Miniaturized High-Resolution CZT Modules for Drone-Based Waste Characterization

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Introduction to H3D’s 3D CZT

- NaI: 7% @ 662 keV, room temperature operation
- HPGe: 0.2% @ 662 keV, -200C operation temperature
- CZT: <1% @ 662 keV, room temperature operation, up to 24 cm$^3$
  - HPGe-like resolution + rugged + low power operation + high efficiency

Source: Eu-152
3-D CZT single-pixel events
Resolution = 0.7% FWHM
Gamma-Ray Imaging

Compton Imaging: > 250 keV

Number of photons: 233

Acknowledgement: Prof. Zhong He, et. al, U. of Michigan for original research
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Compton Imaging Example

Center region of pump hottest from direct $^{58}$Co emissions.

Contamination on floor and wall just behind H100.

Left region of pump hottest from direct $^{60}$Co emissions.
Coded Aperture Imaging

Coded Aperture: < 500 keV
Major Pivot to M-series Design (2019)

- Reduce weight from 3.6 kg to 0.5 kg
- Reduce size from 4100 cc to 332 cc
- Reduce power consumption from variable up to 30 W to constant 5 W
- Increase count rate from 35 kcps to 120 kcps
- Maintain 2.5 keV FWHM @ 140 keV
- Maintain 0.7 mm position resolution @ 140 keV
- Medical markets – high density
  - 20% active volume
  - Drone-mounted sensors
  - Integrable modules
Drone Platform & Measurement Site

- DJI Matrice 300 Drone
  - Manually controlled
- M400 on non-articulating gimble
- Real-time GPS and altitude recorded at 1 Hz
- Spectra summed at same rate
- Measurements at orphan natural gas well in Michigan, USA
- $^{226}$Ra contamination
- Dose rates varied from 0.2 $\mu$Sv/hr up to 50 $\mu$Sv/hr
- July 19$^{th}$, 2021
Example Spectra Recorded - Summed

Peaks from $^{226}$Ra (186 keV) and its progeny:
- $^{214}$Pb (241/295/351/... keV)
- $^{214}$Bi (609/1120/1764/... keV)
Attenuation Differences

![Graph showing energy vs. counts per keV for high and low attenuation cases.](image)
Comparison to Earlier NaI Drone Measurement
Additional Information from Gamma-ray Imaging

A – Settling Tanks with ~ 1 mCi $^{226}$Ra
B – Ground contamination near pipes
C – One barrel significantly more activity than others
SourceTerm Software Package

Isotope library

Geometry model

$^{58}\text{Co} \; \text{uCi/mL}$

$^{95}\text{Nb} \; \text{uCi/mL}$

$\ldots$

$^{51}\text{Cr} \; \text{uCi/mL}$
Hotspot Activity Measurement

- Numerous settling tanks in area “D” – not driving dose!
- Garbage bags full of insulation driving dose
- Leaky valve was another hot spot
- Estimated 200 μCi of $^{226}\text{Ra}$ contamination
Contributions

• CZT sensors can be manufactured in small form factors and easily mounted as payload for drones
• CZT detectors provide high resolution spectroscopy for easy identification and quantification of contamination
• Inherent imaging capabilities provide even more information about contamination sources and help aide quantification calculations

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