

Preface

In 1958, Rudolf Mössbauer, a student of Heinz Maier-Leibnitz, professor of technical physics at the Technische Hochschule München, published his doctoral thesis in the journal *Zeitschrift für Physik*, **151**, 124 (1958) with the unpretentious title “Kernresonanzfluoreszenz von Gammastrahlung in ^{191}Ir ”. It contained “dynamite” in science. A second article with a very similar title “Kernresonanzabsorption von Gammastrahlung in Ir”,¹⁹¹ published in *Naturwissenschaften* **45**, 538, (1958), showed a spectrum of 129 keV γ -rays with the natural line width of 10^{-5} eV, a resolution never observed before. The science community, busy with studying parity break down of the weak interaction, did not care for these exotics, or even thought these results were likely to be wrong. They were checked in 1959 by two US groups. In one of them, a participant betted a dime that Mössbauer was right. It was soon proven that all of the Mössbauer’s findings were correct and now physicists were truly electrified. Following the discovery of the resonance absorption of other γ -lines in crystals with “zero energy loss,” such as the 14.4 keV γ -transition in ^{57}Fe , unique uses of what was soon called the “Mössbauer Effect” spread rapidly into many fields of research. The Second International Mössbauer Conference in Paris held in the summer of 1961 was the show case for these fascinating applications and lead directly in the fall of 1961 to the Nobel Prize for the discovery of Rudolf Mössbauer with the citation: *For his researches concerning the resonance absorption of gamma radiation and his discovery in this connection of the effect which bears his name.*

In January 2009, Dr. Claus E. Ascheron from Springer Science and Business Media invited us to edit a book in honor of Rudolf Mössbauer on the occasion of the 50th anniversary in 2011 of the award of the Nobel Prize (1961) for the discovery of the “Mössbauer Effect.” We accepted gladly this offer to honor Mössbauer’s scientific work and its impact on science and history including his later pioneering work on neutrino oscillations. Mössbauer spectroscopy has provided many new insights in nearly all fields of natural sciences and into technological problems as well. One other unique feature is that, except for the recent applications using synchrotron radiation, the standard experimental setup is simple and measurements can be carried out in a standard laboratory. Its educational value is very high: it introduces

the experimenter, especially students, into the basic phenomena of nuclear and solid state physics together with applications of quantum theory. Funding agencies like the International Atomic Energy Agency soon became aware of this aspect of the Mössbauer effect and provided special grants to set up Mössbauer spectrometers in countries with an emerging scientific community. This important development was especially pleasing to Rudolf Mössbauer to whom scientific education was a prime issue.

We decided to present in this book a mixture of contributions reflecting the discovery of the effect and its early history followed by reports on unique applications in various areas of science and views on future developments. For the historical part, we invited contemporary witnesses using a last opportunity to get their views on record. The authors of the scientific contributions dealing with important applications of the Mössbauer spectroscopy have highest scientific reputation and most of them are still working in the field.

After a reprint of Rudolf Mössbauer's Nobel lecture, the first book chapter, entitled *Rudolf Mössbauer in Munich*, makes the reader familiar with the fascinating discovery story of a diploma and a follow-up doctoral thesis on the temperature dependence of nuclear resonance absorption of γ -rays. Remarkably, it started in the after-war time when nuclear physics was still forbidden in Germany. In careful experiments, performed at the Max-Planck-Institut für Medizinische Forschung in Heidelberg – the Munich institute of Maier-Leibnitz was too crowded with students and equipment was scarce – Mössbauer found that by decreasing the temperature of source and absorber to that of liquid nitrogen the resonance absorption effect *increased*, instead of the expected decrease. He explained this unexpected discovery, using basically a paper published by Lamb in 1939 on the resonance absorption of *neutrons* in nuclei bound in a crystal, as an increasing fraction of “zero recoil energy loss” events in the emission and absorption of γ -rays by a nucleus bound in a crystal when its temperature was lowered. In a follow-up experiment, Mössbauer directly showed by introducing a small Doppler shift between the source and the absorber that the measured resonance absorption cross section as function of the energy introduced by the Doppler shift is given by the folding of the emission line of Lorentz shape with natural line width with the corresponding resonance absorption cross section. A subchapter *Dawn of the Mössbauer Spectroscopy in Munich* reports on technical developments for recording Mössbauer spectra and unique studies of isomer shifts, electric quadrupole, and magnetic dipole splitting of rotational transitions in deformed rare-earth nuclei, important for determining the exceptional properties of rotating super-fluid deformed nuclei. In a short personal report on a failed visit of the Louvre of one of us (PK) with Maier-Leibnitz on the occasion of the Second Mössbauer Conference in Paris in 1961, the tale is narrated why the Nobel Prize award for the discovery of the Mössbauer effect was given to Rudolf Mössbauer alone. In a final paragraph, the story how Mössbauer changed his field of research and got involved in the new adventure “Neutrino Physics” is told.

Following a reprint of Rudolf Mössbauer's own account of the discovery of his effect, the early days of the Mössbauer Effect and the exciting discovery of the 14.4 keV Mössbauer line of ^{57}Fe , which allowed many new applications until

today, are recalled by authors who acted at the forefront of fundamental discoveries during these pioneering times. Early developments of the theory of the Mössbauer Effect are communicated by a famous pioneer who paved the way for understanding “zero energy loss” transitions of γ -rays in a solid and who may well be credited for introducing the term “Mössbauer Effect” into the world of science. The section is concluded by original contributions on the CalTech years of Rudolf Mössbauer and by the review on “The World beyond Iron” written by one of us (MK).

This historical Part is then complemented by comprehensive reviews of highlights about the impact of Mössbauer spectroscopy in the fields of nuclear physics, applications of isomer-shift measurements in solid-state chemistry, and studies of internal magnetic fields in solids. A review of studies of dynamic processes in condensed matter, extraordinary biological and medical applications, and unique results of extraterrestrial Mössbauer spectroscopy follows. Scientific highlights continue with investigations of fundamental relativistic phenomena, studies of phase coherence in nuclear resonant scattering and by a chapter on performing Mössbauer-Effect studies using synchrotron radiation, which points into a bright future of ultrahigh-resolution, time-resolved synchrotron radiation spectroscopy. In particular, unique aspects of nuclear resonance scattering of synchrotron radiation as a probe of atomic vibrations are described.

The third Part reports on future developments of the Mössbauer spectroscopy. In a contribution *Dreams with Synchrotron Radiation*, the author describes challenges and opportunities for Mössbauer spectroscopy in the next 50 years showing that its future is bright indeed. The most challenging performance requirement for the Mössbauer studies of non-equilibrium systems is, first, to collect information, preferably with a single X-ray pulse from the radiation source when the system dwells in the non-equilibrium (excited) state and second, to probe mesoscopic structures with a spatial resolution of nanometers. A second contribution, *Mössbauer Effect with Electron Antineutrinos*, discusses in detail the proposal to use the mono-energetic neutrinos from bound-state β -decay of ^3H to ^3He to perform an ultra-high resolution neutrino resonance absorption experiment. There could be a very interesting fundamental physics program ahead if such an experiment would work, but the authors concluded that this is rather unlikely at present.

The last Part, termed “Epilogue” contains two contributions. The first, entitled simply *Neutrinos*, refers to the second Love of Rudolf Mössbauer, the study of the physics of neutrino oscillations. As pointed out Rudolf Mössbauer and Felix Böhm initiated more than 30 years ago first experiments to study the mass and the mixing matrix of neutrinos by observing neutrino oscillations, following a proposal of Bruno Pontecorvo. Nowadays, such experiments created a so-called Neutrino Industry. Two Nobel Prizes went already into this exciting field which is thoroughly reviewed in this chapter; more are expected to come. The second and final contribution to this book, *The Second Mössbauer Effect*, uses the title of a headline of the “Spiegel” magazine, announcing the foundation of the Physik-Department at the Technische Hochschule München on the occasion of Mössbauer’s return from CALTEC in 1964. It is a short review honoring the engagement of Maier-Leibnitz and his former student Mössbauer in successfully reforming

the structure of German universities several years before the even more famous “Spiegel” article *Unter den Talaren der Muff von tausend Jahren* appeared, a trigger of the 1968 student revolution in Germany.

The selection of themes treated in this book certainly is short of reflecting all the aspects of Mössbauer spectroscopy. As editors we had to make choices, but we hope the reader gets an idea of Rudolf Mössbauer’s outstanding contribution to modern science. One special other aspect of the Nobel Prize to Rudolf Mössbauer should be pointed out. It signaled to the world that Germany after a dark past and the destructions of World War Two had returned into the world of science. All of us are particularly grateful to Rudolf Mössbauer for his long-lasting efforts in that direction.

We appreciate the excellent collaboration with the authors of the contributions, the advices we got from various members of the “Mössbauer Community” and are especially grateful for the help in editing of the book by Dr. Josef Homolka and the steady support of Dr. Claus E. Ascheron and his staff from Springer Media.

This book was intended for appreciation of the Fiftieth Anniversary of the presentation of the Nobel Prize to Rudolf Mössbauer in 1961 and planned to be delivered to him December 10, 2011 in Munich. Sad enough he passed away during printing September 14, 2011 in the arms of his beloved wife, Christel Mössbauer. We express our sincere condolence to her.

Garching
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His Scientific Work and Its Impact on Science and
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