PTB news
Metrology
Technology
Services
Cooperation
04.2

Rapid simulation of the heartbeat

Electrocardiography (ECG) is one of the measurement procedures most frequently applied in the everyday business of clinics. To improve the diagnostic significance of ECG signals it is necessary to analyze exactly the relation between the source of these signals, i.e. the electrical propagation of excitation in the myocardial, and the ECG signals measured on the body surface. Until now, this required a calculating time of several days. The numerical heart model presently in development at PTB now works fast enough that parameter variations can be performed within a few hours.

To an increasing extent numerical simulation procedures are being applied in biology and medicine to check hypotheses in physiology and pathophysiology. At PTB, a numerical heart model is being developed as part of a multisectoral project of the Federal Ministry of Education and Research (BMBF) with Schering AG, Berlin, and the Charité Clinical University Centre Benjamin Franklin, Berlin, and other partners (University of Calgary, Canada, and Graz University, Austria). The PTB heart model simulates the electrical propagation of excitation in the myocardial in detail. The model is verified by a comparison with courses of electrical excitation measured in animals hearts.

Basic requirements for practical application are rapid algorithms and the use of parallel computers. Implementing special techniques (preconditioning, multigrid) recently enabled PTB to reduce the calculating time for one single human heartbeat, which so far amounted to approximately one week, by one order of magnitude. This time reduction makes parameter studies feasible at last.

Agreement between simulation results and experiment was impressively confirmed in an investigation into the effect of drugs.

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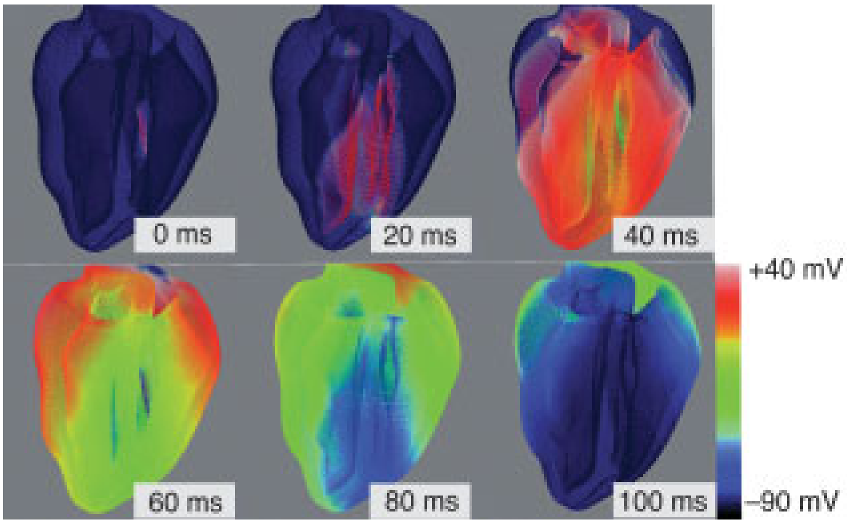

False colour representation of the sequence of a simulated electrical propagation of excitation in the heart of a rabbit

Single nanomagnets made visible

Smallest magnetic particles are newly deployed in medicine for diagnostics and therapy. In particular, the magnetic properties of so-called magnetosomes – magnetite particles encased by a lipid membrane – are of interest for these applications. PTB has now succeeded in imaging these very small particles with a size of approx. 40 nm and in showing that single particles really behave like nanomagnets.

Besides its significance for data storage technology, nanometrology for magnetic quantities is also increasingly gaining importance in medicine. At PTB, a magnetic force microscope has been further developed for this field. This microscope scans line by line with an extremely sharp magnetic tip. In a first step, it scans the surface of a sample and in a second cycle the magnetic field at a small distance to this surface. The radius of the stylus tips is smaller than 20 nm. This set up allows investigating a great variety of sample geometries at highest resolution. Biological samples can also be analyzed under ambient conditions.

Complete magnetosome ensembles were manufactured at the Max Planck Institute for Microbiology in Bremen. The magnetic properties were measured with the aid of spatially integrating measuring techniques. Finally, single nanoparticles have now been investigated with PTB's magnetic force microscope. Before the measurements were performed, the samples were magnetized perpendicular to the sample plane. In a surface image several single particles with a diameter of approximately 40 nm can be recognized as light spots. These are single magnetosomes.

In the image of the magnetic field, the particles appear as white spots surrounded by a darker ring. This appearance corresponds to that of a bar mag-

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Single nanomagnets made visible

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net standing perpendicular to the surface, its pole being viewed from above. This demonstrates for the first time that single magnetosomes are single-domain nanomagnets. This insight opens up new fields of application: contrary to conventional contrast agents, the particles, which also reach smallest capillaries, can be directed to any place in the body with the aid of magnetic fields. This considerably increases the spatial resolution when contrast agents are used and also improves the therapeutic effectiveness.

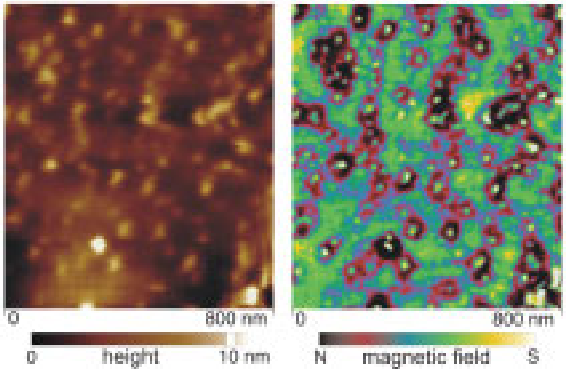

Image of single magnetosomes taken with the magnetic force microscope. On the left: topographic image, on the right: magnetic field.

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Intensity monitor for free-electron lasers

In cooperation with DESY (Deutsches Elektronen-Synchrotron) in Hamburg and the Ioffe Institute, St. Petersburg, a detector for high-intensity vacuum UV-(VUV) radiation has been developed and calibrated at PTB's radiometry laboratory at the Berlin Electron Storage Ring BESSY II.

The detection principle is based on photo-ionization of rare gases and allows pulse-resolved detection of radiation with a temporal resolution of a few nanoseconds. The detector is linear over a wide range of radiant power because only a small fraction of the rare gas atoms is ionized – even at very high radiant powers – and because electrons and ions are detected without further amplification. Therefore, it could be calibrated with monochromatized synchrotron radiation at mean radiant powers of less than 1 μW and used on the VUV free-electron laser (VUV-FEL) at DESY for quantitative measurements of highly pulsed VUV radiation in the wavelength range around 90 nm with peak powers up to 150 MW.

As the detector is operated at a gas pressure of only 10^{-3} Pa, it is transparent to more than 99%. Therefore, the principle is presently being further developed and from 2005 on, four detection systems will start operation as online-intensity and beam position monitors for the DESY-VUV-FEL project. It will also be tested whether the detector can be used as a calibrated monitor detector for EUV radiation from pulsed plasma sources for microlithographic applications at 13 nm and for X-radiation on the Sub-Picosecond-Photon-Source (SPPS) at Stanford.

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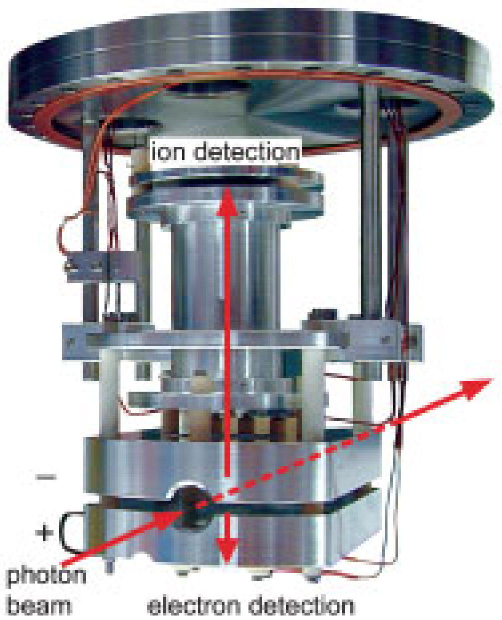

The VUV radiation detector exploits the photo-ionization of rare gases for measurement of the radiant power.

DCF77 suitable for public warnings

So far, in the first fourteen seconds of each minute, the DCF77 time signal transmitter has broadcast only status information and no time code. On behalf of the Federal Ministry of the Interior it has been investigated whether warnings to the general public could be transmitted instead in hazardous situations. The final report now available favours such an extended use of the time signal transmitter.

The Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (BBK, Federal Office for Civil Defense and Disaster Relief) in the sphere of business of the Federal Ministry of the Interior is looking for an alternative to the siren systems which are practically no longer available, to alert the population in cases of crises or catastrophes via a "reveille". HKW Elektronik GmbH was commissioned to perform

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DCF77 suitable for public warnings
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and evaluate a field test. For this purpose, the DCF77 long-wave transmitter was integrated into the SatWas satellite warning system of the Federal Government, to emit (initially fictive) warning information in the second marks 1 to 14.

Between October 13 and December 10, 2003, a total of 39 test alarms were emitted which were to be registered by 1000 receivers distributed all over the country. Additional silent alarms could only be registered by 50 industrial radio controlled clocks. The alarm protocols covered 3 · 14 bits and were emitted in 3 successive minutes. The clocks used were modified, commercially available radio controlled clocks (wrist watches, alarm clocks, wall clocks, PC radio controlled clocks) which, in addition to their standard functionality, were equipped with optical and acoustic alarms. The participants in the field test had committed themselves to report the alarms (also false alarms) via the Internet.

In its final report, HKW now informs that alarming time and the availability of SatWas information are consistently good all over Germany. The environment (countryside vs. congested urban areas, indoors vs. outdoors) and the distance to the emitter had only little influence on the reception probability. However, it turned out that the location selected for stationary clocks and the wearing habit for wristwatches exerted a considerable influence. The number of false alarms was negligibly small.

The results of this field test are also of interest to PTB, as this test offered the rare possibility to systematically investigate the reception conditions for information encoded in the DCF77 signal. The results confirms the assessments PTB made through many years of contact with developers and owners of radio controlled clocks: Malfunctions of the clocks are almost exclusively due to individual handling errors by users.

Now, based on the final report the Federal Ministry of the Interior must decide whether DCF77 will become part of the overall system for public warnings in the long run. The positive results suggest this.

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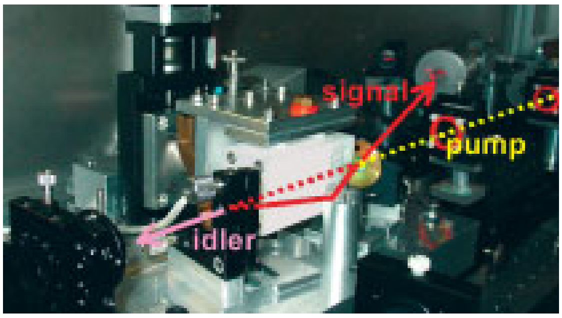
Tuneable IR laser radiation, generated with high efficiency

Increasing requirements for the accuracy of infrared radiation measurements require the use of tuneable laser radiation to calibrate IR radiation detectors. In the development of appropriate laser systems, PTB applies a combination of latest laser technology and non-linear optics. This set-up has demonstrated the very efficient generation of pulsed IR radiation which is tuneable in the wavelength range from 0.7 µm to 2 µm.

To an increasing extent measurement procedures exploiting IR radiation are not only used in telecommunications, but also in industrial process control and monitoring, in medical diagnostics, climatology, for the exploration of raw materials as well as in global and local environmental protection. Commensurately, the accuracy requirements for calibrations are increasing as well. In the medium term it will no longer be possible to meet these requirements with mono-chromatized thermal IR radiation of low spectral intensity. Laser radiation will be required which has so far been available only for single wavelengths or narrowly limited wavelength ranges.

Within the scope of a project promoted by the Federal Ministry of Economics and Labour (BMWA), PTB has therefore started to develop laser systems to generate tuneable monochromatic radiation over the entire IR range up to 10 µm wavelengths. In this project, the first important success has now been achieved: the prototype of a signal-resonant optical parametric oscillator (OPO) allowed tuneable radiation in the near infrared



Tuneable IR radiation is generated by frequency splitting in a periodically poled KTP crystal. Simultaneously, radiation of each individual wavelength in the ranges from 700 nm to 980 nm and from 1080 nm to 2000 nm is generated (as signal or idler) and separately available at the two outputs of the delta resonator used.

from 700 nm to 980 nm and from 1080 nm to 2000 nm to be generated with a conversion efficiency of approximately 20 %. Pump light source for the OPO was a pulsed Yb:YAG disk laser with frequency doubling developed in cooperation with Spectra-Physics GmbH. A procedure has been developed at PTB which enables longitudinal single-mode operation of this laser and a patent application has been filed.

This unique combination of latest laser technology and non-linear optics provides the basis to generate monochromatic infrared radiation up to 10 µm as aspired. In the next step it is to be demonstrated that the procedure can also generate continuous IR radiation with a continuously (cw-) pump laser.

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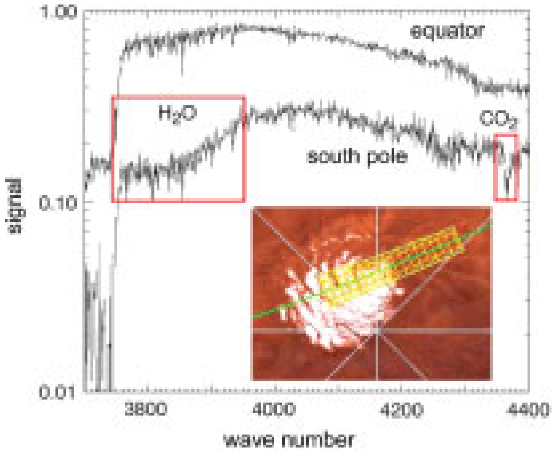
Reliable due to PTB calibration: Mars Express discovers water and methane

The European Spacecraft Mars Express discovered considerable, hitherto unknown water quantities as "permafrost" ice at the south pole of the red planet. Recently, one of the measuring instruments, the Planet Fourier Spectrometer (PFS), also succeeded in providing evidence of methane in the Martian atmosphere. PTB contributed to these discoveries: the radiometric calibration of the short-wave PFS channel is traced back to PTB standards – not only prior to start, but also in the Mars orbit.

At the end of last year, Mars Express as the first European Mars mission reached its Martian orbit. Only a short time afterwards, infrared measurements of OMEGA (combined camera and spectrometer), SPICAM (UV and IR spectrometer) and PFS (the Planet Fourier Spectrometer) enabled the sensational discovery of water at the south pole. Shortly after that, methane was detected as trace gas in the carbon dioxide atmosphere of Mars by PFS measurements.

The PFS, developed, constructed and operated in a cooperation project between Italy, Poland and Germany, is a two-channel spectrometer for the wavelength range from 1.2 µm to 45 µm. PFS measures the solar radiation reflected by Mars. This also allows ice mixed with sand and stones, which is "hidden" in the visible spectral range, to be detected on the Mars surface.

The short-wave channel of the spectrometer (1.2 µm to 4.8 µm) was radiometrically calibrated with traceability to PTB standards. For this purpose, the spectral radiant intensities of five infrared miniature radiators in the PFS calibration device were calibrated over the channel's whole spectral range by direct comparison with the PTB primary standard for spectral radiance, a high-temperature cavity radiator. The radiators calibrated by PTB first provided "preflight" calibration of the PFS. One of the calibrated infrared radiators was then integrated into the PFS and now allows regular "inflight" calibration of the short-wave channel in the Mars orbit. This ensures that no structures will be pretended in the measured spectra as a result of unrecognized modifications of the PFS sensitivity.



Details of two PFS spectra taken at the south pole of Mars and the equator. The pole spectrum clearly shows the absorption band of water ice between 3750 cm^{-1} and 3950 cm^{-1} which is lacking in the equator spectrum. Both spectra show absorption lines of water vapour. In addition, the pole spectrum shows an absorption band of solid carbon dioxide at 4370 cm^{-1}. Inserted is a view of the Mars surface at the south pole in visible light. The grid of the PFS measurements which provide proof of water ice is superposed.
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Helmholtz Prize for Metrology 2005

In summer 2005, the Helmholtz Prize – endowed with a certificate and 20 000 Euro – will be awarded in the specialist field of precision measurement in physics, chemistry and medicine. Closing date for applications will be the 15th of December 2004.

The award is addressed to scientists from the whole European area. The work to be submitted until December 15 must deal with a recent research result from theory or experiment which makes a fundamental contribution or aims at concrete applications. The work must have been performed in the European area or in cooperation with scientists working in Germany. To enter the competition, applications must be sent to the President of the Helmholtz-Fonds e. V., Prof. Dr. E. O. Göbel, President of the Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany.

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