Mössbauer Spectrometer Using an Electromechanical Transducer in Conjunction with a Multichannel Pulse-Height Analyzer

Rintaro KATANO*

(Shimizu Laboratory)

Received August 20, 1966

Some details of Mössbauer spectrometer using an electromechanical transducer as a constant acceleration driving device and a time-to-pulse-height converter in conjunction with a multichannel pulse-height analyzer are described. The motion of a moving part of the transducer on which a recoilless gamma-ray source is mounted is maintained in triangular velocity waveform by applying a motional feedback to the transducer. The linearity of the vibrating system for a triangular velocity waveform is achieved better than 0.8% during 80% of the half-period.

I. INTRODUCTION

The basic principle of the Mössbauer effect study is to observe the resonance absorption of nuclear gamma rays in solids. The primary rays used in this study are the nuclear gamma rays emitted by the recoil-free emission and endued with the Doppler energy shift to some extent by the application of an adequate vibration mechanism to the gamma-ray source or absorber. An essential feature of the Mössbauer effect apparatus is to measure the absorption of the recoilless gamma rays as a function of the Doppler velocity of the gamma-ray source. Many devices have so far been reported, however, these may be classified into two schemes; one using only a unit of single-channel pulse-height analyzer with the fixed channel widths measures the gamma-ray spectrum as a function of the source velocity and the other using a multichannel pulse-height analyzer to record the whole spectrum automatically. In the former method[1], one can measure fairly accurately the gamma rays transmitted through the absorber for the selected Doppler velocities of which values can also be determined exactly, while the method with the use of a multichannel analyzer[2-4] has an advantage to measure easily and rapidly the whole absorption spectrum for adequate range of the shifting velocity of the gamma-ray source. In the latter method, in general, employing the constant acceleration mode, a multichannel analyzer is used to sort and store the counting data by assigning an increment of velocity to each channel. In some spectrometers of this type, a time analyzer logic connected with the multichannel analyzer has recently been adopted[5].

The spectrometer reported here has not such a time analyzer logic but contains a time-to-pulse-height converter with a saw-toothed wave generator

* 片野林太郎

and as a vibration mechanism is used an electromechanical transducer[6] with a constant acceleration driving amplifier. Since by this spectrometer the observed Mössbauer spectrum is independent on the mode of vibration, sinusoidal or parabolic drive, a flat no-absorption spectrum can be obtained. The present paper describes some details of our Mössbauer spectrometer now being used successfully in our Laboratory.

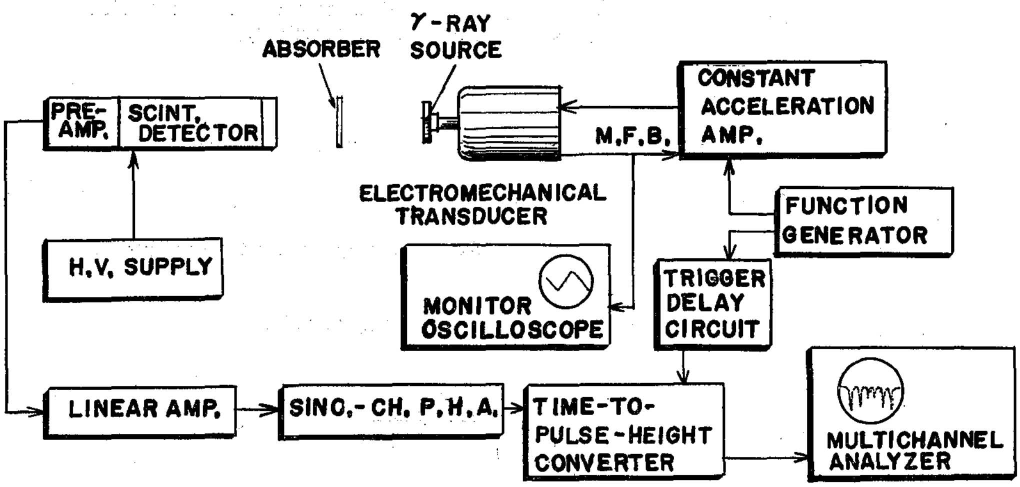


Fig. 1. Block diagram of the Mössbauer spectrometer.

II. OUTLINE OF APPARATUS

The block diagram of our Mössbauer spectrometer is shown in Fig. 1. The gamma-ray source is moved in constant acceleration mode by mounting it at the moving part of an electromechanical transducer driven by a motional feedback arrangement of a constant acceleration driving amplifier fed with a triangular function generator. The outputs of the gamma-ray scintillation detector are fed to the time-to-pulse-height converter through a conventional single-channel analyzer, which is used to select only the pulses corresponding to photon energies concerned with the Mössbauer absorption. The time-to-pulse-height converter serves to make the pulses from the single-channel analyzer proportional to the velocity by modulation using the saw-toothed wave. The output pulses from this converter are then fed to a multichannel pulse-height analyzer to observe the absorption spectrum. The saw-toothed wave is ignited by a trigger pulse which is supplied from the function generator through an appropriate delay circuit. The waveforms at some part of the spectrometer are shown in Fig. 2.

III. CONSTANT ACCELERATION UNIT

As shown in Figs. 3 and 4, the constant acceleration unit consists of an electromechanical transducer and constant acceleration driving amplifier. The triangular wave from the function generator is made parabolic by an integrator[7] using V_{101a}, and then after a one-stage amplification by V_{102a} this parabolic wave passes into a phase inverter V_{102b}, which drives a push-pull stage V_{103} con-

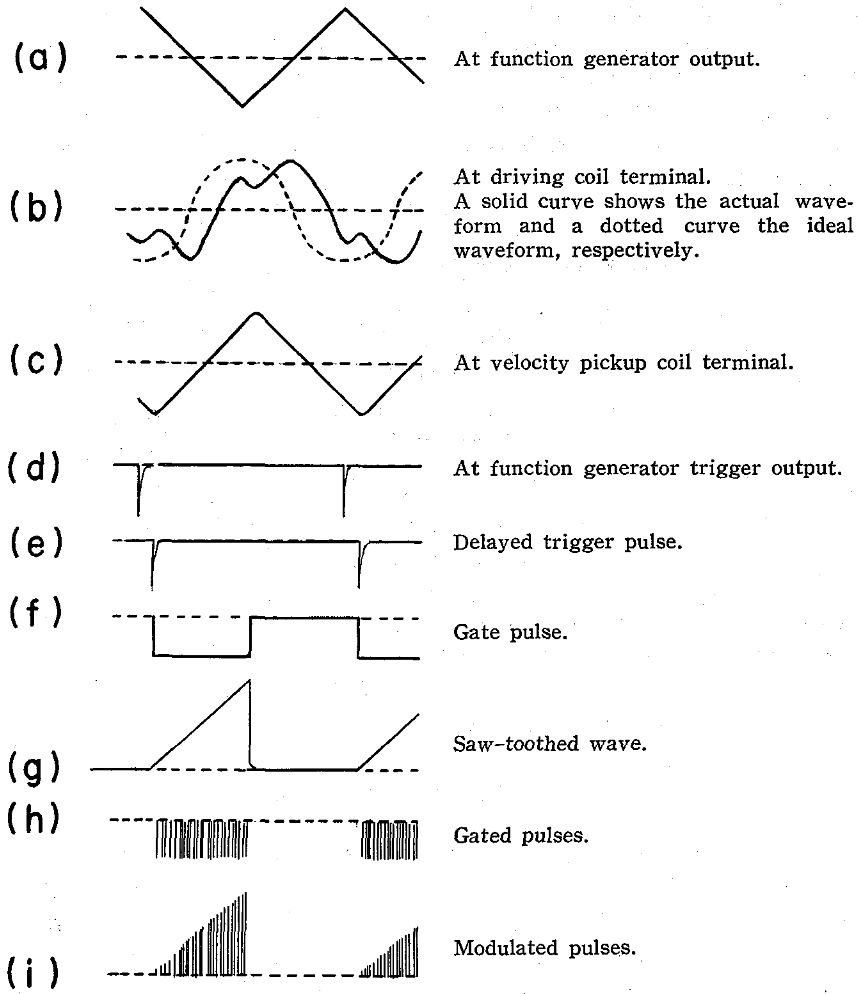


Fig. 2. Waveforms at some parts of the spectrometer.

nected to a transducer through an output transformer of 8 kΩ : 8 Ω. From the secondary side of this transformer the negative feedback is applied to a cathode of V_{102a}.

The construction of the electromechanical transducer used successfully is shown in Fig. 5. As shown in the figure, a driving coil of d.c. resistance 5 Ω and pickup coil of 270 Ω are inserted into the magnetic fields of a parmanent magnet, respectively. Both coils are attached to a central axis, whose ends are held by plate springs of circular shape. The moving axis can be vibrated at the maximum amplitude of ± 1.5 mm by this mechanism. Sensitivity of the pickup coil is 21 mV/cm/sec and its output is amplified by V_{101b} and then fed back to the integrator circuit. The output of the pickup coil can also be used to observe the vibration characteristics of the transducer. The adjustment of the vibration velocity is performed by changing the amplitude under a constant frequency. The maximum velocity of the present vibration has been adjusted to cover the whole range of

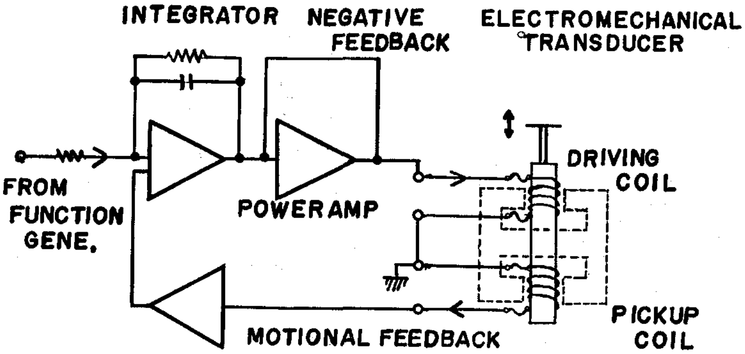


Fig. 3. Block diagram of the constant acceleration unit.

the absorption spectrum with a ^{57}Fe source as to be ± 8 mm/sec, but it can be easily varied at will by changing the amplitude and delay, while the vibration frequency is chosen to be 35 Hz in accordance with the resonance frequency of the whole vibration system. Stability of the amplitude is achieved by two feedback devices and by maintaining carefully the stability of the voltage stabilized power supply.

The velocity linearity of the moving part of the transducer may be achieved theoretically by supplying the palabolic waves into the driving coil. However, in the practical case, owing to mass of the vibration system of the transducer and damping force of the plate springs holding the moving axis, integrator constants and amount of the motional feedback had to be adjusted carefully so as to make the output waveform from the velocity pickup coil to be triangular. In our apparatus, therefore, the observed wave being applied to the driving coil is quitely different from the parabolic form, as shown in Fig. 2-(b). By this device the linearity of the vibrating system is achieved better than 0.8% during 80% of the

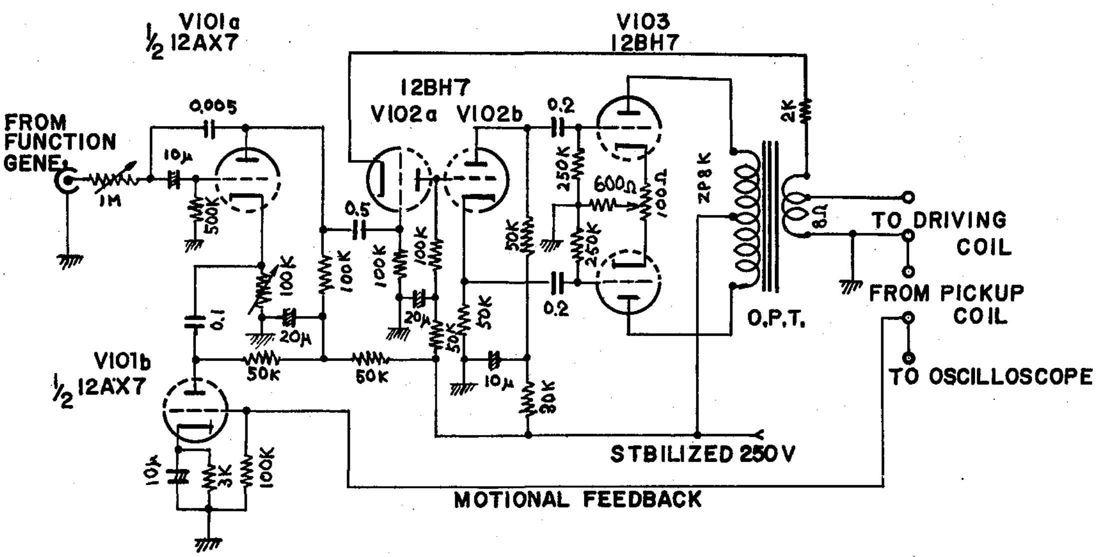
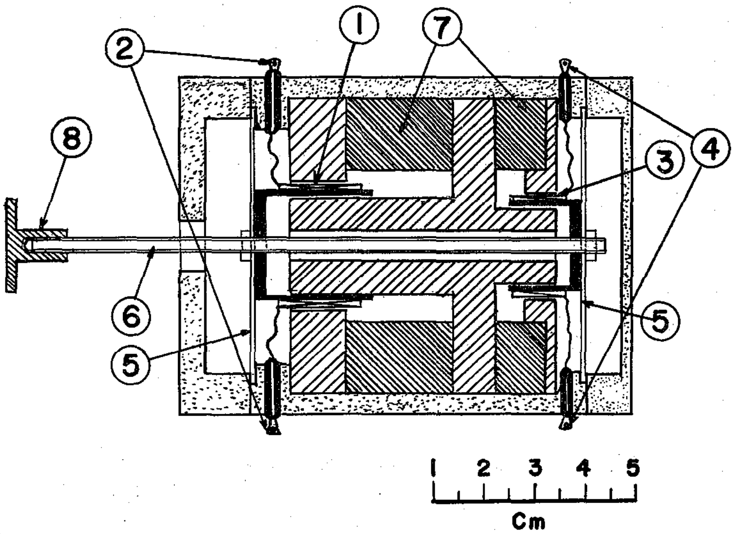


Fig. 4. Circuit of the constant acceleration driving amplifier.



① driving coil
② driving coil terminals
③ velocity pickup coil
④ velocity pickup coil terminals
⑤ suspension springs
⑥ central axis
⑦ permanent magnet
⑧ gamma-ray source holder

Fig. 5. Details of the electromechanical transducer.

half-period.

IV. TIME-TO-PULSE-HEIGHT CONVERTER UNIT

The output pulses of a single-channel analyzer must be converted to the pulses proportional to the corresponding Doppler velocities of the gamma-ray source and then fed to a multichannel analyzer. For this purpose a circuit unit

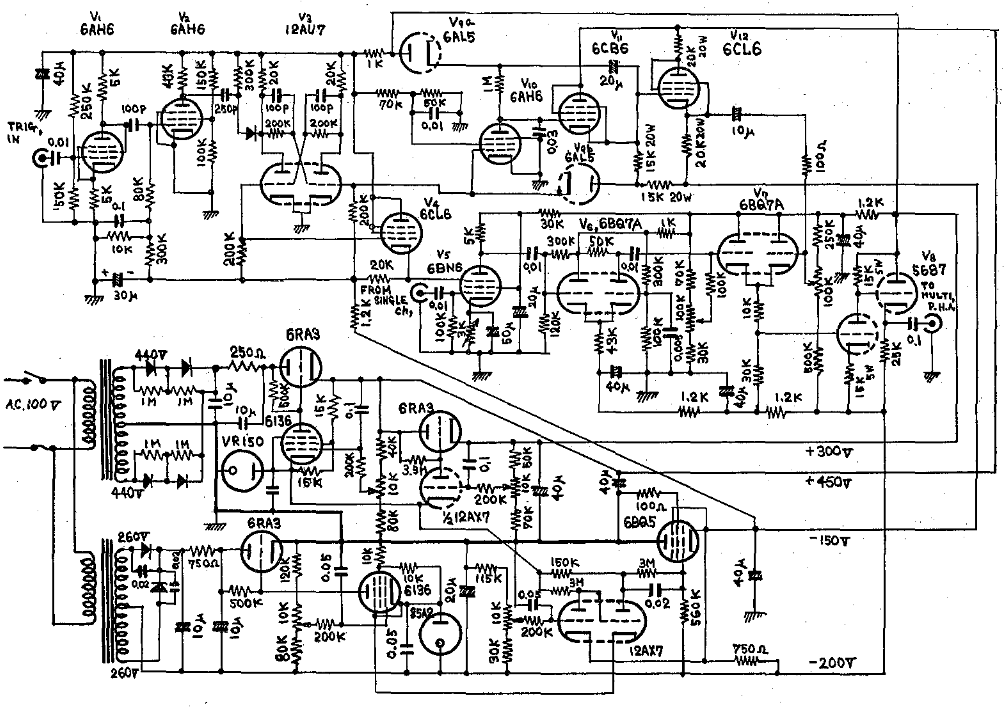


Fig. 6.

called *time-to-pulse-height converter* is used.

The converter we designed is composed of a gate pulse generator, saw-toothed wave generator and modulation circuit, which are all connected to an extremely stabilized power supply. As shown in Fig. 6, the pulse from the single-channel analyzer is fed to a gate tube V_5 followed by V_6 and then modulated by the saw-toothed wave using V_7. The output pulse of a cathode follower V_8 is used as the input pulse to the multichannel analyzer. On the other hand, synchronizm between the saw-toothed wave and mechanical motion is maintained by a trigger pulse from a function generator. In this case, the trigger pulse is delayed adequately in order to fit the position of the resonance absorption in the favorable channel of the multichannel analyzer when we observe the resonance absorption spectrum. This adjustment is achieved by changing the time constant of the monostable multivibrator shown in Fig. 7.

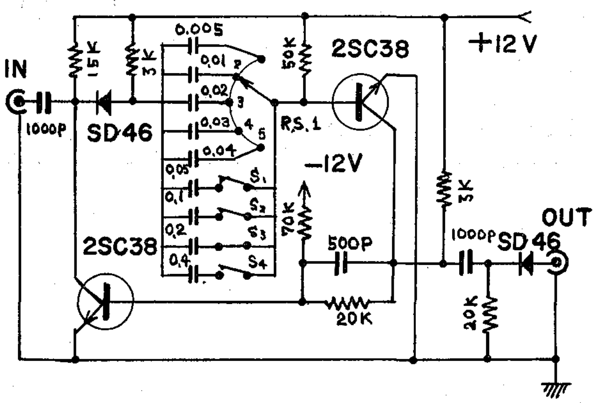


Fig. 7. Trigger delay circuit of monostable multivibrator type.

The delayed trigger pulse goes through V_1 and V_2 and reverses the state of a bistable multivibrator V_3 used as the gate pulse generator to generate the gate pulse. The sweep of the saw-toothed wave is kept during this gate pulse is continuing and the gate tube V_5 is being opened. Returning to the initial state is initiated when the linear sweep of the saw-toothed wave reached the pre-fixed value by detecting the voltage at the dividing point in the cathode resistance of V_{11}. The gradient of the saw-toothed wave is determined by the capacitor connected to the first grid of V_{11}. In the present design, this capacity was selected as to be 0.03 μF. Modulation adjustment by V_7 is accomplished by adjusting its grid-bias voltage; modulated pulses obtained by the present circuit is shown in Fig. 2-(i). The modulated pulse can be obtained from the cathode follower V_8. In our circuit, the peak voltage of this output pulse was about 40 V, which was sufficient to operate even an old-fashioned multichannel analyzer using the vacuum tubes. The final adjustment is performed by controlling the input gain and lower level of the multichannel analyzer so that the pulses from the time-to-pulse-height converter can be accumulated in the whole range of the channels.

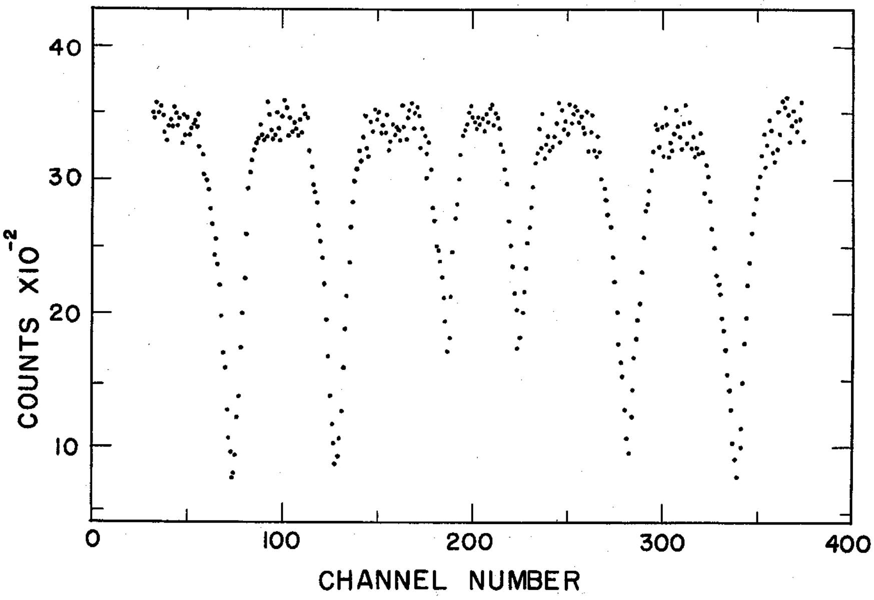


Fig. 8. Mössbauer spectrum of ^{57}Fe in an iron foil (90% enriched ^{57}Fe and 2 mg/cm^2 thick) with a source of ^{57}Co embedded in Cu.

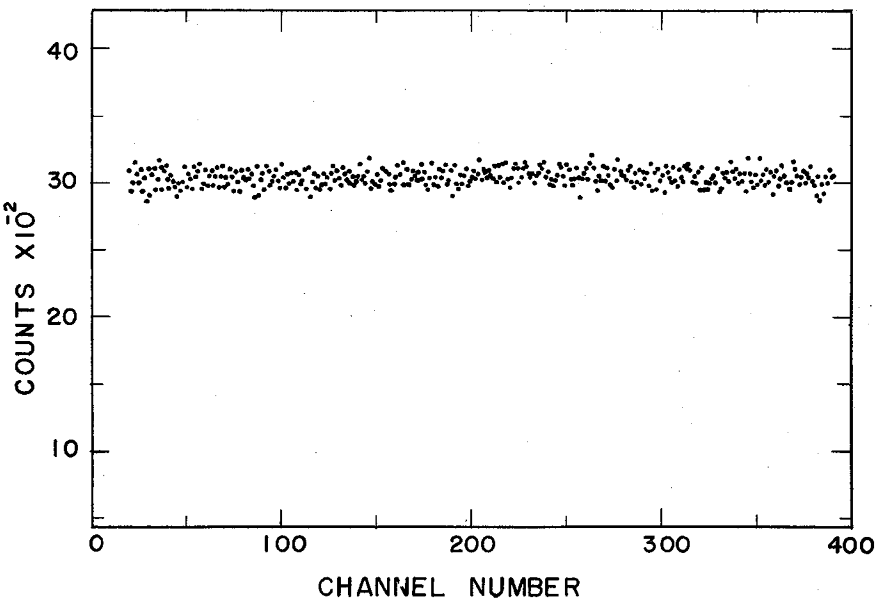


Fig. 9. No-absorption spectrum observed by the present spectrometer.

V. PERFORMANCE

We have been using successfully the spectrometer described here to observe the Mössbauer spectrum of ^{57}Fe in some iron compounds with a TMC 400-channel analyzer. In Fig. 8 is shown the absorption spectrum of an ^{57}Fe foil (90% enriched and 2 mg/cm^2 thick) with a source of ^{57}Co embedded in Cu. From this spectrum it can be known that the linearity of the velocity scale is achieved as to be less than 0.8% and the line-width of the absorption peak is about 3.8 times larger than the natural line-width of the gamma rays. The no-absorption spectrum being flat, as shown in Fig. 9, indicates the good utility of the present instrument.

The author wishes to thank Professor Sakae Shimizu for his kind advice and encouragement. He is also grateful to his colleagues for valuable discussions.

REFERENCES

(1) For example, R. L. Mössbauer, *Z. Physik* **151**, 124 (1958).
(2) S. L. Ruby, L. M. Epstein and K. H. Sun, *Rev. Sci. Instr.* **31**, 580 (1960).
(3) T. E. Cranshaw, *Nucl. Instr. & Meth.* **30**, 101 (1964).
(4) L. Lövborg, *Nucl. Instr. & Meth.* **34**, 307 (1965).
(5) E. C. Ruegg, J. J. Spijkerman and J. R. DeVoe, *Rev. Sci. Instr.* **36**, 356 (1965).
(6) In the following works an electromechanical transducer is also used as a vibration mechanism : F. J. Lynch and J. B. Baumgardner, in *Proc. Second International Conference on the Mössbauer Effect*, edited by D.M.J. Compton and A. H. Schoen (John Wiley & Sons, Inc., New York, 1962), p. 54 ; E. Kankeleit, *Rev. Sci. Instr.* **35**, 194 (1964) ; J. Lipkin, B. Schechter, S. Shtrikman and D. Treves, *Rev. Sci. Instr.* **35**, 1336 (1964).
(7) D. Rubin, *Rev. Sci. Instr.* **33**, 1358 (1962).