PTB news
Scientific Newsletter
3
2021

Three times a year, PTB News provides topical information from the varied spectrum of activities of the Physikalisch-Technische Bundesanstalt (PTB) consisting of fundamental research, legal metrology and PTB's various activities in the service of the economy.

A neuromagnetic view through the skull

First noninvasive measurement of fast brain signals

Especially interesting for
- neurology
- magnetometry

Our brains process information via slow and fast brain currents. Up to now, it has been necessary to introduce electrodes into the brain to examine the latter. Within a cooperation between PTB and the Charité, these fast brain signals have been made visible from the outside for the first time – and a surprising variability has been observed. The measurements of these extremely small magnetic fields generated by the brain were made possible by a particularly sensitive sensing system for magnetic fields which was developed at PTB.

When information processing in the brain experiences disruptions, this often results in serious neurological diseases. Investigating signal transmission inside the brain is therefore the key to a better understanding of diseases such as Parkinson's or epilepsy. In this context, two noninvasive methods have established themselves: electroencephalography (EEG) and magnetoencephalography (MEG). Both methods detect the slow brain currents reliably, but not the fast ones.

Slow brain currents (postsynaptic potentials) occur when neurons receive signals from other neurons. However, if a neuron fires an impulse to other downstream neurons or to muscles, this generates fast brain currents with a duration of merely a thousandth of a second (so-called action potentials). Such fast brain currents that occur in response to individual sensory stimuli have now been made visible in the investigations conducted jointly by PTB and the Charité.

This was made possible by considerably reducing the intrinsic noise of the sensing system used. The magnetic field sensors – superconducting quantum interference devices (SQUIDs) – are immersed in liquid helium to cool them down to −269 °C. The insulation of the cooling vessel used for this purpose is

Conceptual image of a neural network. Information processing in the brain is one of the most complex processes in the entire body. (Picture credits: Adobe Stock / Ktsdesign)

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very elaborate and consists of so-called superinsulation which is made from aluminized foils. Even though aluminum is not ferromagnetic, electrons moving inside the metal generate magnetic noise which interferes with small magnetic fields of neurons, for instance. In this new approach, the superinsulation of the cooling vessel was implemented in such a way that its intrinsic noise was negligible. This enabled an increase in the sensitivity of the sensor technology by a factor of ten.

Measurements carried out after stimulating an arm nerve in healthy subjects confirmed that MEG is able to measure the fast stimulus responses. What was surprising, however, was that the fast brain currents were not uniform despite the constant stimulation. The brain currents varied from one stimulus to the next, independent of the slow brain currents. This suggests that the brain processes the information pertaining to the touch of a hand with surprising variability although all neural stimuli are of the same type.

The results open up new answers to fundamental neurological issues such as the influence of attention or tiredness on the processing of information by the brain. The new sensing system may also contribute to a deeper understanding and the better treatment of neurological diseases. ▪

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Scientific publication
G. Waterstraat, R. Körber, J.-H. Strom, G. Curio: Noninvasive single-trial analysis of human neocortical population spikes. Proc. Natl. Acad. Sci. U.S.A 118, 2017401118 (2021)

Imaging of antiferromagnetic domains

Magneto-Seebeck microscopy enables insight into switching mechanisms

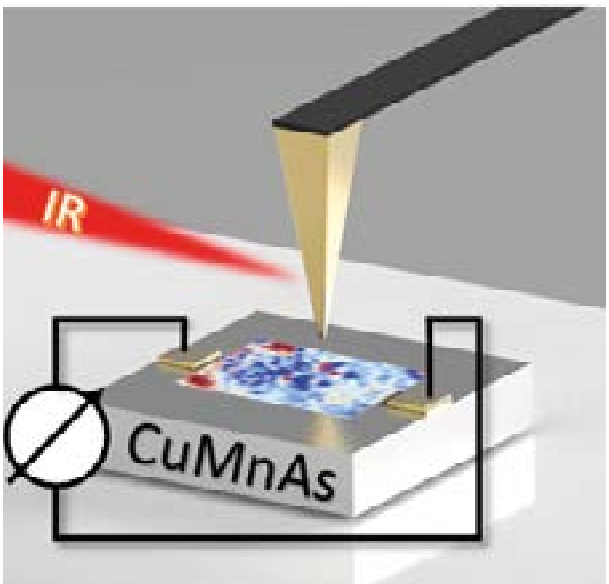
Especially interesting for
- materials sciences
- applications in spintronics

Internally, antiferromagnetic materials are magnetic, but the order of their microscopic moments changes directions between individual elementary magnets. This is why there is no net magnetic moment. The magnetic state of an antiferromagnet has now become measurable using magneto-Seebeck microscopy. This magnetic state can be used in applications such as spintronics.

Finding out that the elementary magnets in antiferromagnetic materials can be switched by applying an electric current has been a milestone for the use of antiferromagnets in spintronics (e.g., for extremely fast memory components). The antiferromagnetic order is characterized by the formation of domains. These domains have a well-defined magnetic orientation of the elementary magnets and a magneto-Seebeck coefficient that depends on the magnetization direction.

In collaboration with the University of Regensburg, a method has been developed to shed light on the local order of these domains. Switching domains using current pulses could be analyzed for the first time in the CuMnAs material system, which is particularly relevant for various applications. The method is based on atomic force microscopy (AFM). In order to measure the antiferromagnetic order, a metal-coated AFM tip is irradiated by an IR laser, which generates a very strong local temperature gradient. A voltage, which depends on the material, the temperature and the magnetization (magneto-Seebeck effect), occurs at this hot spot and is then measured. If the tip passes an area in which a domain is changing directions, this change is indicated by the measured voltage. Magneto-Seebeck microscopy can thus be used to characterize the antiferromagnetic order. This procedure was used to image not only the magnetic domains in a thin 20 nm antiferromagnetic layer of CuMnAs but also its manipulation by means of current pulses.

This new procedure for imaging antiferromagnetic domains with high spatial resolution will become an important instrument for future investigations of the fundamental physical properties of novel switching mechanisms, which are essential elements in the emerging field of antiferromagnetic spintronics.▪



Principle of magneto-Seebeck microscopy: An AFM tip is moved across the surface and couples IR radiation into the CuMnAs layer. There, a hot spot and a measurable voltage occur at the connections. This voltage is recorded as a function of the place. It is characteristic of the individual domain orientation at hand.

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Scientific publication
T. Janda, J. Godinho, T. Ostatnicky et al.: Magneto-Seebeck microscopy of domain switching in collinear antiferromagnet CuMnAs. Phys. Rev. Mater. 4, 94413 (2020)

On the path to a "nanometer standard"

Absolute measurement of the thermal expansion and compressibility of single-crystal silicon

Especially interesting for
- materials characterization
- fundamentals of metrology
- nanoscale length measurement

At PTB, absolute length measurements on a single-crystal silicon gauge block have been performed using imaging interferometry. These measurements have a smaller measurement uncertainty than all previous measurements. They provide more accurate values for the CODATA reference data and are valuable for a new secondary realization of the meter.

Since it was necessary to have a reference material for high-accuracy measurements of thermal expansion, a large number of measurements used to be performed on silicon over a wide temperature range. Due to its diamond-like crystalline structure, single-crystal silicon expands uniformly in all spatial directions, meaning that it is isotropic with regard to thermal expansion. In addition, high-grade silicon is readily available at an industrial scale.

As early as six years ago, PTB had already presented results of thermal expansion measurements between 7 K and 293 K obtained by means of imaging interferometry. A systematic deviation from the CODATA reference values was, however, noticed in this temperature range. In contrast to dilatometric measurements obtained by others, PTB's results were derived from absolute length measurements. The present thermal expansion study is based on this work. In this study, the temperature range has been extended to 320 K and the measurement uncertainty reduced. In addition, the study includes the simultaneous determination of the compressibility of silicon.

The measured data were analyzed by means of a new method that provides for the fact that the thermal expansion coefficient (calculated by derivation) is a quantity that is sensitive to the data evaluation model chosen. The approach is based on Bayesian model averaging (BMA) and allows different models to be dealt with at the same time and also to be taken into account when calculating model probabilities.

The results have shown that in the temperature and pressure ranges covered, the thermal expansion coefficient hardly depends on the ambient pressure. The new measurements provide more accurate values than the previous reference values. Furthermore, the measurement uncertainty is smaller than that of previously obtained results by up to one order of magnitude.

Since the latest revision of the *mise en pratique* for the definition of the meter in the SI refers to the lattice spacing of silicon as a basis for nanoscale secondary realization methods for the meter, these findings can also be used in this context.■

Gauge block made of single-crystal silicon.
Dimensions: 197 mm × 35 mm × 9 mm

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Scientific publications
G. Bartl, C. Elster, J. Martin, R. Schödel, M. Voigt, A. Walkov: Thermal expansion and compressibility of single-crystal silicon between 285 K and 320 K. Meas. Sci. Technol. 31, 065013 (2020)

J. Martin, G. Bartl, C. Elster: Application of Bayesian model averaging to the determination of thermal expansion of single-crystal silicon. Meas. Sci. Technol. 30, 045012 (2019)

Diode lasers for optical metrology

Iodine-stabilized diode lasers could replace gas lasers as wavelength standards

Especially interesting for
- manufacturers and users of laser interferometers and devices for length measurement
- calibration laboratories
- optical metrology

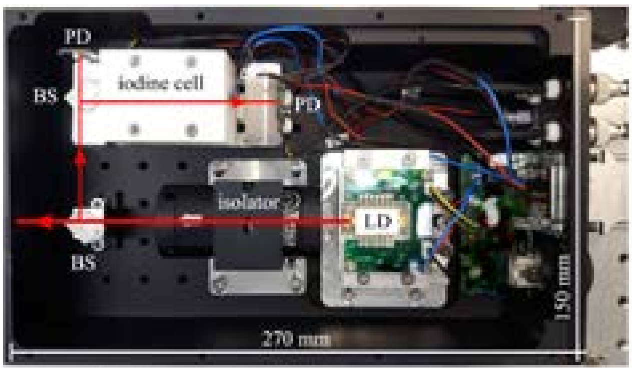
In collaboration with an industrial partner, PTB has developed and assessed a very compact wavelength standard. This standard is based on a diode laser whose frequency is stabilized to transitions of the iodine molecule. In the future, this type of lasers could replace power-intensive and bulky helium-neon lasers as a wavelength standard for interferometric length measurement.

Helium-neon lasers with a wavelength of 633 nm have been used for a long time as wavelength references for industrial interferometric length measurements. With comparatively little effort, they can achieve a relative accuracy of 10^{-8}, which corresponds to an uncertainty of 10 nm per meter and is absolutely sufficient for most applications. This technology is, however, obsolete, and the number of manufacturers has been constantly decreasing. Moreover, compared to modern diode lasers, these gas lasers are bulky, they need high voltage, and they exhibit rather poor efficiency as well as a low output power.

Alternative solutions must keep the wavelength of 633 nm to make it possible to continue using the large number of existing interferometers for length measurement seamlessly. For this reason, diode lasers are a suitable solution, although their inherent wavelength accuracy is not sufficient. This is where stabilization with iodine comes into play: Iodine molecules have numerous absorption lines in the relevant wavelength range. These absorption lines can serve as a wavelength reference.

A special laser diode chip (with internal optical wavelength selection at 633 nm) has been combined with an iodine cell of only 3.3 cm in length in a housing of 27 cm × 15 cm. This has been undertaken by Toptica Photonics AG, a laser manufacturer, within the scope of a project funded by the German Federal Ministry of Education and Research. The laser frequency is automatically stabilized at a defined Doppler-broadened iodine absorption line. A comparatively high power of approx. 5 mW is available at the output of an optical fiber. The device was evaluated with an optical frequency comb against atomic clocks of PTB. This evaluation yielded a relative instability of less than 10^{-10} for averaging times of more than 10 s. This is considerably less than the values provided by commercially available helium-neon lasers with simple stabilization. The absolute frequency obtained was in agreement with expected values. The line shape and the stabilization were modelled to be able to easily predict the absolute frequency and stability when other iodine lines are selected.

Integrated with micro-optical elements into a small housing (only a few centimeters in size), the prototype has the potential to enable very compact and accurate interferometers in the future.▪



Top view of the prototype – the optical path is indicated by the red arrows with the laser diode (LD), the beam splitter (BS) and the photodetectors (PD).

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Scientific publication
F. Krause, E. Benkler, C. Nölleke, P. Leisching, U. Sterr: Simple and compact diode laser system stabilized to Doppler-broadened iodine lines at 633 nm. Appl. Opt. 59, 10808–10812 (2020)

A benchmark for single-electron circuits

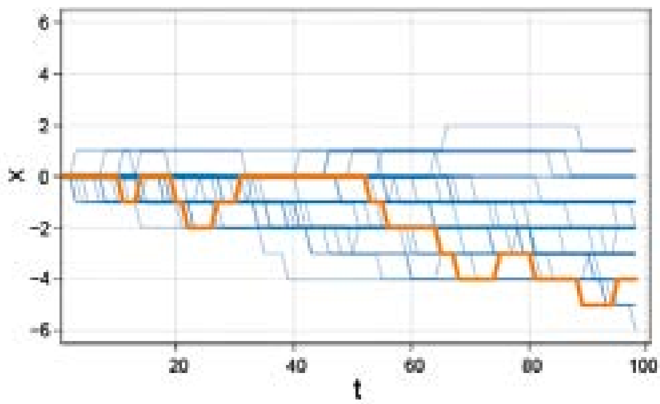
Methodology for a universal description of the accuracy of quantum circuits

Especially interesting for
- nanotechnologies
- quantum information processing
- electrical quantum metrology

Manipulating individual electrons with the goal of employing quantum effects promises qualitatively new applications in electronics. However, these single-electron circuits, which are governed by the laws of quantum mechanics, exhibit statistical deviations from error-free operation. This results in a fundamental uncertainty that is essential to understand and to quantify for further developments. To this end, PTB and the University of Latvia have collaborated to develop a statistical testing methodology.

Single-electron circuits are being developed as electric-current quantum standards and are already being used in quantum-computer prototypes. In these mesoscopic quantum circuits, interactions and noise-related processes impede the investigation of fundamental uncertainties. This therefore represents a considerable challenge for metrology at the highest level of precision.

In the field of quantum computers, a testing procedure is frequently used in which the operating principle and the accuracy of the entire circuit are evaluated via the accumulation of errors following a sequence of operations. Based on this, researchers from PTB and the University of Latvia have now developed a benchmark for single-electron circuits. Here, the circuit's accuracy is described by the random steps of an error signal recorded by an integrated sensor while the circuit repeatedly executes an operation. The statistical analysis of this sequence, which is also called the "random walk", can be used to identify the



Simulated developments of possible random-walk progressions of the error signal x across the number t of repetitions of the circuit operation, taking the counting statistics of the error signal that was measured experimentally into account. The orange curve emphasizes the example of one of these possible progressions. The linewidths of the blue curves correspond to the statistical frequencies of each of the assumed states.

rare but unavoidable errors that occur when individual quantum particles are manipulated.

By means of this "random-walk benchmark", the transfer of individual electrons was investigated in a circuit consisting of single-electron pumps. These single-electron pumps were developed at PTB as a primary standard for realizing the ampere, an SI base unit. In this experiment, sensitive charge detectors record the error signal with single-electron resolution. The statistical analysis made possible by counting individual particles not only shows fundamental limitations of the circuit's accuracy induced by external noise and temporal correlations but also provides a robust measure of assessing errors in electrical quantum metrology.

The methodology developed within the scope of this work provides a rigorous mathematical foundation for validating quantum standards for electrical quantities and opens new paths for the development and analysis of the operating principle of complex quantum systems.▪

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Scientific publication
D. Reifert, M. Kokainis, A. Ambainis, V. Kashcheyevs, N. Ubbelohde: A random-walk benchmark for single-electron circuits. Nat. Commun. 12, 285 (2021)

Radiation protection for ultrashort pulse lasers

PTB has been contributing to the modification of legislation by performing radiation protection measurements on its new ultrashort pulse laser machine

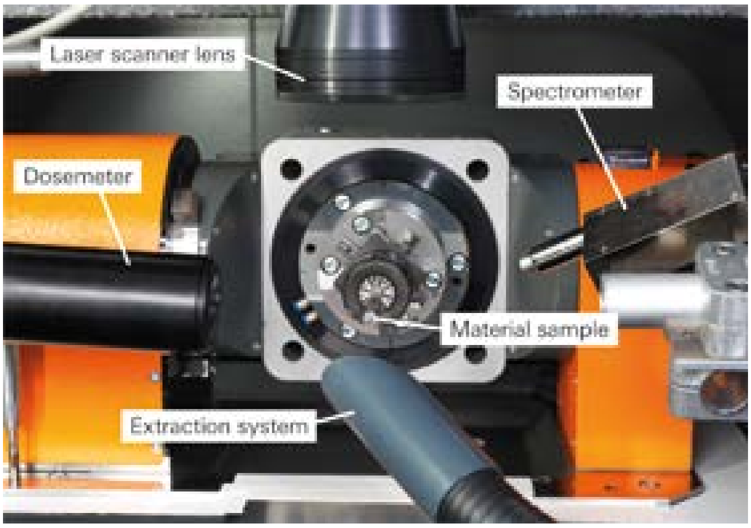
Especially interesting for
- materials processing
- radiation protection

Ultrashort pulse lasers in which an individual pulse only lasts a few picoseconds are increasingly being used in materials processing. Since these devices may generate undesired X-rays, the German Radiation Protection Act has made them subject to prior authorization since 20 May 2021. PTB has contributed to this legal amendment by performing exhaustive radiation protection measurements on its new ultrashort pulse laser machine.

Ultrashort pulse (USP) lasers are used, for example, for cutting Gorilla Glass for cell phone displays or for drilling injection nozzles for lower-emission engines. In these processes, single laser pulses are fired at a workpiece with very high intensities in the range of 10^{15} W/cm^2. This generates a plasma that removes material. Pulse durations in the picosecond range allow accurate material removal without heating up the surrounding material.

However, high-energy plasma electrons accelerated by laser-plasma interactions can emit X-rays with photon energies of more than 5 keV. Due to this undesired emission, USP laser machines are subject to the German Radiation Protection Act (StrlSchG). The legal regulations for USP laser machines within the scope of the Radiation Protection Act have to be specified in more detail. The first amendment makes an authorization procedure mandatory for operating a USP laser machine. Moreover, it specifies that an ambient dose rate limit of 10 µSv/h at a distance of 10 cm from the surface of the protective housing has to be observed.

PTB has contributed to this legal amendment by performing exhaustive radiation protection measurements which were carried out within the scope of the authorization application for its modern USP laser machine. For this purpose, PTB's radiation protection experts worked in close collaboration with their colleagues from the Precision Engineering Division who are experienced in operating the machine. Measuring the strongly pulsed X-ray emissions is demanding due to typical photon energies that are in the range from less than 5 keV up to approx. 30 keV. The energy range of commercial measuring equipment starts at around 20 keV; typical X-ray devices start at around 25 keV. The radiation was measured using traceable measuring equipment, and various processing steps, materials, and laser settings were examined regarding the generated photon energy and X-ray dose rate. These detailed investigations were made necessary by the complexity and nonlinearity of the laser-plasma interaction.



Example of measurement setup with a spectrometer and a dosemeter at PTB's USP laser machine. The material used for this measurement was a tungsten rod.

At the same time, PTB, together with the Bundesanstalt für Materialforschung und -prüfung (German Federal Institute for Materials Research and Testing) (BAM) is taking part in two related departmental research projects of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), which were assigned by the Federal Office for Radiation Protection. The objective of these projects is to gain reliable data from traceable measurements in the above-mentioned radiation fields and to develop testing concepts to ensure radiation protection when working with USP laser machines.

Based on the data obtained, PTB advises the BMU, the German Commission on Radiological Protection, as well as the Bund-Länder-Ausschuss (Committee of the Federal German Government and of the federal states) regarding this new topic. PTB is thus supporting the development of an urgently needed uniform directive on the testing of protection against ionizing radiation when working with USP laser machines. And it is therefore also supporting the corresponding adjustment of the legal and other regulations.▪

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The Radiation Protection Act (StrlSchG) (in German only)
https://www.gesetze-im-internet.de/strlschg/

The Radiation Protection Ordinance (StrlSchV) (in German only)
https://www.gesetze-im-internet.de/strlschv_2018/

Aging of lithium-sulfur batteries

Insight into atomic processes in various charging states

Especially interesting for
- electromobility
- smart grids
- manufacturers of mobile devices
- battery manufacturers

At present, lithium-sulfur batteries cannot reach their theoretical maximum capacity and lifetime. According to time-resolved, species sensitive and traceable measurements performed for sulfur at the BESSY II synchrotron radiation source, the accumulation of polysulfides at the anode could be the main reason for these shortcomings.

Lithium-sulfur batteries could be an environmentally friendly alternative to conventional lithium-ion batteries. With lithium as the anode and sulfur as the cathode material, they could offer enhanced capacity and longer lifetimes. In addition, sulfur is abundant, making it inexpensive, and more environmentally friendly. Moreover, with sulfur being a lighter element than the heavy metals such as mangane, nickel and cobalt which are used in conventional lithium-ion batteries, the theoretical energy density of a Li/S cell is considerably higher than that of lithium-ion batteries. Whereas conventional lithium-ion batteries reach 220 Wh/kg, LI/S cells can theoretically reach 2500 Wh/kg. Only 25 % of this energy density has, however, been achieved up to date.

In addition, such batteries age fast and cannot yet attain the minimum number of 1000 charge-discharge cycles required by industry.

One of the reasons for this fast decrease in their capacity was assumed to be the formation of polysulfides. Polysulfides are chain-like molecules consisting of lithium and sulfur – i.e., of those elements that ensure energy storage in cell chemistry. When polysulfides dissolve in the electrolyte, they are no longer available to store energy, which leads to a decrease in capacity. Polysulfides are formed at the cathode while the battery is in operation. They then dissolve in the electrolyte and move on towards the anode. When the battery is being recharged, they accumulate at the anode in ever greater numbers with each charging cycle.

The investigations carried out at PTB have shown for the first time how the polysulfide molecules move between the electrodes and, in particular, how they accumulate at the anode with each new charging cycle. The time-resolved measurements performed on the cell in operation (operando analysis) allow changes at the atomic level to be attributed to the electric properties of the battery. In addition, the change in the polysulfide molecule length, which has a significant influence on solubility and reactivity, was also determined.

The measurements were carried out in Berlin, at the BESSY II synchrotron radiation source. They used near edge X-ray absorption fine structure analysis (NEXAFS) as well as quantification without a reference sample by means of X-ray fluorescence analysis (XFA) to analyze sulfur in the dissolved polysulfides. These procedures are very accurate, traceable to the SI and can dispense with reference material.

The results have shown that it is not primarily the formation of polysulfides, but rather their moving and accumulating at the anode that are responsible for the capacity decrease. This leads to new strategies for cell design, such as the use of polysulfide-impermeable separators.▪

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Scientific publication
C. Zech, P. Hönicke, Y. Kayser, S. Risse, O. Grätz, M. Stamm, B. Beckhoff: Polysulfide driven degradation in lithium-sulfur batteries during cycling – quantitative and high time-resolution operando X-ray absorption study for dissolved polysulfides probed at both electrode sides. J. Mater. Chem. A 9, 10231–10239 (2021)

Novel mirror holder

Especially interesting for
- optics
- manufacturers of optomechanical components

In some optical assemblies, it is necessary to independently adjust two beams which are separated by a few millimeters. Such situations make it desirable to perform the adjustment of both beams with a single mirror holder to reduce the beam spacing and the total mechanical footprint while the mechanical stability is improved. PTB's concept of a double mirror holder offers a simple solution to this problem. The two D-shaped mirror halves are kept in one module but can be adjusted independently of each other. Both half mirrors therefore have the same stability. (Technology Offer 525) ▪

a) Front view of the mirrorholder b) rear view of the mirrorholder

Advantages
- independent adjustment of two beams
- reduced beam spacing and mechanical footprint
- high mechanical stability

Particle flow charging

Especially interesting for
- explosion protection
- the pharmaceutical industry
- the food and petroleum industry

For the explosion protection of industrial plants, it is extremely important to know the electrostatic charging behavior of particles (e.g., powders) during transport in flows. The new technology is based on two different measurements which use particle image velocimetry (PIV). A test channel is located between two defined measurement sections. An electrostatic field is applied to this test channel which affects the particle trajectories depending on their charge. The change in charge between the two measurement sections is determined by observing the individual particles in these sections. This procedure allows the electrostatic charging of laminar or turbulent flows (powders or liquids) to be measured online and non-invasively. It may also contribute to enhancing the safety of many transport processes. (Technology Offer 527) ▪

Function principle of the measurement procedure for detecting the electrostatic charging of powder flows

Advantages
- measurement of the electrostatic charge distribution of flows
- applicable to turbulent flows
- suitable for both powders and liquids

Artefacts for the determination of mass

Especially interesting for
- manufacturers of weighing instruments and weights
- metrology institutes

When calibrating mass standards, it is important to determine the mass of substances that may have accumulated on the surface of the standard. The mass of these substances can be determined by means of sorption artefacts that consist of several individual disks. The values gaines in this way are taken into account in the form of a correction to increase the measurement accuracy. A new concept from PTB allows each of the disks to be handled efficiently and cleaned simply. This was achieved by a tilting- and rocking-resistant bearing by means of which the individual elements can be assembled and taken apart again. (Technology Offer 519) ▪

Schematic representation of a sorption artefact consisting of three disks.

Advantages
- tilting-resistant, reproducible stacking
- increased measurement accuracy
- user-friendly handling

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Appointments and Awards

Cornelia Denz
Prof. Dr. Cornelia Denz, a physicist from the University of Münster, will become the new President of PTB on 1 May 2022. The current President, Prof. Dr. Dr. h.c. Joachim Ullrich, who has held the presidency since 2012, will leave at that time when he retires. Cornelia Denz will be the first woman to lead PTB in the institute's 135-year history. She was appointed to this top position in German metrology by Peter Altmaier, Germany's Federal Minister for Economic Affairs and Energy. PTB is an institute under the auspices of his ministry. With this appointment, the Ministry followed the unanimous proposal of a search committee made up of prominent representatives from science and industry.

Frank Härtig
Dr.-Ing. Prof. h.c. Frank Härtig, Vice President of PTB, assumed the presidency of the International Measurement Confederation (IMEKO) on 3 September 2021. Over the next three years, he will spearhead this non-governmental federation of 42 member organizations concerned with the worldwide advancement of measurement technology. PTB will therefore host the 2024 IMEKO World Congress which will take place in Hamburg.

Jörn Stenger
Dr. Jörn Stenger, a Member of the Presidential Board, is the new Chairperson of EURAMET, the association of European metrology institutes. He was elected to this position, which he is now taking on, during EURAMET's General Assembly in 2020. His position as EURAMET's Chairperson will last until 2024.

Frank Lienesch
Dr. Frank Lienesch, Head of Division 9, *Legal and International Metrology*, is the new Vice President of COOMET (Euro-Asian Cooperation of National Metrology Institutions). He was elected to the position for three years at the celebratory session to mark the 30th anniversary of COOMET on 15 June 2021.

Piet O. Schmidt
Prof. Dr. Piet O. Schmidt, Head of the *QUEST Institute at PTB*, has received an ERC Advanced Grant. With this grant, the European Research Council (ERC) is supporting a project for the first realization of optical clocks which use quantum techniques to control highly charged ions and measure them via laser spectroscopy. The project will run for five years and is being supported with 2.5 million euros in funding from the ERC.

Nearly 16 million euros going toward quantum computer research

The German Federal Ministry of Education and Research (BMBF) is providing the MIQRO joint project with 15.8 million euros in funding. In this project, a quantum computer is to be developed which is based on high-frequency-controlled ions. In addition to PTB, Leibniz University Hannover, the University of Siegen, Heinrich Heine University Düsseldorf, and the QUARTIQ and eleQtron companies are also taking part as associated partners. This four-year project intends to scale the quantum computer that it will develop and operate to one thousand quantum bits after its completion, paving the way toward diverse industrial and academic applications which will surpass the abilities of classic super computers. (Contact: Christian Ospelkaus, +49 531 592-4740, christian.ospelkaus@ptb.de)

Hydrogen innovation laboratory

The hydrogen innovation laboratory called "Nachhaltige Verbrennungskonzepte" (sustainable combustion concepts) has been launched. The project is entering its three-year implementation phase with funding provided by Lower Saxony's Ministry of Science and Culture totaling 1.2 million euros. PTB is participating alongside Leibniz University Hannover, TU Braunschweig, TU Clausthal and Jade University of Applied Sciences in Wilhelmshaven. (Contact: Ravi Fernandes, +49 531 592-3300, ravi.fernandes@ptb.de)

Underground laboratory turns 30

UDO, PTB's underground laboratory, has now been in existence for 30 years. As it has one of the lowest radiation levels in the world, it offers optimum conditions for environmental radioactivity monitoring and, thus, also indirectly has optimum conditions for the observation of climate change and its parameters by means of the radon tracer method. Originally, the laboratory was set up in the Asse II mine in 1991. In 2011, it was moved to a salt mine belonging to esco (Kali + Salz AG) in Grasleben. In the last 30 years, the UDO laboratory has studied and calibrated many of the dosimetry systems used in Europe. (Contact: Faton Krasniqi, +49 531 592-6223, faton.krasniqi@ptb.de)

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Federal Ministry for Economic Affairs and Energy

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.