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Measurement of Energy Spectrum by Nuclear γ-Resonance Analyzer

Ro Chun Hwan, Kim Jin Guk

In the past we considered the Mossbauer effect using spectrum analyzer, but we never mentioned the nuclear spectrum data and only considered about property of the Mossbauer analyzer based on 8 channel differential discriminator [1].

We carry out the measurement experiment of energy spectrum of standard γ-sources and low energy γ-sources by the nuclear resonance analyzer based on the 8 channel differential discriminator and confirmed that it can be used in both energy spectrum and Mossbauer spectrum measurement.

1. The Energy Spectrum Measurement of Standard γ-Sources

We measured energy spectrum by means of the standard γ-sources ^{137}Cs and ^{60}Co in order to evaluate an energy analisation property by nuclear γ-resonance analyzer that we investigated and manufactured. Scintillation detector based on NaI scintillator and photo amplifier "ФЭУ-93" as the detector was used and high voltage of −1 300V was given to the cathode of its detector.

We set up the amplifying coefficient of the linear amplifier as 3 and conducted the experiment for 5min. on 256 channels and the result was shown at Fig. 1, Fig. 2.

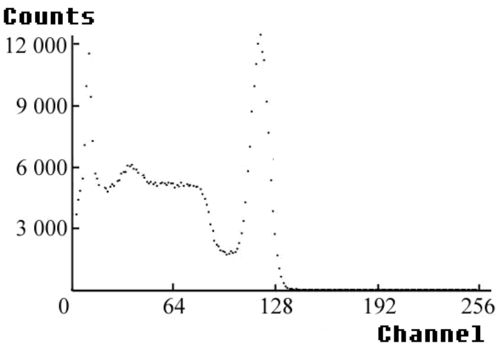

Fig. 1. γ-ray spectrum of ^{137}Cs

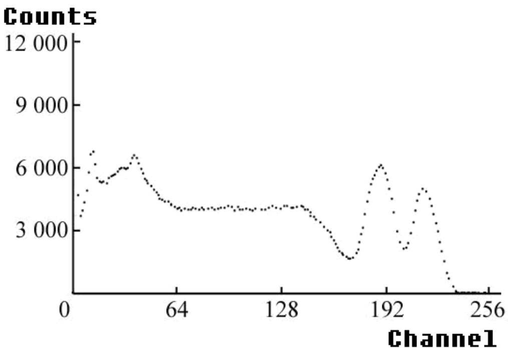

Fig. 2. γ-ray spectrum of ^{60}Co

As shown in the Fig. 1, 2, the results coincided with the standard spectrum. The position of the whole absorption picks and the corresponding energy and channel-energy coefficients are shown in the Table 1.

Table 1. The whole absorption picks and the corresponding energy and channel-energy coefficients

Source	Energy/keV	Channel	Coefficient	Counts
^{137}Cs	662	107	6.186	14 405
^{60}Co	1 170	189	6.190	6 147
	1 330	213	6.244	5 568

The result of calculation of the mean coefficient from table1 is as follows.

$$\bar{k} = \frac{\sum_{i=1}^{3} k_i}{3} = 6.206$$

The integral non-linearity(%) is

$$\eta_{\text{int}} = \left(1 - \frac{k}{\bar{k}}\right)_{\max} \cdot 100 \approx 0.6$$

For the determination of the resolving power, we separate the whole absorption pick of ^{137}Cs from spectrum and considered it as Gaussian distribution. Here, we caught 5 points and drew $n - \ln Q(n)$ line and determined the position of the pick to be the cross of that line and the axis of channel.

Then n_0 =107.20 channel and a half width is as follows.

$$\Delta n_{1/2} = 2\sigma\sqrt{\ln 2} \approx 9.86$$

From that, the resolution is

$$\eta = \frac{9.86}{107.2} \cdot 100 \approx 9.19$$

2. The Energy Spectrum Measurement of Low Energy γ - Sources

The energy range of Mossbauer isotopes is generally below 150keV. So in order to measure Messbauer spectrum it is necessary to measure γ -ray of low energy. In experiment we measured spectrum of ^{241}Am (17.8, 26.3, 59.5keV), ^{239}Pu (53keV) and ^{57}Co (14.4, 122, 136keV) as low energy sources and analyzed it. We used scintillation detector based on 1.0mm NaI (Tl) scintillator and photomultiple tube “ФЭУ-93” as low energy γ -ray. We set the Be window of 0.1mm for the reduction of γ -ray at detector windows and in order to reduce absorption of the γ -ray into source self we used disk form ^{239}Pu, ^{241}Am source of thickness 1.5, 2.0mm and thin ^{57}Co source of mass width 20mmg/cm^2 that was made by absorption of $CoCl_2$(^{57}Co 17.3%) solution into filter paper. The radioactivity of used ^{241}Am, ^{239}Pu, ^{57}Co sources are respectively $3.8 \cdot 10^9$, $5 \cdot 10^6$, $6 \cdot 10^7$ Bq.

Energy spectrum of ^{241}Am measured in 5min is as Fig. 3.

Energy spectrum of ^{239}Pu measured for 20min in the same condition is as Fig. 4.

Energy spectrum of ^{57}Co measured for 2min in the same condition is as Fig. 5.

As shown in the Fig. 3－5, three picks of 17.8, 26.3, 59.5keV was separated obviously on ^{241}Am and one pick of 53keV on γ -ray spectrum of ^{239}Pu was observed.

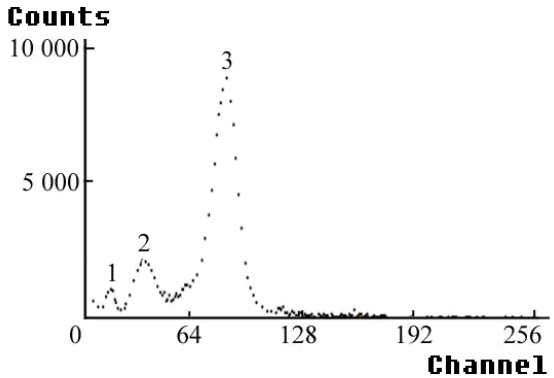

Fig.3. γ -ray spectrum of ^{241}Am

1－ $E_\gamma = 17.8$keV,2- $E_\gamma = 26.3$keV,3- $E_\gamma = 59.5$keV

In the mean time, two picks of 14.4keV and 122keV were detected but two picks of 122keV and 136keV were not detected. This is because the resolution of the detector is not high. Energy difference of 122keV and 136keV is small and relative intensity (91%) of 122KeV ray is much bigger than relative intensity(9%) of 136KeV ray.

The relation between the whole obtained absorption pick and energy is shown in Table 2.

Table 2. The relation of the position of the whole absorption pick and the energy

Energy/keV	Channel
14.4	21
17.8	26
26.3	38
53.0	77
59.5	87
122.0	178

On the minimal square method, we made scaling on the basis of measurement value.

$$E_i = a \cdot n_i + b$$

$$a = \frac{n\sum n_i \cdot E_i - \sum n_i \sum E_i}{n\sum n_i^2 - \left(\sum n_i\right)^2} \approx 0.685$$

$$b = \frac{\sum n_i^2 \cdot \sum E_i - \sum n_i \sum n_i E_i}{n\sum n_i^2 - \left(\sum n_i\right)^2} \approx -0.367$$

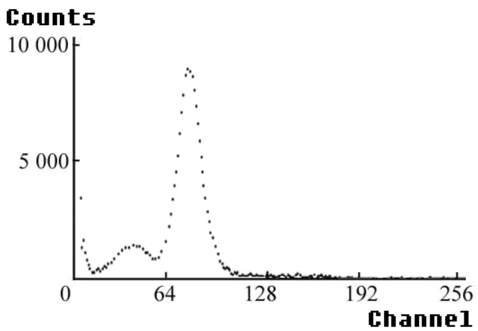

Fig 4. γ -energy spectrum of ^{239}Pu

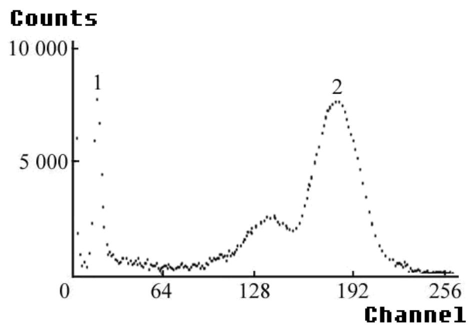

Fig 5. γ -energy spectrum of ^{57}Co

1, 2; $E_\gamma = 14.4$, 122keV

That is

$$E_i = 0.685 n_i - 0.367$$

Based on this, we determined the integral non-linearity(%)

$$\eta_{\text{in}} = \left(1 - \frac{k}{\bar{k}}\right)_{\max} \approx 2.61.$$

This shows that the integral non-linearity of thin scintillator of 1.0mm thickness is a little bigger at low energy band than in the thick scintillator.

Conclusion

We confirmed that the nuclear γ-resonance analyzer can be used as a nuclear spectrum analyzer by evaluating γ-spectrum property of some standard γ-ray sources by means of the nuclear γ-resonance analyzer.

We also confirmed that this device can be used in Mossbauer spectrum and nuclear spectrum measurement by taking measurement of the energy spectrum of several low energy γ-sources and analyzing the result.

Reference

[1] **김일성**종합대학학보(자연과학), 54, 7, 84, 주체97(2008).