PTB news
Scientific Newsletter
2
2013

The PTB-News is the scientific newsletter of the Physikalisch-Technische Bundesanstalt (PTB). It is addressed to PTB's cooperative partners in science, economy and to all other interested readers.

Quantum metrology with PTB-made SQUIDs

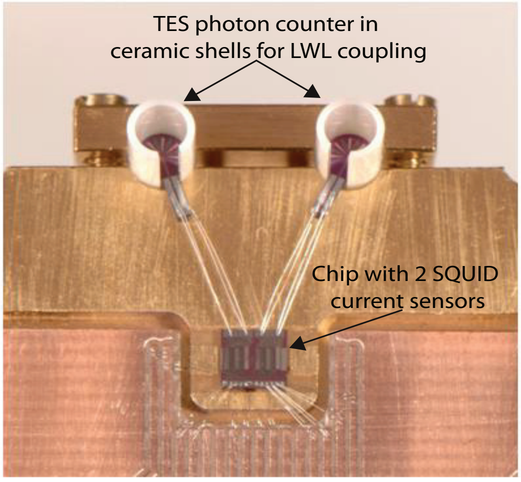
Superconducting sensors of PTB used in demanding experiments in quantum optics and to investigate superconducting helium-3

Especially interesting for
- metrology institutes
- SQUID users

Within the scope of two international cooperation projects, SQUID sensors from PTB provided the required measurement accuracy for exciting experiments in fundamental physics. In the first case, the goal was to detect photons with great efficiency. In the second, PTB's SQUIDs were applied to measure the magnetic moments of atoms of the rare isotope helium-3 with extreme sensitivity.

PTB plays a worldwide leading role in developing SQUIDs. These superconducting quantum interference devices are sensors used to measure extremely small changes in magnetic flux with great accuracy. PTB's SQUIDs are employed for the most various types of measurements. Whereas they have been used in biomagnetic experiments for two decades in order to detect, for instance, the very weak magnetic fields of the human heart or brain, they are continuously involved in new metrological developments. SQUIDs are used, e.g., as sensitive current sensors in the most diverse configurations or as full, integrated susceptometers. PTB supplies not only the SQUID chips themselves, but also the electronics and the metrological know-how to implement the sensors in the respective cryogenic setup and experimental periphery. This was also the case in the two international cooperation projects.

One of these projects was a so-called “Bell experiment” of Anton Zeilinger's group from the Austrian Academy of Sciences (Österreichische Akademie der Wissenschaften – ÖAW). In order to detect quantum-mechanically entangled photons with high efficiency and – what is decisive – a sufficient number of them, PTB's SQUIDs were used to amplify the output currents of single-photon detectors based on superconducting transition edge sensor microcalorimeters. The highly efficient single-photon counters have been developed by the quantum detector group of the National Institute of Standards and Technology (NIST, USA). The TES/SQUID detector modules used were configured and tested at PTB. In addition, for the experiments which took place at ÖAW, cryogenic technology and electronics of the companies Entropy and Magnicon (development partners of PTB) were used. The experiments allowed the most complete detection of the quantum-mechanical entanglement of photons so far. This makes photons the first quantum



Detector module with 2 TES photon counters and a SQUID sensor chip with 2 current sensors

particles for which the so-called “loopholes” in Bell experiments have been closed.
The second experiment is part of a close cooperation which has existed since the mid-1990s between PTB's “Cryosensors” Working Group and John Saunders' group of the Royal Holloway University, London, in which particularly sensitive NMR spectrometers are developed for experiments at ultra-low temperatures. This experiment is, among other things, aimed at investigating the isotope helium-3 which, at very low temperatures, becomes superfluid – which means that it can flow without friction. Together with colleagues from Cornell University, Ithaca, NY, USA, the cooperation partners from London locked the fluid under pressure and at extremely low temperatures below a millikelvin in thin traps which were only a few hundreds of nanometers thick. The properties of the helium-3 fluid confined in a nanofluidic cavity, in which the interactions of the magnetic moments of the atomic nuclei of helium-3 play a decisive role, were investigated by means of a sensitive SQUID-NMR spectrometer. The measurements showed that the complex phase pattern of helium-3 is strongly modified by the confinement and by the properties of its surface towards its environment. ■

Bell experiment:
Contact
Jörn Beyer
Department 7.2 Cryophysics and Spectrometry
Phone: +49 (0)30 3481-7379
E-mail: joern.beyer@ptb.de

Scientific publication
M. Giustina, A. Mech, S. Ramelow, B. Wittmann, J. Kofler, J. Beyer, A. Lita, B. Calkins, T. Gerrits, S. W. Nam, R. Ursin, A. Zeilinger: Bell violation using entangled photons without the fair-sampling assumption, Nature 497, 227(2013)

Helium-3 experiment:
Contact
Thomas Schurig
Department 7.2 Cryophysics and Spectrometry
Phone: +49 (0)30 3481-7290
E-mail: thomas.schurig@ptb.de

Scientific publication
L.V. Levitin, R.G. Bennett, A. Casey, B. Cowan, J. Saunders, D. Drung, Th. Schurig, J.M. Parpia: Phase diagram of the topological superfluid ^{3}He confined in a nanoscale slab geometry, Science 340, 841-844 (2013)

Optical strontium clock to become much more accurate

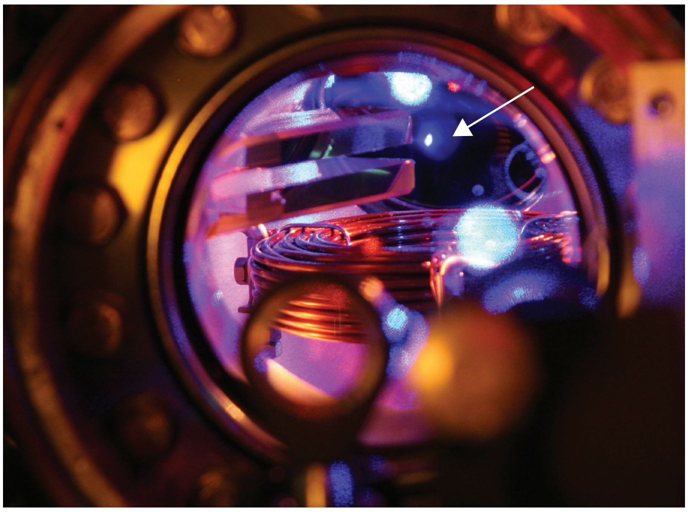
For the first time, PTB measures the influence of the ambient temperature

Especially interesting for
- developers of optical atomic clocks
- fundamental research

Optical clocks with neutral strontium atoms are being successfully developed worldwide at a number of institutes. From now on, it will probably be possible to determine their frequency more accurately, by one order of magnitude, since the influence of the most important uncertainty factor, namely the ambient temperature, has been measured at PTB for the first time. To date, its influence could only be derived theoretically.

Optical clocks are deemed the clocks of the future. There are several reasons for this: they could allow the SI base unit the second to be realized even more accurately. Its definition would then no longer be based on the interaction between microwave radiation and caesium atoms, but on the interaction of optical radiation with strontium (or other) atoms or ions. But also beyond the definition issue, high-precision optical clocks are useful: for example in geodesy, where they can contribute to determining the gravitational potential of the Earth more accurately. In fundamental research, they can be used to improve the search for changes in fundamental constants such as the fine-structure constant.

The reason why optical clocks are so accurate is that optical radiation oscillates considerably faster than microwave radiation – the latter being currently used in caesium atomic clocks to “produce” the second. The faster the oscillation, the finer the scale, which is



View of the ultra-high vacuum chamber where strontium atoms are cooled and stored. There, we can see the parallel-plate capacitor in front of which a blueish cloud of some millions of strontium atoms is fluorescing (arrow). Prior to the excitation of the transition, the atoms are transported into the capacitor.

advantageous when it comes to the accuracy and stability of the clock. In an optical strontium clock, a cloud of neutral strontium atoms is cooled using laser radiation. In these atoms, a transition between two energy levels is excited by means of a laser. This is used to stabilize the frequency of this laser. Unfortunately, strontium atoms react relatively strongly to changes in the ambient temperature; their atomic levels are then shifted energetically, which causes the clock to become inaccurate. This is the highest contribution to the uncertainty of this clock, and PTB scientists have now succeeded in measuring it for the first time. This, however, required an auxiliary construction: the effect was considerably increased when using a static electric field rather than the alternating electromagnetic field of thermal radiation. To generate this electric field, a parallel-plate capacitor was conceived whose electric field is known with an accuracy of a few hundredths of per mille.

This capacitor was used to measure, for the first time, the influence of electromagnetic fields on the two decisive (for the clock) eigenstates in the strontium atom. In this way, the PTB scientists determined its uncertainty contribution to the total measurement uncertainty as being $5 \cdot 10^{-18}$. This is an accuracy increase by one order of magnitude – compared to the previously known value. And as just this influence had, to date, been the most restrictive influence on the total measurement uncertainty, one can expect the next frequency measurements to lie well below the previously attained $1 \cdot 10^{-16}$ with regard to their relative measurement uncertainty. ■

Contact
Christian Lisdat
Department 4.3 Quantum Optics and Unit of Length
Phone: +49 (0)531 592-4320
E-mail: christian.lisdat@ptb.de

Scientific publication
Th. Middelmann, St. Falke, Chr. Lisdat, U. Sterr: High accuracy correction of blackbody radiation shift in an optical lattice clock. Phys. Rev. Lett. 109, 263004 (2012)

Near-field microscopy with synchrotron radiation

FTIR spectroscopy at the MLS enables chemical analytical investigations in the nanometre range

Especially interesting for
- the chemical industry
- materials research

In collaboration with the Freie Universität Berlin, a scattering-type Scanning Near-field Optical Microscope (s-SNOM) for the infrared (IR) range has been commissioned, using, for the first time, also broadband synchrotron radiation provided by PTB's electron storage ring Metrology Light Source (MLS) in Berlin-Adlershof. This now allows IR spectroscopic investigations on sample systems to be carried out with a lateral resolution of less than 100 nm in a large spectral range.

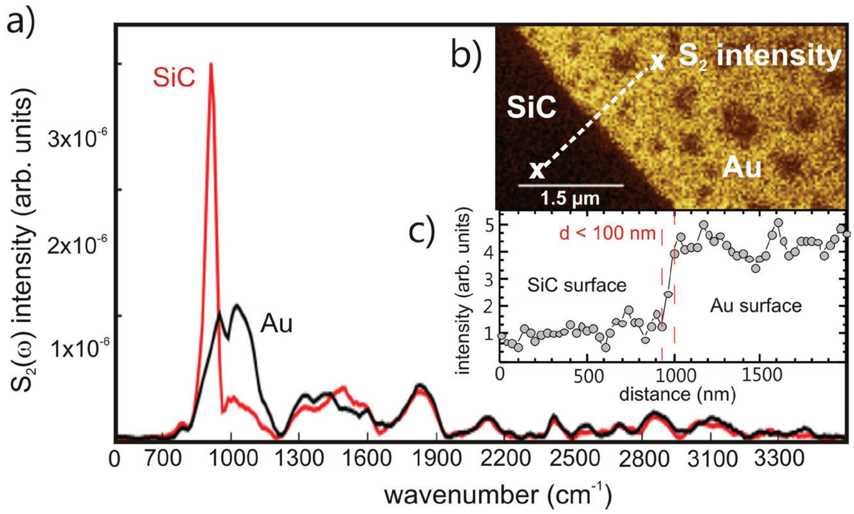


Figure: a) Comparison of the nano-FTIR spectra of silicon carbide (SiC) and gold (Au), recorded with broadband synchrotron radiation at the IR beamline of the MLS. The two measurement positions are identified with an “X” in the near-field microscopic image of the sample surface (Figure b, top right). When performing a scan along the white line in b), a lateral resolution of less than 100 nm is achieved at the gold edge (see Figure c, bottom right).

Fourier Transform Infrared (FTIR) spectroscopy is often used for the chemical characterization of organic and inorganic substances or to investigate the conductivity of diverse sample systems. Since the spatial resolving power of this spectroscopic method is, however, limited due to diffraction, FTIR investigations on structures on a sub-micrometre scale are not possible without limitations.

The new scattering-type scanning near-field microscope at the MLS is based on the principle of a scanning force microscope and makes it possible to investigate, in addition to the topography, also the optical and the dielectrical properties of the sample, respectively. For this purpose, a sharp gold- or platinum-coated tip – a so-called “near-field probe” – is placed in a focused laser or synchrotron beam. During the subsequent scanning process, the position of the tip remains unchanged, only the sample is moved. Hereby, the nearfield probe, with a typical diameter between 20 nm and 50 nm, acts like an antenna and amplifies the electromagnetic field in the immediate vicinity of the metallic tip, which allows a lateral resolution clearly below 100 nm to be attained. Compared to conventional FTIR methods, this procedure represents a considerable improvement of the local resolution and of the sensitivity.

The main radiation sources used to date for near-field investigations in the IR spectral range have been CO- and CO_2 gas lasers. These provide a sufficiently high radiation power, but can only cover the relatively narrow wavelength ranges from 5.2 µm to 6.1 µm and 9.2 µm to 10.8 µm, respectively. In order to extend the wavelength range, the nearfield microscope was combined with the IR beamline of the MLS, so that a wide wavelength range from the near IR up to the THz range can be used continuously. Hence, it is now possible to perform nano-FTIR spectroscopy with a lateral resolution clearly below the diffraction limit and to characterize surfaces and nanostructures with IR spectroscopy in a wavelength range from, for a start, 1 µm to 20 µm. Later, it is planned to extend the wavelength range even further. ▪

Contact
Peter Hermann
Department 7.2 Cryophysics and Spectrometry
Phone: +49 (0)30 3481-7184
E-mail: peter.hermann@ptb.de

Scientific publication
P. Hermann, A. Hoehl, A. Patoka, F. Huth, E. Rühl, G. Ulm: Near-field imaging and nano-Fourier-transform infrared spectroscopy using broadband synchrotron radiation. Optics Express 21, 2913 (2013)

AC quantum voltmeter for industry

Technology transfer of a Josephson measuring system for DC and AC voltages

Especially interesting for
- metrology institutes
- calibration laboratories
- manufacturers of high-precision electronics

Within the scope of a technology transfer programme, PTB has developed a new AC quantum voltmeter in order to establish quantum-based AC voltage standards for calibrations in industry. A prototype has now been successfully tested for AC voltage at frequencies of up to 4 kHz.

Within the scope of a technology transfer project involving PTB and two partners from industry, which was supported by the Federal Ministry of Economics and Technology, a Josephson measuring system for DC and AC voltages – an AC quantum voltmeter – has been developed for use in industrial calibration laboratories. With this new system, the considerable advantages of electrical standards based on quantum effects will also become available to industrial laboratories: very low measurement uncertainties are possible without tedious re-calibrations, which have thus become more economical.

The system is based on Josephson arrays, which are manufactured at PTB, and is designed for peak voltages of up to ± 10 V and frequencies of up to 10 kHz. With a prototype, AC voltages from 10 Hz to 4 kHz have already been measured at PTB, whereby uncertainties of a few µV/V within a measuring time of one minute were attained. This makes the new AC quantum voltmeter approximately 20 times more accurate than conventional calibrators and 60 times faster than the measurement procedures with thermal converters used to date.

A commercial high-precision calibrator (centre) is calibrated by means of the AC quantum voltmeter in the AC voltage mode.

In addition, the AC quantum voltmeter can also calibrate commercial DC voltage standards (DC references and DC voltmeters) and, thus, also covers the range of commercially available DC quantum voltmeters. During a direct 10 V comparison between a DC quantum voltmeter and the new AC prototype, no significant deviation was observed within a measuring time of 15 minutes within the uncertainty limit of 0.1 nV/V.

The new AC quantum voltmeter is now being optimized by means of on-site tests at the partner's (esz AG) accredited laboratory. With this valuable end-user input, it will be developed to become a fully automated, user-friendly measuring system. The main objective is to reach a relative uncertainty of 2.5 µV/V at 1 kHz. The system will be developed in a modular approach which will allow a future extension of the system to a universal ”quantum calibrator“ for voltage, resistance and current standards. Supracon AG (instrument manufacturer), the other project partner, will be in charge of the subsequent marketing. ■

Contact
Ralf Behr
Department 2.6 Electrical Quantum Metrology
Phone: +49 (0)531 592-2630
E-mail: ralf.behr@ptb.de

Scientific publication
J. Lee, R. Behr, L. Palafox, A. Katkov, M. Schubert, M. Starkloff, A. C. Böck: An AC quantum voltmeter based on a 10 V programmable Josephson Array. Submitted to Metrologia (2013)

Low radon concentrations accurately measurable for the first time

Novel low-level radon reference chamber and appurtenant transfer standard

Especially interesting for
- radiation protection in private residential as well as public buildings
- manufacturers of measuring instruments for radiation protection, radiation protection institutes

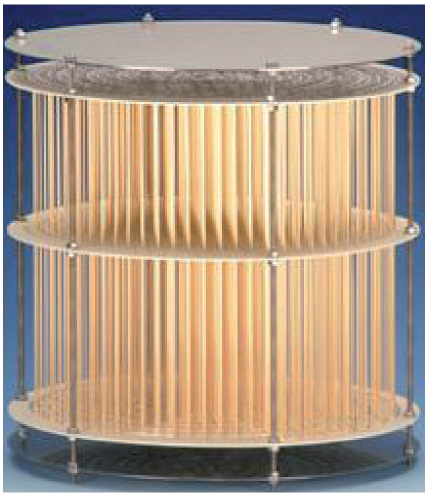
According to the latest findings, radon contributes just as strongly to the exposure rate of the general public as medical diagnostic and therapeutic procedures (such as CT). With a view to the lowering of the reference values planned in the EU – triggered by the re-evaluation of radon by the International Commission on Radiological Protection (ICRP) – a novel facility for the calibration of radon measuring instruments has been developed at PTB and is now available for customers.

Radon (Rn-222) is a radioactive noble gas that occurs especially in the ground of mountainous regions due to the decay of various, naturally occurring radioactive substances. Despite relatively low activity concentrations from approx. 50 Bq/m^3 to 200 Bq/^{3}, radon represents such a strong contribution to the total exposure rate of the German population that the main share in the dose can be attributed to radon according to the ICRP's re-evaluation. Exposure due to medical examinations is approximatively as strong. Hence with its new European Radiation Protection Ordinance, the EU is aiming to reduce radon levels in buildings. However, the measuring instruments used to date, which were calibrated at 1000 Bq/m^3 and more – thus a value much higher than the typically encountered concentrations – did not allow compliance with the new reference values to be checked reliably.

Thus, a novel facility for the calibration of radon measuring instruments has been developed at PTB. The low-level radon reference chamber is now available as an additional standard facility for the realization of the unit of activity concentration in Bq/m^3. It consists of three parts: a traceable volume to generate the reference atmosphere, a facility to generate and transport defined radon activities, and a transfer standard to maintain and disseminate the unit. In order to generate constant reference atmospheres, the radon emanated from a radium-226 activity standard is transferred, via a noble-gas-tight circuit, into a reference volume. With the aid of the known quantities ”radium activity“, ”emanation degree“, and ”volume“, measuring instruments can be calibrated with this chamber to determine the Rn-222 activity concentration in air in the range below 1000 Bq/m^3 in a traceable way.

In order to determine the emanation power of the radium-226 activity standard, an emanation measuring facility based on γ spectrometry was developed. Within the scope of a doctoral dissertation, several emanation sources were produced and characterized. The eight existing emanation sources of different activity now allow stable reference atmospheres from 150 Bq/m^3 to 1900 Bq/m^3 to be generated so that now, also commercially available measuring instruments can be used to carry out a long-term calibration over more than 5 days.

The new facility extends PTB's calibration offer to a previously not available but socially extremely relevant range: the calibration procedure considerably increases the measurement accuracy of the collected data relating to the exposure rate of people. It is expected that this will have influences on future radon studies dealing with the re-evaluation of the lung cancer risk due to radon. ■



PTB's new transfer standard allows radon activity concentrations of 200 Bq/m^3 to be measured with a measurement uncertainty of 2 %.

Contact
Annette Röttger
Department 6.1 Radioactivity
Phone +49 (0)531 592-6130
E-mail: annette.roettger@ptb.de

Scientific publication
D. Linzmaier, A. Röttger: Development of a low-level radon reference atmosphere. Applied Radiation and Isotopes (2013) doi: 10.1016/j.apradiso.2013.03.032

Strong emitter for high field

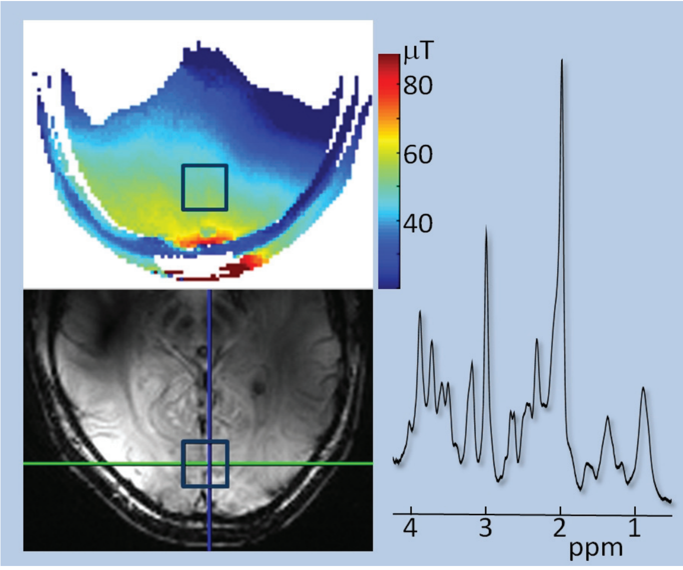
New hardware for sensitive metabolite determinations in the brain at 7 tesla

Especially interesting for
- neuroscientists
- physicians
- manufacturers of MR tomographs

The trend towards higher magnetic fields in magnetic resonance (MR) diagnostics is of major benefit to MR spectroscopy. However, to exploit its potential for the non-invasive quantification of metabolite concentrations in the human organism, new high-frequency coils with high local transmit power are needed. PTB has developed such a coil for 7-tesla tomographs and characterized it by means of numerical simulations and measurements in such a way that it can be used in vivo.

With magnetic resonance spectroscopy (MRS), biochemical substances such as neurotransmitters and amino-acids can be differentiated due to the protons that are bound in them, and quantified in vivo and non-invasively. This measurement technique benefits from the increasingly high magnetic fields of modern MR tomographs. Their sensitivity and their spectral resolution, as well as their capacity to identify an increasing number of metabolites, increase nearly proportionally to the field strength. Hence, attempts are currently being made to make MRS exploitable at ultrahigh-field tomographs at 7 tesla. But although being well-suited for imaging, the radiofrequency (RF) excitation coils currently used for such field strengths generate transmit fields that are too weak for MRS. In order to attain the necessary excitation of the spin system to be measured, the high-frequency pulses thus have to be transmitted for a relatively long time. The resulting low spectral bandwidth causes a strong "chemical shift artefact", causing the measuring volumes for the various metabolites of an MR spectrum to be clearly spatially shifted against each other.

At the 7-tesla MR tomograph – which PTB operates together with partners at the Berlin Ultrahigh Field Facility (B.U.F.F.) in Berlin-Buch –, a two-channel RF excitation coil has been developed for MRS in the occipital lobe of the human brain; thanks to stronger transmit fields, this coil succeeds in minimizing this undesirable effect. In order to maximize the transmit field of the coil in the target volume, simulations of the field distribution were carried out and validated by means of field measurements in the tomograph. The optimum coil geometry was determined using a multichannel transmit array with which pulse amplitudes and phases can be adjusted independently of each other. This allows a circularly polarized magnetic RF field of 45 µT to be generated in the target volume – the visual cortex. In addition, the results of the simulations and field measurements allowed the specific absorption rate to be limited to such an extent that hazards for test persons due to tissue heating are ruled out. With this coil, MRS pulse sequences can be applied which reduce the chemical shift artefact to a few percent, so that the measuring volumes for all metabolites are practically congruent with each other.



MR-spectroscopic target volume (voxel) in the visual cortex of a volunteer (left) with an HF transmit field generated by the coil (top). The lines in the MR spectrum from the voxel (right) represent metabolites.

The low pulse durations also allow pulse sequences with very short echo times to be used, so that the resulting MR spectrum includes the resonance signals of a large number of metabolites. Tests with volunteers have shown that the concentrations of 18 metabolites can be determined with an acceptable measurement uncertainty. A Notified Body has certified the technical safety of the new coil, so that it can now be used for measurements on external volunteers. First application studies dealing with neurological issues have been started. ▪

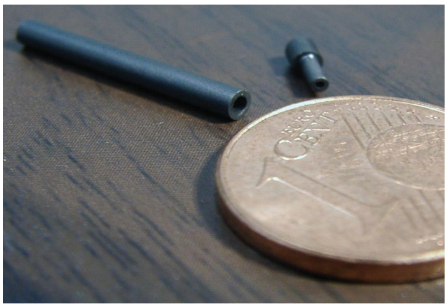
Contact
Florian Schubert
Department 8.1 Medical Metrology
Phone: +49 (0)30 3481-7477
E-mail: florian.schubert@ptb.de

A dosemeter for small radiation fields

Especially interesting for
- doctors and hospitals for radiotherapy

Licence partner wanted

By means of a newly developed dosimetric measurement procedure for teletherapy accelerators, the dose can – despite the small air volume of the chamber of 1 mm^3 – be determined reliably and within just a few seconds.
The underlying patented procedure is based on the pulse-resolved analysis of the detector to enable the deduction of undesirable signals in feed lines, in connections as well as in the electronic evaluation unit. Thanks to the microdosimetric information obtained additionally, it will, in future, be possible to make statements on the relative biological effectiveness for the treatment of patients. ■



The dosemeter in comparison to a coin

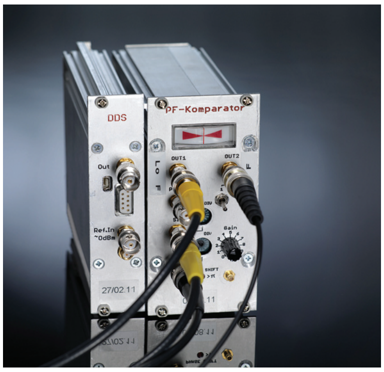
Contact
Jens Illemann
Phone: +49 (0)531 592-5344
E-mail: jens.illemann@ptb.de

Long-term stable single-frequency laser

Especially interesting for
- spectroscopy
- astrophysics
- ultraprecise metrology

Licence partner wanted

Narrow-band lasers with extremely small bandwidths are increasingly being used in spectroscopy and in ultra-precise measurement technologies. Thanks to the coupling (for which a patent application has been filed) to a radio-frequency source with the aid of a frequency comb, PTB has demonstrated an additional, high long-term stability of the optical frequency of better than $5 \cdot 10^{-15}$ over several hours for these applications. The resulting narrow-band optical frequency source thus opens up the possibility to carry out optical long-term precision measurements. ■



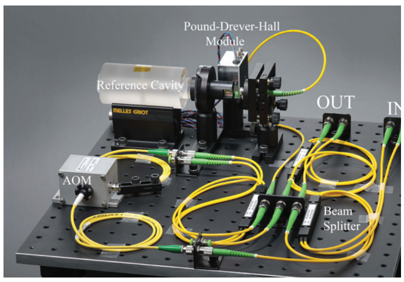
Contact
Sebastian Raupach
Department 4.3 Quantum Optics and Unit of Length
Phone: +49 (0)531 592-4341
E-mail: sebastian.raupach@ptb.de

Optical phase noise measurement device

Especially interesting for
- precision spectroscopy
- fibreglass sensors
- telecommunications

Licence partner wanted

Commercial laser systems now attain linewidths in the range of a few kHz, so that their phase noise is difficult to measure using the self-heterodyne method. For such measurements, PTB's invention generates a reference signal by means of a highly stable optical cavity. Even without an additional reference laser, this allows highly sensitive phase noise measurements in the range from 10 mHz to a few MHz. A patent application has been filed for the laser characterization procedure. ■



Contact
Thomas Legero
Department 4.3 Quantum Optics and Unit of Length
Phone: +49 (0)531 592-4306
E-mail: thomas.legero@ptb.de

Contact person for questions about technology transfer
Andreas Barthel, Phone: +49 (0)531 592-8307, E-mail: andreas.barthel@ptb.de,
Internet: www.technologietransfer.ptb.de

Awards

Steffen Buschschlüter

This member of staff from Department 1.6 "Sound" received an award for the best scientific brief lecture on cataract surgery. The prize was handed over to him on the occasion of the 26th International Congress of German Ophthalmic Surgeons which took place from 13 to 15 June in Nuremberg, Germany.

Ulrich von Pidoll

This staff member of Department 3.7 "Prevention of Ignition Sources" received the Helmut Krämer Award of the EFCE (European Federation of Chemical Engineering) which is given every fourth year and is deemed the highest international award in the field of electrostatics. The award ceremony took place on 18 April at the Hungarian Academy of Sciences in Budapest.

Fritz Riehle

The head of Division 4 "Optics" was designated a "Fellow of the American Physical Society" for his pioneering work in the fields of optical frequency standards, high-resolution spectroscopy, atomic interferometry, and ultra-cold atomic gases as well as for his leading role in international metrological research.

Dates

23 October 2013

New results of current investigations and their influence on actual rules and standards

International Workshop on Water and Heat Meters

Venue: PTB Braunschweig, Germany, Bundesallee 100, Kohlrausch Building, Main lecture room (Hörsaal)

Contact: Gudrun Wendt

Phone: +49 (0)531 592-1500

E-mail: gudrun.wendt@ptb.de

24/25 October 2013

VUV and EUV Metrology

273rd 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

5/6 November 2013

6th Symposium "Messunsicherheit praxisgerecht bestimmen" (How to determine measurement uncertainty in a practice-oriented way)

Venue: PTB Braunschweig, Germany, "Seminarzentrum" Kohlrausch Building

Contact: Klaus-Dieter Sommer

Phone: +49 (0)531 592-3010

E-mail: klaus-dieter.sommer@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

Helmholtz Prize 2014

With the Helmholtz Prize, outstanding scientific and technical research work in the field of metrology has been honoured since 1973. It is awarded in the field of precision measurements in physics, chemistry and medicine. The prize consists of a certificate and is endowed with 20,000 EUR.

The competition

The work submitted must have been developed in Europe or in cooperation with scientists working in Germany and must represent an original achievement which has been completed only recently. The work may be of experimental or theoretical nature and may address either fundamental research or concrete applications.

Applications have to be submitted by 15 January 2014 to

Prof. Dr. Joachim Ullrich
Chairman of the Helmholtz-Fonds e. V.
c/o Physikalisch-Technische Bundesanstalt
Bundesallee 100
38116 Braunschweig
Germany

For more details concerning the documents to be submitted for application, please visit the Helmholtz Fonds's website: www.helmholtz-fonds.de.

The award ceremony

The Helmholtz Prize 2014 will be awarded on 24 June 2014 at the "Haus der Wissenschaft in Braunschweig" within the scope of the Helmholtz Symposium.

Contact for further enquiries:

Robert Wynands
Coordinator Helmholtz Prize
E-mail: helmholtzpreis@ptb.de
Phone: +49 (0)531 592-1009

Imprint

PTB-News 2/2013, English edition, Issue September 2013, ISSN 1611-163X

The PTBnews is published three times each year in a German as well as in an English edition and can be subscribed to free of charge.

Subscription form: www.ptb.de > English Version > Publications > PTB-news > Subscribe the PTBnews

Publisher: Physikalisch-Technische Bundesanstalt (PTB), Braunschweig und Berlin

Editors: Andreas Barthel, Ludger Koenders, Christian Lisdat, Dirk Ratschko, Mathias Richter, Hansjörg Scherer, Erika Schow, Florian Schubert, Jens Simon (responsible)

Layout: Volker Großmann, Alberto Parra del Riego (concept)

Translation: Cécile Charvieux (PTB Translation Office)

Editorial Office: Press and Information Office, PTB, Bundesallee 100, D-38116 Braunschweig, phone +49 (0)531 592-3005, fax +49 (0)531 592-3008, e-mail: ptbnews@ptb.de