The Mössbauer Effect in a Student Laboratory

(how today discoveries are tomorrow exercises)

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Laboratory History

- ORIGIN: This Laboratory was introduced in 1990 at the University of Milano (Italy) for the students in their last year (4th) in Physics, Elem. Particle course.

- GOAL: To reproduce in the Laboratory one important experiment which can be done "on the top of a table".

  In this way the students can realize an experiment from its planning to the final data analysis: they assemble and optimize the set-up, verify the good functioning of all the electronics, take data, analyze them, and produce results.

- ORGANIZATION: Each year 2 groups of max 4 students: 5 years so far for a total of $\approx$ 40 students.

  A final written relation is required.

The Apparatus

- RADIATION SOURCE:
  Fe^{57} (1 mm X 1 mm, 2 mCi) in a Palladium matrix [AMERSHAM-Italia], inserted in a polymethyl methacrylate holder with an internal thread to be screwd to the mechanical support.

- ABSORBERS:
  stainless steel and natural iron (30 mm X 30 mm 25μm thickness) [AMERSHAM-Italia];
  "*rust*": some rust scratched off an old gate in a student's garden and placed in between mylar tape ($\approx$ same dimensions of the other absorbers).

- RADIATION DETECTOR:
  proportional counter: an alluminum cylindrical tube (2 cm internal diameter and 18.2 cm long) with a Be window (20 mm diameter and 500μm thickness) with a gold plated tungsten wire and filled with Ar-Xe

at 5000 mbar [OUTOKUMPU Electronics, Finland, type 490].

- BOX:

  For safety reasons the full set-up has been put into a Pb box with a transparent lead glass on top of it.

The Electronic Chain

The signal from the proportional tube (set at 920 V)[HV power supply SILENA mod. 7712] is fed into a charge-sensitive preamplifier [ORTEC mod. 142 PC] then into an amplifier [ORTEC mod. 472].

The signal is then split into two Multi Channel Analyzers [SILENA mod.Varro with ADC SILENA mod. 7422], to take data separately for positive (toward the source) and negative velocities.

The data taking is allowed (or inhibited) by a NIM level coming from the mechanical driver electrical circuit during the positive or negative volocities (switch selectable choice).

This same NIM level is fed into a Scaler [CAEN mod. N145] gate to count the pulses coming from a Dual Timer [CAEN mod. N93B] used as pulse generator at 10kHz for the velocity calculation.

Each electronic component is tested and the electronic chain final linearity check is shown in figure 8.

Constant Velocity Driver

The relative motion of the absorber versus the radiation source has been obtained by placing the absorber on a special *home made* (by S. Latorre) mechanical device which provide uniform velocity (see fig. 6a and 6b).

The rotary motion of a DC controlled speed motor is transformed by a special cam to the very uniform rectilinear motion needed for this measurement: the special cam is a modified computer disk access arm (see figure 6c).

In this mechanical construction special care has been taken to remove all possible sources of vibration, friction and non-uniformity (granularity) by selecting suitable materials (like *teflon* for example), inserting rubber bands as vibration dampers around the rotary stabilizer and placing an additional weight on it.

The direction of motion is reversed automatically by means of microswitches. Other microswitches, used to exclude the region of non uniform motion, provide gate signals for the data taking logic.

The distance of travel between the limits of the counting gates is 42.55 mm.

The absorber velocity is calculated by counting the pulses from the 10 kHz pulse generator.

A velocity up to 1.29 mm/sec can be selected using the *low speed* motor and between 0.80 mm/sec and 8.28 mm/sec using the *high speed* motor; for both motors a coarse (external) and fine (internal) DC voltage regulation was possible.

In figures 7a and 7b the linearity curves are shown for both velocity ranges.

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and ....

all my students for their enthusiasm !!!

Figure Caption

Fig.1: Laura Perasso and Stefano Latorre in the Laboratory.

Fig.2: The 1994-1995 Students in the Laboratory. From left to right: Rossella Pagliarani, Alessandro Soldera, Daniele Cusari, Valerio Gatti.

Fig.3: Schematic Diagram of the Electronic Chain.

Fig.4a: Top-view of the Experimental Setup. Starting from the left: the mechanical driver, the source holder, the absorber frame (on the shaft), the radiation collimator (using lead bricks) and the proportional tube.

Fig.4b: Schematic Diagram of the Experimental Setup.

Fig.5a: Fe^{57} 14.4 kev Gamma Ray Intensity normalized to the 6.5 kev Gamma Ray Intensity for the Stainless Steel Absorber;
FWHM = $(3.01\pm0.08)\cdot10^{-8}$ eV;
shift = -0.3 mm/sec ($1.4\cdot10^{-8}$ eV); absorption = 30%.

Fig.5b: Fe^{57} 14.4kev Gamma Ray Intensity normalized to the 6.5 kev Gamma Ray Intensity for the Natural Iron Absorber; shift = -1.23 mm/sec ($5.92\cdot10^{-8}$eV); for the 6 peaks we get:
FWHM 1 = $(4.90\pm0.05)\cdot10^{-8}$ eV; absorption 1 = 8%;
FWHM 2 = $(4.23\pm0.04)\cdot10^{-8}$ eV; absorption 2 = 9%;
FWHM 3 = $(2.01\pm0.05)\cdot10^{-8}$ eV; absorption 3 = 6%;
FWHM 4 = $(1.75\pm0.02)\cdot10^{-8}$ eV; absorption 4 = 7%;
FWHM 5 = $(3.49\pm0.04)\cdot10^{-8}$ eV; absorption 5 = 9%;
FWHM 6 = $(4.17\pm0.02)\cdot10^{-8}$ eV; absorption 6 = 11%;

Fig.5c: Fe^{57} 14.4kev Gamma Ray Intensity Normalized to the 6.5 kev Gamma Ray Intensity for the "*rust*" Absorber; shift = $0.9\cdot10^{-8}$eV; for the 2 peaks we get:
FWHM 1 = $(2.1\pm0.05)\cdot10^{-8}$ eV; absorption 1 = 9%;
FWHM 2 = $(2.1\pm0.05)\cdot10^{-8}$ eV; absorption 2 = 9%;

Fig.6a: Right Side view of the Mechanical Driver: the DC controlled speed motor and the modified computer disk access arm.

Fig.6b: Left Side view of the Mechanical Driver: the electrical circuit and the knob for the fine (internal) DC adjustment.

Fig.6c: Schematic drawing of the Mechanical Driver.

Fig.7a: Driver Low Velocity as a function of the applied voltage: the non linearity is below 1.8% for the external DC regulation and below 3.5% for the internal DC regulation.

Fig.7b: Driver High Velocity as a function of the applied voltage: the non linearity is below 0.6% for the external DC regulation and below 3% for the internal DC regulation.

Fig.8: Electronic chain linearity check.

Fig.9a: Co^{57} Spectra without Absorber: the Energy Resolution is 13% at 6.5 keV and 6% at 14.4 keV.

Fig.9b: Working HV Choice for the Proportional Tube: the observed pulse amplitude (in MCA channels) is plotted (in log scale) for different energy gamma rays from Am^{241} and Co^{57} sources.

Fig.9c: Proportional Tube Relative Efficiency: measured values compared with the values provided by the manufacturer.

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or see WWW page: HTTP://WWW.MI.INFN.IT/MOESSBAUER.HTML