Fraunhofer

IPM

FRAUNHOFER INSTITUTE FOR PHYSICAL MEASUREMENT TECHNIQUES IPM

Mission: Efficiency
Good ideas for better solutions

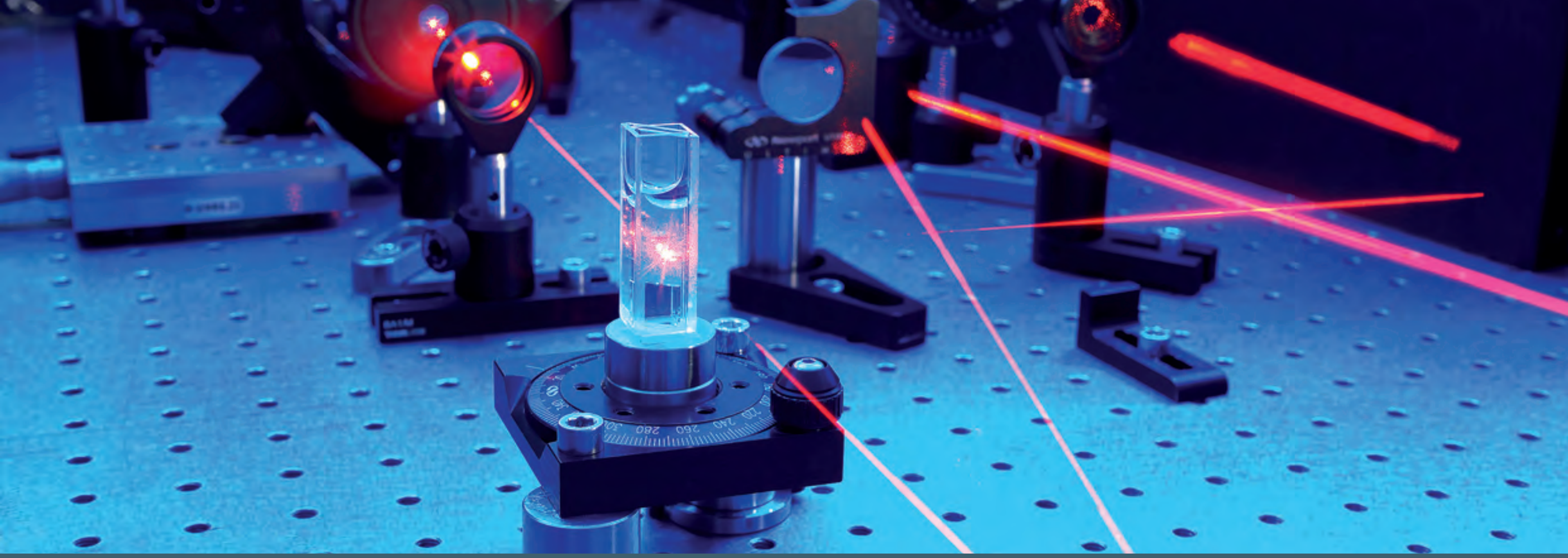
2011
2012

Title *A foveal camera sees in a similar way to the human eye. Micro-mirrors that can be steered very rapidly in any direction capture a 3D image that dynamically adapts its resolution to complex settings. A distance-measuring module developed by Fraunhofer IPM works behind the scenes.*

Mission: Efficiency
Good ideas for better solutions

FIELDS OF ACTIVITY

- GAS AND PARTICLE MEASUREMENT TECHNIQUES
- INTEGRATED SENSORS
- OPTICAL SURFACE ANALYSIS
- OPTICAL MATERIALS
- 3D MEASUREMENT TECHNOLOGY
- INLINE MEASUREMENT SYSTEMS
- IMAGING AND LIGHTING TECHNOLOGY
- THERMOELECTRICS
- TERAHERTZ MEASUREMENT AND TESTING TECHNOLOGY
- ULTRA-FAST ELECTRO-OPTICAL MEASUREMENT TECHNIQUES



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EDITORIAL

Dear clients and partners,

The year 2011 again saw Fraunhofer IPM carry out a very wide range of projects – on behalf of our clients or as part of early-stage research. Our annual report highlights a number of these developments. Whenever it is necessary to measure more precisely or faster than the current state of the art, that is the time when we come into action. In-depth know-how can be found in the field of analytical measurement systems, namely in optically characterizing the chemical compositions of gases, liquids and solids. We apply ourselves similarly to the fields of optical 3D measurement techniques and high-resolution optical 2D imaging. In thermoelectrics, our Institute is on the way to becoming an international reference address for determining the efficiency of new thermoelectric materials. And terahertz measuring technology is setting benchmarks in the contactless characterization of layers and the non-destructive testing of objects for defects and hazardous potential.

Focusing through synergies

The broad subject area of »physical measurement techniques« has the advantage that we are firmly rooted in a large number of fields and industrial sectors. However, this breadth also brings with it the challenge of achieving the synergies between the different subject areas. They are necessary because our resources do not enable us to achieve a leading position worldwide in many fields at the same time. Yet a leading position such as this is necessary to secure success on the market. This is why Fraunhofer IPM introduced various measures in 2011 and, in particular, a strategy process: we have started to analyze each of our subject areas in relation to our position, synergies and the market potential. In autumn 2012 the results will be presented to and discussed with a prestigious audience. Suggestions from outside as to which subject areas we should focus on more intensely are always welcome.

Efficiency and sustainability

Finally, another trend that became especially prominent in 2011: more and more projects at Fraunhofer IPM concern the topic of »sustainability«. Often it is a case of raising efficiency in production, decreasing scrap, reducing raw material use and also minimizing energy demand. Efficient combustion engines and the generation of electricity from heat otherwise lost are also in keeping with the topic of sustainability. Fraunhofer IPM is well equipped to create a continuous flow of innovations that lead to a more responsible way of living on our planet. The strategic process and the injection of our know-how into the subject area of sustainability allow us to join our customers and partners in looking ahead to the future with much joy and optimism.

Sincerely.

Prof. Dr. Karsten Buse
Executive Director

NEWS

FROM FREIBURG AND KAISERSLAUTERN

And the Oscar goes to…

The Munich-based producer of motion picture technology ARRI and Fraunhofer IPM have received the »Academy Award of Merit« for their jointly developed ARRILASER cine film recorder. Each year this Technology Oscar honors personalities who are responsible for a technical achievement that »has demonstrably contributed to improving filmmaking processes in a significant way«. Franz Kraus and Johannes Steurer from ARRI and Wolfgang Riedel from Fraunhofer IPM have each been awarded a golden Oscar statuette for the design and development of the ARRILASER. The basic concept of the ARRILASER was developed by a research team led by Wolfgang Riedel, who had already developed a successful large-format recorder for the photography industry as project manager at Fraunhofer IPM. The idea to use the acquired know-how for the motion picture industry led to an extremely successful partnership with ARRI. The experience in imaging technology together with specialist knowledge of the motion picture industry's needs allowed the team to define the requirements on a laser-based, high-quality, high-resolution film recorder. In 1998, the first prototypes of such laser film recorders were

The »Award of Merit« is the highest technical accolade that Hollywood has to award. The Oscar statuettes were presented to Franz Kraus (left) and Johannes Steurer (right) of ARRI and to Wolfgang Riedel (center) of Fraunhofer IPM.

subjected to testing. Today, more than 280 devices are in use worldwide for the recording of digital film data onto analog film reels.

Joseph-von-Fraunhofer Prize 2012 for eye-safe 3D laser scanners

Heinrich Höfler, Harald Wölfelschneider and their team have been honored with the Joseph-von-Fraunhofer Prize 2012 for the development of eye-safe 3D laser scanners. Functioning extremely fast and precisely, these scanners are sold all over the world, above all for applications in railway measurement technology. The high-speed devices measure distances at up to one million times per second and are therefore able, for example, to take spatial measurements of contact wires from a moving inspection train – and to do so at speeds in excess of 100 kilometers per hour. Another important application, particularly for eye-safe laser scanners, are stationary measurement portals next to the railway track. They are able to capture the profile of passing trains in order to discover any load slippage in good time before the train enters a tunnel and thus prevent accidents.

To make the laser scanners safe for the human eye, the researchers have exploited the infrared wavelength range for their measuring application. The team is currently working on further developments to the scanners for use on roads: mounted on a vehicle, the scanners record the road surface and thus generate a 3D image of the carriageway which provides information on the state of the coating down into the sub-millimeter range.

Heinrich Höfler (right) and Harald Wölfelschneider (left) received the Joseph-von-Fraunhofer Prize 2012 on behalf of the Railway Measurement team. The eye-safe 3D laser scanners are used worldwide for safety on railways and roads.

New building in Kaiserslautern: groundbreaking ceremony in April 2013
Laying of the foundation stone at the Fraunhofer Center in Kaiserslautern in April 2013 will finally provide the starting signal for construction of the new Department for Terahertz Measurement and Systems. Complex tendering regulations for research buildings of this magnitude have resulted in a slight delay in the planning work. The Institute's Kaiserslautern site will see the construction of a block for an initial 50 employees over a total area of 1,400 square meters. The building will also house the »TeraTec« applications center for terahertz technology, founded in 2010, which provides a technical infrastructure revolving around the subject of terahertz technology for clients from industry.

The European Union is supplying half of the approximately 9 million euros required for the building project; the other half is being shared equally by the federal government and the state of Rhineland-Palatinate. Fraunhofer IPM has already purchased a plot in the immediate vicinity which is intended as an experimental site for outdoor trials – such as signal transmission via terahertz waves.

Green light for new Institute building at the Freiburg site
Faster than expected, the state of Baden-Württemberg and the Fraunhofer-Gesellschaft have given their approval for a new building at the Institute's site in Freiburg. The basis for the decision was a location development concept submitted jointly by Fraunhofer ISE and Fraunhofer IPM. It includes plans to further expand the Fraunhofer site in Freiburg as a »Sustainable Energy Valley« and to strengthen the links between Fraunhofer IPM and the university. A plot of 30,000 square meters in the immediate neighborhood of the technical faculty of the University of Freiburg is to be the site of a new Institute building for Fraunhofer IPM. The new building will take account of the expansion in personnel at the Institute and the need for state-of-the-art technical infrastructure. Consequently, it will include a pilot-plant hall for transferring developments from the laboratory to the scale prior to industrial production. Fraunhofer ISE will take over the present premises of Fraunhofer IPM where it will establish a center for the research and development of technologies for transformation of the energy system. The construction program amounts to a total of 54 million euros for Fraunhofer IPM alone, of which the building itself accounts for 42 million euros and the initial equipment for 12 million euros. The move to the new building is scheduled for the end of 2016.

The saving straw
In the contest of ideas »Elevator Pitches« at the Fraunhofer Symposium »Netzwert 2011«, Manuel Kemmler put in a convincing performance with his idea »The saving straw: quick in-situ blood preparation«. In only 90 seconds, the holder of a doctorate in engineering presented his innovation, with the audience pressing their buttons to award him second place.

Using a simple procedure, the convenient »straw« – a narrow plastic tube – separates the cellular blood constituents from the liquid plasma. This is often necessary because it is easier to detect pathogens in plasma than in

Deutschland
Land der Ideen
Ausgewählter Ort 2012

whole blood. Thanks to the new procedure, the blood does not have to be sent to a central laboratory beforehand for centrifugation. Diagnosis can take place directly in situ – thus gaining valuable time for the patient. In order to implement this idea, Fraunhofer IPM has received prize money in the form of a project advance amounting to 25,000 euros.

»Selected Landmark« in the Land of Ideas

Fraunhofer IPM has been honored as a »Selected Landmark« for its research activities connected with the topic of »microsystems in the food industry«. Every year, the nation-branding initiative »Germany – Land of Ideas« selects 365 projects from all over Germany which stand out due to their inventive talent, ingenuity and high degree of innovation. With their partners from a number of European countries, scientists from the Integrated Sensor Systems group are jointly developing miniaturized measuring systems for the quality assurance and monitoring of foodstuffs. The use of intelligent measuring technology is intended to help reduce the amount of food that perishes on the way from the producer to the consumer. The prize-giving ceremony was accompanied by an exhibition for school students on the topic of »Better measurement, better food«.

Hugo Geiger Prize for mobile air pollution monitoring

Sven Rademacher, a post-graduate student at Fraunhofer IPM, has been awarded the first Hugo Geiger Prize 2012 for the development of an infrared, optical filter photometer. The measuring device for gas detection originated as part of his Master's thesis. It is designed for mobile use and, in contrast to commercially available devices, measures the concentrations of several gases at the same time. The pho-

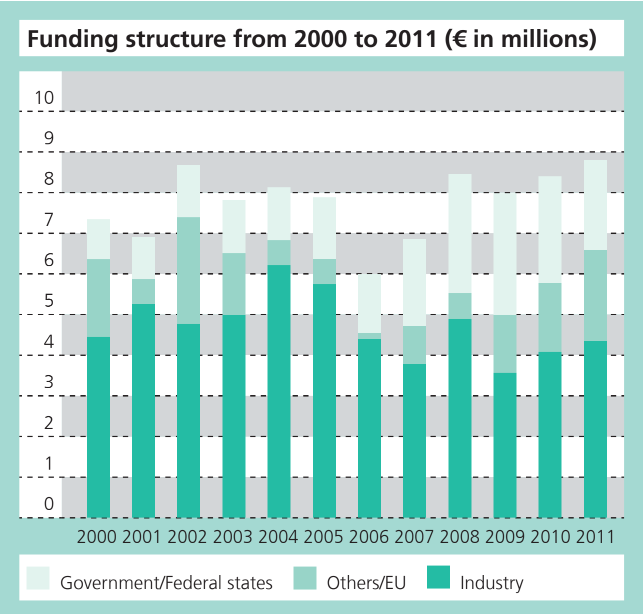
The innovative microsystems in the food industry from Fraunhofer IPM give the Institute the status of a »Selected Landmark« in the Land of Ideas. From left to right: Sibel Sagdic (Germany – Land of Ideas), Katrin Schmitt, Jürgen Wöllenstein, Marie-Luise Bauersfeld, Carolin Peter and Karsten Buse (Fraunhofer IPM) as well as Sven Feldheim (Deutsche Bank).

Sven Rademacher of Fraunhofer IPM (right) won the Hugo Geiger Prize 2012 for a mobile air pollution measuring device which monitors air quality and displays emission loads. The runner-up was Harry Kummer of Fraunhofer ISE (center), and the third-place prize went to Anna Marie Kruspe of Fraunhofer IDMT (left).

tometer is the centerpiece of a measuring system for mobile air pollution monitoring developed jointly with Fraunhofer IPK. In future, systems such as this are intended to measure air pollution over a large area and thus improve the quality of urban pollutant analyses. Until now, fine dust and gases have merely been measured at individual permanent stations. Installed on an inspection vehicle, the system can be located with the aid of the European satellite navigation system GALILEO. This enables the positions of the measuring sites to be determined precisely, thus permitting conclusions to be drawn about the specific sources of emission loads. The Bavarian Ministry of Economic Affairs, Infrastructure, Transport and Technology presents the Hugo Geiger Prize to outstanding and applications-oriented Master's and Diplom degree theses. The prize is worth 5,000 euros and was presented during the Fraunhofer annual conference.

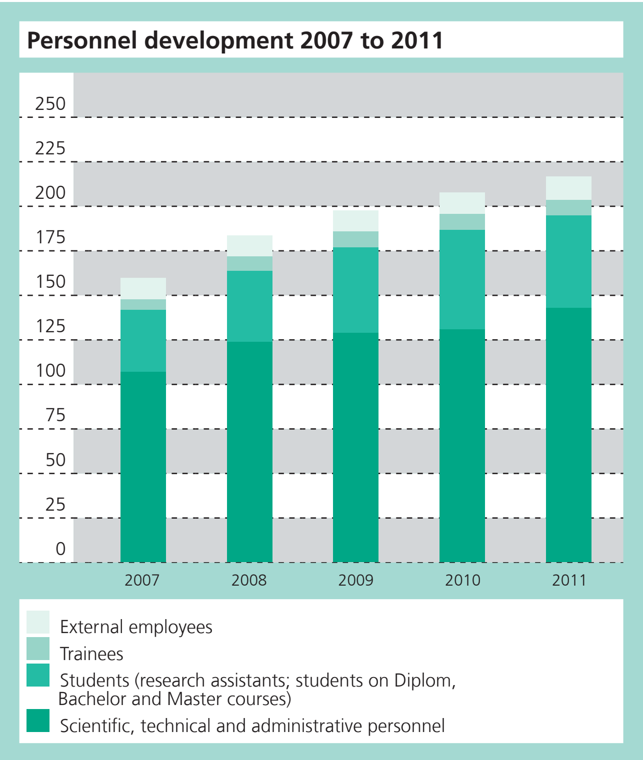
International Terahertz Workshop in Kaiserslautern

Innovative procedures and technologies in terahertz measuring technology open up new perspectives in non-destructive materials testing, tomography and security technology. This was one of the findings at the »International Forum on Terahertz Spectroscopy and Imaging«, which was organized by Fraunhofer IPM in Kaiserslautern from 6 to 7 March 2012. During the workshop arranged jointly with the VDI, 120 scientists and users from all over the world discussed the advances in research and applications in the field of terahertz technology. Twelve industrial firms used the opportunity to present components, measuring systems and services connected with terahertz technology. Particular interest focused on the mail scanner from Hübner GmbH, which was developed together with IANUS Simulation GmbH and Fraunhofer IPM.



Operating budget

At a level of 13 million euros, the Institute's operating budget for 2011 is 0.3 million euros up on that of the previous year. The operating budget is made up of revenues from industry, money from publicly financed projects and the basic funding. The proportion of revenues from industry amounts to 4.3 million euros. This represents an increase in revenues from industry of roughly 7.5 percent on last year (4 million euros). In total, revenues from industry account for a 32.8 percent share of the operating budget. In 2011, the investment budget for modernization of equipment amounted to 1.5 million euros.



Personnel

As of May 2012, the number of employees at Fraunhofer IPM is approximately 220, of whom some 140 are in permanent employment and, in turn, ten of these are at the Kaiserslautern site. Since July 2011, ten new jobs have been created. Fraunhofer IPM is thus continuing its expansion course. Job capacity amounts to 118 full-time posts. Amongst the workforce, an average of 45 percent are scientific personnel, 40 percent are engineers and technical staff while 15 percent are employees in the field of infrastructure and workshops. In addition to the employees recorded in the staff planning scheme, there are roughly 65 trainees, postgraduates, undergraduates on Master, Diplom or Bachelor courses, work experience students and assistants. Furthermore, 13 external employees work for the Institute.

ADVISORY BOARD | PARTNERS | ALLIANCES

Our Advisory Board

A 15-member Advisory Board with personalities from science, industry and politics is on hand to assist the Institute management when it comes to dealing with strategic issues and setting the course for the future. Intensive discussions and visits to the individual departments and groups have given the Board Members comprehensive insight into the Institute's work during the past year.

- Reinhard Hamburger, Chairman of the Advisory Board, C-FOR-U Business Coaching
- Wolfgang Bay, Sick AG
- Arno Bohn, Bohn Consult Unternehmerberatung GmbH
- Dr. Bernd Dallmann, Freiburg Wirtschaft Touristik und Messe GmbH & Co. KG
- Dr. Hans Eggers, Federal Ministry of Education and Research
- Prof. Dr. Maximilian Fleischer, Siemens AG
- Dr. Ehrentraud Graw, Ministry of Finance and Economics Baden-Württemberg
- Siegfried Groß, Agilent Technologies Deutschland GmbH
- Prof. Dr. Jan G. Korvink, University of Freiburg, Department of Microsystems Engineering (IMTEK)
- Dr. Volker Nussbaumer, Telekom AG
- Dr. Paul Schwabbauer, EADS Deutschland GmbH
- Dr. Augustin Siegel
- Reinhilde Spatscheck, SHS Gesellschaft für Beteiligungsmanagement mbH
- Dr. Michael Totzeck, Carl Zeiss AG
- Dr. Achim Weber, Ministry of Education, Research, Youth and Culture, Mainz

Partners & Networks

Fraunhofer IPM is a member of the Fraunhofer Group Light & Surfaces. In addition to this, the Institute is also actively involved in the following Alliances within the Fraunhofer-Gesellschaft:

- Fraunhofer Energy Alliance
- Fraunhofer Food Chain Management Alliance
- Fraunhofer Traffic and Transportation Alliance
- Fraunhofer Vision Alliance

Employees of Fraunhofer IPM are involved in many associations, specialist organizations and networks and thus take part in a permanent process of exchange with colleagues from their respective areas of specialization.

Deutschland

- AMA – Association for Sensor Technology
- BBA – Batterie- und Brennstoffzellenallianz BW
- CAST – Competence Center for Applied Security
- DGZfP – German Society for Non-Destructive Testing
- DTG – German Thermoelectric Society
- DTZ – Deutsches Terahertz Zentrum
- MSTBW – Mikrosystemtechnik BW
- Photonics BW
- VDI – The Association of German Engineers
- VDMA – Photovoltaic, Electromobility, Productronics
- VDSI – Verband Deutscher Sicherheitsingenieure

International

- APS – American Physical Society
- ETS – European Thermoelectric Society
- ITS – International Thermoelectric Society
- IEEE – Institute of Electrical and Electronics Engineers
- MRS – Material Research Society
- OSA – Optical Society of America
- SPIE – International Society for Optical Engineering

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DEPARTMENT
ANALYTICAL MEASUREMENT SYSTEMS

The white light of supercontinuum lasers is employed in modern multi-parameter analysis.

ANALYTICAL MEASUREMENT SYSTEMS

»We reveal what normally remains concealed«

Dr. Armin Lambrecht

The Department of Analytical Measurement Systems with its four groups develops and produces optical and sensor-based measuring systems to customer-specific requirements. Short measuring times, high precision and reliability are the distinguishing characteristics of the systems – even under extreme environmental conditions. The expertise includes laser spectroscopic procedures for gas analysis, particle measuring techniques for particulate matter analysis, energy-efficient sensors, e.g. for logistics monitoring, fluorescent procedures for optical surface analysis and measuring techniques for optical materials and defect analysis. The range of materials that can be analyzed is correspondingly broad: from car exhaust fumes to UV radiation in the ionosphere – spectroscopic analysis renders information visible that is concealed from the human eye.

Integrated Sensor Systems – ISS

The focus of the ISS Group is on the development, conceptual design, characterization and manufacture of functional surfaces, miniaturized gas sensors and compact gas measurement systems. Gas sensor technology and electronics are combined in compact and economical microsystems for this purpose.

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Spectroscopic Analysis and Space Measurement Techniques – SAW

Activities in the SAW Group center on the development of spectroscopic systems for the detection and analysis of gases, liquids and solids. In this field, the Group makes use of its long-established experience in exhaust gas and particle measurement technology as well as in systems adapted to space.

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Optical Bioanalytical Systems – OBS

Work in the OBS Group focuses on the development of turnkey devices for surface analysis. The methods employed are fluorescence measuring technology as well as infrared and Raman spectroscopy. Special know-how is to be found in microfluidics, automated microscopy and biochip technology.

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Technology of Optical Materials – TOM

The focus of the TOM Group is on investigating the optical properties of liquids and solids by means of innovative spectroscopic procedures. Examples include photothermal and photoacoustic methods as well as spectroscopy with supercontinuum laser sources.

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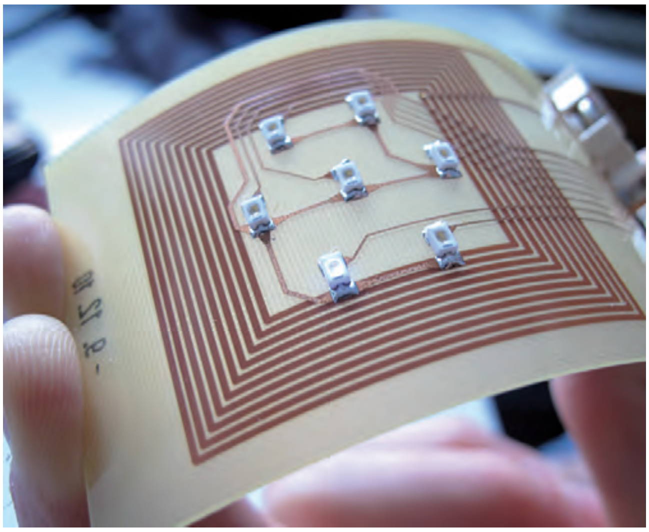
INTEGRATED SENSOR SYSTEMS

SMART DETECTIVES: ENERGY-EFFICIENT GAS SENSORS FOR TRANSPORT MONITORING

The commercially available banana comes by no means directly from the plant to the supermarket. For weeks on end, bananas are kept temporarily in cold stores. The ripening is practically brought to a standstill by removing gases such as ethylene and oxygen. When retailers need the bananas, they are able to ripen on the way to their destination. If the ethylene content could be measured during transport, it would be possible to control the ripening process exactly by regulating the gas concentration. RFID-based sensor technology makes it possible to monitor transport conditions such as temperature, humidity, gas concentration and light perfectly. To do this, small, flexible sensors are integrated on a thin, adhesive label. Communication and data transmission with the sensor system takes place by wireless means using »radio frequency identification« (RFID).



Sensors for temperature, light, gas and humidity are applied to flexible labels that provide comprehensive monitoring of their environment. They communicate wirelessly by means of RFID (»Radio Frequency Identification«).

Commercially available devices connected to a PC by methods such as Bluetooth or USB interface are able to read the RFID labels. In the project Sens-RFID, supported by the leading-edge cluster MicroTEC Südwest, Fraunhofer IPM is developing suitable gas sensors especially for RFID labels. Even at room temperature, the colorimetric sensors show a gas reaction which functions on the principle of color-changing materials, as is the case with pH indicators. This involves applying a dye to a waveguide into which light is fed. If the color of the gas-sensitive layer changes due to the contact with the gas to be detected, the intensity of the light changes as well. For instance, the dye bromocresol blue changes from yellow to blue on contact with ammonia. The change in light intensity due to the color change is determined as a change in voltage on the photodetectors.

Fraunhofer IPM is currently looking for an appropriate gas-sensitive layer for ethylene. Colorimetric sensors for the gases carbon monoxide (CO), nitrogen dioxide (NO_2) and ammonia (NH_3) are already successfully in operation. An RFID with a CO-sensitive label, for example, transmits the signal: »Caution: danger of poisoning« if the gas heating emits too much CO or a fire breaks out.

The RFID labels can be produced to customer specifications with already established sensor technology from Fraunhofer IPM. Temperature, light, gas and moisture sensors combined on one RFID label provide comprehensive monitoring of transport routes and intermediate stations for a number of foodstuffs or pharmaceuticals. The sensors are produced economically in large quantities.

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OPTICAL BIOANALYTICAL SYSTEMS

IMMACULATE: CLEAN SURFACES THANKS TO FLUORESCENCE

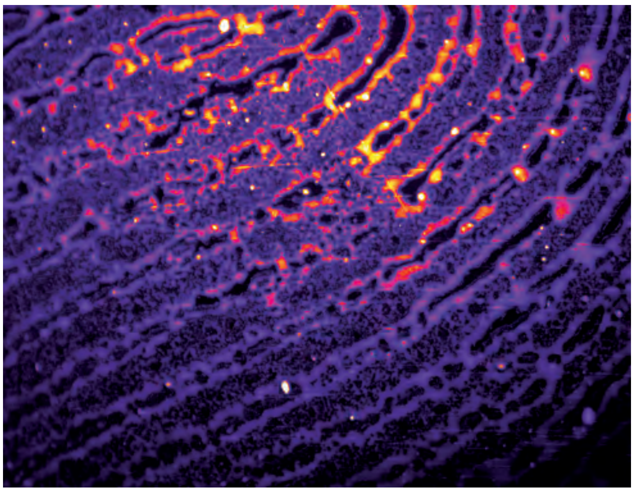
Many modern products rely on residue-free or immaculately homogeneous surfaces. Even a tiny droplet of oil can have a devastating impact on any adhesive joint. If the surfaces of workpieces and products are soiled or defective, they are either segregated or have to be cleaned.

Fraunhofer IPM has developed a fluorescence measuring system in order to detect impurities or defects on surfaces in the production line. The system functions on an imaging principle so that impurities and defects can be localized and the manufacturing processes continuously optimized – for instance when impurities frequently occur at the same location. In this application, Fraunhofer IPM exploits a simple principle: oils, greases and residues of wet chemical cleansing agents light up when illuminated with light of the correct wavelength – they fluoresce.

During the manufacturing process, the system monitors the surfaces of every component or product directly and without contact, by means of imaging fluorescence analysis. Adapted to the manufacturing speed, the system records a fluorescence image of the surface and analyzes the fluorescing objects. As many substances used for processing or cleaning materials fluoresce inherently, the system records such residues effortlessly, rapidly and precisely. The fluorescence image provides information on the quantity and distribution of the impurities or defects. This enables conclusions to be drawn on the cause of the contamination. With localized evaluations a 100 percent control becomes possible; this enables the quality of the products to be guaranteed and scrap levels minimized. At the same time, the system can be adapted customer-specifically to various problem scenarios and defect types, with the results being integrated into the production process.

Detection is possible on both transparent and non-transparent surfaces. With each image, the prototype captures an area of approximately 1 cm × 1 cm in size, which can be easily adapted to different requirements and assignments. The surfaces to be inspected are recorded within a few milliseconds. As a matter of principle, both significantly larger areas and objects with microscopic dimensions can be detected.

Also possible is the detection by imaging of fluorescence markers, namely substances that can be selectively bonded to substances in order to detect them with fluorescence measurement technology. This means – albeit in connection with a preparatory step – that it is also possible to detect substances that do not automatically fluoresce. Applications for this technique are to be found in biotechnology and diagnostics.



Fluorescent fingerprint: the imaging fluorescence measuring system detects impurities or defects on surfaces directly in the production line.

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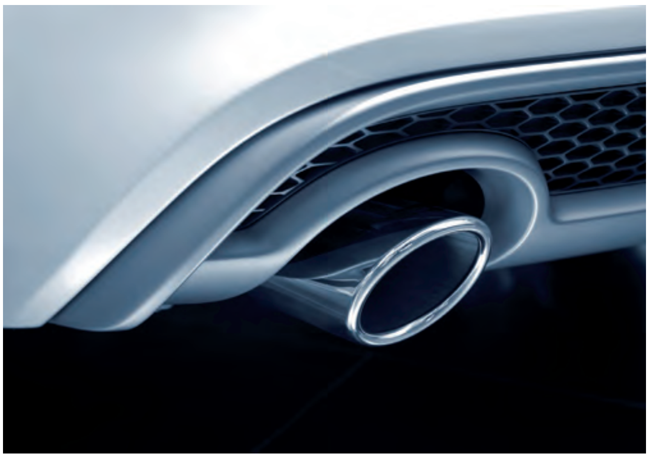
SPECTROSCOPIC ANALYSIS AND SPACE MEASUREMENT TECHNIQUES

FASTER MEASUREMENTS: EXHAUST MEASURING TECHNOLOGY FOR ENGINE TEST BEDS

Even today automotive manufacturers have to meet very strict emission regulations. And the Euro 6 emissions standard due to come into force for the type testing of passenger cars as from autumn of 2014 will be one of the most stringent regulations. For the developers of engines, the composition of exhaust gases is therefore a crucial quality parameter. In order to meet the forthcoming standards, the developers have to continuously optimize all cycles of the combustion engine, including the exhaust system. In addition to an understanding of the mechanical and tribological relationships, this work also calls for optimization of the entire engine management. Here modern exhaust gas measuring systems play an important role because they yield sound data.

The greatest challenge in optimizing engines comes from the dynamic processes. Industry demands two things from exhaust gas measuring technology: high temporal dynamics and high detection sensitivity. This is because engine developers need to measure the combustion exhaust gases with fine temporal resolution if they are to draw the conclusions required to gain a better understanding of the complex combustion processes of efficient high-performance engines and optimize them accordingly. Furthermore, sampling must not affect the operation of the engine. It should also be possible to analyze the gases without artifacts and without any reciprocal influence.



The concentrations of different gas components in the exhaust fumes can be measured simultaneously and with high temporal resolution using a quantum cascade laser spectrometer.

The exhaust gas measuring system developed by Fraunhofer IPM for the DEGAS-Next engine test bed has been designed in line with these requirements and thus sets new benchmarks that will also live up to the forthcoming requirements from industry. The key to a high measuring rate is the use of modern quantum cascade laser technology in conjunction with thermoelectrically cooled detectors.

The portable measuring system is integrated into a 19-inch rack and merely needs an electricity connection as a source of supply; liquid nitrogen for cooling is not necessary. In this way, it is relatively easy to measure different gas concentrations. The standard model is designed for the detection of nitrogen monoxide (NO), nitrogen dioxide (NO_2) and ammonia (NH_3). Suitable lasers also enable additional gases to be detected.

For most components, the detection limit of DEGAS-Next lies in the range of a few ppm (one molecule in one million molecules). In terms of the investigation and optimization of dynamic processes on multistage catalytic converter systems, DEGAS-Next has six measuring channels for the simultaneous measurement of three exhaust gas components at two different sampling points.

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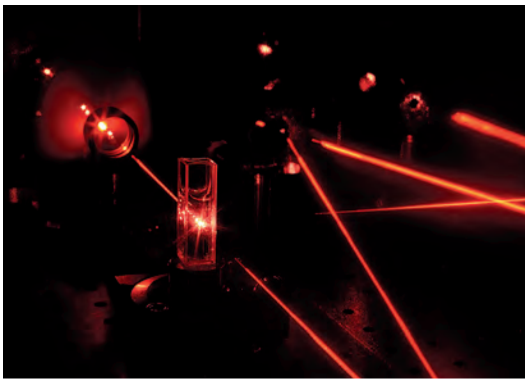
IT'S THE TWIST THAT COUNTS: CHIRAL ANALYSIS IN MICROVOLUMES

In Germany there are currently more than 80,000 approved medicines. As is the case with many naturally occurring compounds, most of the active pharmaceutical ingredients they contain are substances that exist in two forms which are symmetrical mirror images of each other – known as enantiomers. Enantiomers are each built of exactly the same atoms but have symmetrically mirrored structures – like a left hand to a right hand. The term for such substances is chiral. Natural molecules like genes (DNA) and enzymes are just as chiral as ibuprofen or penicillin. This symmetry has more serious effects than one would have thought possible from a single molecule: the biochemical and physical effect of the mirror images can be very different. For example, the Contergan scandal in Germany was the result of the chirally active ingredient thalidomide, a sedative and sleep-inducing drug. Studies soon indicated that one of the thalidomide enantiomers was responsible for severe deformities in newly born children. Ultimately, the biochemical relationships proved to be not that simple but the case was a very drastic illustration of how important it is to distinguish and separate the enantiomers of chirally active ingredients.

But how is it possible to distinguish between enantiomers? Chiral molecules are »optically active«: when passing through the substance, linearly polarized light undergoes a rotation of the polarization plane. In other words, one of the enantiomers is »laevorotatory« – meaning that it rotates the light to the left – while the other is »dextrorotatory«. As the effect is very small, commercially available detectors use long light paths through the substance and therefore need large quantities of specimen in order to achieve the desired sensitivity. During the development of new pharmaceuticals, in particular, often there are only a few microliters of sample available because the synthesis of new substances is time-consuming and cost-intensive.

Fraunhofer IPM has developed a new procedure that makes it possible to distinguish between the enantiomers even in small (micro) volumes. The measuring principle exploits the optical effect in a new way: the light waves that have undergone laevorotatory and dextrorotatory polarization propagate at different speeds within the medium, i.e. they have different refractive indices. On entering the substance, the light beam is therefore split into two component beams. However, the angle between the two components beams is in the order of several nanoradians. This is equivalent to a distance of a few millimeters after a path of one kilometer! With the aid of suitable detectors sensitive to position and using modulation techniques it is, however, also possible to measure the split in the laboratory. This allows the two enantiomers to be reliably distinguished from one another and the concentrations to be determined. As the separation of the component beams takes place directly when the light enters the substance, specimen volumes in the microliter range are all that is necessary. The procedure therefore opens up new measuring opportunities for chiral refractometry in modern analysis.



A red helium-neon laser reveals whether the active ingredient in the solutions is laevorotatory or dextrorotatory.

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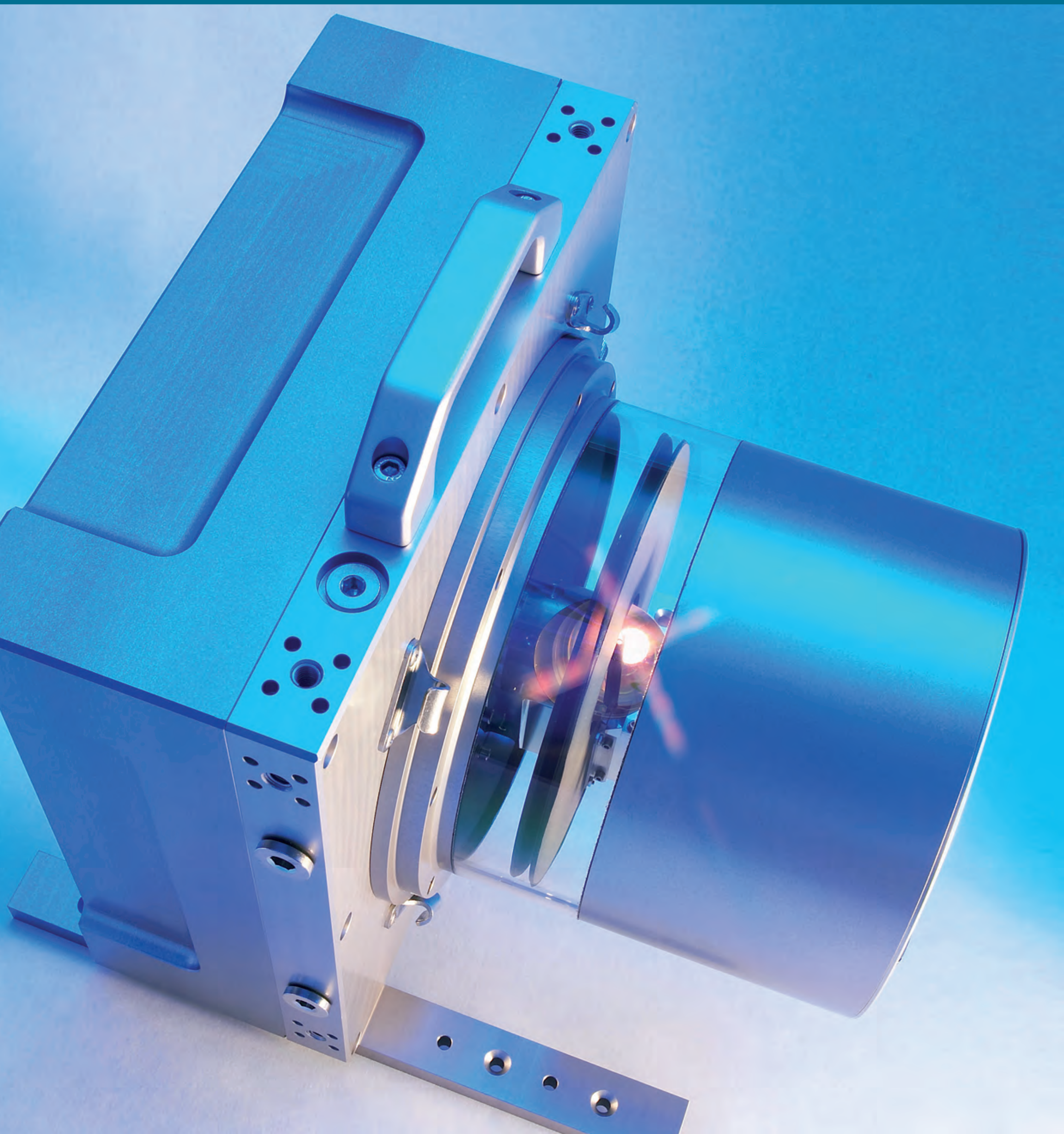
DEPARTMENT
OPTICAL MEASUREMENT FOR PRODUCTION

Laser scanners detect obstructive objects on railway lines – even at high speeds.



OPTICAL MEASUREMENT FOR PRODUCTION

»We develop optical systems and methods for industry and production«

Dr. Heinrich Höfler

The Department of Optical Measurement for Production develops optical systems and imaging techniques for the analysis of surfaces and 3D structures deployed for a wide range of applications: the tailor-made systems optimize industrial production processes, ensure higher safety in rail traffic, authenticate products or open up novel advertising formats. From distance measurement in the 10-meter range to the detection of microstructures, the measuring systems developed within the four groups cover different orders of magnitude – and always work at extremely high speeds.

Railway Measurement – BMT

The focus of the BMT Group is on developing laser scanners for industry. The turnkey systems are employed on railway lines and on roads around the world and monitor features such as clearance and train profiles, contact wires or the condition of road surfaces.

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Laser Distance Imaging – LDI

Activities in the LDI Group center on the development of measuring systems based on time delay measurement. These systems can be used to measure distances and geometries of surfaces with extreme speed and high precision – an important attribute for control engineering.

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Inline Measurement Techniques – IMT

Work in the IMT Group concentrates on measuring systems that provide evaluated data in real time – e.g. for regulating sensitive manufacturing processes. This is achieved by combining optical measurement techniques with extremely fast evaluation procedures.

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Optical Microstructures – OMT

The focus of the OMT Group is on linking optical know-how with modern digital technology. Development aims are special exposure and illumination techniques. Microstructures often play a key role in applications such as color imaging techniques and holographic structuring.

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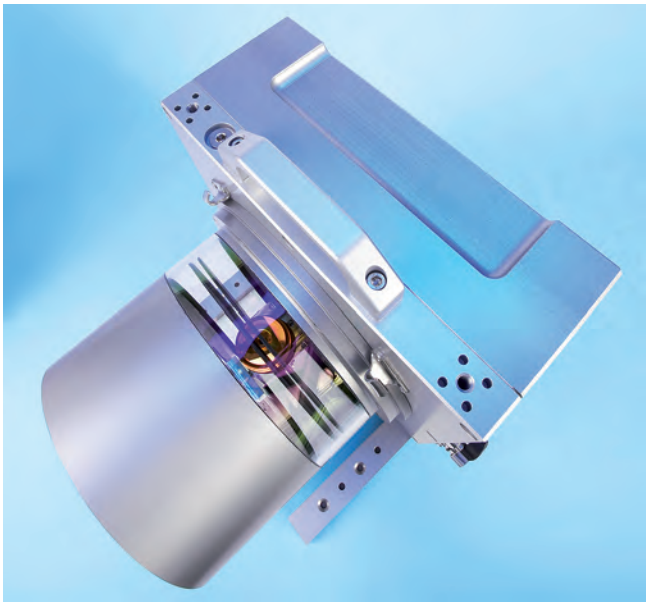
RAILWAY MEASUREMENT

PRECISE MEASUREMENT AT –40 °C: A LASER SCANNER FOR RUSSIA'S RAILROADS

For many communities in the territory of the Russian Federation, the railway network represents the most important lifeline. It covers an overall length of more than 80,000 kilometers and extends over several climatic zones. Fluctuating temperatures mean that it is exposed to especially heavy loads. Regular servicing and maintenance is especially important here and only possible with efficient technology. Since autumn 2011, the first inspection train equipped with IPM technology has been operating in the Russian Pacific region. Fraunhofer IPM has already installed more than 35 railway measurement systems in 17 countries. Deployment of a measurement system on Russia's railways marks the entry into a promising market – and presents very special challenges: the high-precision measuring technology occasionally has to function in the searing heat of summer but also in the severe winter. Consequently, the system components underwent prior testing in a climate chamber at temperatures from –40 °C to +50 °C. Certain adhesive layers were unable to withstand the extreme cold. As a result, an optical window consisting of laminated glass especially for use on Russian territory had to be replaced by a monolithic window.



Mounted on an inspection train, the Clearance Profile Scanner measures the clearance profile of the railway track – the space that has to be free to ensure safe travel.

The CPS 202 Clearance Profile Scanner employed in the Russian Pacific region measures the clearance profile of railway sections – an exactly defined virtual space around the railway tracks that has to be free of objects. For instance, any trees, signs or poles that project into this space represent a hazard for passing trains. The laser measurement system is installed at the front of the train and works without making contact. The measuring system delivers a distance value one million times a second – and does this so precisely that an object at a distance of 5 meters can be localized with a precision of a few millimeters. The rotational frequency of the scanner can be adapted so that it permits either a high profile density in the direction of travel or an especially high-resolution measurement within a profile. This makes the scanner so flexible that, in addition to the clearance profile, it is also able to measure the position of the overhead wires, the distance to the adjacent track, the quality of the platform edge or the profile of the ballast bed with high accuracy. The laser measuring technology has undergone refinement especially for the Russian railways so that it covers a measuring range of 50 meters.

Deployment of the CPS 202 on the railway tracks of the Russian Federation means that a very versatile and robust measuring instrument is in operation which is capable of coping with the difficult operating conditions.

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LAYER CONTROL: DETECTING SMALL DEFECTS ON LARGE SURFACES

Industry is relying increasingly on functional coatings to selectively generate mechanical or optical surface properties. Coated glass substrates, for example, play a role in the manufacture of solar cells. If they are to perform their actual purpose, functional surfaces must be as free as possible of defects. However, minute defects cannot be reliably detected with the usual visual examination and conventional image processing systems.

During the course of various industrial projects, Fraunhofer IPM has developed measuring systems that detect small defects on large surfaces. The fully automatic inline microscopes are integrated into the production line and function so quickly as to make completely automated optical inspection possible. A prerequisite for this is a very fast image processing. Here simultaneously functioning computing architectures such as cellular neural networks have the advantage that every individual pixel has its own processor. This means that identical computing operations are executed fully simultaneously. However, at a high production rate and with defects of only a few millimeters in size, full inspection of areas measured in square meters is sometimes not possible even with very fast image processing. The measurement of skillfully selected areas yields representative random samples for a reliable quality inspection – without unnecessarily slowing down the process. The images can be recorded in vertical and transmitted light microscopy at the same time. Depending on the spectral properties of the layers, it then becomes possible to differentiate the extent to which the defects merely affect the surface or also deeper layers.

Measuring rates of more than 10,000 evaluated full images per second demand short, flash-like illumination because little time remains for the actual exposure. The flash illuminations also enable measurements to take place in motion, which significantly reduces the time for motorization and handling. Fraunhofer IPM employs a specially developed LED lighting unit that illuminates the sample with more than one hundred times the intensity of sunlight. The inspection systems are equipped with automatic focus tracking in order to reliably compensate for unevenness of the substrate materials. In addition, a record and printout of the autofocus signal are kept for quality control of the substrate evenness.

The requirements on measuring systems for functional surfaces vary greatly. A project therefore always commences with experimental proof of the function. As part of a preliminary study, the scientists find the optimum balance between accuracy and rate of measurement and define all the software interfaces needed for the integration. On this basis, they define the functional specification for an individually adapted inspection system.

Fully automatic inline microscopes detect tiny defects on large surfaces – even in fast production processes.

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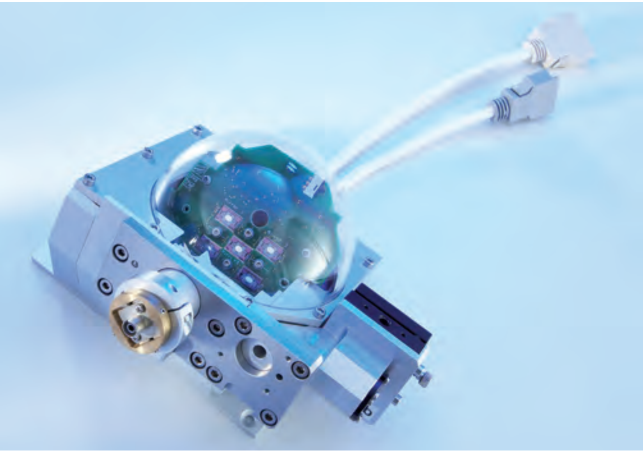
LASER DISTANCE IMAGING

SEEING LIKE HUMANS: 3D SCANNERS WITH MICRO-MIRRORS

The third dimension is not only a megatrend in the cinema. Various industrial applications also demand images with depth information. The exclusion zone of machines can be protected with significantly more reliability using 3D measuring technology than with conventional 2D systems. In crime scene documentation, 3D rendering enables the sequence of events to be reconstructed under the conditions at the site even years after the offence. Equipped with three-dimensional perception, robots learn how to guide themselves in their environment.

For most applications a particularly detailed resolution is only important for selected image sections. Together with other Fraunhofer Institutes and international partners, Fraunhofer IPM is developing a 3D camera that detects relevant objects and represents them with increased resolution. This makes significantly faster image recording possible while maintaining the same information content. The scientists are thus copying one of nature's recipes for success: the human eye functions on a very similar principle. In what is known as foveal vision, maximum visual acuity is only achieved in a very narrowly limited field of view.



The foveal camera permits high resolutions and short recording times: a distance measuring module developed by Fraunhofer IPM makes it possible to achieve a 3D image with dynamic focus.

The use of micro-mirrors that can be guided very quickly in any required directions makes it possible for the first time to capture a 3D image that dynamically adjusts its resolution to the complexity of the scene. Working in the wings is a distance-measuring module developed by Fraunhofer IPM which enables rapid image recording in a broad measuring range thanks to its efficiency. Laser scanners have decisive benefits in 3D data recording: they work independently of an external light source and deliver more precise depth information than alternative systems of a comparable size. The accuracy of the depth information for a stereo camera system thus decreases significantly faster than for a laser measurement system. In addition, 3D laser scanners prove to be very robust to interference such as sunlight or rapid variations in intensity of artificial lighting.

The 3D image of a laser scanner is generated on the basis of many individual distance measurements. How close the measuring points are located next to each other, in other words how detailed the resulting image is, can be selected almost freely. In practice it has previously been necessary to weigh up the benefits between high resolution and short recording times. With the foveal camera, it is now possible to switch very rapidly between these two modes. A feature such as this is especially interesting for applications in the field of machine vision and robotics.

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OPTICAL MICROSTRUCTURES

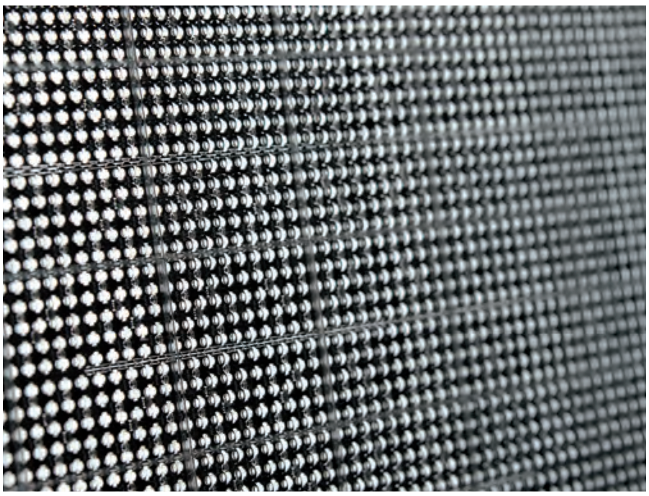
3D WITHOUT SPECTACLES: DISPLAYS WITH AN IMPRESSION OF DEPTH

Innovative advertising formats are required to attract the attention of overstimulated viewers. Under the scientific management of Fraunhofer IPM, Fraunhofer IPT and the Christian-Albrechts-Universität Kiel, the company REALEYES GmbH has succeeded in adding a third dimension to advertising: As part of a project funded by the Federal Ministry of Economics and Technology, the partners have developed technologies for the manufacture of large-format 3D displays that can even be viewed without the need for special glasses. The three-dimensional advertising displays captivate their beholders with a hitherto unachieved spatial effect. Joining the displays, each with an area of one square meter, makes larger formats possible as well. Fraunhofer IPM has developed the imaging system for producing the 3D displays.

A display surface of A0 format is fitted with some 250,000 individual lenses which each show an individual micro-image consisting of approximately 30,000 individual pixels. For this purpose, 250,000 photo-realistic perspectives each with approximately 30,000 viewing angles are computed from a 3D model, which corresponds to a data quantity of more than 230 gigabytes. The arrangement of the lens systems produces an overall image in which each lens system produces one pixel. Different pixels from the lens image are perceived according to the viewer's position, so that each eye sees the virtual scene from a slightly different perspective. This creates the 3D impression.

In one single step, the system developed by Fraunhofer IPM copies the digitally prepared microimages through the lenses onto color microfilm. To do this, the imaging system addresses each of these micro-optical systems individually. The color image is copied sequentially onto the color microfilm by means of a three-color LED lighting system (RGB). In this process, imaging optics specially developed for the project and the subject of a joint patent application with the client guarantees the quality of the 3D rendering.

Thanks to rapid data connections, the corresponding imaging optics and efficient control electronics, the copying takes place in one continuous movement. Only in this way is it possible to achieve the cost-effective production of large-format posters with hundreds of thousands of lenses. During the development, particular attention was paid to the durability and the ease of operation of the system. Audi, Deutsche Telekom, Marlboro, Moët & Chandon and the Swiss watchmaker Hublot are among the customers already using the 3D displays for their advertising.



The large-format 3D displays consist of 250,000 individual lenses per square meter, which each depict an independent micro-image. This creates the 3D effect – entirely without special spectacles.

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DEPARTMENT
THERMOELECTRIC SYSTEMS

The properties of thermoelectric materials can be improved through spark plasma sintering.

THERMOELECTRIC SYSTEMS

»We make electricity from waste heat«

Dr. Kilian Bartholomé

Converting lost heat energy into electricity – this is one of the key prospects for thermoelectrics. Thermoelectric »energy harvesting«, in other words the gathering of waste heat, will in future play a key role in making more efficient use of energy. Here, the potential range of applications for thermoelectric components for converting thermal energy extends from the µW range for operating energy-autarkic sensor systems to the kilowatt and megawatt range when exploiting waste heat in motor vehicles, combined heat and power stations and large-scale industrial plants.

For more than 15 years, Fraunhofer IPM has been conducting research in order to integrate novel thermoelectric materials efficiently into applications with a future. Today, the range of the Department's activities with its two groups encompasses materials research, the development of thermoelectric modules, simulation of these modules as well as thermoelectric measuring technology and systems. Apart from increasing conversion efficiency, another aim is to develop cost-effective manufacturing processes for materials and modules that are compatible with environmental and recycling needs and also to investigate and optimize their long-term stability.

Energy-Autarkic Systems and Thermoelectric Measurement Techniques – ETM

Work in the ETM Group centers on the development of metrological systems for characterizing thermoelectric raw materials, modules and entire systems. It also includes the design of sensor systems that supply themselves with energy.

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Thermoelectric Energy Converters – TEW

The focus of the TEW Group is on »energy harvesting«. In order to convert heat into electricity, the Group is developing more efficient thermoelectric materials and optimizing production methods for converters.

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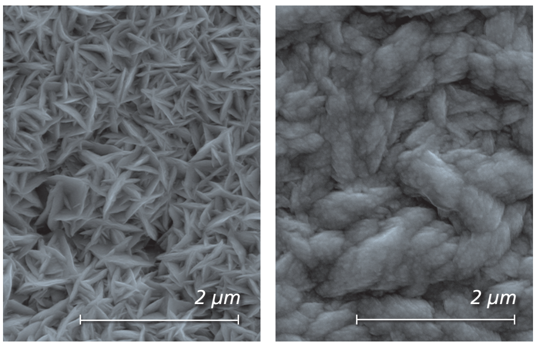
ENERGY AUTARKIC SYSTEMS AND THERMOELECTRIC METROLOGY

OPTIMIZED PRODUCTION: THERMOELECTRICS FOR EVERYDAY UTILITY

More than two-thirds of primary energy used is lost as heat. Thermoelectric modules convert part of this otherwise unproductive waste heat into valuable electrical energy. Thin-layer technology is used to produce thermoelectric converters that supply energy-autarkic sensors with electricity or support the alternator in motor vehicles. However, until now the mass production of thermoelectric modules has only been possible to a limited extent. Innovative electrochemical separation methods now mark a decisive step for thermoelectrics. If success is achieved in producing cost-effective large-area thermoelectric layers, thermoelectric modules will be ready for manufacture in series. As part of the EchemTE project, scientists from the Institute of Applied Physics and the Institute for Inorganic and Applied Chemistry (both at the University of Hamburg) are working together with Fraunhofer IPM on the development of economical electrochemical production methods for thermoelectrical semiconductor layers with thicknesses of 10 – 100 µm, with an efficiency in the range of the thermoelectric layers that are usual today.



At the beginning of the project, the bismuth telluride layer still has a very rough surface (left). Now the layer can be deposited so smoothly that a significantly higher electrical potential is created (right).

Thermoelectrical modules are built with a sandwich structure: located between two ceramic plates is the thermoelectric semiconductor layer, connected by metal contacts and fastened to the ceramic plates. If the ceramic plates each exhibit different temperatures, an electrical potential is produced in the thermoelectric layer. The efficiency of the module does not depend solely on the thermoelectric material and its chemical composition, but also on the crystallinity. These properties depend crucially upon the manufacturing process. Since 2009, therefore, investigations have been taking place into the thermoelectric properties of bismuth telluride layers that have been deposited electrochemically with different parameters.

In order to obtain as much electrical energy as possible, the metal contacts on the semiconductors must have the smallest possible transition resistances. The smoother the surface of the thermoelectric layer, the better the contact is. As scanning electron micrographs of the bismuth telluride layers show, the layers deposited are now visibly smoother.

Significant progress has also taken place in the tempering process; this process is intended to modify the material chemically in order to achieve the most efficient energy conversion possible. One of the parameters that changes here is the crystalline structure of the material. Fraunhofer IPM uses a new procedure to measure the thermal properties during the tempering process. Considerable achievements have been possible in the deposition procedure and tempering process so that the thin layer has been deposited homogeneously on a 4-inch wafer. The thermoelectric properties of the economical layers are comparable with those of the much more expensive layers used to date.

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THE INTELLIGENT COFFEE POT: ENERGY-AUTARKIC SENSORS IN USE

Sensors are increasingly becoming invisible assistants in everyday life: in navigation devices, smoke detectors or temperature controllers, for example. Wherever possible, the small, smart helpers are intended to carry out their work without any maintenance. A new sensor from Fraunhofer IPM has now perfected this: not even the batteries have to be changed anymore! The sensor obtains its electrical energy from a thermoelectric generator that converts heat into electricity.

Scientists from Fraunhofer IPM have integrated a sensor such as this into the lid of a coffee pot. There it measures the level and temperature of the coffee and transmits the data by radio signal, for example to the PC in the secretary’s office. Thanks to this small service provider, there is always a sufficient supply of hot coffee at the hotel buffet or in lengthy meetings.

The thermoelectric sensor derives its energy from the temperature difference between the coffee and its environment. The temperature difference of a few degrees is sufficient for the thermoelectric generator to supply an electrical current. The thermal electromotive force – known as the Seebeck effect – is created by two ceramic plates being brought to different temperatures. Thermoelectric semiconducting material pieces alternately p-doped and n-doped are located between the plates. The temperature difference creates an electric voltage across each semiconductor piece which is summed by the serial connection of the semiconductor pieces. A »step-up« converter transforms the energy into a voltage that can be used for electronic components. Thermoelectric generators only need slight temperature differences of one kelvin. In the case of the coffee pot, the generator is powerful enough to supply the electronic systems for both measurement and radio transmission.

Until now, thermogenerators have been reliably operating where conditions make a battery change very difficult: in space, in aircraft but also in cars. New generators and improved »low-power« electronics mean that it is now possible to exploit minimal temperature differences to supply complex sensors with electricity. For instance, the warmth of a hand, a finger or even small temperature fluctuations in an air-conditioned room are sufficient to operate a complete sensor network with its own independent energy supply.

Energy-autarkic sensors or wireless sensor networks are suitable for various applications: the air-conditioning of buildings can be regulated automatically with thermoelectric sensors. Sensor networks could monitor material fatigue in inaccessible sites within aircraft and motor vehicles. Human body heat could also be utilized for the continuous monitoring of vital data such as pulse frequency or oxygen saturation of the blood and for the operation of hearing aids without batteries.

An energy-autarkic sensor supplies enough energy to measure the temperature and quantity of coffee and to transmit the data by radio signal to a PC.

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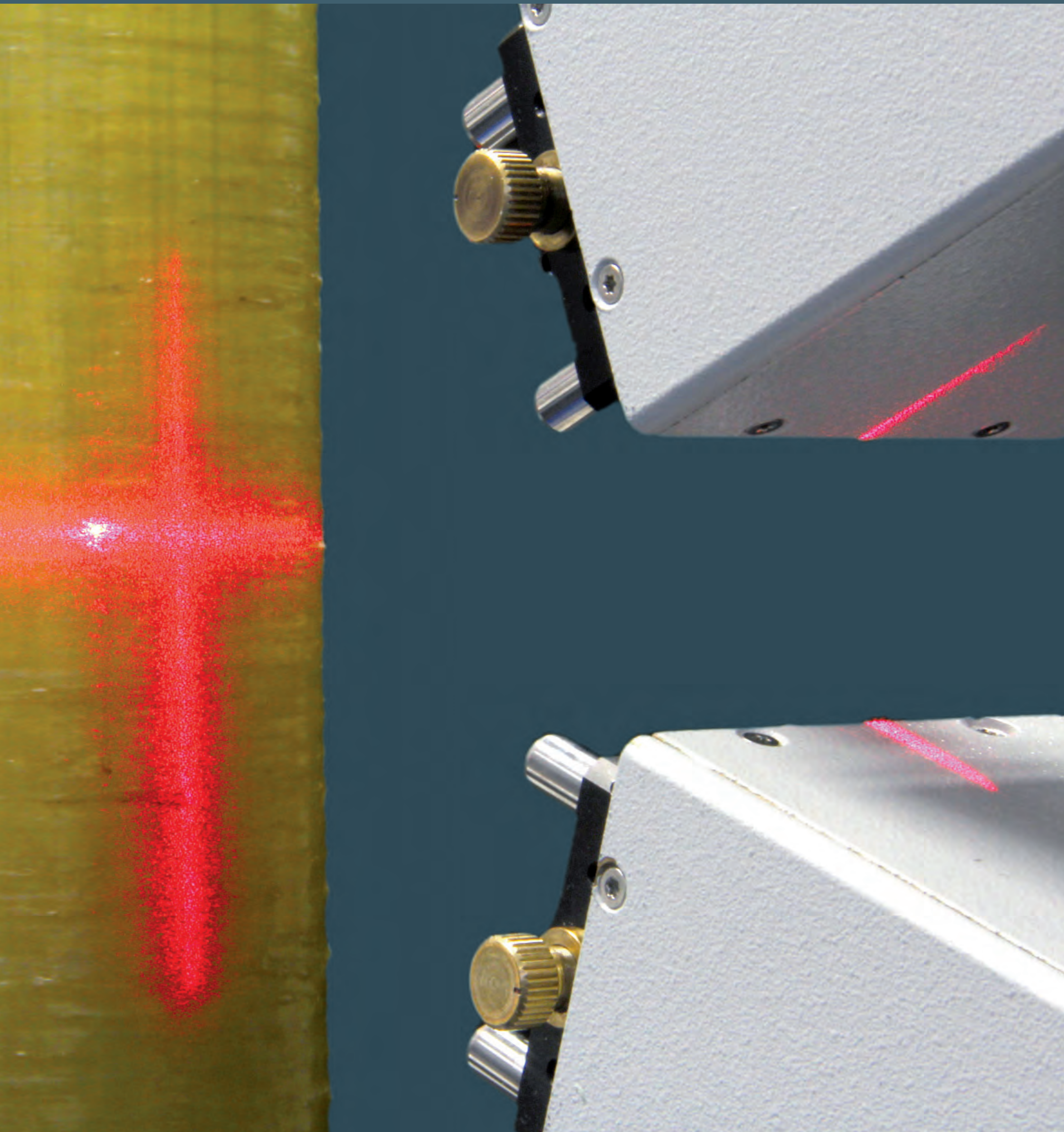
DEPARTMENT TERAHERTZ MEASUREMENT AND SYSTEMS

Terahertz measuring technology enables inline quality control with up to 40 measurements per second.



TERAHERTZ MEASUREMENT AND SYSTEMS
»We test materials with terahertz waves: without touching or destroying them«

Prof. Dr. René Beigang

The Department of Terahertz Measurement and Systems with its three groups develops terahertz systems suitable for applications including novel emitter and detector components. To help them in this task, the scientists make use of their skills in the technology of optical systems and measurement, IR spectroscopy and the development of crystal and semiconductor components. The aim is to achieve compact, industry-capable terahertz systems for process measurement techniques, materials analysis and testing as well as quality assurance. Promising fields of application include the plastics, ceramics and coatings industries as well as the security sector. Research into terahertz measuring technology is mainly conducted at the Kaiserslautern site in collaboration with the Technical University of Kaiserslautern.

Industrial Terahertz Measurement Techniques – ITM

Work in the ITM Group concentrates on the development of industrial terahertz systems in line with customer requirements for the non-contact or non-destructive testing of objects or the spectroscopic identification of chemical substances.

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Terahertz Opto-Electronics – TOE

The TOE Group develops measuring technology for ultrafast electronics extending into the terahertz frequency range, e.g. for characterizing electronic super-high frequency circuits. Extremely fast electro-optical converters are combined with ultrafast optical systems.

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Terahertz Meta-Materials – TMM

At the focus of the work carried out by the TMM Group is the development of innovative, adaptive optical systems for terahertz technology, which have hitherto been unattainable by conventional techniques. These included terahertz near-field sensors as well as passive optical systems such as beam splitters, wave plates or lenses.

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INDUSTRIAL TERAHERTZ MEASUREMENT TECHNIQUES

GREATER SECURITY: TERAHERTZ WAVES SCAN SUSPICIOUS MAIL

Letter and parcel bombs have been repeatedly making the headlines in recent times. Employees in the post centers of institutions take a critical look at suspicious mail. However, it is not always possible to detect hazardous consignments in time. T-Cognition, the terahertz mail scanner developed by Fraunhofer IPM in conjunction with the companies Hübner GmbH and IANUS Simulation GmbH, identifies suspicious contents in letters and small parcels without the need for them to be opened.

The letters are drawn into the system to be irradiated with terahertz waves. The control monitor indicates by color signal whether any explosives or drugs are present and, if so, which.

Unlike, the x-ray scanners already used today in isolated cases, the non-contact terahertz scanners not only detect hazardous objects but also supply a chemical analysis of suspicious substances. Employees on site are thus able to instantly assess how dangerous the content of a consignment really is. Spectroscopic examination also supplies drug enforcement officers with crucial indications of smuggled substances. In contrast to an x-ray scanner, the use of terahertz mail scanners does not call for any protective measures against radiation because terahertz waves are not harmful to humans.

Terahertz waves effortlessly penetrate many non-metallic materials such as cardboard, various plastics, wood or textiles. Thanks to their high depth of spectral penetration, it is possible to make structures inside the body visible. Furthermore, many molecules exhibit a distinctive chemical fingerprint in the terahertz range, which permits conclusions to be drawn about the composition of the substance. The terahertz scanner is based on terahertz time-domain spectroscopy, which makes the chemical fingerprint visible and leads to higher selectivity. The broadband spectra are evaluated by means of chemometric methods, which are founded on statistical and mathematical methods, as also used for evaluating infrared spectra.

In future, the widespread use of terahertz scanners, such as in mail logistics facilities, might make it possible to provide better protection for persons at risk from parcel bombs or to prevent drug smuggling in places such as penal institutions.

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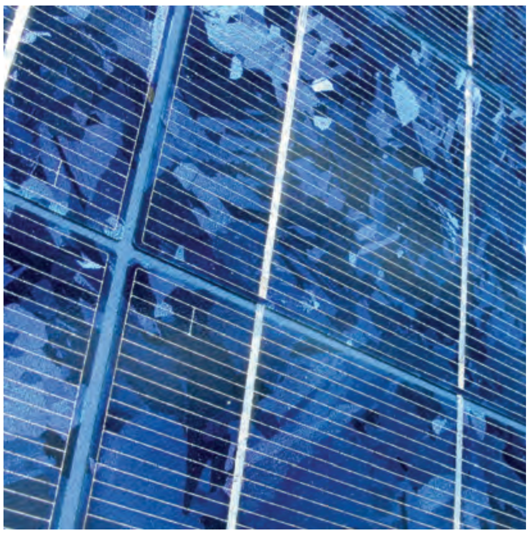
A DETAILED VIEW: TERAHERTZ SPECTROSCOPY IN THE NEAR-FIELD

In the past few years, terahertz waves have established themselves as a modern optical tool for the non-destructive examination of dielectric materials, insulators and construction materials. However, despite many benefits, there are also physical disadvantages: usually electromagnetic waves are only able to detect structures in the same order of magnitude as their wavelength. Terahertz waves occupy a position in the spectrum between the infrared and microwave range and are therefore only able to detect details down to some tenths of a millimeter in size – that is relatively poor in comparison to visible light. One way round this physical limitation of the resolution is achieved if it becomes possible to detect the near-field components of the terahertz waves scattered by the object. This is because they also contain the information of very small spatial details.

A terahertz near-field measuring station is the logical further development of conventional terahertz measuring technology. It can be used to capture finer details that remain concealed from the far field of terahertz waves. For this purpose, Fraunhofer IPM has set up a spatially high-resolution terahertz near-field spectroscope that enables both the amplitude and the phase of terahertz fields to be measured with sensitivity to polarization and with spectral details over time. A terahertz near-field spectroscope of this type has a spatial resolution of some 60 µm – which corresponds to roughly one fifth of the wavelength. Suitable optical systems enable the resolution to be improved still further. The measurement is based on an electro-optical detection of terahertz radiation in reflection mode. In order to measure the spatial distribution of the terahertz fields with sub-wavelength resolution, the detection beam is scanned freely over the terahertz beam.

The procedure can be used in applications such as the pharmaceutical industry: it is not uncommon for tablet coatings to exhibit tiny cracks with widths of approximately 100 µm, which can already have dramatic effects on therapeutic efficacy. Such cracks are detected. In the production of solar cells too, terahertz near-field spectroscopy can in fact be used for non-invasive measurement of the spatial distribution of charge carriers in structured solar cells. In modern solar cells, tiny areas are doped differently. Due to the expense of the manufacturing process, their quality should be monitored at the earliest possible stage. A similar principle applies to the manufacture of microchips and other semiconductor elements. Here too, the use of terahertz near-field sensors is able to close some technological gaps in the measuring techniques.



The spatial distribution of charge carriers in structured solar cells can be measured non-invasively with a terahertz near-field spectroscope.

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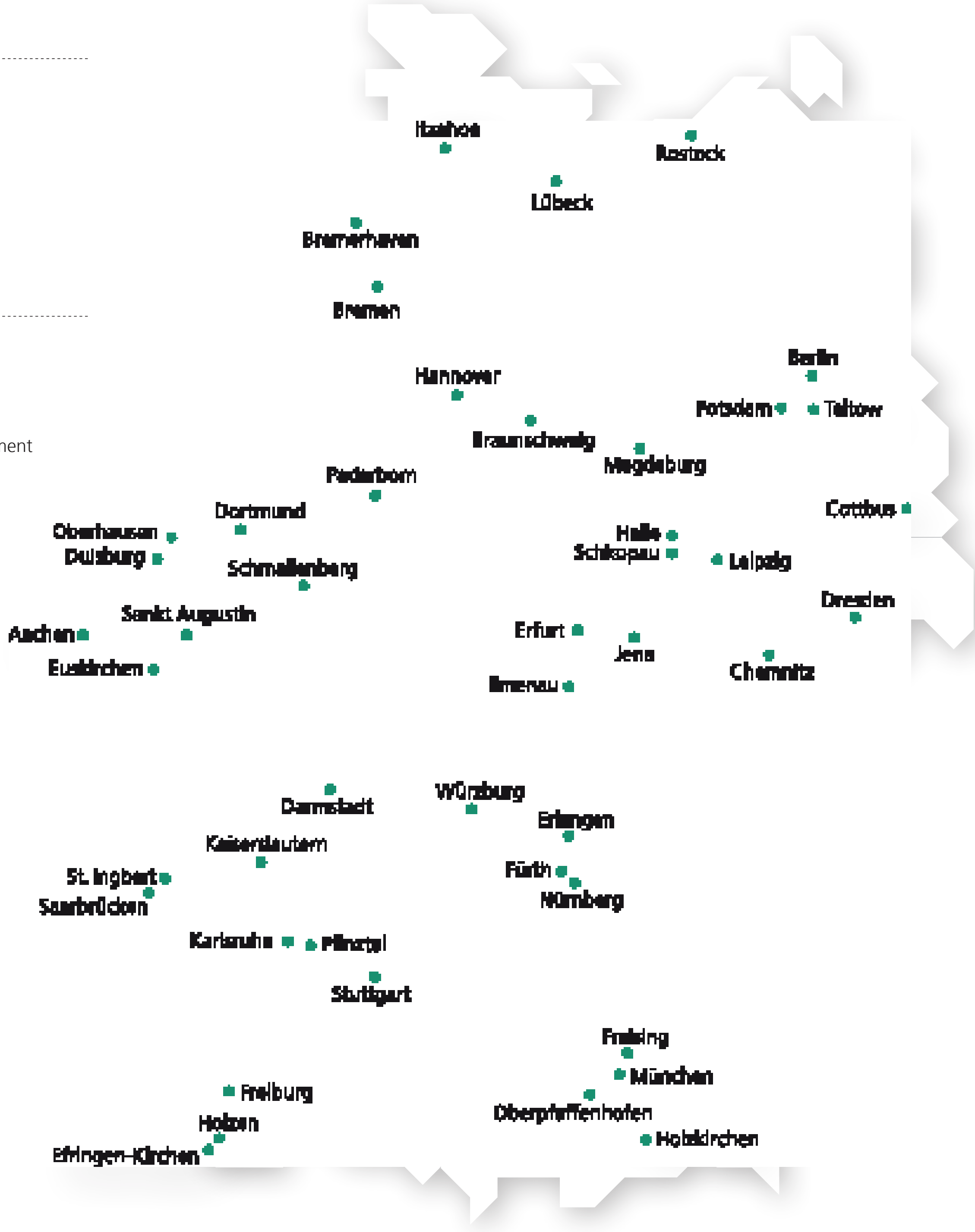

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