Fraunhofer

IPM

FRAUNHOFER INSTITUTE FOR PHYSICAL MEASUREMENT TECHNIQUES IPM

Measuring · Monitoring · Optimizing

2012
2013

FRAUNHOFER IPM

Title *Multi reflection gas measurement cells with long optical paths allow the detection of very low gas concentrations.*

Measuring · Monitoring · Optimizing

BUSINESS UNITS

- PRODUCTION CONTROL
- MATERIALS CHARACTERIZATION AND TESTING
- OBJECT AND SHAPE DETECTION
- GAS AND PROCESS TECHNOLOGY
- ENERGY SYSTEMS

TABLE OF CONTENTS

EDITORIAL

Prof. Dr. Karsten Buse
Executive Director

Dear clients and partners,

The year 2012 proved to be exciting for us in many respects, both in terms of economic development and with regard to our specialist areas and our strategic positioning.

Technologies and systems developed by Fraunhofer IPM are in demand internationally and are deployed around the world. This success provides us with the scope to constantly improve our R&D work. However, the first half of the year was characterized by noticeable restraint on the part of our foreign clients. This was no doubt a consequence of the uncertainty surrounding the euro. Nevertheless, the fact that 2012 has ultimately turned out to be a very successful year is a major achievement by the workforce. Business revenues accounted for more than 35 percent of the total.

Numerous large systems were shipped out to clients. Examples include a high-speed, sensitive exhaust spectrometer, which employs quantum cascade lasers for the first time, and a wire inspection system that uses cameras with their pixels interconnected through cellular neural networks. In these and other cases, we have succeeded in integrating optics, electronics, mechanics and software in such a way as to produce robust systems for solving our clients' problems with measurement technology – often with novel components coming straight from research.

In 2012 we also conducted numerous studies on a very wide range of topics: almost every industry and every measurement technique has featured here. Results of the studies have helped our clients to take far-reaching decisions – from the acquisition of companies to the placing of major development orders. Many enquiries have reached us thanks to the redesigned Internet presence. On the Web too, Fraunhofer IPM is now perceived internationally as an expert for measurement techniques.

Autumn 2012 witnessed a technology strategy audit, for which we called in ten experts from the free market economy and the realms of science to act as consultants. Now we are implementing their recommendations: core competencies are being more clearly defined and structurally refined; the business units are being named more distinctly and managed with greater focus. These changes will become visible in 2013 – and consequently in this annual report as well.

We have consciously selected a number of themes for the annual report that are typical of what we do and what we are capable of doing. If you cannot find the topic you are looking for here, simply get in touch. We cover a broad spectrum of fundamental education and expertise in our team – from the urologist working on the detection of kidney stones to the geodesist helping to safeguard road and rail infrastructure.

We wish you an enjoyable read and a stimulating exchange of ideas with Fraunhofer IPM.

Sincerely,

NEWS

FROM FREIBURG AND KAISERSLAUTERN

Baden-Württemberg Turns 60

On 23 June 2012, the five Freiburg Fraunhofer institutes jointly opened their doors to interested visitors. The occasion was to mark 60 years of Baden-Württemberg existing as a federal state. An individual program was on offer at every location to provide insight into the scientific specializations of the individual institutes. At Fraunhofer IPM, Executive Director Karsten Buse was present to welcome guests with demonstrations of experiments. Visitors were then offered guided tours under the motto of »hands-on science«.

The state of Baden-Württemberg has been an important supporter and funding body for Freiburg's five Fraunhofer institutes for many years now. Last year alone, the state provided a total of more than 14 million euros in support for the Fraunhofer-Gesellschaft.

More than 80 Participants in the 5th Gas Sensor Workshop

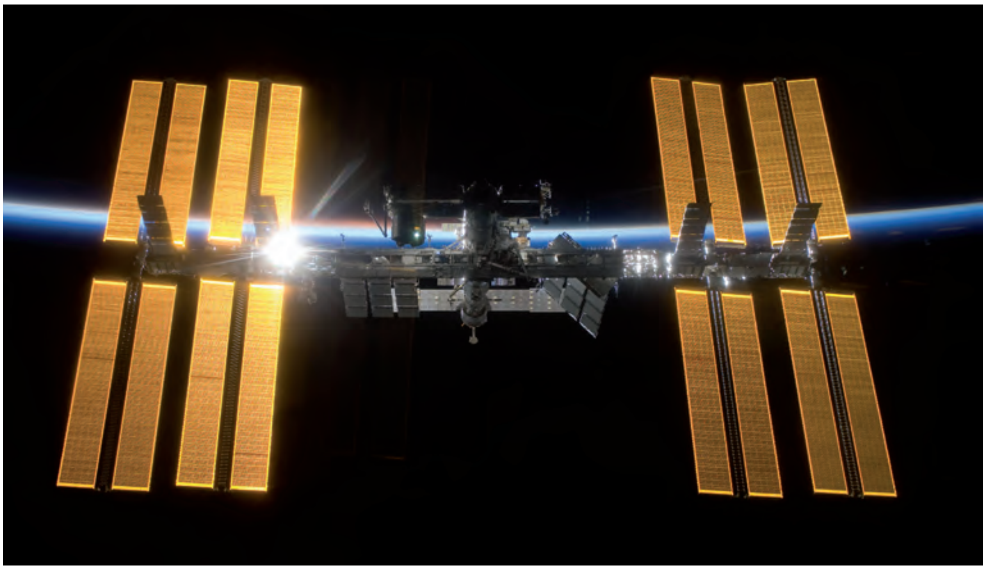
In March 2013, Fraunhofer IPM issued its invitation to the gas sensor workshop for the fifth time. Some 80 participants, mainly from industry, used the forum as an opportunity to exchange ideas on the latest developments and trends in gas measuring technology. Among the items on the agenda were talks on the classical topic of metal oxide gas sensors, but also on flow sensor technology, electrochemical gas sensors and photoacoustics as well as UV and laser spectroscopy. The speakers presented a broad range of new applications – from the analysis of breath and trace gases through to the detection of process gases and air quality. During the breaks, participants were able to congregate around the exhibition stands and posters for an intensive exchange of ideas on science, technology and new product ideas. Companies providing support to the workshop were Axetris, Dittrich Elektronic, IST Innovative Sensor Technology, Micronas and UST Umweltsensortechnik.

Fraunhofer IPM Turns the ISS International Space Station Upside Down

At the end of 2012 a unique 27-day experiment took place at an altitude of 400 kilometers. The entire International Space Station ISS was rotated so that the solar spectrometer developed by Fraunhofer IPM known as SolACES (Solar AutoCalibrating EUV Spectrometer) was able to gather data. Normally, the ISS is never directed towards the sun for longer than two weeks. However, as the sun takes some four weeks to revolve once around its own axis, rotating the space station has made it possible to capture an entire solar cycle for the first time.

Since March 2008, SolACES has been measuring the extreme ultraviolet (EUV) radiation of the sun. This energy-rich EUV ionizes gases in the near-earth ionosphere and thermosphere. It thus influences the earth's climatic condi-

WIR FEIERN IN
DIE ZUKUNFT REIN.
Landesjubiläum Baden-Württemberg 2012



The International Space Station, ISS, was rotated in order to measure EUV radiation for 27 consecutive days using a solar spectrometer from Fraunhofer IPM.

tions and the satellite signals from navigation systems. Knowledge of the intensity of EUV radiation therefore provides information on the possible effects of the fluctuating solar intensity. The data recorded by the control center in Brussels have been evaluated by Fraunhofer IPM.

Contract Measurements Online – Competent, Fast, Simple

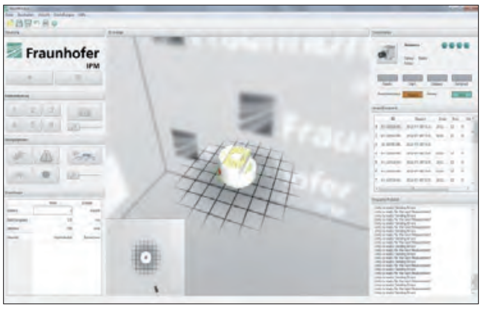
Since the beginning of 2013, it has been possible to place orders for Fraunhofer IPM ServiceLab via the homepage. Here clients have the opportunity to obtain quotations for contract measurements online quickly and easily using a web form. Fraunhofer IPM supplies the measuring results including a scientific evaluation and a brief expert report. The Fraunhofer IPM ServiceLab is available to German customers and currently covers three service groups:

- ServiceLab »Gas and process technology«
- ServiceLab »Energy systems«
- ServiceLab »Material characterization and testing«

ServiceLab
Fraunhofer-Institut für Physikalische Messtechnik IPM

Here, for example, clients can commission absorption measurements or fluorescence characterizations, test gas sensors and systems or also classify materials with Terahertz waves or have the material parameters of thermoelectric materials determined. The ServiceLab by Fraunhofer IPM is undergoing further expansion – plans not only include additional types of measurements but also additional service groups.

The uniform user interface of the Fraunhofer IPM measurement systems has been designed to take account of the latest findings in ergonomics.



Corporate Design for Software Interfaces

In collaboration with Furtwangen University, Fraunhofer IPM has developed a uniform corporate design for the software interfaces of its measuring systems. Thanks to clear styling and specific colors together with a uniform arrangement and labeling, the redesigned graphical user interface (GUI) is user-friendly and has a high recognition value. Arranged in two or three columns, the layout thus facilitates intuitive perception of the program elements from left to right. The result is a better overview: the left-hand side of the screen is the standard location for controls such as »Start/Stop« or »Measure«. Displayed as a key element in the center of the page is the result in the form of charts, measuring values and the like. The optional right-hand column can be used for additional displays, such as »System status« or »Measurement progress«.

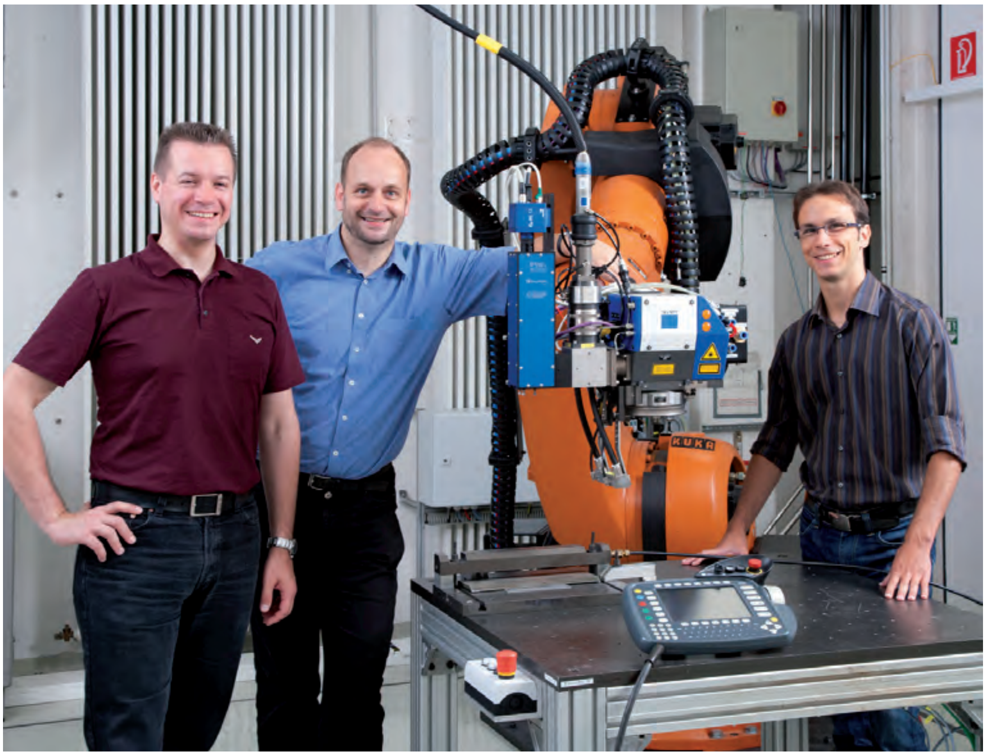
In April 2013 Prof. Karl Rawer, former director of Fraunhofer IPM celebrated his 100th birthday.

A Life Dedicated to Space Research: Karl Rawer Celebrates his 100th Birthday

On 19 April 2013, the founder of the present-day Fraunhofer Institute for Physical Measurement Techniques IPM, Professor Karl Maria Alois Rawer, turned 100.

Rawer's life's work has been concerned with research into the ionosphere, namely that part of the near-earth atmosphere in which the short waves so important for radio communication are reflected. His work in the field of ionosphere research places him among the pioneers of European space research. In 1963 he brought his knowledge to the working group on Physical Space Research (APW) which he founded in Freiburg. In 1973, when this group officially became the Fraunhofer Institute for Physical Space Research – today's Fraunhofer Institute for Physical Measurement Techniques IPM – Rawer took over the directorship until his retirement in 1979.

As an honorary doctor of the University of Düsseldorf, his declared aim was to foster cross-border scientific exchange: in this connection he gave lectures over a number of years at the Paris Sorbonne University. A recipient of the Order of Merit First Class of the Federal Republic of Germany, Rawer lives in Hugstetten near Freiburg.



Andreas Blug of Fraunhofer IPM (centre) and his development partners Felix Abt (Stuttgart University, left) and Leonardo Nicolosi (TU Dresden, right) received the »Stahl-Innovationspreis« (Steel Innovation Award) and the »Berthold Leibinger Innovation Award 2012« (third prize) for the real-time control of laser welding processes.

Twin Honors for Real-time Laser Welding Control

Together with its project partners, Fraunhofer IPM has been honored on two counts for a measurement system aimed at real-time laser welding control. At the Steel Innovation Awards, the measurement system secured third place in the category for »Steel in research and development«. The team also won the third prize worth 10,000 euros at the Berthold Leibinger Innovation Awards.

Laser welding has established itself as standard practice in modern production. Nevertheless, there have previously been no satisfactory solutions available for the control of this production process. Fraunhofer IPM project manager Andreas Blug, Felix Abt of Stuttgart University and Leonardo Nicolosi of the Technical University Dresden have achieved a breakthrough in the field. Their system for controlling laser welding uses a new type of image processing that makes statistical analysis of the keyhole possible within the reaction time of the welding process. To achieve this, a camera records up to 14,000 images per second, while a cellular neural network (CNN) simultaneously processes the information from each of the individual 25,000 pixels. Thanks to this high image-processing rate, the CNN technology represents a first opportunity for laser welding processes to be evaluated and regulated in real time. As a result, unavoidable fluctuations in production can be evened out and the quality of the weld bead can be guaranteed.

VDI Medal of Honor for Professor Elmar Wagner

The former Executive Director of Fraunhofer IPM, Professor Elmar Wagner, has received the medal of honor of the Association of German Engineers (VDI). The Association is thus honoring Prof. Wagner's special services in the field of measurement techniques and sensor technology.

In 1994, Prof. Wagner founded the specialist congress OPTO, which is intended to promote exchange between scientists and users in the field of optics and optoelectronics. Today, OPTO is regarded as the most important event connected with optical measuring technology in Europe. The journal »tm – Technisches Messen«, of which Prof. Wagner has been the editor for many years, established its reputation as a recognized scientific publication while Prof. Wagner was in charge. For many years, Elmar Wagner worked for the VDI in the field of »Optical Technologies«. Before he took over the directorship of Fraunhofer IPM in 1986, he was involved in research for organizations including AEG-Telefunken, Hewlett Packard, the Technical University of Munich and the Max Planck Institute for Solid State Research in Stuttgart.

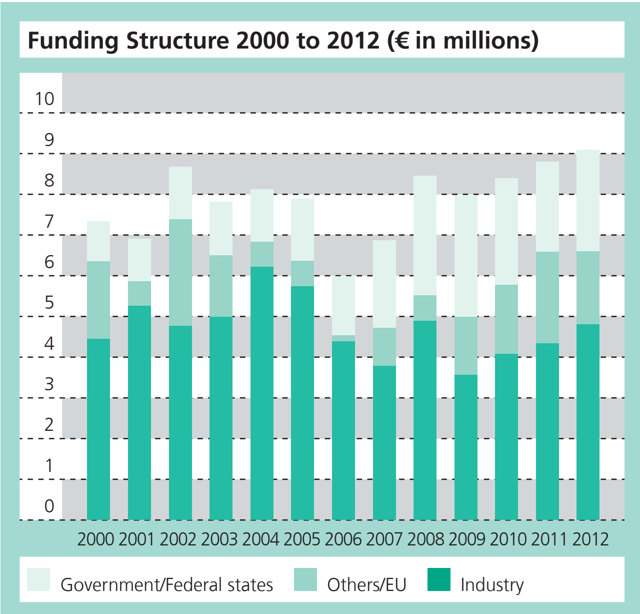
The VDI medal of honor has been awarded since 1959 as an accolade for especially deserving honorary VDI employees, politicians and personalities from public life or from a technical/scientific discipline.

Professor Elmar Wagner (left) has been awarded the VDI medal of honor for special services in the field of sensor technology and measurement techniques. Professor Gerald Gerlach (right) of TU Dresden presented the award at a festive ceremony during the trade fair Sensor + Test 2012.

Farewell to Professor Joachim Hesse

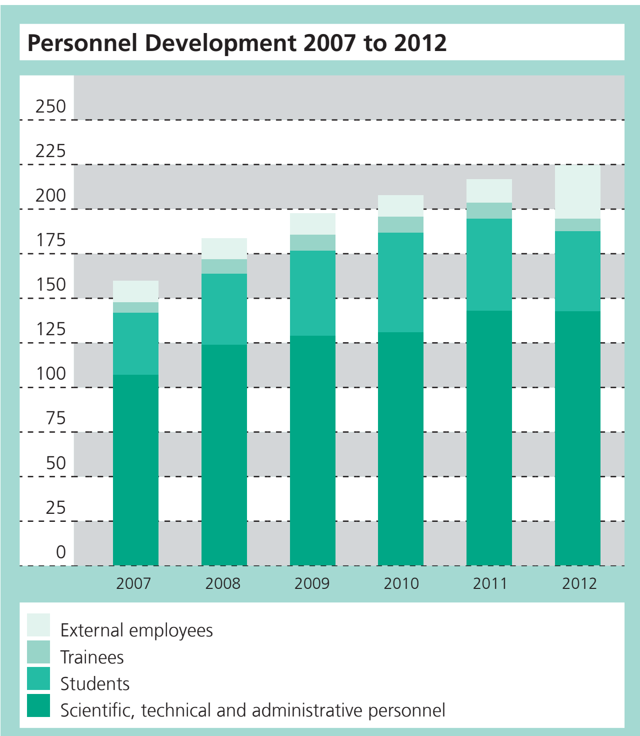
Professor Joachim Hesse, former Executive Director of Fraunhofer IPM, passed away on 8 February 2013 in Berlin at the age of 75. Hesse headed the Institute from 1980 to 1986. His directorship saw attention turn to new subject areas, such as laser spectroscopy, semi-conductor technology and integrated optics, which have helped to define the Institute up to the present day. During his period of office, the strategic direction increasingly turned towards close collaboration with industry. On account of the strong growth, Hesse was responsible for several extensions to the premises, the development of the precision engineering workshop and a number of fundamental organizational adaptations. In consultation with the Fraunhofer-Gesellschaft, Hesse continued his career with the Carl Zeiss optical group from 1986, where he served as general representative and head of research until the start of his retirement in 2002. He subsequently took over the directorship of the Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institut HHI.

OPERATING BUDGET | PERSONNEL



Operating Budget

In 2012, the operating budget of Fraunhofer IPM is 13.7 million euros and thus 0.7 million euros higher than in 2011. The operating budget is made up of revenues from industry, publicly financed projects and the basic funding. Of this figure the proportion of external funding consisting of external public funds and revenues from industry amounts to 67 percent or 9.1 million euros. Revenues from industry at 4.8 million euros account for 35.3 percent of the operating budget. This corresponds to an increase of some 12 percent on the previous year (4.3 million euros). Despite the crisis surrounding the euro, stable growth is becoming apparent. In order to pursue this trend, Fraunhofer IPM invested a sum amounting to some 1.3 million euros in the modernization of equipment in 2012.



Personnel

Compared with the previous year, the number of employees has remained relatively stable at roughly 225. A total of 143 employees occupy permanent posts at Fraunhofer IPM, of whom 11 are at the Kaiserslautern location. In February 2013, job capacity included 125 full-time posts. In addition, Fraunhofer IPM is providing support for the careers of some 53 school and college leavers as well as students, of whom eight are apprentices and 45 are students on various degree courses and work experience schemes or hold posts as assistants. Thirty external employees are also engaged at Fraunhofer IPM. In percentages, the employees can be classified into three basic categories: on average 45 percent of the employees work as research assistants, 40 percent as engineers and technical staff and 15 percent are employees in the field of infrastructure and workshops.

ADVISORY BOARD | PARTNERS | ALLIANCES

Our Advisory Board

An 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.

- 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
- 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 actively involved in the following Groups and Alliances within the Fraunhofer-Gesellschaft:

- Fraunhofer Group Light & Surfaces
- Fraunhofer Cleaning Technology Alliance
- Fraunhofer Energy Alliance
- Fraunhofer Food Chain Management Alliance
- Fraunhofer Optic Surfaces 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.

Germany

- AMA – Association for Sensor Technology
- Arbeitskreis Prozessanalytik der Dechema
- Biovalley
- BBA – Batterie- und Brennstoffzellenallianz BW
- CAST – Competence Center for Applied Security
- Cluster Green City Freiburg
- CNA – Center for Transportations & Logistics Neuer Adler e.V.
- DGZfP – German Society for Non-Destructive Texting
- DPG – Deutsche Physikalische Gesellschaft
- DTG – German Thermoelectric Society
- DTZ – Deutsches Terahertz Zentrum
- FAIM IMTEK – Forum Angewandte Informatik und Mikrosystemtechnik
- GDCh – Gesellschaft Deutscher Chemiker
- LRBW – Forum Luft- und Raumfahrt BW
- MSTBW – Mikrosystemtechnik BW
- Optence e.V.
- Photonics BW
- VDI OPTAM Optical Analysis Technology
- VDI/VDE – Gesellschaft für Mess- und Automatisierungstechnik
- VDMA German Engineering Federation – Photovoltaic Means of Production; E-Battery
- VDSI – Verband Deutscher Sicherheitsingenieure

International

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

ORGANIZATION | CONTACT

Executive Director
Prof. Dr. Karsten Buse
Phone +49 761 8857-111
karsten.buse@ipm.fraunhofer.de

Deputy Director
Dr. Heinrich Höfler
Phone +49 761 8857-173
heinrich.hoefler@ipm.fraunhofer.de

Assistant
Dr. Rosita Sowade
Phone +49 761 8857-222
rosita.sowade@ipm.fraunhofer.de

Administration and Infrastructure
Jörg Walter
Phone +49 761 8857-120
joerg.walter@
ipm.fraunhofer.de

New Technologies and Patents
Holger Kock
Phone +49 761 8857-129
holger.kock@
ipm.fraunhofer.de

Quality Management
Dr. Arno Feißt
Phone +49 761 8857-288
arno.feisst@
ipm.fraunhofer.de

Production Control

Head of Department
Dr. Heinrich Höfler
Phone +49 761 8857-173
heinrich.hoefler@
ipm.fraunhofer.de

Deputy Head of Department
Harald Wölfelschneider
Phone +49 761 8857-161
harald.woelfelschneider@
ipm.fraunhofer.de

Inline Measurement Techniques
Dr. Daniel Carl
Phone +49 761 8857-549
daniel.carl@
ipm.fraunhofer.de

Optical Surface Analytics
PD Dr.-Ing. Albrecht Brandenburg
Phone +49 761 8857-306
albrecht.brandenburg@
ipm.fraunhofer.de

Materials Characterization and Testing

Head of Department
Prof. Dr. Georg von Freymann
Phone +49 631 205-5225
georg.vonfreymann@
ipm.fraunhofer.de

Deputy Head of Department
Dr. Joachim Jonuscheit
Phone +49 631 205-5107
joachim.jonuscheit@
ipm.fraunhofer.de

Industrial Terahertz Measurement Techniques
Dr. Frank Ellrich
Phone +49 631 205-5109
frank.ellrich@
ipm.fraunhofer.de

Terahertz Opto-Electronics
Prof. Dr. Georg von Freymann
Phone +49 631 205-5225
georg.vonfreymann@
ipm.fraunhofer.de

Object and Shape Detection

Head of Department
Dr. Heinrich Höfler
Phone +49 761 8857-173
heinrich.hoefler@
ipm.fraunhofer.de

Deputy Head of Department
Harald Wölfelschneider
Phone +49 761 8857-161
harald.woelfelschneider@
ipm.fraunhofer.de

Laser Scanning
Dr. Alexander Reiterer
Phone +49 761 8857-183
alexander.reiterer@
ipm.fraunhofer.de

Gas and Process Technology

Head of Department
Dr. Armin Lambrecht
Phone +49 761 8857-122
armin.lambrecht@
ipm.fraunhofer.de

Deputy Head of Department
Gerd Sulz
Phone +49 761 8857-293
gerd.sulz@ipm.fraunhofer.de

Integrated Sensor Systems
Prof. Dr. Jürgen Wöllenstein
Phone +49 761 8857-134
juergen.woellenstein@
ipm.fraunhofer.de

Spectroscopy and Process Analytics
Dr. Raimund Brunner
Phone +49 761 8857-310
raimund.brunner@
ipm.fraunhofer.de

Technology of Optical Materials
Dr. Frank Kühnemann
Phone +49 761 8857-457
frank.kuehnemann@
ipm.fraunhofer.de

Energy Systems

Head of Department
Dr. Kilian Bartholomé
Phone +49 761 8857-238
kilian.bartholome@
ipm.fraunhofer.de

Deputy Head of Department
Martin Jägle
Phone +49 761 8857-345
martin.jaegle@
ipm.fraunhofer.de

Deputy Head of Department
Jan König
Phone +49 761 8857-329
jan.koenig@
ipm.fraunhofer.de

Energy Autarkic Systems and Thermoelectric Metrology
Martin Jägle
Phone +49 761 8857-345
martin.jaegle@
ipm.fraunhofer.de

Thermoelectric Energy Converters
Jan König
Phone +49 761 8857-329
jan.koenig@
ipm.fraunhofer.de

BUSINESS UNIT
PRODUCTION CONTROL

TOPICS

- Surface analysis
- 100 percent quality inspection
- Inline production monitoring and control

EXPERTISE

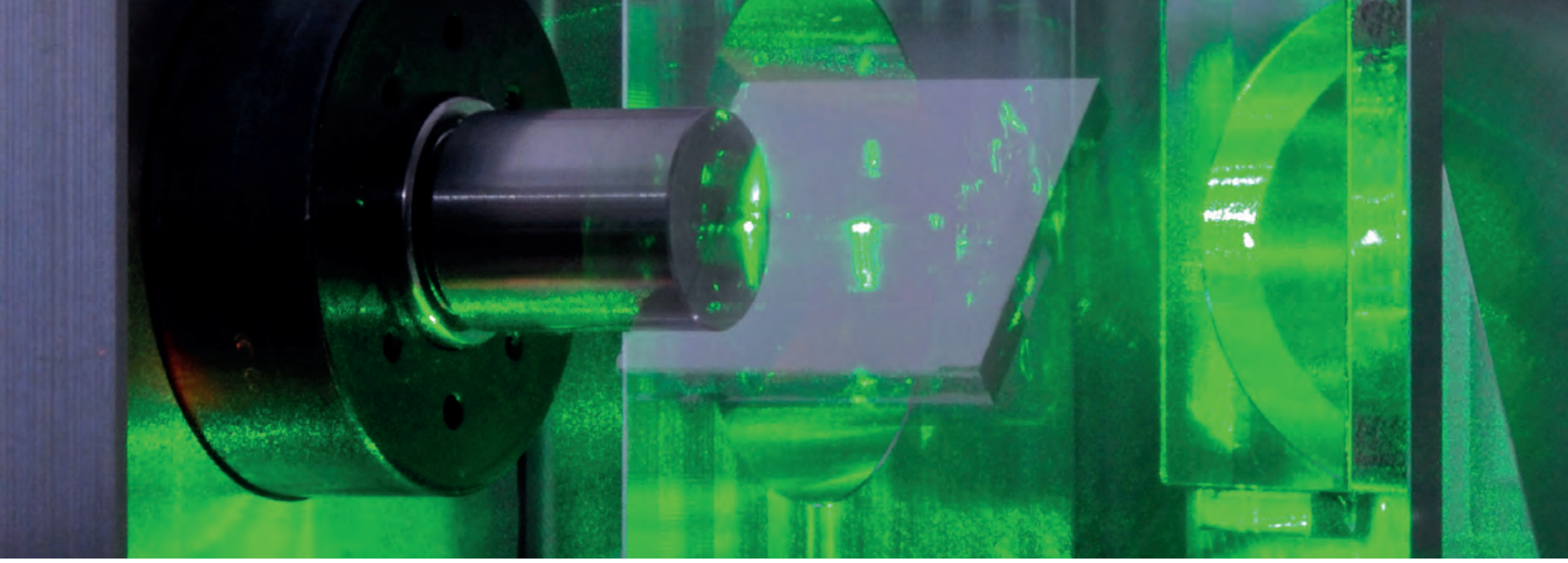
- Fluorescence measurement techniques
- Rapid image processing
- Digital holography
- Laser imaging systems
- Imaging techniques

CONTACT

Dr. Heinrich Höfler, Head of Department
Phone +49 761 8857-173, heinrich.hoefler@ipm.fraunhofer.de

Inline Measurement Techniques
Dr. Daniel Carl
Phone +49 761 8857-549, daniel.carl@ipm.fraunhofer.de

Optical Surface Analysis
PD Dr.-Ing. Albrecht Brandenburg
Phone +49 761 8857-306, albrecht.brandenburg@ipm.fraunhofer.de



PRODUCTION CONTROL

»We develop optical systems for 100 percent inspection«

Dr. Heinrich Höfler

Fraunhofer IPM develops optical systems and imaging techniques that enable surfaces and 3D structures to be analyzed in production and processes to be controlled. The systems measure fast and accurately so that small defects or impurities can be detected even at high production speeds. This makes 100 percent inspection possible in production. A wide variety of methods are employed, which include digital holography, infrared reflection and fluorescence techniques combined with very fast hardware-related image and data processing. The systems are used in applications such as forming technology and the automotive sector.

Optical Surface Analysis

Work in the group focuses on the development of turnkey devices for surface analysis. The methods employed are amongst others fluorescence measuring technology as well as infrared spectroscopy. The group's extensive experience in systems engineering encompasses know-how in optical units, image recording and processing.

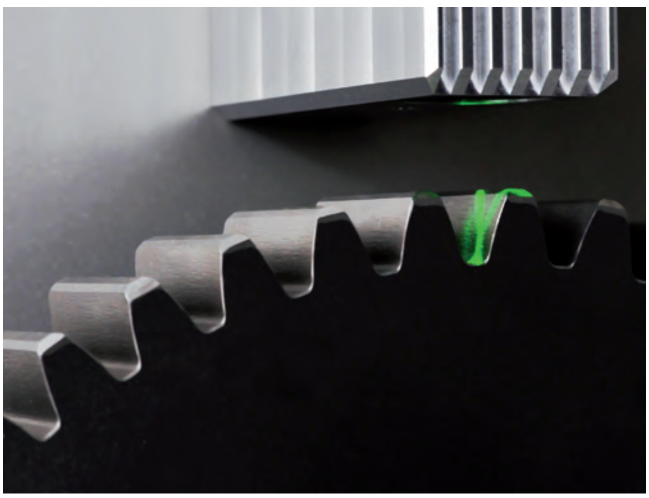
Inline Measurement Techniques

Work in the 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.

INLINE MEASUREMENT TECHNIQUES

A PERFECT FIT DESPITE THE TOLERANCE: 100 PERCENT INSPECTION IN REAL TIME

In modern production processes the accuracy of fit for components is crucial for the efficiency of a machine. The more exactly two gearwheels in a transmission match each other, the lower the wear, energy input and vibration will be. Producing components with a large tolerance and still combining them with each other at a later stage to achieve a perfect fit – a new inline measurement system by Fraunhofer IPM now makes this possible. In one example the inspection system measures the absolute geometry of gearwheels directly in the production line. This enables the exact dimensions of each individual gearwheel to be recorded at the time of manufacture – if necessary, with an accuracy extending into the nanometer range. Data recorded includes the respective positions of the cogs, the addendum and root circles, gear errors or also the cog gradients. Such complete monitoring located directly in the production line permits the gearwheels to be classified and ideally combined according to accuracy of fit.



A new inspection system ensures that components always fit together exactly – regardless of the manufacturing tolerance.

To carry out the measurement, the inspection system exploits the benefits of multiwavelength interferometry. Initially, this contactless, fast and precise measuring principle involves directing a laser beam onto the surface of a measuring object. The light that is scattered back is then superimposed on the original laser beam. The result is an interferogram, which contains all the necessary 3D information of the measuring point – according to surface roughness with height resolution accurate to the nearest nanometer. This is possible even on steep flanks such as gear cogs. Thanks to the hardware-based data evaluation, which is adapted to the measuring assignment, the system achieves great accuracy of measurement while maintaining a very high measuring speed of some 10 mm/s and a measuring rate in the kHz range. In contrast to the conventional tactile methods which are still in use today, the interferometric measuring system classifies the components directly in production without delay.

The inspection system can be adapted to various requirements and functions on very different materials with black, rough and even shiny surfaces. For users, the industrial added value of the measuring system is especially high in cases where a subsequent step is required to match components with each other according to accuracy of fit. In complex assemblies, exact inspection of each individual component is able to dramatically reduce the scrap rate of the entire assembly – which itself is generally significantly more expensive. Ultimately, one gear cog then meshes perfectly into the next.

Dr. Daniel Carl, Phone +49 761 8857-549, daniel.carl@ipm.fraunhofer.de

INLINE MEASUREMENT TECHNIQUES

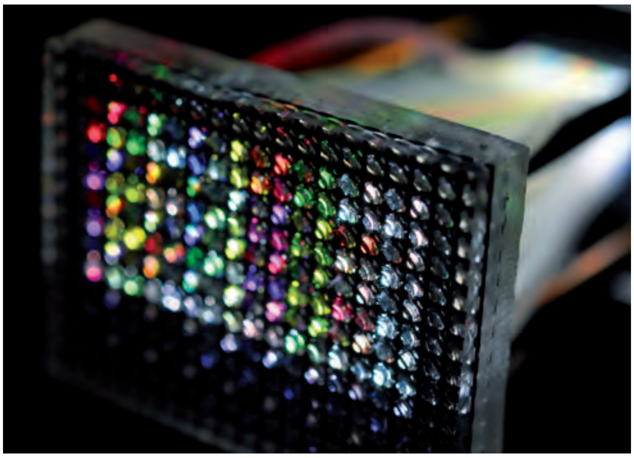
ARRIVAL IN THE FUTURE: MOVING 3D ADVERTISING SCREENS

In Hollywood's version of the year 2015, as portrayed in the cinematic gem »Back to the Future II«, the three-dimensional advertising screen already exists: Newly arrived in the future, Michael J. Fox alias Marty McFly is swallowed by a shark that attacks from the depths of an advertising panel. In 1989, a large-scale 3D display such as this was pure fiction. Now scientists from Fraunhofer IPM have produced the first functioning sample of a display that brings animations to the screen with a 3D effect – without the need for the viewer to wear 3D spectacles.

The trick lies in the utilization of special micro-optics that show the many perspectives of a three-dimensional image from different spatial angles, thus making the light field of a real object visible to the viewer. To do this, researchers at Fraunhofer IPM use a plate equipped with a large number of micro-optical systems joined to each other. Each micro-optical system projects several thousand different perspectives towards the viewer who perceives this rendering as an effect of depth. For the first time, Fraunhofer IPM constructed a miniature screen the size of a postage stamp from 96 micro-optical systems, which was able to demonstrate the correct functioning of the technology. Using special optical fibers enables such small tiles to be joined together as required so that in principle there are no limits to the size of the 3D advertising display.

Working together with Fraunhofer COMEDD, the team is now working on a demonstrator of A4 paper size. This uses some one hundred micro-OLED displays with an especially high pixel density to make the compact structure possible. When moving images are displayed, the high number of perspectives leads to a further challenge: conventional transmission technology is unable to cope with the higher quantities of data, which can be up to 30,000 times greater than two-dimensional images. Even for a static 3D advertising panel, the quantity may be as high as five gigabytes. Fraunhofer ISIT is therefore developing hardware and software components to enable the necessary bandwidth required for the display. Even with compression, large volumes of data remain, which the client then has to transfer securely to the advertising panel. Fraunhofer ESK is developing a tailor-made software solution for this.

Returning to our film, we see McFly meet other blessings from the future: some of them, such as video telephony and rain forecasts accurate to the nearest minute, have become reality in the 21st century while others remain in the realms of fiction. With the dynamic 3D large-scale display, Fraunhofer IPM has brought another Hollywood vision of the future a little closer to reality.



Every single lens of the miniature screen is fed by its own optical fiber. By joining them together, they form the basis for animated 3D advertising displays of any size.

Dr. Daniel Carl, Phone +49 761 8857-549, daniel.carl@ipm.fraunhofer.de

OPTICAL SURFACE ANALYTICS

FLUORESCENCE FOR CLEANLINESS: IMAGING FOR MONITORING SURFACES

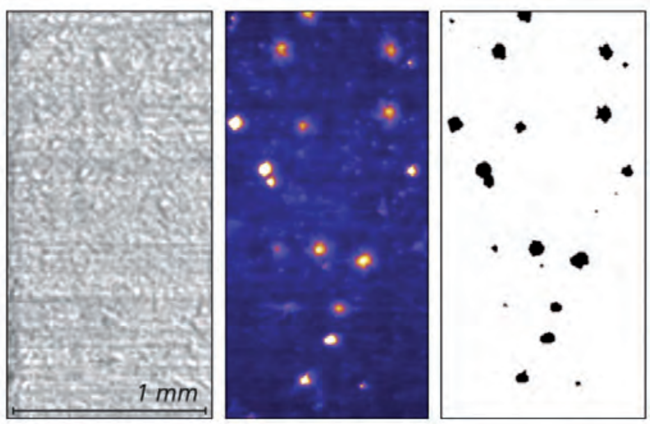
A tiny contaminated metal contact in a motor vehicle, for example, may be responsible for it failing to function from one day to the next. Repair is time-consuming and expensive – because first of all the minute defect has to be found.

To prevent such defects from occurring in the first place, Fraunhofer IPM has developed an imaging fluorescence measurement system. It provides automatic surface inspection directly in the production line. After all, the first commandment in bonding technology states that surfaces can only be connected or coated with care if they are clean. Contaminated metal contacts will not be accurately bonded and dirty surfaces will not be thoroughly coated. Inspectors examining the quality of the finished product are therefore well advised to start by checking the production process.

The fluorescence measurement system by Fraunhofer IPM measures shape, position and quantity of impurities or defects within 40 to 100 milliseconds in a contact-free method on areas of 5 x 8 square millimeters at a resolution of 20 micrometers. With suitable wavelengths in the UV range, the system excites the autofluorescence of undesired substances and detects quantities as small as a few micrograms per square centimeter with a camera. In a second step, pattern recognition automatically checks the quality of the surface with the aid of a previously defined limiting value in just under 30 milliseconds. If defects or impurities exceed this threshold, the next step in the process undergoes adaptation: this may involve cleaning the component again or rejecting it. In this way, the spatially resolved evaluation helps to provide an ideal means of inspecting, documenting and hence sustainably optimizing production processes.

Very small quantities of lubricating oils on a metal contact of 1 mm x 2 mm are already too much for thorough processing – so that the small metal contact may ultimately cause major problems. Quantities such as this are extremely difficult to detect at all with the naked eye or an optical microscope. In contrast, the fluorescence procedure detects even tiny quantities of unwanted residues, such as lubricating agents, cleaning substances or photoresist coatings.

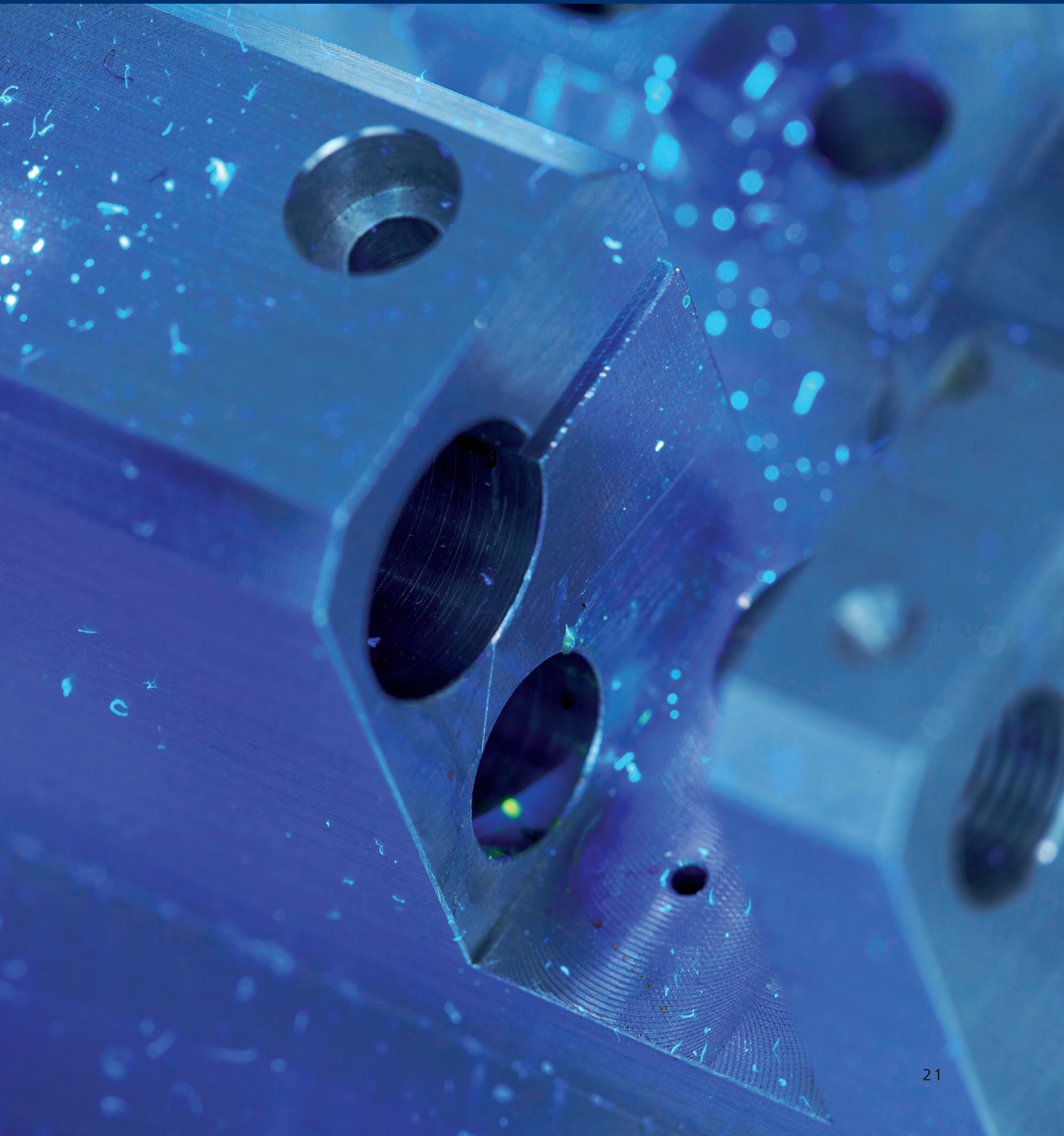
The fluorescence measurement system by Fraunhofer IPM is already being successfully deployed in the inspection of metallic and other functional surfaces as well as in photolithographic exposure techniques. Measuring procedure and detection range are adapted flexibly to the client’s assignments. Depending on the specification, it is also possible to inspect significantly larger areas. The surface inspection achieves a great impact with comparatively low input.



The system tests the purity of metal contacts (left) with the aid of an imaging fluorescence procedure (centre) and, by means of pattern recognition, checks whether the impurity exceeds a certain limit value (right) .

PD Dr.-Ing. Albrecht Brandenburg, Phone +49 761 8857-306, albrecht.brandenburg@ipm.fraunhofer.de

With images recorded in up to 3 milliseconds, the fluorescence measuring system inspects surfaces directly within the production line.



BUSINESS UNIT
MATERIALS CHARACTERIZATION AND TESTING

TOPICS

- Non-destructive materials testing
- Measurement of layer thickness
- Chemical analysis (pharmaceuticals, hazardous substances)
- Safety applications

EXPERTISE

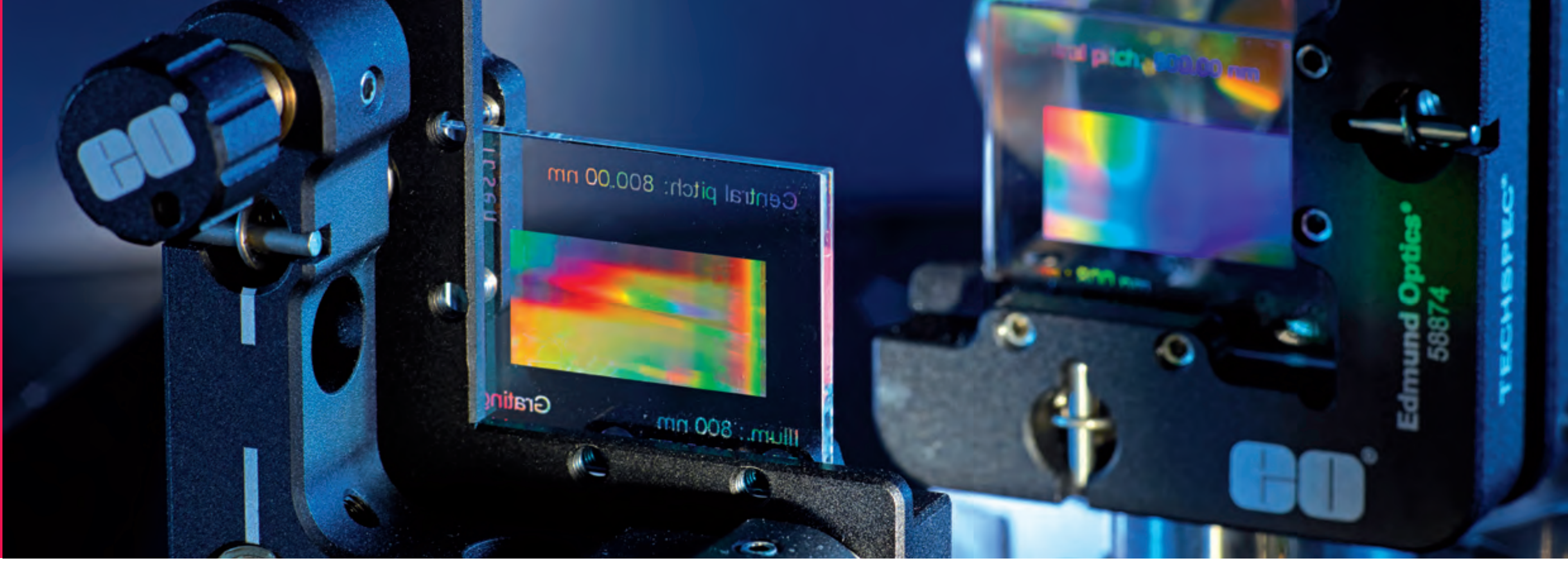
- Production of Terahertz components
- Spectroscopy systems
- Terahertz imaging
- Ultra-fast electro-optical high-frequency measurement techniques

CONTACT

Prof. Dr. Georg von Freymann, Head of Department
Phone +49 631 205-5225, georg.vonfreymann@ipm.fraunhofer.de

Dr. Frank Ellrich
Industrial Terahertz Measurement Techniques
Phone +49 631 205-5109, frank.ellrich@ipm.fraunhofer.de

Prof. Dr. Georg von Freymann
Terahertz Opto-Electronics
Phone +49 631 205-5225, georg.vonfreymann@ipm.fraunhofer.de



MATERIALS CHARACTERIZATION AND TESTING

»We test materials without touching or destroying them«

Prof. Dr. Georg von Freymann

Fraunhofer IPM develops measuring systems that work with terahertz and microwaves suitable for practical application in the characterization and testing of materials. To help them in this task, the scientists make use of their skills in the technology of optical systems and measurement, spectroscopy and the development of crystal and semiconductor components. Terahertz or microwave measurement techniques are an interesting alternative to ultrasound measurements when no mechanical contact is possible but also to X-ray measurements when ionizing radiation raises problems. Using the measurement systems developed by Fraunhofer IPM it is possible to characterize materials through packaging and thus find concealed drugs or explosives. In materials testing, it is possible to detect defects in ceramics, plastics or also carbon-fiber and glass-fiber reinforced composites by non-destructive means. There is particular interest in measuring the thickness of layers, e.g. in coating processes or also in the production of tablets. Through our terahertz know-how, we are in a position to characterize the behavior of materials in rapidly changing fields, which, for example, is of relevance for electro-optical modulators.

Industrial Terahertz Measurement Techniques

Work in the 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.

Terahertz Opto-Electronics

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

INDUSTRIAL TERAHERTZ MEASUREMENT TECHNIQUES

NON-DESTRUCTIVE TESTING: TERAHERTZ MEASUREMENT FOR MODERN MATERIALS

The nose of an aircraft is a sensitive organ that houses important measuring instruments such as the navigation and weather radar. Protection against influences of the weather is provided by the so-called radome, a front fairing made of glass-fiber composite materials. Minute irregularities in the curing of the synthetic resin – the inclusion of foreign bodies or air bubbles – may lead to cracks in the long term. Any penetration of moisture here will disrupt signal reception via the radome. In the EU-funded DOTNAC project (Development and Optimisation of THz NDT on Aeronautics Composite Multi-layered Structures), Fraunhofer IPM is jointly developing a prototype of a terahertz measuring system for the non-destructive testing of aeronautical composites made of multilayered structures, which will be demonstrated on a test radome. The system is intended to detect defects both during production and during the course of regular maintenance, thus supplementing established test methods in aircraft construction – such as ultrasound and X-ray techniques, infrared thermography and acoustic methods.

Terahertz measurement techniques are intended to supplement conventional non-destructive test methods in aircraft construction.

Two different terahertz imaging techniques in reflection configuration have been tested on modern materials in order to determine the specific advantages and disadvantages with respect to conventional test procedures. Terahertz time-domain spectroscopy (THz-TDS) works with broadband Terahertz waves from 120 GHz to 1.2 THz, which scans the surface of the radome point by point. A fiber-coupled sensor based on this principle has been built by the University of Kaiserslautern. The task of Fraunhofer IPM was to develop a frequency-modulated continuous wave (FMCW) radar system capable of scanning the surface of the radome with frequencies of 100, 150 and 300 GHz. Both systems have been tested on different samples – carbon-fiber reinforced and glass-fiber reinforced composites, laminates and sandwich structures.

Both sensors were integrated into a 3D scanner of an industrial scale. A motion platform moves the currently mounted sensor on three axes so that the angle at which it is inclined to the curved surface of the rotating radome always remains the same. Here the distance to the sample is kept constant via an additional axis. The systems integration included the connection of the mechanical, electrical and software components of the TDS as well as the FMCW sensor into the scanning platform.

The quality of the FMCW measurements can still be significantly increased by means of a data fusion software package developed by Fraunhofer IPM. This involves combining the results obtained with different measuring frequencies by computational methods in order to achieve a virtually higher penetration depth and higher depth resolution.

Dr. Frank Ellrich, Phone +49 631 205-5109, frank.ellrich@ipm.fraunhofer.de

TERAHERTZ OPTO-ELECTRONICS

OPTIC HELPS ELECTRONICS: MEASUREMENT TECHNOLOGY FOR FAST ELECTRONICS

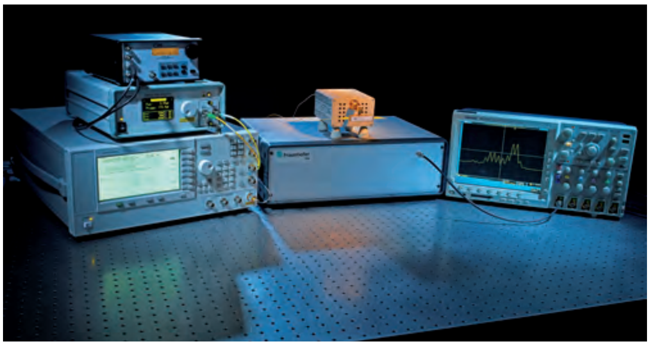
Advances in microelectronics during recent decades have been gigantic. Smartphones, for example, are now significantly more powerful than entire data processing systems used to be. Responsible for this development are the increasingly more efficient and faster electronics components. They are now forging ahead into frequency ranges that were inconceivable a few years ago. Circuits with signal frequencies of up to 760 GHz have already been developed. Conventional measurement techniques are no longer capable of providing a time-resolved display of the signals produced by such circuits. Important signal information therefore remains inaccessible for present-day measurement technology: small signalling errors on short time scales that occur non-reproducibly in every cycle are just as impossible to measure as rapid non-periodic signals. Together with its partner institutes IAF and ITWN, Fraunhofer IPM has thus set itself the target of developing ultra-fast measuring technology for such high frequencies.

The measuring technology for extremely high-frequency signals at the boundary between electronics and optics first needs function generators with terahertz bandwidth and, secondly oscilloscopes that can measure the electrical signals with terahertz bandwidth. The same principle is applied in each case: electronic impulses are converted into optical impulses and vice versa.

In the »TeraGenerator« function generator ultra-short light impulses from a frequency comb are modified by pulse shaping so that they reproduce the desired signal pattern. The conversion of this ultra-fast optical signal into the desired electronic signal takes place via photoconductive switches. Such switches are familiar from the generation and detection of terahertz waves and are already able to guarantee bandwidths extending into the terahertz range. The »TeraGenerator« delivers input signals for ultra-fast circuits which can then, for example, be amplified and processed.

In the »TeraScope« oscilloscope, which is able to measure electrical signals with Terahertz bandwidth, electronic signals of a short duration are stamped onto a laser pulse. This enables the signals to undergo further processing as frequency information. This stamping process is carried out by combining ultra-fast electro-optical converters with ultra short laser pulses. In order to detect the signals with conventional measuring electronics at a later stage, the available optical information is stretched in time via dispersive elements – known as a time lens.

Both of these ultra-fast measuring devices currently exist as prototypes which can measure into the frequency range of 0.1 THz. Through further development stages, they have the potential to revolutionize measuring technology in extremely high frequency electronics. As to what products and technologies this will enable the electronics to develop and put onto the market – well let's just wait and see.



The »TeraScope« stamps short electronic signals onto laser pulses and is intended to open up measurement techniques for electrical signals with terahertz bandwidth.

Prof. Dr. Georg von Freymann, Phone +49 631 205-5225, georg.vonfreymann@ipm.fraunhofer.de

BUSINESS UNIT
OBJECT AND SHAPE DETECTION

TOPICS

- Transport and logistics
- 3D measurement of trains and railway tracks
- Examination of road surfaces
- Safety applications

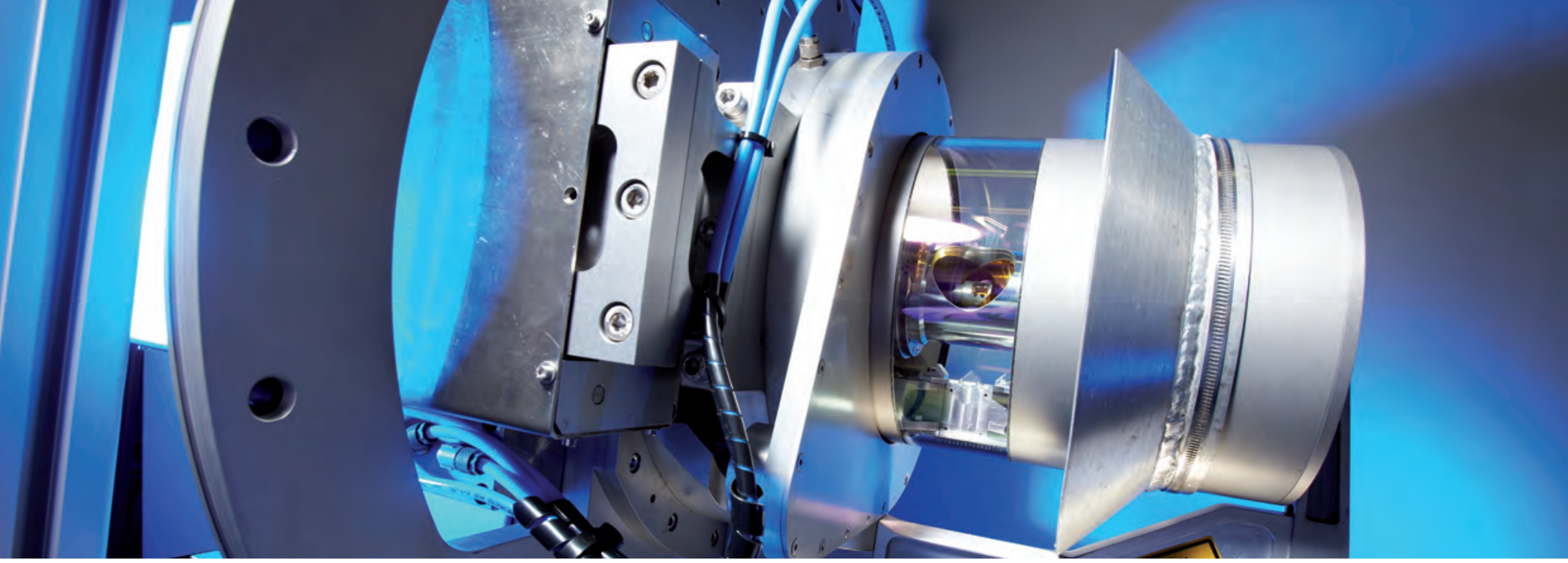
EXPERTISE

- 3D laser scanners, 3D cameras, 3D data processing
- Capture of moving objects even at 100 km/h
- Rapid image evaluation
- Robust casing technology

CONTACT

Dr. Heinrich Höfler, Head of Department
Phone +49 761 8857-173, heinrich.hoefler@ipm.fraunhofer.de

Dr. Alexander Reiterer
Laser Scanning
Phone +49 761 8857-183, alexander.reiterer@ipm.fraunhofer.de



OBJECT AND SHAPE DETECTION

»We capture objects and shapes with light – even at high speeds«

Dr. Heinrich Höfler

Laser scanners together with customized lighting and camera systems that capture the geometry and position of objects three-dimensionally in their surroundings are the focus in the Business Unit for Object and Shape Detection. The systems measure at high speed and with high precision, particularly from moving platforms. Particular attention is attached to the robustness and long service life of the systems as well as to efficient data evaluation. Objects and shapes are detected over a broad size range: extending from tenths of a millimeter to dimensions of 10 meters. The measurement systems are in use around the world – in rail traffic and in the surveying of road surfaces. Supplementing them are special applications in the fields of safety as well as transport and logistics.

Laser Scanning

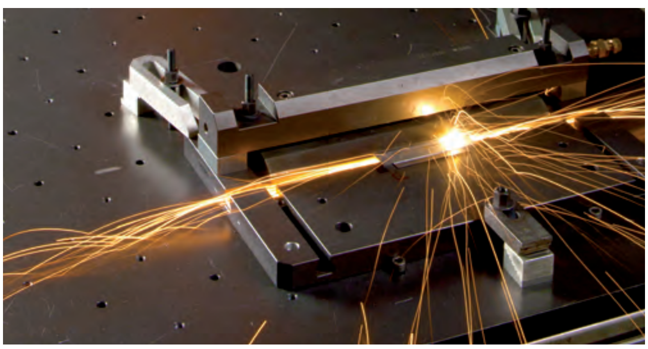
The group focuses on developing optical measurement systems based on time-delay measurements of light, which enable the distance and geometry of objects to be measured at high speed and with great precision. The systems developed are employed worldwide and in a variety of applications.

LASER SCANNING

PEEPING INTO THE »KEYHOLE«: TIME DELAY MEASUREMENT IN LASER WELDING

Laser welding is the technology of choice when it is necessary to join components in a stable yet at the same time optically inconspicuous manner. In order to avoid unwanted joint penetration, the specified welding depth must be maintained exactly. Until now, it has only been possible to check this retrospectively, for example with X-rays. Fraunhofer IPM has already achieved control of the welding depth for certain laser welding processes. In a project funded by the Baden-Württemberg Stiftung gGmbH, scientists from the Institute are working together with colleagues from the Institut für Strahlwerkzeuge (Stuttgart Laser Technologies) at the University of Stuttgart to tackle the problem with a geometric depth measurement, which makes high resolutions possible in a small measurement range.

A phenomenon known as the »keyhole« – a tube-shaped capillary in the direction of the beam that occurs during the welding process – provides information on the penetration depth. Scientists determine the depth of the keyhole using the principle of phase delay technique. Here a high-frequency modulated laser beam with a wavelength of 850 nm travels through the distance to the workpiece. The reflected light is received by a detector. From the phase delay between transmitting and receiving signal, the distance to the workpiece can be determined using the modulation wavelength together with the speed of light.



The penetration depth in laser welding processes can be measured by means of time-of-flight measurement. Combining this method with a confocal measuring procedure promises significantly higher depth resolutions.

The particular geometry of the keyhole calls for a special optical structure: the cavity with steep edges and a narrow form can only be recorded with a coaxial measuring apparatus, in which the optical axes of the paths for the illumination and imaging beams overlap exactly. An oscillating galvanometric scanner guides the measuring laser towards the welding head where it is combined with the welding laser. In this way, a 3 to 5 millimeter wide profile is recorded perpendicularly to the direction of feed, enabling continuous referencing to the surface of the workpiece.

Through the studies in the project, the scientists have in principle been able to show that the penetration depth in the laser welding process can be measured by means of time-of-flight measurement. Factors that impair the quality of the measurement – such as deformation of the keyhole by movement of the weld puddle, stray light or unwanted reflection – can largely be eliminated. However, the quality of the measurements is not yet sufficient for genuine process control. In a follow-up project, the team of developers is working on a combination of time delay process and a confocal measuring procedure that promises significantly higher depth resolutions and is intended to compensate for the drawbacks of time delay measurement in the close-up range. The future aim is to not only measure welding depth in laser machining processes but also drilling depth, material removal and joint offset.

Dr. Alexander Reiterer, Phone +49 761 8857-183, alexander.reiterer@ipm.fraunhofer.de

LASER SCANNING

STREETS IN PROFILE: LASER SCANNER MEASURES ROAD SURFACES

Every four years, highway and road maintenance agencies record the condition of major roads. With strict specifications for the measurement technique, the Federal Highway Research Institute (BASt) ensures that the end result is a uniform assessment of the road conditions. Using the PPS Pavement Profile Scanner developed by Fraunhofer IPM, the BASt has for the first time authorized a measuring system with a single laser scanner for measuring the evenness of transverse profiles for a limited period of time. Integrated on an inspection vehicle the scanner, together with other sensors, records a detailed profile of the road surface

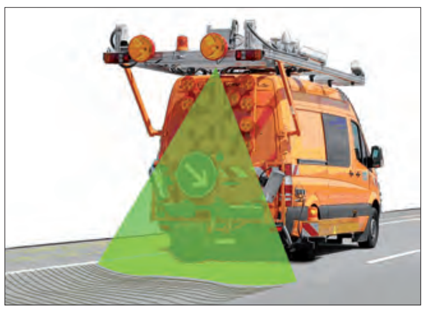
Compared with systems previously employed, the laser scanner developed by Fraunhofer IPM offers numerous advantages: it measures the transverse profile of the road across the full carriageway width of four meters with a single scanner. Conventional measurement systems work with up to 40 individual lasers which are affixed to a cross-beam on the inspection vehicle and cover a maximum width of 3.3 meters. This bulky measuring device proves to be obstructive in flowing traffic and is impossible to use on narrow municipal roads.

The Fraunhofer IPM solution also yields considerably more accurate measurement data. Travelling at a speed of 80 km/h, the Pavement Profile Scanner generates up to 100 measurement points over an area of 10 x 10 cm^{2}. The system measures the distance to the road surface one million times per second and functions on the principle of time-of-flight measurement. A rapidly rotating mirror directs a laser beam over the road 800 times per second, yielding a transverse profile with 900 measuring points in each case. A three-dimensional image of the road surface is then generated from the distance values, the rotation of the scanning mirror and the motion of the vehicle.

Whereas non-scanning, single-laser systems in transverse profile merely record a measurement value every 10 cm, the Pavement Profile Scanner supplies a reading perpendicular to the direction of travel every 5 mm and thus records deformations such as ruts with great accuracy.

The dark surface of the road presents a technical challenge because it only reflects the laser light very weakly and therefore demands a correspondingly high laser output. At the same time, the laser is intended for use in public areas without any restrictions. Consequently, to achieve a balance between risk to the eyes and high laser output, the Pavement Profile Scanner uses an infrared laser with a wavelength of over 1500 nm, thus complying with the requirements of Laser Class 1.

In addition to conducting road surveys, Lehmann + Partner GmbH, the company collaborating in the development, also uses the device for assessing traffic surfaces not in state ownership. Recently the operator of Hamburg Airport arranged for the evenness of the runway to be inspected – to ensure a safe and smooth landing for aircraft.



One single laser scanner measures the transverse profile of the road surface across a width of four meters. With 800 profiles per second the scanner attains high accuracy.

Dr. Alexander Reiterer, Phone +49 761 8857-183, alexander.reiterer@ipm.fraunhofer.de

BUSINESS UNIT
GAS AND PROCESS TECHNOLOGY

TOPICS

- Gas analysis
- Particle measurement techniques
- »Food chain management«

EXPERTISE

- Spectroscopy from EUV to MIR
- Gas sensor technology
- Robust integrated systems
- Light source development

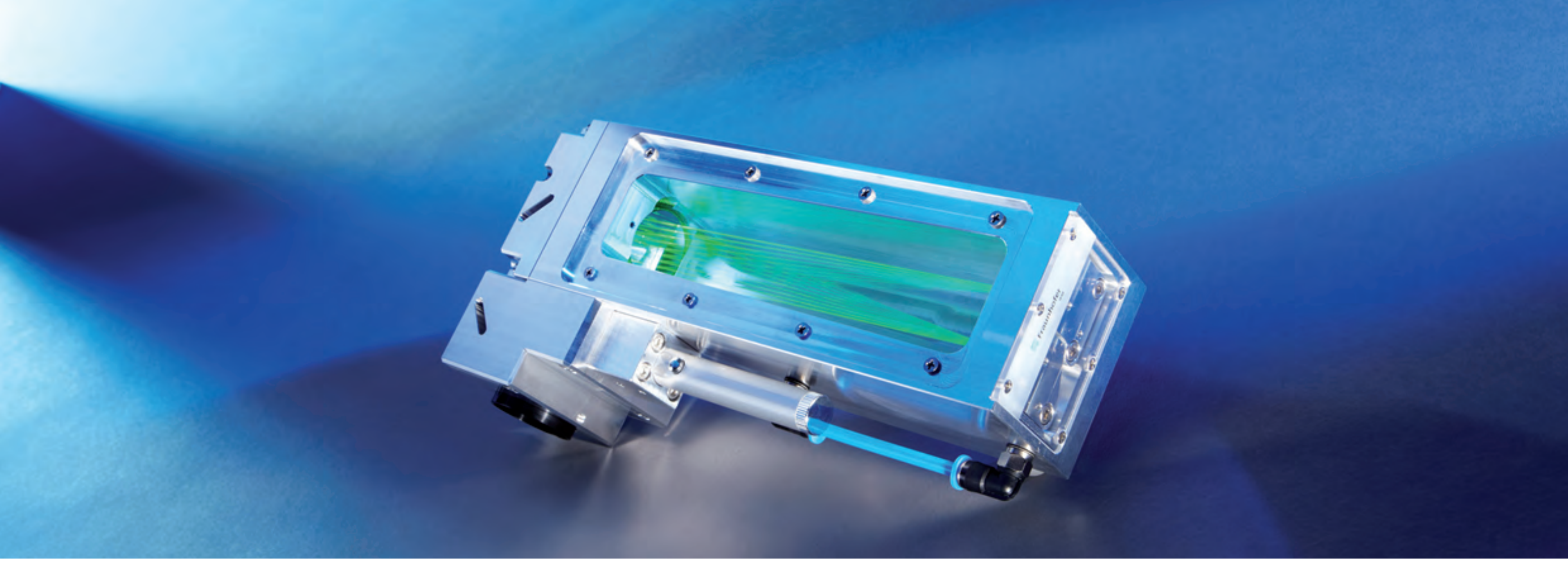
CONTACT

Dr. Armin Lambrecht, Head of Department
Phone +49 761 8857-122, armin.lambrecht@ipm.fraunhofer.de

Prof. Dr. Jürgen Wöllenstein
Integrated Sensor Systems
Phone +49 761 8857-134, juergen.woellenstein@ipm.fraunhofer.de

Dr. Raimund Brunner
Spectroscopy and Process Analytics
Phone +49 761 8857-310, raimund.brunner@ipm.fraunhofer.de

Dr. Frank Kühnemann
Technology of Optical Materials
Phone +49 761 8857-457, frank.kuehnemann@ipm.fraunhofer.de



GAS AND PROCESS TECHNOLOGY
»We make the hidden visible and monitor processes«

Dr. Armin Lambrecht

In the Gas and Process Technology business unit, Fraunhofer IPM produces measurement and control systems to customer-specific requirements. Short measuring times, high precision and reliability are the distinguishing characteristics of these systems – even under extreme conditions. The expertise includes laser spectroscopic procedures for gas analysis, energy-efficient sensors, particle measuring techniques for the analysis of fine dust, process measuring techniques and the characterization of laser materials. The bandwidth of applications is broad and among those already implemented are instruments for exhaust gas analysis, sensor networks for monitoring the food transport chain, EUV spectrometers for measurements in the ionosphere, systems for the in-situ measurement of wear on tools and optical parametric oscillators as a tunable laser light source.

Integrated Sensor Systems

The focus of the 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 have been combined in compact and economical microsystems for this purpose.

Spectroscopy and Process Analytics

Activities in the 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.

Technology of Optical Materials

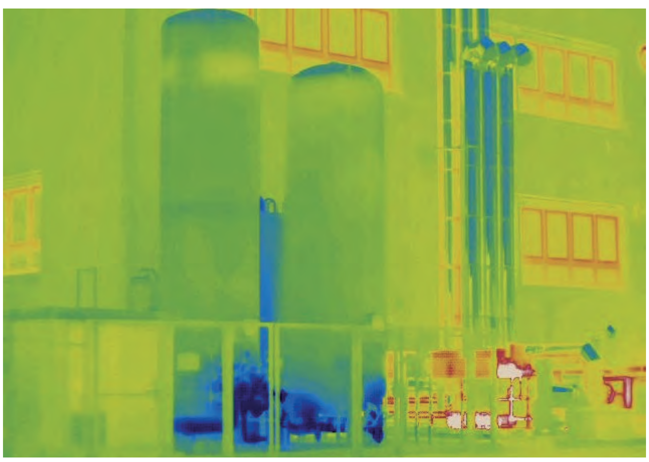
The focus of the group is on investigating the optical properties of solids and liquids by means of innovative spectroscopic procedures. Examples include photothermal and photo-acoustic methods as well as spectroscopy with supercontinuum laser sources. Years of experience in handling non-linear optical materials make it possible to construct efficient optical systems.

SPECTROSCOPY AND PROCESS ANALYTICS

SNIFFING FROM A SAFE DISTANCE: LEAK DETECTION IN BIOGAS PLANTS

More than 7500 biogas plants have been installed in Germany. It is not unusual for them to cause a stink for the neighbors, who then complain of odor pollution, primarily caused by leaks. Escaping gas not only spreads an evil smell, but also involves a considerable safety risk. Even small leaks additionally reduce the cost-effectiveness of the plants and cancel out their ecological benefits, because methane and carbon dioxide as the main constituents of biogas act as particularly strong greenhouse gases.

Together with Fraunhofer UMSICHT and the specialists in measurement techniques Schütz Messtechnik GmbH, Fraunhofer IPM is working on an optical measurement system that locates leaks on biogas plants from a distance of several meters. The aim is to achieve an imaging system that is faster, more sensitive and more economical than present-day measuring devices.



Discovering leaks in biogas plants from a distance of several meters: The optical system measures the thermal radiation emission of the gas, excited by a specific laser.

Hand-held sniffer devices that are usually employed for gas detection scan surfaces on a point-focused basis from a distance of a few centimeters – such a solution is less practicable for plants where access is difficult. Consequently, gas cameras that detect methane emissions by means of absorption spectroscopy are used today for the remote detection of gas leaks over large areas. However, they are expensive, demand trained personnel and optimum measuring conditions. Laser-based measuring devices that work on the principle of backscattering spectroscopy are another alternative. However, they only function sensitively and reliably with a suitable background surface as a backscatterer. This means that measurements against the open horizon are not possible. Such measuring systems also lack an imaging function for positioning and documentation.

Scientists are using a principle, patented by Fraunhofer IPM, of laser-based emission spectroscopy for the first time in the remote detection of gas and are bypassing the problem of backscattering. Furthermore, emission spectroscopy proves to be very gas specific and less susceptible to cross-sensitivities. Specific laser light is irradiated into the spectrum of an individual methane absorption line with a quantum cascade laser. The absorption stimulates oscillations in the molecule which give off their energy in the form of thermal radiation. A photodetector sensitive to infrared measures the thermal radiation emission, thus indicating the leak. An integrated distance measurement enables the background methane from the air to be calculated so that the gas concentration can be determined. The aim is to achieve a hand-held system for point-based measurements for quantifying leaks as well as a screening device for locating leaks, which swiftly scans large surfaces.

Dr. Raimund Brunner, Phone +49 761 8857-310, raimund.brunner@ipm.fraunhofer.de

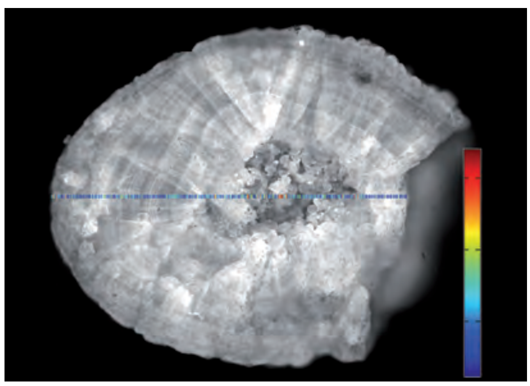
ADDED VALUE FROM MEASUREMENTS: CHEMOMETRY ADDS TO SPECTROSCOPY

Modern spectrometers supply a large quantity of measuring data. Only with efficient data analysis is it possible to gain the maximum information from the measuring data. Fraunhofer IPM uses what are known as chemometric methods to obtain chemical information from experimental data. In cooperation with the Department of Urology at the University Medical Center Freiburg, various chemometric procedures have been developed for analyzing kidney stones. The composition of the stones is determined as a standard procedure after the operation to remove them in order to define the medicines required in after-care. Today this analysis generally takes place in specialized laboratories by means of Fourier transform infrared spectroscopy, with the results taking up to three weeks to arrive. Scientists at Fraunhofer IPM are working on a system that analyses the extracted stones on site. This enables further therapeutic measures to be discussed immediately, without the need to arrange a new appointment for the patient.

In order to analyze the stones, the developers are using Raman spectroscopy, which manages with comparatively economical optical components under the given conditions and also functions without difficulty for aqueous samples. This obviates the need for elaborate sample preparation. First of all, the pure substance was examined to determine whether all potential constituents of kidney stones supply a usable Raman signal and which excitation wavelength yields a favorable ratio between signal and background fluorescence.

In order to analyze the composition of natural kidney stones, it is necessary to trace the signals made of up to ten individual components back to their basic constituents and discard any background or interference signals. Chemometric methods such as multivariate linear regression, Principal Component Analysis or Support Vector Machines help to separate and categorize the spectral data. Each of the spectra read with a CCD camera consists of 1024 intensity values. With the aid of statistical algorithms, significant differences are determined between the measured intensity values, from which feature clusters can be derived. Using these clusters, it is possible to separate genuine signals from interference signals and train a classification algorithm, which then enables unknown samples to be analyzed with high accuracy.

Just how useful the mathematical processing of the data is can be seen by the problem of overlapping fluorescence backgrounds in the measurement of the kidney stones. Attempts to eliminate these background signals using various Raman excitation wavelengths failed to produce any success. Only a specially developed method of chemometric analysis was able to remove the interfering fluorescence on the software side and thus enable analysis of the urinary calculus to accompany the operation.



Fraunhofer IPM uses different chemometric methods to analyze kidney stones and thus enable analysis of the urinary calculus to accompany the operation.

Dr. Raimund Brunner, Phone +49 761 8857-310, raimund.brunner@ipm.fraunhofer.de

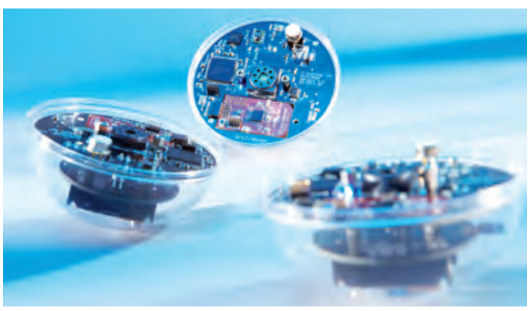
INTEGRATED SENSOR SYSTEMS

COMMUNICATING SPHERES: GAS SENSORS GET WIND OF DANGER

Natural disasters, terrorist attacks and industrial accidents have one thing in common: they bring about chaos. In the event of a catastrophe, the most important task is to conduct a thorough search for victims and sources of danger. Rescue personnel risk their lives, and sometimes a mission of this kind is all but impossible – as was the case in Fukushima.

To enable swift reaction in the wake of a catastrophe, the six Fraunhofer Institutes IOSB, IAIS, IIS, IOSB-AST, IPA and IPM are developing different sensors as well as mobile air-borne and land-based robots as part of the SENEKA project. These robots are intended to inspect the site instead of the rescue services and provide comprehensive reconnaissance for the area surrounding the catastrophe through an ad hoc wireless network adapted to the situation.

After a chemical accident, for example, special sensor spheres from Fraunhofer IPM are able to detect gases that represent a hazard for the rescue workers. Roughly the size of a tennis ball, the spheres are equipped with different types of sensors that can precisely survey their surroundings. Mobile robots initially distribute the sensors roughly around the area affected by the catastrophe. Once in place, the sensors then measure various gases such as ammonia and carbon monoxide as well as the temperature and humidity. These data are enough to allow initial deductions to be made about toxic gases, hazardous chemicals or the possible outbreak of fires. For each sensor node a 360° anemometer including a compass is intended to provide information on wind direction and speed. Consequently, the sensor nodes are not only able to pinpoint sources of hazard but also calculate the potential spread of fires or gas clouds.



Mobile robots spread interlinked sensor spheres throughout the area in the event of a catastrophe. They localize sources of hazards such as toxic gases or chemicals and pass on the information to the rescue services.

A positioning unit based on radio and ultrasound is installed in each of the nodes so that the sensors can locate each other and exchange the measured environmental parameters. The sensor network combines the data of the individual sensors using the principle of swarm intelligence and links them with each other to produce an evaluation. This leads to a spatially resolved display of the hazardous sources for the affected area. When the mission control centre receives the information, it is able to coordinate the subsequent action.

A sensor network intended for emergencies must be as cost-effective as possible: after all, the larger the area, the more sensors will be required, and it will not always be possible to recover the sensors after the rescue mission. Fraunhofer IPM is therefore developing »best-price« sensors for these missions, which are not only economical to produce but also consume very little energy and can thus be deployed for lengthy missions or multiple use. As from next year, the SENEKA concept will be undergoing trials using a realistically staged disaster scenario on a test area provided by the Federal Agency for Technical Relief (THW).

Prof. Dr. Jürgen Wöllenstein, Phone +49 761 8857-134, juergen.woellenstein@ipm.fraunhofer.de

TECHNOLOGY OF OPTICAL MATERIALS

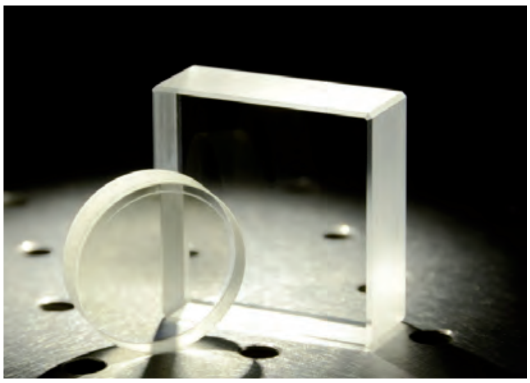
MAKING SOUND FROM LIGHT: LISTENING TO LIGHT ABSORPTION WITH PHOTOACOUSTICS

Laser pointers, laser printers, motor vehicles – every day we use products that function with lasers or are produced with the aid of lasers. Industrial applications such as laser welding are proving to be a prime driving force in the development of extremely powerful lasers. Optical components such as lenses and crystals that guide, focus or convert the laser light assist in this process. However, these optical components do not always keep pace with the development of the lasers themselves. Operating high-performance lasers with standard optical components is rather like sending a sports car into a race with wooden wheels.

This development lag is generally due to the optical materials that make up the components. Even minimal »colorations« of the glasses, polymers or crystals caused by minor residual absorptions can have grave consequences for powerful laser systems: the optical system overheats, beam control is lost and, in extreme cases, the optical component may even be destroyed.

To raise the level of technology of the optical components to match that of today's high-performance lasers, it is therefore necessary to monitor the purity of the materials used. Here the most important quality indicator is the quantity of light that an optical material absorbs when irradiated. Nevertheless, in modern optical materials, this quantity is so small that it cannot be detected directly by means of conventional spectroscopic methods. Fraunhofer IPM therefore makes use of an especially sensitive measuring technique: in order to measure the absorbed light, the scientists exploit a phenomenon known as the photoacoustic effect, discovered by Alexander Graham Bell as long ago as 1880. This initially involves illuminating the optical material with a focused laser light pulse. Part of the light is absorbed by the material, with the light giving off its energy to the material. As a result, the material undergoes local warming, expands and produces a pressure wave. A highly responsive sensor is then used to monitor or "listen to" this sound. The rule here is: the louder the sound, the greater the impurity of the optical material.

This photoacoustic method allows Fraunhofer IPM to detect material colorations one hundred times smaller than is possible with standard procedures. The photoacoustic measuring station from Fraunhofer IPM is characterized by a modern, tunable laser system, which allows measurements to be taken over a wide range of wavelengths: from the far-UV through the entire visible spectrum into the infrared. The absorbed wavelength range provides details on the color and consequently the type of contamination, and hence crucial information for the manufacture of enhanced optical materials. The substantially higher detection sensitivity therefore helps in the selection and optimization of materials – so that laser systems stay in the running even at higher output.



Only pure optical materials will also withstand extreme laser outputs. Fraunhofer IPM opts for photoacoustics to monitor the purity of optical materials.

Dr. Frank Kühnemann, Phone +49 761 8857-457, frank.kuehnemann@ipm.fraunhofer.de

BUSINESS UNIT
ENERGY SYSTEMS

TOPICS

- Converting waste heat into electrical current
- Metrological systems
- Energy-autarkic sensor technology and wireless sensor networks

EXPERTISE

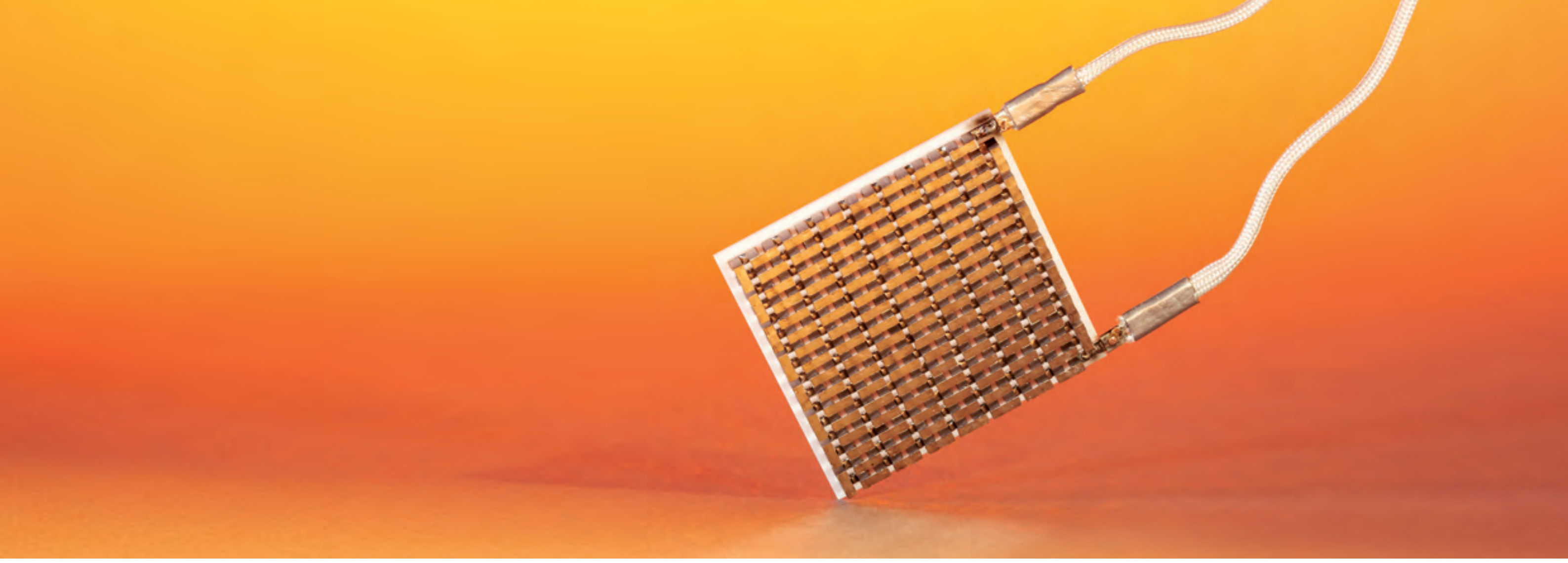
- Material synthesis and optimization
- High-temperature materials and nanomaterials
- Development of modules, converters and systems
- »Energy harvesting«

CONTACT

Dr. Kilian Bartholomé, Head of Department
Phone +49 761 8857-238, kilian.bartholome@ipm.fraunhofer.de

Martin Jägle
Energy Autarkic Systems and Thermoelectric Measurement Techniques
Phone +49 761 8857-345, martin.jaegle@ipm.fraunhofer.de

Jan König
Thermoelectric Energy Converters
Phone +49 761 8857-329, jan.koenig@ipm.fraunhofer.de



ENERGY SYSTEMS

»We make electricity from waste heat«

Dr. Kilian Bartholomé

Converting lost heat energy into electricity – this is what Fraunhofer IPM achieves with the aid of thermoelectrics: in future thermoelectric »energy harvesting« will play a key role in making more efficient use of energy. Here, the future range of applications for thermoelectric energy converters extends from the microwatt range for operating energy-autarkic sensor systems to the kilowatt range for exploiting waste heat in motor vehicles, combined heat and power stations and large-scale industrial plants.

Fraunhofer IPM has been conducting research for more than 15 years in order to integrate the technology of thermoelectrics into energy systems fit for the future. Today the research activities encompass materials research, the development of thermoelectric modules, their simulation and thermoelectric measurement techniques. The aim is to raise conversion efficiency as well as to develop materials and modules with long-term stability and environmentally friendly production processes. For applications, we design and implement systems in which thermoelectric generators can be integrated with optimum effect into complex plants.

Energy Autarkic Systems and Thermoelectric Measurement Techniques

Work in the 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.

Thermoelectric Energy Converters

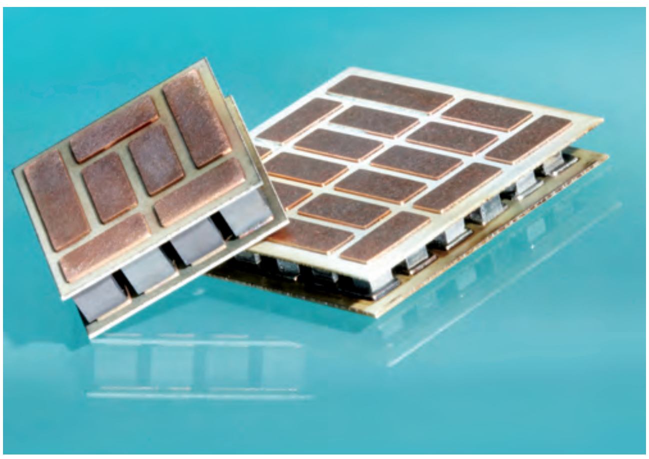
The focus of the group is on »energy harvesting«. In order to convert heat into electricity, the group is developing more efficient thermoelectric materials, modules and systems and optimizing production methods for converters.

THERMOELECTRIC ENERGY CONVERTERS

VALUABLE EXHAUST GAS HEAT: THERMOELECTRIC GENERATORS SAVE FUEL

In many combustion processes far more than 60 percent of the energy of fossil and renewable fuels is lost. A motor vehicle, for example, only uses 30 percent of the chemically bonded energy in the fuel for propulsion. The remaining energy is primarily lost as waste heat. Thermoelectric generators render this previously squandered waste heat usable by converting it into electrical energy.

In order to exploit waste heat in automobiles, Fraunhofer IPM is researching into thermoelectric materials for the construction of thermoelectric generators. The principle of such generators is based on a phenomenon known as the Seebeck effect: the flow of heat from a hot side through the thermoelectrical material to a cold side generates electrical current. Here the performance of the generators primarily depends on the efficiency of the thermoelectric material. In various projects, Fraunhofer IPM has successfully tested bismuth telluride, lead telluride, skutteridites, half-Heusler alloys and silicides. The generators thus developed can be deployed in wide ranges of temperature and are thus able to produce a substantial electrical output.



In automobiles, thermoelectric modules have so far saved up to 3.9 percent of fuel and thus reduce CO_2 consumption by 9.6 grams per kilometer.

One of the most efficient thermoelectric generators has now been jointly developed with partners from industry and research in the »HeatReCar« project funded by the European Union. Bismuth telluride was used as the thermoelectric material. In a small transport van, the generator is attached directly to the exhaust pipe. Using the waste heat of the exhaust gas, it produces a maximum output of 500 watts of electrical energy.

To calculate the fuel savings exactly, trials took place according to specific driving cycles, which enable the fuel consumption of motor vehicles to be determined in a standardized form. In the »New European Driving Cycle« (NEDC), the thermoelectric generator achieved a fuel saving of 2.2 percent, which is equivalent to a saving in CO_2 emissions of 6.7 grams per kilometer. In the globally standardized cycle »Worldwide Harmonized Light Duty Test Procedure« (WLTP) fuel savings amounted to as much as 3.9 percent and the reduction in CO_2 emissions achieved was 9.6 grams per kilometer. Bismuth telluride is especially well-suited to exhaust gas temperatures of around 450 °C. For passenger cars with spark ignition engines which operate at higher combustion temperatures and thus achieve higher exhaust gas temperatures, thermoelectric modules achieve even greater efficiencies. This calls for so-called segmented modules, which are composed of bismuth telluride and suitable high-temperature materials such as skutterudites and half-Heusler alloys. Segmented modules are to undergo testing in motor vehicles before the end of 2013.

Jan König, Phone +49 761 8857-329, jan.koenig@ipm.fraunhofer.de

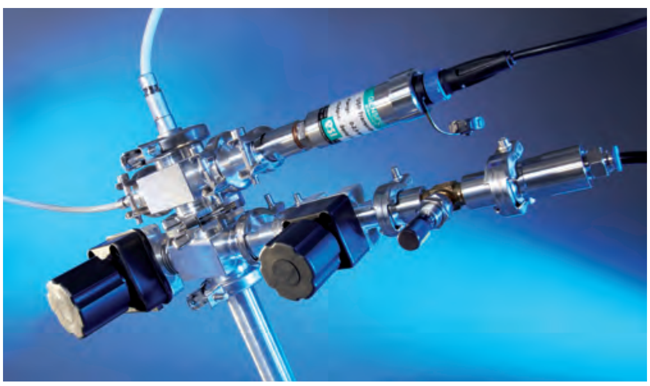
MAGNETISM MAKES IT POSSIBLE: HALL STATION MEASURES CHARGE CARRIERS

Waste heat occurs in all areas of daily life – in industry, in the household and in traffic. From this unused waste heat thermoelectric modules are able to generate electricity – without emissions, noise or maintenance. In this process, the efficiency of thermoelectric modules depends crucially on the material and its properties, including the number, type and mobility of the charge carriers. In order to determine these material parameters at temperatures of up to 650 °C, Fraunhofer IPM has developed a high-temperature Hall measuring station. This is because modern thermoelectric materials are now employed at very high temperatures.

The measuring principle is based on the Hall effect discovered by the American physicist Edwin Herbert Hall in 1879. He observed that electrical energy in a conductor is influenced by applying a magnetic field. If the charge carriers are normally distributed evenly across the material, the magnetic field generates an imbalance in the distribution of the charge carriers. This leads to a voltage which provides information on how many charge carriers are present in the conductor material under investigation, how mobile they are and what charge they have.

In thermoelectric semiconductors it is usual to influence the charge carrier density by atoms known as dopants. These are atoms that can be selectively added to the semiconductor in order to increase the electrical conductivity of the material. However, this increase causes the Seebeck coefficient to fall. The Seebeck coefficient indicates the electric voltage occurring in the thermoelectric material due to a temperature difference and is consequently an additional decisive parameter for the optimum efficiency of the thermoelectric material. For an enhanced efficiency of the thermoeletric material both parameters, the Seebeck coefficient and the charge carrier concentration, have to achieve the highest possible values. To this end, the dopant atoms must be added in very exact quantities and thus be measured with similar accuracy. This resembles looking for a needle in a haystack because less than one dopant atom is required for 1,000,000 atoms of thermoelectric material. Nevertheless, the high-temperature Hall measuring station of Fraunhofer IPM is sensitive enough to measure the influence of these dopant atoms.

In such cases, not only the doping has an effect on the number of charge carriers but also the temperature. The higher the temperature, the more charge carriers will be activated. In high temperature ranges of 600 °C there have hitherto been no commercially available Hall measuring systems. Fraunhofer IPM has therefore developed the new measuring station »IPM-HT-Hall« for Hall measurement from 20 to 650 °C. It represents an important tool for increasing the efficiency of thermoelectric materials. The maximum working temperature is to be increased to 800 °C by the end of the year.



The high-temperature Hall measuring station by Fraunhofer IPM determines the number, type and mobility of charge carriers in semiconductors at temperatures from 20 °C – 650 °C.

Martin Jägle, Phone +49 761 8857-345, martin.jaegle@ipm.fraunhofer.de

THE FRAUNHOFER-GESELLSCHAFT

Research of practical utility lies at the heart of all activities pursued by the Fraunhofer-Gesellschaft. Founded in 1949, the research organization undertakes applied research that drives economic development and serves the wider benefit of society. Its services are solicited by customers and contractual partners in industry, the service sector and public administration.

At present, the Fraunhofer-Gesellschaft maintains 66 institutes and independent research units. The majority of the more than 22,000 staff are qualified scientists and engineers, who work with an annual research budget of 1.9 billion euros. Of this sum, more than 1.6 billion euros is generated through contract research. More than 70 percent of the Fraunhofer-Gesellschaft's contract research revenue is derived from contracts with industry and from publicly financed research projects. Almost 30 percent is contributed by the German federal and Länder governments in the form of base funding, enabling the institutes to work ahead on solutions to problems that will not become acutely relevant to industry and society until five or ten years from now.

Affiliated international research centers and representative offices provide contact with the regions of greatest importance to present and future scientific progress and economic development.

With its clearly defined mission of application-oriented research and its focus on key technologies of relevance to the future, the Fraunhofer-Gesellschaft plays a prominent role in the German and European innovation process. Applied research has a knock-on effect that extends beyond the direct benefits perceived by the customer: Through their research and development work, the Fraunhofer Institutes help to reinforce the competitive strength of the economy in their local region, and throughout Germany and Europe. They do so by promoting innovation, strengthening the technological base, improving the acceptance of new technologies, and helping to train the urgently needed future generation of scientists and engineers.

As an employer, the Fraunhofer-Gesellschaft offers its staff the opportunity to develop the professional and personal skills that will allow them to take up positions of responsibility within their institute, at universities, in industry and in society. Students who choose to work on projects at the Fraunhofer Institutes have excellent prospects of starting and developing a career in industry by virtue of the practical training and experience they have acquired.

The Fraunhofer-Gesellschaft is a recognized non-profit organization that takes its name from Joseph von Fraunhofer (1787–1826), the illustrious Munich researcher, inventor and entrepreneur.

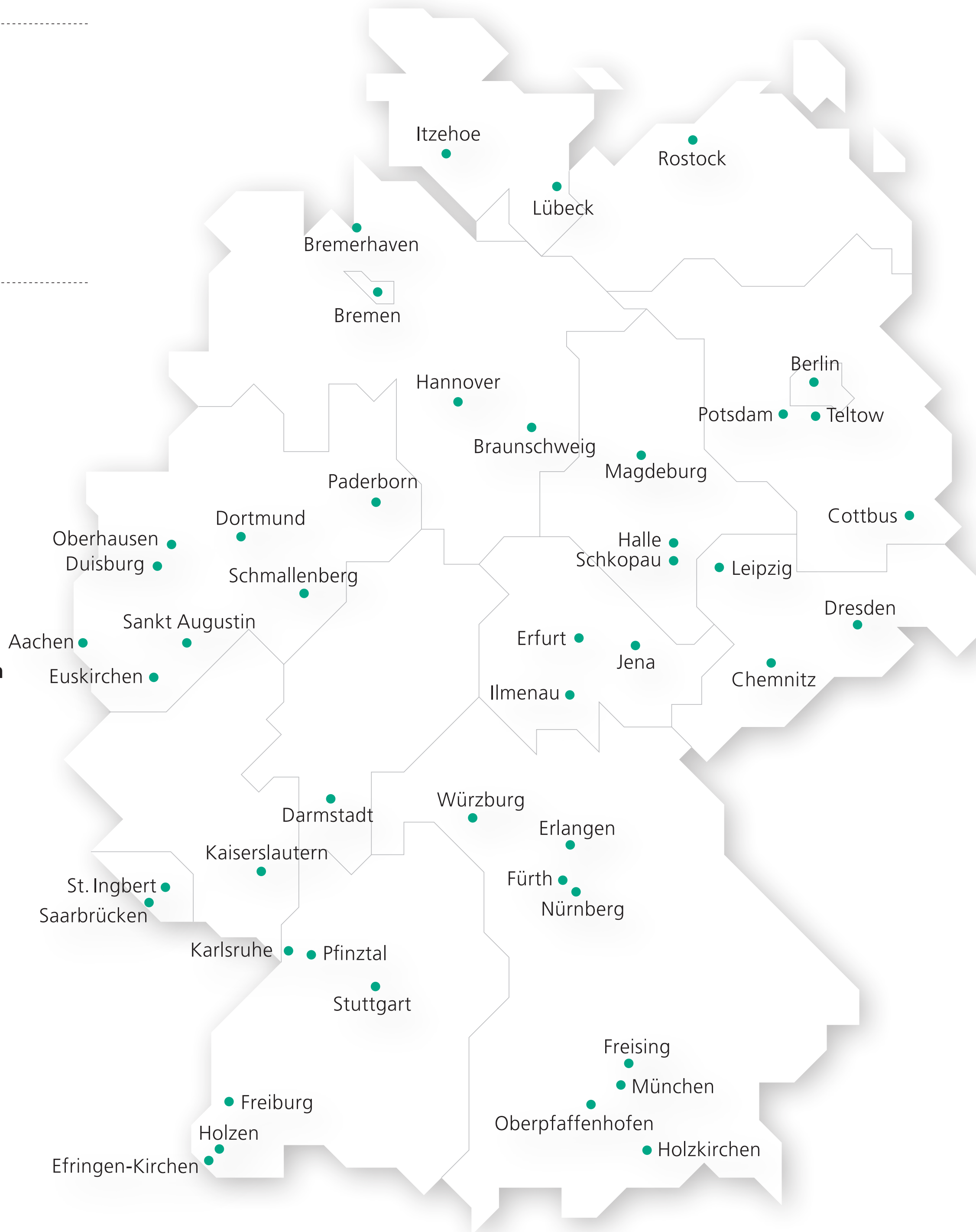
www.fraunhofer.de

Fraunhofer IPM

Freiburg
Fraunhofer Institute for Physical
Measurement Techniques IPM
Heidenhofstrasse 8
D-79110 Freiburg
Phone +49 761 8857-0
Fax +49 761 8857-224

Kaiserslautern
Fraunhofer Institute for Physical
Measurement Techniques IPM
Department Materials
Characterization and Testing
Building 56
Erwin-Schrödinger-Strasse
D-67663 Kaiserslautern
Phone +49 631 205-5100
Fax +49 631 205-5102

www.ipm.fraunhofer.de/en



Brook, A.; Cristofani, Edison; Vandewal, Marijke; Matheis, Carsten; Jonuscheit, Joachim
3-D radar image processing methodology for Non-Destructive Testing of aeronautics composite materials and structures
2012 IEEE Radar Conference, RADAR 2012. Proceedings Vol.2 , 806 (2012)

Brook, A.; Cristofani, E.; Vandewal, M.; Matheis, C.; Jonuscheit, J.; Beigang, R.
A 3D THz image processing methodology for a fully integrated, semi-automatic and near real-time operational system
Terahertz physics, devices, and systems VI , Art. 8363 0E (2012)

Molter, D.; Torosyan, G.; Klier, J.; Matheis, C.; Petermann, C.; Weber, S.; Ellrich, F.; Jonuscheit, J.; Beigang, R.
All-solid-state THz ATR spectroscopy module
3rd EOS Topical Meeting on Terahertz Science and Technology: TST 2012. CD-ROM

Pelz, U.; Kaspar, K.; Schmidt, S.; Dold, M.; Jägle, M.; Pfaadt, A.; Hillebrecht, H.
An aqueous-chemistry approach to nano-bismuth telluride and nano-antimony telluride as thermoelectric materials
Journal of Electronic Materials 41 (6), 1851 (2012)

Kontermann, S.; Ruf, A.; Preu, R.
Atomistic simulations of the silicon surface structure at the interface of silver thick film contacts on n-type silicon
Advanced materials processing for scalable solar-cell manufacturing , 131 (2012)

Feige, V.K.S.; Berta, M.; Ellrich, F.; Jonuscheit, J.; Beigang, R.
Berührungslose Mehrlagen-Schichtdickenmessung industrieller Beschichtungen mittels THz-Messtechnik
Technisches Messen : TM 79 (2), 87 (2012)

Werner, C.S.; Beckmann, T.; Buse, K.; Breunig, I.
Blue-pumped whispering gallery optical parametric oscillator
Optics Letters 37 (20), 4224 (2012)

Petermann, Christian
Breitbandspektroskopie mit Superkontinuum-Quellen

Ellrich, Frank; Torosyan, Garik; Wohnsiedler, Sabine; Bachtler, Sebastian; Hachimi, A.; Jonuscheit, Joachim; Beigang, René; Platte, F.; Nalpantidis, K.; Sprenger, T.; Hübsch, D.
Chemometric tools for analysing Terahertz fingerprints in a postscanner
37th International Conference on Infrared, Millimeter, and Terahertz Waves, IRMMW-THz 2012 , 2 (2012)

Herrmann, M.; Platte, F.; Nalpantidis, K.; Beigang, R.; Heise, H.M.
Combination of Kramers-Kronig transform and time-domain methods for the determination of optical constants in THz spectroscopy
Vibrational spectroscopy 60, 107 (2012)

Zouaghi, W.; Ospald, F.; Molter, Daniel; Beigang, René
Comparison of high-speed terahertz optical sampling techniques at different wavelengths
37th International Conference on Infrared, Millimeter, and Terahertz Waves, IRMMW-THz 2012 , 2 (2012)

Ospald, F.; Zouaghi, W.; Rämer, J.-M.; Beigang, René
Comparison of THz emitters and detectors pumped at 1560 nm: DAST, ErAs:InGaAs and LTG GaAs
37th International Conference on Infrared, Millimeter, and Terahertz Waves, IRMMW-THz 2012 , 2 (2012)

Paul, O.; Urzhumov, Y.; Elsen, C.; Smith, D.; Rahm, M.
Construction of invisibility cloaks of arbitrary shape and size using planar layers of metamaterials
Journal of applied physics 111 (12), Art.123106, 8 (2012)

Jacquot, A.; Bayer, B.; Winkler, M.; Böttner, H.; Jaegle, M.
Coupled theoretical interpretation and experimental investigation of the anisotropy of the lattice thermal conductivity of Bi2Te3 single crystal
Journal of solid state chemistry 193

Jacquot, A.; Bayer, B.; Winkler, M.; Jaegle, M.
Coupled theoretical interpretation and experimental investigation of the lattice thermal conductivity of Bi2Te3 single crystal
9th European Conference on Thermoelectrics, ECT 2011 , 61 (2012)

Gerhard, M.; Theuer, M.; Beigang, R.
Coupling into tapered metal parallel plate waveguides using a focused terahertz beam
Applied Physics Letters 101 (4), Art. 041109, 4 (2012)

Paul, Oliver; Rahm, Marco
Covariant description of transformation optics in nonlinear media
Optics Express 20 (8), 8982 (2012)

Winkler, Markus; Liu, Xi; Schürmann, Ulrich; König, Jan D.; Kienle, Lorenz; Bensch, Wolfgang; Böttner, Harald
Current Status in Fabrication, Structural and Transport Property Characterization, and Theoretical Understanding of Bi_2Te_3 / Sb_2Te_3 Superlattice Systems

Zeitschrift für anorganische und allgemeine Chemie 638 (15), 2441 (2012)

Vandewal, M.; Depauw, J.; Rombaut, K.; Beigang, R.; Jonuscheit, J.; Mounaix, P.; Sáez de Ocáriz, I.; Martinez Edo, R.; Priegue, A.; Sternberg, Y.
Development and optimization of THz NDT on aeronautics composite multi-layered structures
Terahertz physics, devices, and systems VI , Art. 8363 0Y (2012)

Carl, Daniel; Fratz, Markus; Giel, Dominik; Höfler, Heinrich
Digital-holographischer Mehrwellenlängensensor HoloTop zur 100-Prozent-Kontrolle von Oberflächen
Technisches Messen : TM 79 (11), 489 (2012)

Blug, Andreas; Abt, Felix; Nicolosi, Leonardo
Echtzeit-Regelung mittels schneller Bildverarbeitung optimiert das Laserschweißen
Photonik 44 (6), 42 (2012)

Winkler, M.; Liu, X.; König, J.; Buller, S.; Schürmann, U.; Kienle, L.; Bensch, W.; Böttner, H.
Electrical and structural properties of Bi_2Te_3 and Sb_2Te_3 thin films grown by the nanoalloying method with different deposition patterns and compositions
Journal of Materials Chemistry 22 (22), 11323 (2012)

Ospald, F.; Zouaghi, W.; Rämer, J.-M.; Beigang, R.
Emitters and detectors for a THz time domain material inspection system pumped at 1560 nm
3rd EOS Topical Meeting on Terahertz Science and Technology: TST 2012. CD-ROM

Rahm, M.; Akalin, T.; Nahata, A.; Beruete, M.
Focus on terahertz plasmonics: In memory of Professor Mario Sorolla Ayza
New journal of physics. Online journal 14 (Editorial)

Petermann, Christian; Beigang, René; Fischer, Peer
Fourier-transform photocurrent spectroscopy using a supercontinuum light source
Applied Physics Letters 100 (6), Art. 061108, 3 (2012)

Blug, A.; Abt, F.; Nicolosi, L.; Heider, A.; Weber, R.; Carl, D.; Höfler, H.; Tetzlaff, R.
The full penetration hole as a stochastic process: Controlling penetration depth in keyhole laser-welding processes
Applied Physics. B 108 (1), 97 (2012)

Luedtke, F.; Buse, K.; Sturman, B.
Hidden reservoir of photoactive electrons in $LiNbO_3$ crystals
Physical review letters 109 (2), Art. 026603 (2012)

Schumacher, Soeren; Nestler, Jörg; Otto, Thomas; Wegener, Michael; Ehrentreich-Förster, Eva; Michel, Dirk; Wunderlich, Kai; Palzer, Silke; Sohn, Kai; Weber, Achim; Burgard, Matthias; Grzesiak, Andrzej; Teichert, Andreas; Brandenburg, Albrecht; Koger, Birgit; Albers, Jörg; Nebling, Eric; Bier, Frank F.
Highly-integrated lab-on-chip system for point-of-care multiparameter analysis
LAB on a chip 12 (3), 464 (2012)

Herbst, Johannes; Scherer, Benjamin; Ruf, Alexander; Erb, Jochen; Lambrecht, Armin
Hollow fiber based quantum cascade laser spectrometer for fast and sensitive drug identification
Quantum Sensin and Nanophotonic Devices IX , Paper 82681Q (2012)

Schürmann, U.; Winkler, M.; König, J.; Liu, X.; Duppel, V.; Bensch, W.; Böttner, H.; Kienle, L.
In Situ TEM investigations on thermoelectric Bi_2Te_3/Sb_2Te_3 multilayers
Advanced engineering materials 14 (3), 139 (2012)

Jonuscheit, J.
In the news: THz spectrometer tests substances
Trends in analytical chemistry 36, IX (2012)

Cristofani, Edison; Vandewal, Marijke; Matheis, Carsten; Jonuscheit, Joachim
In-depth high-resolution SAR imaging using Omega-k applied to FMCW systems
2012 IEEE Radar Conference, RADAR 2012. Proceedings Vol.2 , 725 (2012)

Konz, Werner
Integrated total analysis systems
Comprehensive sampling and sample preparation. Analytical techniques for scientists. Vol.1: Sampling Theory and Methodology , 99 (2012)

Bessas, D.; Sergueev, I.; Wille, H.C.; Persson, J.; Ebling, D.; Hermann, R.P.
Lattice dynamics in Bi_2Te_3 and Sb_2Te_3: Te and Sb density of phonon states
Physical Review. B 86 (22), Art.224301, 9 (2012)

Schmitt, Katrin; Rist, Jonas; Peter, Carolin; Wöllenstein, Jürgen
Low-cost fiber-optic waveguide sensor for the colorimetric detection of ammonia
Microsystem Technologies 18 (7-8), 843 (2012)
Schmitt, K.; Rist, J.; Peter, C.; Wöllenstein, J.
Low-cost fiber-optic waveguide sensor for the colorimetric detection of ammonia
Microsystem Technologies 18 (7-8), 843 (2012)

Peter, Carolin; Schmitt, Katrin; Apitz, Martin; Wöllenstein, Jürgen
Metallo-porphyrin zinc as gas sensitive material for colorimetric gas sensors on planar optical waveguides
Microsystem Technologies 18 (7-8), 925 (2012)

Reinhard, B.; Schmitt, K.M.; Wollrab, V.; Neu, J.; Beigang, R.; Rahm, M.
Metamaterial near-field sensor for deep-subwavelength thickness measurements and sensitive refractometry in the terahertz frequency range
Applied Physics Letters 100 (22), Art. 221101, 4 (2012)

Reinhard, B.; Fip, T.; Volk, M.; Schmitt, K.M.; Neu, J.; Hoeh, M.; Rahm, M.
Metamaterial Terahertz Transmission Optics and Surface Waves
3rd EOS Topical Meeting on Terahertz Science and Technology: TST 2012. CD-ROM

Satzer, Britta; Baulig, Claudia; Sandner, Thilo; Schwarzer, S.
Micromirror-based sending and detection optical assembly for time-of-flight laser scanners
Optical Sensing and Detection II , Paper 84390Z (2012)

Pfeifer, Marcel; Fischer, Peer; Lüdeke, Steffen
Mid-IR laser-based vibrational optical activity
Biomedical Vibrational Spectroscopy V. Advances in Research and Industry , Paper 821906 (2012)
Böttner, Harald; Nurnus, Joachim
Miniaturized thermoelectric converters, technologies, and applications
Thermoelectrics and its Energy Harvesting. Vol.2: Modules, Systems, and Applications in Thermoelectrics , 17/1 (2012)

Breunig, Ingo; Beckmann, Tobias; Buse, Karsten
Monolithic optical parametric oscillators
Laser Resonators, Microresonators, and Beam Control XIV , Paper 82360S (2012)

Nicolosi, Leonardo; Tetzlaff, Ronald; Abt, Felix; Blug, Andreas; Höfler, Heinrich
Multi-feature detection for quality assessment in laser beam welding: Experimental results
13th International Workshop on Cellular Nanoscale Networks and their Applications, CNNA 2012 , 6 (2012)

Aabdin, Z.; Peranio, N.; Eibl, O.; Töllner, W.; Nielsch, K.; Bessas, D.; Hermann, R.P.; Winkler, M.; König, J.; Böttner, H.; Pacheco, V.; Schmidt, J.; Hashibon, A.; Elsässer, C.
Nanostructure, excitations, and thermoelectric properties of Bi_2Te_3-based nanomaterials
Journal of Electronic Materials 41 (6), 1792 (2012)

Petermann, Christian; Fischer, Peer
Eine neue Form von Cavity Enhanced Absorption Spectroscopy
Technisches Messen : TM 79 (1), 10 (2012)

Reiterer, Alexander; Dambacher, Martin; Maindorfer, Ingo; Höfler, Heinrich; Ebersbach, Dirk; Frey, Carsten; Scheller, Steffen; Klose, Dirk
Neue Laserscanner-Technologie zur Ebenheitsmessung von Straßenbelägen
VDV-Magazin 63 (5), 376 (2012)
Nicolosi, L.; Abt, F.; Blug, A.; Heider, A.; Tetzlaff, R.; Höfler, H.
A novel spatter detection algorithm based on typical cellular neural network operations for laser beam welding processes
Measurement Science and Technology 23 (1), Art. 015401, 8 (2012)

Blug, Andreas; Strohm, Peter; Carl, Daniel; Höfler, Heinrich; Blug, Bernhard; Kailer, Andreas
On the potential of current CNN cameras for industrial surface inspection
13th International Workshop on Cellular Nanoscale Networks and their Applications, CNNA 2012 , 6 (2012)

Beckmann, Tobias; Buse, Karsten; Breunig, Ingo
Optimizing pump threshold and conversion efficiency of whispering gallery optical parametric oscillators by controlled coupling
Optics Letters 37 (24), 5250 (2012)

Brunner, R.; Lambrecht, A.; Herbst, J.; Heubuch, A.; Jacob, E.
Quantenkaskadenlaser-Spektrometer für die schnelle und artefaktfreie Abgasanalyse
7. Internationales Forum Abgas- und Partikelemissionen 2012. Beiträge , 110 (2012)

Miernik, A.; Wilhelm, K.; Bolwien, C.; Eilers, Y.; Lambrecht, A.; Schönthaler, M.
Raman spectroscopy: In-vitro analysis of urinary stone composition at different excitation wavelengths
European urology. Supplements 11 (1), E102 (2012)

Peranio, N.; Winkler, M.; Aabdin, Z.; König, J.; Böttner, H.; Eibl, O.
Room temperature MBE deposition of Bi_2Te_3 and Sb_2Te_3 thin films with low charge carrier densities
Physica status solidi. A 209 (2), 289 (2012)

Peranio, N.; Winkler, M.; Bessas, D.; Aabdin, Z.; König, J.; Böttner, H.;

Hermann, R.P.; Eibl, O.
Room-temperature MBE deposition, thermoelectric properties, and advanced structural characterization of binary Bi_2Te_3 and Sb_2Te_3 thin films
Journal of alloys and compounds 521, 163 (2012)

Aabdin, Z.; Peranio, N.; Winkler, M.; Bessas, D.; König, J.; Hermann, R.P.; Böttner, H.; Eibl, O.
Sb_2Te_3 and Bi_2Te_3 thin films grown by room-temperature MBE
Journal of Electronic Materials 41 (6), 1493 (2012)

Strohm, Peter; Blug, Andreas; Carl, Daniel; Höfler, Heinrich
Schnelle 100-Prozent-Oberflächenkontrolle in der Produktion mit Zellularen Neuronalen Netzwerken
Automatisierungstechnik : AT 60 (5), 289 (2012)

Kuntze, Helge-Björn; Frey, Christian W.; Tchouchenkov, Igor; Staehle, Barbara; Rome, Erich; Pfeiffer, Kai; Wenzel, Andreas; Wöllenstein, Jürgen
SENEKA – sensor network with mobile robots for disaster management
IEEE International Conference on Technologies for Homeland Security, HST 2012 , 5 (2012)

Lerch, R.; Werthschutzky, R.; Wagner, E.; Gerlach, G.
SENSOR + TEST Konferenzen 2011 in Nürnberg
Technisches Messen : TM 79 (1), 3 (2012)

Weis, P.; Garcia-Pomar, J.L.; Hoh, M.; Reinhard, B.; Brodyanski, A.; Rahm, M.
Spectrally wide-band terahertz wave modulator based on optically tuned graphene
ACS nano 6 (10), 9118 (2012)

Knabe, Bastian; Buse, Karsten; Assenmacher, Wilfried; Mader, Werner
Spontaneous polarization in ultrasmall lithium niobate nanocrystals revealed by second harmonic generation
Physical Review. B 86 (19), Art.195428, 9 (2012)

Winkler, M.; Liu, X.; König, J.; Kirste, L.; Böttner, H.; Bensch, W.; Kienle, L.
Sputtered p-type Sb_2Te_3/$(Bi,Sb)_2Te_3$ soft superlattices created by nanoalloying
Journal of Electronic Materials 41 (6), 1322 (2012)

Fuchs, F.; Hugger, S.; Kinzer, M.; Yang, Q.K.; Bronner, W.; Aidam, R.; Degreif, K.; Rademacher, S.; Schnürer, F.; Schweikert, W.
Standoff detection of explosives with broad band tunable external cavity quantum cascade lasers
Quantum Sensin and Nanophotonic Devices IX , Paper 82681N (2012)

Molter, D.; Torosyan, G.; Ballon, G.; Drigo, L.; Lótin, J.; Beigang, R.
Step-scan terahertz time-domain magneto-optics
3rd EOS Topical Meeting on Terahertz Science and Technology: TST 2012. CD-ROM

Molter, D.; Torosyan, G.; Ballon, G.; Drigo, L.; Beigang, R.; Leotin, J.
Step-scan time-domain terahertz magneto-spectroscopy
Optics Express 20 (6), 5993 (2012)

Schmitt, Klemens; Wollrab, Viktoria; Neu, Jens; Beigang, René; Rahm, Marco
Terahertz thin film and refractive index sensing with a metamaterial near-field sensor
37th International Conference on Infrared, Millimeter, and Terahertz Waves, IRMMW-THz 2012 , 2 (2012)

Molter, D.; Theuer, M.; Jonuscheit, J.; Torosyan, G.; Beigang, R.
Terahertz-Spektroskopie: Messung von Gasen, Flüssigkeiten und Festkörpern
GIT. Labor-Fachzeitschrift (6), 446 (2012)

Hinsche, N.F.; Yavorsky, B.Y.; Gradhand, M.; Czerner, M.; Winkler, M.; König, J.; Böttner, H.; Mertig, I.; Zahn, P.
Thermoelectric transport in Bi_2Te_3/Sb_2Te_3 superlattices
Physical Review. B 86 (8), Art. 085323, 13 (2012)

Lenz, E.; Haupt, S.; Edler, F.; Ziolkowski, P.; Pernau, H.-F.
Traceable measurements of electrical conductivity and Seebeck coefficient of β-$Fe_{0.95}Co_{0.05}Si_2$ and Ge in the temperature range from 300 K to 850 K
Physica status solidi. C 9 (12), 2432 (2012)

Jonuscheit, J.; Molter, D.; Ellrich, F.; Beigang, R.; Platte, F.; Nalpantidis, K.
Unsichtbares sichtbar machen – versteckte Substanzen mittels Terahertz-Spektroskopie identifizieren
Photonik (6), 58 (2012)

Strohm, Peter; Blug, Andreas; Carl, Daniel; Höfler, Heinrich
Zellulare Neuronale Netzwerke zur schnellen bildbasierten Regelung von Materialbearbeitungsprozessen
Technisches Messen : TM 79 (3), 152 (2012)

EDITORIAL NOTES

Editorial Address

Fraunhofer Institute for
Physical Measurement Techniques IPM
Press and Public Relations
Holger Kock

Heidenhofstrasse 8
79110 Freiburg
Phone +49 761 8857-129
holger.kock@ipm.fraunhofer.de

Editorial Team

Holger Kock, Verena Schreiber, Anja Strobel

Design

emigre | Christian Lampe,
Freiburg, www.emigre.de

Photo Acknowledgements

Kai-Uwe Wudtke/Fraunhofer IPM (Titel, S. 21, 27, 31, 34, 37, 38, 39); Felix Groteloh/Fraunhofer IPM (S. 5); Klaus Polkowski/Fraunhofer IPM (S. 6, 14, 15); NASA (S. 8); Berthold Leibinger Stiftung GmbH (S. 10, 28); M. Gillert (S. 11); Thomas Brenner/Fraunhofer IPM (S. 23, 25); Airbus S.A.S. (S. 24); Lehmann+Partner GmbH (S. 29)

Print

Poppen & Ortmann KG,
www.poppen-ortmann.de

This report was printed on climate-neutral paper.

www.ipm.fraunhofer.de/en