ENERGY PEAK STABILITY WITH COUNT RATE FOR DIGITAL AND ANALOG SPECTROMETERS

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An experimental comparative study analyzing the effects of input count rate on gamma-ray peak shift has been done using an analog and a digital spectrometer, each optimized in turn for energy resolution or throughput and two HPGe gamma-ray detectors of low and medium efficiencies. The analog spectrometer produced energy spectra with more stable peaks relative to input count rate, than the digital spectrometer.

Key words: high resolution gamma-ray spectrometry, HPGe, peak shift.

1. INTRODUCTION

High resolution gamma-ray spectroscopy (HGRS) is employed for the detailed analysis of the spectra corresponding to nuclear decay schemes and radionuclide identification and quantification in various types of applications. Energy resolution and energy peak stability are the most important factors in these types of applications. Both of them are dependent on the input count rate at which spectra are recoded. The excellent energy resolution characteristic of high purity Germanium (HPGe) detectors makes them suitable for these types of applications [1]. In order to obtain an estimate of the detector efficiency influence on peak drift, two high purity germanium detectors were used for data acquisition. Both detectors were cooled using mechanical coolers.

The type of acquisition system used to collect the energy spectra also influences results in terms of energy resolution and peak drift. Recent studies have shown that digital spectrometers can offer better energy resolution compared to their analog counterparts. Also, the spectrometer's acquisition parameters influence performance both in terms of energy resolution and throughput [2, 3]. Studies showed notable differences between the two types of spectrometers in terms of throughput and peak shape under different optimizations of parameters [4].

The goal of the present work was measuring and comparing the peak drift of several gamma-ray peaks in energy spectra acquired through a digital desktop spectrometer and an analog counterpart. These spectra were acquired for input count rates ranging from 1 kHz up to 20 kHz. The analyzed peaks were chosen in the 50keV – 1.5MeV energy range. The analysis of experimental measurements had to be done regarding all factors mentioned above. A discussion of the obtained results was presented in section 3 of this paper.

2. EXPERIMENTAL METHOD

Although digital and analog spectrometers are functionally alike they present differences both in structure and in operation [3, 5, 6]. The present work is part of a series of experiments aimed at comparing analog spectrometers to digital ones. Comparisons between the two types of spectrometers showed differences in spectra energy resolution and acquisition statistics reflecting throughput. It has also been shown that optimizing the acquisition parameters of the two systems for energy resolution or throughput had very strong influences on the resulting spectra [3, 4].

The gamma-ray energies analyzed in the present paper were 59.5keV, 356keV, 778keV, and 1332.5keV and were obtained using a stack of four radioactive spectroscopic sources [4] with activities ranging between 16 to 47 kBq.

To analyze the effect of the detector's efficiency on results, experiments were carried out using two germanium detectors with different relative efficiencies: one with medium-high efficiency (60%; 60GEM) and the other one with a lower efficiency (25%; 25GEM) [7], both cooled by the mechanical cooler X-Cooler from ORTEC.

Acquisition parameters maximized the throughput in one set of experiments and optimized the energy resolution in the other. Measurements were done increasing the count rate from 1 kHz to 20 kHz in 1 kHz increments steps. As a result 80 different measurements were performed using two spectrometers, resulting in 160 spectra for analysis.

The parameters for the spectroscopy amplifier of analog system (gain, shaping time, and shaping method) were determined on the basis of several experimental trials [3]. On the digital system, the optimization of acquisition parameters was done through the software command interface of the Polaris DGF [8]. As each detector and each optimization required a different set of acquisition parameters (preamp gain, decay time, rise time, flat top, and trigger threshold) they were set up by monitoring the signal using the software oscilloscope, and analyzing the resulting test spectra. The parameters employed for these two optimizations are presented in table 1 of reference [4].

Spectra were gathered for each count rate, each spectrometer and each detector. Energy resolution [4] and position for the peaks of interest was measured on each spectrum. The calibration for the spectra was done using each of the four peaks at an ICR of 1kcps and preserved throughout the 20kcps ICR interval. The four calibration points lead to a more accurate calibration curve which in terms minimizes possible spectra calibration errors [9]. Peak shift was measured as the difference in energy between the calibration (starting) value and the peak energy value at a given ICR. The error associated with ICR was less than 1%. As a prerequisite for minimizing statistical errors in peak position determination, the considered peaks had to have a minimum net area of the order millions of counts. The resulting error in peak position determination was lower than 0.1% [10].

3. RESULTS AND DISCUSSIONS

In the course of the first set of measurements, acquisition parameters were optimized for throughput on the analog system and the digital one. The relative peak positions in keV were plotted against the input count rate (ICR), for each of the analyzed energy peaks.

Spectra analyzed from the analog spectrometer acquiring data through the 25GEM detector, presented in Fig. 1, panel a, showed a slight descending trend with increasing ICR for the position of all peaks. This means that with the increase of count rate, all the energy peaks shifted to lower energies. This was the most stable evolution of energy peak positions with count rate. As the analog system was optimized for throughput, stability with input count rate was expected both in terms of resolution and in terms of peak position.

Spectra analyzed from the digital spectrometer acquiring data through the 25GEM detector, presented in Fig. 1, panel b, showed fluctuating peak shifts that seem to be energy dependent. Here, the shift in energy peak positions with ICR has a strong correlation with the energy of the peak. While the low energy peak presents almost no shift and excellent stability with ICR, for higher energies there appears to be a linear dependency between the value of the peak shift and the energy of the peak. While the two spectrometers were acquiring data from the same detector, using the same gamma-ray sources and the same optimizations, it is worth mentioning that the variations in Figure 1 panel b bear no resemblance to the descending trend in panel 1 of the same figure.

Spectra analyzed from the analog spectrometer acquiring data through the 60GEM detector, presented in Fig. 1, panel c, showed a slight ascending trend with increasing ICR for the position of all peaks. This result points to the conclusion that for the throughput optimization, the analog spectrometer offers much better peak position stability compared to the digital one.

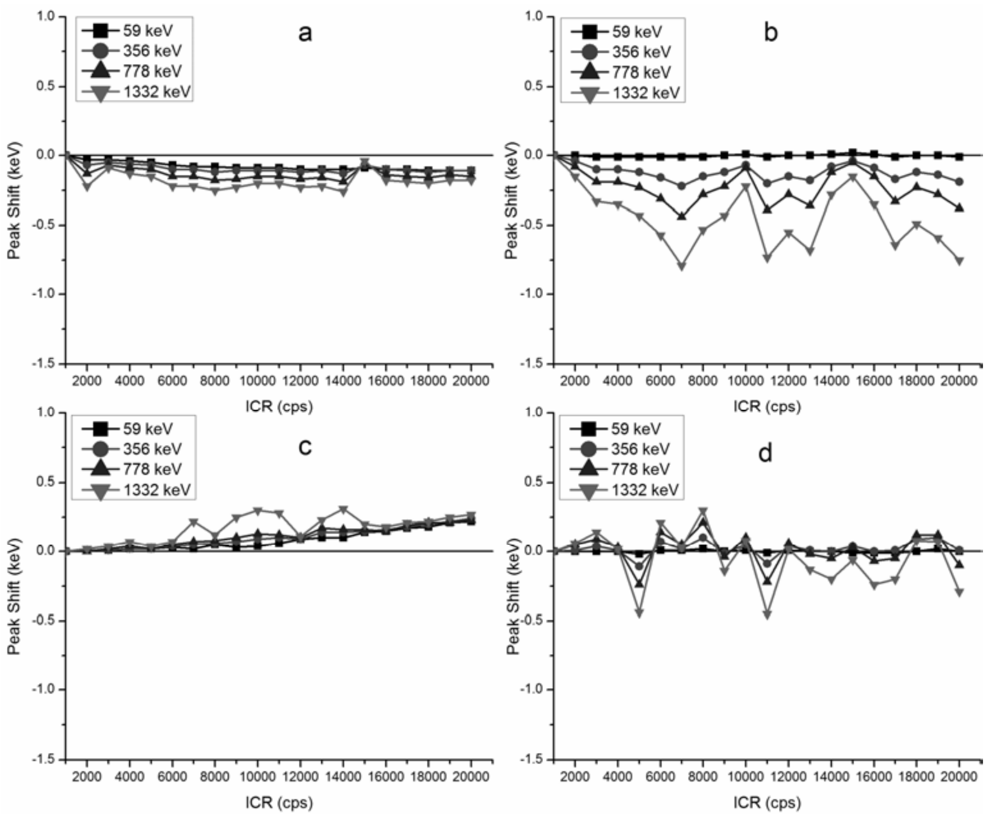

Fig. 1 – Peak shift for the throughput optimization. Panel a - 25GEM, Analog. Panel b -25GEM, Digital. Panel c - 60GEM, Analog. Panel d - 60GEM, Digital. See text for discussion.

Spectra analyzed from the digital spectrometer acquiring data through the 60GEM detector, presented in Fig. 1, panel d, showed fluctuating peak shifts that also seem to be energy dependent. The two graphs showing peak shifts for the digital spectrometer point to an empirical linear relationship between peak energy and peak shift. On the higher efficiency detector, the shifts in energy peak positions with ICR are significantly lower compared to the lower efficiency detector.

In the second set of measurements, acquisition parameters on both the analog system and the digital one were optimized for energy resolution. The peak shift scale was preserved from the previous plots in order to compare the amplitude of the peak position variations.

Spectra analyzed from the analog spectrometer acquiring data through the 25GEM detector, presented in Fig. 2, panel a, showed again a slight descending trend with increasing ICR for the position of all peaks. It can be concluded that using any of the two optimizations, a general characteristic for the analog spectrometer acquiring data through a small efficiency detector is the fact that the energy peaks shift to lower energies with increasing ICR.

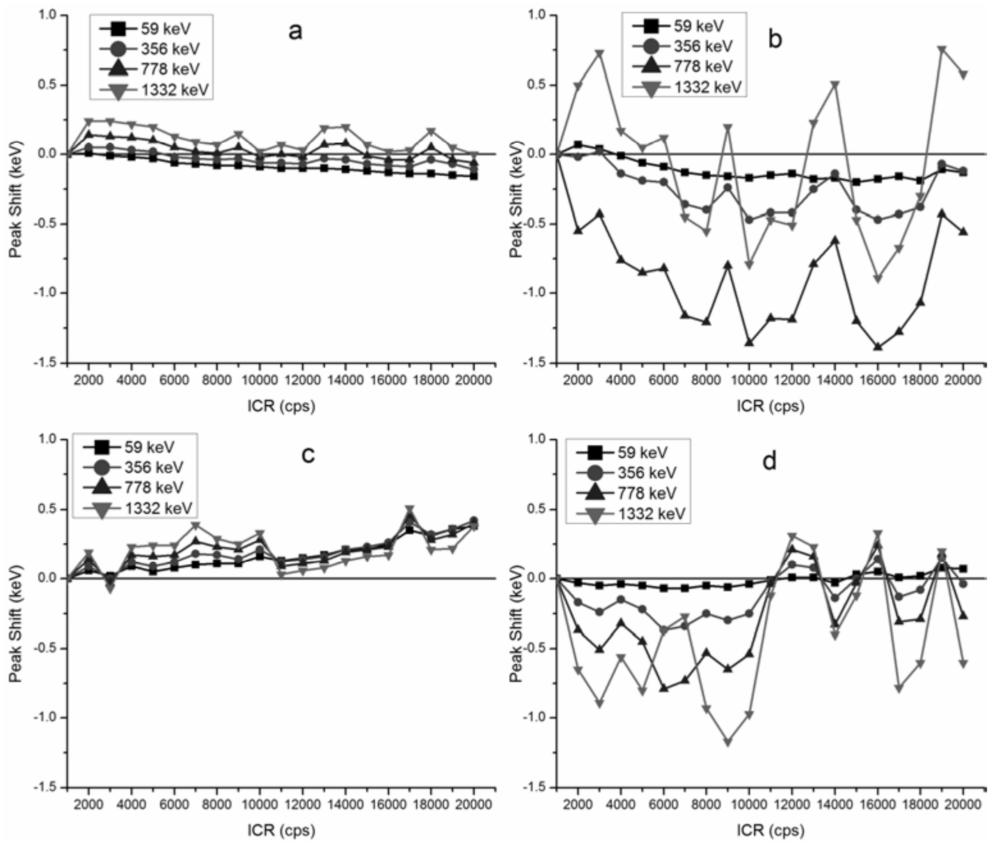

Fig. 2 – Peak shift for the energy resolution optimization. Panel a-25GEM, Analog. Panel b-25GEM, Digital. Panel c-60GEM, Analog. Panel d-60GEM, Digital. See text for discussion.

Spectra analyzed from the digital spectrometer acquiring data through the 25GEM detector, presented in Fig. 2, panel b, showed fluctuating peak shifts that also seem to be energy dependent. Here the peak shifts are larger than for the lower efficiency detector. The two graphs showing peak shifts for the digital spectrometer acquiring data through both detectors point to an empirical relationship between peak energy and peak shift.

Spectra analyzed from the analog spectrometer acquiring data through the 60GEM detector, presented in Fig. 2, panel c, showed a slight ascending trend with increasing ICR for the position of all peaks. It can be concluded that using any of the two optimizations, a general characteristic for the analog spectrometer acquiring data through a medium efficiency detector is the fact that the energy peaks shift to higher energies with increasing ICR. The lower energy shifts presented in this graph also point to the conclusion that for both optimizations, the analog spectrometer offers much better peak position stability compared to the digital one.

Spectra analyzed from the digital spectrometer acquiring data through the 60GEM detector, presented in Fig. 2, panel d, showed fluctuating peak shifts that also seem to be energy dependent. All data acquired through the digital spectrometer points to an empirical linear relationship between peak energy and peak shift for this device. It can also be concluded that for both optimizations, on the higher efficiency detector, the shifts in energy peak positions with ICR are significantly lower compared to the lower efficiency detector.

4. CONCLUSIONS

An experimental comparative study on ICR's effects on peak shift was done by using an analog and a digital spectrometer, each optimized in turn for energy resolution or throughput and two HPGe detectors of different efficiencies.

Small differences between the two optimizations have been observed in terms of effects on peak shift. Spectra acquired through the analog device presented energy peaks which were more stable in position with ICR compared to the ones acquired through the digital spectrometer. All data acquired through the digital spectrometer points to an empirical relationship between peak energy and peak shift in this case. The energy peaks in the spectra corresponding to the lower efficiency detector shift with ICR to lower energies while the ones corresponding to the higher efficiency detector shift with ICR to higher energies.

Further research will be conducted on the relationship between peak energy and peak shift in the spectra corresponding to the digital spectrometer. This relationship was found in the course of the experiments described in this paper.

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