NUKLEONIKA—VOL. 21—No. 11-12/76

Józef J. Bara, Zbigniew M. Stadnik

Institute of Physics, Jagiellonian University, Cracow

AUTOMATIC MÖSSBAUER POLARIMETER

The paper describes the automatic Mössbauer polarimeter in which the linear velocity of the source and the angle of analyzer rotation is changed step-by-step in a programmed manner.

The utilization of polarized gamma rays in Mössbauer spectroscopy considerably expands the research potentialities of this method. It results from the fact that in polarized Mössbauer spectra one has to take into consideration not only the energetic matching of appropriate source and absorber lines but also the matching of their polarizations. Using polarized gamma rays unique directional information on hyperfine interactions in solids can be obtained, such as the orientation of the principal axis of the electric field gradient and the spin orientation of the magnetic atoms [1, 2]. Furthermore, it is possible to determine the magnetic structure of different materials [3, 4], the sign of the internal magnetic field [5, 6], to study texture problems [7], magneto-"optical" effects (Faraday effect [8, 9], magnetic double refraction [10, 11]) as well as to test the time-reversal invariance [12].

In most cases the Mössbauer effect polarization experiments have been performed with 14.4 keV gamma rays of ^{57}Fe.

There are three methods used to produce the linearly polarized 14.4 keV gamma rays:

1. The source in the form of ^{57}Co embedded in a magnetic material, e.g. iron metal, magnetized perpendicularly to the direction of gamma ray propagation, emits six totally linearly polarized lines with intensity ratios 3:4:1:1:4:3. Lines corresponding to $\Delta m = \pm 1$ transitions are polarized parallel with respect to magnetization and $\Delta m = 0$ lines are perpendicularly polarized.

2. The source of ^{57}Co embedded in a paramagnetic single crystal with the axially symmetric electric field gradient emits in the direction perpendicular to the V_{zz} axis two linearly polarized lines. The line corresponding to the transition from the $m = \pm 3/2$ state is totally polarized parallel to the V_{zz} axis and that from $m = \pm 1/2$ state is partly polarized. To produce a single polarized line a special filter has to be used to absorb the unwanted second line [13].

3. Using the selective absorption of one plane polarized component of non-polarized gamma rays (dichroism) one can obtain partial linear polarization of the transmitted gamma beam.

The Mössbauer effect polarization experiments may be performed with specially designed Mössbauer polarimeters. A Mössbauer polarimeter is very similar in nature to an optical polarimeter. It consists of a gamma ray source, polarizer, transmitter, analyzer and detector. The iron metal foils magnetized perpendicularly to the direction of gamma ray propagation may be used as a polarizer and an analyzer. In some experiments the transmitter containing ^{57}Fe atoms and used as a sample to be studied is placed between the polarizer and the analyzer. A transverse or longitudinal external magnetic field with respect to the direction of the gamma ray propagation is applied to the transmitter in magnetic double refraction or Faraday effect experiments, respectively. The transmitter is not used when the source or the polarizer or the analyzer is a sample to be studied. To perform a polarization experiment one has to bring into resonance the gamma ray transitions in the source, the polarizer (if used), the transmitter (if used) and the analyzer. To do it the Doppler energy shift, commonly used in Mössbauer spectroscopy, may be applied to the source and sometimes to the transmitter. The samples need not be magnetized when single crystals or polycrystalline materials with magnetic texture are used. The angle ω between the directions of magnetization of the source (or polarizer if used) and the analyzer can be changed step-by-step or continuously and the pulses due to the Mössbauer line investigated are registered in scalers or a multichannel analyzer operating in the time mode, respectively. The count rate $R(\omega)$ measured behind the analyzer depends on the angle ω. It can be described by a sinusoidal function known as a Malus curve [14]: $R(\omega) = R_0 - R_1 \cos(2\omega + 2\varphi)$, where R_0 is the background due to non-resonant and non-rotating circulary polarized components, R_1 is the amplitude of the Malus curve and φ is the angle of rotation of the gamma ray polarization plane caused by the transmitter.

In the Mössbauer polarimeter described here the polarized gamma ray source or the polarizer with non-polarized gamma ray source may be used. The polarimeter was con-

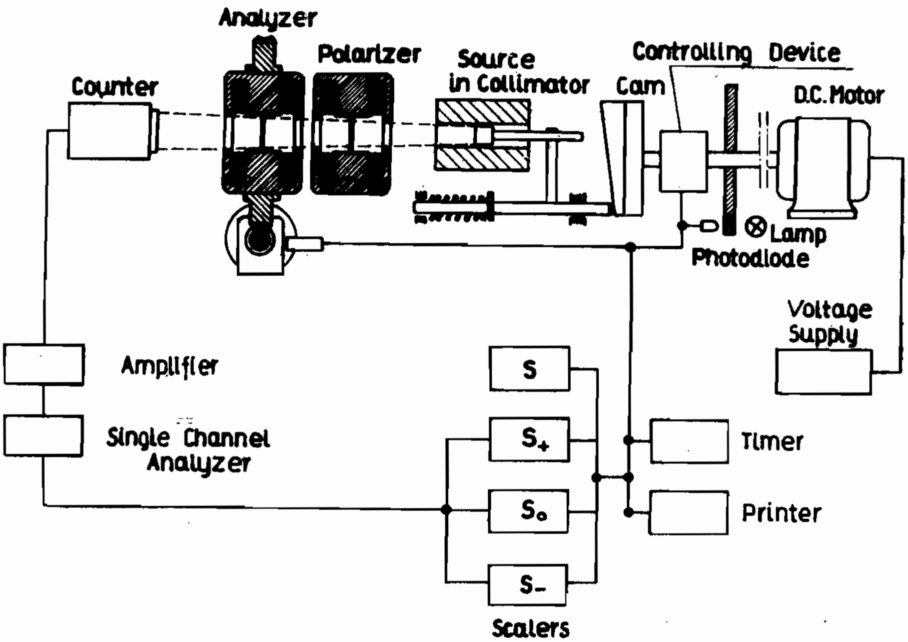

Fig. 1. Diagram of the Mössbauer polarimeter

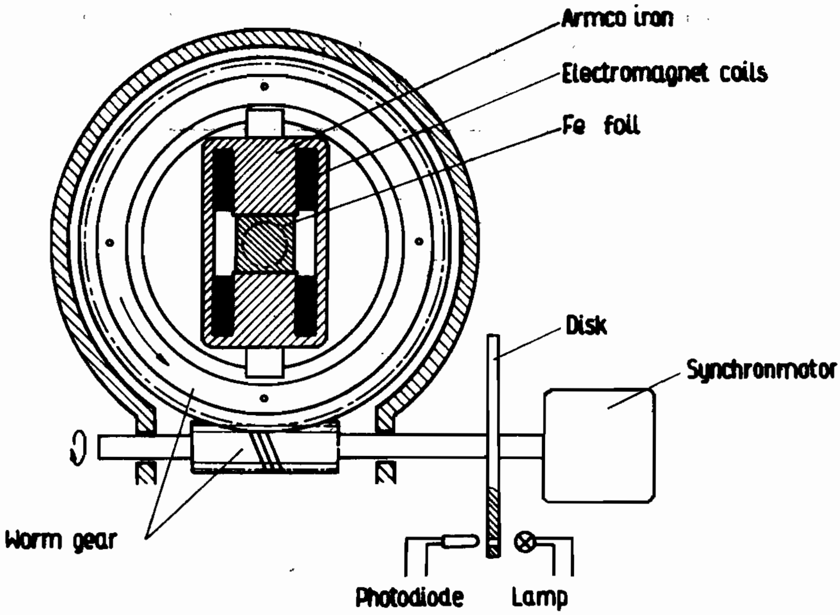

Fig. 2. Diagram of the rotational drive with closed magnetic circuit

structed on the basis of the automatic mechanical Mössbauer spectrometer [15] and is shown schematically in Fig. 1. Fig. 2 shows the closed magnetic circuit of the analyzer attached to its rotational drive. The Mössbauer polarimeter can be programmed to perform automatically one of the two following operations:

1. Measurements of the gamma ray transmission through the polarizer (is used) and the analyzer at a given constant source velocity as a function of angle ω.

2. Measurements of the absorption spectrum at a given velocity range for a given angle ω which can be changed step-by-step in a programmed manner.

The polarimeter enables separate measurements of gamma ray transmission through the polarizer (if used) and the analyzer for plus, minus and zero velocity. The zero transmission counting rates are used for normalization, which eliminates the error caused by slow drifting of parameters of the electronic circuits. In the first type of Mössbauer polarimeter operation the non-uniformity of the source motion can produce a small error in the counting rate. This error can be considerably diminished in the second type of operation in which polarization information is derived from the area under the absorption line. The Doppler constant velocity shift of the source is provided by uniform rotation of precisely machined linear cam. The polarizer is at rest, whereas the analyzer is revolved every two degrees by means of a worm gear with a transmission factor of 1:180. The revolution is controlled externally. Pulses created in the counter after amplification are selected by a single channel analyzer and registered at equal time intervals τ in scalers S_+, S_0 and S_- according to plus, zero and minus velocity of the source. To calculate the exact value of the actual velocity of the source the number of revolutions of the cam at time τ is registered in the scaler S. All these scalers are operated by the controlling device which works synchronously with the rotation of the cam. Scalers S_+, S_0 and S_- are blocked for short time intervals when the velocity changes from plus to zero, zero to minus and minus to plus. When the controlling device is switched on it waits for a pulse from the photodiode which is created only at those mements when the velocity is changed from minus to plus. The controlling device,

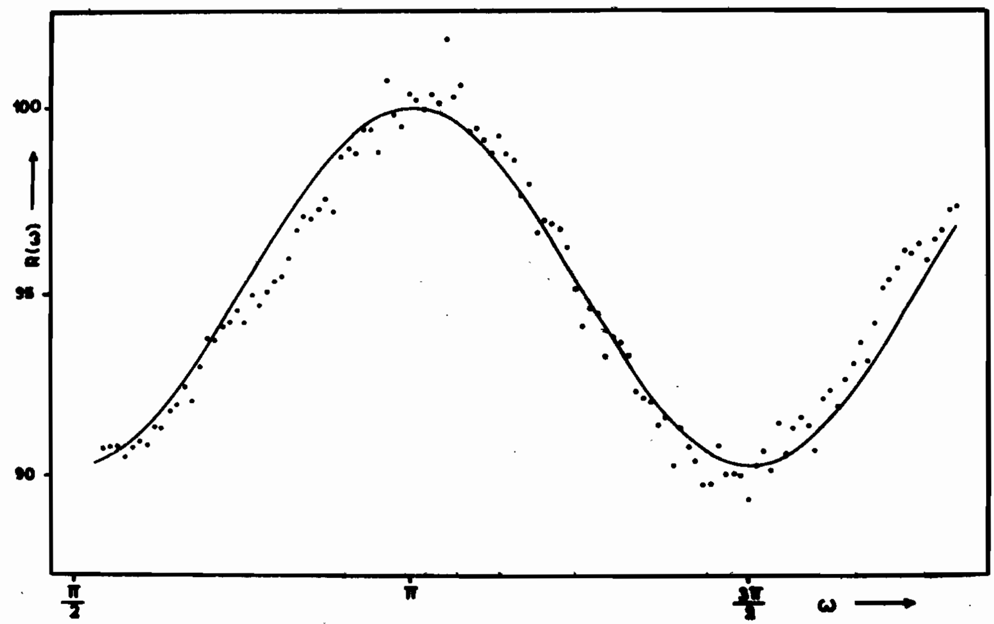

Fig. 3. Malus curve for the case when the source line is on-resonance with the fifth absorption line of the polarizer and the analyzer

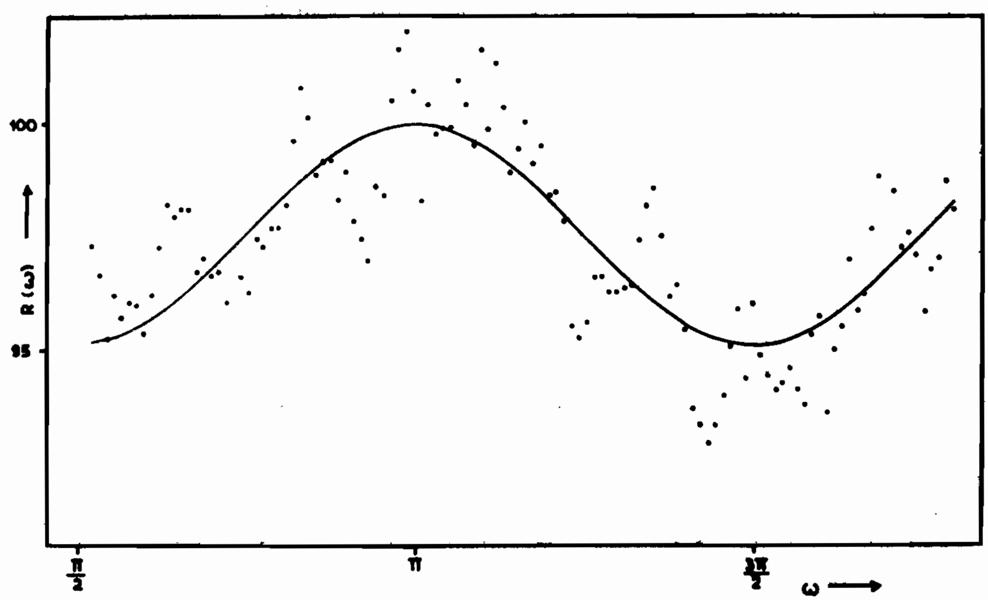

Fig. 4. Malus curve for the case when the source line is about 1.3 Γ_{nat} off-resonance with the second absorption line of the polarizer and the analyzer

after receving a pulse from the photodiode, begins to operate scalers S_+, S_0, S_- and S. After the exact time programmed for one point of measurement, a pulse from the timer arrives at the controlling device and opens the gate for a pulse from the photodiode. After the arrival of this pulse, the controlling device blocks the timer and all scalers, changes the angle ω for a given source velocity in the first type of operation (or vice versa in the second type) and starts the printer. When printing is completed the scalers and the timer are reset, the controlling device obtains a pulse from the photodiode and a new run of measurements begins.

The polarimeter was calibrated with the 25 mCi $^{57}Co(Cr)$ source, and 1.87 mg/cm² (92.8% ^{57}Fe) and 1.83 mg/cm² (90.6% ^{57}Fe) iron metal foils were used as the polarizer and the analyzer, respectively. The polarizer and analyzer were placed in specially designed closed magnetic circuits (Fig. 2). This type of circuit gives a negligible scattered magnetic field outside. The calibration curves are shown in Figs. 3 and 4. For the plus velocity the emission gamma line from the source was brought into resonance with the fifth absorption line of the polarizer and the analyzer, whereas for the minus velocity it was about 1.3 Γ_{nat} off-resonance with the second absorption line. The Malus curves were fitted by a least square computer program in which CERN library subroutine was used [16].

Received 4 June 1976

REFERENCES

1. U. Gonser, R. W. Grant: *Phys. Stat. Sol.*, **21**, 331 (1967).
2. T. C. Gibb: *J. Phys.*, **8C**, 229 (1975).
3. U. Gonser, R. W. Grant, H. Wiederserich, S. Geller: *Appl. Phys. Letters*, **9**, 18 (1966).
4. R. W. Grant: *J. Appl. Phys.*, **42**, 1619 (1971).
5. N. Blum, L. Grodzins: *Phys. Rev.*, **136A**, 133 (1964).
6. P. Reivari: *Phys. Rev. Letters*, **22**, 167 (1969).
7. E. Kreber, U. Gonser: *Nucl. Instrum. Meth.*, **121**, 17 (1974).
8. P. Imbert: *Phys. Letters*, **8**, 95 (1964).
9. R. M. Housley, U. Gonser: *Phys. Rev.*, **171**, 480 (1968).
10. P. Imbert: *J. Physique*, **27**, 429 (1966).
11. U. Gonser: Hyperfine Structure and Nuclear Radiations (North-Holland Publ. Co., Amsterdam, 1968), p. 343.
12. E. Zech, F. Wagner, H. J. Körner, P. Kienle: Hyperfine Structure and Nuclear Radiations (North-Holland Publ. Co., Amsterdam, 1968), p. 314.
13. R. M. Housley: *Nucl. Instrum. Meth.*, **62**, 321 (1968).
14. H. D. Pfannes, U. Gonser: *Nucl. Instrum. Meth.*, **114**, 297 (1974).
15. J. Bara, M. Janicki: *Nukleonika*, **XI**, 517 (1966).
16. F. James, M. Roos: CERN Library, subroutine Minuits, D506.

J. J. Bara, Z. M. Stadnik

AUTOMATYCZNY POLARYMETR MÖSSBAUEROWSKI

Streszczenie

Opisano automatyczny polarymetr mössbauerowski, w którym liniowa prędkość źródła i kąt obrotu analizatora są zmieniane skokowo w sposób programowany.

Ю. Ю. Бара, З. М. Стадник

АВТОМАТИЧЕСКИЙ МЕССБАУЭРОВСКИЙ ПОЛЯРИМЕТР

Резюме

В этой работе описывается автоматический мессбауэровский поляриметр, в котором програмированным образом меняются скочком линейная скорость источника и угол обращения анализатора.