Product Application Notes

Characterizing CdTe, CdZnTe, HgI_2 and Similar Detectors

INTRODUCTION

Evaluating room-temperature semiconductor detectors requires more than just a spectrometer. A detector may perform poorly for a number of reasons: It might be generating too much noise; Its charge collection time could be too long; or there might be excessive charge trapping. The Polaris is a digital spectrometer that is ideally suited for investigating these questions.

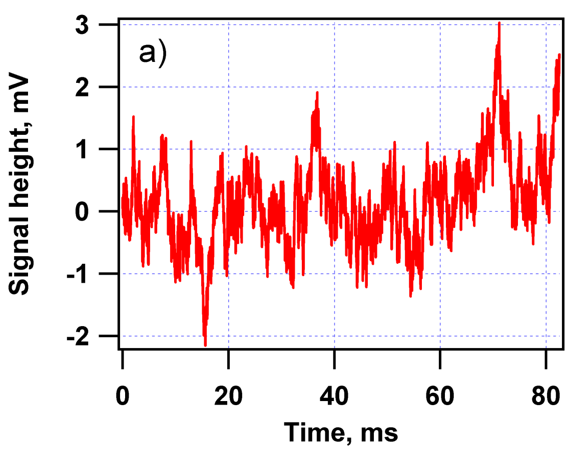
ANALYSIS TOOLS

The Polaris offers a palette of analysis tools:

* Built-in 14-bit oscilloscope displays input signals measured in mV, or calibrated in keV.
* Built-in fast Fourier transform (FFT) to measure spectral noise density.
* Triggered waveform capture. Store sets of captured signal traces from different radiation sources for later analysis.
* Input signals are not restricted to having a 50µs decay time. Signals with decay times from 200ns to infinity are OK.
* High quality energy spectroscopy.
* IGOR PRO, by WaveMetrics, the powerful data presentation and analysis package.

OSCILLOSCOPE AND FFT

The built-in oscilloscope displays 8192 data points from the 14-bit waveform digitizing ADC, and offers a high resolution Fast Fourier Transform using all 8K data points. The displayed trace can span 600µs to 9.8s. The following two graphs illustrate this feature.



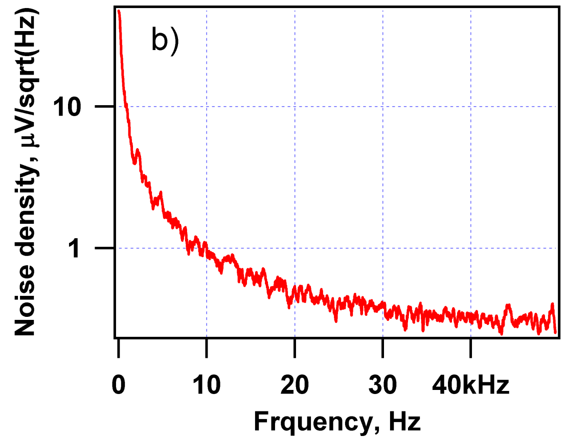


Figure 1: Graph a) shows a noise trace from a CZT detector after a charge-integrating preamplifier. Graph b) shows its (smoothed) Fourier spectrum. Note the large increase in noise density at low frequencies, which is typical in systems where dark current dominates the detectors noise performance.

TRIGGERED PULSE SHAPES.

Alpha particles are a great tool to investigate the electron and hole transport characteristics. Since a 5 MeV alpha particle only penetrates a few µm into the crystal, the charge carriers have to traverse the entire detector. Alpha particle-induced signals can be used to determine the charge carrier mobilities and to map the electric field distribution in the detector.

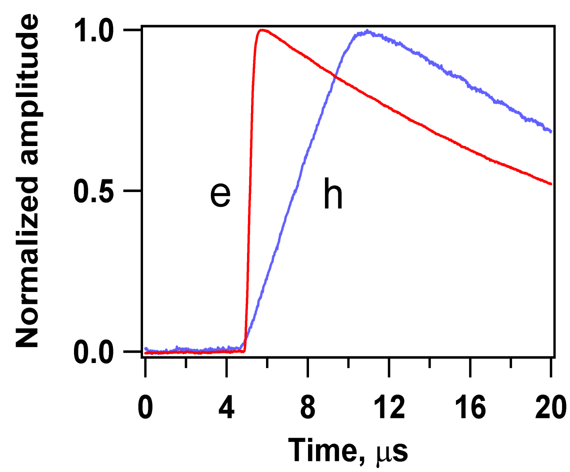


Figure 2: Normalized electron and hole signals caused by illuminating the detector with an alpha source on the positively (e) and negatively (h) charged side, respectively. Note how the signals rise straight and without kinks in this CdTe detector (2mm thick, E=500V/cm)

Instruments That Advance The Art

SPECTROSCOPY

In CdTe and similar materials the charge collection times depend very much on the applied bias. In an analog spectrometer the measured energy reduces with increased charge collection time due to an effect called ballistic deficit. Hence, it is impossible to use an analog spectrometer to measure the charge collection efficiency as a function of applied bias. The Polaris, however, can accommodate signal rise times of up to 30µs and will still measure the collected charge correctly, even if a standard preamplifier with a 50µs decay time is used.

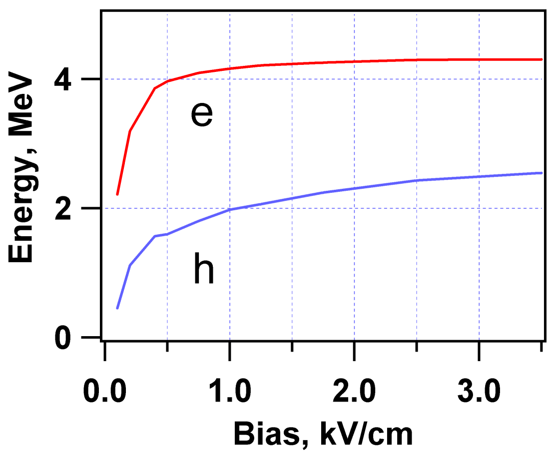


Figure 3: Charge collection vs. applied bias for electrons and holes using a 241-Am source (5.4MeV). While the electrons are collected with higher efficiency beginning at a fairly low bias, there is a fair amount of hole trapping even at a high applied bias in this 2mm thick CdTe detector.

LOOKING FOR THE UNEXPECTED

Not all detectors are created ideal and some have undesirable characteristics. For instance, the electric field across the detector maybe inhomogeneous. (See figure 4.)

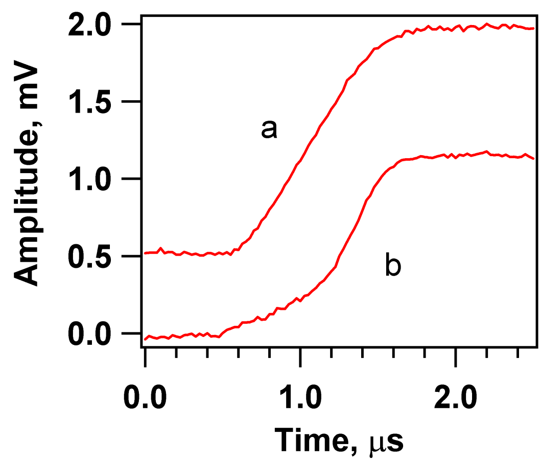


Figure 4: Two gamma rays absorbed at different places in a 5mm thick CZT detector biased at 350V. Trace a) shows uniform electron collection rate along the entire drift path. In trace b) the drifting electrons apparently began their travel in a low field region and accelerated only after escaping from it. The total collected charge corresponds to about 84keV for trace a) and 56keV for trace b).

SUMMARY

The Polaris spectrometer is a very versatile data acquisition tool that can be employed to study the performance of CdTe and other compound semiconductor detectors in great detail. The Polaris comes with a graphical user interface built using IGOR Pro from WaveMetrics. IGOR Pro is a powerful data presentation and analysis software package running on PCs and Apple computers. It features a simple, C-like programming language and a large number of built-in functions for data analysis.

While the Polaris specific functions are all encapsulated in a C-library, the full power of IGOR Pro is available to users to analyze and display all their data within the same environment in which the data were first acquired.

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