PTB news
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01.3

Micro ion beam for radiobiology

At PTB's ion acceleration facility a new micro ion beam apparatus has been developed. The new machine is dedicated for applications in radiobiology. It can irradiate living cells with a defined number of ions at a lateral accuracy in the sub-cellular range. Such micro ion beam experiments serve above all to investigate relevant phenomena in radiobiology, such as tumour formation.

Tumour growth is a complex, multistage process. Initially the genetic material of a normal healthy cell is damaged. This initial damage can occur spontaneously or it can be induced by interactions with various agents, e. g. chemical substances, viruses or ionising radiation. With the new apparatus scientists can expose living cells to ionising radiation in a controlled manner. This makes it possible to investigate the mechanisms responsible for the creation of cancer cells induced by exposure to ionising radiation. In result, improved estimates of the hazards of occupational and natural radiation exposure can be made.

In recent years, a few research institutes have endeavoured to improve their ion beam facilities to such an extent that cells could be irradiated with a defined number of ions at sub-cellular lateral accuracy (< 5 µm) (micro ion beam). Advantages of applying micro ion beams are that the contingencies of conventional irradiation are eliminated and important control parameters such as dose, dose rate and target location can be pre-selected with high accuracy. Effects of low doses can be investigated with higher reliability than was hitherto possible.

The apparatus at PTB's ion accelerator facility utilizes magnetic lenses to focus a proton or alpha particle beam on a lateral diameter of about 1 µm. The intensity of the beam is reduced to a few particles per second. Thin scintillation detectors measure the impingement of an ion on the sample with an efficiency of 98 % to 100 %. A substantial advantage over other operating facilities is the wide range of ion energies available at PTB. Significant investigations of the effects induced by the different kinds of radiation found in nature (i. e.: alpha, beta and gamma radiation) can now be carried out.

Micro ion beam apparatus with optical microscope

First cell irradiations have been carried out in co-operation with the Faculty of Medicine of Göttingen University. Other scientists working in radiobiological research and other fields, for example materials research, intend to use the PTB facility for novel experiments. Cell irradiations in routine operation will be possible from summer 2002.

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New apparatus to measure crystal orientation with unsurpassed accuracy

The phase angle between surface and lattice planes of wafer disks is a crucial quantity for the semiconductor industry. It must be traced back to the SI units. To use silicon in metrology, for instance, to re-determine the Avogadro constant, precise determination of the phase angle is an important issue. For this purpose a new apparatus for high precision crystal orientation measurements has been designed and constructed at PTB. It has now gone into service.

The measurement method exploits X-ray beam interferences on single crystal samples to determine the orientation of a certain lattice plane normal in relation to defined geometrical directions. The main components of the apparatus are an X-ray goniometer with rotary table, goniometer head, X-ray tube, X-ray detector and an optical measuring system with an autocollimator and a reference mirror. The sample holder with the sample is rotated around the goniometer axis until, after rotating through 90°, a maximum intensity is found and the lattice plane normal is adjusted parallel to the goniometer axis. The angular deviation of geometrical directions from this crystallographic direction are then determined by optical methods.

The apparatus is set up in an air-conditioned laboratory. It is used to check the so-called off-angle between the wafer surface and the lattice planes of selected Si, Ge and GaAs reference samples. The

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New apparatus to measure crystal orientation with unsurpassed accuracy

accuracy achieved by this method depends on the specific meaurement task and ranges from 1″ to 25″ (angular seconds). It is thus more than an order of magnitude higher than the measurement accuracies achieved so far with comparable measuring methods (DIN 50 433).

For industrial applications such as semiconductor processing knowing the precise orientation of wafers is fundamental, i. e.: for the growth of epitaxial layers. It is of great economic relevance in this field.

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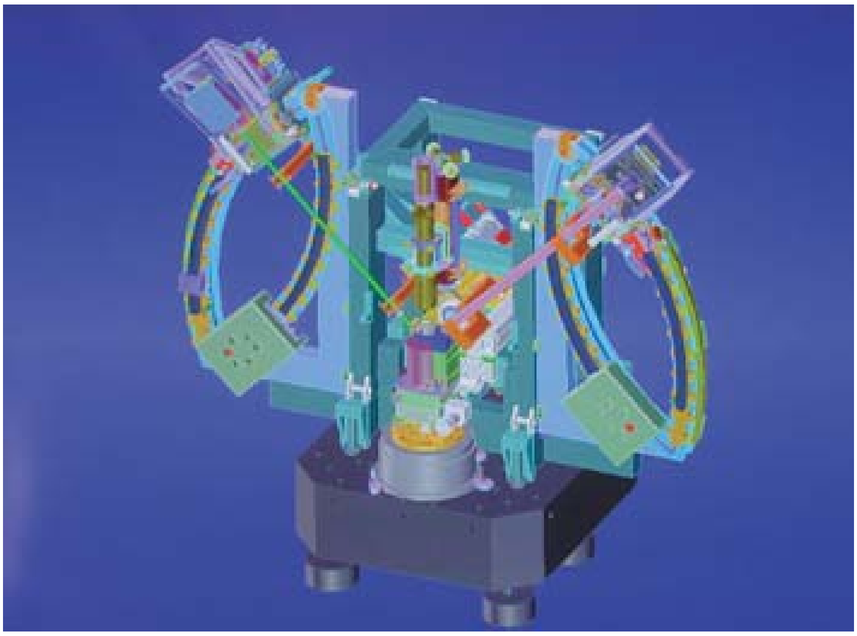
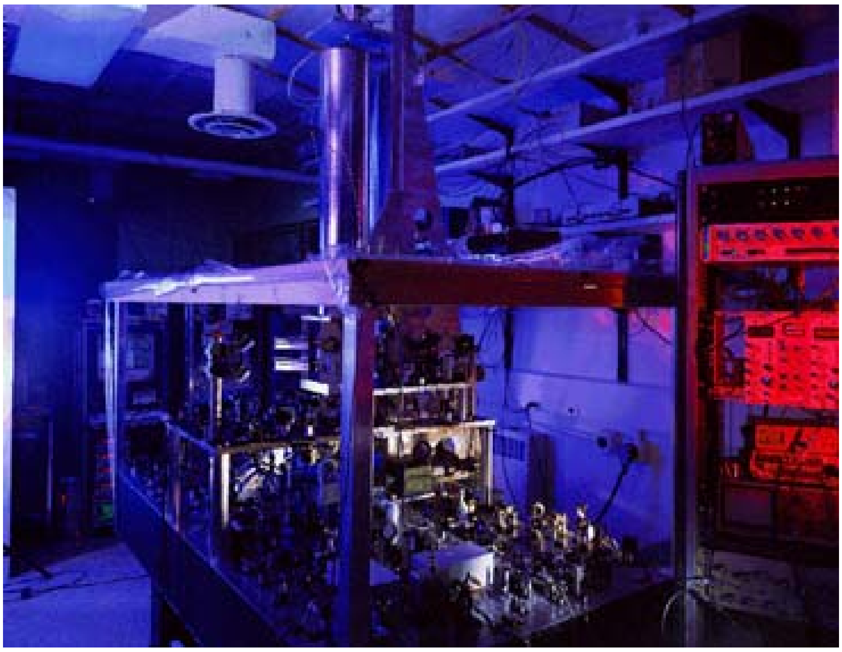


Single crystal orientation apparatus
Geometrical dimensions: roughly 2 m × 2 m; mass: around 1 ton (1000 kg)

Highly precise comparisons of fountain frequency standards



Fountain frequency standard: NIST-F1

PTB and the US National Institute of Standards (NIST) have carried out a joint project to compare two laser-cooled caesium clocks over a period of several weeks. The measured relative deviation between the two clocks was lower than $0.5 \cdot 10^{-15}$, significantly lower than the estimated uncertainty of $1.5 \cdot 10^{-15}$ for each frequency standards. The relative deviation was determined with a very small measurement uncertainty of $0.6 \cdot 10^{-15}$.

Today the most accurate atomic clocks, also called caesium fountains, utilize laser-cooled caesium atoms. PTB operates such a clock CSF1 since 1999. The well defined and low velocity of the atoms yields a stability and accuracy at least one order of magnitude higher than what was formerly achievable with caesium atomic clocks using thermal atomic beams. The stability of CSF1 had already been confirmed by comparison with an active PTB hydrogen maser. Then, during a two month operational period PTB's CSF1 and the caesium fountain, NIST-F1, at NIST were compared. The two clocks are of similar type and accuracy although they were constructed following different design principles.

First, NIST-F1 and CSF1 were compared with active hydrogen masers available at the respective locations. Then the two masers were compared with each other by two different methods. One method recorded the travelling time of time signals exchanged between the two institutes via telecommunication satellites. The other method was a further development of the well-established technique to register the arrival times of signals from the **G**lobal **P**ositioning **S**ystem (GPS), which has been applied for many years. The results obtained by both methods over the period of the project differed by $0.3 \cdot 10^{-15}$. This value was taken into account in the measurement uncertainty stated above. The deviation found does not indicate a systematic difference between the two fountains. Both fountains are thus very accurate at measuring time. The small measurement uncertainty is remarkable inasmuch as the two fountains are operating 9000 km apart from each other.

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Characterization of analogue-to-digital converters

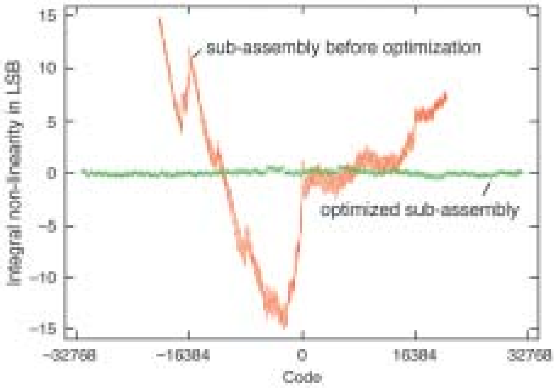
Users of analogue-to-digital converters (ADC) often are unaware of how crucial the accuracy of the converters can depend upon the wiring of the modules. In particular, the influence of the wiring can be very decisive when dealing with high signal bandwidths and high signal dynamics.

PTB has developed a new measuring set-up to perform high-standard metrological characterization of analogue-to-digital converters and complete ADC sub-assemblies.

Modern measurement and data acquisition systems demand for ADCs and ADC subassemblies with ever higher resolution and linearity at high bandwidth. In practice, however, simply substituting higher resolution ADCs (e. g.: 16-bit or even 24-bit converters) for lower resolution types (e. g.: 12-bit converters) often does not improve the accuracy to the anticipated extent: Proper wiring of ADC modules becomes increasingly important with higher resolution. This is often underestimated. The higher the aspired accuracy is the more important are proper and stable mass and voltage supplies, exact timing, correct routing of the critical signals, layout of interference suppression, and the shielding or partial shielding of important components.

Increasingly more time and effort must be spent on testing ADC sub-assemblies. Dynamic testing of sub-assemblies with test signals that vary in duration is especially difficult at high scanning rates. The measurement adapter required for the test as the link between ADC sub-assembly and measuring set-up must be modified, too.

Engineers who design the circuits often are not in a position to carry out these important measurements by themselves because the suitable technical equipment is not readily available. Investigations and tests of ADC modules and complete sub-assemblies can now be carried out with high metrological quality at the new PTB measuring set-up. Such investigations of ADC sub-assemblies have already been carried out, for example, for the automobile industry. In most cases, the measurement results lead to a marked improvement of the ADC sub-assemblies.



Improvement of a 16-bit data acquisition card by circuit optimization
The figure shows the integral non-linearity of a 16-bit ADC data acquisition card measured at PTB. The red curve represents the behaviour of the first specimen of the sub-assembly. On the basis of the measurement results, the error sources could be identified and the card optimized. The green curve represents the result of optimization where the linearity is very good. An integral non-linearity of 0 LSB (least significant bit) in the entire code area is the theoretical limiting value for an ideal ADC.

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Thermal conductivity of water and ice

The thermal conductivity of water and ice can now be determined in a single short-time measurement with a very simple new device.

The non-stationary hot strip technique has already been applied to measure the thermal conductivity of solid matter (cf. PTBnews 2.2000). In principle, a thin metal strip is clamped between two cuboidal sample halves and the temperature increase in this strip – as a measure of the thermal conductivity – is recorded during a four-conductor resistance measurement at high currents.

By fixing the strip lengthwise inside a tube sealed at both ends, liquids and gases contained in the tube can be investigated, too. Using such a simple measuring cell the thermal conductivity of water and ice has been measured simultaneously for the first time. Water was cooled down to – 3 °C and the thermal conductivity of the ice was measured. Once the experiment is carried on beyond freezing point the ice begins to melt around the heated strip. A "solid–liquid" phase border is created which moves through the container as the heat gradually dissipates outwards to the tube wall. The transition energy needed for this process is continuously withdrawn from the strip. The temperature signal from the strip changes accordingly. The signal is now a measure of the thermal conductivity and the heat of transition of water. By arranging a thin platinum wire parallel to the strip as an additional temperature sensor the thermal diffusivity of the sample liquid can be determined as well. Despite the simple design of the measuring set-up, comprising merely a strip, current sources, platinum wire, voltmeters and a PC, uncertainties of 3 % can be reached.

The experiment outlined above, using water as the model substance, has already confirmed impressively results of the theory of heat conduction with phase change. Now measurements "across the phase border" are feasible. Such measurements can quickly provide reliable values of transport quantities in this temperature interval which is not easily accessible. These transport quantities are crucial, for example, for improving gentle deep-freezing of food or for transport and processing of crude oil.

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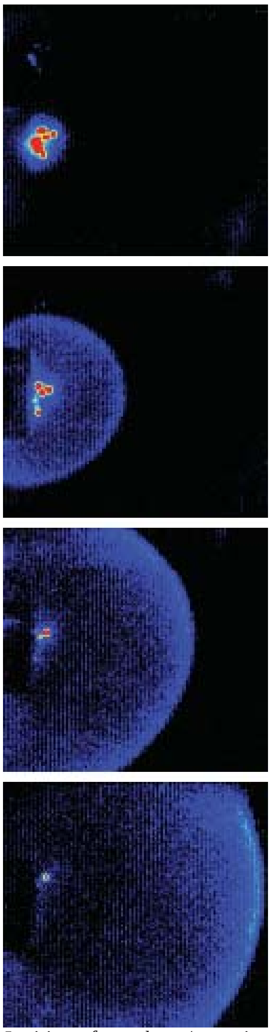
Ignition by laser irradiation



Ignition of an ethene/gas mixture by a laser pulse impinging on the absorber (absorber marked in yellow)

Two international projects with PTB participation have, for the first time, determined limiting values for laser radiation in potentially explosive atmospheres.

Drawing-up recommendations for the intrinsically safe use of optical radiation in a potentially explosive atmosphere has become an important task in the field of explosion protection because of the manifold applications of lasers in research and industry, for example, in material machining or data transmission. In particular environments optical radiation can be an ignition source if the irradiance exceeds a critical value. PTB has therefore participated in two projects of the European Community to determine limiting values for optical radiation.

For this purpose, the lower power limits to ignite various gas/air mixtures were determined for near infrared radiation. As a result different radiation limits must be laid down for pulsed and continuous radiation, respectively, as the ignition mechanism is different in both cases. To investigate the case of pulsed radiation, nanosecond pulses and modulated microsecond pulses from lasers were compared in experiments with and without solid absorbers. The pulse energies required for ignition were found to be clearly reduced when solid absorbers were used. Comparison of different absorber materials shows that the lowest ignition-capable energies are obtained with flammable materials. The energies lie in the range of the minimum electric ignition energies of the gases investigated, they are, however, never lower than the latter. Non-flammable materials are found to induce ignition at distinctively higher energies. Contrarily however, these materials were identified as optimum absorber materials for ignition by continuous irradiation.

It was not possible to induce ignition below a limiting value of 50 mW continuos radiant power in any of the fuels and gas mixtures investigated. Taking an adequate safety distance into account a recommended limiting value of 35 mW radiant power should not be exceeded. This value applies to the wavelength range extending from the near infrared to visible light and under the condition that non-flammable or averagely-flammable absorbers are used. For laser beam of greater diameter (above 7 mm^2), this value can be increased to a less restrictive value, i.e. an irradiance of 5 mW/mm^2.

The results obtained prove that, in isolated cases, it can be possible to determine a less restrictive limiting value for a specific beam/absorber combination. In other cases, it will be useful to encapsulate the radiation by suitable means instead of basing the design on an assessment of the intrinsic safety. The results of the work performed will have an impact on international standardization, i. e. they will be incorporated in a standard concerning the use of instruments in mines.

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Trade facilitated for exporters of weighing machines

PTB and Chinese partner institutes have signed an agreement on mutual recognition of measurement results. In the future German exporters of weighing machines will find trade with China much easier.

Professor Manfred Kochsiek, vice-president of PTB, signed an agreement between the Physikalisch-Technische Bundesanstalt (PTB) and several Chinese partner institutes in Beijing on November 1, 2001. The agreement regulates the mutual recognition of measurement results. Presently, the agreement is valid for measurement results of weighing machines and load cells. From now on China and Germany will recognize metrological tests carried out at PTB or one of the Chinese partner institutes. A corresponding agreement with Japan has been in force since 1999. German metrology which holds a leading position in the world will profit from the new agreement. This will also set a signal for future multilateral agreements with other countries around the world.

The agreement was signed in Beijing within the framework of the second ministerial meeting of the German-Chinese Dialogue Forum – a meeting in which Gerhard Schröder, the German Chancellor, Werner Müller, the German Federal Minister of Economics, and a delegation of top German industrialists participated.

Manfred Kochsiek, PTB (left) and Xuan Xiang; AQSIQ (State General Administration of People´s Republic of China for Quality Supervision and Inspection and Quarantine) (right) sign the Mutual Recognition Agreement of Test Results concluded between the metrology institutes of Germany and China

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