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Disclaimer:

Gamma Imaging and Mapping Advancements

The Savannah River National Lab (SRNL) in partnership with Los Alamos National Lab (LANL) developed an *in-situ* GrayQb™ radiation mapping device eliminating the need to remove the radiation sensitive phosphor storage plate (PSP) from the device for scanning between exposures. By incorporating a customized version of the LANL patented MiniMax camera-based PSP reader system into the GrayQb™ housing, the exposed PSP can now be read *in-situ* and digitally transmitted to a remote computer for viewing. The ability to generate radiation contour maps showing source locations and relative radiological levels present in an area has high utility for targeting clean-up efforts, maintaining worker ALARA, determining leak locations and radiological situational awareness. *In-situ* GrayQb™ reduces the number of required interactions with the device providing deployment cost savings, increasing personnel safety and removing human handling errors during the manual scan process. Additionally, by negating the need for an external scanner, the device becomes more mobile. Other upgrades to the device included identification of a more sensitive imaging medium and incorporation of a dual pinhole rendering the device physically capable of obtaining 3D images. Laboratory tests with Am-241 sources using a mockup of the *in-situ* GrayQb™, Fig 1, successfully demonstrated the ability to digitally capture radiation source information using the dual pinhole and camera-based PSP reader.

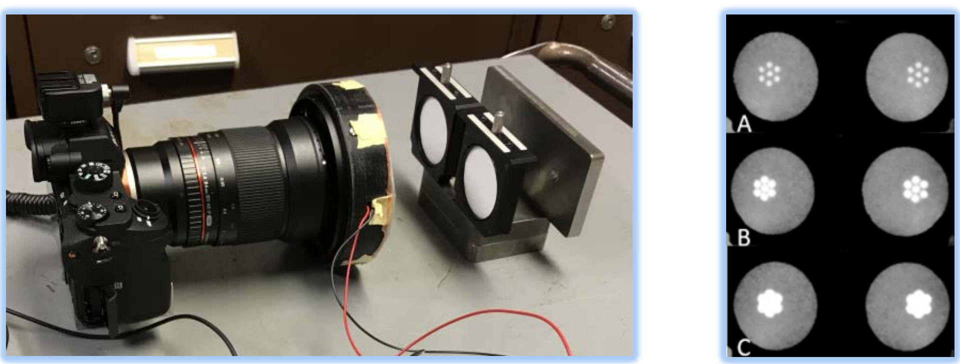

Fig 1. In-situ *GrayQb™ test system (left) dual pinhole Am-241 20mR radiation images digitally captured with in-situ GrayQb™ using different pinhole sizes (right)*

Awards and Recognition

Intellectual property will be pursued.

Intellectual Property Review

This report has been reviewed by SRNL Legal Counsel for intellectual property considerations and is approved to be publically published in its current form.

SRNL Legal Signature

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Signature **Date**

Gamma Imaging and Mapping Advancements

Project Team

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Collaborators: LANL - Scott Watson, Nicola Winch

Thrust Area: ES

Project Start: Oct 2017

Project End: Sept 2018

Budget: FY18 Funding: $200k (FY17&FY19 Funding: $0k)

The Savannah River National Lab (SRNL) collaborated with Los Alamos National Lab to develop an in-situ GrayQb™ radiation mapping device eliminating the need to remove the radiation sensitive phosphor storage plate (PSP) from the device for scanning between exposures. This was accomplished by developing a variant of the LANL patented MiniMax camera-based system capable of reading x-ray images from Phosphor Storage Plates (PSP) and incorporating it into the GrayQb housing. Digital images captured in-situ can be readily uploaded and analyzed on a remote computer. Additionally, testing identified a new PSP material 4 times more sensitive than the previous PSP film for use as the GrayQb™ detection medium. Lastly, test mockups indicated that the field of view of the camera-based reader would support a multiple pinhole collimator without increasing the dimensions of the system, therefore a dual pinhole collimator was developed to acquire stereoscopic gamma images rendering this new device physically capable of obtaining 3D images.

FY2018 Objectives

- Develop an *in-situ* gamma mapping device by combining the technologies employed in the SRNL patented GrayQb™ radiation mapping device with the LANL patented MiniMax camera-based PSP reader.
- Increase GrayQb™ detection sensitivity by identifying more sensitive detection mediums and collimating configurations.
- Maintain GrayQb™ advantages of small size, affordability and deployability.

Introduction

The SRNL developed GrayQb™ device has successfully accomplished objectives to identify and map radiological conditions to increase efficiencies and promote worker safety for DOE-EM D&D activities, Figs 2&3. Deployments, while successful, have demonstrated opportunities for additional high value features to include *in-situ* mapping and increased detection sensitivity. The ability to read the radiation image from the exposed PSP *in-situ* would negate the need to remove the PSP for processing by an external scanner after exposure, Fig 4. This provides significant deployment cost savings in radiation areas by removing the need to retrieve GrayQb™ for scanning between each image acquisition. Additionally, *in-situ* processing removes the human handling of the PSP which

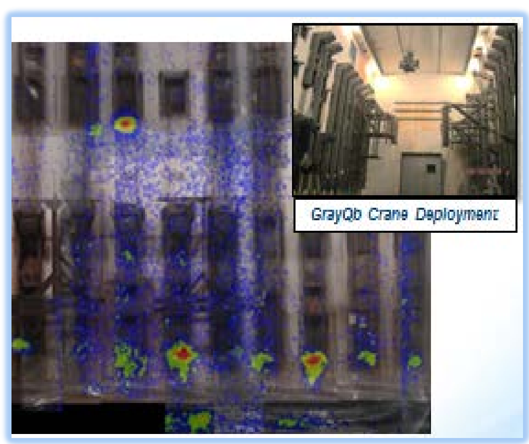

Fig 2. GrayQb™ Hanford PRF Canyon Results

reduces potential human error in the processing and promotes ease of use. Identifying more sensitive detection mediums and better performing collimating configurations can increase detection sensitivity leading to faster results which may make the device more attractive for time sensitive missions.

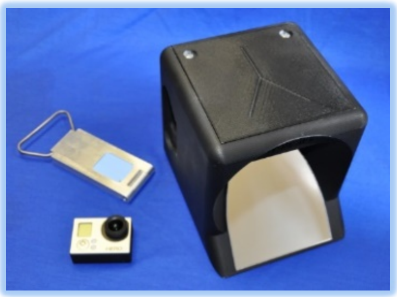

Fig 3. GrayQb™ device with PSP imaging cartridge & camera

Fig 4. Current Gamma Image results processing requires PSP to be removed from device and externally scanned

The LANL patented MiniMax (Miniature, Mobile, Agile X-ray) was developed as a mobile compact lightweight device capable of reading x-ray images captured in the field on photostimulable material. A main objective of this LDRD was to explore the ability to employ this technology for radiation imaging and include it into the GrayQb™ housing to obtain *in-situ* results. Based on previous x-ray and radiological testing with PSPs, it was thought that this would be feasible. The MiniMax is a camera-based system capable of capturing a photostimulable image using a single flash from a bright red LED source filtered through a blue dichroic filter, Fig 5. It was desired to customize this method for GrayQb™ where the PSP is much smaller than x-ray applications and where it was desired preserve the small size and affordability of the GrayQb™.

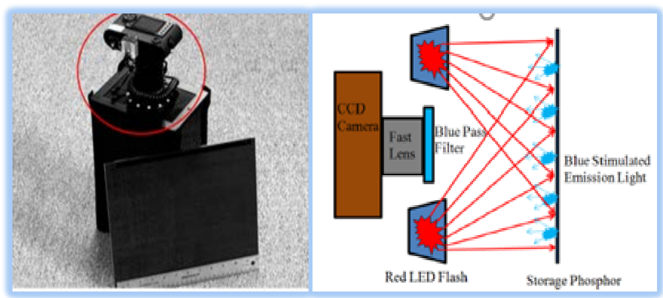

Fig 5. Proposed gamma image results processing method will incorporate a camera-based PSP reader based on the LANL developed MiniMax into the GrayQb™ housing for in-situ results

Approach

SRNL partnered with LANL to develop a customized version of their patented MiniMax camera-based PSP reader system for use in the GrayQb™ device to perform gamma imaging *in-situ*. Component alternatives and configurations were explored and tested to minimize the cost and size increase to the GrayQb™. Of interest was identifying COTS components to replace high end custom components found in the MiniMax. One area of greatest potential for savings in both cost and footprint was the camera selection for GrayQb™. Identification of cameras with high sensitivity photodetectors representing small, medium and large footprints and respective costs were identified for test.

A PSP gamma image simulator was designed, built and validated, Fig 6. The simulator provided repeatable PSP test samples simulating radiation exposures to easily perform camera testing and comparisons without rad sources. The test cameras as well as the MiniMax were performance tested in the R&DE lab using the simulator. Two days of testing were performed with radiation sources at the SRNL Calibration Facility. The first visit in June focused on testing alternate PSP materials which were thicker and potentially more sensitive and various collimator and PSP configurations. The second visit in September focused on characterizing the Sony as7II camera, considered the most promising of the candidate cameras, and the MiniMax system with radiation sources. Additionally, tested during the second visit was the dual pinhole collimator.

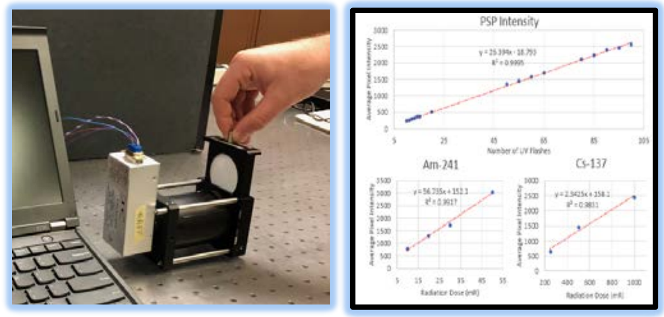

Fig 6. PSP Image Simulator (left) validation and correlation to radiation dose (right)

Results/Discussion

A new PSP material purchased from Carestream medical was selected as the new imaging medium for the GrayQB™. Laboratory testing with sources showed the new PSP to be up to four times more sensitive than the currently used dental PSP. The new PSP is much thicker which increases the likelihood that radiation will be absorbed by the film. Testing also demonstrated the higher sensitivity significantly reduced the necessary exposure times as expected, especially for higher energy isotopes such as Cs-137.

The PSP image simulator was verified to be a viable method for simulating gamma images onto a PSP. The simulator produced a programmable number of UV flashes and the PSP response to the number of flashes was related to the PSP response of a radiation dose using data collected at the HPICL facility, Fig 6.

Several cameras were selected to be tested as candidates for the GrayQb™ PSP reader system; the Sony αs7 II, the Mightex CXE-B013-U, and the Allied Vision Guppy. Test mockups were developed for these camera systems, Fig 7. Camera evaluation metrics included footprint, cost, resolution, sensitivity, and noise. PSPs were exposed with various amounts of "dose" using the image simulator and then imaged with each camera system, Fig 8. The Sony camera was selected as the best overall camera due to having very high sensitivity and low noise, Fig 8. The Mightex camera was small in footprint and had high sensitivity but suffered from high noise which degraded the images. Its small size makes it attractive for a possible high dose GrayQB™ when signal would not be in short supply. The Guppy has the smallest footprint but relatively poor sensitivity which makes it useful only for high dose situations. The cost of the Sony and Mightex cameras plus the lenses (~$2500) keeps the GrayQB™ in an attractive price range.

Fig 7. Camera test setups used with PSP image simulator - A: Mightex CXE-B013U, B: Sony as7 II, C: MiniMax

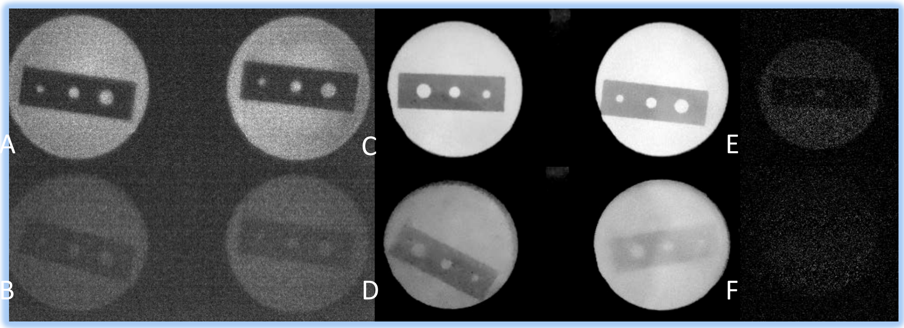

Fig 8. Test images from the Camera test setups used with PSP image simulator

The Sony based PSP reader mockup system and the MiniMax were characterized at the SRS Calibration Facility using Am-241 and Cs-137 button sources, Fig 9. The wide field of view of the Sony and Mightex camera made it possible to add pinholes to the collimator without requiring an increase in GrayQb^{TM} size; a dual pinhole tungsten collimator with removeable 1mm and 2mm pinholes was manufactured and used, Fig 10. Capturing images with the dual collimator allows for stereoscopy to be performed in the future and different pinhole sizes to be tested. The pinholes performed as expected with the 1mm pinhole showing better resolving power compared to the 2mm pinhole, but less overall intensity captured on the PSP, an Am-241 multisource configuration was used to help determine resolution, Fig 11 & 12. Resolution drops off considerably as distance increases, but this was expected. The removable pinholes give the GrayQb^{TM} excellent flexibility moving forward.

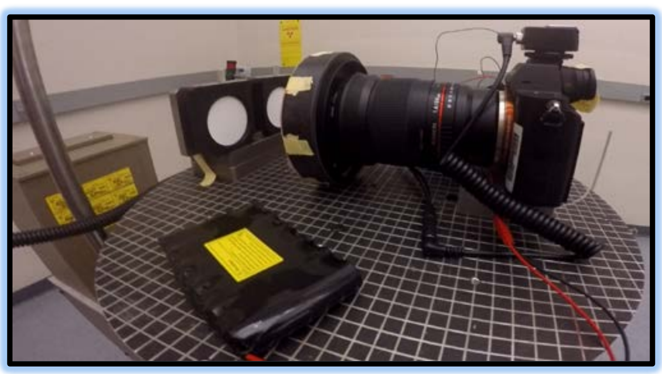

Fig 9. Sony test mock up at calibration facility.

Fig 10. Dual pinhole collimator with removable pinholes..

Fig 11. Am-241 multi source used.

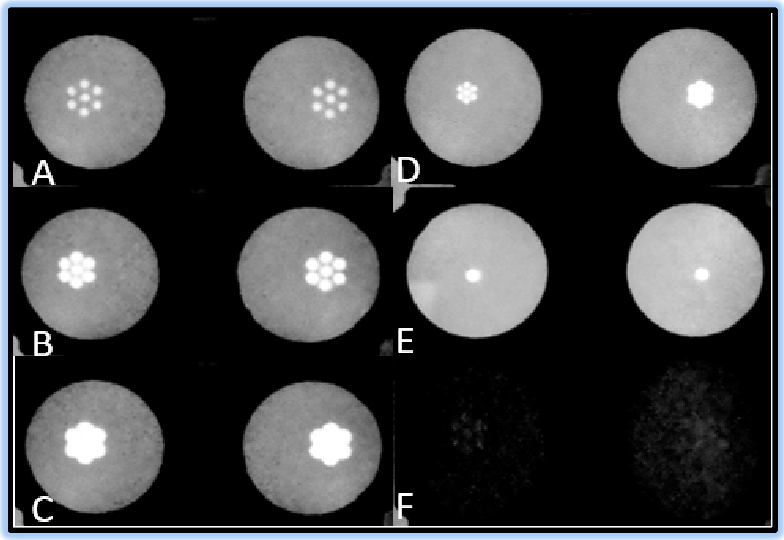

Fig 12. Results for 20mR Am-241 dose except where noted. A: 1mm Pinhole @ 28 cm B: 2mm Pinhole 28 cm C: 17mmPinhole @ 28 cm D: 1mmPinhole (Left) and 2mm Pinhole (Right) @ 50cm E: 1mmPinhole @ 100cm F: 1mmPinhole @ 28cm 1.5mR.

FY2018 Accomplishments

- Successfully tested MiniMax system to read a radiation source exposed PSP during SRNL visit to LANL
- Developed PSP Image Simulator
- Verified that new PSP material from Carestream Medical is 4 times more sensitive than previous PSP films
- Performance tested selected cameras against MiniMax custom camera to identify smaller less expensive alternatives
- Characterized Sony and MiniMax cameras with radiation sources
- Developed physical capability to acquire stereoscopic radiation images for 3D mapping by incorporating a dual pinhole collimator
- Characterized dual pinhole and various pinhole sizes with radiation sources
- Housing redesign first iteration complete

Future Directions

- **3D *In-Situ* Radiation Mapping.** Incorporation of the dual pinhole collimator in the *in-situ* device facilitates future development to locate hot spots in 3D space using stereoscopic techniques; additional software development is required for image processing to produce a user-friendly result.
- **Mini *In-Situ* GrayQb™.** The Mightex camera is much smaller than the Sony but not as sensitive; for applications with higher dose rates, i.e. 100mR and above, a very small (6” x 8”) Mini *in-situ* GrayQb™ could be developed for use.

FY 2018 Publications/Presentations

An abstract has been submitted to the Waste Management 2019 Symposia titled "*In-Situ* Radiation Mapping Device"

References

"GrayQb^{TM} Single-Faced Version 2 (SF2) Hanford Plutonium Reclamation Facility (PRF) Deployment Report" SRNL-STI-2015-00673, November 2015.

"GrayQb^{TM} Single-Faced Version 2 (SF2) Open Environment Test Plan," SRNL-TR-2014-00196, August 2014.

Immel, D., Bobbitt, J., Plummer J.; "Radiation Imaging System". U.S. Patent 9,291,719 issued 2016 March 22.

Immel, D., Bobbitt, J., Plummer J.; "Radiation Imaging System". U.S. Patent 9,377,536 issued 2016 June 28.

Acronyms

COTS- Commercial off the Shelf
PSP – Phosphor Storage Plate

Intellectual Property

An invention disclosure will be submitted

Total Number of Post-Doctoral Researchers - 0