PTB news
Metrology
Technology
Services
Cooperation
01.2

Traceable power measurements in laser radiometry

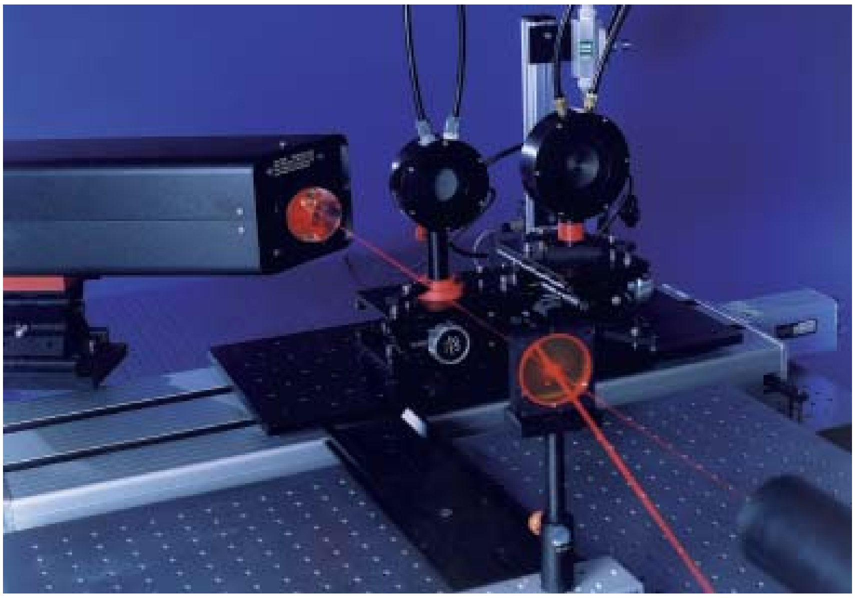
For the most frequently used lasers in the ultraviolet to infrared spectral region (wavelengths from 0,2 µm to 10,6 µm) PTB offers precise power measurements. These measurements are traced back to a cryoradiometer. The uncertainties achieved range between 0,2 % and 1 %.

Whether in medical diagnostics and therapeutics, or in industrial manufacturing, telecommunications technology, precision metrology or fundamental research: in all of these fields lasers play a significant role and their effective radiant power must be measured with high accuracy. However, commercial power meters calibrated by the manufacturers often display measurement readings that deviate by as much as 10 %.

For this reason, PTB has established laser radiometry with the goal to achieve far lower uncertainties (between 0,2 % and 1 %) on the basis of traceable power measurements. All standard laser radiometers of PTB are linked by a traceability chain to a cryo-radiometer – at present the most accurate optical radiant power standard. The radiometers are of very different design and have been optimized for different power and wavelength ranges so that power meters in the nanowatt range (for optical communication engineering in the visible and near infrared) as well as power meters for high output powers above 1 kW (e. g.: high-power CO_2 lasers for material treatment) can be calibrated. PTB calibrates the high precision power meters using the same type of laser and the same laser line as the customer intends to use.

The detector standards are substitution radiometers which absorb the radiation as completely as possible. The electrical power that produces the same thermal heating is determined. Measurements performed with additional electrical heating – starting from the level of the cryo-radiometer (about 1 mW) – allow extending the meter range to higher and lower powers over more than twelve orders of magnitude.

Within the framework of a recently approved BMBF project the measurement engineering and instrumentation for the 157 nm line is presently being developed. Radiation at 157 nm is of significant importance for future semiconductor lithography.



Set-up for the calibration of laser power detectors. The red adjusting beam marks the optical path.

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Chromosome changes after exposure to neutron radiation

The question of how harmful neutron radiation is plays an important role in radiation protection. In a project jointly carried out by PTB and other research institutes a new lower detection limit for chromosome changes in human lymphocytes has been achieved.

Different kinds of radiation fields induce different effects in living cells, even if the cumulative dose is the same. The varying relative biological effectiveness is described by the RBE factor. It indicates the ratio of the dose in a reference field (frequently the ^{60}Co photon field) to the dose in the radiation field to be investigated, which leads to the same biological effect. RBE factors thus provide information about radiation-induced risks. Especially high RBE factors are obtained in the case of neutron irradiation in the energy range between 10 keV and 2 MeV.

In a cooperation between PTB and the Forschungszentrum für Umwelt und Gesundheit (GSF, Research center for environment and health) in München-Neuherberg, human lymphocytes were irradiated in a neutron field and, parallel to this, in a ^{60}Co photon field. Lymphocytes are especially well-suited to yield information in the low-dose range (< 0,2 Gy).

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Chromosome changes . . .

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After irradiating the cells in the PTB's reference fields, the number of damaged chromosomes in human lymphocytes was determined in vitro (in cell cultures) at GSF as a function of the neutron dose. As dicentric chromosomes impede or even suppress the regular process of cell division, fewer changes are observed in each successive cell cycle. Using modern methods of analysis, the GSF has, however, succeeded in determining correction factors which allow to extrapolate the number of dicentric chromosomes shortly after irradiation. This has led to a new lower detection limit in the case of dicentric chromosome changes in human lymphocytes to such an extent that even at low dose values between 26 mGy and 145 mGy a linear dose-effect-relation was detectable. An RBE factor of roughly 70 was related to neutrons with energies of about 200 keV. This has been confirmed by investigations on other cell cultures carried out in cooperation with the universities of Münster and Göttingen.

The results are of considerable importance for the assessment of neutron radiation in radiation protection.

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The arrow points to a dicentric chromosome developed after neutron irradiation. The additional constriction is clearly visible.

Spherical interferometry in the nm range

The new determination of the Avogradro constant N_A requires measuring the volume of an almost perfect silicon single-crystal sphere (1 kg in mass, with a diameter of approximately 93,6 mm) with a relative uncertainty of a few 10^{-8}. A novel interferometer with a purely spherical beam path and a tunable laser system has been developed and set up for this purpose. The new system can determine the diameter as has been common practice to date, yet furthermore, it can display extensive topographies of spherical surfaces.

The novel interferometer concept relies on spherical waves to probe the sphere. The optical set-up comprises a spherical etalon formed by two reference surfaces integrated into special spherical objectives. These objectives transform plane waves behind the input collimators into spherical waves. The pick-up angle of the objectives is 60° so that only a few different orientations of the sphere are needed for a complete topographical image of the sphere surface. To measure a sphere diameter d, first the diameter D of the empty etalon is determined. In a second step, the sphere is introduced into the etalon so that two new interferometers are formed, with spacings d_1 and d_2 between the reference surfaces and the corresponding sphere surface. The diameter of the sphere results from the difference $d = D - d_1 - d_2$.

The interference pattern is photographed with a CCD camera and evaluated using phase shifting interferometry. The phase steps required are produced by a change in the laser wavelength.
A novel laser system developed in the laboratory is used for this purpose. This system can be tuned over a range of 12 GHz and, moreover, it can be stabilized to a desired frequency, with an uncertainty of a few 100 kHz.

Initial measurements were carried out on a sphere of black filter glass. The reproducibility of the sphere topography and of selected diameters is at present in the range of a few nanometers. It can therefore be expected that the aspired uncertainty of 1 nm in the measurements of the diameter of the silicon sphere can in fact be achieved.

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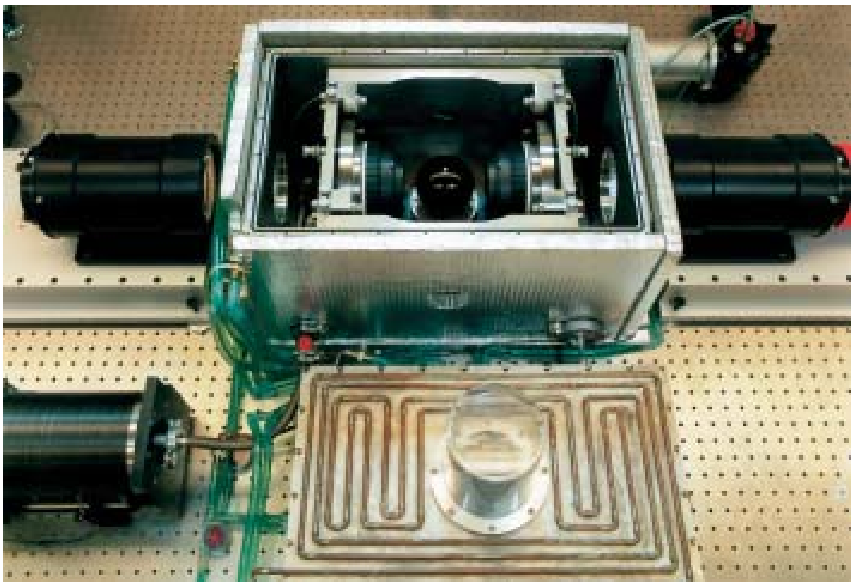
Precise thermalization and the measurement of the absolute temperature are the prerequisites for measurement uncertainties in the nm range. The measurements are carried out in vacuum to eliminate an influence of the air on the refractive index.



Fiber-optical microprobe for ultrasound and temperature

The ultrasonic pressure and the temperature in liquids can now be detected simultaneously by means of a fiber-optical microprobe. The properties of the microprobe, e. g. extreme miniaturization and high temporal and spatial resolution, open up novel applications in medicine and technology.

Appropriately prepared optical fiber ends constitute an efficient alternative to conventional electrical sensor systems. In particular, for measurement tasks requiring high temporal and spatial resolution, minimal invasiveness, high shock resistance or small heat conduction, very small optical sensors offer important advantages.

In the sensor developed at PTB, the sensitive element is the front face of an optical fiber coated with a system of optical interference layers. Ultrasound detection is based on the elastic deformation caused by an incident sound wave in the layer system which itself acts as a microinterferometer. The total thickness of the layer system is less than 2 µm. It is designed to yield a sensitive change in the optical reflectance as a function of the deformation at the operational light wavelength. The change in optical reflectivity is detected with a simple optical arrangement. As the refractive indices and the thicknesses of the layers also depend on the ambient temperature - and thus the resonator length of the microinterferometer, too -, the same sensor can be used simultaneously for temperature measurements. The time scales on which the acoustic and thermal measurands change are significantly different and the different signals can be separated by frequency filtering.

In a first application, the new measuring technique was applied in cooperation with the University of Kaiserslautern to investigate shock wave propagation and heat development in the vit-reous body of an eye during tissue removal by infrared laser pulses. Such in-situ measurements are important to assess the potential damage vitre-ous-body laser surgery may cause in the surround-ing tissue, in particular, in the retina. Some other examples where ultrasonic pressure and tempera-ture are to be measured simultaneously are ultra-sound exposimetry and applications in chemical process technology, sonochemistry and ultrasound cleaning technology, where the entire ultrasonic pressure range up to 100 MPa and temperature increases by more than 100 K can be covered

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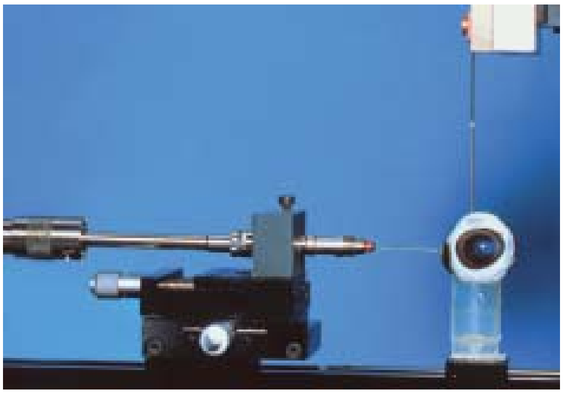

Photo taken at the Physics Department of the University of Kaiserslautern

Arrangement for shock wave and temperature measurements in the vitreous body of a pig's eye during exposure to infrared laser pulses. Sound pressures of several MPa and temperature increases up to 15 K were measured.

Data storage for weighing instruments harmonized in Europe

Weighing instruments belong to a category of measuring instruments widely used in commercial transactions and therefore subject to legal control. For more complex applications, computer-based weighing systems of modular design, capable of being operated in local or other networks, can be verified with much lower effort if data storage devices subject to legal control have been incorporated.

Legal control of measuring instruments is one consequence of the legislator's intention to protect consumers and to guarantee fair trade and fair competition in commerce. In the simple case of a counter scale, the customer can trust the measured values indicated or printed, because the weighing instrument has been verified as a compact device. In trade and industry there is, however, a trend towards modular and computer-aided weighing systems. These systems can be operated in local or other networks. They can comprise a chain of individual instruments or modules: from a load cell and signal converter to more complex communication equipment (to transmit and receive weighing data) for indicating measured values or further processing in a computer system. A typical application is the weighbridge to determine the net load of lorries and other vehicles.

In principle, to create measurement results which are safeguarded against manipulation and trustworthy would require that all components in the measurement chain are type-approved and verified – a requirement which can hardly be achieved in practice. To meet the commercial wish to use company-own data processing systems and communication networks, which are not subject to legal

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Data storage for weighing instruments...

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control, in the processing of weighing data, the European Weighing Instruments Directive 90/384/EEC exempts data processing systems from legal control provided the results of the weight measurements are recorded by a verified data storage device or printer ("alibi printer"). This means that – in order to maintain an unbroken chain of trust – the weighing system must contain at least one indicating unit with a data storage or printer output subject to legal approval and control in order to compare the weight measurement results with those of the non-verified modules in the chain.

The legal requirements for these data storage devices and alibi printers had been formulated in rather general terms in the past. This gave way to a very insufficient harmonization of type approvals and practically no verification technological supervision of the systems could be realized. On instigation by PTB, WELMEC, the European Cooperation in Legal Metrology, attended to the matter. It has now published new, supplementary rules for data storage devices acceptable for verification in WELMEC document 2.5 "Guide for modular approach and testing of PCs and other digital peripheral devices". The technical requirements in the document were decisively affected by the experience PTB had gained in consumer protection exercised in Germany. For the first time there are now Europe-wide uniform requirements for data storage devices so that the technical progress of complex, computer-based weighing systems is not impeded.

Weighbridge inserted in the floor to determine the net load of lorries. Source: Schenck Process GmbH

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Helmholtz Prize for 2001 awarded

The winners of the Helmholtz Prize for 2001 with Ruprecht von Siemens, Treasurer of the Helmholtz-Fonds (in the centre): Stefan Hell, Jochen Bonn, Christian Weinheimer and Thomas Klar (from the left).

This year's Helmholtz Prize, the most important prize awarded in the field of metrology, acknowledges two topics: Accomplishments in research of neutrinos and the technology of microscopy. The prize was presented on June 25 within the framework of a festive event in PTB's lecture hall. It was shared in equal proportions of 20 000 DM by Dr. Jochen Bonn and Dr. Christian Weinheimer, Institute of Physics of Johannes Gutenberg University in Mainz, for their work "High-precision measurement of the tritium beta spectrum near its endpoint and upper limit on the neutrino mass", and Dr. Stefan W. Hell and Dr. Thomas A. Klar, Max Planck Institute of Biophysical Chemistry, Göttingen, for their work "Durchbruch der Auflösungsgrenze in der Fernfeld-Fluoreszenz-mikroskopie (STED-Mikroskopie)" ("Breaking through the limits of resolution in far-field fluorescence microscopy").

Subscription to PTBnews

In the last edition of the PTBnews we asked you to confirm your subscription of PTBnews. We have received a large number of (mainly positive) replies. However, still a large number of our readers have not reacted at all. May we remind you that we can only mail future editions of PTBnews to you if you update your entry in the subscriber list? To do so, please contact the editors by letter, fax or e-mail. As to the e-mail alternative: You will find an online form (Subscription to PTBnews) on our homepage (www.ptb.de). Thank you for your cooperation.

The editors of PTBnews

Erratum

In the last English edition of the PTBnews (01.1), an additional dot slipped into the contribution "Software Test Centre Accredited" creating an erroneous web address. The correct Internet address of the PTB's software test centre is: www.softwarepruefstelle.de

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