PTB news
Metrologie
Technologie
Dienstleistungen
Zusammenarbeit
05.2

Radiography with fast neutrons

Novel neutron cameras developed by PTB and tested at the existing accelerator facility can be used to detect explosives and drugs in air flight luggage and air cargo containers.

Neutrons are excellent probes for non-destructive material investigations. Neutrons can reveal properties and material compositions which x-rays cannot or only with insufficient resolution. Radiography and tomography with slow (thermal) neutrons are already widespread methods to measure the distribution of substances containing hydrogen in samples – predominantly at stationary facilities such as research reactors and spallation sources. Contrarily, high energy neutrons, like those produced at the PTB accelerator, so far have been scarcely deployed. Due to their specific interactions with the atomic nuclei of matter and their high penetration power, however, they are particularly suited for investigating voluminous objects such as travel luggage, containers, heavy machine parts or minerals. Until nowadays though the complexity of facilities to produce neutrons and a less well-developed status of image-producing detection systems prevent a wider employment of this method.

At PTB efficient high-resolution cameras for energy-resolved radiography with 2 MeV to 10 MeV neutrons are developed in cooperation with the University of Frankfurt and the Weizmann Institute in Rehovot/Israel. To date several prototypes of such cameras, based on two different functional principles, have been developed and investigated at PTB's neutron facility. Combined with intense pulsed neutron sources these cameras will enable measuring light elements such as C, N, and O in closed containers, for instance to identify explosives or drugs.

For practical applications at airports, border installations or in industry, however, in addition to efficient imaging procedures compact high power facilities to produce neutrons are needed. Therefore, in a new project together with the University of Jena PTB will investigate if high power neutron sources, driven by high power lasers, can be built for these applications.

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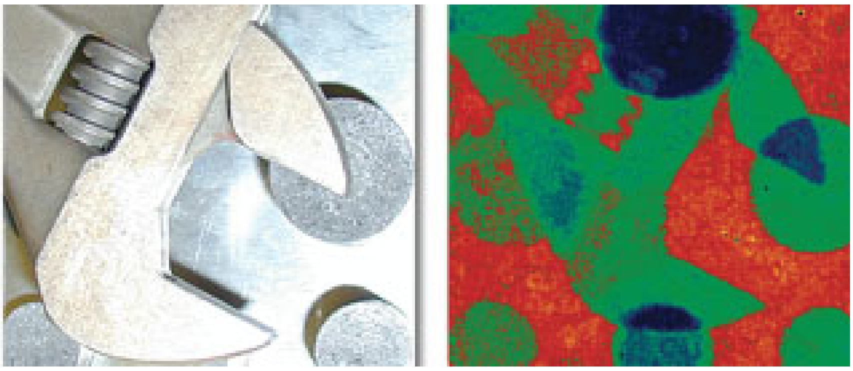

Photograph of a sample made of steel and carbon. In the neutron picture on the right the carbon disks covered by the wrench are clearly imaged.

High-precision length measurements in space

A new interferometric measuring system has been developed at PTB. The LaserTracer can carry out high-precision length measurements in space. With the patented laser beam guide a ten times higher accuracy was achieved in comparison to conventional laser trackers.

The LaserTracer developed at PTB belongs to the category of laser trackers. These are laser-based 3D coordinate measuring machines that determine positions in a 3-dimensional space by measuring two solid angles and an interferometric length. By neglecting the angular information they can still be deployed, in principle, for intereferometric length measurements in a volume – however often with insufficient measurement accuracy, impaired by the mechanical quality of the axes of movement.

The new LaserTracer carries out interferometric length measurements exclusively whereas the increased accuracy is provided through a novel tracing system for the laser beam. A stationary steel precision sphere serves as spherical reference mirror, while the entire optical unit is guided around its centre. Because of the low shape deviation of the sphere (< 50 nm) all interferometric measurements relate to the centre of the sphere. This principle significantly reduces the measuring uncertainty: at a measuring length of 5 m the measurement uncertainty of a conventional laser tracker is roughly 13 µm, that of the LaserTracer, however, is merely 1.5 µm.

One application for the LaserTracer is to improve the accuracy of coordinate measuring machines. The uncertainty in profile deviation of a gear measurement can be reduced from 1.5 µm to 0.8 µm, for instance, by means of a special procedure. In result

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High-precision length measurements in space

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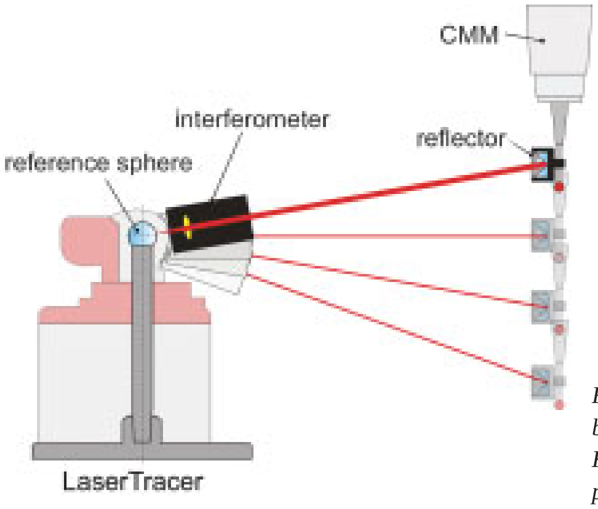
PTB can provide standards to industry with distinctly higher accuracy.

A second field of deployment is the recording and correction of systematic errors of coordinate measuring devices and production machines. This procedure, which was developed together with the National Physical Laboratory (NPL) in England, not only enables the considerable increase in accuracy but also a significant reduction of the measurement time.

A complete parameter set for correction can be recorded within four hours. In the mean time the LaserTracer and this procedure have become available on the market.



The laser beam of the LaserTracer automatically follows a reflector attached to the probe of a coordinate measuring machine (CMM) or to the tool head of a production machine.

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High field microkelvin facility

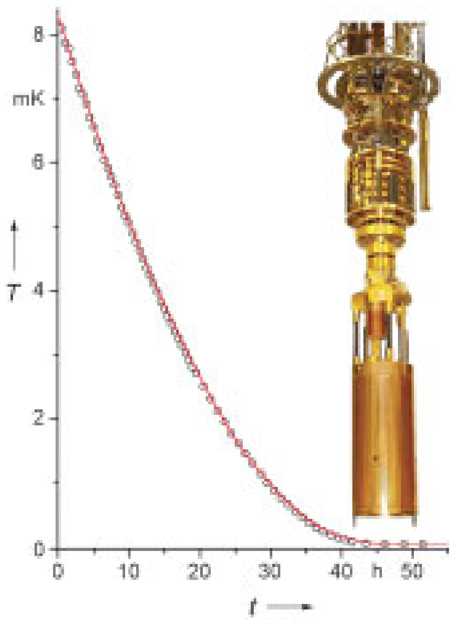
The PTB microkelvin facility in Berlin has been set up and successfully tested. It is now possible to maintain temperatures of only a few millionths of a degree above absolute zero. In addition, the behaviour of condensed matter in strong magnetic fields can be investigated in this temperature range.

The novel threefold nuclear stage, developed in cooperation with Max-Planck-Institute for Physics of Complex Systems in Dresden, consists of concentrically arranged cylinders of high-purity copper and aluminium. The stage can cool a "payload" down to temperatures in the lower microkelvin range by means of adiabatic demagnetization of the nuclear moments from 8.5 Tesla down to a few millitesla.

Already in first tests using a thermodynamically optimized demagnetization function lattice temperatures below 25 μK were achieved and maintained for several hours. Expensive measures were taken for HF screening, to attenuate mechanical vibrations and to minimize an internal heat leak by the appropriate selection of materials. The measures have reduced the heat leak to below 1.5 nW.

Thanks to the more effective exploitation of the field of the first magnet the concentric set-up of the threefold cooling nuclear stage allows the application of a second large magnet below the cooling stage. With this magnet, which has a very high field homogeneity, the magnetic behaviour of ultracold matter can be investigated in magnetic fields up to 9 Tesla – in this form currently a unique experimentation environment.

In the focal point of the investigations with the cooperation partners from Dresden, Heidelberg, and Berlin are magnetic field induced macroscopic quantum effects and basic metrological questions concerning definition and measurement of the base unit temperature as well as their quantum mechanical limitations.



Lattice temperatures measured on the 105-mol-copper stage of the Berlin microkelvin facility with Pt-NMR. The achieved minimal temperature was 23.3 μK. The red line depicts the calculated course of temperature for the thermodynamically optimized demagnetization function.

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Purely optical generation of Terahertz current pulses

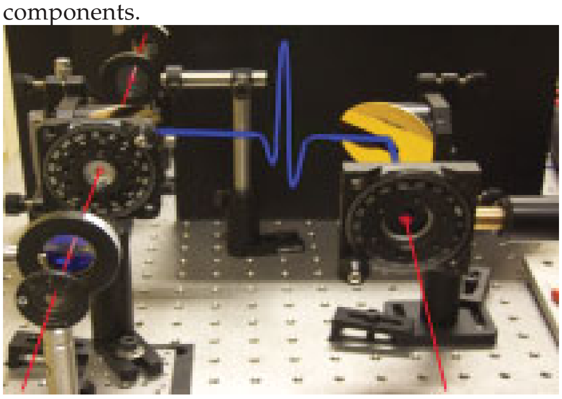
The generation of electrical currents in semiconductor structures by optical excitation alone has been achieved at PTB. The procedure applied had so far only been realized at a few laboratories in the world. Special feature of the procedure is that it does not require an electrical field to accelerate the charge carriers. In a sense this corresponds to creating a current flow without a voltage source. Such procedures can become important in the future, among other things for high-frequency signal processing.

For characterization of highest-frequency components it is desirable to produce ultrashort current pulses, the temporal form of which can be varied arbitrarily. Hitherto methods to produce current pulses of a few hundred femtoseconds in length are based on a combination of electronic and optical procedures that do not allow a variation. PTB has now succeeded in producing ultrashort current pulses by means of a solely optical method. With this method it is, in principle, possible to modify the shape of these current pulses.

At PTB special semiconductor nanostructures were produced and excited with short optical pulses to create the purely optically generated currents. Certain symmetry conditions had to be taken into account for the excitation process. By exploiting non-linear optical processes an electrical current is created in the semiconductor. In the process the charge carriers are not accelerated in an existing electric field as would be for a normal electrical current.

The pulses are measured via the simultaneously generated electromagnetic radiation: the pulses produce a polarization variation which acts as a source for electromagnetic radiation emitted into free space. Due to the ultrashort optical excitation the current pulse and radiated electromagnetic pulses are merely a few 100 fs in duration. Such short pulses contain frequency components of several Terahertz which is why they are usually called Terahertz pulses. The temporal shape of the emitted Terahertz pulses is measured with electro-optic methods.

Further experiments will investigate the coupling of the optically generated current pulses into planar waveguides. Such waveguides are important for the characterization of high-frequency components.



Part of the experimental set-up. The propagation paths of the laser pulses and the Terahertz pulses (red and blue lines, respectively) and the typical temporal shape of a Terahertz pulse are colour-marked.

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Non-invasive measurement of blood perfusion in the brain

PTB has developed a new measurement procedure based on near-infrared reflectometry and spectroscopy. The new method can distinguish between variations in blood perfusion occurring in the cerebral cortex and in overlying tissue layers (skin, bone). This enables optical and thus non-invasive monitoring of the blood perfusion in the brain of stroke patients.

Near-infrared reflectometry exploits the fact that the penetration depth of light into biological tissue can reach several centimetres in the spectral range between 650 nm and 900 nm. It can be applied as a spectroscopic probe for medical-diagnostic purposes. For instance, near-infrared reflectometry can reach through skin and bones to the cerebral cortex. Changes in perfusion as well as oxygen saturation of the blood can be measured. Using short laser pulses and measuring the dwell time (time of flight) of the photons in the tissue the depth at which photons were absorbed can be concluded. The time resolution of the method is in the sub-nanosecond range.

A promising application of this method is monitoring of blood perfusion in the brain of stroke patients. In case of reduced perfusion in certain areas of the cerebral cortex as a result of a stroke this can be detected and monitored, since an intravenously applied optical contrast agent will arrive there with a time delay. This has been demonstrated by PTB in cooperation with the Department of Neurology of the Charité, Berlin, within the framework of the Berlin Neuroimaging Centre (BNIC), a joint project funded by the German Federal Ministry of Education and Research (BMBF).

In a project funded by the German Federal Ministry of Economics and Labour, BMWA, PTB is currently cooperating with the companies Pico Quant GmbH and Loptek GmbH to set up an imaging

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Non-invasive measurement of blood perfusion in the brain

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system based on the measurement procedure described before. The aim is to localize variations in blood perfusion of the cerebral cortex within a larger section on the surface of the head.

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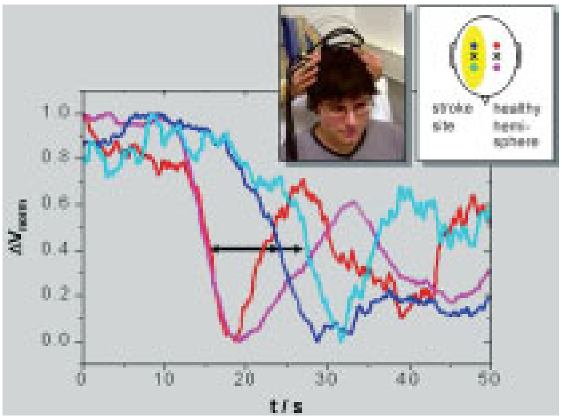

The change in variance DV of the time-of-flight distribution of photons reveals the delayed arrival (see arrows) of the bolus of an optical contrast agent (indocyanine green) in the brain area with impaired perfusion due to an acute vascular occlusion.

Galileo enters the next stage

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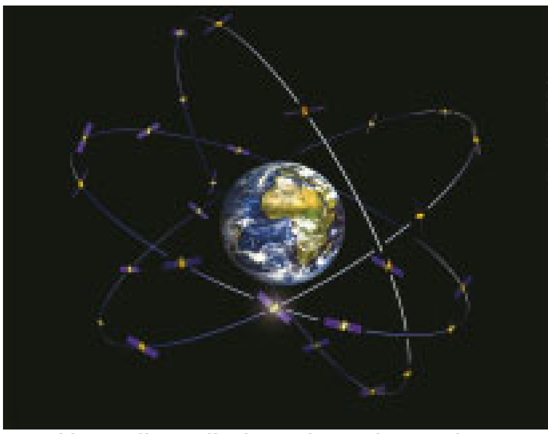
Galileo is the new European satellite-based navigation system. Now, the installation phase for Galileo with PTB participation has begun after a long preparation and concept development period. In this year still the first test satellite is to be launched into orbit and Galileo-signals are to be received.

Galileo will be a satellite-based navigation system under European civilian control and independent of the existing systems GPS (global positioning system, USA) and GLONASS (the Russian pendant system). After completion of Galileo 30 satellites will orbit the earth at a distance of 24 000 km. Each of them will have several atomic clocks on board and will send continuous time signals to earth. The time signals can be exploited by means of propagation time measurements to determine a position with an accuracy of a few metres. Concerning the technical features Galileo is very similar to the American and Russian systems, so that currently negotiations are being held with the goal to make the three systems "interoperable". Signals from all satellites of the three systems are to be made receivable to enable a position determination with just one receiver.



(Quelle: ESA)

30 Galileo satellites will orbit earth in such a way that time signals from at least four different satellites can be received simultaneously at all locations.

In December 2003 the preparation phase was completed with the so-called "Galileo complete definition" and the phase for detail planning, set-up, testing and inspection began. During this phase the first four satellites of the subsequent constellation are to be placed in orbit and a first set-up stage of the ground segment is to be created by mid 2008. Operation of the satellites will be controlled from this ground segment. Additionally, the time signals of the satellites are to be produced and controlled at the ground station. This will be achieved with support from the "Precise Time Facility" together with other components. The "Precise Time Facility" will produce the "Galileo System Time" (GST). PTB is consulting the European Space Agency and the participating industry in the realisation of GST and the design of the "Precise Time Facility".

Any Satellite-based navigation system is also a system for time distribution. At a known position receiving the satellite signals can be used to transmit GST to a user. GST is to be kept in excellent agreement with coordinated universal time, UTC, and the relation between the two is to be made known to the user. This was seen as an additional attractive feature of Galileo, however, not immediately justified through the primary task of the system. Therefore, an independent entity will be created to provide the necessary time information to the Galileo system. This so-named "Galileo Time Service Provider" is currently set-up by "Galileo Joint Undertaking", a joint enterprise in public and private holding in Brussels, with funds from the European Commission. Together with NPL (National Physical Laboratory, UK) and IEN (Istituto Elettrotecnico Nazionale Galileo Ferraris, Italy) PTB has determined the requirements concerning organization and function of the Time Service Provider. An important part of PTB's duties will be to organize and conduct time comparisons between several European timing institutes and the PTF.

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