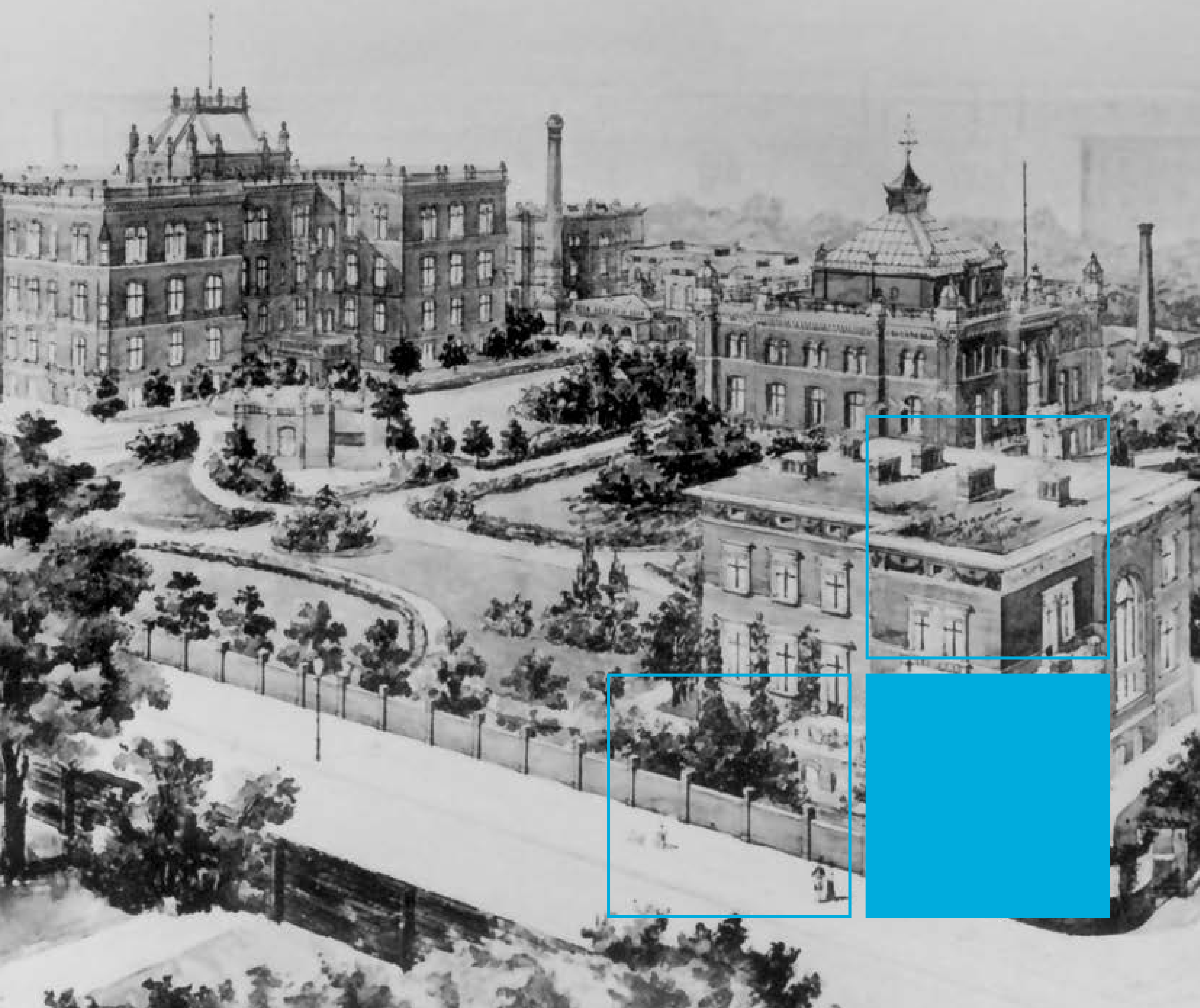
Physikalisch-Technische Bundesanstalt
National Metrology Institute

PTR and PTB:
History of an Institution



PTR and PTB: History of an Institution

Since 1887, accurate measurement has had an institutional home in Germany. When the first budget of the Physikalisch-Technische Reichsanstalt (PTR), the predecessor of PTB, was approved on 28 March 1887, this was the birth of the first national major research institution and the beginning of a success story that hasn't ended yet by a long shot.

From Ells and Feet to the Metre – The Prehistory of Metrology

The body size of rulers – in many cases the ell (cubit) or the foot – were popular measures in the past which formed the basis of trading. In the middle of the 18^{th} century there were more than forty different ells with lengths between 40 and 80 cm in the area covering the later German Empire alone – a real obstacle to trade. Along with the French Revolution there was also a change for the units of measurement: the original metre and the original kilogram were born. It still took until 1875, however, until the then most important industrialized nations agreed to an international contract, the Metre Convention. From this moment on, for the very first time, uniform measures came into effect for everyone.

In the middle of the extremely dynamic industrial developments of the 19^{th} century, several Prussian scientists joined together in 1872 to further promote precision metrology in what is now Germany. This was all in the interest of science, trade and the military. In their so-called "Schellbach Memorandum" they demanded the establishment of a separate state institute for this purpose. Included among the supporters were the later PTR President Hermann Helmholtz and the mathematician and physicist Wilhelm Foerster, who later contributed decisively to the formation of the Metre Convention in Paris, became a member of PTR's Kuratorium (Advisory Board) and was head of the Comité International des Poids et Mesures (CIPM) for almost 30 years. Yet initially Prussia rejected their demands.

Werner von Siemens, Hermann von Helmholtz and the Founding Years

The industrialist Werner von Siemens and the scientist Hermann von Helmholtz are considered to be the founding fathers of the PTR. It is especially due to their vision and their persistent commitment that on 28 March 1887, the Imperial Diet (Reichstag) finally adopted a first annual budget for the thus newly founded Physikalisch-Technische Reichsanstalt (PTR). Hence, the foundation was laid for the first state-financed, university-external, major research institution, which was both responsible for material interest-free fundamental research and also supported industry with its current problems.

Werner Siemens – not yet ennobled in the early 1880s – was deeply impressed by the progress made in natural science and converted the knowledge gained industrially for the benefit of the rising German industrial and exporting nation. With his memoranda, he provided politics with reasonable grounds for the urgent need for a PTR and, to this end, ceded private land to the German Empire in Berlin-Charlottenburg.

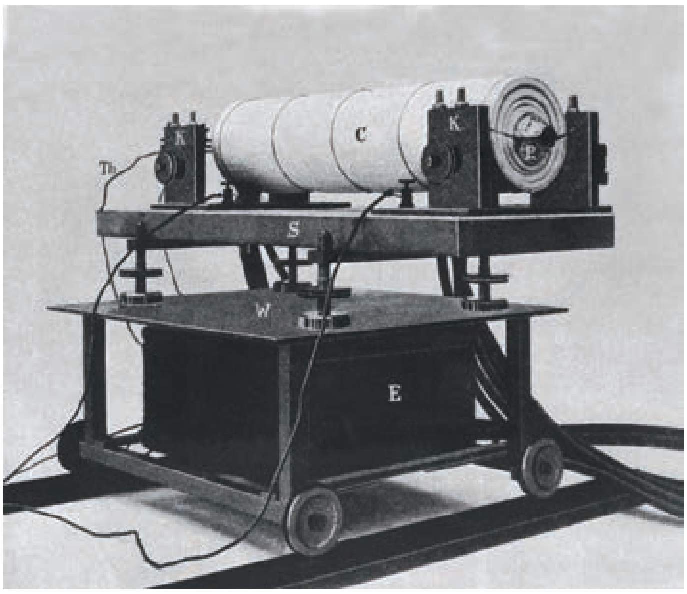
At the same time, Hermann Ludwig Ferdinand Helmholtz, who was born in Potsdam in 1821, was one of the most influential natural scientists of his time. His colleague, James Clerk Maxwell – a physicist – even called him an "intellectual giant". As the PTR's first president, he shaped its construction from 1888 to 1894. The heyday of the Physikalisch-Technische Reichsanstalt in its initial decades is linked with the names of prominent scientists, as staff members of the PTR and active members of the Kuratorium (Advisory Board), such as, e.g., Wilhelm (Willy) Wien, Friedrich Kohlrausch, Walther Nernst, Emil Warburg, Walther Bothe, Albert Einstein and Max Planck.

Hermann von Helmholtz

Werner von Siemens

The Black Body and the Birth of Quantum Mechanics

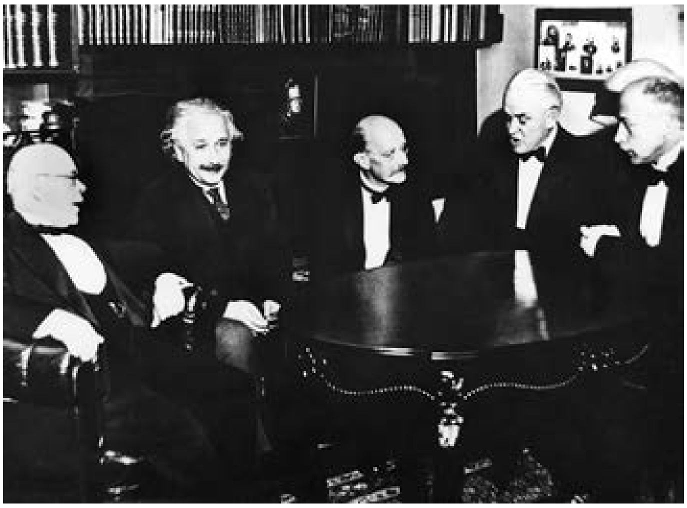
Soon after the founding of the PTR, the measurement of the radiation of a black body (i.e., an object that completely absorbs all light) became an important task of the PTR Optics Laboratory. The reason for the investigations made by the PTR was the need for a more precise standard for luminous intensity – to decide which type of street lighting in Berlin would be more economical: electricity or gas. The measurements led to one of the most spectacular successes of the experimenting expertise of the PTR: the exact determination of the spectrum of blackbody radiation. These results were so precise that they were able to uncover inconsistencies in the "classic" (world) conception of physics prevalent at that time. The measurements could only be explained with a new theory: In an "act of desperation" (as he himself later called it), Max Planck "quantized" thermal radiation without further ado, i.e., he broke it down into packages of a certain size. This was the birth of quantum theory. It took decades until this "crazy" theory which describes the microscopic world under the smooth, macroscopic surface as grainy and layered and in which our usual logic is rendered powerless, was understood and accepted. Today, quantum mechanics is the best description of reality that we have, and our high-tech world could not be imagined without its applications – from the computer chip to the laser, and to satellite navigation.



In 1895, Otto Lummer and Willy Wien developed the first cavity radiator for the practical generation of the thermal radiation of black bodies.

The Kuratorium (Advisory Board)

From the very beginning, the PTR had a management tool which, from our present-day perspective, was really quite modern: the Kuratorium (Advisory Board). Now as then it fulfils – on the one hand – the role of a scientific advisory board, discussing content-related questions and the future orientation of the PTR/PTB, and it represents – on the other hand – the interests of PTB's customers from the scientific, economic and social sectors. The list of the members of the Kuratorium reads like a "who's who" of science and technology: in the first twenty years alone, scientists such as Wilhelm Foerster, Hans Heinrich Landolt, Rudolf Clausius, Friedrich Kohlrausch, Ernst Abbe, August Kundt, Georg Quincke, Emil Warburg and Karl Schwarzschild worked on this board. To date, a total of thirteen Nobel Prize winners have been members of the Kuratorium of the PTR/PTB – a sign of the high significance which both sides attribute to this type of advice.



Meeting of Nobel Prize winners in Berlin in 1923: Walther Nernst, Albert Einstein, Max Planck, Robert Andrew Millikan and Max von Laue. Apart from Millikan, all of them were closely connected to the PTR for many years, for instance as members of the Kuratorium.

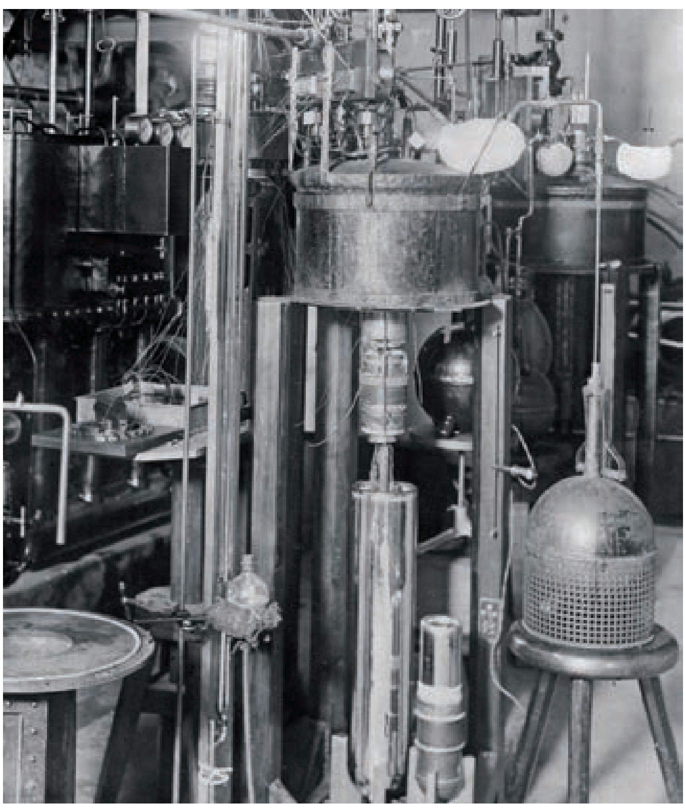
One of the Nobel Prize winners in the Kuratorium (1916–1933) was Albert Einstein, who PTR President Emil Warburg would gladly have employed at the PTR. At least in 1914 the PTR managed to have Einstein work as a guest scientist and to allow him – the theoretical physicist – to perform one of the few experiments of his scientific career (in cooperation with the young physicist Wander Johannes de Haas) in the excellently equipped laboratory of the PTR: the experiment was supposed to confirm the hypothesis of Ampère's molecular currents. An amusing footnote in the history of physics is that the claimed agreement between theory and experiment is merely apparent – as only ten years later the theory was reconsidered with the discovery of the electron spin, which led to a change in the theory by a factor of 2.

"New Physics" and a New Structure

At the beginning of the 20^{th} century, the PTR under Emil Warburg, its president at the time, addressed itself increasingly to the so-called "New Physics". This included, among other things, the newly discovered X-rays, the new conception of the atomic structure, Einstein's Special Theory of Relativity, quantum physics based on the blackbody radiator, and the properties of the electron. The renewal of the research topics of the PTR succeeded, above all, thanks to two exceptional personalities in the field of research: There was, for example, Hans Geiger, who set up the first laboratory for radioactivity of the PTR and within a short time turned it into a world-class scientific research centre.

Walther Meissner, too, was able – delayed due to World War I – in the course of this re-orientation to celebrate his great scientific successes, such as the liquefaction of helium, the discovery of the superconductivity of a series of metals and somewhat later, the fundamental effect of expulsion of the magnetic field from a superconductor – which was named after him.

The new contents were accompanied by a new organizational structure: In 1914, President Emil Warburg dissolved the former structure of the PTR (i.e. the sub-division into a "Physical" and a "Technical" Division) and re-structured the PTR into thematically organized divisions dealing with the following subjects: optics, electricity and heat – each of them having a purely scientific sub-division, as well as a sub-division dedicated to testing. When in 1923 the Reichsanstalt für Maß und Gewicht (Imperial Weights and Measures Office) was incorporated into the PTR, above all for financial reasons, an additional division was created, whose task was the length, weight and volume measurements – attendant with many duties dealing with verification matters. As a result of this step, the PTR received a unique task profile which combined the tasks of a modern research institute with those of an authority: Through its own research and development and the resultant services, it was to ensure the uniformity of metrology and its continual further development for the service of the citizens, the economy and science – a profile which PTB is still committed to, even today.



With his self-designed liquefying facility, Walther Meissner succeeded in 1925 in producing 200 cm3 liquid helium for the first time in Germany. It is indispensable as a coolant in low temperature physics, e.g., for investigating superconductivity.

The PTR in the "Third Reich"

Under the Nazi regime, a dark chapter began, too, for the PTR. The staunch National Socialist and protagonist of "German Physics", Johannes Stark, was appointed to the office of president in opposition to the "unanimous advice of all experts". In his endeavour to enforce the "Führer" principle in the PTR, in 1935 Stark dissolved the Kuratorium and credited himself with all competences for the direction of the PTR. Jewish staff members and critics of the NSDAP, such as, for example, Max von Laue, were dismissed. Albert Einstein, a member of the Kuratorium and for years closely connected with the PTR, felt compelled to emigrate already in 1933 – unlike von Laue, he did not re-establish contact with the PTR/PTB after the end of World War II. Under Stark, the PTR shut down numerous research institutions, since antisemitic ideology brusquely rejected branches of modern physics apostrophized as "Jewish" – such as, for example, quantum theory or the Theory of Relativity. Instead, subjects were seized on that appeared to serve the "Third Reich" with its military armament and had potential military importance. Thus, Stark set up an acoustics laboratory and stressed its militarily important tasks. These tendencies towards militarization also increased under Stark's successor, Abraham Esau – an expert in the field of high-frequency physics – whose term of presidency fell almost completely within the duration of World War II and who directed the PTR even more strongly towards military-technical subjects. The bombing raids on Berlin forced the relocation of several divisions to other places in Germany, for instance in Thuringian Weida. In 1945, the PTR was virtually destroyed and scattered over all federal states outside of Berlin.

The war left its mark, causing great damage to the main building of the PTR in Berlin.

PTB: New Beginning in Braunschweig

Thanks to the idealism of several former staff members of the PTR, the selfless commitment of some scientists outside of the PTR and the benevolent support of the British military government, parts of the old PTR were able to take up their work again as early as in 1947, even though this was under the most difficult conditions. Of crucial importance was Max von

Laue, a former advisor of the PTR for Theoretical Physics, who developed initial ideas for the refounding of the PTR as early as his internment in Farm Hall. He succeeded in convincing the British occupational authorities to make available the former Luftfahrtforschungsanstalt Völkenrode (Aeronautical Research Institute Völkenrode) in Braunschweig for rebuilding the PTR. As an advance party, the Acoustics Division relocated from Göttingen to Braunschweig in January of 1947. When in the summer of 1948, Wilhelm Kösters, for many years a director of Division 1 and at that time head of the remaining PTR in Berlin, was appointed the first president, numerous former staff members from the PTR in Berlin, Weida and Heidelberg came to Braunschweig, so that establishing the institute received a sustainable impulse. As a result, in 1948, 38 scientists, 47 technicians and 20 labourers worked at the site in Braunschweig-Völkenrode again.

The physicist Max von Laue was an advisor of many years' standing of the PTR and contributed significantly to its refounding at the end of World War II.

Two years later, the institute received its new designation: the Physikalisch-Technische Bundesanstalt, and starting from this time, came under the auspices of the government of the still young Federal Republic of Germany. Since the complex political situation in the historic site of Berlin-Charlottenburg delayed the reconstruction, the "Berlin Institute" – the new name of the restored buildings and laboratories in Berlin – was not assimilated into the new PTB until 1953.

A Growth Spurt and Reunification

The new PTB in Braunschweig and Berlin experienced – at the same time as the new Federal Republic of Germany – rapid growth. With the growth of the gross national product, PTB's budget also rose, the number of employees grew continuously, science steadily conquered new metrological terrain and the metrological services, above all the number of calibrations for German industry, increased constantly. This led to the foundation of the Deutscher Kalibrierdienst (German Calibration Service – DKD) in the middle of the 70s. Privately-run laboratories, accredited by PTB, were then able to perform calibrations for industry independently, leaving PTB to concentrate on more demanding measurement tasks. In 1990 PTB grew larger in one go: as a result of the political reunification of Germany there was also a "metrological reunification". After the Amt für Standardisierung, Meßwesen und Warenprüfung (Office for Standardization, Metrology and Quality Control – ASMW) of the former German Democratic Republic (GDR) was dissolved, PTB took on the site in Berlin-Friedrichshagen as an additional branch (which, however, was given up step-by-step in the following years for economic reasons). It also became responsible for a large proportion of the ASMW's metrological tasks and over 400 members of staff. After this large, one-off increase in personnel, PTB had to fall in line with the political will and in the years to come (and even today) continually reduce its numbers of staff. Regardless of this, PTB's tasks are still increasing – and not only within the national framework, in which PTB with its metrological competence (formally defined in the Units and Time Act) holds the central position. PTB's influence is felt far beyond Germany's national borders, it is taking on ever closer links with its European partners (up to the establishment of a joint metrology research programme) and plays a leading role in global metrology. Today PTB numbers among the largest national metrology institutes in the world and it significantly contributes to putting into practice the demands of worldwide uniform metrology.

Meeting at PTB's 100-year anniversary celebration in Braunschweig: Federal President Richard von Weizsäcker, PTB President Dieter Kind and ASMW President Helmut Lilie (from the left).

Ausgewählte wissenschaftliche Ergebnisse

1895 Otto Lummer and Willy Wien develop the first cavity radiators.
1896 Willy Wien formulates a radiation law for the black body (Nobel Prize in physics awarded to him in 1911).
1899 Otto Lummer and Ernst Pringsheim measure deviations from Wien's radiation law.
1900 Max Planck finds an exact description of black body radiation on the basis of the measurement results obtained by the PTR (Nobel Prize awarded to him in 1918).
1913 Hans Geiger sets up the Radioactivity Laboratory and develops a counting tube to detect single radiation quanta.
1913 Walther Meissner starts low-temperature experiments and investigates the characteristics of liquid hydrogen and of other materials.
1915 Albert Einstein develops, in cooperation with Wander Johannes de Haas, an experiment (the only one of his scientific career as a theoretical physicist) to confirm the hypothesis of Ampère's molecular currents.
1920 Harald Schering develops a bridge method for the measurement of the capacity and the loss angle at high AC voltages ("Schering bridge").
1920 Ernst Gehrcke and Ernst Lau measure the fine structure of the H2 spectrum.
1924 Walther Bothe and Hans Geiger develop the coincidence measurement technique and demonstrate that the Compton effect is the scattering of a photon on an electron (Nobel Prize in physics awarded to Walther Bothe in 1954).
1925 Walther Meissner succeeds in liquefying helium in his low-temperature laboratory.
1925 Ida Tacke and Walther Noddack succeed in detecting a so far undiscovered element in the periodic table (atomic number 75, rhenium).
1928 Wilhelm Kösters introduces standard lamps for the interferential length measurement of gauge blocks.
1929 Walther Bothe and Werner Kolhörster demonstrate that cosmic rays are actually relativistic charged particles.
1932 Adolf Scheibe and Udo Adelsberger develop the first quartz clock in Germany.
1932 Walther Meissner and Rudolf Ochsenfeld discover the full expulsion of the magnetic flux from the inside of a superconductor (Meissner-Ochsenfeld effect).
1951 Ernst Engelhard develops a krypton lamp which enables a wavelength to be reproduced very precisely.
1957 New fundamental determination of the ohm (on the basis of a calculable inductance).
1959 Beginning of the official emission of time signals and of the standard frequency via the DCF77 transmitter in Mainflingen.
1967 The Forschungs- und Messreaktor (FMRB – Experimental and Research Reactor Braunschweig) is put into operation.
1969 PTB's first caesium atomic clock CS1 is ticking.
1972 First uniform value for the Josephson constant (measured by PTB and its sister institutes in the USA, Great Britain and Australia) determined.
1980 Suitability of the quantum Hall effect for the reproduction of the unit "ohm" detected.
1984 Electron storage ring BESSY I becomes primary radiation standard.
1986 PTB's second Cs atomic clock, CS2, the most precise clock of its time, is put into operation.
1987 First measurement of biomagnetic signals from the brain stem.
1987 Generation of the voltage unit "volt" achieved with the aid of a series array of 1400 Josephson tunnel junctions.
1990 The radiation-thermometric measurements performed at PTB provide the basis of the high-temperature range of the International Temperature Scale (ITS-90).
1993 "Metrological scanning tunnelling microscope" realized for the first time worldwide.
1995 First phase-coherent measurement worldwide of an optical frequency by direct comparison with a caesium atomic clock performed at PTB.
1996 As the first institution in Germany, PTB puts a 3T whole-body MR tomograph into operation.
2000 PTB's caesium fountain clock CSF1 contributes to the realization of International Atomic Time.
2006 First worldwide programmable 10-volt Josephson voltage standard in SINIS technology for tracing electrical AC quantities back to fundamental constants completed.
2010 New value for Avogadro constant from 28Si is a milestone on the way to the redefinition of the kilogram on the basis of fundamental constants.

PTB

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The Physikalisch-Technische Bundesanstalt, Germany's national metrology institute, is a scientific and technical higher federal authority falling within the competence of the Federal Ministry for Economic Affairs and Energy.

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Cover photo: PTB