PTB news
Metrology
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06.3

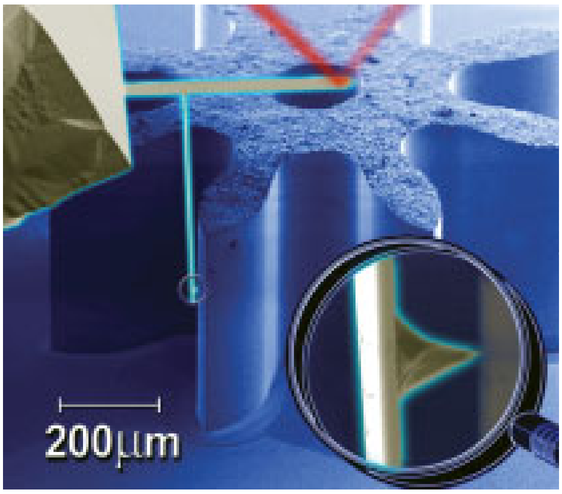
Probing of complex micro- and nanostructures

Novel micromechanical sensors have brought production control of complex micro- and nanocomponents a decisive step forward. These sensors allow the position, form, measure – and even the roughness – to be metrologically determined also on vertical walls of smallest structures. Core piece of the sensors – for which a patent has been applied for – are cantilevers as they are also known from scanning force microscopy.

Already for some years, measuring instruments and microscopes have been available which enable lateral structures – down to nanostructures – on plane surfaces to be made visible. However, on rough surfaces, on structures with high aspect ratio or even on vertical object surfaces, precise measurements have so far not been possible.

These measurements can now be performed with the newly developed sensors. As in a typical scanning force microscope, the sensor consists of a horizontal cantilever. What is new is that to this cantilever, a vertical probe shaft is attached, with the probe tip at its end. The movements of the cantilever which occur when the measurement object is touched, or (in dynamic operation) the changes in the probe oscillation are determined by the optical beam deflection method with the aid of a quadrant photodiode.

Due to the very small radius of the probe tips of approx. 20 nm, the lateral resolution of the new sensors – which are referred to as "ACPs" (Assembled Cantilever Probes) – is very high. Moreover, small contact forces of < 0.01 µN prevent a scratching of delicate surfaces. Another advantage of these



While the microprobe measures the vertical flank of a microgear, the movement of the probe is read out optically. The figure shows the holding chip with the cantilever and the vertical probe shaft.

sensors is that they are composed of commercially available mass-produced microcomponents and can be adapted to the respective measurement task. For applications to microgears and to line edges of printed circuit boards, standard deviations of approx. 1 nm have already been achieved.

It is envisaged to replace the simple probe tip used so far with a star-shaped probe which effects the three-dimensional measuring capability of the ACP sensors. If these sensors are then used in 3D measuring systems (e.g. coordinate measuring machines), an effective solution for testing the quality of complex micro- and nanoproducts can be expected for the near future.

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Broadband reference hydrophones for ultrasound

For a safe application of this diagnostic technique, the sound generated by medical ultrasound equipment must be known. For the calibration of sound pressure sensors (hydrophones), a novel reference hydrophone has been developed at PTB which – due to its high measuring bandwidth – is particularly suited to measure the short sound pulses of medical devices.

Correct measurement of the short – and thus – broadband pulses which are emitted by diagnostic transducer heads requires hydrophones with a transfer function which is, in the ideal case, as flat as possible over a large frequency range. Non-ideal transfer functions can be compensated for with the so-called impulse deconvolution method which will be a part of future standards for hydrophone measurements. This requires, however, calibration data whose magnitude and phase are known in a large frequency range. This is why several bodies are working intensively on an extension of the frequency range of hydrophone calibration.

At PTB, special broadband reference membrane hydrophones have been developed and manufactured. They are characterised by a small diameter of the receiver electrode pair (200 µm) which is applied to the upper and lower side of a thin piezoelectric foil of only 9 µm in thickness. In combina-

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Broadband reference hydrophones for ultrasound

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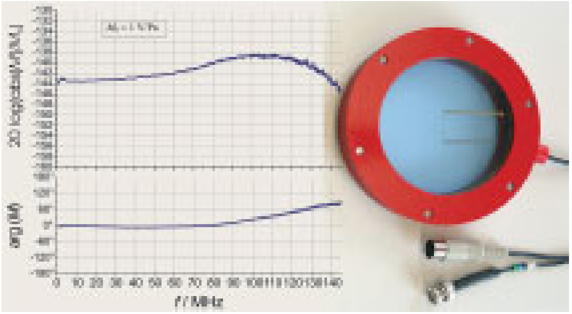
tion with a particular broadband differential amplifier electronics, this construction results in a significantly larger useable frequency range than obtainable from all currently commercially available hydrophones. Up to 40 MHz, the frequency response is extremely flat, and the thickness-mode resonance typical of hydrophones does not occur until approx. 105 MHz for this foil thickness. However, for calibrations beyond 70 MHz, no primary standards have been available so far worldwide, so calibration data here rely on model assumptions or extrapolations.

An important auxiliary means easy to use is now available for the extension and verification of calibration procedures. Hydrophones of this instrument type can, of course, also be advantageously used directly for exposimetry on the medical product, in addition to their use as a secondary standard.



Core piece of the new reference hydrophone is the thin foil supported by the red ring with an electrode pair (0.2 mm) in the centre.

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New calibration facility for brachytherapy

The possibilities available at PTB for the calibration of radiation sources for brachytherapy could be essentially improved with a new calibration facility which has now been put into operation. A collimated beam geometry with a significantly lower scattered radiation component has allowed both radiation protection and the uncertainty of the correction for scattered radiation to be significantly decreased. With the aid of an industrial robot, the secondary standards used for calibration can be precisely positioned, which leads to a further reduction in the measurement uncertainties.

In addition to conventional radiation therapy, brachytherapy is important for the treatment of tumours. Here, a radioactive radiation source is placed as close as possible to the tumour or directly in the tumour tissue via body openings or through hollow needles. Typically, iridium-192 sources approx. 5 mm in length and 1 mm in diameter are used which are brought into irradiation position in a catheter.

For calibration, the radiation source has up to now been positioned freely in the room, at a distance of at least 2 m from the walls, and the radiation measured with an ionisation chamber at a distance of 1.00 m. In the case of this measuring set-up, the component of the scattered radiation from air and walls amounted to approx. 5 % of the total air kerma rate and had to be determined separately. As a result of the free positioning of the source in the measurement room and due to the tendency to use ever stronger sources for therapy (up to approx. 500 GBq), it was, however, difficult to comply with all radiation protection requirements.

The new facility avoids these problems as the calibrations are now performed in a collimated radiation field. For this purpose, a lead box is installed in an especially established radiation protection area, in the centre of which the brachytherapy source to be calibrated is placed. With a commercial industrial robot, the secondary standard is positioned on the central axis of the radiation field defined by a diaphragm with an uncertainty of less than 0.1 mm. By collimation, the undesired scattered radiation component from the air – and thus the necessary correction – is considerably reduced (to below 1 %). Uncertainties in the positioning of the radiation source (approx. 0.3 mm) are largely eliminated through several measurements at different distances between radiation source and secondary standard. The clearly reduced uncertainties directly benefit the manufacturers of the radiation sources and thus ultimately the patient.

Measuring set-up for the calibration of ^{192}Ir brachytherapy sources in collimated radiation geome

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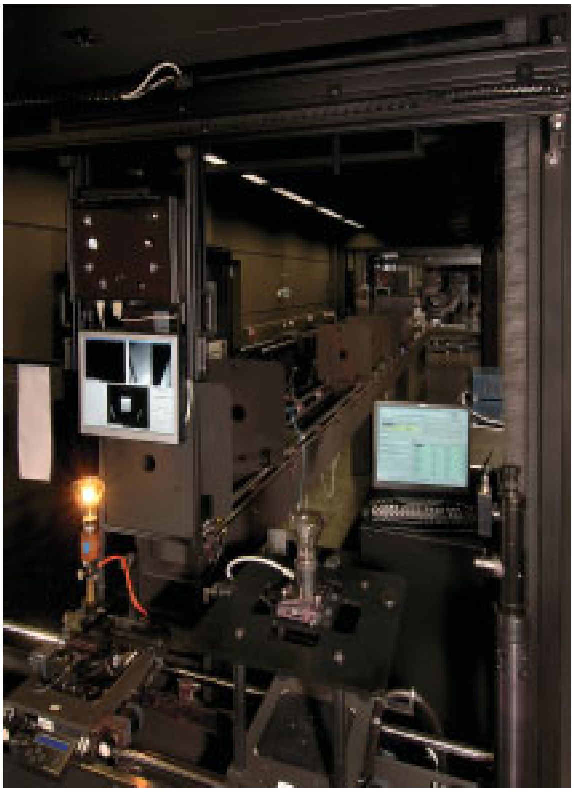
Innovative photometer bench system

With an extensively equipped photometer bench system for the characterisation of both light sources and photometers, distances up to 40 m can now be achieved for the measurement of directed photometric quantities. Thus, the facility – which is unique worldwide – also makes it possible to calibrate even extremely strong light sources with only a small associated measurement uncertainty.

A photometer bench serves to align specific light sources, detectors and/or reference photometers horizontally in relation to each other, and to vary the distance between them by means of different carriages. PTB thus fulfils the main tasks for the realisation, maintenance and dissemination of the SI base unit for luminous intensity, candela, as well as for the derivation of other units of directed photometrical quantities.

The new photometer bench system is composed of three different photometer benches aligned in a row. They can be used singly or together, so that measuring distances up to 40 metre become possible. This system is unique worldwide (normally, even in national institutes, photometer benches up to only 6 metre are in use). At PTB it is now possible to vary (by means of distance modifications) the illuminance over more than three orders of magnitude. Especially for extremely strong lamps, which require a larger distance for their light to appear point-like and provide a more homogeneous illumination, the achievable associated measurement uncertainty could be significantly reduced: at daylight-like radiation by one percent, and for less bright lamps still by approx. one per mil. New monitoring systems for detecting the stability of the luminous intensity, as well as the camera-aided adjustment, contribute significantly to this improvement. Furthermore, an automatic photometer carousel makes it possible to carry out several measurements simultaneously so that the time needed for many of the measurement tasks is reduced by half.

Due to this novel facility, new possibilities for calibration are opening up in four fields: first, for large-scale novel light sources as standard lamps for luminous intensity; second, for luxmeters with illuminances up to 20 klx (illuminant A) or 100 klx (daylight with an HMI lamp); third, for luminance meters with luminances up to 10 kcd/m^2; and fourth, for luminance standards considering the dependence on inhomogeneity and direction.



With the new photometer bench system, calibrations – as in the case of this luminous intensity standard lamp – have become more precise and also much faster – thanks to the camera-supported adjustment aid clearly recognisable in the picture.

The photometrical bench system will also be available for scientists from other institutes and countries. In addition, one of the essential international tasks of the near future will be to conduct a key comparison of the unit of luminous intensity within the scope of EUROMET, with PTB as pilot laboratory. For the comparison, in which 19 European countries will take part, measurements will be carried out on more than 120 standard lamps of luminous intensity.

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PTB is now a Notified Body for Measuring Instruments

Starting October 30, 2006, the European Measuring Instruments Directive (MID) published in 2004 has to be applied within the European Economic Area. The Federal Ministry for Economics and Technology (BMWi) has assigned PTB the task of performing the conformity assessment procedures, and PTB has started to issue corresponding certificates for manufacturers of measuring instruments.

With the coming into force of the MID, the requirements for water meters, gas meters, electrical energy meters and heat meters, as well as for measuring systems for liquids, for automatic weighing instruments, taximeters, material measures, dimensional measuring instruments and exhaust analysers have been harmonised. Before placing a measuring instrument on the market, the manufacturer must issue a declaration of conformity after a conformity assessment procedure has been performed by a notified body. The conformity assessment processes are composed of different modules. Essential modules are the type examination (Module B), the approval of the quality assurance in produc-

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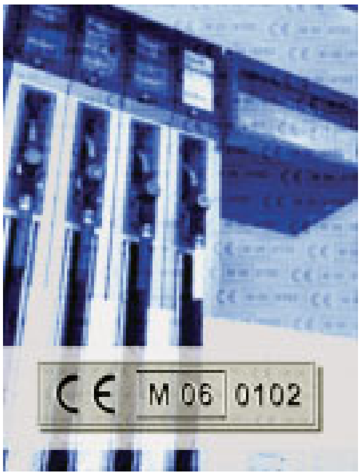
tion (Module D), the design examination including approval of the quality assurance in development and production (Module H1), as well as the verification of serial instruments (Module F).

As the MID has not been transposed into the national Verification Law as of October 30, 2006, it applies directly now. Already on July 11, 2006, PTB was appointed – with the number 0102 – as notified body for the modules B, D and H1 for all measuring instruments mentioned in the MID. For the procedure according to Module F, which more or less corresponds to the "initial verification", verification authorities and state-approved test centres were appointed as notified bodies so that also in future, this task does not have to be carried out by PTB. A comprehensive list of the Notified Bodies in Europe is available in the Internet Information System NANDO IS of the European Commission.

As PTB had prepared itself in due time for the tasks as a notified body, some manufacturers were able to obtain the first MID certificates as EC type examination certificate, EC design examination certificate or EC QM approval certificate already on October 30, 2006. An overview of all MID certificates which have already been issued by PTB so far has been published in the "PTB-Mitteilungen" and in PTB's database "MICert". Further instructions for applicants are listed on the website of the PTB certification body.



Conformity marking of a measuring instrument that was assessed by PTB in 2006.

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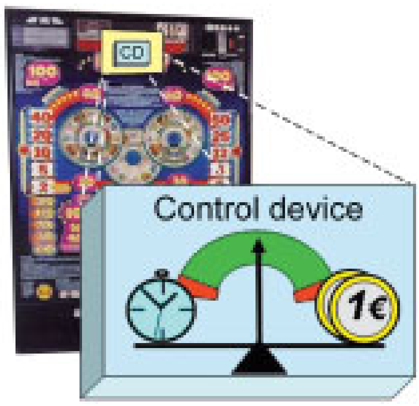
Gaming machines now control themselves

At the beginning of 2006, the German Gaming Ordinance was fundamentally altered – and type examination at PTB thus placed on a new basis. For the protection of players, the modified Ordinance sets limits for winnings and losses and prescribes the installation of a mandatory monitoring unit which continuously ensures – in the background – compliance with these limits.

The previous Gaming Ordinance was chiefly based on the capacities of mechanical gaming machines operating with rolls. It mainly controlled the course of the individual games and limited losses by suppressing certain gaming features. This had the disadvantage that in type examinations, newly created games realised by means of modern, electronically operated machines could hardly be traced back to the Gaming Ordinance any more. Consequently, this led to a growing insecurity not only in type examinations, but also in the surveillance of the gaming business.

By means of the new Gaming Ordinance, a transparent and technically up-to-date principle is now being introduced for the legal protection of players. The core element of this new Ordinance is the concept of a monitoring unit. This concept was developed at PTB and registers all stakes and winnings during the operation of the machine. These registered data serve to monitor the gaming process directly and permanently, with the aim of controlling compliance with certain money-to-time ratios (for example, the sum of losses must not exceed 80 Euro per hour). Since the essential regulations of the Gaming Ordinance are incorporated in the software of the monitoring unit, the focus of the type examination is now on the testing of the functions of the monitoring unit itself and on compliance with a high technical realisation level for a tamper-proof integration of this unit in the gaming machine. Besides a more effective type examination, this brings about more security for the inspectors of the Trade Supervisors Authorities checking the machines at their place of installation.

In contrast to the old Gaming Ordinance, where the period of installation was limited, the new Gaming Ordinance offers the opportunity to extend the period of installation of a machine if a technical inspection has been carried out before. This modification was essentially based on a field study by PTB on the reliability of gaming machines; in the course of this study, approx. 250 machines had been observed during commercial operation for a period of approx. two years. With regard to the failure behaviour, no significant differences were observed between older and younger machines.



Self-controlling of the machines at the place of installation, supplementary to type examination.

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