PTB news

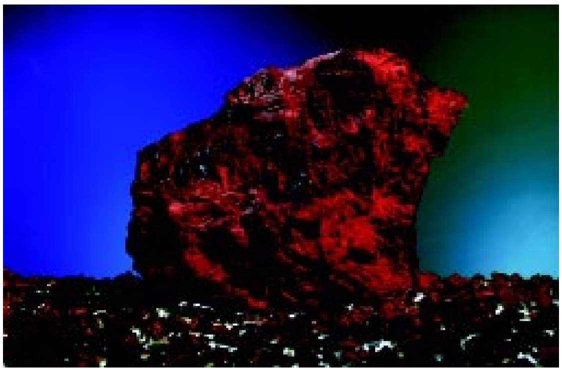
Metrology
Technology
Services
Cooperation

99.1

On Radon's Track

The radioactive noble gas radon causes about 40 % of the ionising radiation exposure of an individual. Consequently, the detection of elevated radon concentrations and reduction thereof are prominent tasks of environmental protection. PTB now offers reliable measuring techniques by the establishment of calibration facilities for radon detectors.

Radon originates from the decay of uranium, which can be found everywhere in the crust of the earth. A small amount of radon reaches the surface and is distributed in the air where radon and its radioactive progenies are inhaled by humans. In some regions, e. g., where granite is in the ground or considerable mining activities take place or special building materials are used, radon can accumulate in buildings up to levels which are relevant with regard to radiation protection regulations. The German radiation protection commission recommends to improve the conditions in buildings with radon concentrations exceeding 1000 Bq/m^3.



Uranium minerals like this stone from the uranium mining at Freiberg (Saxony) are sources of the radioactive noble gas radon

Several reference chambers from 0,05 m^3 to 21 m^3 are now available at PTB for the calibration of radon detectors. The chambers are used to control and adjust not only the radon concentration, but also environmental parameters such as air pressure, temperature, humidity, and aerosol concentration. The radon concentration is generated by standards of up to 2 MBq calibrated at PTB, which are lossfree introduced in small containers into the reference chambers. After a short time the radon is homogeneously distributed in the chambers by diffusion. The concentration decreases continuously as a result of the radioactive decay of radon with its half-life of 3,8 days.

Radon detectors can be calibrated with these facilities in the range from 100 Bq/m^3 to 100 kBq/m^3; the calibrations are traceable to PTB radon standards. In the range from 1 kBq/m^3 to 100 kBq/m^3, the relative calibration uncertainties are between 3,5 % and 5 %. Future work will be aimed at reduced uncertainties and an increased calibration range.

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100 Years of Radiometry

PTR
1899

1999
PTB

At the end of the last century, scientists at the Physikalisch-Technische Reichsanstalt (PTR) in Berlin laid the foundations of radiometry. In commemoration of this achievement the 3rd Hermann von Helmholtz Symposium of the PTB – successor to the PTR – was held as an international meeting dealing with the «Precision Measurement of Electromagnetic Radiation» in Berlin-Charlottenburg on 30 March 1999. On the evening before the Symposium, the new PTB synchrotron radiation laboratory was formally inaugurated at the electron storage ring BESSY II in Berlin-Adlershof.

Within a few years after the foundation of the Reichsanstalt in 1887, a team of PTR scientists (Holborn, Kurlbaum, Lummer, Pringsheim, and Wien) developed the electrically calibrated bolometer for absolute measurements of spectral radiant power, the «air thermometer» for the measurement of high temperatures, and the «electrically heated black body» as the source of high-temperature black-body radiation. At last, Lummer and Pringsheim succeeded in measuring the black-body radiation spectrum in 1899. Together with the correct black-body radiation law found by Planck in 1900, this work established a firm foundation of radiometry and radiation thermometry which is valid to this day. It was only during the last two decades that the use of the calculable synchrotron radiation emitted by electron storage rings allowed to extend radiometry to short wavelengths and thus to supplement radiometry based on black bodies.

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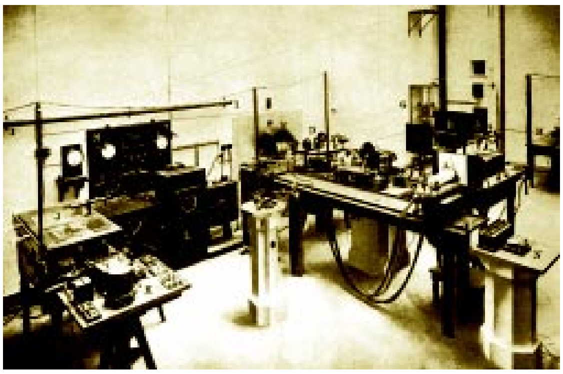

Black-body radiator in the Optical Laboratory of the Physikalisch-Technische Reichsanstalt in Berlin-Charlottenburg

Automatic Determination of Trunk Dimensions

In the past the volume of wood was usually determined directly in the forest by manual measurement of the trunks' lengths and diameters, using mechanical measuring means. Nowadays round wood measuring facilities are used, laser scanning the trunks by non-contact measurement, thus leading to lower measurement uncertainties. These new facilities were developed in close co-operation between the manufacturers and PTB.

View of the measurement area of a modern round wood measuring facility
The trunk diameters are determined with the help of laser beams during trunk feed

In Germany, about 14 million cubic metres of round wood such as spruces and firs are delivered per annum to sawmills for further processing. Formerly the volume of trunk wood was usually determined in the forest by manual measurement of the trunks' lengths and diameters using measuring tapes and calipers. This did not only lead to considerable labour costs – increasing the price of the wood – but also caused great errors of measurement due to differences in the handling of the measuring equipment. For example, the caliper jaws were often pressed too firmly against the trunks so that the measured values were lower than the true values. Moreover, when large numbers of trees had been felled and piled up, individual trunks were overlooked and thus not measured at all. In order to avoid these shortcomings, round wood measuring facilities based on non-contact measurements have been developed and are successfully employed today. They measure the minimum diameters by laser scanning in the region of the trunk centre. The trunk lengths required to obtain the wood volume are determined with the aid of special pulse generators.

The patterns of these round wood measuring facilities are subject to legal metrology control. The mandatory verification, which is required in Germany today, is likely to stay in force also after implementation of the European Directive for Measuring Instruments. For the determination of the diameter, the maximum errors amount to ± 2,5 mm for the arithmetic mean of 10 individual measurements and to ± 10 mm for the individual measurement. For the determination of the trunk length, the maximum permissible error is ± 1%, but not less than 5 cm. The pattern approval of round wood measuring facilities, which is performed by PTB, ensures that the facilities comply with the small maximum permissible errors on verification and that the measured values for the volume of wood provide a reliable basis for transactions between wood suppliers and sawmills.

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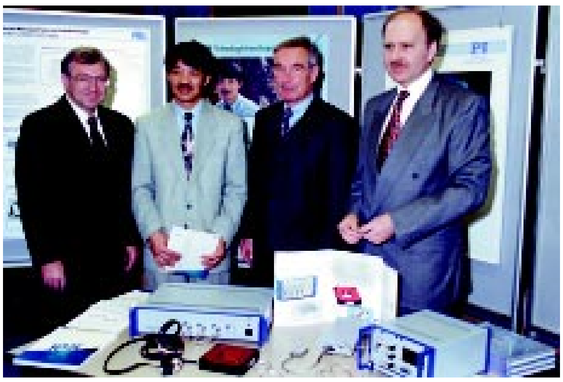
Technology Transfer Prize for Günter Wilkening and Xianbin Zhao



After the awards have been presented: Prizewinners Dr. Xianbin Zhao (next to left) and Dr. Günter Wilkening (right) with PI's president Dr. Karl Spanner (left) and Dr. Klaus Schuberth, president of the Chamber of Industry and Commerce of Braunschweig

The Chamber of Industry and Commerce of the city of Braunschweig has awarded its Technology Transfer Prize for 1998 to Dr. Günter Wilkening, head of the PTB department for micrometrology, and to Dr. Xianbin Zhao, a former guest scientist from China at PTB who is now employed with Physik Instrumente (PI).

The prize is awarded annually in recognition of the completed transfer and economic success of a newly developed product. The two scientists received the award – which they share with another prizewinner – for a capacitance position sensor with ultra-high resolution and reproducibility in the sub-nanometre range. The device is meanwhile applied with great success by PI in positioning stages for the micro-and nanotechnologies.

First Pattern Approval of Evidential Breath Analysers

The first pattern approval of evidential analysers to measure breath alcohol concentrations by PTB makes way for the application of breath analysers in traffic control, alternatively to the conventional determination of blood alcohol concentrations.

Following a recent change in German traffic law, intoxicated automobile drivers in Germany now can be charged and prosecuted for driving under influence of alcohol based on the alcohol concentration in either their blood or their breath as evidence. Therefore, the development, pattern approval and calibration of measuring devices for breath alcohol concentrations have gained importance over the past years. PTB has been engaged in breath alcohol analysis from the start: initially, as a member of an advisory commission; then, by casting the results of the expert opinion of the German Federal Health Agency into the standard DIN VDE 0405.

According to the standard all relevant quantities have to be measured simultaneously by two separate sensors. The breath temperature has to be measured and its influence on the result must be corrected. The minimum breath volume to be analysed has to be set according to age and sex of the test person. In order to reduce the uncertainties, these requirements essentially exceed the regulations of the corresponding recommendation of the International Organisation for Legal Metrology (OIML R126).

After the first pattern for an evidential breath alcohol analyser has been approved by PTB the periodical verification of the performance of the instruments must be realised in close cooperation with the legal metrological authorities to improve confidence and public acceptance.

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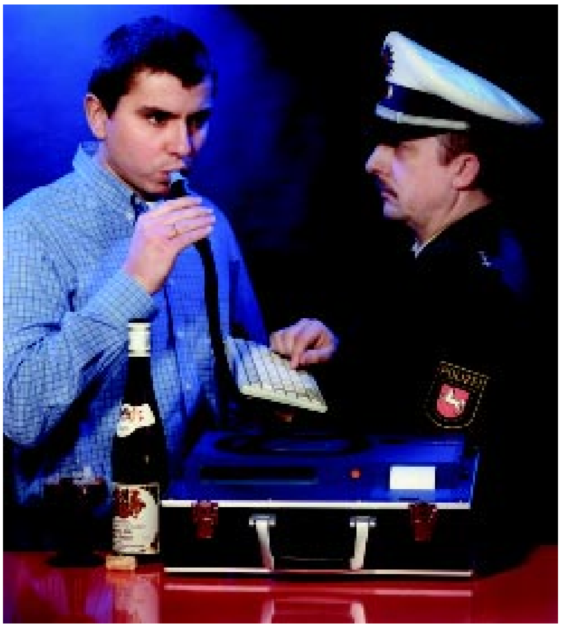

PTB has performed the first pattern approval of evidential analysers for the measurement of the breath alcohol concentration.

Probing System for Microscopic Structures

A stylus tip with a diameter below 50 µm is the heart of a novel probing system developed at PTB. Tiny structures on micromechanical parts can now be measured in a contacting mode.

The continuous miniaturisation of mechanical components often confronts dimensional metrology with so far unsolvable tasks. Optical techniques are commonly applied for the measurement of small structures, but their application is often restricted by the geometry of the features to be measured and the optical properties of technical surfaces. On the other hand, conventional tactile probes are limited by their minimum size of about 200 µm for the stylus tip diameter.

The novel opto-tactile probe developed at PTB allows contacting measurement of small structures with optimal accuracy. Its principle is based on the determination of the stylus tip position by a CCD camera. The stylus tip at the end of an optical fibre is illuminated through the fibre and its light spot is imaged onto the CCD chip. When contacting the workpiece, the fibre bends and the stylus tip is displaced relative to the camera. The resulting change in the position of the image on the CCD chip can be evaluated with submicrometre accuracy.

A fundamental advantage of the system is that the fibre can be extremely thin: fibre diameters below 30 µm and stylus tip diameters below 50 µm have been realised without any problem. The probing system is well suited for utilisation in various dimensional measuring instruments. Employed in a highly accurate coordinate measuring machine (CMM), measurement uncertainties of 0,2 µm for the diameter and of 0,3 µm for the form of a ring gauge were achieved.

The novel, patented system has been transferred to industry. It will contribute to the solution of difficult measurement tasks in the field of precision engineering and micro-mechanics. An example for an application which is both economically and ecologically important is the measurement of spray holes in engine injection nozzles.

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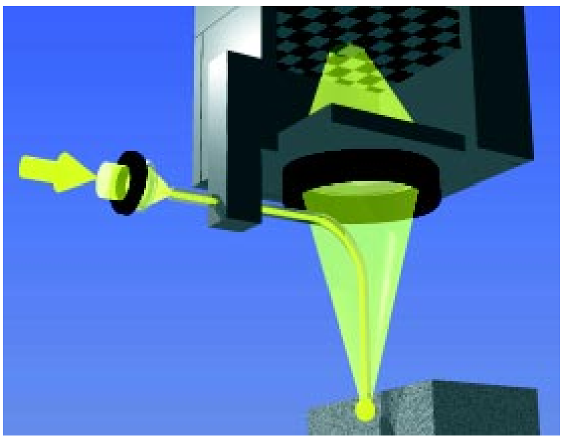
Schematic view of the opto-tactile probing system
The stylus tip located in the focus plane of the camera is illuminated through the fibre and imaged onto the CCD chip of the camera.



100 Years of Radiometry
(continued from page 1)

Along with modern heat-pipe and high-temperature graphite black bodies, PTB uses the electron storage ring routinely for radiometric and optical measurements and calibrations today. The radiometry laboratory of PTB at the storage ring BESSY I in Berlin-Wilmersdorf started operation 17 years ago and proved in 1984 that the storage ring can be operated as a primary radiator standard with calculable synchrotron radiation emission. The PTB laboratory has become a European centre of radiometry with a world-wide field of activity. This is demonstrated in particular by the work done in co-operation with the ESA and NASA space agencies in solar physics and x-ray astronomy during the last years.


Initial stage of the synchrotron radiation laboratory of PTB at the Berlin electron storage ring BESSY II in Berlin-Adlershof

The new laboratory at BESSY II, which was inaugurated on 29 March 1999, will enable PTB to comply with current and future demands in the field of optical and x-ray metrology. Examples are the support of the development of high-performance objectives for microlithography by the German optical industry and the development of novel methods of quantitative analysis for the quality control of high-purity semiconductor materials. The higher photon energies which are available at BESSY II as compared to BESSY I will also enable PTB to extend radiometry based on synchrotron radiation into the x-ray range and to perform basic investigations in the field of radiation protection.

The lectures given by international experts at the Helmholtz Symposium next day showed that the demand for radiometric and optical techniques of measurement is steadily increasing in particular at short wavelengths. These techniques are required by applications such as space-based astrophysical observations, extreme-ultraviolet interferometry or quantitative x-ray fluorescence analysis. Nevertheless, further development of radiometry is also necessary in the infrared to improve the reliability and accuracy of radiation thermometry and remote sensing, especially if small long-term variations are to be determined, for example changes in climatic or atmospheric conditions. In both the short- and long-wavelength spectral ranges PTB has established outstanding facilities which will enable it to meet the future requirements of industry and research.

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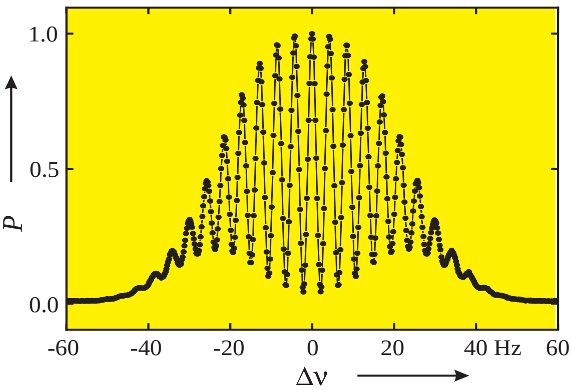
First Signals of PTB's Atomic Fountain Clock

A new atomic clock CS5 utilising laser-cooled caesium atoms is currently developed by PTB. The first signals of this clock have recently been recorded. In addition, after a recent upgrade, the primary clock CS1 now represents the most accurate continuously operating atomic clock in the world with an estimated standard uncertainty of $7 \cdot 10^{-15}$.

Continuous improvements of the realisation of the international atomic time scale (TAI) and the Universal Coordinated Time (UTC) derived from the scale are required by accurate measurements at the forefront of basic research and applied technology, such as the determination of the tiny movements of continental plates, the basic investigation of astronomical objects like pulsars, or the synchronisation of telecommunication networks.

After almost two decades of continuous operation, PTB's primary atomic clock CS1 has been refurbished. As a result of various improvements, the estimated relative standard uncertainty is now only $7 \cdot 10^{-15}$, which represents the world-wide highest accuracy of a continuously operating Cs atomic clock. Since July 1998, CS1 again contributes routinely to the TAI scale, together with PTB's other primary clocks CS2 and CS3.

In order to further increase the accuracy of primary clocks and time scales, PTB is setting up a new clock CS5 based on laser-cooled Cs atoms. A sample of 10^7 atoms are laser cooled to 2 µK and follow ballistic trajectories similar to the water droplets in a fountain. The slow atoms have an increased interaction time of about 0,5 s with the microwave radiation. This leads to a fiftyfold reduction of the width of the clock transition which is now routinely measured in CS5. Investigations of systematic frequency shifting effects will start in 1999 to evaluate the relative uncertainty which is expected as small as $1 \cdot 10^{-15}$. With both generations of clocks PTB is well-prepared to meet the challenges of the future.



Measured resonance signal P of the clock transition in CS5
The new atomic fountain clock CS5 is expected to represent the next generation of PTB's primary Cs atomic clocks.

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