Large detector for small particles
Vacuum-compatible X-ray detector allows measurements at low photon energies

In cooperation with PTB, the Swiss company Dectris has developed a vacuum-compatible version of its X-ray detector “Pilatus” to attain even photon energies below 5 keV. This device allows, for example, experiments for the size determination of nanoparticles to be carried out with Small-Angle X-ray Scattering (SAXS) also at the absorption edges of the light elements calcium, sulphur, phosphor or silicon with high dynamics and spatial resolution. This is essential especially when it comes to investigating biological samples.

At PTB’s laboratory at the electron storage ring BESSY II, the size of nanoparticles or the dimensional parameters of nanostructured surfaces are determined by means of SAXS with synchrotron radiation. With the new detector, the measurement capabilities have decisively improved, especially in the case of low-scattering samples and of element-specific investigations. This is applied, for instance, within the scope of projects of the European Metrology Research Programme (EMRP), where complex biological nano-objects and nanoparticles are dimensionally characterized in complex biological matrices using SAXS measurements with synchrotron radiation. Hereby, work is currently focused, among other things, on the microvesicles that occur in all body fluids. Medical en-

Small-angle X-ray scattering image of a multilamellar liposome sample, recorded at a photon energy of 3 keV with a vacuum-compatible Pilatus detector at PTB’s FCM beamline at BESSY II.
At present, the Superconducting Quantum Interference Devices (SQUIDs) are the most sensitive magnetic field sensors. However, they require complex cooling in a cryogenic vessel which must be regularly filled with liquid helium. But helium is becoming scarcer all around the world, so that the users of SQUIDs technologies are becoming increasingly worried about the diminishing resources. Furthermore, the arrangement of the SQUIDs inside the thermal insulation of the cryogenic vessel is fixed. Small and flexible sensors would be ideal for biomedical applications which require them to be easily attached to the head.

A typical application is the so-called MEG (magneto-encephalogram), which measures the very weak magnetic fields that are generated by the brain while it is working. Such an MEG recording is important, for instance, to diagnose epilepsy or for fundamental research in neurology. Another example of a possible application is the measurement of the fields of magnetic nanoparticles which are regularly filled with liquid helium. But helium is becoming scarcer all around the world, so that the users of SQUIDs technologies are becoming increasingly worried about the diminishing resources. Furthermore, the arrangement of the SQUIDs inside the thermal insulation of the cryogenic vessel is fixed. Small and flexible sensors would be ideal for biomedical applications which require them to be easily attached to the head.

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**Mini-sensor measures magnetic fields of the brain**

Highly sensitive magnetic field measurements can now be carried out with room-temperature sensors

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**Especially interesting for**

- neurologists
- users of therapeutic magnetic nanoparticles
Dynamic forces, such as those occurring in dynamic tests performed with material-testing machines, could previously be measured only with insufficient accuracy. A procedure developed at PTB now allows traceable calibrations of dynamic (i.e. time- and frequency-dependent measurements) to be carried out in a frequency range from 40 Hz up to 2 kHz with forces up to 2 kN.

Industrial applications require dynamic force calibrations, e.g. for material-testing machines or test benches in the automotive and aviation industries. Whereas high-precision procedures have been available for several decades for the static calibration of force transducers allowing traceable calibration by means of deadweight force standard machines, the dynamic calibration of such force transducers is not as advanced.

PTB’s new method is essentially based on the same principles as static calibration: the force is generated by the loading of deadweights. According to Newton’s laws, force = mass × acceleration, with gravitational acceleration acting.

Dynamic calibration becomes possible by inducing sinusoidal vibrations on the force transducers using an electrodynamic shaker. The displacement amplitude of the shaker essentially depends on the frequency and lies in the range from a few micrometres up to several centimetres. The force transducer to be calibrated is loaded with an additional mass whose acceleration is then measured with a laser vibrometer. The product of acceleration by mass yields the acting dynamic force. The calibration result is the dynamic sensitivity as a quotient from the electric signal of the force transducer and of the dynamic force as a function of the frequency. Using a laser scanning vibrometer allows the acceleration to be measured not only in one single point, but over the whole surface of the additional mass. This allows certain parasitic influences, such as, e.g., wobbling displacements of the additional mass, to be detected and to be taken into account when indicating the uncertainty.

This procedure allows relative measurement uncertainties of 0.5 % to 1.0 % to be administered to patients for therapeutic purposes and whose distribution inside the body has to be precisely monitored.

The new sensor type developed at NIST is well suited for such applications, especially as it works at room temperature. The so-called Chip-scale Atomic Magnetometer (CSAM) essentially consists of a cell filled with rubidium gas and associated microoptics. The interaction between the electron spin of the rubidium atoms and a magnetic field serves as a highly sensitive measure of the field strength. These sensors – which are no larger than a sugar cube – can be positioned on the patient’s skin wherever needed, similar to electrodes.

The practical suitability of this type of sensor has now been tested in Berlin – in PTB’s “magnetically most quiet room on Earth”. Compared to the “gold standard”, the SQUID, its noise is higher by a factor of 5 to 10. This is, however, compensated by the fact that the sensor can be positioned very close to the source. In addition, its scope of application is much wider. One can reasonably expect that the new sensor type will find its place in magnetic measurement technology requiring high-sensitivity – perhaps not only for biomagnetic investigations.
attained below the resonance frequency of the measuring set-up – which depends on the size of the additional mass – and of a few per cent above this frequency. PTB has recently started offering servic-es based on this new technique.

Accurate wind velocity measurements
Traceable doppler lidar system for wind potential analysis and power curve characterization of wind turbines

Wind potential analyses, used to assess the cost effectiveness of wind farms, are currently based on the measurement of wind velocity by means of cup anemometers mounted on meteorological masts. As an alternative to these expensive met masts which are difficult to erect, a doppler lidar system for traceable, ground-based laser-optic wind velocity measurements has been developed at PTB.

The planning of wind farms is essentially based on wind potential analyses to assess the wind energy regime at the site planned for the wind farm. Together with the characterized power curve of the wind turbines which are to be installed in such wind farms, the annual mean of the expected production of electric energy can thus be computed. This is indispensable when it comes to assessing the profitability of a wind farm.

Both for wind potential analyses and for power curve characterization, it is necessary to measure the wind velocity profile at the level of the rotor blades. At present, this is still done using traceable anemometers – i.e. cup anemometers calibrated by accredited calibration laboratories – mounted onto meteorologi-cal masts. Since wind turbines tend to become ever higher, erecting such met masts is becoming correspondingly difficult and expensive. According to investigations results published in the wind power sector, remote measurement pro-cedures based on the Doppler lidar tech-nique could be more economical, but for lidar systems, no suited procedures of measurement traceability are available yet.

Conventional wind lidar systems used in the wind power sector usually contain common emitting/receiving optics (see Fig. left), so that the emitting and the receiving beam overlap (monostationary and monaxial). As only the flow velocity component in the direction of the beam is measured, with a height resolution of approx. 20 m, the beam is conically tilted into different directions in order to compute a velocity vector. For the planned application, a higher resolution would, however, be desirable. Furthermore, flow inhomogeneities via the scanning range of the beam can lead to deviations in the order of 10 %, especially on uneven terrain, preventing lidar wind velocity measure-ments from being traceable with the required measurement uncertainty.

The bistatic Doppler lidar system with spatially separate emitting/receiving de-vices (see Fig. right), which was devel-
Undisturbed excitation with pulsed light

PTB presents a new excitation procedure using a laser in optical atomic clocks

At PTB, a procedure, which had until then only been predicted theoretically, has now been confirmed experimentally; this procedure allows so-called "light shifts" to be prevented and, thus, PTB’s optical ytterbium atomic clock to be made even more accurate. Furthermore, "hyper" Ramsey excitation, which is the subject of this investigation, can be helpful for numerous applications where the focus lies on a precise, controlled interaction between atoms and laser light.

The best method to obtain extremely precise information on the inner structure of atoms and molecules is to excite them by means of resonant laser light. Unfortunately, just this laser light (above a certain intensity) can lead to measurable modifications within the atom's electron shell. In the event of such a “light shift”, the position of the atomic energy levels is modified; the extent of this shift depends on the intensity and the wavelength of the laser used. If one is seeking the properties of the atom as an undisturbed quantum object, this shift must be either prevented or corrected.

During the so-called "hyper" Ramsey excitation, a series of laser pulses with a specific pattern of frequency and phase shifts allows the undisturbed transition frequency to be rendered directly. This had recently been demonstrated theoretically within the scope of a cooperation between Russian, American and PTB scientists. The “hyper” Ramsey excitation has now been realized at PTB in an atomic transition which allows very slight frequency variations to be detected and, at the same time, exhibits a large light shift, since a high laser intensity is necessary for its excitation. It is an electrical octupole transition in the Yb⁺ ion which is being investigated as a basis for an optical clock. The experiment confirmed the theoretical predictions concerning the advantages of “hyper” Ramsey excitation and attained a 10 000-fold suppression of the light shift.

By combining the maximum spectral resolution currently achievable with an optimized control of the experiment, it is possible to reduce the contribution of the light shift to the systematic uncertainty of the ytterbium clock to less than 10⁻¹⁷, the clock thus becomes clearly more accurate. Furthermore, this method could also be interesting for other investigations aimed at obtaining a precisely controlled interaction between atoms and laser light, for instance in the field of quantum information processing.

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Scientific publication
A base for long range

PTB’s 600 m baseline developed as a calibration base for geodetic electro-optical distance meter

Electro-optical distance meter can be calibrated with low uncertainty for applications at ambient conditions on a newly equipped calibration base of PTB. In addition, the baseline, which is equipped with a broad range of environmental sensors, an air-conditioned laboratory and laser-protection measures, allows its users the possibility of verifying and optimizing their geodetic equipment during its development phase.

Areas at risk from landslides, potential radioactive waste repositories, but also regions with interesting tectonics are monitored worldwide with the aid of geodetic networks as to position/situation shifts. Hereby, often changes of a few 1/10 millimetres per year are to be detected. But also in classic geodesy, e.g. for cadastral work in expensive locations in the centre of cities, the requirements placed on measurement accuracy are increasing. For this purpose, electro-optical distance meter are used; for their verification and traceability, reference baselines are normally used. Given the required accuracy, various factors influencing the measurement and used for optical distance measurements – the propagation velocity of light – have to be checked accurately. Among these factors are, e.g., the ambient pressure, the temperature, and the humidity. In a measurement over 1000 metres, e.g., to attain an accuracy of 1 mm, the mean temperature along the whole section to be tested has to be known with an accuracy of 1 K.

The worldwide unique calibration base developed by PTB makes such accuracies possible for the first time. The 600 m baseline which was set up in the 1970s was equipped with an extensive network of calibrated sensors: 60 temperature sensors, 6 humidity sensors as well as at least 2 pressure sensors allow the effective parameters along the beam path to be determined anew every 30 seconds with low uncertainties. Along the section, the important correction factors of an electronic distance meter can be determined under optimal conditions, in a traceable way, with expanded uncertainties of 61 µm for the offset correction and of 8.2 · 10⁻⁷ for the standard correction. In order to be able to use sensitive light sources on site, such as those used in latest-generation electro-optical distance meter, the first post of the calibration base is equipped with an air-conditioned container accommodating a lab. The calibration base is also available to land surveyors, companies and land surveying offices to carry out their own measurements.

Especially interesting for
• manufacturers of geodetic ranging instruments
• institutes of geodetic engineering
• engineering offices
• land-surveying

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Scientific publication
Microsensor for nanoforces

Especially interesting for
• medical research
• micro- and nanotechnologies

Licence partner wanted

It is necessary to measure small forces when investigating, for example, new functional surfaces or the properties of biological tissue samples in medicine. PTB’s new nano-force sensor is equipped with a probe whose displacements are detected via capacitive comb sensors.

Measuring objects in concealed places

Especially interesting for
• coordinate metrology
• dimensional metrology

Licence partner wanted

In order to measure the dimensions of large objects with high accuracy, traceable laser interferometers are integrated into coordinate measuring machines. Hereby, the measurement points located on the object’s surface are sampled, and their position is determined interferometrically. In the case of large objects, such as, e.g., gears, the beam might be interrupted by the object itself which then cannot be measured completely. By means of an additional measurement during which the object is not located inside the measuring volume, additional coordinated are acquired and taken into account in a subsequent computation of the object’s geometry. In this way, systematic errors are corrected. This procedure is also suited for the high-precision detection/positioning for manipulators such as robot’s arms or working tools.

Continuous radiation from laser pulses

Especially interesting for
• photovoltaics
• spectroscopy

Licence partner wanted

A laser converter from PTB allows monochromatic, temporally continuous, intensive radiation to be generated across a wide spectral range for the first time. Hereby, pulsed laser radiation with a sufficiently high repetition rate (e.g. 80 MHz) is temporally homogenized by means of an optical device. A continuous light beam is available at the converter output; this light beam is tunable across the full wavelength range of the source – at narrow band and high luminance. The procedure is very well-suited, among other things, to calibrate solar cells or for spectroscopic applications, for example in biological-medical analysis.
Awards

Martin Thedens
This staff member from the Department 3.5 “Flame Transmission Processes” received the IEC 1906 Award. This prize is granted by the International Electrotechnical Commission (IEC) to technical experts who show great commitment in the IEC committees and who earn special recognition for their contribution to current standardization projects.

PTB and Europe

The following EMRP projects coordinated by PTB scientists have just been launched or are to start soon:

July 2013:
- Spintronics and spin-caloritronics in magnetic nanosystems
- Metrology for long distance surveying
- Force traceability within the meganewton range

October 2013:
- Crystalline surfaces, self-assembled structures, and nano-origami as length standard in (nano)metrology

If you wish to obtain more information about these projects or to consult the project descriptions (pdf), please read the online issue of the PTB-News (www.ptb.de > Publications > PTB-News) or visit www.euramet.org

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Dates

12 September 2013
Informative meeting for the sound test centres members of the Verband der Materialprüfungsanstalten (VMPA)
08:00 o’clock until 18:00 o’clock,
PTB Braunschweig, Auditorium
Contact: Werner Scholl;
Marion Wittwer
Phone: +49 (0)531 592-1700;
+49 (0)531 592-1710
E-mail: werner.scholl@ptb.de;
marion.wittwer@ptb.de

1 October 2013
Image Processing Forum: Standardization and performance analysis
272th PTB Seminar
Contact: Frank Härtig
Phone: +49 (0)531 592-5300
E-mail: frank.haertig@ptb.de

24/25 October 2013
VUV and EUV Metrology
273th PTB Seminar
Contact: Frank Scholze;
Alexander Gottwald
Phone: +49 (0)30 3481-7120;
+49 (0)30 3481-7130
E-mail: frank.scholze@ptb.de;
alexander.gottwald@ptb.de

18/19 November 2013
Radioprotection dosimetry in pulsed photon radiation fields
274th PTB Seminar:
Contact: Oliver Hupe
Phone: +49 (0)531 592-6310
E-mail: oliver.hupe@ptb.de

Further dates:
www.ptb.de > What’s new

Publications

maßstäbe 12th Edition: Meilensteine (in German)
The milestones in more than 125 years of metrological research. Subscribe for free or order a class set from PTB’s Press Office (presse@ptb.de). A few copies of the last edition (maßstäbe 11: Kräfte messen) are still available.
Imke Frischmuth, Jens Simon (editors):
Metrological Reader
The art of measuring at PTB – in the past, present and future. (Miscellany of the PTB-Mitteilungen of the year 2012 on the occasion of the 125th anniversary of PTB/PTR).
Editor: nw-Verlag Bremerhaven,
(Will be published in October 2013)

PTB-Mitteilungen Vol. 1/2013 (in German)
In the focus: The PTR in exile in Thuringia

PTB-Mitteilungen Heft 2/2013 (in German)
Focus: Ionization radiation in medicine

For further information:
www.ptb.de > English Version > Publications