PTB news
Metrology
Technology
Services
Cooperation
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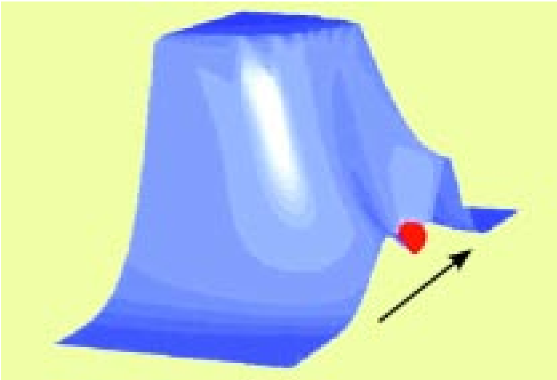
Single Electrons Riding the Surface Acoustic Waves



Artist's view of a single electron transported in a «scoop» formed by the moving electrostatic potential near the surface of a semiconductor

PTB has developed semiconductor devices in which single electrons are transported with the help of surface acoustic waves. The novel device was used to produce a current of up to 0,75 nA determined by the charge of the electron and the applied frequency. The device has possible applications as a quantum current standard.

The quest for tracing back the ampere, the unit of electric current and one of the seven base units of the international system of units (SI), to quantum standards is a hitherto unsolved problem. Worldwide research now focuses on the investigation of single-electron devices. In these devices, an electron with electric charge e transported with the frequency f realises a current $I = e \cdot f$.

Novel techniques may allow to increase the realised currents by orders of magnitude as compared to single-electron tunnelling devices (SET) where the current is limited to a few picoamperes. In the GaAs devices developed at PTB, an applied high frequency produces a surface acoustic wave by means of the piezo-electric effect. The associated propagating modulation of the electrostatic potential near the surface can act as a microscopic «scoop» which transports single electrons with the speed of sound through a narrow constriction. Recently, PTB successfully manufactured a device in which a DC current of 0,75 nA was generated applying a frequency of about 4,7 GHz. By using devices in parallel, the achieved current level can easily be increased by an order of magnitude. This now allows to set the goal for a quantum current standard with metrologically relevant small uncertainties even after transfer to the technologically more suitable microampere range.

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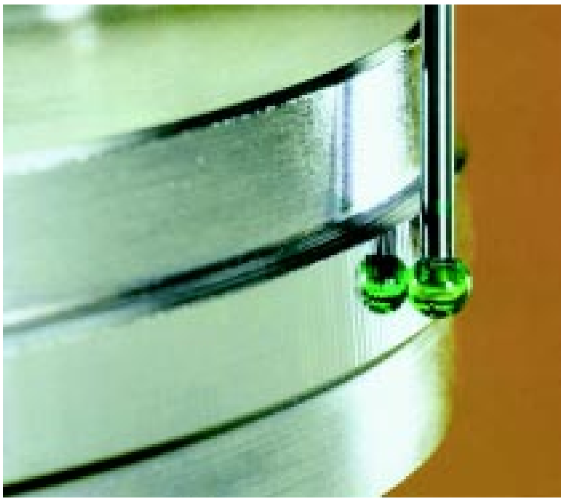
Multi-wave Standards – a Breakthrough in Form Measurement



The partial view of the multi-wave standard (diameter 80 mm) shows the lateral wave pattern. The standard is turning underneath the mechanically touching sphere, the horizontal movement of which produces the measurement signal.

Cylindrical bodies carrying a special wave pattern on their surface establish the new state of the art for transfer standards for form measurements. The signal characteristics of these so-called multi-wave standards make it possible to calibrate the signal transmission chain of form-measuring instruments in a highly stable manner.

The sensitivity calibration of form-measuring instruments is in general performed by doing roundness measurements for standards with defined deviations from the circular cylindrical form. Flick standards (cylinders with a flat) have so far been used for this purpose. However, their signal characteristics are typically small-band, and data evaluation is based on only very few data points of the profile.

In contrast to this, a new measurement procedure developed by PTB provides information about a broad spectral band. Moreover, this

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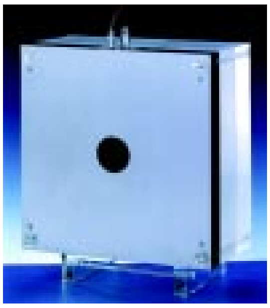
Secondary Standard for Personal X-ray Dosimetry

PTB has developed a new secondary standard for the operational quantity «personal dose equivalent», $H_p(10)$, in use in X-ray radiation protection. The standard resolves several problems concerning the calibration of whole-body personal dose meters with low-energy photon fields.

In order to evaluate the risk of ionising radiation to human bodies in a more specific way rather than measuring the dose on the surface of a person's body, the quantity «personal dose equivalent» $H_p(10)$ has been introduced by international institutions. The quantity $H_p(10)$ is defined in 10 mm depth in a person's body in order to take into account, e. g., the radiation exposure of deep-lying organs. This quantity has to be transferred into national legislation of the countries of the European Community in 2000. For calibration purposes, the quantity is defined in a slab phantom, and is determined from the «old» quantity air kerma (*k*inetic *e*nergy *re*leased in *ma*terial, here: released in air) by means of conversion coefficients. For reference radiation fields, these coefficients are tabulated in the international standard ISO 4037-3.



PTB's new secondary standard for the operational quantity «personal dose equivalent» $H_p(10)$ comprises an ionisation volume inside a polymethyl metacrylate (PMMA) slab (30 cm × 30 cm × 15 cm). A step cylinder in the centre of the front surface leads to an almost constant energy and angle dependence with respect to $H_p(10)$.

A problem not solved in this standard is the calibration in photon fields with a mean energy lower than about 25 keV. In this range of photon energies, the conversion coefficients depend strongly on the spectral distribution of the photon radiation, which is influenced by both the air density and the characteristics of the X-ray facility used to generate the reference photon field. Small spectral differences may lead to conversion coefficients for nominally the same X-ray field which differ by up to several ten per cent.

PTB has developed a new secondary standard for photon radiation which measures the true value of the personal dose equivalent $H_p(10)$ on a slab phantom directly. This procedure avoids the use of conversion coefficients. The standard is optimised to provide a nearly constant response with respect to $H_p(10)$ for photon energies from about 10 keV to 1400 keV and for angles of incidence from 0° to 75°. The secondary standard is commercially available.

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The «New» Helmholtz Prize

The 2001 Helmholtz prize will no longer have three, but only one prizewinner. The prize, which is endowed with 30000 DM, is jointly awarded by the Helmholtz-Fonds, a society for the promotion of metrology, and the Stifterverband für die Deutsche Wissenschaft, the donors' association for the promoting of sciences and humanities in Germany.

The biennial Helmholtz prize is awarded to honour outstanding scientific and technological achievements in the field of metrology since 1973. The prize for 2001 has recently been announced and will be awarded for work in the fields of

- precision measurement of physical quantities
- metrology in medicine and environmental protection
- informatics and mathematics applied to metrology.

Submitted papers may emphasise theoretical as well as experimental or applied aspects. To take part in the competition, a manuscript in writing or electronic form has to be submitted until 15 December 2000. The prizewinner will then be chosen by an independent jury of experts.

Further information is available via http://www.helmholtz-fonds.de or by contacting J. Helmcke, fax: (+49 531) 592-4305, e-mail: juergen.helmcke@ptb.de

New Building for Optical Metrology

On 23 June 2000, the ground was broken for a new optics laboratory building of PTB in Braunschweig.

The new building replaces a building from the time before World War II, and is expected to be ready for occupation in 2002. It will provide 3000 m^2 of scientific laboratories, workshops and offices offering PTB the opportunity to increase its support of measurement techniques and research for key technologies in modern optics. Particular emphasis will be laid on laser radiometry, quantitative microscopy for the nanometre range, radiometry and photometry of novel light sources and displays, as well as metrology for optical communications.

Dr. Alfred Tacke, State Secretary of the Federal Ministry of Economics and Technology (at the right), and Prof. Ernst O. Göbel, president of PTB, jointly break the ground for the new laboratory building dedicated to optical metrology.

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Magnetoneurography

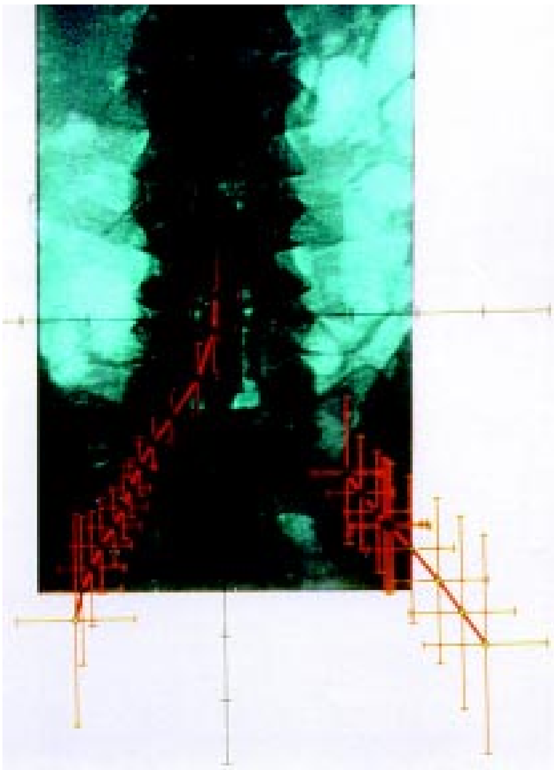
The temporal and spatial measurement of biomagnetic fields associated with nerve impulse propagation allows to localise impulse blockades in patients.

In the human body, sensations are mediated by impulse propagation along peripheral nerves through the spine to the brain. Blockades or irritations of nerves affected, e. g., by intervertebral disc herniaton, may lead to sensory loss or palsy. The localisation of the damaged area is of great importance for diagnosis and therapy.

The extremely weak biomagnetic fields associated with the electrical currents in the nerves which mediate a sensation and its strength ask for sensors of extremely high sensitivity. The most sensitive magnetic field sensors based on SQUIDs (*s*uperconducting *qu*antum *i*nterference *d*evices) worldwide are developed by PTB. They are used for contactless multichannel measurements of such biomagnetic fields.

Recently, PTB developed the technique of clinical magnetoneurography in cooperation with neurologists of the Benjamin Franklin School of Medicine of the Free University Berlin. This technique allows to trace the path of an impulse along the nerves from an arm or leg to the spine with high temporal and spatial precision. Detection of the weak signals is a true challenge because they are hidden in magnetic fields of the earth, technical devices, or the human heart that are up to thousand million times stronger. Therefore, sophisticated methods for shielding and signal processing had to be developed and implemented to enable the measurement of magnetic signals produced by nerve currents. Once the spatial and temporal magnetic field distribution is recorded, mathematical models allow to reconstruct the way taken by the underlying stimulus.

The first visualisation of the impulse block of a leg nerve in a patient caused by a herniated intervertebral disc was recently accomplished and opens very attractive future possibilities for clinical diagnosis and therapy.



From the recorded magnetic field distribution, the path of the impulse propagation along right and left leg nerves can be calculated. The result for a patient with a nerve blockade on the right side is shown. On the left side, the nerve impulses reach the spinal cord undisturbed. On the right side, however, the impulse propagation is interrupted at the site where the herniated intervertebral disc compresses the nerve.

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Dynamic Power Measurement by Means of Ergometers

Ergometers for foot crank work are used to induce a defined physical stress on patients in medical checks of the cardiovascular system known as «exercise ECG» and as a means of therapy control during rehabilitation and in sports medicine. In order to ensure the legally required measurement accuracy a facility for the measurement of dynamic power was installed at PTB.

Facility for the measurement of dynamic power at ergometers

The exact diagnosis of the fitness of patients requires measurements of dynamic power as a product of torque and rotational frequency with an error of less than 5 %. This metrological requirement cannot be met by the manufacturers if only static checks of the torque sensor are performed and the power losses caused by the mechanical measurement parts like crank bearings, chains and transmissions are only estimated and corrected. Therefore, PTB has installed an ergometer driven by an electric motor as a national standard of dynamic torque measurement. In addition, a transfer standard simulating an ergometer with very small measurement error was developed.

The new devices enable ergometer testing equipment of manufacturers and standards for the metrological control to be linked up with adequate uncertainty of measurement. From the number of applications for testing, which rose from two in 1997 to 22 in 1999, it can be seen that the demand for such metrological traceability in the field of ergometer measurements is in fact increasing on the part of the manufacturers, sellers and measurement services.

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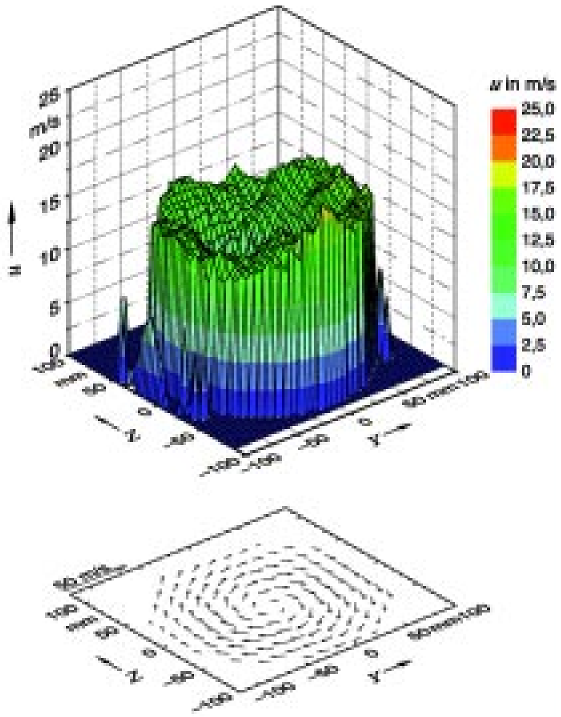
Fast Three-dimensional Measurement of Flow Fields

PTB has developed a test facility based on Doppler global velocimetry to investigate flow fields in pipe configurations. The new facility allows a complete determination of the three velocity components and drastically shorter measurement time for a flow field characterisation.

A detailed characterisation of flow fields in pipes is of high economic importance, e. g., for the measurement of natural gas delivered and charged to customers. Often, the uncertainty of the gas flow meter arrangement depends on perturbations of the flow field at the inlet of the gas meter caused by installation effects. In unfavourable cases, the uncertainty can be as high as several per cent .

PTB has developed a test facility for Doppler global velocimetry in collaboration with DLR, Cologne, the German centre of aerospace research. Laser Doppler techniques evaluate the Doppler frequency shift of laser light scattered by tracer particles embedded in the flow. In contrast to conventional laser Doppler anemometer systems which measure the Doppler shift by optically heterodyning of the scattered light, Doppler global velocimetry converts the Doppler shift on the steep slope of an absorption line into an intensity variation. By imaging the whole field of view through an absorption cell onto a CCD camera, an image is obtained the local intensity of which corresponds to the spatially resolved Doppler shift. A frequency-to-velocity calibration of the absorption allows one to directly map out the velocity components of the total field.

The new facility allows to perform fast routine measurements of a complete three-dimensional velocity field including the radial velocity component with a local resolution limited only by the number of pixels of the CCD camera. With the new facility, the influence of perturbations caused by installed elements on the reading of gas flow meters can be investigated and modelled. Potential future applications include accurate routine gas flow measurements independent of flow perturbations.



Representation of a measured three-dimensional velocity field in a pipe configuration with a swirl in the plane of observation
In the upper part of the figure, u denotes the axial velocity.

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Multi-wave Standards – a Breakthrough in Form Measurement

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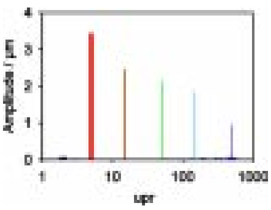

In the spectrum of a multi-wave standard, the characteristic lines correspond to the embodied sinusoidal waves.

procedure is based on all data points of the profile. Prerequisite is the multi-wave standard, a cylinder with a well-defined superposition of sinusoidal form deviations of different amplitudes and wavelengths.

The spatial signal of the multi-wave standard corresponds to a line spectrum. The wavelengths have been selected according to ISO Standards (5, 15, 50, 150, and 500 upr). The measured form profile is evaluated by Fourier analysis. This is made possible by the purely harmonic signal of the multi-wave standards. The form-measuring instrument is calibrated by comparing the measured amplitude heights of the spectral lines with the calibrated line spectrum. Small local disturbances hardly influence the calibration result, because the amplitude spectrum is integrally evaluated by the analysis procedure.

First practical tests of multi-wave standards have been completed successfully. Comparison measurements with DKD laboratories concerned with form measurements showed agreement within 30 nm in the amplitude height for form deviations of 20 µm as calibrated by PTB. These results prove the progress achieved in comparison with the methods currently applied. Drafts of new standards and guidelines for form measurements have already been influenced by this development.

In summary, multi-wave standards provide a solid basis for the traceability of form measurements. Therefore, they are of great significance for users in calibration laboratories and for industrial quality assurance.

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