PTB NEWS

THE SCIENTIFIC NEWSLETTER OF PTB

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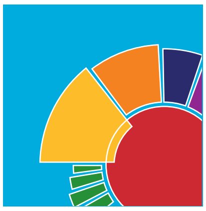
2012

The PTB-News is the scientific newsletter of the Physikalisch-Technische Bundesanstalt (PTB). It is addressed to PTB's cooperative partners in economy, science and to all other interested readers.



SCIENTIFIC NEWS

TECHNOLOGY TRANSFER

MISCELLANEOUS

New measurement room with assembled reference wall (left) consisting of thermally stable carbon-fibre composite rods

Large and precise

Reference wall for the characterization of mobile 3D measuring systems

Especially interesting for
- the aerospace industry
- manufacturers of mobile 3D measuring instruments
- machine and plant construction

Mobile 3D measuring systems are used for the production and the assembly of large components, for example, in the aerospace and aviation industry or in plant construction. PTB's new reference wall allows the metrological performance of these 3D measuring systems to be verified for the first time in accordance with the guidelines and with great accuracy. Also PTB's customers can make use of this new facility.

Laser trackers are mobile optical 3D coordinate measuring machines which are used to determine the dimensions, shape and position of large components in numerous industrial fields. Here, the spatial position of a retroreflector is determined by combining laser-based distance measurement (distance between the laser tracker and the retroreflector) with two angle measurements (azimuth angle and elevation angle of the laser beam whilst tracking the beam). The measurement uncertainty of the systems depends on a number of influence factors. Among these are errors of the three measurement axes for distance as well as horizontal and vertical direction from their ideal orientation, as well as form errors of the retroreflectors. These errors overlap in a different way, depending on the position of a certain measurement point, so that a statement on the measurement uncertainty based on the individual errors is hardly possible. A simple method of checking the accuracy consists in measuring calibrated reference artifacts.

For this purpose, a reference wall with artifacts of up to 12 m in length has been set up for laser trackers at PTB. The test lengths are realized with temperature-stable material measures made of carbon-fibre-reinforced plastic and mounted on the wall free of strain. The expanded measurement uncertainty (k = 2) of the different embodied test lengths amounts to less than 5 µm. For laser trackers, the testing is in line with the series of standards EN ISO 10360 on the "Acceptance and reverification tests for coordinate measuring machines (CMM)" and allows a statement on the compliance with the maximum permissible length measurement error. The realization and evaluation of the measurements are described in the new guideline VDI/VDE 2617, sheet 10. By measuring the test lengths from various positions, the test is comparable to a testing of the laser trackers inside a large measuring volume of 10 m × 6 m × 3 m. Both service providers and users of laser trackers can use PTB's reference wall to check the specified accuracy of laser trackers on their own responsibility and/or determine the length measurement uncertainty of a system at ambient conditions similar to those found in industrial applications. ■

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Scientific publication
Komornik, I. et al.: Test Location for Traceability of Laser Trackers, LVM Conference, Manchester, 16th November 2011

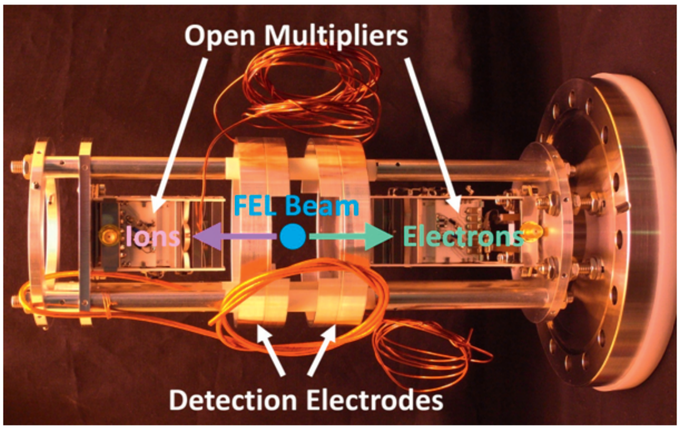
X-ray laser calibrated

Japanese-German cooperation at SACLA successful

Especially interesting for
- X-ray laser applications
- investigations of materials' structures
- accelerator technology

Scientists from PTB – together with colleagues from the *Deutsche Elektronen-Sychrotron* (DESY), from the Japanese Research Centre RIKEN and from the Japanese metrology institute AIST/NMIJ – measured absolute photon fluxes and impulse energies in the photon energy range around 10 keV at the new 700 m long X-ray laser facility SACLA in Japan, using two independent methods. SACLA has been in operation since the summer of 2011 and is the first free-electron laser (FEL) worldwide that is suited for the hard X-ray range.

The history of FELs – which are based on electron linacs, for the generation of femtosecond laser impulses in the soft and hard X-ray ranges according to the principle of "self-amplified spontaneous emission" (SASE) – took its course some ten years ago with FLASH – the Free-electron LASer in Hamburg. At that time, it was still called "Tesla Test Facility" (FFT) and emitted electromagnetic radiation at 0.01 keV only. Within the scope of a cooperation between PTB, DESY (Hamburg), and the Ioffe Institute (St Petersburg), a gas monitor detector (GMD) has been developed and already tested at the TTF, in order to detect the strong intensity variations of the SASE process and to measure absolute impulse intensities. This GMD can detect X-rays by photoionization of atomic gases and by detection of photoions and photoelectrons. The gaseous detection medium is radiation-hard and, due to the low gas pressure in the range of 10^{-3} Pa, practically fully transparent (see PTB News 3/2011).



Gas monitor detector (GMD) for the measurement of the photon flux at an FEL beam (vertically to the image plane) by photoionization of a gas at a gas pressure in the range of 10^{-3} Pa and electrostatic extraction (horizontally) and detection of photoions and photoelectrons.

Today at FLASH, GMDs are operated as a permanent part of online photon diagnostics. Furthermore, different GMD versions have been used for intensity measurements at the five FELs worldwide over the past few years. The detectors were calibrated with synchrotron radiation in the PTB laboratories at the storage ring facilities BESSY II and MLS in Berlin, respectively.

In the past few years, besides the absolute measurement of photon flux, impulse energy, and beam position via linear photoionization, methods have also been developed to determine the diameter of an FEL microfocus or the duration of the femtosecond impulses via non-linear photoionization processes. Today, investigations also extend to fundamental issues of non-linear photoionization in the X-ray range. In the coming months, however, the cooperation partners' agenda will focus more particularly on the characterization of GMDs for the 3.4 km long European XFEL in Hamburg, which is expected to be commissioned in 2015 at photon energies up to 25 keV. ■

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Scientific publication
Tiedtke, K. et al.: Gas detectors for x-ray lasers. J. Appl. Phys. 103 (2008) 094511

Semiconductor quantum voltage source

PTB can, for the first time, generate a quantized voltage without superconductivity

Especially interesting for
- metrology institutes
- the semiconductor industry

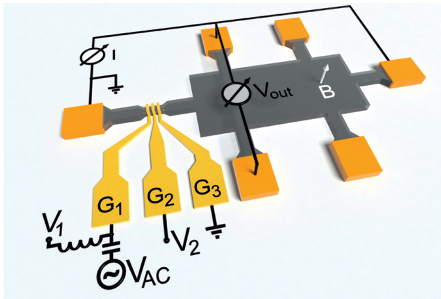
At PTB, a quantized voltage was generated for the first time with an integrated semiconductor circuit. This task was tackled by connecting a single-electron pump and a quantum Hall resistor on a semiconductor chip. So far, such quantized voltages have only been generated by means of superconducting circuits.

Semiconductors have been the most important material system for electronic circuits and IT applications for the past decades. Also in the field of electrical metrology, semiconductors are commonly used to reproduce resistance: due to the quantum Hall effect, the Hall resistance R_H is quantized in special semiconducting samples in the magnetic field B. Hereby, its value $R_H = h/e^2$ is determined using solely the two fundamental constants h (Planck's constant) and e (elementary charge). Until recently, it had, however, not been possible to generate a quantized voltage based on semiconducting components. Such quantized voltages could only be realized by means of the Josephson effect, which occurs in superconducting circuits.

In the past few years, semiconductor-based quantized current sources – so-called single-electron pumps – have been developed at PTB. Driven by an alternating voltage of frequency f, these pumps generate a current of quantity $I = e \cdot f$ if a single electron per pump cycle is transported. When combining these single-electron pumps with a quantum Hall resistor in an integrated semiconducting quantum circuit (see Fig.), one obtains a quantized output voltage of $V_{out} = (h/e) \cdot f$. What is particularly interesting about this is that this output voltage is, on principle, identical to the output voltage of a superconducting Josephson circuit but is based on totally different physical effects.

The generation of a quantized voltage using such an integrated semiconducting quantum circuit has recently been demonstrated experimentally. For this purpose, the single-electron pump and the quantum Hall resistor were manufactured in a joint production process from a semiconductor layer system on a chip. To operate the component shown in the picture, only two DC voltages are required, as well as a high-frequency AC voltage to control the single-electron pump. The component exhibits a robust quantization of the output voltage up to frequencies of a few GHz, so that output voltages of up to 10 µV can be generated.

In future, the output voltage of the novel semiconductor quantum voltage source is to be increased even more considerably. The output voltage can, in principle, be increased by a factor of up to 1000 by connecting several single-electron pumps in parallel and by connecting several quantum Hall resistors in series on the semiconductor chip. The quantum voltage having been increased in this way could then be used for fundamental experiments, for example, to close the metrological triangle. ■



Schematic diagram of the semiconductor quantum voltage source. Above a narrow semiconductor channel, three control electrodes (G_1 to G_3) are positioned, two of which are controlled by two DC voltages (V_1 and V_2). Due to the additional AC modulation V_{AC} on electrode G_1, the quantized current – which, in turn, generates a quantized voltage V_{out} in the adjacent quantum Hall resistor – is produced.

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Scientific publication
F. Hohls, A. C. Welker, Ch. Leicht, L. Fricke, B. Kaestner, P. Mirovsky, A. Müller, K. Pierz, U. Siegner, and H. W. Schumacher: Semiconductor quantized voltage source. Physical Review Letters (2012), accepted. arXiv:1103.1746v1

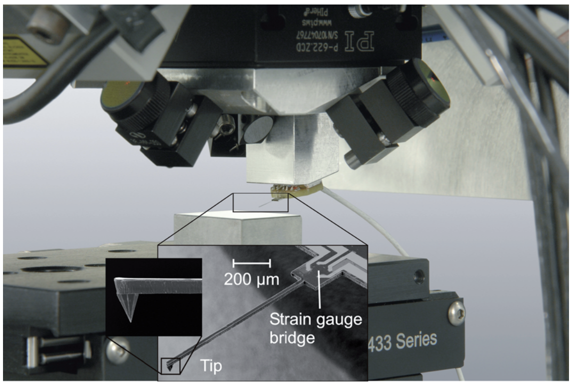
Small, deep, steep? – This is no longer a problem!

Tactile surface scanner for structures with high aspect ratio

Especially interesting for
- micro-systems technology
- dimensional metrology

A traceable surface scanner allows the dimensional characterization of micro-systems, especially of structures with high aspect ratio. The fine stylus can dip into microscopic holes or channels with diameters as small as 30 µm as well as into depths of up to 5 mm.

Micro-optical components often include steep and simultaneously deep structure which are difficult or even impossible to access for conventional profilometers, optical microscopes and scanning force microscopes. Besides the geometrical dimensions, also the roughness of such surfaces is highly interesting. The new device allows traceable dimensional measurements on and in structures with high aspect ratio or in nozzles. Its core component is a long silicon bending beam with an integrated tip and a piezoresistive measuring bridge for deflection detection. The sensor was developed in cooperation with the *Forschungsinstitut für Mikrosensorik und Photovoltaik* (Microsensor systems and photovoltaics research institute – CiS) in Erfurt and the Institute of Semiconductor Technology (*Institut für Halbleitertechnologie – IHT*) of Braunschweig Technical University. Sensors are available in different lengths (1.5 mm, 3 mm, 5 mm) and widths (30 µm, 100 µm, 200 µm) at tip heights of up to 70 µm and a noise of 6 nm at a bandwidth of 20 kHz. For the measurement of soft surfaces, the measuring force of the stylus tip can be adjusted down to values of 1 µN. The tactile microsensor is affixed to a 3D piezo table and can be displaced over a positioning range of 800 µm × 800 µm × 250 µm. One of the advantages of this microsensor is its light weight which allows extremely high displacement rates – and, thus, short measuring times. Microsensors with displacement rates of up to 1 mm/s have been tested successfully in experiments on technical surfaces at PTB. Hereby, the sensor proved to be very robust. The measuring head of the device contains, besides the microsensor, also three laser interferometers which are arranged vertically to each other and have a resolution of 1 nm to guarantee the direct traceability of the measurements to the SI unit “metre”. The measuring beams of the interferometers intersect on the stylus tip of the sensor at one point to ensure practically Abbe-error-free measurements. With the measurement and control software of the device (LabWindows), operating the device is easy. The complete surface scanner is equipped with a coarse positioning table of 12.5 mm × 12.5 mm × 12 mm, a rotating range of 360° and the possibility of measuring very large test objects with dimensions up to 80 mm × 100 mm × 100 mm. The sensor and the device were presented to the interested public at the trade fair “Control” in Stuttgart in May 2012. ▪



Profile scanner with measuring and scanning head and enlarged view of the bending beam microsensor.

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MRI system measures its own high-frequency field

New TEM cell for the calibration of E-field sensors in MRI systems

Especially interesting for
- physicians and patients
- manufacturers of MR equipment

A transversal electromagnetic mode (TEM) cell developed at PTB allows electro-optical E-field probes to be calibrated directly in a clinical magnetic resonance imaging (MRI) system. With a first test arrangement, the uncertainty of the E-field reached at 123 MHz and 300 MHz, respectively, was better than 0.4 dB. This procedure is suited for all whole-body MRI scanners, since the TEM cell itself is broadband.

The rapid development of novel procedures of magnetic resonance imaging (MRI) requires, among other things, radio frequency (RF) electromagnetic fields within or in the immediate vicinity of the MR system to be measured with great precision. These measurements are used, on the one hand, to evaluate the efficiency of RF components of the MRI system and, on the other hand, to further develop concepts for the limitation of the specific absorption rate (SAR) in the human body, in conformity with the relevant standards. Another metrological challenge is the EMC testing of medical devices, e. g. injectors for contrast agents or implants such as, e. g., pacemakers, that are operated inside or on the body and are therefore exposed to the strong pulsed RF fields of the MRI system. The measurement of pulsed RF electromagnetic fields inside an MRI system is considerably complicated by the simultaneous presence of the static magnetic field (from 1.5 T to 7 T) and of strong magnetic field transients of > 50 T/s. Electro-optical RF field sensors are actually suited for such measurements, their calibration does, however, not exhibit a good long-term stability, as the optical components used (laser, fibre connectors) drift strongly.

For the on-site calibration of electro-optical RF field probes, a non-magnetic open TEM cell was, thus, developed as a computable field source and optimized for use in strong magnetic field transients. It is positioned in the MRI system, together with the sensor to be calibrated. The calibration procedure consists in measuring the flip angle of the nuclear magnetization of an aqueous sample in the TEM cell; the flip angle is directly related to the E-field of the TEM cell via fundamental constants. The particularity of the new procedure resides in the fact that the MRI scanner itself is used as a measuring instrument by exploiting the excited nuclear spin of the water protons in the system as "traceable" field sensors for a RF magnetic field component. This measuring concept was implemented directly in the hardware and the software of PTB's 3-tesla MRI system and of the 7-tesla MRI system in Berlin-Buch, respectively, and used to calibrate an electro-optical E-field sensor. The measurement yielded an uncertainty of the E-field of < 0.4 dB at a frequency of 123 MHz (in the 3-tesla MRI scanner) and 300 MHz (in the 7-tesla MRI scanner), respectively. After having been calibrated in this manner, the sensor can then be immediately used for E-field measurements inside the magnet and its surroundings. The new procedure allows numerical simulations on the spreading of RF electromagnetic fields inside the human body to be validated and will, thus, facilitate compliance with requirements laid down in standards. ■

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Scientific publication
Seifert, F. et al.: TEM cell for calibration of an electro-optic E-field sensor in a clinical scanner. Proc. Intl. Soc. Mag. Reson. Med. 19 (2011) 3777

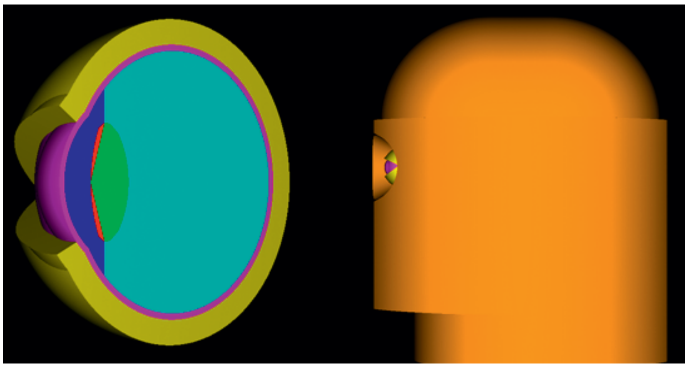
Radiation to the eye: which dosemeter to use?

PTB investigations have shown: there is a need for action, especially for beta radiation.

Especially interesting for
- manufacturers of dosemeters
- medical staff

The International Commission on Radiological Protection (ICRP) has drastically lowered its recommended annual dose limit for the eye lens. Detailed calculations made at PTB have shown which kinds of dosemeters are suited to monitor the dose received by the eye lens.

The human eye is even more sensitive to ionizing radiation than previously assumed. There is mounting evidence that the dose limit currently valid does not suffice to prevent cataract. For this reason, the International Commission on Radiological Protection (ICRP) has drastically lowered its recommended dose limit for the eye lens, namely from 150 millisievert (mSv) to 20 mSv per year. With the previous dose limit, one supposed that it was sufficient to monitor the values for the whole body (by means of whole-body dosemeters) and for the skin (with skin dosemeters) as a routine. Should the dose limit for the eye lens be lowered also in Germany, this could imply that suitable dosemeters must be worn in the direct vicinity of the eye behind appropriate eye protection. Staff members who have attained their maximum annual dose may then no longer be employed in a radiation controlled area for the rest of the year. With the aid of Monte Carlo simulations, PTB has performed dose determination specifically for the eye lens and then examined the different kinds of dosemeters as to their applicability in this precise case. It turned out that skin dosemeters are suited, however, for X-rays only (e. g. in radiology). They have to be worn in the direct vicinity of the eye, and they have to be permeable to X-rays at the back. For beta radiation – which often occurs in nuclear medicine – skin dosemeters might overestimate the actual dose by a factor of 100 or more and are therefore not suited. Eye dosemeters – which estimate the dose in the part of the eye lens that is particularly sensitive to radiation – are fundamentally suited. However, only very few types of this kind of dosemeter exist, as the measurand has so far not been used. Their fitness for purpose in the case of beta radiation is still to be tested. Whole-body dosemeters are categorically not suitable as they underestimate the radiation dose to the eye lens, especially in the case of beta radiation and of low-energy X-rays.



Stylized model of the eye (including details in the inner part of the lens) as was used for the high-precision dose calculations. The different colours represent different materials. The right part of the image shows the full skull model including the inserted eye.

PTB's results, with the support of the BMWi project "Innovation with Standards – INS: Improved monitoring of the eye lens dose", are to be transposed into national and international standards. ■

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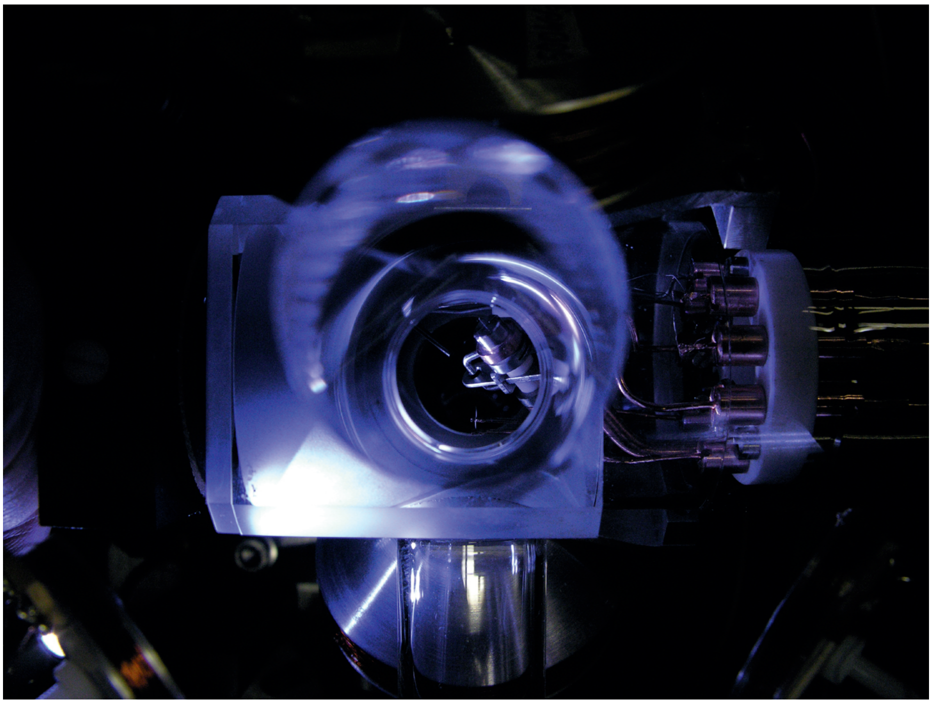
Scientific publication
Behrens, R.; Dietze, G.: Monitoring the eye lens: which dose quantity is adequate? Phys. Med. Biol. 56 (2010) 4047

New "pendulum" for the ytterbium clock

A transition which is difficult to excite in the ytterbium ion turns out to be particularly well suited for an optical clock of the greatest accuracy

Especially interesting for
- developers of optical clocks
- atomic spectroscopy

A "forbidden" transition in the ytterbium ion and its frequency have been investigated at PTB with unprecedented accuracy. Exploiting this new transition, the ytterbium clock achieves a relative measurement uncertainty of $7 \cdot 10^{-17}$.



Ion trap of the ytterbium clock at PTB

Optical transitions are the modern counterpart of the pendulum of a mechanical clock. The faster the pendulum swings, the more precise the clock can be. In the case of atomic clocks, the "pendulum" is the radiation that excites the transition between two atomic states of different energy. In the experiment performed at PTB, the scientists devoted themselves to a special forbidden transition. In quantum mechanics, "forbidden" means that the jump between the two energy states of the atoms is almost impossible due to the conservation of symmetry and angular momentum. The excited state can then be very persistent: In the case investigated here, the lifetime of the F-state in the ytterbium ion Yb^+ amounts to approx. six years. Due to this long lifetime, an extremely narrow resonance – whose linewidth only depends on the quality of the laser used – can be observed when this state is excited by means of a laser. A narrow resonance line is an important prerequisite for an exact optical clock. At the British National Physical Laboratory (NPL), the laser excitation of this Yb^+ F-state from the ground state was achieved for the first time in 1997. As the transition is, however, strongly forbidden, a relatively high laser intensity is required for its excitation. This disturbs the electron structure of the ion as a whole and leads to a shift of the resonance frequency, so that an atomic clock based on it would exhibit a rate depending on the laser intensity. At PTB, it has now become possible to show that alternating excitation of the ion with two different laser intensities allows the unperturbed resonance frequency to be determined with high accuracy. This has allowed other frequency shifts often occurring in atomic clocks – e. g. by electric fields or the thermal radiation of the environment – to be investigated. It has turned out that these are unexpectedly small in the case of the Yb^+ F-state, which can be attributed to the special electronic structure of this state. This is a decisive advantage for the further development of this atomic clock. In the experiments carried out at PTB, the relative uncertainty of the Yb^+ frequency was determined with $7 \cdot 10^{-17}$. This corresponds to an uncertainty of the atomic clock of only approx. 30 seconds over the age of the universe.

Both groups at NPL and PTB have measured the frequency of the Yb^+ transition with their caesium clocks, and the results are in agreement within the scope of the uncertainties ($1 \cdot 10^{-15}$ and $8 \cdot 10^{-16}$), which are mainly determined by the caesium clocks. In a research project recently approved within the scope of the European Metrology Research Programme, the two institutes will, in future, cooperate with other European partners even more intensively in the development of this optical clock. In the case of the Yb^+ ion, what is of particular interest is that it has two transitions which are suitable for optical clocks: less strongly forbidden, but also very precise – at a wavelength of 436 nm the excitation of the D-level can be used. This opens up the possibility of investigating the accuracy of the optical clock by comparing the frequency of the two transitions in one ion, without having to refer to a caesium clock. ▪

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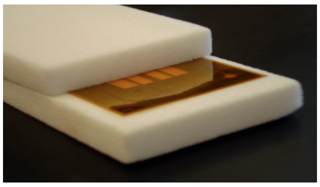
Scientific publication
Huntemann, H. et al.: High-accuracy optical clock based on the octupole transition in $^{171}Yb^+$. Phys. Rev. Lett. 108 (2012) 090801

Thermal conductivity of liquids and gases

Especially interesting for
- process control
- chemical reactors

Licence available

When determining thermal transport properties, natural convection can easily provoke considerable measurement errors in liquids and gases. An arrangement, for which a patent has been applied for, is designed to prevent exactly this. So far, during a run, it has been possible to prevent or reduce convection of the sample fluid only by microgravity (e. g., in a drop tower) with measurements being performed at low temperature differences, at small layer thicknesses or by a fast transient technique. These precautions, however, lead to correspondingly high signal-to-noise ratios – which, in turn, has a negative impact on the measurement uncertainty. The new sensor concept allows thermal conductivity to be determined practically without the influence



of convection. The sample fluid is fed into a suitable porous material until saturation is reached. Then, solely the thermal conductivity of the gas- or liquid-filled porous material is determined by a transient or steady-state method. With the aid of a calibration curve, the thermal conductivity of the sample fluid is evaluated. ■

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Acoustic probe for measurements at the eardrum

Especially interesting for
- medical engineering
- acoustic measurement technology

Licence available

Measuring otoacoustic emissions (OAEs) in the ear is used for objective auditory checks (e. g. in infants) by testing the function of the inner ear (cochlea). OAEs are active acoustic emissions of the ear which – in a direction opposite to that of perceived sound find their way into the auditory canal via the ossicles and the eardrum, and can be detected there by means of highly sensitive measuring microphones. Such OAEs can be detected in approx. 97 % of human subjects. The properties of the human ear canal, however, differ significantly from one person to another, so that for the measurement of OAEs, the sound pressure can be determined with limited accuracy only. PTB's invention consists in a probe with an adjustable microphone placement and an alterable acoustic impedance, which can be varied, for example, using micromechanical or micropneumatic control devices. At first, the source impedance and the open-circuit sound pressure of the probe can be calculated from additional measurements performed outside of the ear canal. Further measurements using the probe in the ear canal enable, in a second step, the determination of the source impedance and open-circuit sound pressure characterizing the emission from the cochlea. This invention is dedicated to determining the auditory sensitivity of patients in a safe and accurate manner. ■

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Ultra-low-noise preamplifier

Especially interesting for
- cryoelectronics
- cryophysics

Licence available

The ultra-low-noise preamplifier developed by PTB considerably reduces measurement uncertainties, e. g., for the traceability of impedance standards. This preamplifier is characterized by the fact that selected field effect transistors are connected in parallel at the input; these have the lowest possible noise current and noise voltage values. The circuit is designed in such a way that a stable standby current is generated by the input transistors and also that the drain resistance is increased dynamically. In this way, the noise of the pre-stage can be optimally adapted to that of the main stage. This guarantees very low noise. The optimized feedback network adjusts a stable gain. This novel circuit concept enables the so far unprecedented combination of an input noise voltage smaller than 0.5 nV, an input noise current smaller than 5 fA and an input impedance of 1 GΩ parallel to approx. 100 pF (stated for a noise bandwidth of 1 Hz at a measuring frequency of 1 kHz). ■

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Awards

Guido Bartl

This member of Department 5.4 "Interferometry on Material Measures" was awarded the Metrology Prize of the XXVth Metrological Symposium of the annual session of the Arbeitskreis der *Hochschullehrer für Messtechnik* (Association of university lecturers of metrology – AHMT). This prize, which is endowed with 2000 EUR, is an appreciation of his doctoral thesis entitled "Interferometric determination of absolute sphere radius topographies".

Klaus Beissner

The IEC 1906 Award 2011 was given to this member of Department 1.6 "Sound". This prize from the International Electrotechnical Commission (IEC) decorates international standardization experts for their commitment in the IEC committees.

Dates

19 September 2012: Informative meeting for the sound test centres who are members of the *Verband der Materialprüfungsanstalten* (VMPA)
8:00–18:00. Location: PTB Braunschweig, Lecture Hall in the Kohlrausch Building.
Contact: Marion Wittwer.
Phone: +49 (0) 531-592-1700

25.–26. April 2013: NanoScale 2013
Location: Paris, France. Contact: Katrin Wolff. Phone: +49 (0) 531-592-5101

Anniversary events in October 2012
The 17th of October has historical significance for PTB. On this day in 1887, the Technical Department of the Physikalisch-Technische Reichsanstalt commenced its work in the main building of today's TU Berlin.

17 October 2012
Weltzeit, zukünftige Chip-Technologien und moderne medizinische Bildgebung (Universal Time, future chip technologies and modern medical imaging)
Lectures on the occasion of the 125th anniversary of PTB. Location: Berlin, Audimax of the Technische Universität.
13:00: Lectures (in German language)

- **Prof. Dr. Ernst O. Göbel** (President of PTB, 1995–2011): *Über die experimentellen Herausforderungen zur Darstellung der physikalischen Einheiten* (On the experimental challenges of the realization of the physical units)
- **Prof. Dr. Michael Kaschke** (Chairman of the Board of Carl Zeiss AG): *Über die Zukunftstechnologien der EUV-Lithografie* (On future technologies of EUV lithography)
- **Prof. Dr. Hermann Requardt** (Member of the Board of Siemens AG): *Über die faszinierenden Entwicklungen in der medizinischen Bildgebung* (On the fascinating developments in medical imaging)

Afterwards: Dedication of the Observatory
Dedication of the oldest building of PTB on the original premises in Charlottenburg (with lecture and tour). The Observatory shines with renewed splendor after having undergone a complete renovation to restore its original look.

Anniversary Publications

Book series on the history of the Institute
Reprint of the PTB book series (published by *Wirtschaftsverlag* NW) on the historical development from the founding in 1887 to German reunification. These books are only available in German.

- **David Cahan**: *Meister der Messung. Die Physikalisch-Technische Reichsanstalt im Deutschen Kaiserreich*
- **Ulrich Kern**: *Forschung und Präzisionsmessung. Die Physikalisch-Technische Reichsanstalt zwischen 1918 und 1948*
- **Dieter Kind**: *Herausforderung Metrologie. Die Physikalisch-Technische Bundesanstalt und die Entwicklung seit 1945*

Another approach to the roots of PTR has been chosen by the authors Huebener and Lübbig. They do not concentrate on the history of the institute, but rather on the history of science – based on selected research subjects of PTR. The book is available in German and English.

- **Rudolf Huebener, Heinz Lübbig.** *Die Physikalisch-Technische Reichsanstalt. Ihre Bedeutung beim Aufbau der modernen Physik.* (Vieweg-Teubner Verlag, 2011). English edition: A Focus of Discoveries (World Scientific, 2008)

PTB-Mitteilungen
Between the end of 2011 and the end of 2012, five special issues of the PTB-Mitteilungen – the metrological journal of PTB – are published. Usually, the PTB-Mitteilungen are published in German only. These five issues, however, will also be published in English.

- *Die Technische Zusammenarbeit der PTB*/PTB's Technical Cooperation (December 2011)
- *Das System der Einheiten*/The System of Units (March 2012)
- *PTR/PTB: 125 Jahre metrologische Forschung*/125 Years of Metrological Research (June 2012)
- *Vom Werden moderner Messtechnik*/ The Development of Modern Metrology (September 2012)
- *Metrologie für die Zukunft*/Metrology for the Future (December 2012)

maßstäbe
The popular-science magazine of PTB takes advantage of the occasion of the anniversary to journalistically highlight outstanding scientific themes of PTR and PTB – with reports, reportages and interviews on current topics and their scientific-historical roots. The maßstäbe are published in German.

- *Enthüllungen*$_{125}$
  Issue No. 12 of maßstäbe will be published in the end of 2012.

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