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Hand-held Gamma-ray Spectrometer Based on High-efficiency Frisch-Ring CdZnTe Detectors

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DISCLAIMER

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Abstract – **Frisch-ring CdZnTe detectors have demonstrated good energy resolution, <1% FWHM at 662 keV, and good efficiency for detecting gamma rays. This technique facilitates the application of CdZnTe materials for high efficiency gamma-ray detection. A hand-held gamma-ray spectrometer based on Frisch-ring detectors is being designed at Brookhaven National Laboratory. It employs an 8x8 CdZnTe detector array to achieve a high volume of 19.2 cm^3, so that detection efficiency is significantly improved. By using the front-end ASICs developed at BNL, this spectrometer has a small profile and high energy resolution. The spectrometer includes signal processing circuit, digitization and storage circuit, high-voltage module, and USB interface. In this paper, we introduce the details of the system structure and report our test results with it.**

SUMMARY

CdZnTe (CZT) is a very attractive material for room-temperature semiconductor detectors due to its wide bandgap and high atomic number [1]. Due to the poor hole mobility in CZT material, several special techniques have been developed to make this material suitable for radiation detection. Among these techniques, the Frisch-ring CZT detector is the most attractive one with simple configuration and yet outstanding spectral performance. Our group in Brookhaven National Laboratory (BNL) has expended efforts in improving the performance of the Frisch-ring CZT detectors; our most recent work focused on the non-contacting Frisch-ring detector [2]-[4]. Our achievements allow us to build an inexpensive large-volume detector array, which has high energy resolution and a large effective area.

In addition, compact efficient radiation spectrometers are needed in non-destructive detection, radiation imaging, and homeland security (for example, non-proliferation safeguards, custom inspection, and radiation field survey). Most of these applications desire an instrument with compact size, room-temperature operation, high gamma-ray energy resolution and absorption efficiency, and low cost. Gamma-ray spectrometers based on CZT detectors have been developed in the past; they either are very expensive or have low gamma-ray absorption efficiency. Our improvements on the Frisch-ring technique makes it possible to assemble a detector array that meets the above requirements.

To demonstrate the feasibility of employing Frisch-ring CZT detector in the above applications, we are developing a handheld gamma-ray spectrometer based on Frisch-ring detectors. The system employs an 8x8 Frisch-ring CZT detector array. Each detector is 5x5x12 mm^3. The whole system achieves an effective detection volume of 19.2 cm^3, 10 times larger than commercial co-planar grid (CPG) CZT detectors. Therefore, the detection efficiency is improved significantly.

In this paper, we will talk about the fabrication of the Frisch-ring CZT detector, followed by the detailed description of the system structure and our test results.

The system is self-contained. Its detailed structure is shown in Fig. 1(a). Signals from CZT detectors are amplified by a 16-channel preamplifier ASIC [5], and buffered a by peak detection/derandomization (PDD) ASIC [6]. Both ASICs are designed at BNL. Buffer outputs are digitized by 12-bit ADC on the controller board. The conversion results are readout by FPGA and sent to a PC through USB bus. There are 512 Kbytes of SRAM on the device to store data and spectra, allowing the device to work alone or do real-time spectra fitting.

A programmable HV module is also embedded in the device, supplying up to 2000 V bias voltage to the CZT detectors.

The whole system can be powered either by an external 5-V power supply or by the USB bus.

Fig. 1(b) shows the 3-D model of the whole system assembly. The whole system is 6.3-in long, 2.8-in wide, 2-in thick (with detector).

A prototype system has been finished in the last year. Results from the prototype system with single detectors were published [7]. As shown in Fig. 2, a high resolution of 1.39% FWHM can be reached with this system.

Design of the final system was just completed. The PCB boards are being fabricated. The system will be assembled and tested soon. In this paper, we will report the details of the system design. Because some variation of gain exists between

detectors, we will discuss the system calibration and data processing. Detection efficiency and energy resolution from the whole detector array will also be reported.

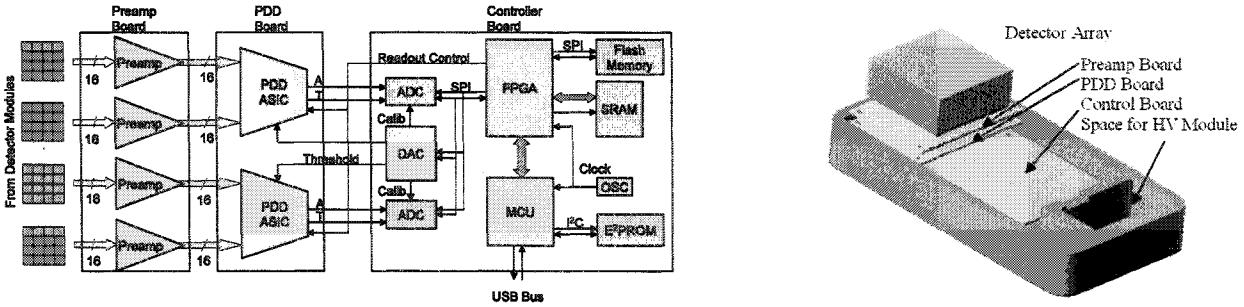

Fig. 1. Gamma-ray spectrometer based on Frisch-ring CZT detectors. (a) System structure; (b) 3-D model of the system assembly.

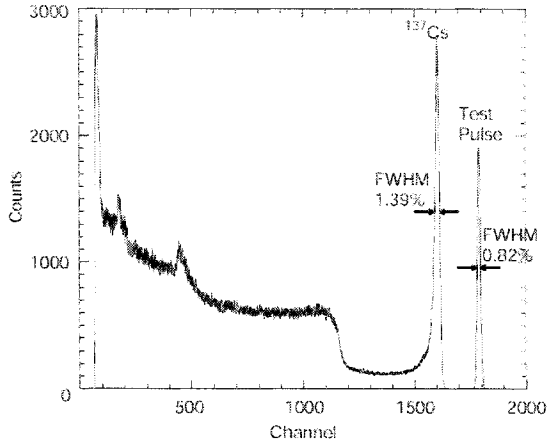

Fig. 2. Spectrum of ^{137}Cs obtained from 5x5x12 mm^3 Frisch-ring CZT detector.

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