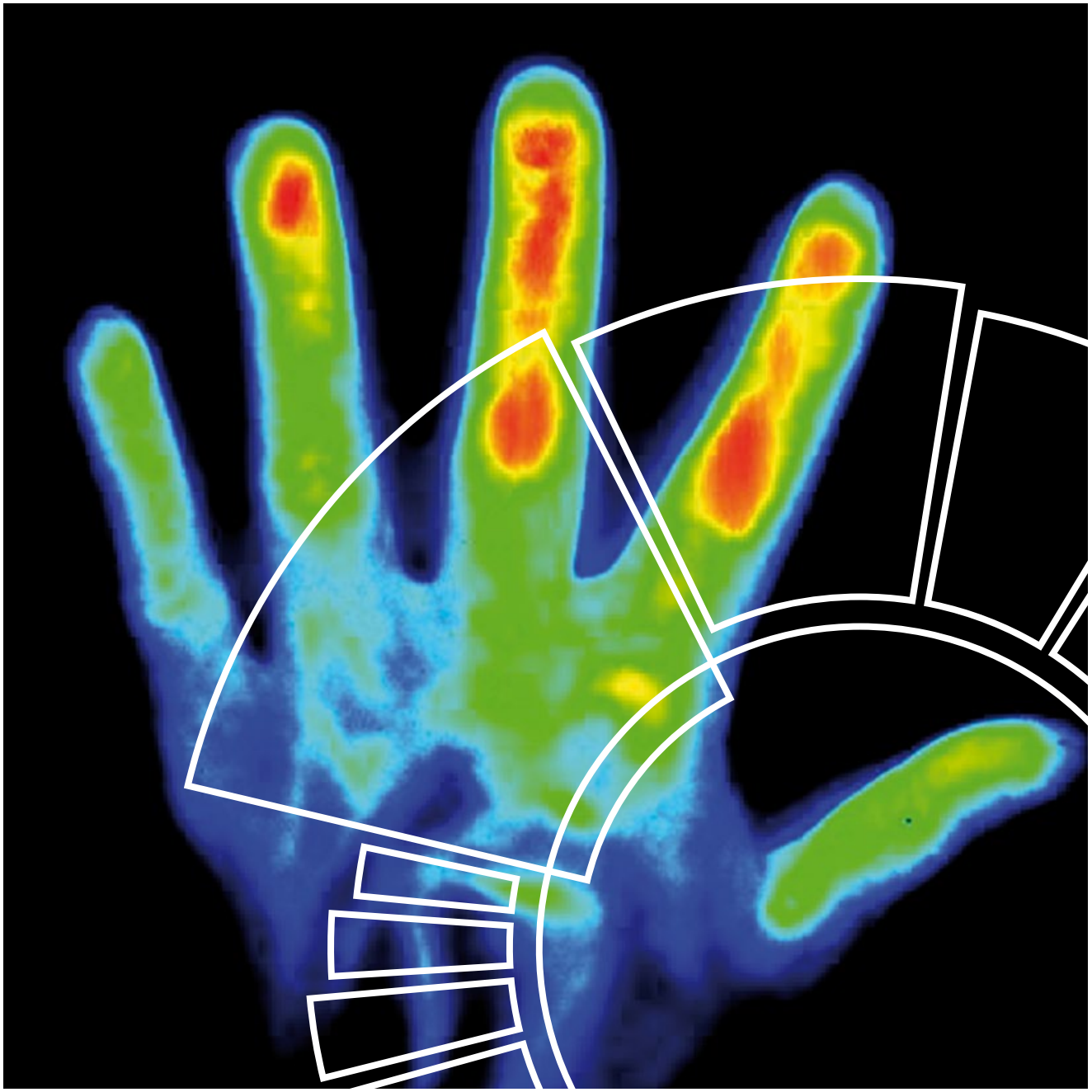
PTB INFO SHEET

PHYSIKALISCH-TECHNISCHE BUNDESANSTALT

DIVISION 8

Medical Physics and Metrological Information Technology



Medical Physics and Metrological Information Technology

Developing measuring methods and measuring procedures in medicine is one major task of Division 8. Furthermore, the other is information technology – from mathematical modelling and software testing to the approval of gaming and voting machines.

Origin

Hermann von Helmholtz, who can be rightly considered one of the greatest universal geniuses, had, as first president, created the scientific-technical orientation of the PTR. He was not only a prominent physicist, but as a "measuring natural observer"he was also a trailblazing physiologist. Following this tradition, PTB is today again active in the field of medical physics, with the goal of contributing to the comparability of measurements in medical science.

In PTB's oldest building, the so-called "Observatory" – in Helmholtz's old workplace – two departments today work on metrological questions of modern medical technology: on methods based on magnetic resonance, and in the field of biomedical optics, on tissue optics and on metrology at the cellular level.

The former quartz clock lab in the basement – Adolf Scheibe developed the first quartz clock here – today accommodates the MR laboratories with a 3-tesla MR scanner as the central research instrument. For the experiments on metrology at the cellular level, space is available which is designed for the security levels necessary for handling biological specimens.

Together with the Max Delbrück Center (MDC), PTB operates an ultra-high field laboratory with a 7-T whole-body MR scanner in the Experimental and Clinical Research Center (ECRC) in Berlin-Buch.

The Hermann von Helmholtz Building – also a beautiful architectural monument –accommodates the biomagnetic centre with the magnetically most quiet room on Earth. Here, the signals of the electrophysiological functions of the human body are analyzed and magnetic nanoparticles are characterized, which are employed in medicine in manifold ways.

Hermann von Helmholtz, the first president of the PTR. The collage highlights his manifold achievements.

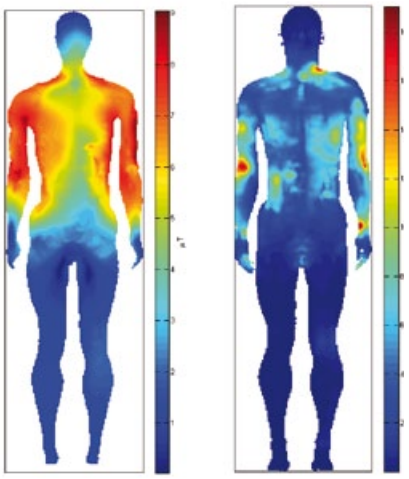
With two additional mainstays – mathematics and information technology – Division 8 takes on important cross-sectional tasks for metrology. Although Helmholtz had also studied information processing in the nervous system and in the brain, he could not presage to what extent information- and communications technology would also determine metrology today. But he certainly appreciated the important role of mathematics in data analysis and in modelling. ■

PTB's oldest building: the "Observatory".

Rheumatism, Cancer, Stroke, Neurodegeneration, ...

The criteria according to which the tasks of the Department are chosen are, besides the legal mission, also the relevance of the topics to society and the German economy. In the field of medical physics, those measurement methods are given priority which can be used for the diagnosis and therapy of widespread diseases and which are of interest for the German medical technology industry. Mathematics, information- and communications technologies – as cross-sectional tasks in metrology – are increasingly gaining in importance. ■

The 3-tesla whole-body tomograph at PTB's Observatory.



Simulation results for the distribution of high-frequency electromagnetic field quantities in MR images.

Magnetic Resonance Imaging and Magnetic Resonance Spectroscopy

Within the past 30 years, magnetic resonance imaging (MRI) has become an indispensable medical imaging procedure which is characterized especially by excellent soft tissue contrast and by the fact that the patient is not exposed to ionizing radiation. Nearly 100 million MRI examinations worldwide each year demonstrate the medical and socio-economic significance of this technology but also give rise to corresponding needs in terms of research for the development and the improvement of both the procedures and the devices. PTB's research activities in this field are focused on new imaging procedures, measurement techniques to guarantee patients' and staff's health and safety when MRI is used, quantification procedures of MRI data, investigations of the comparability of different imaging modalities in medicine, and combined imaging procedures.

With the MR measurement technology, besides diagnostic imaging with high spatial resolution, biochemical substances can be detected in-vivo in a non-invasive way by means of magnetic resonance spectroscopy (MRS). PTB, in cooperation with medical partners, has developed measurement techniques to determine the physiological parameters of the brain. This work is focused on increasing the correctness, the accuracy and the sensitivity of the measurements by using new MRS sequences, by optimizing sequence parameters, by developing dedicated high-frequency pulses and by improving the analytical methods.

Due to the increasing diversity of the methods, such measurements are always difficult to compare internationally. To achieve a better comparability, it is necessary for the measurement data and data protocols to be standardized. PTB is therefore participating in the Task Force "Standards for Data Sharing" of the "International Neuroinformatics Coordinating Facility" which aims to make structural and functional MR studies verifiable and internationally reproducible. ■

The "Magnetically Quietest" Place on Earth

Since 2004, PTB has been operating a walk-in magnetically shielded room (BMSR-2). With a shielding factor of more than 107 and a remaining field of less than 500 pT, this room offers excellent conditions for magnetic field measurements with highest resolution. SQUID magnetometers, which were developed by PTB, are used as sensor systems; they are able to detect magnetic fields down to just a few femtotesla. For many years, this worldwide unique measuring facility has not only been used solely for PTB's metrological activities, but it has also been used by external scientists from universities and industry for investigating issues from the most diverse fields of physics.

BMSR-2 is used for PTB's biosignal tasks, mainly for the further development of medical metrology for functional diagnostics. A novel and very promising technology which has been pursued by PTB is low-field magnetic resonance. This technology could make it possible to obtain both anatomic and electrophysiological information simultaneously with only one device. ■

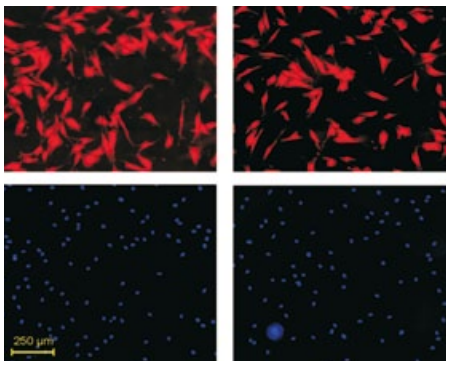
Construction of the Berlin Magnetically Shielded Room in 2001.

Magnetic Nanoparticles

In medicine, magnetic nanoparticles are used for various purposes, for example as contrast agents in magnetic resonance imaging or in hyperthermia therapy, a particular form of cancer therapy. Other applications are magnetic immunoassays and the so-called "magnetic drug targeting". For all these applications, PTB implements procedures (some of which have been developed by PTB itself) for the physical-technical characterization of the particles and for the detection and the non-contact determination of the concentration.

"Magnetic Marker Monitoring" is a successful example of technology transfer: If magnetic particles are added to off-the-shelf pills, the latter become magnetized, so that the pill's journey through the patient's body can be monitored. Where the pill dissolves – i.e. where it releases its active substance – magnetization decreases correspondingly. This is an indication of how and where in the anatomy the active substance is released. ■

Technology transfer: Magnetic Marker Monitoring.



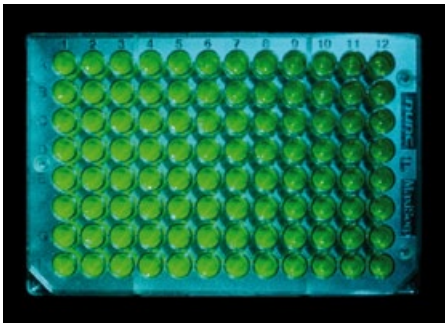
Fluorescence-microscopic images to measure cell density and the degree of cell confluency.

How Many Cells?

The quantitative determination of the concentration of cells in blood, in other body fluids or in cell cultures is indispensable in modern medical diagnostics. To this end, PTB develops, among other things, reference measurement procedures and tests, e. g., the measurement procedures used in laboratory medicine for the complete blood cell count by means of comparison measurements – the so-called "round robin tests". Furthermore, new flow-cytometric and microscopic measurement procedures are developed in collaboration with medical experts and other partners from research and science. Great hopes and expectations are currently placed in the development of new treatment possibilities by means of artificially manufactured cellular or tissue-like transplants. For this, it is necessary to develop internationally accepted metrological procedures, approaches and standards for quality and safety controls of products of regenerative medicine. Together with partners from other metrology institutes, research is conducted in the corresponding fields. ■

Interaction Between Mathematics and Experiment: Immunological Tests

With ELISAs (enzyme-linked immunosorbent assays), it is possible to detect – at very high specificity and sensitivity – antibodies which the body produces to fight viruses or bacteria. To determine the concentration of these antibodies in serum, fluorescence is measured after a chemical treatment. At the same time, calibrations are performed by repeating the same protocol steps with a solution of known concentration. The statistical analysis of the calibration and fluorescence measurements is a demanding task. For example during an international comparative study, some laboratories determined average concentrations which were twice as high as those determined by other laboratories. A new statistical procedure for ELISA analysis has therefore been developed by PTB; with this procedure, the concentration can be determined much more reliably. ■

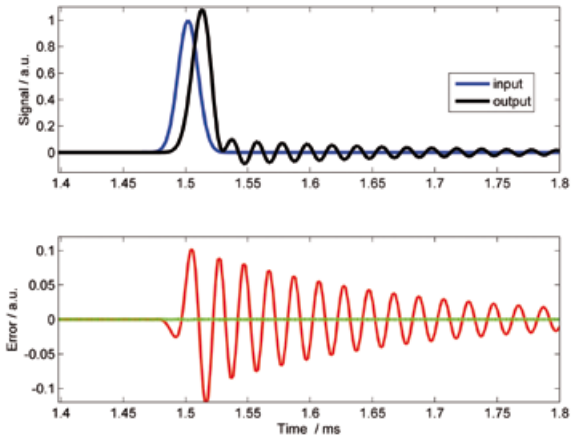


Microtiter plate of an ELISA test.

Analysis of Dynamic Measurements

The requirements industry places on the accuracy of dynamic measurements are constantly increasing. This requires that the specific behaviour of the measuring system for high-frequency signal components is taken into account for the determination of the value of the measurand. For an exact reconstruction of the measurand, procedures of digital signal processing are used. The mathematical and statistical analysis is hereby focused, among other things, on developing procedures for the determination of the resulting measurement uncertainties, which are needed for traceable measurements.

At the European level, the different metrology institutes work in close cooperation, e. g. within the scope of the project "Traceable Dynamic Measurement of Mechanical Quantities", in which nine European NMIs as well as a number of partners from industry are involved. ■



Analysis of the dynamic behaviour of a measuring system.

Test station for the quality assurance of metrological software.

Software and Secure Communications

Scarcely a measuring method can nowadays do without information-technical hardware and software. Confidence in the measuring data must, therefore, always be linked to confidence in the information-technical components used. The necessary quality assurance does by far not only concern the software for measurement data acquisition and the control of measurement processes, but rather also the ITC methods for measurement data transfer, storage and the issuing of consumption invoices. Consumers and partners in the course of business must be able to rely on values measured once and used at any place and at any time. PTB takes on testing within the scope of type approvals and conformity evaluations, works out guidelines and normative provisions, and faces future challenges through work on R&D projects. ■

Cash Gaming Machines

Gaming machines at PTB – how can that be?

Cash gaming in the way that it is permitted in Germany is subject to certain bounds and limitations due to special legal regulations. Insofar as these bounds and limitations are of a technical nature, cash gaming machines have to undergo tests within the scope of type approval procedures which are carried out at PTB. The entire state monitoring system of commercially operated cash gaming machines is essentially based on the type approvals of PTB. Thus, PTB fulfils an important consumer protection function.

At their core, gaming machines are computers of the latest state-of-the-art, but with an exterior face which is designed for a special purpose. In their aims and methods, the tests do not differ essentially from the tests carried out on the IT components used in measuring systems. The methods are similar. This applies, for example, to the hardware- and software-based protective measures against unauthorized changes. As a rule, the tests are very exacting and are permanently adapted to the latest technological developments. ■

Computer-based testing of the so-called control unit, the core piece for the monitoring of the legal requirements during actual operation.

Departments and Contacts

Head of Division

Prof. Dr. Hans Koch
Phone: +49 30 3481-7343
E-mail: hans.koch@ptb.de

Department 8.1
Medical Metrology

- MR Technology
- Standards for Medical Instrumentation
- In vivo MRI

Dr. Bernd Ittermann
Phone: +49 30 3481-7318
E-mail: bernd.ittermann@ptb.de

Department 8.2
Biosignals

- Biomagnetism
- Measurement Technology for Biosignals

Dr. Lutz Trahms
Phone: +49 30 3481-7213
E-mail: lutz.trahms@ptb.de

Department 8.3
Biomedical Optics

- Tissue Optics and Molecular Imaging
- Flow Cytometry and Microscopy

Prof. Dr. Rainer Macdonald
Phone: +49 30 3481-7542
E-mail: rainer.macdonald@ptb.de

Department 8.4
Mathematical Modelling and Data Analysis

- Mathematical Modelling and Simulation
- Data Analysis and Measurement Uncertainty

Dr. Markus Bär
Phone: +49 30 3481-7687
E-mail: markus.baer@ptb.de

Department 8.5
Metrological Information Technology

- Metrological Software
- Data Communication and Security
- Gaming Machines

Prof. Dr. Dieter Richter
Phone: +49 30 3481-7479
E-mail: dieter.richter@ptb.de

The tasks of Division 8 are, on the one hand, to improve the accuracy and the reliability of measuring methods and testing procedures in medicine for quality assurance in diagnostics and therapy and, on the other hand, of information-processing components of scientific, industrial, and consumer-protection-oriented metrology.

For the field of medical physics, this means: The development of new measuring techniques and testing procedures for medical diagnostics, in particular laserassisted measuring techniques, NMR-tomography and -spectroscopy, magneto-cardiography and -encephalography (PTB Biomagnetic Center in Berlin), and the development and calibration of testing devices and reference materials.

In the field of metrological information technology, this encompasses: Quality assurance for the use of information-technological means in metrology, especially in data acquisition, data storage and data processing. The area of work covers hard- and software problems as well as mathematical problems, the focus being on methods of digitizing, interfaces, communication components, software quality assurance, databases, numerical modelling and mathematical algorithms of measurement data processing, including the relevant testing methods and tools. Furthermore, type examinations of cash gaming machines and voting machines are performed in accordance with legal regulations. ■

Secretariat

Annett Weiland
Phone: +49 30 3481-7254
Telefax: +49 30 3481-7502
E-mail: annett.weiland@ptb.de

Physikalisch-Technische Bundesanstalt
Division 8: Medical Physics and
Metrological Information Technology
Abbestr. 2–12
10587 Berlin
www.ptb.de

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