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A PULSE SHAPE DISCRIMINATOR FOR MÖSSBAUER EFFECT MEASUREMENTS

A pulse shape discriminator composed of commercially available electronic blocks is described. It efficiently reduces the background produced in a proportional counter by high energy gamma rays. This is reflected in the form of an increase in magnitude of the Mössbauer effect and spectra quality parameter and consequently in an efficient reduction of the time interval of storing Mössbauer spectra.

1. Introduction

A proportional counter is frequently used in Mössbauer spectroscopy to detect low energy gamma rays or soft conversion *X*-rays. A Mössbauer source often emits also high energy gamma rays in addition to low energy ones. In such a case the pulse height spectrum obtained by a proportional counter is deformed in the low energy region due to the unwanted background produced in the detector by high energy gamma rays. The high energy gamma rays, while interacting with the counting gas and detector walls, produce energetic electrons by Compton and photoelectric processes. These energetic electrons deposit in the counting gas only a small part of their energy, usually up to several keV. The lengths of their ionization tracks are approximatelly comparable with the dimensions of the proportional counter. On the other hand the low energy gamma rays (soft *X*-rays) lose all their energy in the counter by producing photoelectrons. The ionization tracks of these photoelectrons are very small in comparison with those of energetic electrons from the high energy gamma rays. Although thd resultant output pulses from high energy gamma rays correspond in amplitude to output pulses from the low energy gamma rays (soft *X*-rays) they differ from each other in rise time. The rise time of output pulses from long ionization tracks (high energy gamma rays) is much slower than that from short ionization tracks (low energy gamma rays). This property of a proportional counter makes it possible to reject those pulses with slow rise times from the pulse height spectrum of slow energy gamma rays (soft *X*-rays) by the application of a pulse shape (rise time) discriminator. Efficient reduction of the unwanted background, which is produced in a proportional counter by high energy gamma rays, can be obtained by this method. This has already been demonstrated by others [1–5] who used pulse sahpe discriminators specially constructed for this purpose in their experiments.

In this paper we present the results of the application in Mössbauer effect measurements of a pulse shape discriminator composed of commercially available [6] electronic blocks.

2. Operation of the Pulse Shape Discriminator

The block diagram of a constant acceleration Mössbauer spectrometer equiped with the pulse shape discriminator is shown in Fig. 1. A standard Mössbauer spectrometer is composed of source driving units (Mössbauer transducer (MT), transducer driving unit (TDU), wave form generator (WFG), detecting and pulse registering units (proportional counter with high voltage supplyer (HVS), preamplifier (PA), amplifier (AFA), single channel (SCA) and multichannel (MCA) analyzers). The electronic blocks of which the pulse shape discriminator is composed are indicated by a dashed line.

In order to select detector pulses according to their rise times the output pulses from the charge sensitive preamplifier are fed to two separate channels; one is used for energy analysis (energy channel), and the other for pulse rise time analysis (time channel). In the energy channel the pulses are amplified by an active filter amplifier and fed to a single channel analyzer which selects pulses corresponding to the energy of gamma rays (soft conversion X-rays) used in Mössbauer effect investigations. In the time channel the pulses are amplified by the fast amplifier (FA) and fed simultanously to the constant fraction discriminator (CFD) and to the fast discriminator (FD). The time interval of pulse propagation through a constant fraction discriminator is practically independent of the pulse rise time and pulse amplitude. This is not so for a fast discriminator; a pulse with a slow rise time propagates slower than a simultaneous one with the same amplitude but a faster rise time. These properties of the constant fraction and fast discriminators enable one to make a pulse rise time selection by the application of a time-to-amplitude converter (TAC). The pulse from the constant fraction discriminator starts the time-to-amplitude converter which then is stopped by the corresponding pulse from the fast discriminator after being delayed by the nanosecond delaying line (NDL). The nanosecond delaying line is used in order to make the pulse from the fast discriminator arrive later than the corresponding one from the constant fraction discriminator. In the time channel the rise times of pulses from the preamplifier are converted to a pulse height spectrum. The single channel analyzer in the time channel selects the appropriate rise time pulses corresponding to the low energy gamma rays (soft conversion X-rays) used in the Mössbauer effect investigation. Apart from right pulses originating from radiation used in the investigation there are also false pulses (background pulses) accepted by the single channel analyzer of both the energy and time channels. They are efficiently eliminated by a slow coincidence circuit (CU) because most of the false pulses which fall into the energy channel are not in coincidence with those (different) false pulses which fall into the time channel. The pulses from the time channel are delayed by the microsecond delaying line (MDL) before they are put into coincidence with pulses of the energy channel.

If the pulses from the slow coincidence circuit are stored in the multichannel analyzer as a function of the source velocity, the Mössbauer spectrum of the sample under investigation is registered. The multichannel analyzer is operated in the time mode system when it is used as a part of the Mössbauer spectrometer. In order to reject background pulses from a given section of pulse height spectrum of the energy channel the pulses from the active filter amplifier have to be triggered by the pulses from the single channel analyzer of the time channel before being stored in the memory of the pulse height multichannel analyzer.

3. Results

The operation of the pulse shape discriminator was examined by comparing both the pulse heigh and Mössbauer effect spectra measured in the geometry of Fig. 1 with and without the use of the pulse shape discriminator. The 26.5 cm × 7.6 cm × 3.8 cm cuboidal type one wire proportional counter filled with 90% argon + 10% methane under 650 mm Hg

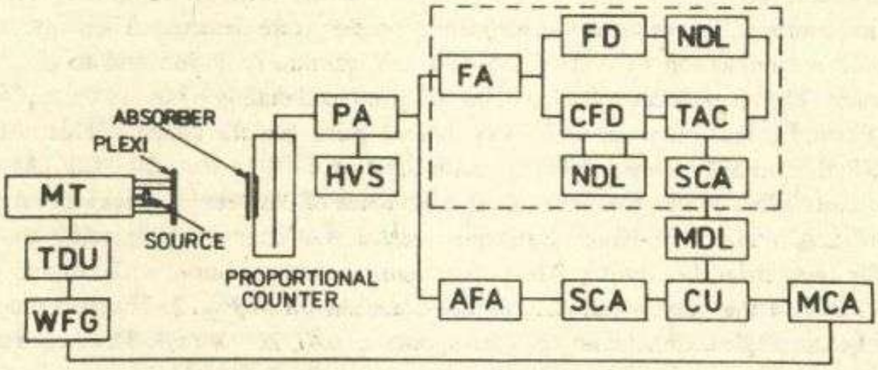

Fig. 1. The block diagram of the constant acceleration Mössbauer spectrometer equiped with the pulse shape discriminator.

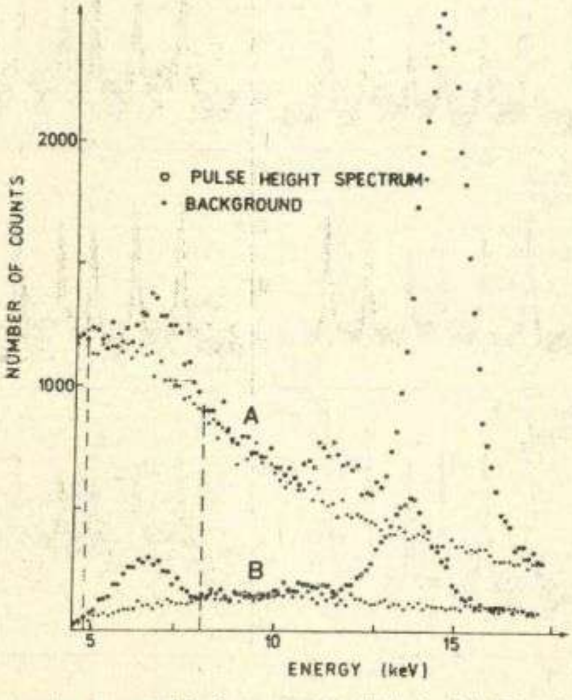

Fig. 2. The height pulse spectra measured in the geometry of Fig. 1 with (B) and without (A) the application of the pulse shape discriminator for the 12 cm of the source-counter separation. The background was determined with the 0.1 mm thick copper foil placed between the source and the counter. The dashed lines indicate the 6.47 keV X-ray energy channel.

pressure was used to detect both the 6.47 keV X-rays and the 14.4 keV gamma rays. The 2 mCi ^{57}Co(Cr) source was at rest when the pulse height spectra were measured, while it was moved with a constant acceleration when Mössbauer spectra were stored. A thin hematite sample 90% enriched with ^{57}Fe was placed directly on the 20 cm^2 beryllium window of the proportional counter. The 6.47 X-rays emitted by the source were absorbed by the 4.5 mm thick plexiglass plate placed between the source and the counter. Thus, only those 6.47 keV X-rays which were produced in the hematite sample by the photoabsorption and nuclear resonance absorption processes were detected. Their intensity was very small in comparison to that of the 14.4 keV gamma radiation and to the detector background. The large detector background was produced mainly by the 144 mCi ^{57}Co(Cr) source which, for that purpose, was always placed quite near the counter. This source was enclosed in the container whose walls were made of Al—Cu—Cd—Pb—Cd—Cu—Al layers in order to absorb low energy gamma rays. The influence of the detector background on both the pulse height and Mössbauer scattering spectra was changed by placing the 2 mCi source far away from the counter. The pulse height spectra measured with (B) and without (A) the usage of the pulse shape discriminator are shown in Fig. 2. The rise time region selected by the single channel analyzer corresponds to 6.47 keV X-rays. The large reduction

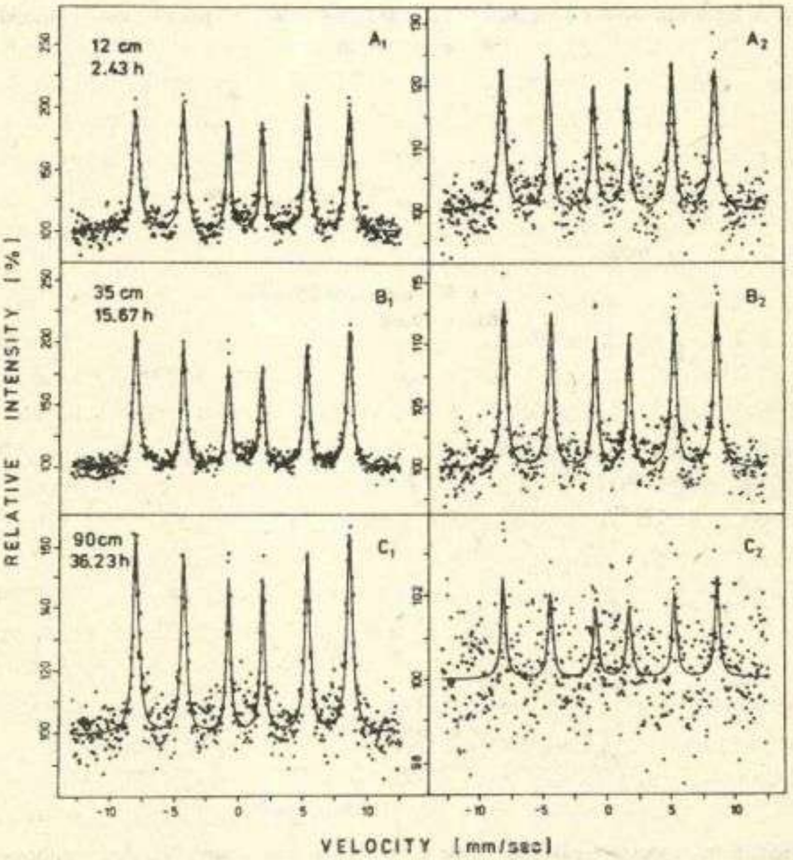

Fig. 3. The conversion X-ray Mössbauer scattering spectra of enriched hematite measured simultaneously with (A_1, B_1, C_1) and without (A_2, B_2, C_2) the application of the pulse shape discriminator. The spectra A, B and C correspond to the 12, 35 and 90 cm source-detector separations, respectively.

in the background in the 6.47 keV *X*-ray energy channel by the application of the pulse shape discriminator can be noticed. From the pulse height spectra the efficiencies of the background rejection and *X*-ray (gamma ray) acceptance were derived for our pulse shape discriminator. 95% of the background pulses falling into the 6.47 keV *X*-ray channel was eliminated with the loss of only 26% of the *X*-ray signals. Similar results were obtained for the 14.4 keV gamma ray selection.

The conversion *X*-ray Mössbauer scattering spectra of enriched hematite measured simultaneously with (A_1, B_1 and C_1) and without (A_2, B_2 and C_2) the application of the pulse shape discriminator are shown in Fig. 3.

The quality of the Mössbauer line can be described by the line quality parameter $Q = |[N(\infty)-N(V_r)]|/[\sqrt{N(\infty)}+\sqrt{N(V_r)}]$, where $N(V_r)$ and $N(\infty)$ are the numbers of counts at resonance and at far from resonance velocities, respectively. The improvement in the quality of the Mössbauer scattering spectra due to the application of the pulse shape discriminator is clearly seen from Fig. 3 and Table 1. The increase in the quality parame-

Table 1. The off-resonance numbers of counts per channel $N(\infty)$, the amplitudes of Mössbauer lines A, the magnitudes of Mössbauer effect ε and the line quality parameters Q of the first, second and third Zeeman lines of conversion X-ray scattering spectra measured at a room temperature, with and without the application of the pulse shape discriminator (PSD), for the 90% enriched hematite sample at 12 cm, 35 cm and 90 cm source-detector separations.

		12 cm*		35 cm		90 cm	
		with PSD	without PSD	with PSD	without PSD	with PSD	without PSD
	$N(\infty)$	192	1035	464	5487	296	11795
first Zeeman line	A	189	236	514	737	191	292
	ε	98	23	111	13	65	2.5
	Q	5.66	3.48	9.73	4.82	4.86	1.34
second Zeeman line	A	197	247	456	685	172	244
	ε	103	24	98	12	58	2.1
	Q	5.87	3.63	8.79	4.49	4.43	1.12
third Zeeman line	A	163	200	377	580	148	202
	ε	85	19	81	11	50	1.7
	Q	4.99	2.97	7.46	3.82	3.87	0.93
storage time (%) of Mössbauer spectra of $Q_{\text{with}} = Q_{\text{without}}$		37.0	100	25.6	100	6.5	100
average value of the ratio $Q_{\text{with}}/Q_{\text{without}}$		1.64		1.97		3.92	

* For the 12 cm source-detector separation the geometric effects [7] caused broadening of Mössbauer lines.

ters of the first Zeeman lines of the A_2, B_2 and C_2 spectra (Fig. 3) by the factors of 1.64, 1.97 and 3.92, respectively, was obtained. The storage time interval for the Mössbauer line is proportional to the square of the desired line quality parameters. Thus, in order to store a Mössbauer line C_1 (Fig. 3) without the usage of the pulse shape discriminator with the same quality parameter as that obtained for line C_2 with the application of the pulse shape discriminator one has to increase time interval of the measurement the by the factor of

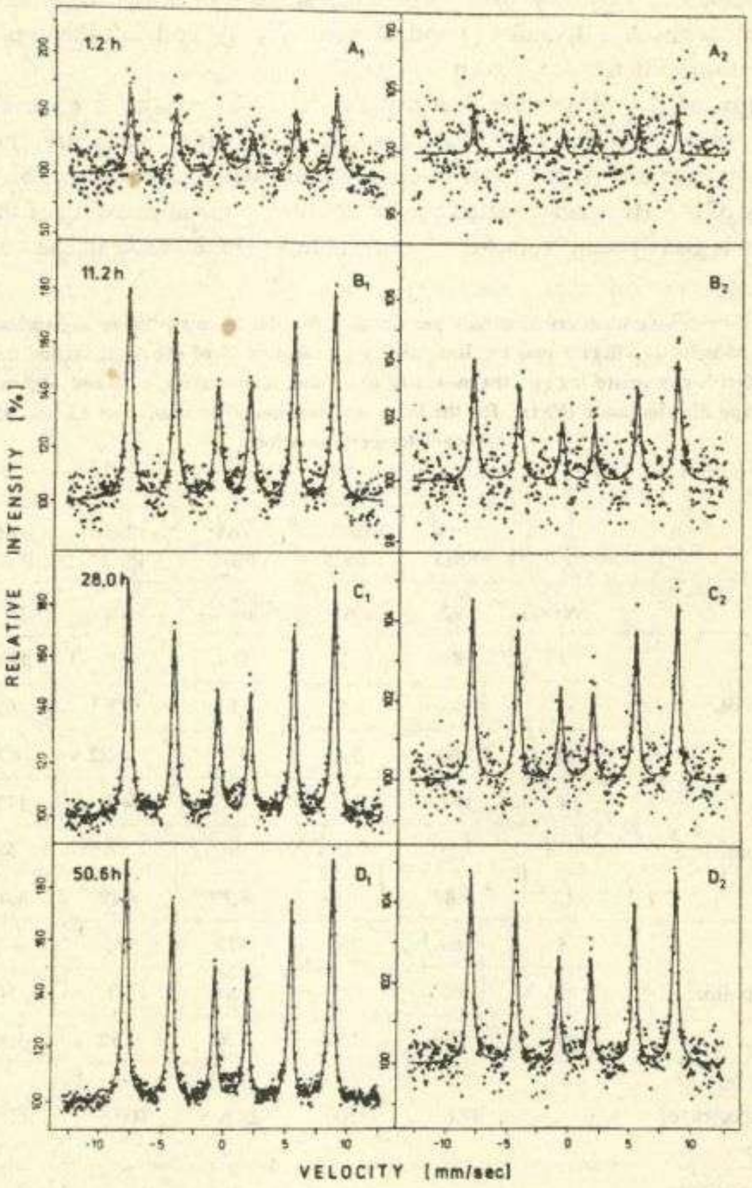

Fig. 4. The conversion *X*-ray Mössbauer scattering spectra of ^{57}Fe hematite measured simultaneously with (A_1, B_1, C_1, D_1) and without (A_2, B_2, C_2, D_2) the application of the pulse shape discriminator. The spectra A_1, B_1, C_1 and D_1 (A_2, B_2, C_2 and D_2) were stored for 1.2, 11.2, 28 and 50.6 hours, respectively.

15.4. The reduction of time intervals for storing Mössbauer scattering spectra by the application of the pulse shape discriminator may be quite a large.

The improvement in the quality of the Mössbauer spectra due to the application of the pulse shape discriminator is also seen from Fig. 4, where conversion X-ray Mössbauer scattering spectra of enriched hematite stored for 1.2, 11.2, 28.0 and 50.6 hours with and without the usage of the pulse shape discriminator are presented. The values of line quality parameters of the A_2, B_2, C_2 and D_2 spectra are by the factor 3.1 larger as compared to those of the A_1, B_1, C_1 and D_1 spectra, respectively. This corresponds to reduction in the storage time interval of Mössbauer spectra by the factor 9.6.

The pulse shape discriminator was also used in measuring the 14.4 keV gamma ray Mössbauer scattering spectra for a 0.016 mm thick metallic iron foil 95.15% enriched with ^{57}Fe. The ordinary scattering geometry with a 90° scattering angle was used in this experiment. The detector background to be rejected was produced only by the 7.6 mCi ^{57}Co(Cr) source used in the experiment. The improvement in the line quality parameter by the factor 1.44 was obtained by the application of the pulse shape discriminator. This corresponds to the reduction in the storage time interval by the factor 2.

The application of the pulse shape discriminator described in this paper enabled us to observe [8] a triple Mössbauer resonance.

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ДИСКРИМИНАТОР ФОРМЫ ИМПУЛЬСОВ ДЛЯ МЕССБАУЄРОВСКИХ ИЗМЕРЕНИИ

Резюме

В работе описана схема дискриминатора формы импульсов от пропорционального счетчика. Схема состоит из промышленно изготовленых электронных блоков.

Применение этой схемы позволяет значительно уменьшить фон, походящий от высокоэнергетических гамма квантов, одновременно усилить величину эффекта мессбауэра и параметр качества линии, а также сократить время сьёмки спектров резонансного гамма поглощения.

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DYSKRYMINATOR KSZTAŁTU IMPULSÓW DLA POMIARÓW MÖSSBAUEROWSKICH

Streszczenie

W pracy opisano dyskryminator kształtu impulsów elektronicznych złożony z bloków Camac dostępnych w handlu. Dyskryminator pozwala na znaczną redukcję tła wytworzonego w liczniku proporcjonalnym przez wysokoenergetyczne kwanty gamma. Uwidacznia się to we wzroście efektu Mössbauera i parametru jakości linii oraz w znacznym skróceniu czasu pomiaru widm mössbauerowskich.