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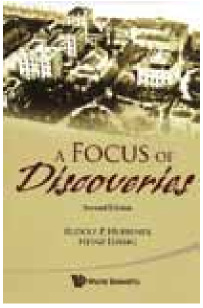

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A Focus of Discoveries
Second Edition

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This is a book on the genesis, the creation in 1887 and the achievements of the Physikalisch-Technische Reichsanstalt (PTR), the German national institute of standards and technology, renamed Physikalisch-Technische Bundesanstalt (PTB) after the Second World War. The present edition, which comes with a convenient CD of the text in pdf format attached to the back cover, marks the 125th anniversary of the PTR.

The PTR-PTB has been and remains an important national establishment and venue for many of the basic discoveries and technical developments achieved in Germany over the period. Much of these have already been covered in other publications[1] but the present one purports to emphasize the background physical science by discussing in detail a few selected, outstanding examples of discoveries made at, or supported by the PTR.

All in all, this interesting book is an outstanding demonstration and eloquent defense, more necessary today than ever, of the principle that fundamental research and practical-technical application can and indeed should go hand in hand.

In chapters 1 and 2, the authors describe the gestation period extending from about 1875 to the creation of the PTR in Berlin in 1887. During that period, Werner Siemens, the celebrated industrialist and key financial sponsor for the project, played a leading and visionary role. In one of his memoranda recommending the creation of the Institute, he declared: "…*a country will never reach and keep an internationally leading position, unless at the same time it is at the top of the advances in the natural sciences*". To this reviewer, an alumnus of the Belgian National Science Foundation (FNRS), this statement evokes a nearly identical pronouncement in a celebrated speech of the Belgian King Albert 1st in 1927: "…*pure science is the indispensable condition of applied science and the fate of nations which will neglect science and scientists is marked for decadence*", a statement which was soon followed by the creation of the FNRS in 1928. In Germany, the very name PTR was chosen to reflect that essential alliance between fundamental physics (or science) and technical applications.

In his own recommendation of 1883 for endowing the *a priori* technical Institution with a strong pure science section, the great 19th century poly scientist Herman von Helmholtz (who was to serve as the first PTR president) wrote a moving survey (see chapter 2, pp. 19-22) listing a set of six outstanding, unsolved problems in gravitation, electromagnetism and thermodynamics, all fundamental fields of the time. He emphasized the necessity of improving the measurement techniques and their accuracy not only for the benefit of fundamental science but also for the gains in the corresponding industrial fields and ultimately for the economy of the country.

Chapters 3 and 4 are devoted to the start of PTR, the progressive erection of the different buildings and laboratories in Berlin, the first laboratory list of tasks designed to complement and carefully balance the corresponding activities in universities, technical colleges and industries in Germany.

In short order after the official opening, under Helmholtz's direction, the PTR hired outstanding scientists to carry out a vast program of basic and applied research in optics, mechanics, metallurgy, electricity, in parallel to the role of certifying technical instruments and practices *e.g.* for the glass industry (*e.g.* water levels needed in geological survey, polarimeters for the sugar industry and many other highly practical devices).

Chapter 5 discusses the great scientific saga which took place in physics at the optics laboratory of PTR and elsewhere, leading up to the birth of Max Planck's quantum theory and its many experimental verifications. Details are given about the roles of such "luminaries" as Wien, Lummer, Kurlbaum, Pringsheim, Paschen, etc in the genesis of Planck's famous radiation law with its new fundamental physical constant *h*. The contributions of the PTR to the later discovery is described in glowing terms by the authors (p. 58) : "*Only a little more that 10 years had passed since the foundation of the Reichsanstalt when its member made the decisive experimental demonstration that led to quantum theory – perhaps the greatest scientific success this facility would ever achieve*".

After this remarkable head start, the PTR continued to harbor several other major research achievements in various fields of physics and chemistry for which the authors give much detail. First in metal physics (chapter 6) the discovery of several new superconductors are reported and, above all, the great discovery of the Meissner effect in the low temperature laboratory of PTR which Walther Meissner himself created and directed. In chemistry (chapter 7), under the presidency of the great Walther Nernst who considerably expanded the activity of the chemical laboratory, Walter Noddack and his wife Ida discovered new, missing elements in the Periodic Table (rhenium and technetium). The PTR became involved in the testing of radioactive substances (chapter 8) in the new field of nuclear physics in rapid development at the beginning of the 20th century. A special radioactivity laboratory was created in 1912 and was headed by no less a personality than Hans Geiger of detector-counter fame. With the appointment of the nuclear physicists Walther Bothe (1913) and with the hiring of James Chadwick as visiting scientist (1914), this new lab quickly became one of the leading laboratories for radioactivity in the world, on a par with those of Marie Curie in France and Rutherford in England. The famous Geiger-Bothe coincidence measurement method for nuclear reactions was conceived and developed at PTR. When applied to the X-ray photon and electron of the Compton effect (1922) the measurement ended up confirming the validity of fundamental conservation laws in microscopic physics temporarily put in doubt by a celebrated paper of N. Bohr, H. Kramer and J. Slater. Somewhat belatedly in 1954, Bothe was to receive the physics Nobel Prize *"for the coincidence method and his*

[1] See D. Cahan, *An Institute for an Empire*, Cambridge UP, 1989).

discoveries made therewith".

Two side stories about the PTR personnel quoted so far are worth mentioning here. The first one is recounted in details in chapter 7 of the book (pp. 87-88) and concerns Ida Noddak in her search of new elements. In 1934, in an attempt to interpret what occurred in Fermi's puzzling experiments to produce "transuranic elements" by slow neutron irradiation of Uranium, Noddak published the great conjecture that "…*It would be conceivable that during the bombardment of heavy nuclei with neutrons these nuclei disintegrate into several large fragments… not neighbors of the irradiated elements*". This was a perfect definition of nuclear fission. But none of the great nuclear specialists, Rutherford, Joliot-Curie, Fermi, Hahn, Meitner, Bohr, Bothe and many others, took Noddak's revolutionary and premonitory suggestion seriously. Scientists know that this sort of rejection is not such an unusual show of blindness from the part of the experts. However here, the world should be thankful to them for their disregard in view of the horrendous consequences that the early confirmation of Noddak's idea could have had, given the political developments of the time in Germany.

The other story, not in the book, involves Bothe and also concerns fission but this time took place after the phenomenon was experimentally observed and understood in 1939. As soon as several secondary neutrons were seen to be emitted by fission, a material suitable as a neutron moderator was searched to allow a chain reaction by neutron multiplication in natural uranium. Carbon in the form of graphite was among the light elements initially thought adequate for having a neutron absorption cross section low enough not to quench the chain reaction. Bothe measured neutron scattering in a large bulk of industrial graphite insufficiently purified from neutron absorbing impurities. Lo and behold! The result was discouraging and graphite was at first excluded in Germany as a possible moderator for the construction of a uranium burner. Heavy water was chosen instead and the rest is history, as the saying goes. Another misunderstanding that changed the course of human affairs!

Back to the book, chapters 9 is specifically devoted to the many interactions that Einstein maintained with the PTR between 1905 and his emigration to the USA in 1933. There is hardly any need to explain why Einstein should have been involved in the business of PTR. Their relationship is perhaps the most iconic and strongest example of the 20th century for documenting the inseparability of technical applications from pure theory. One has only to think of the truly astounding use of ultra accurate atomic clocks (the PTB maintains several of them) for implementing Einstein's concept of relative, local time and the creation of the GPS. The chapter goes into several such Einstein-PTR interactions, the measurement of fundamental constants such as Planck's h, the Avogadro number, the quantum theory of radiation, the Einstein-de Haas experiment, the Bose-Einstein photon counting statistics, etc…

Chapter 9 ends with the "*depressing epilogue*", *i.e.* what happened to the relationship between PTR and Einstein, Bothe, Von Laue, Pashen, and several other anti-Nazi, culminating with the appointment of Johannes Stark as president of PTR in 1933. The last chapter of the book (chapter 14) is devoted to the PTR under the Nazi dictatorship. After the war the PTB, the new metrology establishment in Western Germany, was created to replace the old Reichsanstal. For launching the new beginnings at the PTB, Max von Laue, former theory consultant of the PTR, contributed decisively when he was allowed to return from England where he had been interned with other prominent German scientists captured by the Allies in 1945[2].

Chapter 10 goes in some detail into the way physicists count particles in statistical mechanics, the classical or the quantum statistics of bosons and fermions. Counting is the basic act in the art of measuring, be it counting how many units of measurement there are in a quantity, or counting individual material particles. The chapter then deals in brief outline with the countable electrical unit, the electron charge e. This provides a link with the great postwar discoveries of the Josephson and von Klitzing effects which, for having since provided the physical foundation of the legally fixed units of voltage and resistance, had such a profound effect on metrology at the PTB and throughout the world of standards. Both of these quantum discoveries, one purely theoretical (Brian Josephson) and the other purely experimental (Klaus von Klitzing), were totally unexpected. They show once more how inextricably and unpredictably the basic sciences and major technical applications are linked. Shortly after discovering the integer quantum Hall effect in early 1980, von Klitzing called up a friend, Volker Kose at the PTB in Braunschweig in charge of electrical metrology, and asked him: "*would you like to have the fine structure constant with 6 decimal places?*". Kose was flabbergasted at first but, only a short time later, the PTB realized and maintained the new SI unit of resistance, the Ohm, in terms of the von Klitzing constant $R_K = h/e^2$. Further details on this glorious episode of the PTB and several other advances in quantum metrology there and elsewhere in the world can be found in reference[3].

Chapters 11 and 12 describe the Planck system of natural units related to the four physical constants G, c, h, k_B. Also discussed are a purported dispute between Planck and Einstein as to what constitutes a fundamental constant, the consistency of the SI system of units and some considerations on the epistemology of metrology.

Chapter 13 provides a useful list of the successive presidents of PTR, from von Helmholz in 1887 until Paschen in 1933, giving for each of them a short CV and a summary of their major impact on the Institution. As for J. Stark, on May 1933, "*he was appointed as President of the Reichsanstalt against the unanimous vote of all experts questioned*". One of the experts was von Laue. As mentioned above, what happened to the PTR under Stark and during the Second World War is the subject of the last chapter.

As promised by the authors in the preamble and as reflected by the very title of their book "*a focus of discoveries*", the present account of the PTR story emphasizes the major scientific achievements to which its prominent members took part. Presenting a great institution, or indeed expounding a great scientific theme[4] in this way, is indeed a very valuable approach to foster the history of a field, at least when the expected readership, such as the one of the present book, is composed mostly of professionals of the discipline. The literature on the history of contemporary physics is immense and it is far more enjoyable and lively to learn a fraction of this history via the development of a given successful research center such as the PTR. The book by Huebner and Lübbig is an enjoyable read and, although the literary style does show at places that English is not their native tongue, the authors have indeed succeeded in achieving their promise.

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[2] J. Bernstein, *Hitler's Uranium Club*, Springer-Verlag, N.Y. (2001).

[3] *Quantum metrology and fundamental physical constants,* ed. by P. H. Cutler and A. A. Lucas, NATO ASI Series B 98, Erice, Italy (1981); Plenum Press, N.Y. (1983).

[4] Recent examples of very successful science history books which trace a peculiar scientific theme and are written by professional science writers with great literary style are, in mathematics, Simon Singh's *Fermat Last Theorem,* in physics, Richard Rhodes's *The making of the atomic bomb,* in biology, Horace Freeman Judson's *The eight day of creation.*