

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.

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Mobile atomic clock used as an altimeter

Great potential for uniform measurements of the Earth's surface

Especially interesting for

- geodesy
- fundamental research in physics

The passage of time depends on the position of the observer in a gravitational potential. For a large mass such as the Earth's, this effect can be measured by means of high-precision atomic clocks and used to determine the difference in height between two clocks. For the first time, PTB's portable strontium optical clock has allowed flexibility in the selection of the place where one of the clocks is operated.

Optical atomic clocks are complex devices and, until recently, were found only in the laboratories of some large research institutes. Greater accuracy can be achieved by relying on an optical transition that can be excited using visible light in the atom rather than on a transition triggered by microwaves – as is the case in a cesium clock. Optical clocks have brought us one step closer to detecting differences in height as small as one centimeter.

For the first measurement campaign, PTB's mobile strontium optical clock was placed in its car trailer and driven to the Modane Underground Laboratory (France), which is located halfway through the Fréjus tunnel on the border between France and Italy. There, a team from PTB and from NPL, the national

metrology institute of Great Britain, operated the clock and transmitted its frequency via a 150 km fiber-glass link to INRIM, the national metrology institute of Italy, in Turin, where a second atomic clock was used to measure the frequency of the strontium clock. A second (subsequent) comparison of the two clocks at INRIM allowed the change in frequency of the strontium clock to be determined via the height difference between LSM and INRIM, which amounts to about 1000 meters. A relative change in frequency of approx. $1 \cdot 10^{-13}$ was then observed. By multiplying this change in frequency by the squared speed of light, one obtains the underlying change in potential. The exact difference in the gravitational potential had previously been determined by the University of Hannover with conventional geodesic measurement methods. The results of the two measurements were consistent.

For the new method to become competitive compared to established measurement methods, the portable clocks will have to be improved further. However, it is expected that the new method will



Optical clock in its transport container and optical components for frequency transmission at the LSM underground laboratory.

be able to cover long distances with high spatial resolution and without loss of accuracy. Measurements of the gravitational potential improved in this way may help detect effects such as the displacement of ice sheets and general changes in mass (e.g. of ocean water) more accurately. Such data are crucial for models, since they can contribute to a better understanding of global climate change and to predicting changes. ■

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Scientific publication

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Mechanical characterization of nanopillars

Accurate correction of indentation results from nanoobjects

Especially interesting for

- developers of nano-force sensors
- manufacturers of nanostructures for energy generation and manufacturers of LEDs
- nanoindentation, materials testing devices

Pillar-like nanoobjects can now be characterized mechanically using the indentation technique. This has been made possible by a novel evaluation method developed at PTB and by a correction procedure for the compressibility of the columns.

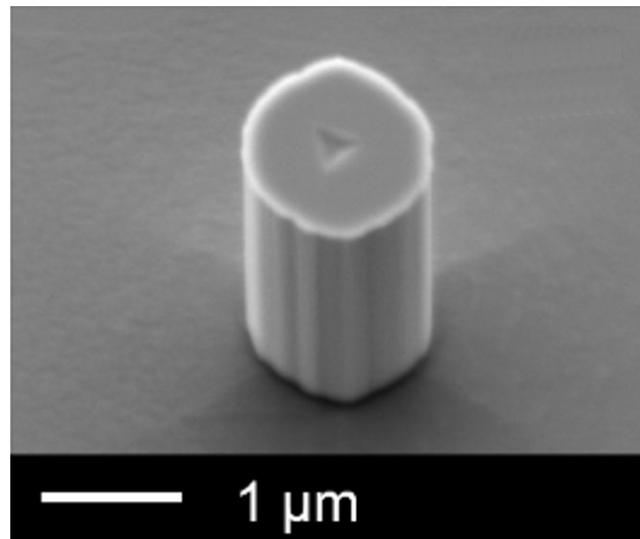
Micro- and nanopillars made of various semiconducting materials are currently being extensively investigated with regard to their properties for energy harvesting, energy storage and light emission (LEDs). When harvesting energy, the mechanical properties (elasticity and hardness) of the flexible columns play an important role. The nanoindentation technique allows the extraction of the mechanical properties of objects in the micro- and nanometer ranges. Here, a fine indenter (usually made of diamond) that has a prescribed pyramidal shape (Berkovich, Vickers) is pressed into a surface. The indentation depth is acquired during the loading and unloading procedures.

For the indentation of micropillars with a relatively high aspect ratio (height to diameter), PTB's initial measurements revealed a considerably smaller indentation modulus than that of the original material, and an unusual dependence of

the modulus on the indentation depth was observed. The initial analyses seem to suggest that this unexpected dependence of the indentation modulus on the indentation depth may be caused by the rigidity of the micropillars, which has not been taken into account so far. The rigidity depends not only on the radius of the columns, but also on their height. The geometrical parameters have been determined by means of scanning force microscopy. Taking the rigidity of the pillars into account, it was revealed that the indentation modulus depends only to a very small degree on the indentation depth and that it is in excellent agreement with the modulus of the original material.

This correction procedure, which was developed at PTB, has been experimentally confirmed on micropillars consisting of crystalline silicon and gallium nitride manufactured by the Institut für Halbleitertechnik (IHT) of TU Braunschweig. The diameter of the columns was measured at IHT by means of scanning electron microscopy, while the height was measured at PTB by means of confocal laser scanning microscopy.

The extended evaluation approach enables a reliable determination of me-



Scanning electron microscopic image of a typical GaN pillar after a nanoindentation measurement with a Berkovich indenter

chanical properties and thus supports the further development of innovative pillar-based micro- and nanostructures. ■

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Scientific publication

Z. Li, S. Gao, F. Pohlenz, U. Brand, L. Koenders, E. Peiner: *Determination of the mechanical properties of nano-pillars using the nanoindentation technique*. *Nanotechnol. Precis. Eng.* 3, 182–188 (2014)

Photoionization of gases

Measuring atomic cross sections with synchrotron radiation

Especially interesting for

- atomic and plasma physics
- solar and atmospheric research
- X-ray diagnostics
- gas analysis

In collaboration with Fraunhofer IPM in Freiburg/Breisgau, interaction cross sections for the photoionization of noble gases in the VUV spectral range have been measured at PTB's Metrology Light Source (MLS). The results have allowed the existing datasets to be extended, and have smaller uncertainties and reliable metrological traceability to the International System of Units (SI). They can be used for applications in solar and atmospheric research, for the characterization of X-ray lasers and for the analysis of combustion gases.

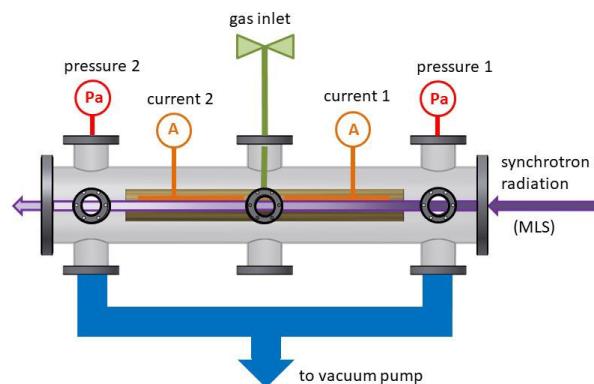
For the measurements, a double ionization chamber was developed at IPM and used at the MLS with synchrotron radiation in a wavelength range from 25 nm to 90 nm. The chamber consists of a gas volume at pressures ranging up to a few 10 Pa, where photoabsorption causes the incident radiant power to be attenuated and photoelectrons to be emitted – specifically, positively charged photoions are generated. Since these photoions are detected after being electrostatically extracted at two consecutively arranged anodes, it is possible to measure the light attenuation and thus to determine the

cross section for photoabsorption and photoionization. Furthermore, the two ion signals provide evidence of the incident radiant power.

During the experiments carried out at the MLS, the double ionization chamber was thoroughly characterized, with a specific focus on the influence of pressure gradients on the signals between the synchrotron radiation entering and exiting the chamber. The relative standard measurement uncertainties for the photoionization cross sections of He, Ne, Ar, Kr, and Xe around a few 10^{-3} are up to one order of magnitude lower than those from previously available data and are in excellent agreement with them within the combined uncertainties.

The results have already been used to validate the measurement data obtained with a double ionization chamber of the same type; this chamber was used in the SolACES module of the International Space Station (ISS) from 2008 to 2017 to investigate solar radiation. Moreover, the new interaction cross sections represent an improved basis for the quantitative detection of free-electron laser radiation using gas monitor detectors optimized specifically for this application. These datasets are also very important for the de-

velopment of a gas analysis method that is traceable to the SI. ■



Representation of the double ionization chamber for the measurement of atomic photoionization cross sections with synchrotron radiation at the Metrology Light Source (MLS)

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Scientific publication

R. Schaefer, A. Gottwald, M. Richter:
Traceable measurements of He, Ne, Ar, Kr, and Xe photoionization cross sections in the EUV spectral range.
J. Phys. B: At. Mol. Opt. Phys. 51, 135004 (2018)

pH of sea water

Results of different measurement procedures made comparable for the first time

Especially interesting for

- oceanography
- climate research

In cooperation with the Leibniz Institute for Baltic Sea Research Warnemünde, pH values of average-salinity sea water (5 to 20 g/kg sea water) have been measured at PTB for the first time

in such a way that they can be traced to PTB's primary pH standard. This ensures comparability of pH values measured in the sea, which is indispensable for applications such as the reliable quantification of sea water acidification.

CO₂ emissions are a problem not only for the global climate but also for the oceans. Carbon dioxide dissolves in sea

water, releasing hydrogen ions that lead to acidification. This has an impact on most biochemical and biological processes that take place in sea water; coral growth, for instance, is extremely sensitive to acidification. Long-term measurements in areas such as the North Pacific near Hawaii have shown that the pH value is presently decreasing by approx. 0.003 per year; the uncertainty of the most accurate pH

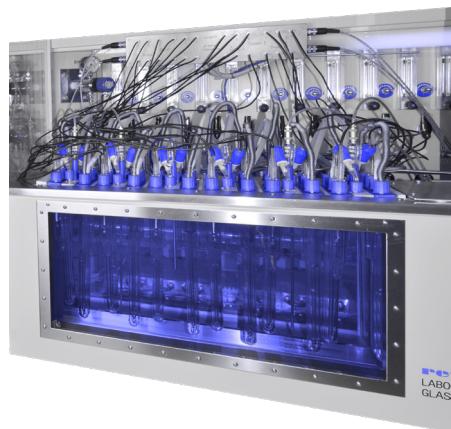
measurements currently available is approx. 0.002.

Moreover, the fact that different definitions of pH exist makes it difficult to compare the measurement results. In metrology (and in its associated industrial applications), the pH value is measured electrochemically. The measurements are based on the fact that an electrode submerged in an aqueous solution generates a measurable voltage compared to a reference electrode; this voltage is determined by the free hydrogen ions present in the solution. This electrochemical procedure allows not only the pH value, but also the so-called pH_T value to be measured. The index T stands for "total" and indicates that, in addition to hydrogen ions, hydrogen sulfate ions also contribute to the transfer of hydrogen ions, which is particularly relevant in sea water. In oceanography, an optical method has established itself for the measurement of the pH_T value. In this method, a dye with a pH-dependent absorption spectrum is added to the sea water.

Within the scope of a cooperation project between PTB and the Leibniz Institute for Baltic Sea Research Warnemünde (IOW), pH_T values obtained by means of the optical method have been linked to the metrologically defined – i.e. electrochemically measured – pH_T value for the

first time. This took place for the salinity that is typical of the Baltic sea, namely 5 g to 20 g per kilogram of sea water, and at temperatures ranging from 5 °C to 45 °C. After having developed a procedure together with IOW, PTB produced artificial sea water standards against which the pH_T reference values were measured with PTB's primary electrochemical measuring device. Then, IOW applied the optical measurement method in the same temperature range. Combining both values closes the gap in the traceability chain for optical pH_T value measurements in the Baltic sea and ensures reliable comparability of the measured values.

In cooperation with PTB's "Mathematical Modelling and Data Analysis" department, the next step will be to calculate a metrologically sound mathematical relation between the pH_T values measured, the salinity and the temperature to



PTB's measurement setup for the electrochemical measurement of the pH_T value. The system contains Harned cells filled with artificial sea water samples whose voltages are measured under temperature-controlled conditions.

make the results available to researchers in the field of oceanography. ■

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Scientific publication

J. D. Müller, F. Bastkowski, B. Sander, S. Seitz, D. R. Turner, A. G. Dickson, G. Rehder: *Metrology for pH measurements in brackish waters – part 1: Extending electrochemical pH_T measurements of TRIS buffers to salinities 5–20*. *Front. Mar. Sci.* 5, 176 (2018)

Natural gas – billed correctly

Determining the measurement trueness of state reconstruction systems used by gas utility companies

Especially interesting for

- regional gas utility companies
- verification authorities
- manufacturers of state reconstruction systems
- consumers

Extensive uncertainty analyses and innovative methods for uncertainty determination allow state reconstruction systems to be used for commercial transactions in the gas grids of regional utility companies in order to determine the energy content of natural gas. PTB has provided the preconditions for the use of these systems.

Supplying biogas to the grid, adding hydrogen, importing LNG, transitioning from L-gas (low calorific gas) to H-gas (high calorific gas), and diversifying supply sources – all these factors cause an increasing variability in the quality of the natural gas provided to the end user. In order to guarantee fair trade conditions in accordance with the Measures and Verification Act and to enable fair and correct billing, natural gas is traded and billed according to its energy content (calorific value × volume). In contrast to volume measurement, measuring the calorific value at each exit point requires considerable technical and financial resources; the gas supply grid is therefore

divided into billing areas, each of which has a single calorific value that is traceable to verified measurements. In these regional distribution grids, gas-grid state reconstruction systems are being increasingly used; if the quantity of gas flowing into and out of the grid and the topology of the gas grid are known, it is possible to track an amount of gas on its way through the grid. Based on the gas quality measured at the entry point of the gas grid, the gas quality – and thus the calorific value – can be determined at each exit point.

To increase the acceptance of these reconstruction systems among gas utility companies, consumers and verification

authorities, PTB has developed technical testing specifications. These specifications allow the abstract requirements of the Measures and Verification Act to be transposed into specific technical requirements that apply to these computing systems, which are not subject to legal verification. Moreover, each system is tested individually by PTB before being used for commercial transactions.

Within the scope of these tests, particular attention is paid to the determination of the measurement trueness by means of comparison measurements and modern uncertainty determination methods. The complexity of reconstruction systems means that the only method that can be applied is that of Monte Carlo simulations. Exhaustive analyses and practical experience have shown that these reconstruction systems can achieve a measurement uncertainty comparable to that of conventional calorific value determination devices; as a result, the errors in service are certain to be within the permissible limit of 2 %. Further

items that are part of the testing include security against intentional and unintentional tampering, the system's stability in the event of changes in the topology



Processed and conditioned biogas is an important part of the German Federal Government's energy concept in pursuit of low-carbon energy generation. (Photo credit: Ökobit GmbH)

or in the entry/exit status, the clear and unmistakable presentation of the results, the verifiability of the system by the verification authorities, and the processing of the computed results. The test results are reported by means of a PTB certificate that attests to the gas utility company and the verification authority that the requirements have been met. ■

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Scientific publication

S. M. Sarge: *Ermittlung von Gasbeschaffenheitskenngrößen für Erdgas im geschäftlichen Verkehr mittels Gasnetz-Zustandsrekonstruktion.* PTB-Mitteilungen 1.2017, 23–31

Improved hydrophone calibration

Novel measurement setup enables more comprehensive calibrations

Especially interesting for

- manufacturers and users of hydrophones
- providers of calibration services

A novel measurement setup has been developed at PTB for the primary calibration of ultrasonic hydrophones. Hydrophones are sensors used to determine ultrasonic pressure wave in liquid media. They are mainly used in medical engineering in order to test ultrasonic equipment. The new facility covers a larger frequency range and simultaneously exhibits lower uncertainty.

Within the field of hydrophone calibration, the hydrophone's sensitivity is defined as the ratio between the electric output voltage of the hydrophone to be calibrated and the actual ultrasonic pressure; it is then transferred as a function of the frequency via the calibration certificate.

In PTB's new measurement facility, a high-frequency vibrometer uses an optical measurement procedure to determine the displacement of a thin foil placed on the water surface; this displacement is caused by the ultrasonic wave. The ultrasonic pressure is determined based on this measurement. Calibration is now performed using short excitation pulses at high amplitudes rather than longer, mono-frequency or tuned sound waves. Since the pulses generated by exploiting non-linear propagation in water exhibit a broad spectrum of frequencies, they allow hydrophones to be characterized in a frequency range from 1 MHz up to 100 MHz. The test assembly is mostly automated, allowing calibrations to be performed faster.

Moreover, pulse excitation allows the phase frequency response of the hydrophone to be determined easily. This piece of information is especially important when pulse deconvolution is used in order to reconstruct ultrasonic wave forms

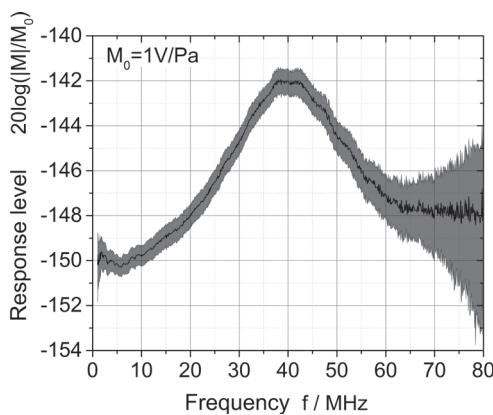
in a standardized way that is as objective as possible. The procedure is also suitable for sensors used in high-intensity



Measurement setup during a measurement with the vibrometer. The vibrometer is located in the blue housing. The foil is placed in the red lens tube and lies on the water surface.

ultrasonic fields that are often less responsive than conventional hydrophones. ■

Response level (sensitivity) of a hydrophone in the frequency range from 1 MHz to 80 MHz. The gray shaded area represents the uncertainty range with a coverage factor $k = 2$.



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Scientific publication

M. Weber, V. Wilkens: Using a heterodyne vibrometer in combination with pulse excitation for primary calibration of ultrasonic hydrophones in amplitude and phase. Metrologia 54, 432–444 (2017)

Calibrating inductive voltage dividers

Pulse-driven Josephson voltage standards used for voltage ratio measurements

Especially interesting for

- AC voltage metrology
- power quality analysis in power grids

PTB is developing a measuring system based on pulse-driven Josephson voltage standards. This system is designed to allow alternating voltages to be measured with great accuracy at frequencies of up to 100 kHz and voltages of more than 100 V. Since the output voltages of Josephson voltage standards are limited to a few volts, it is necessary to use voltage dividers. An inductive voltage divider has now been calibrated for the first time with pulse-driven Josephson voltage standards, and the results have been compared to those obtained using a conventional calibration procedure.

Inductive voltage dividers are high-precision AC transformers used to realize

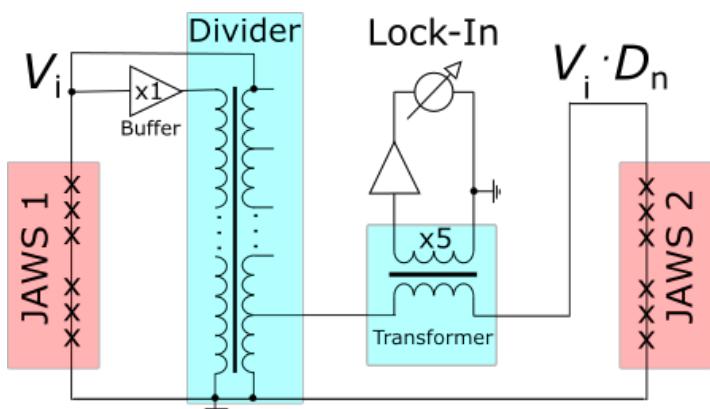
voltage ratios in electric metrology as the core elements of, for example, voltage or impedance bridges. Until recently, they were calibrated using a time-consuming traditional procedure based on the so-called “bootstrapping” method in which each of the individual segments of the divider is compared with the others one by one.

The accuracy of this calibration procedure has now been checked with quantum precision by means of an inductive, decadic voltage divider using two independent, pulse-driven Josephson voltage standards (Josephson Arbitrary Waveform Synthesizers – JAWS). For this purpose, effective voltages of 100 mV were generated by means of one of the JAWS systems and applied to the divider as an input signal, whereas the second JAWS system was used to compensate for the output signal of the divider. The results obtained within the scope of this com-

pensation measurement for the correction of the reactive component showed excellent agreement with the bootstrapping method: the relative difference amounted to less than 10^{-8} .

Furthermore, it was possible to demonstrate that, when applied to the divider, additional harmonic signal components of the input signal had a negligible influence on the calibration of the divider. The conventional bootstrapping procedure has thus been verified with quantum precision and can now also be used for calibrations at higher voltages. In addition, it is planned to test the new quantum-based method for the calibration of new broadband resistive voltage dividers.

Using JAWS systems in combination with voltage dividers paves the way for novel potential applications such as the power quality analysis of sinusoidal voltage signals in power grids. ■



Schematics of the measurement setup for the calibration of the inductive voltage divider (in the figure: "divider") with the two JAWS voltage standard systems. The lock-in voltage amplifier together with the transformer (centre of the picture) amplifies the signal and, thus, increases the sensitivity of the measurement method.

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Scientific publication

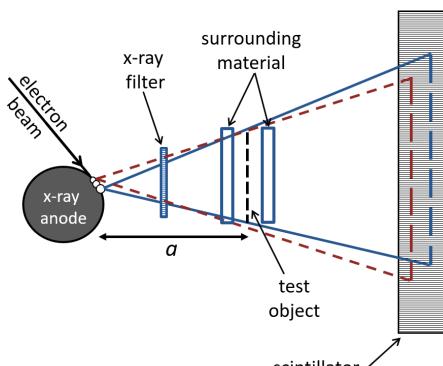
J. Herick, S. Bauer, R. Behr, M. F. Beug, O. F. O. Kieler, L. Palafox: Calibration of an inductive voltage divider using pulse-driven Josephson arrays. Conference Digest CPEM – “Conference on Precision Electromagnetic Measurements”(2018)

CT measurements with enhanced accuracy

Especially interesting for

- manufacturers and operators of industrial computed tomography systems

Until recently, length measurements performed by means of industrial X-ray computed tomography (CT) based on cone beam geometry (without additional tactile reference measurements) exhibited relative measurement uncertainties of approx. $1 \cdot 10^{-4}$. A procedure developed at PTB allows this uncertainty to be improved by a factor of at least 10. This new development relies on a pixel-resolved distance correction between the X-ray source and the flat-panel de-



Geometrical deviations with the cone beam geometry. The images are generated at different depths in the scintillator layer of the detector. The beam path is shown in red without the filter or the surrounding material, and in blue with the filter and the surrounding material. The effect depends on the X-ray spectrum in combination with the material of the sample and the distance a .

tector. Moreover, with this procedure, there is less need for pre-filtering of the X-ray radiation, thus increasing intensity and allowing shorter measuring times. This also reduces measurement uncertainties that may occur during the irradiation of a specimen due to drifting. (Technology Offer 455) ■

Advantages

- reduces measurement uncertainty without additional reference measurements
- increases cost efficiency of CT systems due to reduced measuring times
- can be integrated into existing CT facilities – e.g. as a software update

Efficient Brillouin fiber amplifier

Especially interesting for

- precise optical frequency transmission, e.g. for long-distance comparison of optical clocks

Bidirectional amplifiers are necessary for the transmission of ultra-stable optical frequencies over long-distance optical fiber links in order to compensate for the optical loss of approximately 20 dB per 100 kilometers. Brillouin fi-

ber amplifiers developed at PTB support such bidirectional operation with a gain of up to 45 dB and have been successfully installed in the international optical fiber link between Braunschweig and Paris. These amplifiers have now been outfitted with a new, more efficient optical module that optimizes the input coupling of the pump laser while minimizing signal losses within the setup. By means of an additional monitor port, the polarization between the signal and

the pump laser can now be precisely adjusted and permanently monitored. (Technology Offer 466) ■

Advantages

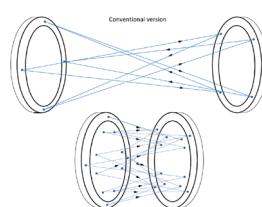
- simple and accurate detection of the correct polarization alignment of the signal
- robust and automatable polarization control
- improved signal-to-noise ratio for cascaded amplifier systems

Herriott cell with enhanced sensitivity

Especially interesting for

- chemical analyses (environmental analysis; industrial safety engineering)
- spectral broadband measurement procedures (FTIR spectroscopy)

Tiny amounts of certain gases can have considerable effects on human health, the environment and industrial processes. It is now possible to detect such gas quantities with enhanced sensitivity resolution by means of a Herriott cell developed at PTB. Plane mirrors inside the cell make it more effective, allowing the optical path



Examples of a beam path: top, with four reflections per mirror; below, in the new Herriott cell, with three times as many reflections (12 reflection points per mirror)

length to be increased by more than one order of magnitude at an equal volume of the cell, which also improves the detection limit. For instance, with a mirror radius of 7 cm and a distance of 1 m between the mirrors, it is possible to

achieve an effective optical path length of more than a kilometer (instead of 100 m until recently). (Technology Offer 397) ■

Advantages

- increases the optical path of the laser/light beam
- considerably improves the detection limit
- can be used for broader spectral ranges
- in contrast to techniques such as mass spectrometry, the sample material is not influenced (non-invasive method)

Contact person for questions about technology transfer

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Awards

Joachim Ullrich



The president of PTB has been awarded an honorary science doctorate by Leibniz University Hannover. By awarding this honorary title, the university has recognized Professor Ullrich's outstanding accomplishments.

ments in the field of experimental quantum physics. These accomplishments include more than 450 publications in renowned specialist journals and numerous research prizes, among them the DFG Gottfried Wilhelm Leibniz Prize, which he received in 1999.

Ekkehard Peik



The head of the *Time and Frequency* department has been appointed as Distinguished Lecturer by the IEEE's Ultrasonics, Ferroelectric, and Frequency Control Society. In this capacity, Peik will

hold lectures on PTB's activities concerning "Optical atomic clocks with single trapped ions" at universities and research institutes from June 2018 to December 2019.

PTB to Support Unique Research Center

The new building housing the Hannover Institute of Technology (HITec) at Leibniz University Hannover was inaugurated on 6 July. This institute is the first in Europe to unite basic and applied research and technology development on quantum physics and geodesy under one roof. The main partner



(Photo credit: Carpus + Partner)

organizations directly involved in HITec's research program are: the Laser Zentrum Hannover e.V. (LZH), the German Aerospace Center (DLR), the Max Planck Institute for Gravitational Physics/Albert Einstein Institute (AEI), the Center of Applied Space Technology and Microgravity (ZARM), and PTB.

The Hannover Institute of Technology brings together three research branches from the fields of physics and geodesy: quantum technologies, optical technologies and the development and application of quantum sensors.

The unique infrastructure in the new, recently inaugurated research building will be available to more than 100 scientists. In addition to laboratories designed for high-precision quantum-level experiments, the building contains three large-scale facilities used in research, each of which is unique worldwide and enables research at the highest possible level. These facilities are the Einstein Elevator (a 40 m tall free-fall simulator); a facility allowing the development and production of optical fibers; and a so-called "atomic fountain" (the Very Large Baseline Atom Interferometer – VLBAI).

German Committee of CIE

A new association, the German National Committee of CIE (Deutsches Nationales Komitee der Internationalen Beleuchtungskommission CIE – DNK-CIE) was founded at PTB on 5 April 2018. Dr. Armin Sperling was elected as the first chairperson of the new association.

Collaborative Research Center on Diagnostic Radiology

A collaborative research centre (CRC) on diagnostic radiology called "Matrix in Vision" has been created at the Charité university hospital in Berlin (contact: Prof. Dr. Bernd Hamm). The Freie Universität Berlin, the Max Planck Institute of Colloids and Interfaces, the BAM Federal Institute for Materials Research and Testing and PTB are also involved in this CRC in addition to Charité. This collaborative research center, which is being funded by the German Research Foundation (DFG) with 11.5 million euros, has been established to find out how pathological changes to the extracellular matrix (the substance in which the body's cells are

embedded) can be visualized by means of diagnostic radiology. The scientists involved hope that their methods will contribute to the early detection of diseases. Members of staff from Division 8 of PTB are overseeing two sub-projects on quantitative and magnetic imaging.

Junior Scientists

PTB is now home to a new publication, *Junge Wissenschaft*, an online journal (<https://www.junge-wissenschaft.ptb.de>). Young scientists (no older than 23 years old) can publish their findings



in accordance with the usual rules applying to scientific publications – including a peer review process. *Junge Wissenschaft* is published, edited, and editorially supported by PTB's Press and Information Office. PTB's considerable role in the publication of this journal dates back many years, starting with a close relationship between its founding editor (Prof. Dr. Paul Dobrinski, 1927–2009) and the then President of PTB (Prof. Dr. Ernst O. Göbel). This relationship came about due to the mutual interest of the journal and PTB in supporting junior scientists in the natural sciences.

Imprint

PTB News 3/2018, English edition, Issue December 2018, ISSN 1611-163X
The PTB News is published three times each year in a German as well as in an English edition and can be subscribed to free of charge. Subscription form: www.ptb.de > English Version > Publications > PTB News > Subscribe the PTB News

Publisher: Physikalisch-Technische Bundesanstalt (PTB), Braunschweig and Berlin
Editors: Andreas Barthel, Thomas Damitz, Ludger Koeniders, Christoph Kolbitsch, Christian Lisdat, Mathias Richter, Hansjörg Scherer, Erika Schow, Jens Simon (verantwortlich)
Layout: Volker Großmann, Alberto Parra del Riego (concept)
Translation: PTB Translation Office (Cécile Charvieux)
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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.