NEW CZT HANDLED SPECTROMETER

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Abstract - The evaluation of risk in contamination situations as well as the identification of radionuclide is of major interest in many incidental or accidental interventions.
CdZnTe semiconductor (CZT) equipped with miniature electronic is a very adequate solution to this kind of problems. Indeed, CZT detectors allow gamma spectrum measurements at room temperature with sufficient intrinsic resolution.
A new handled CZT spectrometer and an innovating electronic including an embedded FPGA module have been developed at the CEA LIST. This system, equipped with USB, RS232 or wireless (ZigBee) connectivity, allows a very complete analogical and numerical analysis of the signal (time, amplitude, charge, etc.) and then multi-parameter processes of the data. The main advantage of this new electronic is the enhancement of energy resolution.

1. Introduction

The identification of radionuclide is essential in many incidental or accidental interventions to evaluate correctly biological risk. It allows the diagnostic of the contamination and the identification of its origin. Moreover, it allows the identification of the different radionuclides and the corresponding equivalent dose rates, to reduce properly workers received doses. In situation contamination measurements present additional constraints. The detector must allow the best mobility and autonomy to its user (the only additional tool should be a notebook to collect data). It must minimize contamination risks and should be available at low price. Therefore, a small gamma spectrometer easy to start and usable at room temperature is becoming a crucial asset in contamination measurements. In this context, a new CdZnTe semiconductor (CZT) detector equipped with miniature electronic has been developed at CEA LIST.

2. Specifications of the detector

The new gamma spectrometer developed by the CEA LIST consists in a portable electronic card which includes a Cadmium Zinc Telluride (Cd-Zn-Te or CZT) detector, the pulse shape circuits and the high voltage power supply. With acquisition of the data occurring in the spectrometer, measurement quality is no longer dependent on external device quality (host instrument, connection etc…)

Depending on the application, different CZT sensors can be implemented without mechanic modification (for example 60 mm^3 or 500 mm^3 CZT sensors). It must be noticed that the sensitivity and the energy resolution of the final device directly depend on the intrinsic characteristics of the CZT sensor. While still having good resolution compared to a scintillation detector, CZT detectors are much smaller and less sensitive than scintillation and can be operated at room temperature.

The device weights 20g and its dimensions are 75 mm × 40 mm. Its power characteristics are USB or automatic battery recharge. It can communicate through USB, RS232 and ZigBee using a serial protocol. The communication allows the readout of the count rate or the spectrum, as well as control and storage of key parameters, settings, calibrations, detector ID, etc. Thus this gamma spectrometer is a fully-integrated subsystem communicating the measurement to the instrument.

This gamma spectrometer, presented as an electronic board in Figure 2, is a technological brick which can be integrated in various systems like robots, sensor network…
In particular, our gamma spectrometer has been integrated in a drone in the frame of the MOBISIC research System@tic project (cf. Figure 1). This drone has been developed for crisis interventions (attacks in urban areas, subways, tunnels, earthquake etc…) and presents a poor load capability. Therefore our CZT spectrometer is very suitable detector able to perform the detection and the identification of radiological threats.

Figure 1 MOBISIC drone

SYSTEM@TIC PARIS-REGION Pôle de compétitivité

Figure 2 : Electronic board with the CZT

3. Tests

Our CZT spectrometer (equipped with a 60mm^3 sensor) has been tested with ^{241}Am (3.5 MBq), ^{137}Cs (160 kBq) and ^{60}Co (320 kBq). In particular, we will show in this paper the linearity of the detector with dose rate and its spectrometry performances.

a) Linearity

First, the linearity of the CZT spectrometer has been evaluated with ^{241}Am and ^{60}Co sources by measuring the count rate in the photoelectric peak for source-detector distances ranging from 10 to 50 cm (smaller distances were excluded because the position uncertainty was too important).
With this experimental set-up the dose rate was between 45 nGy/h and 11 µGy/h for ^{241}Am, and between 0.57 µGy/h and 14 µGy/h for ^{60}Co.
As shown in Figures 3 and 4 the detector presents a very good linearity according to the dose rate for ^{241}Am as well as ^{60}Co sources. The relative differences between measured and reference dose rates are bellow 10 % for ^{241}Am source and bellow 6 % for ^{60}Co source (considering the 1.17 MeV peak).

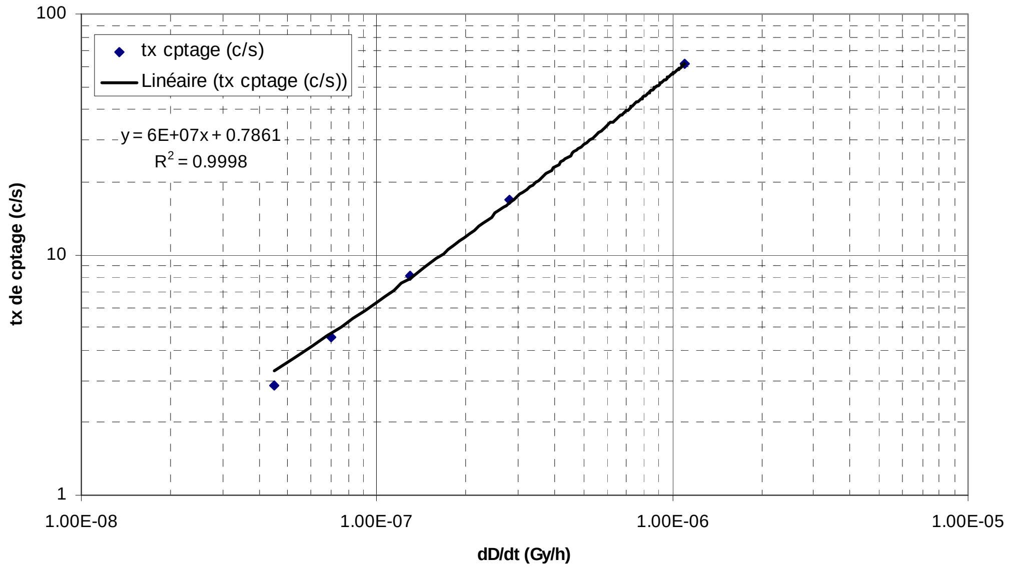

Figure 3 : ^{241}Am vs distance

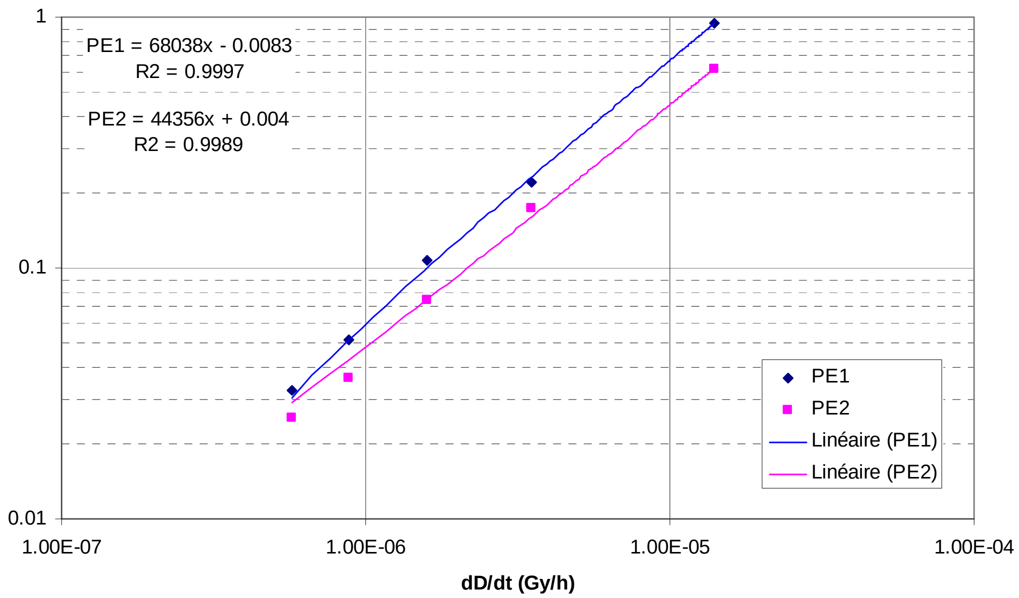

Figure 4 : Integral photoelectric peaks depending on the dose rate for ^{60}Co

b) Energy resolution

In a second time, the spectrometry response of the detector was investigated. The 3 sources were located at 10 cm from the detector where the corresponding dose rates were 1.1 µGy/h, 1.7 µGy/h and 14 µGy/h respectively for ^{241}Am, ^{137}Cs and ^{60}Co.

In each case, the spectrum was acquired during about 1000 s and fitted with Gaussian (describing the photoelectric and leakage peaks) and exponential functions (describing the Compton background). The corresponding spectra are presented in Figures 5 to 7.

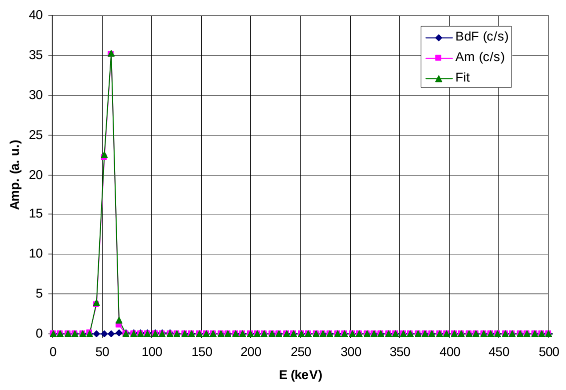

Figure 5 : ^{241}Am gamma spectrum

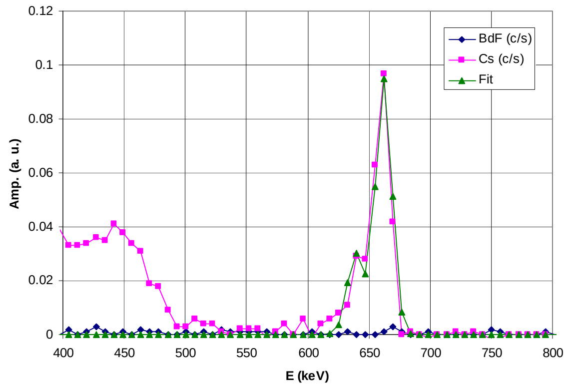

Figure 6 : ^{137} Cs gamma spectrum

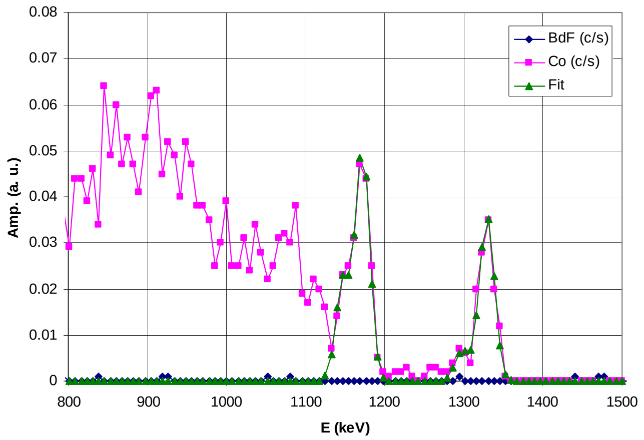

Figure 7 : ^{60}Co gamma spectrum

In this experimental configuration, the counting rates (for the whole spectrum) were 63.4 c/s for ^{241}Am, 7.27 c/s for ^{137}Cs and 11.97 c/s for ^{60}Co, which is consistent with the relative sensitivity of the detector with regard to incident radiation energy.

The energy resolutions were evaluated to 3 keV at 59 keV, 6.7 keV at 662 keV see in figure 8 and 9 keV at 1.17 and 1.33 MeV. These values are representative of improvements made in CZT quality over last years (typically 15 keV at 662 keV).

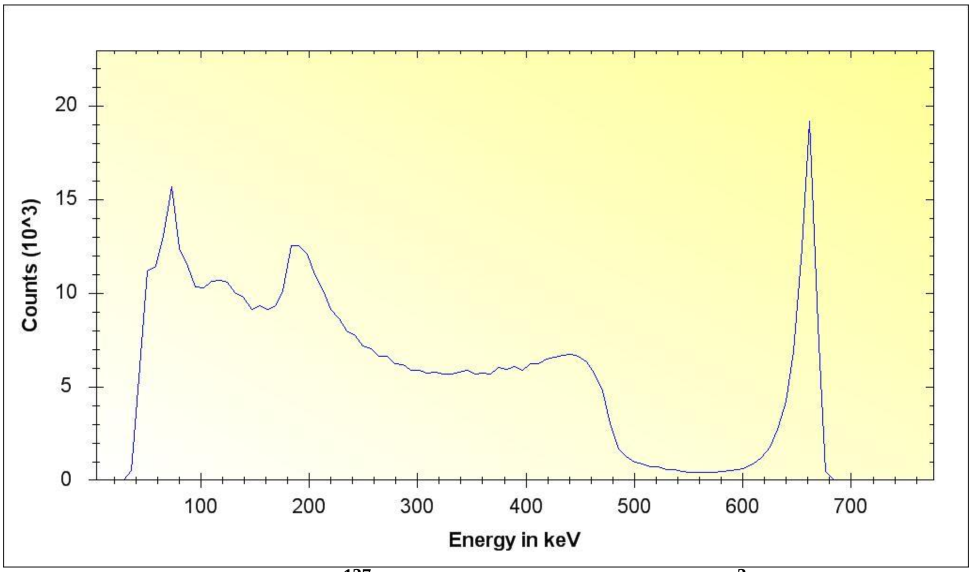

Figure 8 : ^{137}Cs spectrum with a CZT 60 mm^3

c) ^{60}Co vs acquisition time:

The influence of acquisition time has been evaluated for a ^{60}Co spectrum acquired at 2 cm from the source during 10 s, 100 s and 1000 s. The corresponding counting rates were respectively 100.4, 103.2 and 102.8 c/s (on the whole spectrum) which were very stable. The standard deviation is less than 1.5 %.

As shown in the following figure and not surprisingly, the longer the acquisition is, the less noisy is the spectrum. Nevertheless, the different parameters of the fit are quite stable.

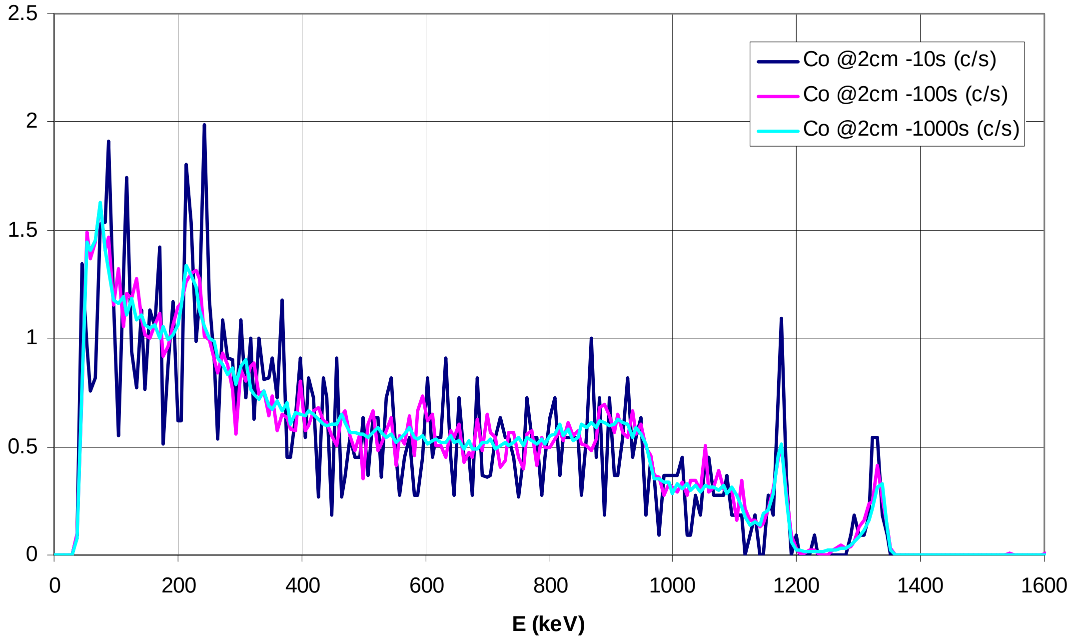

Figure 9 : ^{60}Co acquisition for 3 different times

The figure 10 shows the summary of fit parameters for 3 acquisition times, resolution (σ), average energy (Em) and integral (A) for the different peaks:

		1000s	100s	10s	Standard deviation
	σ	7.83	8.23	5.69	18.81%
PE 1	**Em**	1173.88	1174.64	1174.88	**0.04%**
	A1	9.66	9.59	15.60	**29.70%**
PE 2	**Em**	1335.01	1332.31	1327.68	**0.28%**
	A2	6.63	7.61	9.42	**17.92%**
Exhaust 1	**Em**	1152.35	1155.92	1156.69	**0.20%**
	A	2.41	2.60	2.00	**13.22%**
Exhaust 2-1	**Em**	1317.23	1313.79	1313.92	**0.15%**
	A	2.57	3.01	1.64	**28.95%**
Exhaust 2-2	**Em**	1299.85	1301.53	1293.81	**0.31%**
	A	1.47	1.53	2.60	**34.05%**

Figure 10 : Summary of parameters for 3 acquisition times

The peak position is stable (even for low statistics), in this case the identification is good even for short acquisitions.

Regarding the quantification of the source activity, the uncertainty can vary up to 30% if the statistics are insufficient and reliable dose rate evaluation would need longer acquisition.

4. Discussion and conclusion

In this Paper, we present a new gamma spectrometer as a complete subsystem developed by CEA LIST. Experimental results show a good linearity between measured and reference dose rates and better energy resolution due to CZT quality improvement over last years (6.7 keV at 662 keV and 9 keV at 1.17 and 1.33 MeV). So, this new gamma spectrometer represents a very suitable tool in the frame of dismantling process, incidental or accidental interventions. With its small size and its communication module, this new gamma spectrometer could be used as a wireless sensor. In this context, we study network integration of hundreds of this gamma spectrometer, in term of performances and response time. A second generation of digital gamma spectrometer is currently developed by CEA List to integrate new real time processing.