K 221 Mößbauer effect

K 221.1 Aim of the Experiment

The aim of the experiment is to get familiar with the principle of recoilless emission and absorption of γ–quanta. The Mößbauer effect can be investigated by relativly simple means using a ^{57}Co source. The magnetic hyperfine structure of the 14.4 keV transition in ^{57}Fe is to be measured.

K 221.2 Required Knowledge

- Basics of resonance absorption; natural line width; Doppler broadening and recoil energies for optical and γ–transitions in the free atom and in the solid state
- Definition of the Debye–Waller factor, its dependence on temperature and γ-energy
- Application of the Mößbauer effect; Measuring methods in Mößbauer experiments
- Decay scheme of ^{57}Co; Hyperfine structure (magnetic dipol, electric quadrupole interaction, isomeric shift); magnetic hyperfine components of the 14.4 keV transition

K 221.3 Literature

The textbooks in nuclear physics usually discuss the Mößbauer effect in short. E.g., the basic facts can be found in the following German textbooks:

> Mayer–Kuckuk: Kernphysik
> Teubner Verlag

To prepare for this experiment the book of

> Schatz, Weidinger: Nuclear Condensed Matter Physics
> Teubner Verlag

is especially suited. In it all prompts above mentioned are discussed at length. Furtheron, have a look at

> Bodenstedt: Experimente der Kernphysik und ihre Deutung, Band II
> BI Verlag (1973), p. 507 – 521.

A fundamental treatise on the Mößbauer effect is given by

Wegener: Der Mößbauer-Effekt
BI Hochschultaschenbücher (1965)
p. 9 – 36, 52 – 70, 78 – 82, 90 – 101, 163 – 165

This book is cited in numerous other textbooks. The book of Schatz–Weidinger is a synopsis of the cited pages. A copy of these pages is provided at the experiment. Personal copies can be drawn from a master copy which is available from the tutor. A very interesting treatise on the Mößbauer effect in English language offers the textbook of

Krane: Introductory Nuclear Physics
Wiley & Sons (1987)
p. 361 – 376, 645, 649 – 652

E.g., on p. 650 a method is introduced how the magnetic moment of the excited state can be determined in relation to that of the ground state if already known. A copy of these pages is provided at the experiment. Personal copies can also be drawn from a master copy which is available from the tutor. Finally, we want to draw the attention to an article in English by Mößbauer himself, given in

Kai Siegbahn: Alpha–, Beta– and Gamma–Ray Spectroscopy
North-Holland (1968)
p. 1293 – 1312

A copy of these pages is provided at the experiment. Personal copies can be drawn from a master copy which is available from the tutor.

K 221.4 Assignments

- Measurement of the ^{57}Fe gamma–spectrum and setting of the single channel analyser on the 14.4 keV line.
- Measurement of the Mößbauer spectrum of the 14.4 keV line of ^{57}Fe (Single–line source and metallic Fe–absorber)
- Comparison of the measured line widths with the theoretical value. From the separation of the lines the g–factors for the ground state and first excited state shall be determined. (For the metallic absorber assume a magnetic field of $H = (333 \pm 10)$ kG at the position of the nucleus). Determine the isomeric shift in eV and qualitatively explain the result.

K 221.5 Procedure and analysis

For recording the Mößbauer spectrum the velocity of the absorber shall be varied between 0 and about 6 mm/s. You are advised to map the results during the measurement so that the velocity step width of the motor control may be reduced in the region of high absorption. A sketch of

the counting electronics is provided in figure K 221.1. After pressing the start-buttom of the absorber velocity control a gate pulse is generated as soon as the absorber has reached the left position of return. Then, depending on the running direction of the absorber the detector pulses are fed from the single-channel-analyser into the counters $N(\mathrm{LR})$ and $N(\mathrm{RL})$, respectively. At the same time the pulses from the timer are put into counters $T(\mathrm{LR})$ or $T(\mathrm{RL})$. These counters provide the duration of both measurements. The number of left-to-right turns is indicated by the run counter. After pressing the stop–buttom the counters are only stopped when the number k of left-right and right-left runs is equal. From the total running time for each direction the respective absorber velocities can be calculated. The total swing of the device is $s_0 = 25.1\,\mathrm{mm}$. From $N(\mathrm{LR})$, $N(\mathrm{RL})$, $T(\mathrm{LR})$ and $T(\mathrm{RL})$ the counting rates for both directions can be computed. (Attention when calculating the errors). Due to an offset-voltage in the operational amplifiers of the control circuit $T(\mathrm{LR})$ may differ from $T(\mathrm{RL})$.

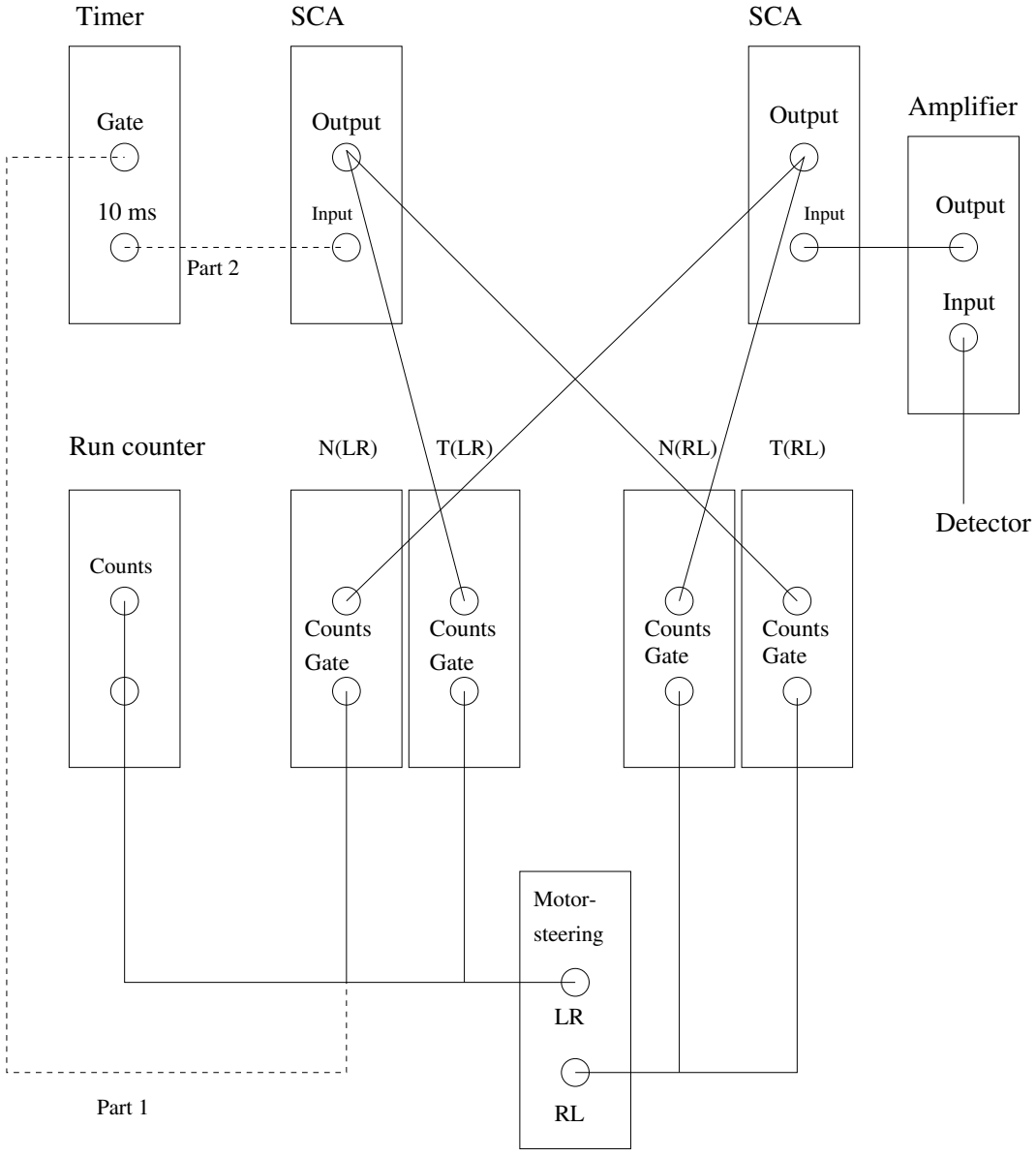

Figure K 221.1: Principal circuit diagram of the apparatus

Best wishes for a successful experiment! Date: March 1998