Comparison of Analogue Setup and Semi-digital Setup for Doppler Broadening Spectroscopy

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1. Introduction

Doppler broadening spectroscopy (DBS) usually consists of a high-purity germanium (HPGe) detector and associated nuclear electronics for energy processing [1]. The developed fast digitizers have enabled new approaches to positron annihilation lifetime and Doppler broadening spectroscopies [2]. The most significant difference between digital and conventional analog processing is that the detector signal is directly sampled in real-time and stored in a computer. The sampled waveforms in the digital setup are analyzed offline using a suitable software procedure. It has several advantages compared to the analog configuration:

(1) The sampled detector signals are more accurate than analog configurations because of reducing random noises.
(2) The amount of recorded information is much higher than that of the analog configuration because of direct access to all detector signals.
(3) Data analysis can be repeated to obtain the necessary physical information and remove undesired distorted and damaged pulses.
(4) The time adjustment by analog NIM devices is not required anymore.

The influence of energy resolutions analyzed using the digital setup needs to be compared with the traditional analog configuration to apply the digital DBS. This study compared the energy resolution analyzed by the semi-digital configuration with the traditional analog setup.

2. Materials and Methods

In this experiment, the semi-digital and analog setups were measured using the HPGe detector (GEM HPGe Coaxial Detector, ORTEC). The analog and semi-digital setups are shown in Fig. 1. In the traditional analog setup, detector pulses were shaped in a spectroscopy amplifier (672, ORTEC), of which amplitudes were converted into numbers by an analog-to-digital converter/multi-channel analyzer (927, ORTEC). The shaping time of a spectroscopy amplifier was 2 μs. The energy per channel in the analog configuration was 0.561 keV/channel. The detector signals in the semi-digital configuration shaped from the spectrometer amplifier were sampled directly by a 12-bit digitizer (NKFADC500-4, NOTICE) with a sampling frequency of 500 MHz. The shaping time of the spectrometer amplifier in the semi-digital setup was the same as the analog configuration. The measurement of detector pulses in the semi-digital setup was performed using bipolar and unipolar modes. The unipolar mode was applied for the digital configuration as it allowed for the optimization of the pulse measurement. The bin width of the 12-bit digitizer was 0.610 keV/channels. A radioisotope of ^{137}Cs and ^{60}Co was used to measure the full width at half maximum (FWHM) of the full energy peak. The cumulative histogram of the primary pulse amplitude was calibrated using the known energies of the photopeak for ^{137}Cs (662 keV) and ^{60}Co (1174 keV and 1332 keV).

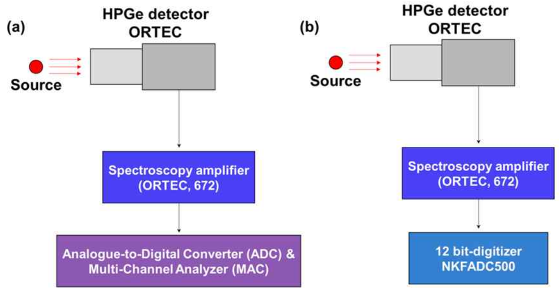

Fig. 1. Scheme of (a) traditional analog configuration for Doppler broadening spectroscopy (DBS) and (b) semi-digital configuration for DBS.

3. Results

The calibrated energy spectrum of semi-digital and analog configurations obtained using the bipolar mode is plotted in Fig. 2. Figure 2 shows that the annihilation peaks of the semi-digital and analog setup are located at the same energy point. Figure 3 shows the energy resolution (FWHM of photopeaks) at various energies obtained by traditional analog and semi-digital configurations. It is known that the width of full energy peaks is proportional to the square root of the energy absorbed in the detector [3]. The points in Fig. 3, plotted for analog and semi-digital configurations versus the square root of energy, are shown on straight lines. The energy resolutions analyzed using the semi-digital setup were broader than that measured by the traditional analog configuration under the same bipolar option. The extrapolated energy resolution of 662 keV in the bipolar mode was (2.61 ± 0.009) keV in the traditional analog configuration and (3.39 ± 0.004) keV in the semi-digital setup, respectively. However, the energy resolutions in the unipolar mode of the semi-digital setup were narrower than that in the bipolar choice of the analog configuration and improved by approximately 50%. The detector pulses obtained using the digital configuration of the unipolar mode can be optimized. Figure 4 shows the detector pulse measured using the semi-digital setup of the bipolar and unipolar modes. The extrapolated energy resolution of 662 keV in the unipolar option was (1.47 ± 0.013) keV in the semi-digital setup. Hence, employing the semi-digital technique using the unipolar option leads to an improvement in energy resolution. The semi-digital setup in the unipolar option can achieve improved energy resolution.

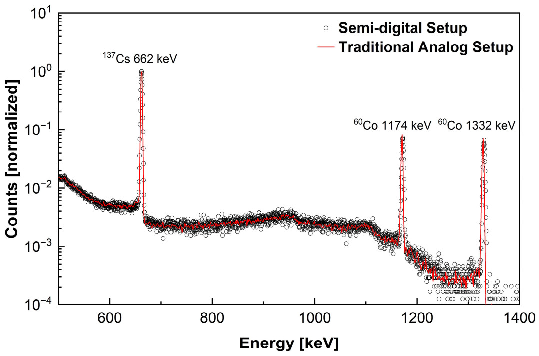

Fig. 2. Comparison of energy spectra obtained by the semi-digital and analog setups.

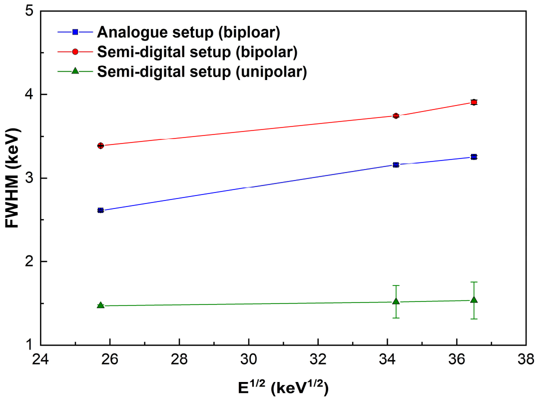

Fig. 3. The full width at half maximum (FWHM) of photo peaks measured in the tested configurations. FWHM of photo peaks produced by ^{137}Cs and ^{60}Co radioisotopes are plotted as a function of the square root of energy.

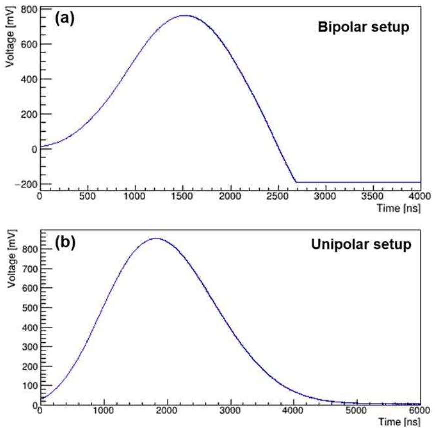

Fig. 4. Comparison of the detector pulse obtained using the digital configuration of the bipolar and unipolar modes. (a): Bipolar mode, (b): Unipolar mode.

3. Conclusions

This study confirmed improved energy resolution by comparing the semi-digital configuration with the analog setup. An improvement of approximately 50% in the energy resolutions of the semi-digital configuration can be achieved compared with that of the bipolar mode in the analog setup. Therefore, it was demonstrated that the semi-digital setup could achieve improved energy resolution than the analog configuration.

Acknowledgment

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