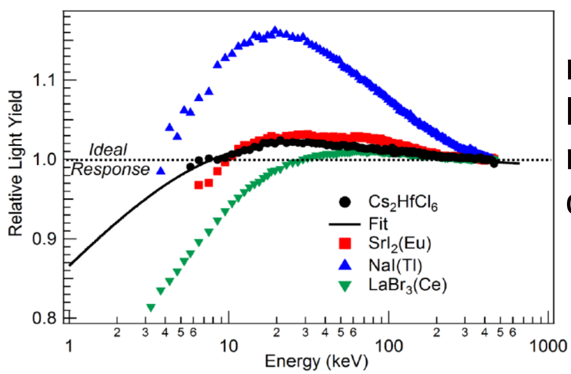


FIG.4. Experimental electron light yield nonproportionality curves for Cs_2HfCl_6, SrI_2(Eu), NaI(Tl), and $LaBr_3$(Ce). The ideal response would have no energy dependence of light yield. A fit to the CHC data indicates better proportionality than any previously reported scintillator

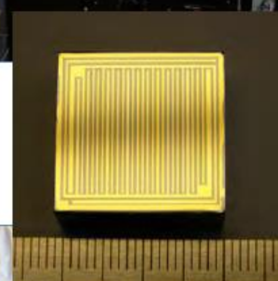
non-proportionality-limited resolution of 1.37% @ 662 keV

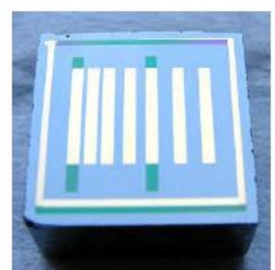
Detector Fabrication

Equipment:

diamond cutting wheel
diamond wire saws
8 in. Lapping Machine
e-beam evaporator
sputtering system
parylene coating system
Photolitography system





That's all Folks!