7.5 An Advanced Avalanche-Photodiode Based Spectroscopic Radiation Imager

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Abstract

The Department of Energy's (DOE) Environmental Management program must reduce the cost of treatment and disposal of potentially radioactive wastes from facilities undergoing decontamination and decommissioning. Site assessment, monitoring, and material release is currently slow and expensive due to the necessity of using off-site analysis techniques. A method of field screening for radioactive contamination is required that can provide reliable, rapid, and useful information to carry out reclamation operations quickly and efficiently.

Under the DOE's Small Business Innovation Research (SBIR) program Radiation Monitoring Devices, Inc. (RMD) is carrying out the research necessary to design, develop, and fabricate a radiation imager of unprecedented sensitivity. This device will be based on the development of a novel detector, a dual-diode-backed silicon avalanche photodiode (DBAPD). Using large arrays of pixelated DBAPDs (total area near 18 in^2) will greatly increase imager geometrical sensitivity while maintaining a position resolution of less than 2 mm. Additionally, use of the avalanche photodiodes (APDs) will establish a system energy resolution that is on the order of 10%, which is necessary for proper isotope identification. Also, the specialized nature of the APDs will allow a reduced pulse processing electronics load and a simplified readout scheme. Preliminary work on this system has been carried out and the favorable results have prompted another round of advanced investigation.

In the initial or Phase I SBIR research, we completed design and assembly of a DBAPD array. The advanced testing on this device yielded extremely encouraging system performance. We have shown the system's definitive ability to acquire energy spectra with the 2 x 2 diode-backed APD array coupled to a CsI(Na) scintillator while operating in a row-column addressing arrangement. We also demonstrated the position-sensitive detection capability of the device using collimated gamma-ray sources. Collaterally, we developed and refined the basic signal processing, storage, and control system for use as a valuable tool for examining array performance and as a basis for Phase II signal processing and data visualization.

More advanced or Phase II SBIR research will build on our successful Phase I project and focus on a detailed investigation of the development of a highly sensitized radiation imager based upon the DBAPD array. Our research goal is to improve imager technology through APD, coded-aperture, electronic, and system development. System field tests will provide performance and operational characteristics of the device and demonstrate its utility for DOE.

We will adapt the resulting device for many applications, since an instrument to image radioactive sources can be used any place where such sources are encountered on a routine basis. This includes nuclear research facilities, hospitals and clinics, nuclear power generation plants, nuclear fuel production facilities, industrial testing sites, airports, border crossings, and military facilities. In some cases, it would be desirable to permanently mount the unit to provide full-time monitoring of an area.

The high-sensitivity imager will be directly applicable to the DOE task of decontamination and decommissioning its facilities and extracting material contaminated with radiation from the process stream.

In April of 1997, Dr. Woodring joined RMD as a Senior Scientist to direct the redevelopment of a nuclear imaging camera, RadCam. Additional work includes development of an ASIC readout system for avalanche photodiodes, development of a "plastic sorter" to allow separation of recyclable plastics based on plastic mass/density, and advanced research into radiation imagers and measurement systems based on radiation interrogation.

Mitchell Woodring received his BS in Physics from University of California, San Diego, CA in June 1988. He received his MS in Physics from the University of Lowell, Lowell, MA in June 1993. Mitchell earned his Ph.D. in Experimental Nuclear Physics from the department of Physics and Applied Physics at the University of Lowell Massachusetts, Lowell, MA in April 1997. The title of his Ph.D. dissertation was "Fission neutron spectra in ^{235}U and ^{239}Pu below the incident energy due to fast neutrons". His research involved use of neutron-insensitive, ultra-fast BaF_2 detectors to assist in the measurement of fission neutron spectra in new energy regions. Additional work included development of a novel PC based data acquisition system and beam resolution monitor for the UML Van de Graff Laboratory.

Mitchell Woodring is an active member of the American Physical Society, Division of Nuclear Physics and of Sigma Xi Scientific Research Society.

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Industry Partnerships for Environmental Science and Technology Conference

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Office of Science and Technology
Small Business Innovative Research Program

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An Advanced Avalanche-Photodiode Based Spectroscopic Radiation Imager

- Company Overview
- Current RMD Radiation Imaging technology
- Project Overview
- Project Progress
- Project Direction

RMD Inc

Company Overview

General:

Founded in 1974
68 technical and manufacturing staff
12 Ph.D. and 10 M.S. research staff
30,000 ft^2 laboratory and manufacturing space
Full digital machine shop
In-house prototyping and production capability

Core Business Interests:

Research & Development
OEM Sensors
Applications Engineering
Custom Products
Standard Product Lines

RM D
Inc

Company Overview

Core Research Interests:

Materials Science
Sensor Development
Instrument Research and Development

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Current RMD Radiation Imaging Technology

RADCAM 2000™

Spectroscopic Gamma-Ray Radiation Imaging

RADCAM 2000™ by Radiation Monitoring Devices, Inc. "visualizes" gamma-ray radiation sources, in real time, and overlays the radiation image on a picture of the corresponding physical environment.

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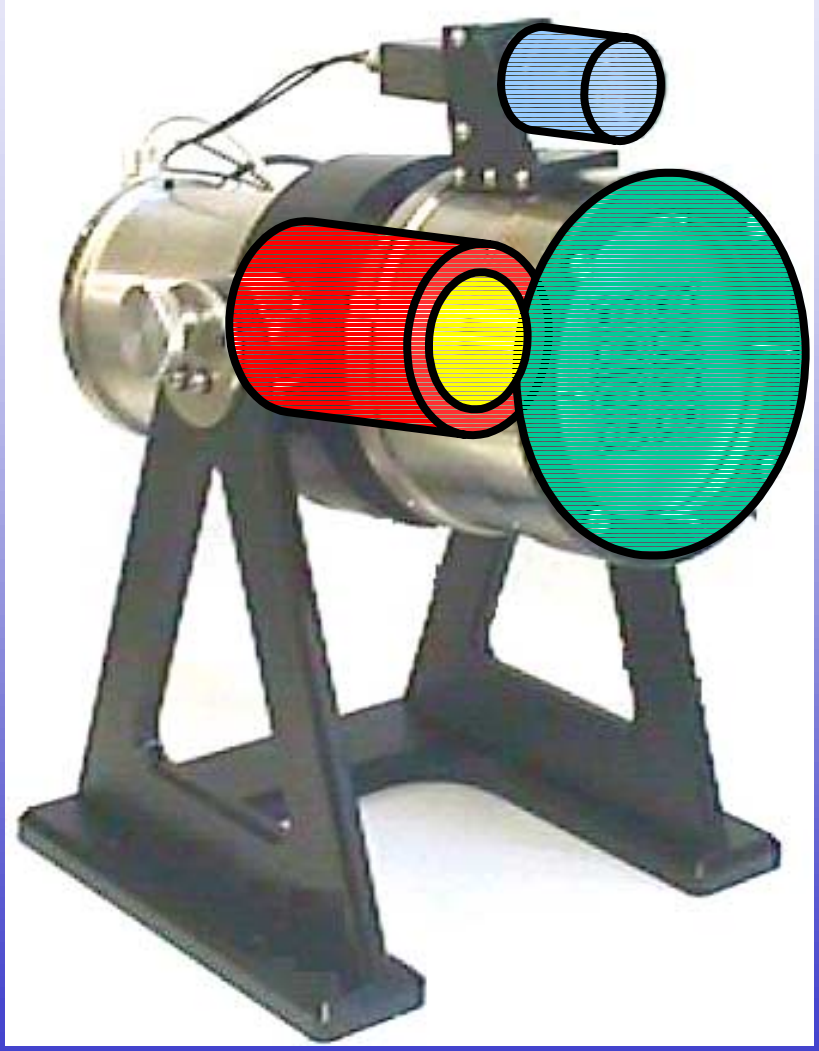
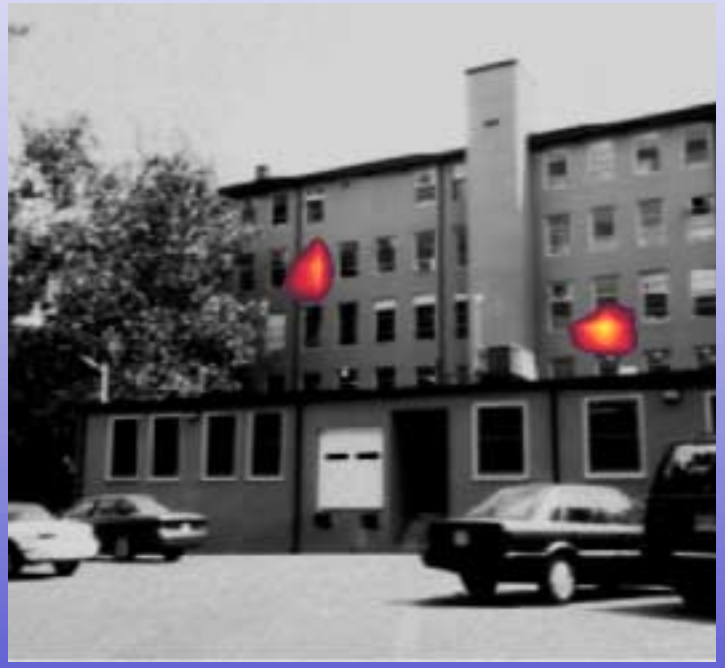
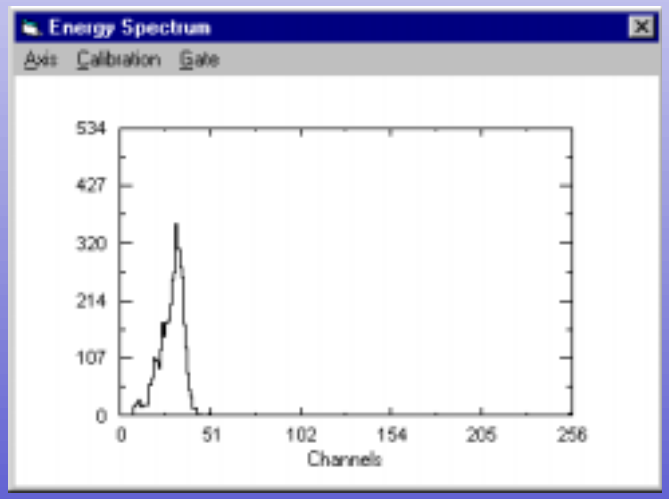
Current RMD Radiation Imaging Technology



Current RMD Radiation Imaging Technology

Standoff radiation visualization and mapping.





Real-time nuclear and video image fusion.

Simultaneous isotope energy identification.

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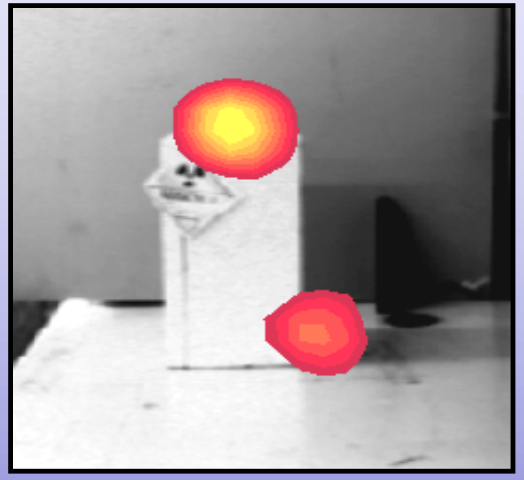
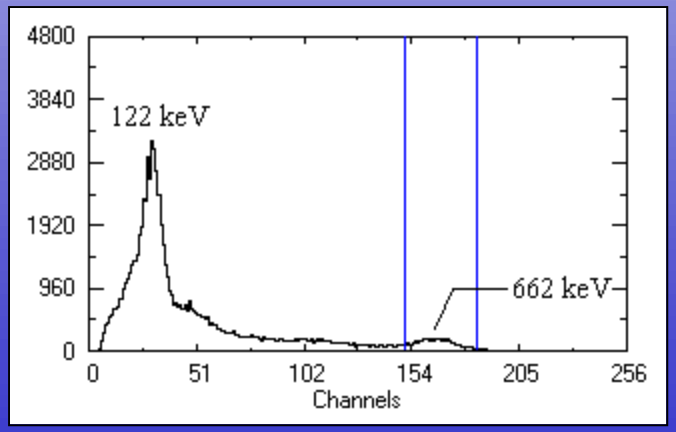
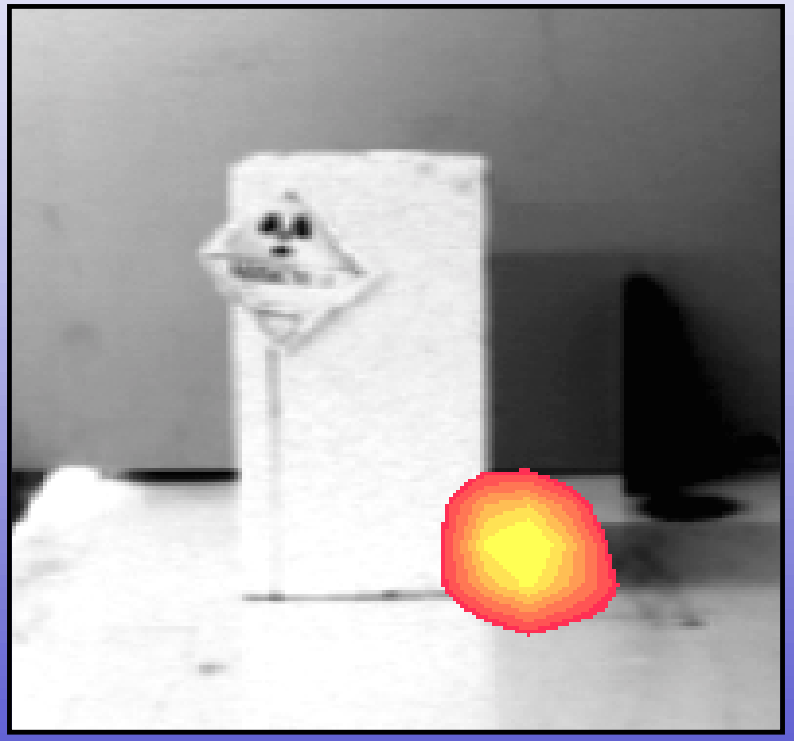
Current RMD Radiation Imaging Technology

Original Image



Associated Energy Spectrum





Energy gated final image.
Isotope identified and located.

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Project Overview

Problem:

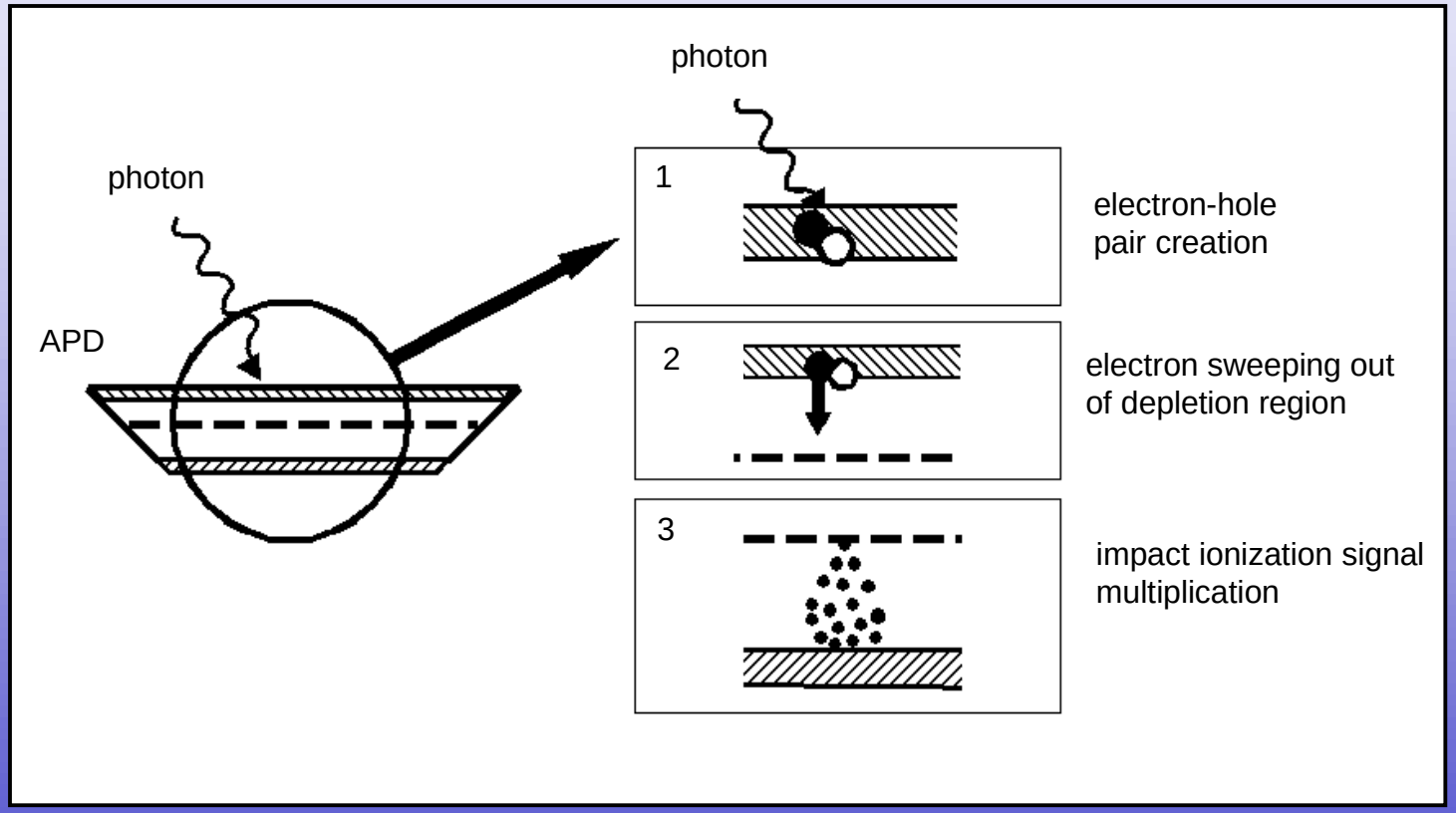
The DOE has to carry out Decontamination and Decommissioning (D&D) work on facilities that were used to support cold war weapons production.

These facilities have a large amount of ‘potentially’ contaminated material (structures, objects, material) that needs clearing from the process stream.

Proposed Solution:

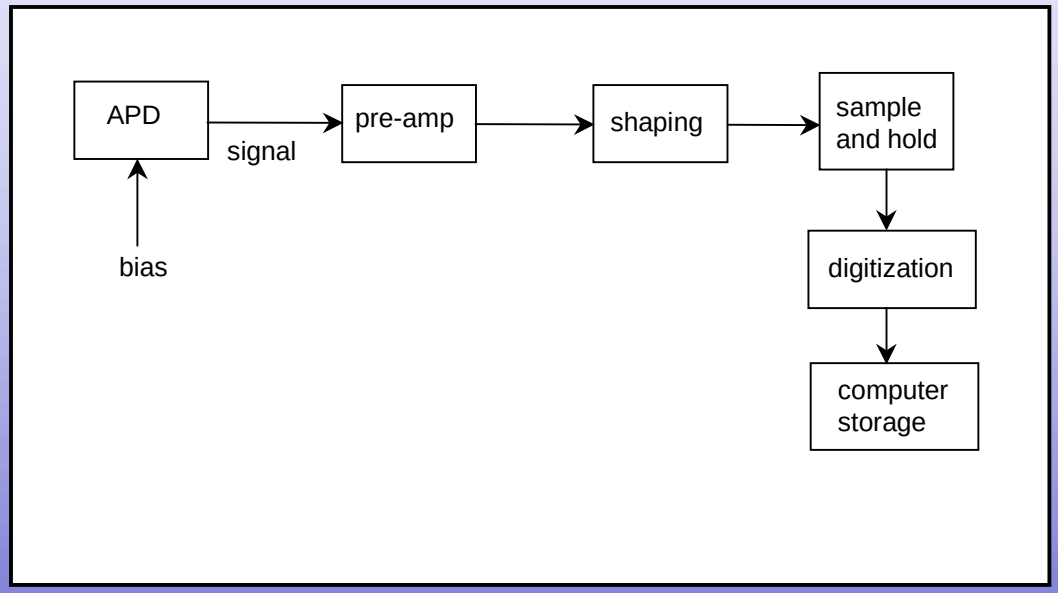
Develop a highly sensitized radiation imager to map radiation contamination and identify radiation source types. The imager will be based upon a new type of detector (a diode-backed APD) and other high-performance imager components.

Project Overview



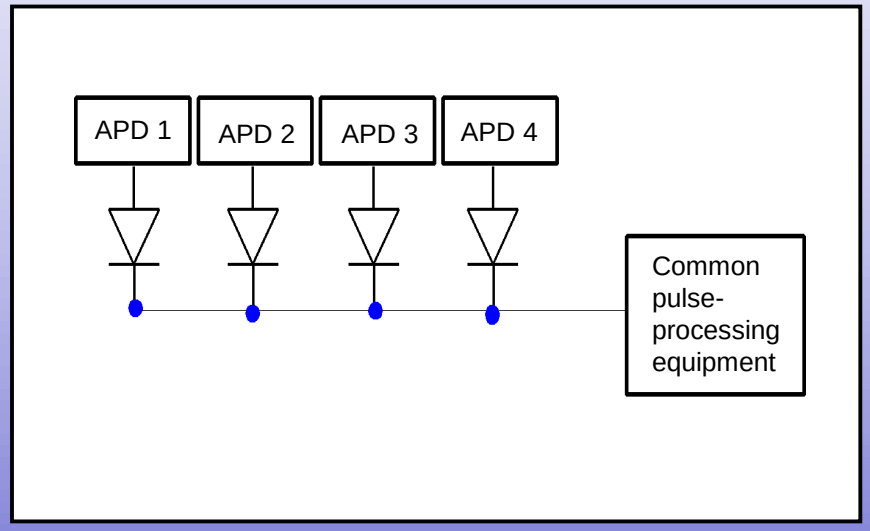
The solid-state, silicon-APD, photomultiplication process.

Project Overview

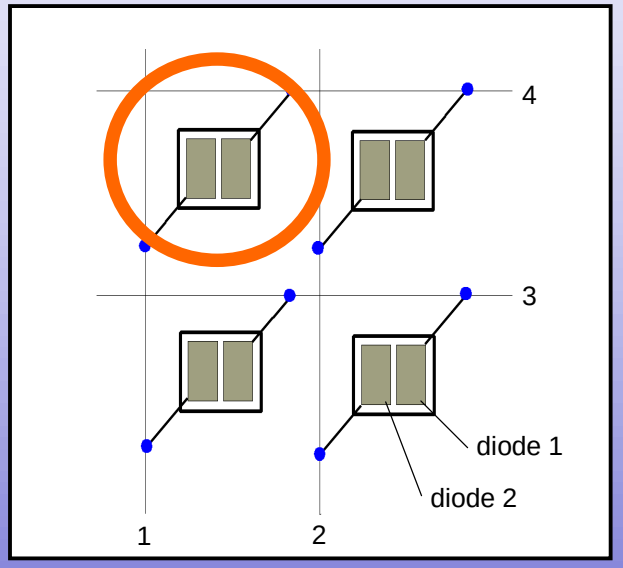


The standard APD pulse processing circuit for a single APD.

Project Overview



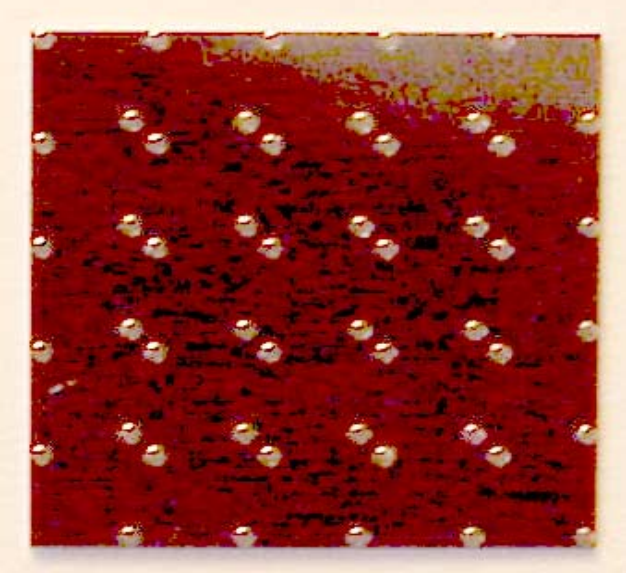
APD diode multiplexing scheme for pulse-processing electronics reduction.



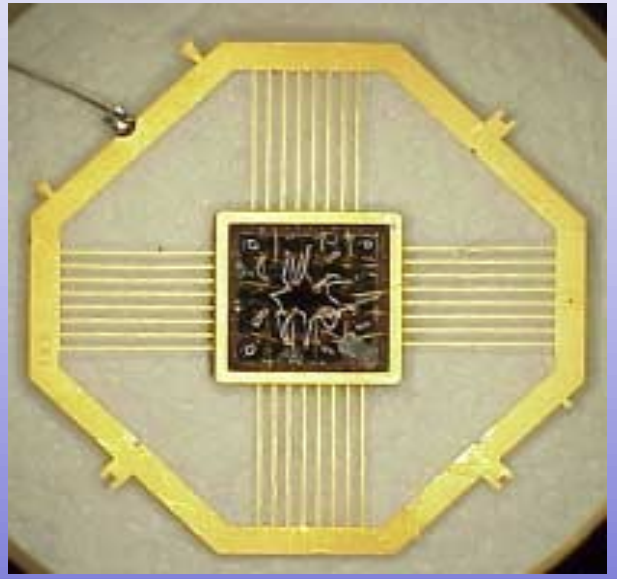
Dual-diode, x-y addressable readout for proposed APD array.

Project Progress - Phase I

Creation...



A picture of the rear contacts of the dual diode-backed APD array



A picture of the dual diode-backed APD as packaged for use.

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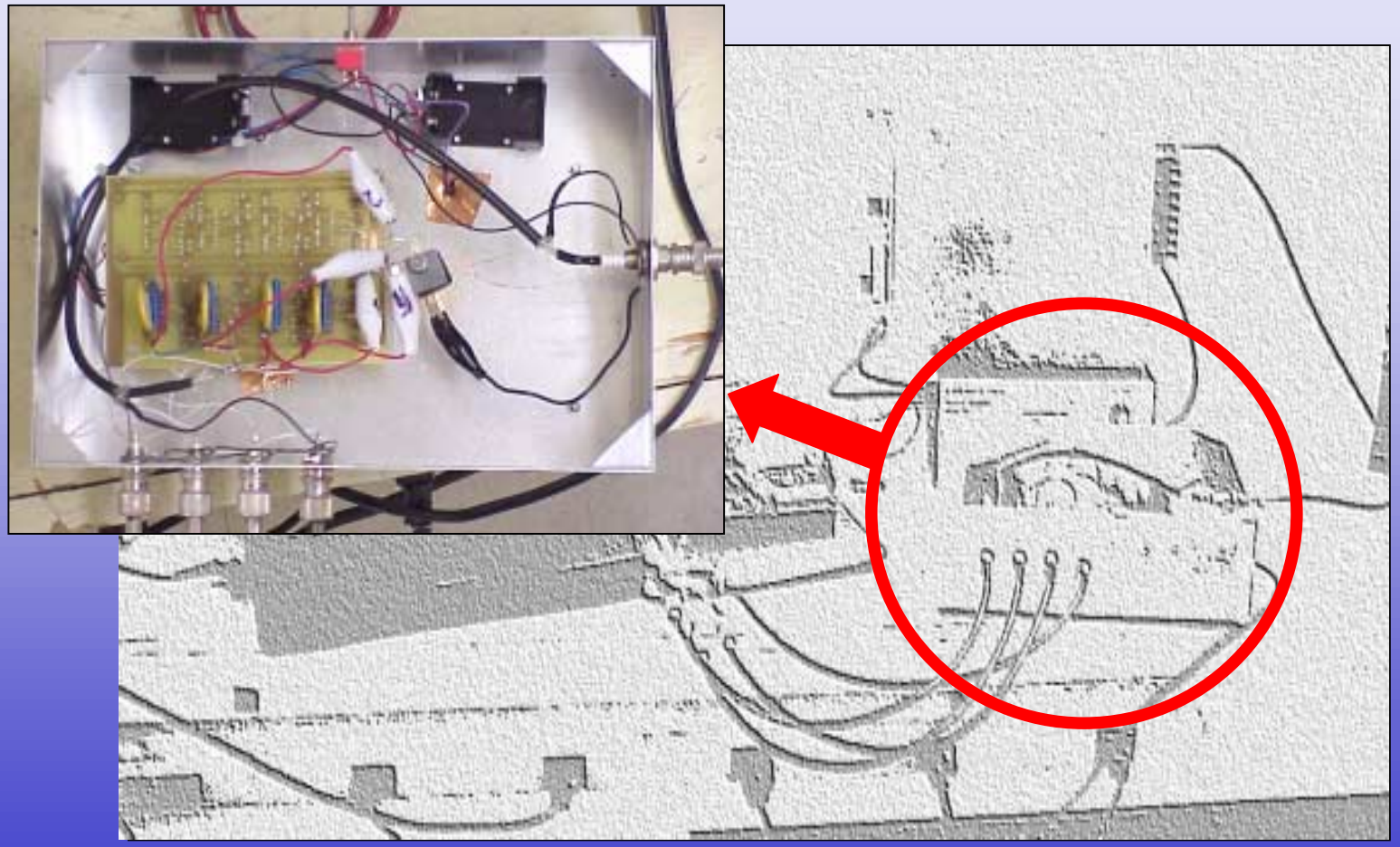
Project Progress - Phase I

Assembly...



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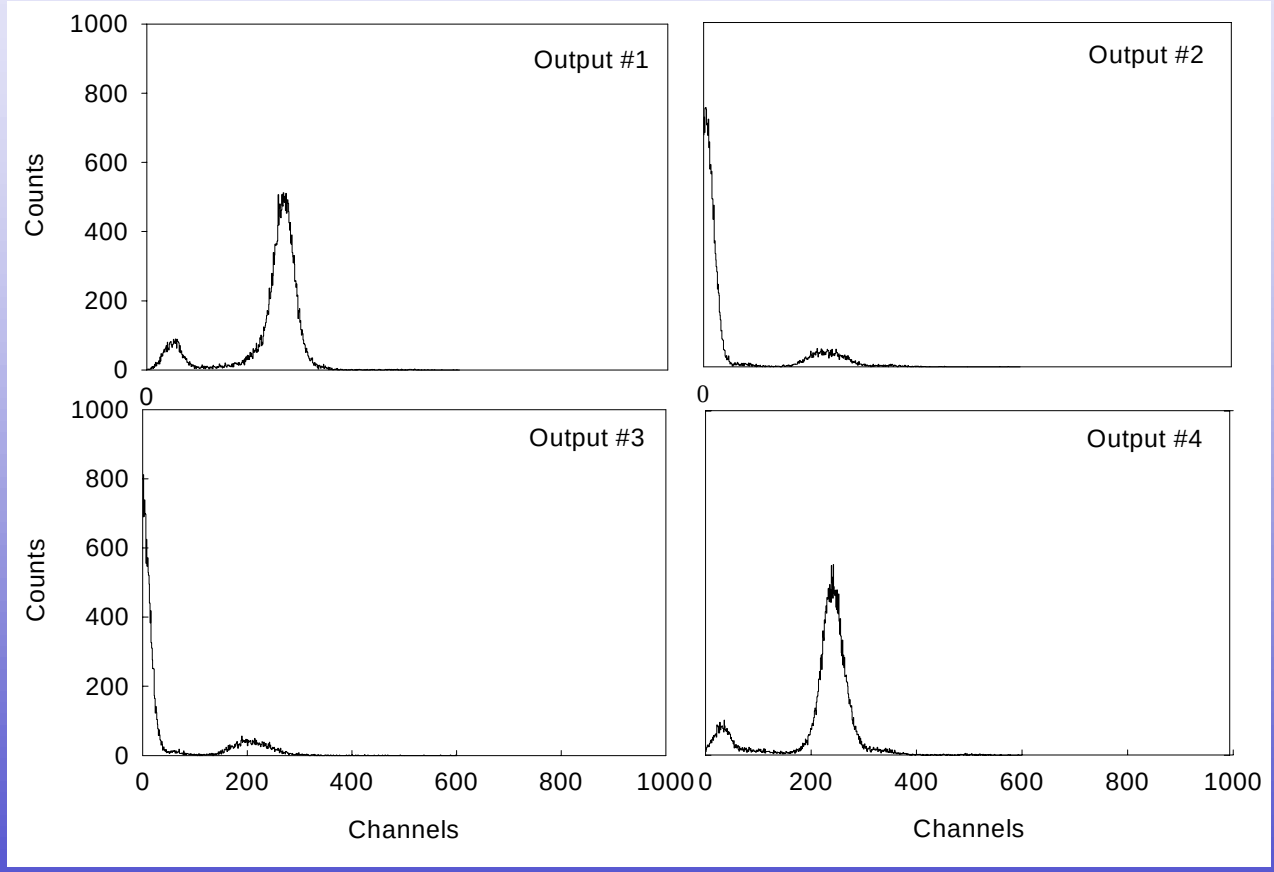
Project Progress - Phase I

Preliminary testing...



Plots of data from all 4 RC-data lines. The ^{57}Co source was collimated and directed onto pixel 1 in the array which was coupled to a CsI(Tl) scintillator.

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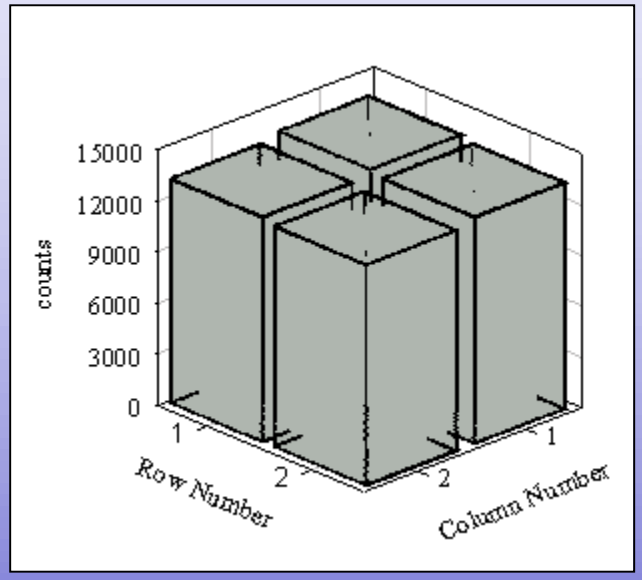
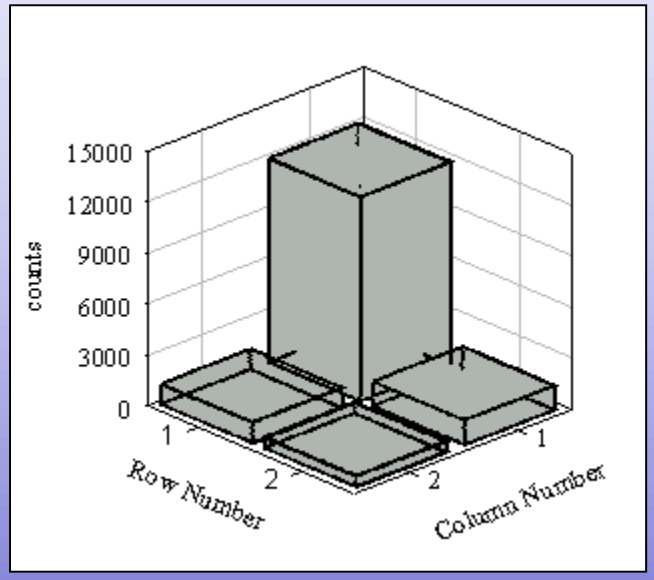
Project Progress - Phase I

Preliminary testing...



Counts per pixel of event-mode data sorted by the RC-decoding.

No channel threshold is set.



Counts per pixel of event-mode data sorted by the RC-decoding.

A channel threshold was set at channel 50.

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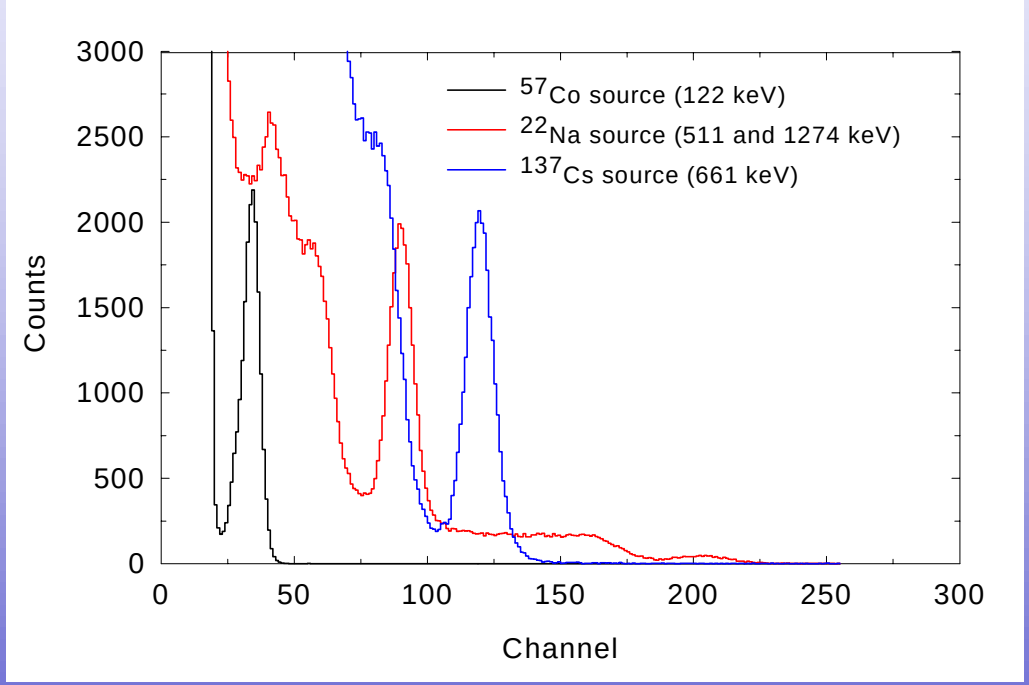
Project Progress - Phase I

Preliminary testing...

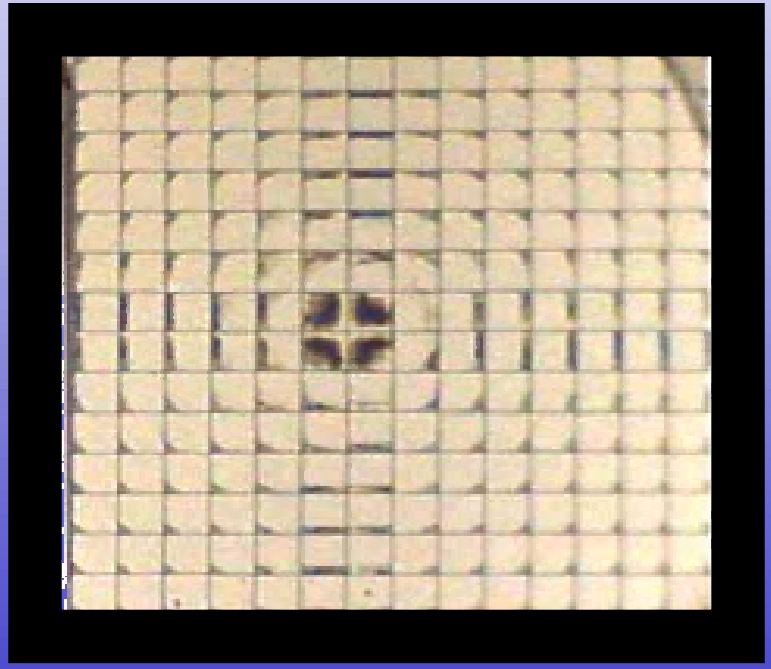


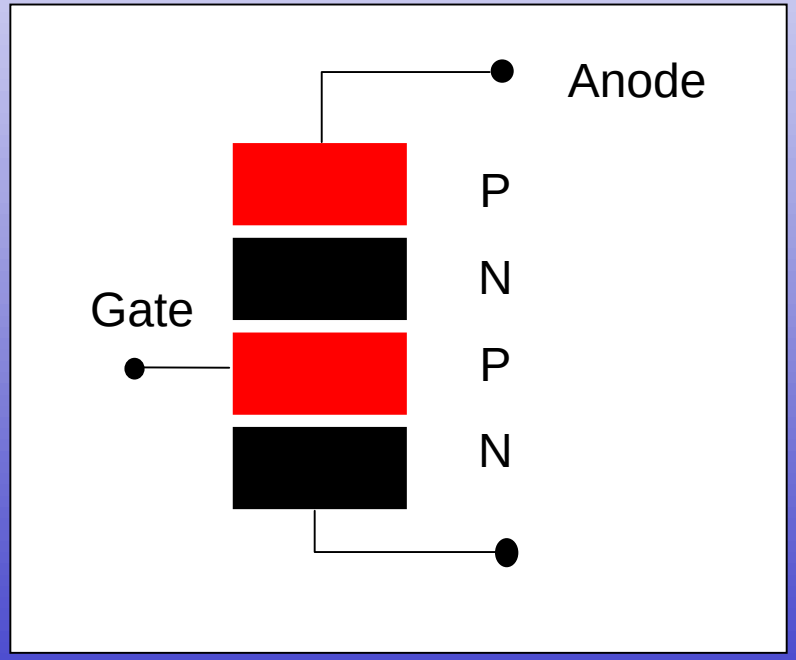
Energy spectra taken from the diode-backed APD array for ^{57}Co, ^{22}Na, and ^{137}Cs isotopes. The data was acquired from pixel 1.

Project Direction - Phase II

Preliminary Design...

Develop large-area, active-element-backed, APD arrays





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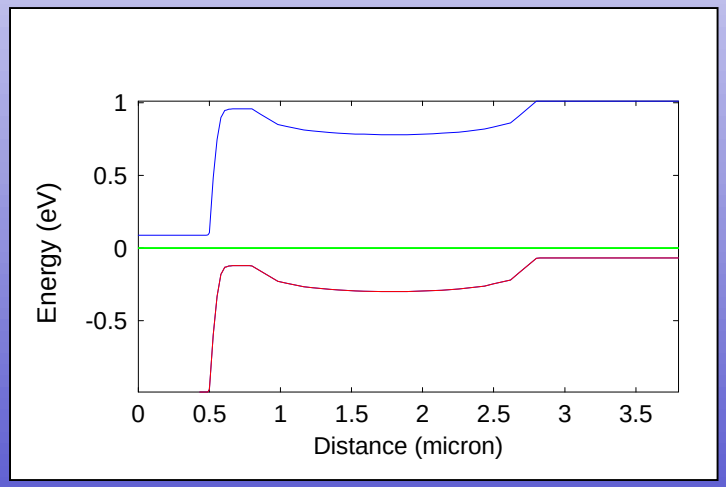
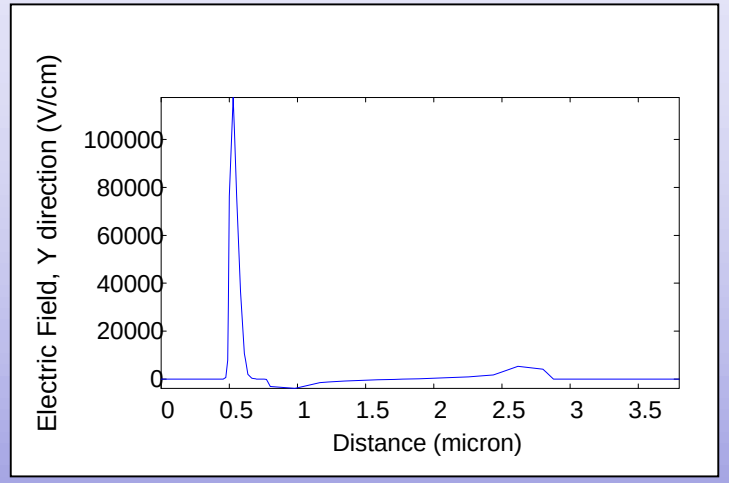
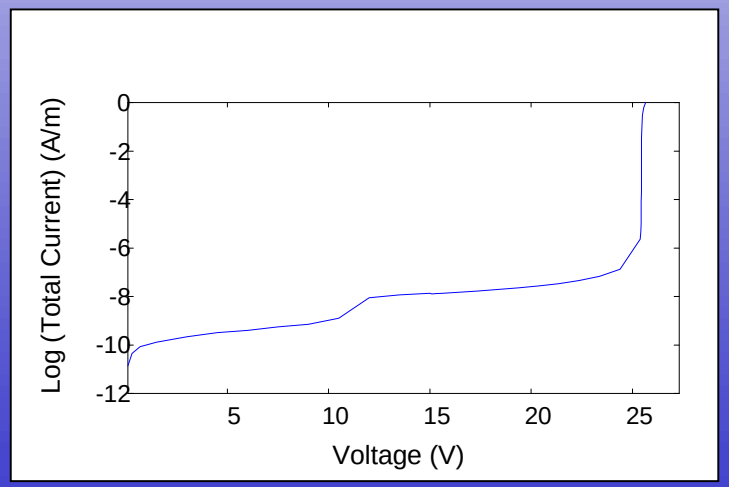
Project Direction - Phase II

Preliminary Design...

Simulation studies for APD, diode, and SCR design







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Project Direction - Phase II

Phase II Goals...

- Develop 14 x 14 element planar-array with active-element contacts.
- Reduce individual APD noise contribution. Implement to array.
- Investigate array packaging. Fabricate.
- Investigate pulse-processing requirements. Assemble
- Determine imager design properties. Assemble.
- Carry-out advanced field-testing