

MÖSSBAUER SPECTROSCOPY SETUP BASED ON PC SOUNDCARD

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1. Introduction

Mössbauer spectroscopy is a versatile technique that can give very precise information about the chemical, structural, magnetic and time-dependent properties of a material. Key to the success of the technique is the discovery of recoilless gamma ray emission and absorption, now referred to as the 'Mössbauer Effect', after its discoverer Rudolph Mössbauer, who first observed the effect in 1957 and received the Nobel Prize in Physics in 1961 for his work. Simple setup based on the computer soundcard is described in the following sections.

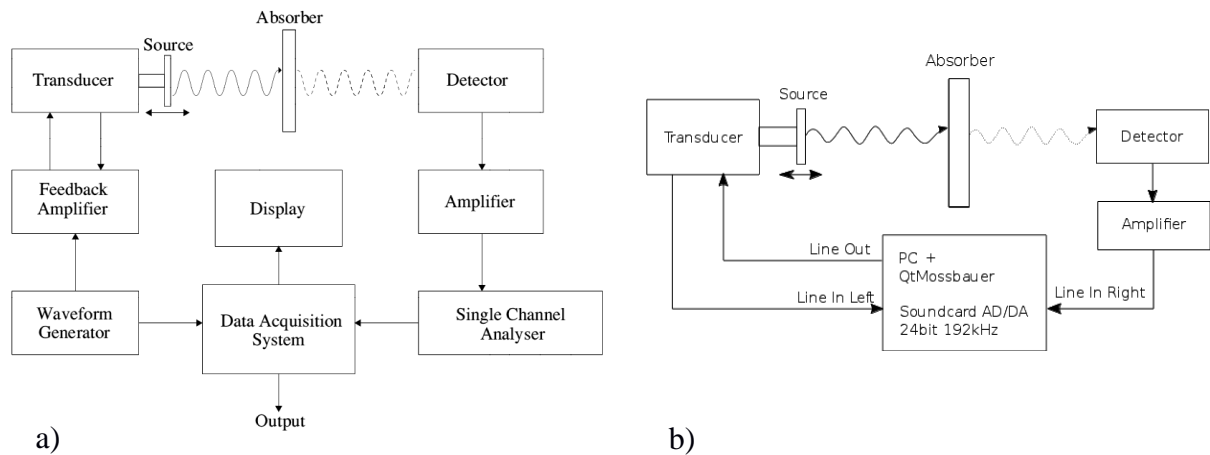


Fig.1: Block diagram of typical Mössbauer spectrometer(a) [1] and PC Soundcard based system (b).

2. Mössbauer setup

Typical Mössbauer spectrometer is based on modules shown in Fig.1a. In our setup *feedback amplifier, waveform generator, data acquisition system, single channel analyzer* were excluded and replaced by personal computer with soundcard and QtMössbauer software [10]. As a result, setup in Fig.1b was constructed and tested. The transducer is driven by soundcard *line out* signal. Loopback signal from transducer is digitized with *left line in* channel and at the same time, *right line in* channel from stereo soundcard input is used to digitize amplified detector signal. As a result, pickup transducer moving signal and detector signal are digitized at the same time. Digitized signal is shown in Fig. 2. Amplitude of individual digitized pulse is proportional to energy of the detected radiation and used to separate 14keV photons, which are used in Mössbauer spectroscopy. Pickup transducer signal

amplitude is also used in software proportional integral derivative regulator to get stable velocity changes.

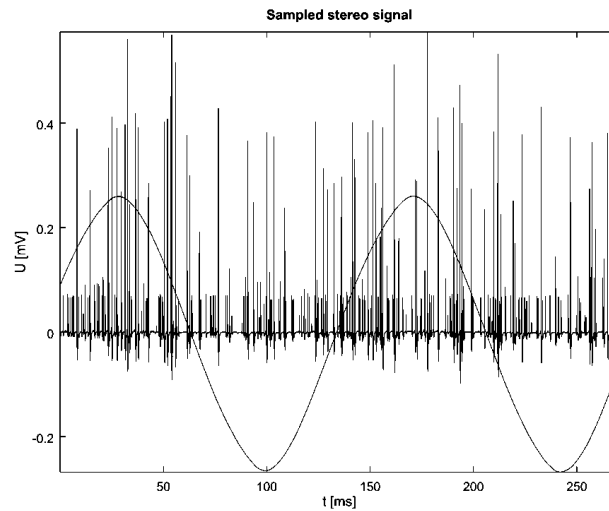


Fig.2: Digitized stereo signal by PC Soundcard: “sine” – pickup coil signal from transducer, “noise” – signal from gas detector

3. QtMössbauer software

To replace hardware modules, *QtMössbauer* software was developed. The software is written in C++, with using Qt [2] for graphical user interface, Qwt [3] for plotting graphs and PortAudio library [4] for soundcard manipulation. The software is multiplatform based, and tested under several platforms (Windows 7, 10, Ubuntu Linux, OSX, Rapsbian OS). Development was divided into several parts: signal generator, detector signal analyzer, and pickup signal analyzer.

2. Transducer signal generator

Signal generator based on PC sound card are used in audio measurement systems which are the parts of software’s like Daquarta [5], REW [6] written for this purpose. Our first test was based on connecting KFKI Mössbauer transducer to computer speaker output and running software signal generator. Soundcard sinus signal output without any external amplifier was sufficient to move transducer. Maximum amplitude of the movement and of the pickup signal using unchanged amplitude was observed when generator frequency around 6 Hz was chosen. This frequency is known as transducer own mechanical resonance frequency and is used as working frequency of the setup. Pickup signal from transducer was observed at the same time with soundcard based Laboratory Audio Analyzer DAA 5224 [7]. Standard bandwidth used by PC Soundcard is in audio area 20Hz – 20kHz. Lower limit of the soundcard bandwidth is higher as transducer resonance frequency, although transducer movement caused by signal from PC soundcard output was stable. On the other side, input signal digitized with soundcard ADC was suitable to get feedback signal to control and analyze transducer movement. In most Mössbauer equipment’s constant acceleration of the ^{57}Co source is used. Standard sound cards do not respond to or produce DC. In our case, it was impossible to obtain triangle signal on pickup coil with standard generator pulse shapes. For this reason, our velocity axis in our output spectrum is not linear and need to be recalculated by calibration on standard Fe samples.

3. PHA – pulse high analysis

The second significant task in constructing this setup was the analysis of signal from gas detector. To select events with energy of the gamma 14keV, pulse high spectrum is made from digitized pulses. There are software's [11] like *PRA*, *Theremino MCA*, *BecqMoni* realizing multichannel analyzer (MCA) for gamma spectroscopy based on computer soundcard, so it was already done to use them for pulse high analysis. In our case, own MCA algorithm was realized in *QtMössbauer* based on measuring difference between maximum and minimum value in differentiated digitized signal from detector. Differentiated signal (Fig.3) is calculated from digitized samples by following formula:

$$y[i] = x[i] - x[i - 1], \quad i > 0, \quad y[0] = 0, \quad i = 0 \quad (1)$$

Advance in using differentiated signal instead of original sampled signal is in removing DC component together with suppression of the pulse summation artifacts.

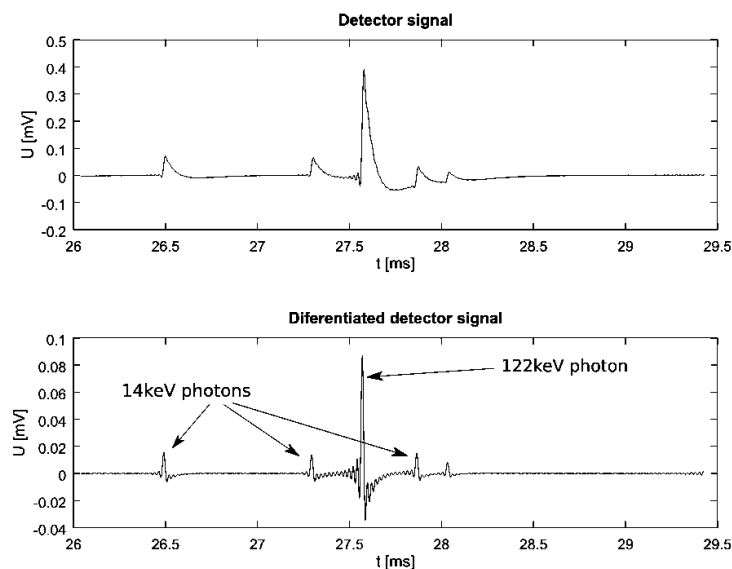


Fig. 3: Original and differentiated detector signal with DC = 0 and pileup suppression

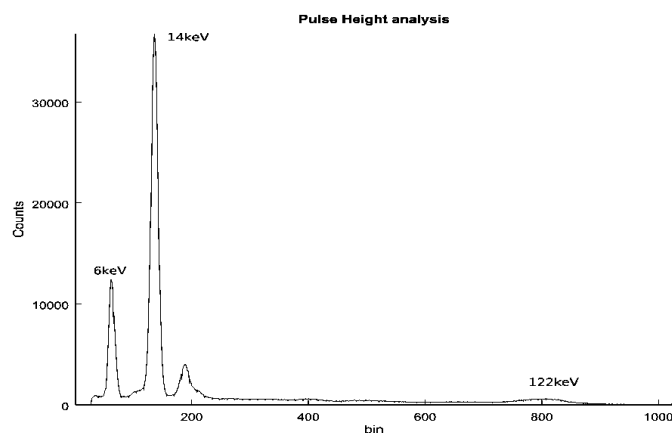


Fig. 4: Pulse high spectrum of the ^{57}Co isotope measured by Gas detector from differential signal digitised by PC soundcard.

4. Time extraction

From digitized differentiated signal information about exact pulse time is found from zero

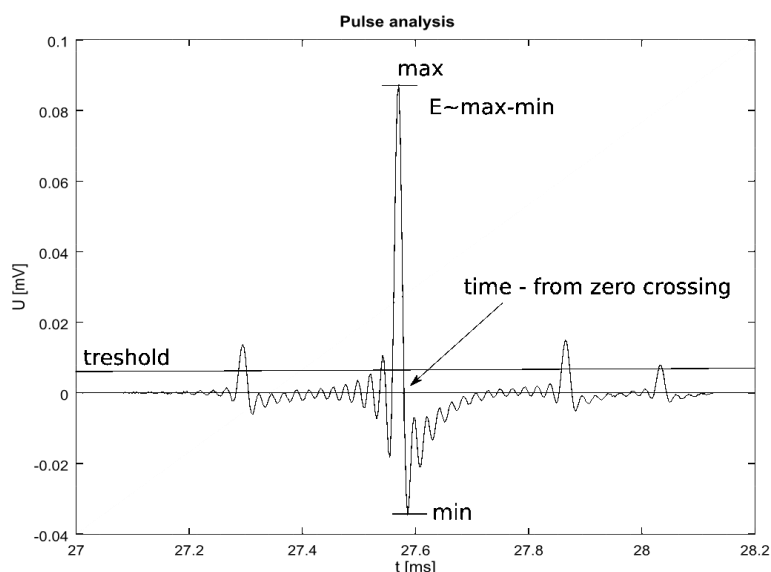


Fig. 5: *Obtaining energy and time information from digitised differentiated pulse*

crossing between maximum and minimum sample value in pulses.

5. Constructing Mössbauer spectra

To obtain Mössbauer spectra we need to know information about current velocity, when 14keV Gamma photon is detected. Time when 14keV photon is registered is extracted from zero crossing point in pulse (Fig.5). At the same time in second channel pickup signal is recorded. According to Lenz's law, induced voltage on pickup coil is proportional to transducer speed, but there is phase shift in recorded signal caused by binding capacitance in sound card. Therefore, constructing Mössbauer spectrum by counting 14keV pulses as function of measured current in pickup coil leads to folding spectra in wrong point (Same transducer speed is in two points in one period of moving). To prevent this problem, pickup signal was used to extract current phase of movement, and Mössbauer spectra was measured as function of current phase of movement. Phase was estimated from six zero crossings of the pickup sinusoidal signal. In this case, we get two unfolded spectra, one when transducer with ^{57}Co source is going towards to sample, and second when transducer is moving away from sample. Change in distance between detector and ^{57}Co is reflected in resulting spectra as background growth in first part, and background decrease in second half of the spectrum. In this case, the phase shift caused by binding reactance should be corrected by simple whole spectra shifting. Final spectra are made by folding in standard software used for Mössbauer spectroscopy spectra evaluation [9].

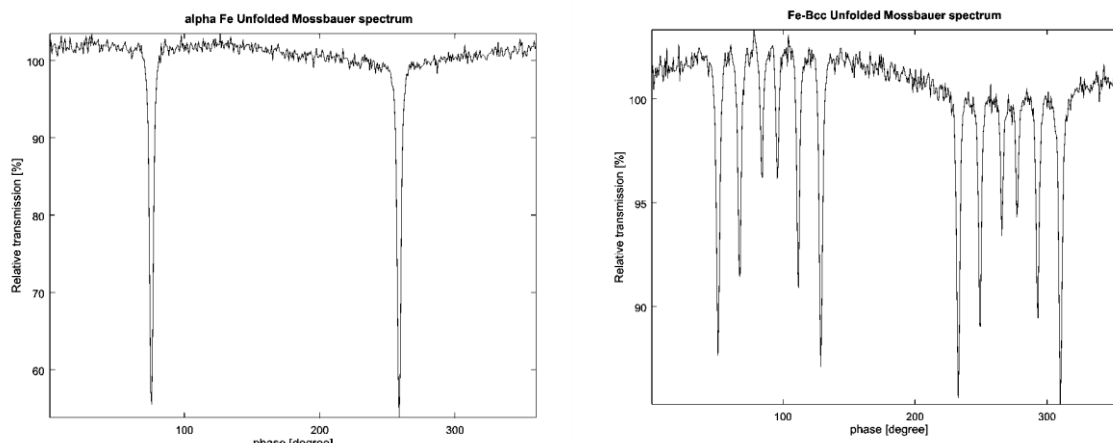


Fig. 6: Unfolded Mössbauer spectra of the calibration samples alpha-Fe and bcc -Fe, measured with PC soundcard spectrometer.

6. Results

To confirm setup functionality, standard calibration samples alpha-Fe and bcc-Fe were measured with constructed system. Obtained spectra has shape like spectra from obvious laboratory measurements, but from detailed analysis of the measured spectra (Fig.6), velocity nonlinearity was observed. To correct this nonlinearity, additional final spectra correction by polynomial linearization is needed or more investigation in transducer signal generation should be made. PC soundcard based generator give us freedom in generated shape of the signal, and this should be answer how to get over this obstacle.

Acknowledgement

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