Fraunhofer

Heinrich Hertz Institute

FRAUNHOFER INSTITUTE FOR TELECOMMUNICATIONS, HEINRICH HERTZ INSTITUTE, HHI

ANNUAL REPORT

2013 2014 2015

CONTENTS

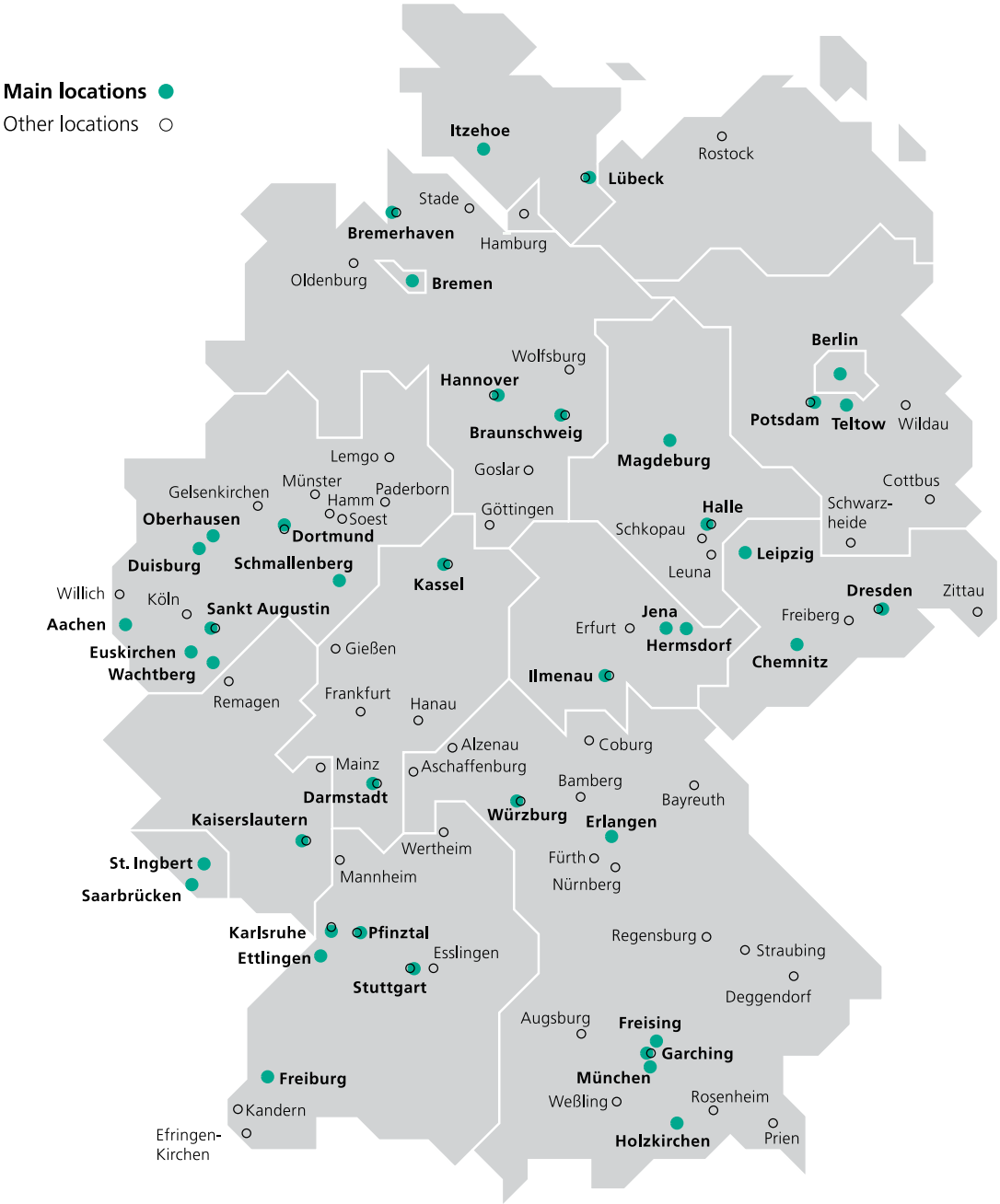
EXPERTISE

Innovations for the digital society of the future are the focus of research and development work at the Fraunhofer Heinrich Hertz Institute HHI. In this area, Fraunhofer HHI is a world leader in the development for mobile and optical communication networks and systems as well as processing and coding of video signals. Together with international partners from research and industry, Fraunhofer HHI works in the whole spectrum of digital infrastructure – from fundamental research to the development of prototypes and solutions. The institute participates in the standardization of information and communication technologies and creates new applications together with industrial partners.

"Communication networks and data processing systems are the core of the digital infrastructure. We explore flexible and scalable solutions that turn the digital transformation of society, science and economy into reality and enable future applications. Every second bit transported via the Internet today involves an optical component from Fraunhofer HHI. And more than one billion devices are using the coding technology co-developed by us, for the distribution of videos. We are continuing to push for research with a worldwide impact."

Prof. Dr. rer. nat. Martin Schell & Prof. Dr.-Ing. Thomas Wiegand
Executive Directors Fraunhofer HHI

THE FRAUNHOFER-GESELLSCHAFT



The Fraunhofer-Gesellschaft is the leading organization for applied research in Europe. Its research activities are conducted by 67 institutes and research units at locations throughout Germany. The Fraunhofer-Gesellschaft employs a staff of 24,000, who work with an annual research budget totaling more than 2.1 billion euros. Of this sum, more than 1.8 billion euros are generated through contract research. More than 70 percent of the Fraunhofer-Gesellschaft's contract research revenue is derived from industry and from publicly financed research projects. International collaborations with excellent research partners and innovative companies around the world ensure direct access to regions of greatest importance for present and future scientific progress and economic development.

THE FRAUNHOFER HEINRICH HERTZ INSTITUTE HHI

INNOVATIONS FOR OVER 85 YEARS

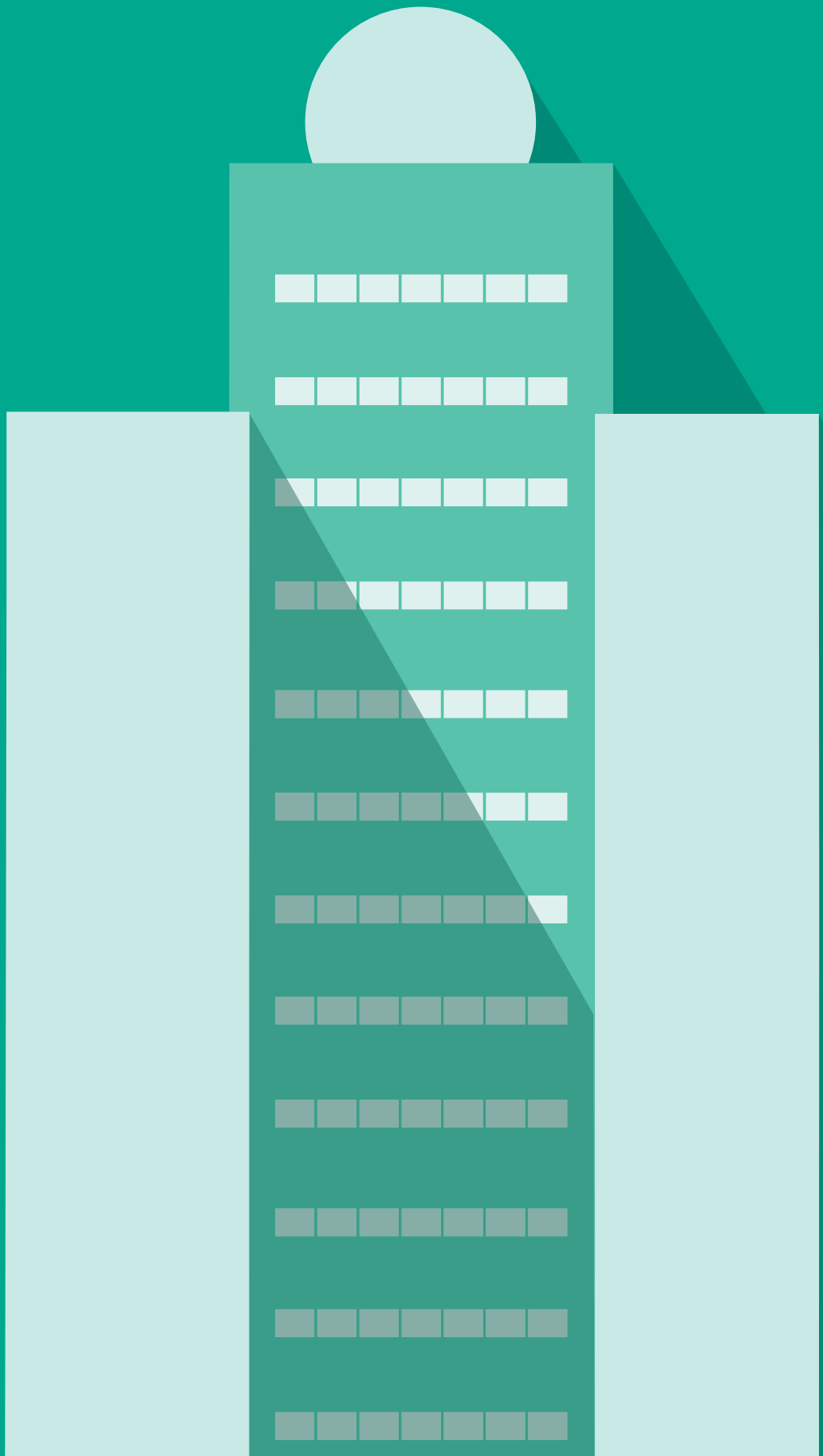
The Berlin-based research institute was founded in 1928 as the Heinrich Hertz Institute for Oscillation Research. HHI with today's focus on digital infrastructure is part of the Fraunhofer-Gesellschaft since 2003.

In its history, Fraunhofer HHI has often produced results with global visibility. Recent successes are that about every second bit is characterized at two points by HHI technologies on the Internet:

- Nearly 50 percent of the bits transported via the Internet are compressed using the video coding standard H.264/AVC, co-developed by Fraunhofer HHI.
- With a 50 percent chance a bit while being transmitted via the Internet hits a photonic component with a core developed at Fraunhofer HHI, sometimes even built in the clean room of the institute.

The diversity of the topics at Fraunhofer HHI is reflected by the setup of the institute's departments. Around 440 researchers work at three locations in the areas of photonic networks and systems, photonic components, fiber optical sensor systems, wireless communications and networks, vision and imaging technologies as well as video coding and analytics.

FRAUNHOFER HHI AT A GLANCE

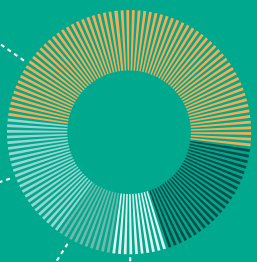


TOTAL BUDGET

49,2 M
2013

Investment: **3,4 M**

47,4%
Orders from the industry



18,9%
National projects

8,3%
EU projects

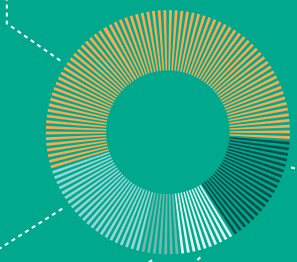
7,5%
Other orders

17,9%
Basic funding

47,4 M
2014

Investment: **4,2 M**

54,6%
Orders from the industry



14,8%
National projects

8,9%
EU projects

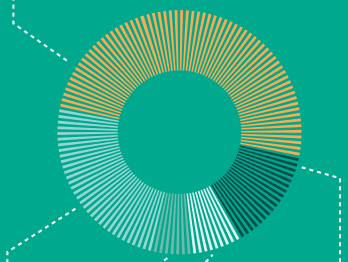
4,2%
Other orders

17,5%
Basic funding

49,2 M
2015

Investment: **6,2 M**

49,8%
Orders from the industry



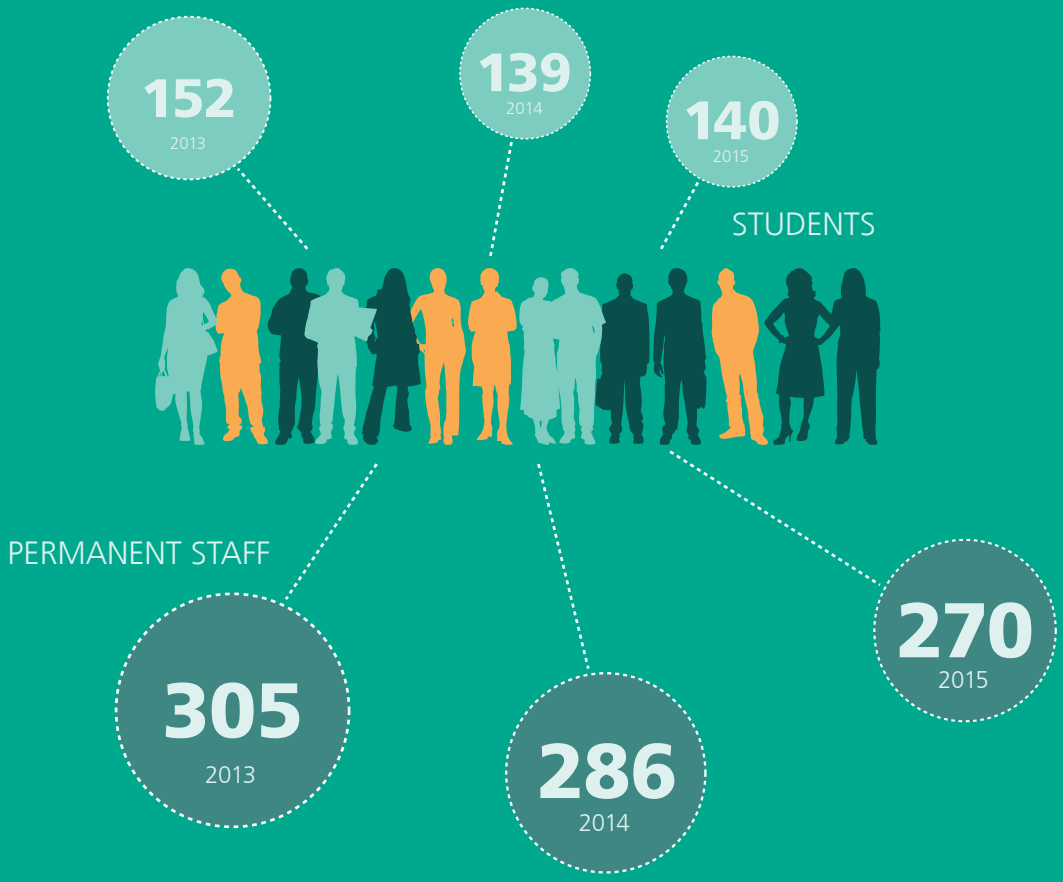
13%
National projects

6,5%
EU projects

5,7%
Other orders

25%
Basic funding

STAFF



CHAIRS

TECHNISCHE UNIVERSITÄT BERLIN

Image Communication/ Image Processing
Prof. Dr.-Ing. Thomas Wiegand

Network Information Theory
Prof. Dr.-Ing. Slawomir Stanczak

Optic and Optoelectronic Integration
Prof. Dr. rer. nat. Martin Schell

Private Lecturers:

Priv.-Doz. Dr. rer. nat. Volker Jungnickel
Priv.-Doz. Dr.-Ing. Oliver Schreer
Priv.-Doz. Dr.-Ing. Gerhard Wunder

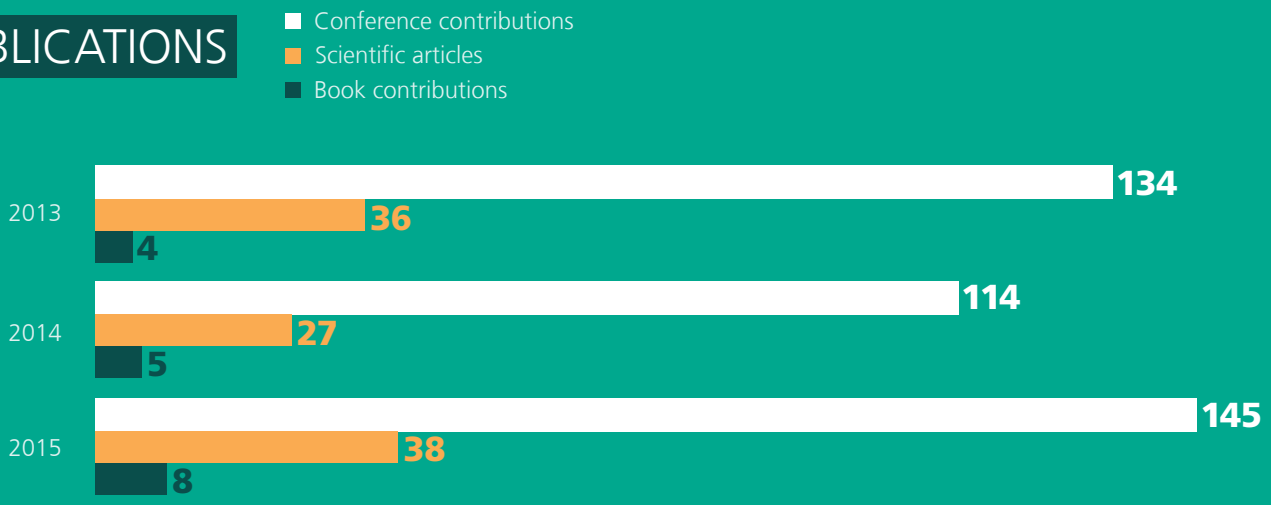
HUMBOLDT-UNIVERSITÄT ZU BERLIN

Visual Computing
Prof. Dr.-Ing. Peter Eisert

CLAUSTHAL UNIVERSITY OF TECHNOLOGY

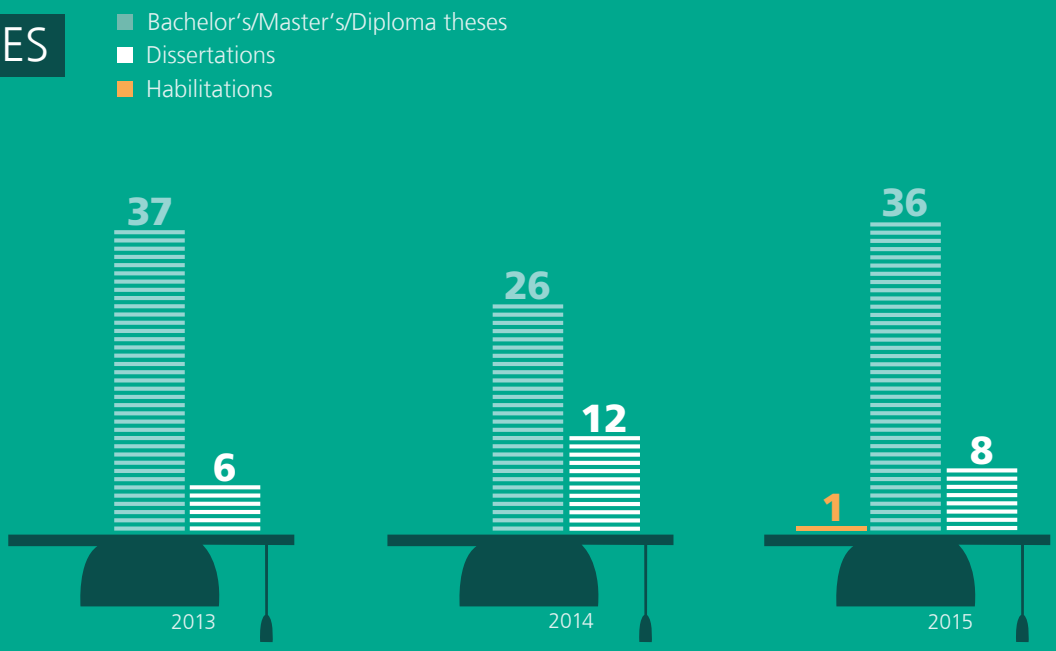
Applied Photonics
Prof. Dr. rer. nat. Wolfgang Schade

PUBLICATIONS



A list of all publications for the years 2013-2015 can be found in a separate brochure.

THESES



LECTURES AND SEMINARS

BOARD OF TRUSTEES

THE BOARD OF TRUSTEES ADVISES THE EXECUTIVE DIRECTORS OF THE INSTITUTE AND PROMOTES CONTACTS OF THE INSTITUTE TO ORGANIZATIONS AND THE INDUSTRY.

Prof. Dr.-Ing. Klaus Petermann, Institute of High-Frequency and Semiconductor System Technologies, Chairman of the Board of Trustees, Technische Universität Berlin

Dr.-Ing. Werner Mohr, subst. Chair of the Board of Trustees, Head of Research Alliances, Nokia Solutions and Networks GmbH & Co KG

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MinDirig Dr. Andreas Goerdeler, German Federal Ministry for Economic Affairs and Energy

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Dr. rer. pol. Michael Meyer, Vice President Government Affairs & Policy, Vice President Strategy & Business Development Germany, Siemens Healthcare GmbH

Prof. Dr. rer. nat. Klaus-Robert Müller, Machine Learning/Intelligent Data Analysis, Technische Universität Berlin

Prof. Dr. rer. nat. Ralf Reulke, Department of Computer Science, Humboldt-Universität zu Berlin

Dr. Fiona Williams, Research Director, Ericsson Eurolab Deutschland GmbH

Dr. Chris Winkler, Head of Research & Senior Principal, Siemens AG, Corporate Technology

NETWORK AND AWARDS

FRAUNHOFER HHI HAS AN INTERNATIONAL FOCUS AND IS ALSO CLOSELY LINKED WITH THE GERMAN RESEARCH LANDSCAPE.

Member of Fraunhofer groups:

- Microelectronics
- Information and Communication Technology (guest)
- Defense and Security (guest)

Member of Fraunhofer innovation clusters:

- Life Cycle Engineering
- Next Generation ID

Member of Fraunhofer alliances:

- Ambient Assisted Living
- Big Data
- Digital Media
- Embedded Systems
- Space
- Vision

From 2013 – 2015 the research work of Fraunhofer HHI scientists was honored with various awards. Including, among others, the following awards:

2015 | At its 150th anniversary, the International Telecommunication Union (ITU) honored the video coding standards H.264/AVC and H.265/HEVC with an ITU150 Prize as pioneering innovations. Prof. Wiegand received the award. Other ITU150-prizes went to Robert Kahn for the Internet Protocol or Martin Cooper for the first mobile phone.

2015 | For her PhD thesis „Image-Based Approaches for Photo-Realistic Rendering of Complex Objects" Dr. Anna Hilsmann received the Science Award of the Association of Berlin Merchants and Industrialists. The award was presented by Prof. Dr. Peter Deuflhard (l.), jury president, and CEO of the VBKI Udo Marin.

2014 | For their article „The New High Efficiency Video Coding Standard" Benjamin Bross (photo), Detlev Marpe and Heiko Schwarz got the „Certificate of Merit" Award of SMPTE Journal.

2014 | The Emmy in the category Technology & Engineering was given to the Moving Picture Experts Group (MPEG) for the development of the MPEG-2 transport stream standards. Dr. Thomas Schierl was a recipient of the award.

TECHNOLOGIES AND SOLUTIONS

Visible Light Communication: high-speed Internet from the ceiling lamp

The demand for wireless communication networks in buildings will continue to increase in coming years. Visible Light Communication offers an alternative by using LED-based light sources for simultaneous data transmission. This significantly expands network capacity while maintaining the mobility desired by users. Optical data transmission avoids all electromagnetic interference with wireless networks and does not use radio frequencies by definition.

Data rates of more than 1 Gbit/s and latencies of less than 2 ms are possible with conventional LEDs, for instance to support broadband video streaming at the highest quality (2/4/8K) and in real-time. A conventional LED lamp becomes a powerful optical WiFi transmitter with just a few add-on components. For transmitting data, the LED is turned on and off in a fast rhythm by a special modulator while being invisible to humans.

Terahertz technology ready for industrial applications: measuring heads made of standard components

Terahertz is a new technology for the non-destructive inspection of components and surfaces. So far the devices and especially the measuring heads have been expensive and unwieldy. Researchers at Fraunhofer HHI have managed to develop much more compact and therefore lower-cost measuring heads. They are significantly easier to handle. Initial prototypes of the terahertz sensor system are already being used in the production of plastic pipes. They are used directly in the production line in order to monitor the pipe wall thickness. Inspecting lacquers and coatings on fiber composite materials is another future application.

The principle used by Fraunhofer HHI to generate terahertz radiation is based on an optoelectronic process. A special semiconductor is used to transform laser light pulses into electrical terahertz pulses that are only one billionth of a second long.

Panorama UHD video production and live streaming with the OmniCam-360

Fraunhofer HHI has developed a series of scalable multi-camera systems with and without mirrors in order to produce high-resolution 2D and 3D panorama video recordings for immersive applications. Three different versions of the OmniCam-360 are equipped with 10, 20 or 24 micro-HD cameras and record a UHD panorama video with a maximum resolution of 10,000 x 2,000 pixels. The flexible system is therefore suitable for a wide variety of 360 degree panorama productions. With its special mechanical and optical characteristics, the mirror-based OmniCam-360 permits the optimum arrangement of several HD cameras for the parallax-free recording (stitching) of video panoramas in real time.

Other important features of the lightweight camera system are its robustness and the compact format. This permits easy handling and minimal adjustment and calibration effort. The camera system has already proven its high performance, functionality and practicability in various commercial productions.

5G: mobile networks of the next generation

The fifth-generation mobile network assumes a key position in the communication landscape of the future. Autonomous driving, Industry 4.0, the Internet of Things, and the tactile Internet for wireless object control in real time require a quantum leap in efficiency, the scope of performance and the availability of mobile communication networks. The new 5G wireless communication technology will be the basis for the digital infrastructure of the future. The industry plans to deploy the first 5G-capable networks starting in 2020. In a consortium with manufacturers, network operators, users and research institutions – especially TU Berlin and Fraunhofer FOKUS – Fraunhofer HHI will realize prototypes of the communication technology infrastructure for 5G early on, allowing it to be experienced in the 5G testbed of Berlin.

New wireless interfaces will enable a continuous increase in the usable data rate of wireless channels compared to today's standards as well as transmission with ultra-low latency and access to many different data sources.

HEVC – software and hardware for efficient encoding and decoding

The next generation of ultra-high resolution televisions uses 4K resolution (3,840 x 2,160 pixels) – four times the full HD resolution. Higher-resolution images compared to HD video result in larger data volumes. Compression is required for transmission. Compared to the H.264/MPEG4-AVC video coding standard, the next-generation ITU-T and ISO/IEC video coding standard – H.265/MPEG-HEVC or HEVC for short (High Efficiency Video Coding) – reduces the data rate by 50 percent with the same image quality. The standard was co-developed by Fraunhofer HHI through cooperation and joint standardization together with renowned manufacturers in the field of information technology.

HEVC encoders and decoders developed by Fraunhofer HHI support the transmission of ultra-high definition (UHD) video data in real time and are a world leader when it comes to quality. The progressive architecture of the encoders and decoders uses resources efficiently and fits a wide variety of applications.

Battery and Sensor Test Center

The Battery and Sensor Test Center (BST) in Goslar is operated jointly by Fraunhofer HHI and the Energie-Forschungszentrum Niedersachsen (EFZN). Joint activities focus on the research, development, testing and subsequent certification of novel safety concepts for stationary battery systems. Apart from existing centers, the BST enables novel limit load tests on batteries, even until they catch fire. The BST is equipped with two furnaces with waste gas purification and downstream waste gas analytics for tests on batteries and innovative protective coverings. In addition to the electrical test stands for battery cell and module tests, complex battery systems with a capacity up to 1.2 MW can now also be charged and discharged under climate-controlled conditions. The offering is complemented by fiber optical sensor systems to record thermal state variables and gas analytics for examining the fire gases that are produced.

TiME LAB – TOMORROW'S IMMERSIVE MEDIA EXPERIENCE LAB

The TiME Lab (Tomorrow's immersive Media Experience Lab), which has its home at Fraunhofer HHI, is dedicated to exploring the research and development potential of immersive media technologies. In addition, TiME Lab serves as a showroom for the technologies and systems used in the projection of 2D and 3D video panoramas, thereby expanding the limits of visual representation possibilities. Equipped with a screen of considerable size with an area of 3.35 x 12 meters and a 180 degree curve, as well as a complex projection system with a total of 14 HD projectors, TiME Lab meets all the requirements for creating an unusual and immersive visual experience.

The visual impression is accompanied by a 140-channel multilayer wave field synthesis system (WFS). This audio system reproduces acoustic scenes with very high authenticity. The extraordinary auditory experience further intensifies the impression of immersion in the visual experience.

The OmniCam technology is used to realize the panorama recordings, which the TiME Lab can present in optimum quality. The mirror-based multi-camera system, which is now able to produce 360 degree video panoramas in its third generation, offers high versatility and can serve a large number of different application scenarios. Ten vertically arranged micro-HD cameras are used for the production of 360 degree video panoramas. The cameras are deflected by a respective 36 degree mirror segment into the horizontal. The real-time transmission of video panoramas is realized with the help of the video coding solutions and the Real Time Stitching Engine (RTSE) especially developed at Fraunhofer HHI. Virtually experiencing sports events or live concerts becomes possible with the high degree of immersion offered by the video panoramas. A fourth generation of the OmniCam is planned for the future.

Thanks to the optimized interplay of the OmniCam technology and the possibilities offered by TiME Lab as a showroom, a chain is formed from panorama production to projection. It covers a broad range of application scenarios, both in the video projection field and in the Virtual Reality segment that is increasingly gaining importance. The application scenarios of the TiME Lab technologies are extended by the mobile version of the TiME Lab.

The TiME Lab team works on trendsetting, innovative projects together with top-class partners from arts, culture, media, sports and industrial environments.

3IT – INNOVATION CENTER FOR IMMERSIVE IMAGING TECHNOLOGIES

Network, research facility, development laboratory, showroom – 3IT, the Innovation Center for Immersive Imaging Technologies, is all of that. In a pre-competitive environment it offers opportunities for networking, establishing contacts and developing new products to drive innovations in the field of immersive imaging technologies.

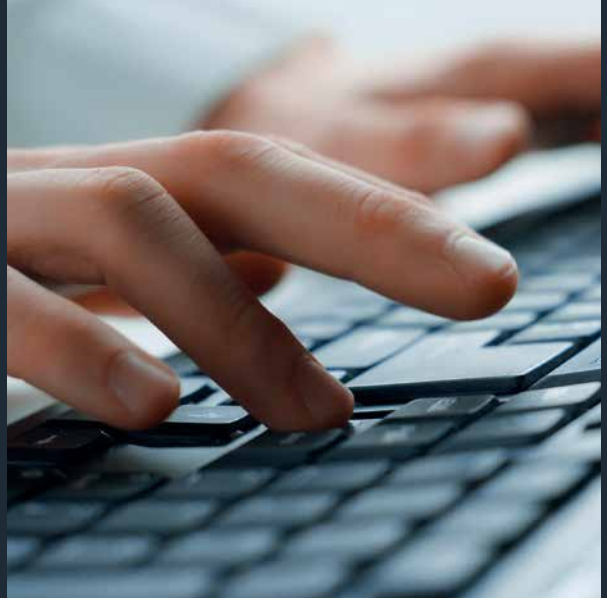
3IT is a venue for testing new products and systems as well as presenting them to various target groups. Here the focus is on technologies such as 3D, UHD, HFR, VR and HDR as well as imaging and video applications for medical and industrial use. 3IT promotes new synergies in product development, marketing and sales. Telecommunication companies, medical technology manufacturers, universities, research institutions, film production companies and camera and display manufacturers partner with the 3IT.

CINIQ CENTER/SMART DATA FORUM

The CINIQ – Center for Data and Information Intelligence – is located in the immediate vicinity of the 3IT. It is an attractive venue for the transfer of technologies and information in the triangle of innovation, science and industry. Events with trendsetting themes such as Big & Smart Data, Cloud Computing and Industry 4.0 are held regularly at the 500 square meter venue offering space for up to 200 guests. One of the focal points is transferring knowledge to small and medium-sized enterprises. An important task of the CINIQ is the implementation of the Smart Data Forum, a demonstration and experience space for Smart Data solutions and a networking platform at European and international levels funded by the German Federal Ministry for Economic Affairs and Energy (BMWi).

The Smart Data Forum supports networking with other initiatives in the Big & Smart Data field, promotes the transfer of technology innovations to SMEs and boosts marketing of results from the "Smart Data – Data Innovations" research program through its international presence.

The forum is operated by a consortium of the German Research Center for Artificial Intelligence (DFKI), the Fraunhofer HHI and the Fraunhofer Big Data Alliance. It works closely with accompanying research under the Smart Data program of the BMWi, consisting of the Research Center for Information Technology (FZI) and the German Informatics Society (GI).



WORKING AT FRAUNHOFER HHI

In addition to excellent working conditions and modern laboratory equipment, Fraunhofer HHI offers a variety of career opportunities, especially in the fields of natural and technical sciences as well as information sciences. The institute as an industry partner develops effective, state-of-the-art and trendsetting solutions jointly with commercial enterprises.

The institute offers numerous opportunities for students, university graduates, young professionals and school graduates to gain insights into working life early on or to start their careers directly. They can apply for student jobs, internships, bachelor's as well as master's theses and postgraduate programs. Fraunhofer HHI also offers apprenticeship training positions:

- Office Manager
- IT Specialist
- Microtechnologist

Continuing education – individual support for employees

At the Fraunhofer HHI every employee has the opportunity to further improve professional knowledge and skills. Fraunhofer HHI offers numerous continuing education programs aligned with the various career stages and key activities. From language courses to job training and program management, individual support is consistently offered.

Promotion of young talents and equal opportunities

Fraunhofer HHI is conducting research today for the digital infrastructure of tomorrow. The promotion of young scientific talents and equal opportunities is a natural component of our human resources strategy.

Girls'Day

Once a year Fraunhofer HHI takes part in the nationwide Girls'Day, inviting female students to the institute and offering practical insights into the working world. Independent experimentation in the laboratory and various workshops are intended to familiarize the female students with STEM careers in particular.

Cooperation with Berlin school

Fraunhofer HHI has been cooperating with Albrecht Dürer High School in the Neukölln district of Berlin since September of 2015. Since then students have the opportunity to independently explore the diversity of career opportunities in application-oriented research through visits or internships and to supplement the curriculum with practical experience. This gives the students professional perspectives of technology and natural sciences beyond the context of STEM education.

DID YOU KNOW, THAT...

- the Heinrich Hertz Institute was established in 1928?
- Fraunhofer HHI maintains a full-service semiconductor fabrication plant in Berlin, in which several of the worldwide fastest optoelectronic components for data transmission are constructed, such as photodetectors, lasers, and modulators?
- researchers of the Fraunhofer HHI, as part of the international expert groups for standards in video-compression (VCEG and MPEG), have already received the Technology & Engineering Emmy three times?
- the foundation for the actual world standard for motion picture transmission – the video coding standard H.264/MPEG-AVC – was co-developed at Fraunhofer HHI?
- the first 3D live concert was made possible through the help of the Fraunhofer HHI-de veloped camera assistance system, STAN?
- researchers of Fraunhofer HHI have developed a method in which data can be transmitted using standard LED lights that can reach transmission speeds of over 1 Gbit/s?
- thanks to the OmniCam-360 you can experience the 2014 World Cup soccer final in a 180 degree UHD-panorama video at the FIFA museum or see the Berlin Philharmonic Orchestra in concert through Virtual Reality glasses in a 360 degree view?
- a majority of the quality management processes of Fraunhofer HHI are certified in accordance with DIN ISO 9001:2008?

kiwa
Partner for progress

Number 91468
Issued on 11-03-2016
Valid from 02-04-2016
Valid until 14-09-2018
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Certificate

Kiwa International Cert GmbH
certifies that

Fraunhofer Institute for Telecommunications
Heinrich Hertz Institute
Einsteinufer 37
10587 Berlin

with location:
Fraunhofer Institute for Telecommunications
Heinrich Hertz Institute, Department Fiber Optical Sensor Systems
Am Stollen 19B
38640 Goslar

for the scope
Research, development and production in the fields of photonics and electronics

has implemented and applies a Quality Management System, which is in compliance with the requirements of

ISO 9001:2008

Kiwa International Cert GmbH
Managing Director

Kiwa International Cert GmbH
Head of Certification Body

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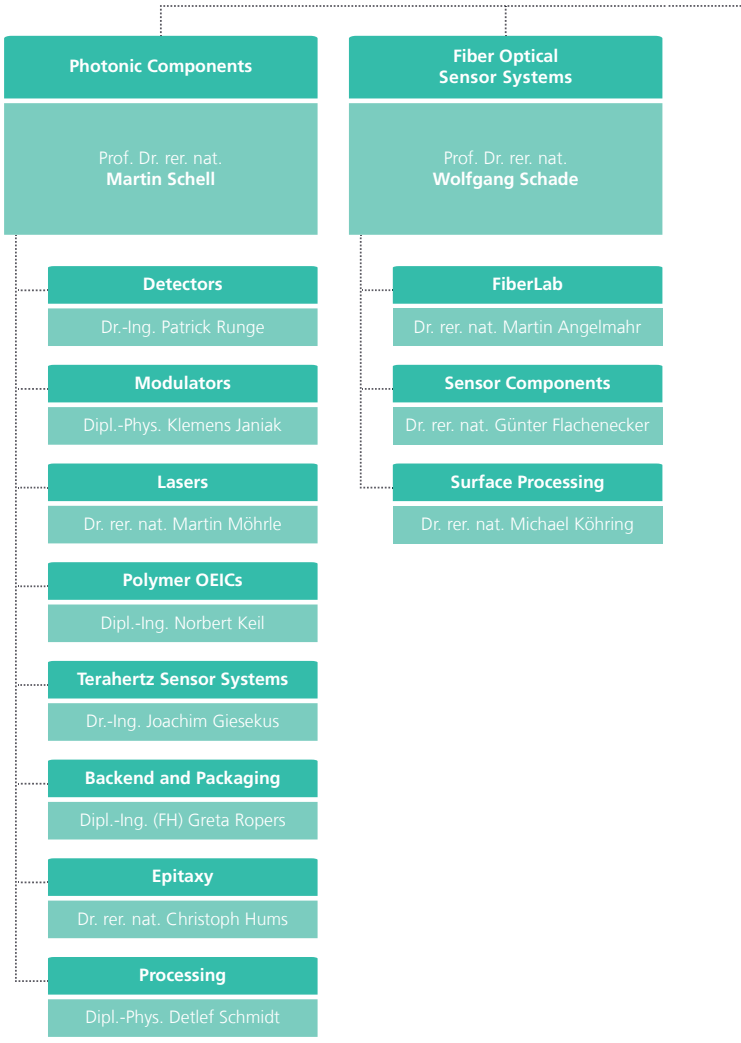
D-ZM-16332-01-00

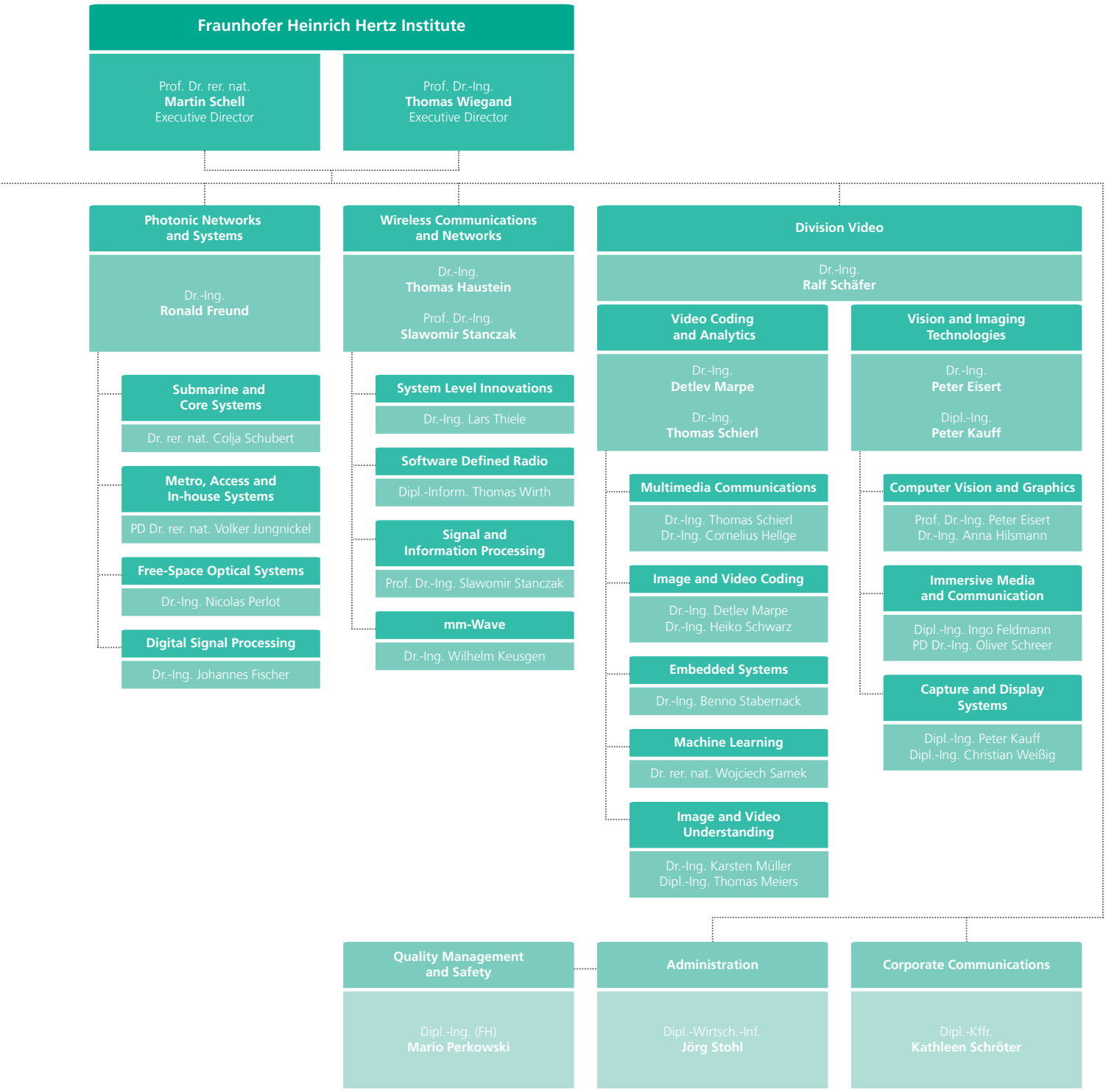
ORGANISATIONAL CHART

DEVELOPMENTS IN THE ORGANISATIONAL CHART OF FRAUNHOFER HHI

Since January 1, 2014 Prof. Dr. rer. nat. Martin Schell and Prof. Dr.-Ing. Thomas Wiegand are the new executive directors of the Fraunhofer HHI. They succeeded Prof. Dr.-Ing. Hans-Joachim Grallert, who has been executive director since 2004.

To be better prepared for future developments and current research topics, the video departments of the Fraunhofer HHI were reorganized in 2015. From the previous departments "Image Processing" and "Interactive Media – Human Factors", the two new departments "Video Coding and Analytics" as well as "Vision and Imaging Technologies" emerged. At the same time the Division Video was established and is since headed by Dr.-Ing. Ralf Schäfer. In mid-2015 Dr. Schäfer was also appointed deputy executive director of the Fraunhofer HHI. Previously he was head of the Image Processing department from 1989 until 2014.




Fraunhofer Heinrich Hertz Institute
Prof. Dr. rer. nat.
Martin Schell
Executive Director
Prof. Dr.-Ing.
Thomas Wiegand
Executive Director
Photonic Networks and Systems
Dr.-Ing.
Ronald Freund
Submarine and Core Systems
Dr. rer. nat. Colja Schubert
Metro, Access and In-house Systems
PD Dr. rer. nat. Volker Jungnickel
Free-Space Optical Systems
Dr.-Ing. Nicolas Perlot
Digital Signal Processing
Dr.-Ing. Johannes Fischer
Wireless Communications and Networks
Dr.-Ing.
Thomas Haustein
Prof. Dr.-Ing.
Slawomir Stanczak
System Level Innovations
Dr.-Ing. Lars Thiele
Software Defined Radio
Dipl.-Inform. Thomas Wirth
Signal and Information Processing
Prof. Dr.-Ing. Slawomir Stanczak
mm-Wave
Dr.-Ing. Wilhelm Keusgen
Division Video
Dr.-Ing.
Ralf Schäfer
Video Coding and Analytics
Dr.-Ing.
Detlev Marpe
Dr.-Ing.
Thomas Schierl
Multimedia Communications
Dr.-Ing. Thomas Schierl
Dr.-Ing. Cornelius Hellge
Image and Video Coding
Dr.-Ing. Detlev Marpe
Dr.-Ing. Heiko Schwarz
Embedded Systems
Dr.-Ing. Benno Stabernack
Machine Learning
Dr. rer. nat. Wojciech Samek
Image and Video Understanding
Dr.-Ing. Karsten Müller
Dipl.-Ing. Thomas Meiers
Vision and Imaging Technologies
Dr.-Ing.
Peter Eisert
Dipl.-Ing.
Peter Kauff
Computer Vision and Graphics
Prof. Dr.-Ing. Peter Eisert
Dr.-Ing. Anna Hilsmann
Immersive Media and Communication
Dipl.-Ing. Ingo Feldmann
PD Dr.-Ing. Oliver Schreer
Capture and Display Systems
Dipl.-Ing. Peter Kauff
Dipl.-Ing. Christian Weißig
Quality Management and Safety
Dipl.-Ing. (FH)
Mario Perkowski
Administration
Dipl.-Wirtsch.-Inf.
Jörg Stohl
Corporate Communications
Dipl.-Kffr.
Kathleen Schröter

PHOTONIC NETWORKS AND SYSTEMS

The Photonic Networks and Systems department researches new technologies and develops solutions for high-performance optical transmission systems to be used for in-house, access, metropolitan, wide-area and satellite communication networks. Here researchers are focusing on increasing the capacity as well as improving security and energy efficiency. The department has the latest measurement technology, very well equipped system laboratories, powerful simulation tools and the ability to conduct field tests.

CONTACT

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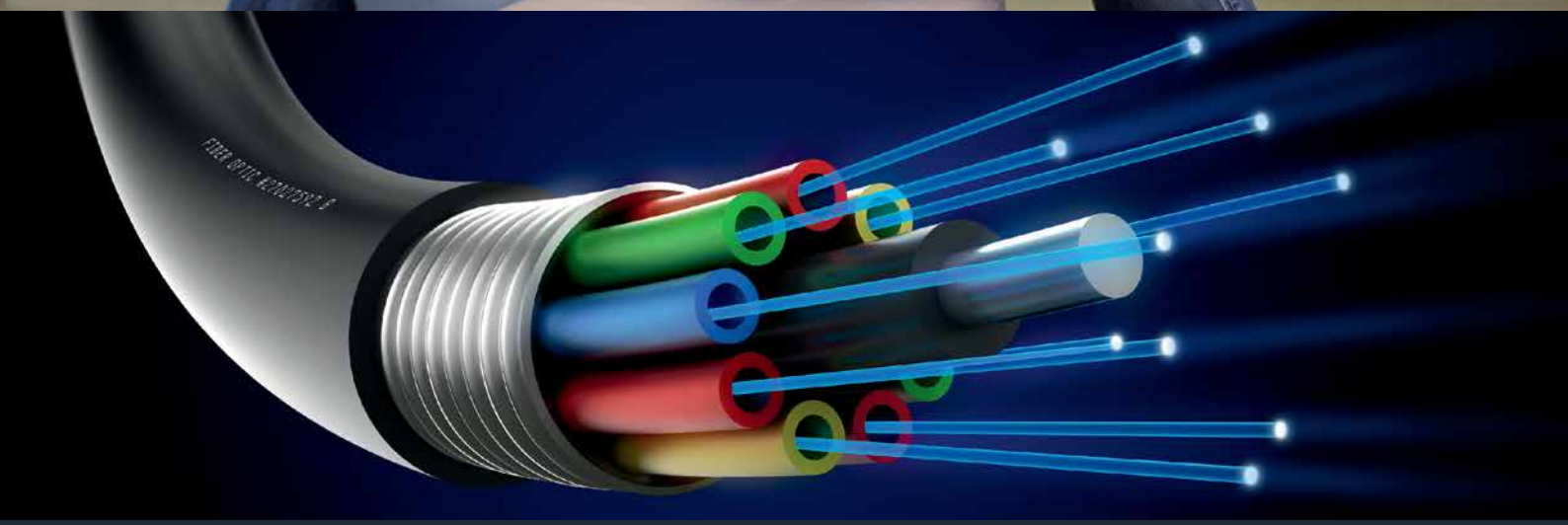


RESEARCH AND DEVELOPMENT

- Elastic optical networks with scalable terabit/s channel capacity
- Terabit/s satellite communication
- Planning of cost effective, hybrid access networks
- Visible Light Communication (VLC)

PHOTONIC NETWORKS AND SYSTEMS

Elastic optical networks with scalable Terabit/s channel capacity

Network operators increasingly have to invest in the flexibility and scalability of their networks. Currently oversized transmission capacities in the network are assigned more or less rigidly. Disassociating from this network sizing in favor of the demand-based allocation of broadband resources in the optical layer enables the more efficient use of the existing, installed fiber optics infrastructure by making capacity reserves available. The research objectives are optical transmission systems with flexible data rates that can be configured through software, able to provide transmission capacities per channel in a fine granularity up to the Tbit/s range over several thousand kilometers.

Terabit/s satellite communication

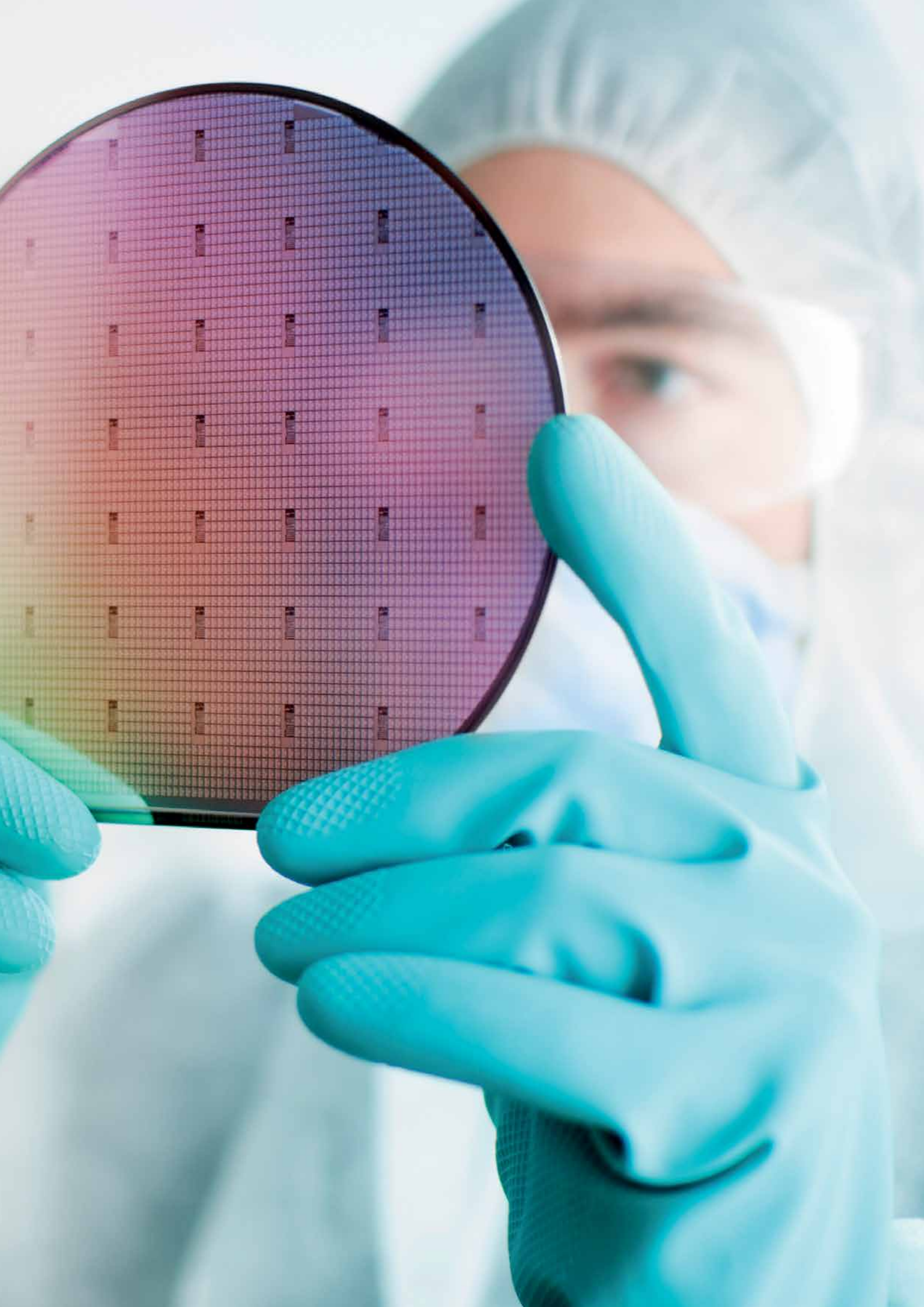
To account for increasing throughput requirements, future telecommunication satellites in geostationary orbit are being sized for Terabit/s throughput. Fraunhofer HHI is developing optical light communication solutions for this purpose, meeting the strict requirements for antenna gain (beam divergence in the 10 µrad range). The required data rates in the Tbit/s range are realized with the help of wavelength-division multiplexing technology (WDM) in the 1550-nm transmission window of the atmosphere. Prototypes designed on behalf of European Space Agency (ESA) enable bidirectional transmission between the ground station and satellite, even in case of atmospheric turbulences.

Planning of hybrid access networks

Fiber optical technology in particular is fit for the future in order to realize high data rates in the access network. However, expanding a fiber optical network is associated with high costs, especially for fiber digging. Hybrid access networks significantly reduce the expansion costs in the last mile by also utilizing wireless communication technologies including WLAN, LTE, millimeter wave or free-space optical data transmission. Fraunhofer HHI is working with partners to develop software modules for planning cost-optimized hybrid access networks, successfully implementing these in bandwidth expansion projects in Germany.

Visible Light Communication

Optical wireless data communication is an attractive solution for areas with especially high security and electromagnetic compatibility requirements. Fraunhofer HHI has created a transmission technology that uses conventional LED lamps for room lighting to realize simultaneous data transmission. Data rates up to several Gigabits per second using wavelength-division multiplexing can be achieved with this technology.



PHOTONIC COMPONENTS

The volume of data transmitted over the Internet doubles approximately every two years. Through intensive research and development, the Photonic Components department has contributed to the functioning of the Internet during this growth. Nowadays, about every second bit comes into contact with technology from Fraunhofer HHI on the way to or from the recipient. Integrated optical circuits are developed in addition to research and development for optoelectronic semiconductor components. The Berlin scientists are also conducting research in related technology fields such as infrared sensor systems, terahertz spectroscopy and high-performance semiconductor lasers for industrial and medical applications.

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PHOTONIC COMPONENTS

Indium phosphide (InP) for processor-to-processor communication

Processor-to-processor connections will be realized optically in the future. This requires switching matrices that connect the input channels with various output channels. Fraunhofer HHI in cooperation with IBM has developed a quadruple optical semiconductor amplifier chip that, in the flip-chip version, is integrated into the silicon waveguide-based 64x64 IBM switching matrix and compensates for its optical losses. Thereby Fraunhofer HHI has taken another step in data center/computer-related applications.

InP Wafer Foundry for industry and research

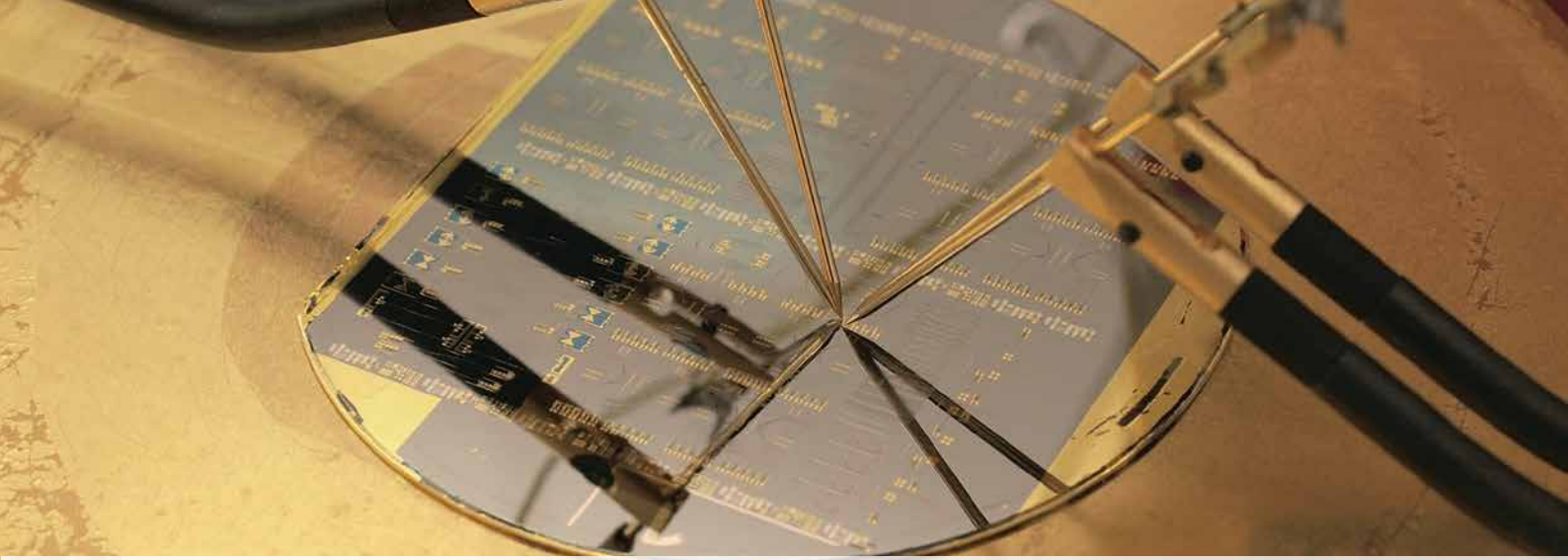
Users in research and industry have the opportunity to create complex PICs (photonic integrated circuits) with the InP Wafer Foundry as well as software tools developed especially for this purpose by Fraunhofer HHI. These circuits are subsequently fabricated at the institute in multi-project runs. Here the customer can combine generic building blocks (BBs) developed by Fraunhofer HHI into a PIC as desired. The HHI library currently includes 20 GHz lasers, optical amplifiers, optical grids, 45 GHz photodiodes, optical tapers, 1 dB/cm waveguides and HF supply lines as well as elements for wavelength and polarization diversity, and is always being expanded. Examples for the successful use of this platform include complex mode multiplexers, optical gyroscopes, THz transmitters and stress sensors in the rotor blades of a helicopter.

Terahertz sensor system for industrial process control: T-Rex

Around 8 billion meters of plastic pipes are installed annually around the world. This corresponds to 200 times the circumference of the earth and ties up 15.8 million tons of raw materials that are getting increasingly scarce and expensive. That is why pipe manufacturers are increasingly realizing multi-layer pipes for economical and ecological reasons, for instance with foam inserts. However, this is causing the failure of established measuring technologies such as ultrasound.
The objective of project T-Rex is to develop a terahertz-based measuring and control system for inline process control in the extrusion of plastic pipes. Terahertz in contrast to ultrasound is contact-free, not dependent on temperature and can also measure foamed pipes and corrugated pipes for the first time. Savings up to 100,000 euros per year can be realized on a single extrusion line through the use of this new technology.

Medical and industrial sensors – micro-rings

Sensor technology and diagnostics are putting steadily increasing demands on both the sensitivity and the compactness of measuring devices. That is why Fraunhofer HHI is developing integrated optical micro-rings that are robust, sensitive and low priced. They permit the highly precise measurement of concentrations and refraction indexes. Through the functionalization of the surface with antibodies or aptamers, the highly specific detection of individual biomolecules is possible in addition. Applications are found in personalized medicine and point-of-care testing with minimal sample sizes (for example infant blood). Further development with clinical partners is ongoing.



Foundry service for InP-based photonic integrated circuits.

Fraunhofer HHI's PolyBoard technology for integrated photonic components in telecom, datacom and sensing applications. Optical micro ring resonators for innovative Point-of-Care diagnostics.

The terahertz sensor head developed by Fraunhofer HHI has the size of a 1-euro coin.

RESEARCH AND DEVELOPMENT

- Detectors, lasers, and modulators for data transmission
- Indium phosphide and polymer based platforms for optoelectronic integration
- Terahertz components and systems, e.g. for non-destructive materials testing
- Sensors for the environment and medicine

FIBER OPTICAL SENSOR SYSTEMS

The Fiber Optical Sensor Systems department is working on a new generation of photonic sensors used in measuring and control systems. These systems are used industrially for early hazard detection, energy management, robotics, and medical technology. The sensors set themselves apart with extreme miniaturization, excellent communication and network capabilities, and high energy efficiency. To produce such sensors, Fraunhofer HHI researches nanostructured materials and develops processing methods for integrated optical components with ultra-short light pulses.

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FIBER OPTICAL SENSOR SYSTEMS

FiberLab technology platform

Fraunhofer HHI provides the extremely flexible and powerful fiber optical technology platform called FiberLab with the help of femtosecond laser technology. It was realized in the course of numerous different research and development projects. The FiberLab platform is structured with the subareas of FiberNavi, FiberChem and FiberSens, making possible several applications including 3D ShapeSensing, Cyberglove and FOMCAS.

3D ShapeSensing: The Goslar scientists developed the world's thinnest fiber optical 3D shape sensor for the reconstruction of a 3D profile with the help of a standard single-mode fiber. These sensors are used in the oil and gas industry as well as numerous Industry 4.0 applications, in medical technology and in maritime applications. Customer-specific, multifunctional sensors are created through coupling with additional fiber optical sensors for pressure, temperature, and strain measurement.

Cyberglove: The department has developed a fiber optical glove as an innovative human-machine interface for the virtual control of robots or the high accuracy capture of movements. Data can be transferred to a higher-level system over WiFi with a low latency so the user's freedom of movement is not restricted.

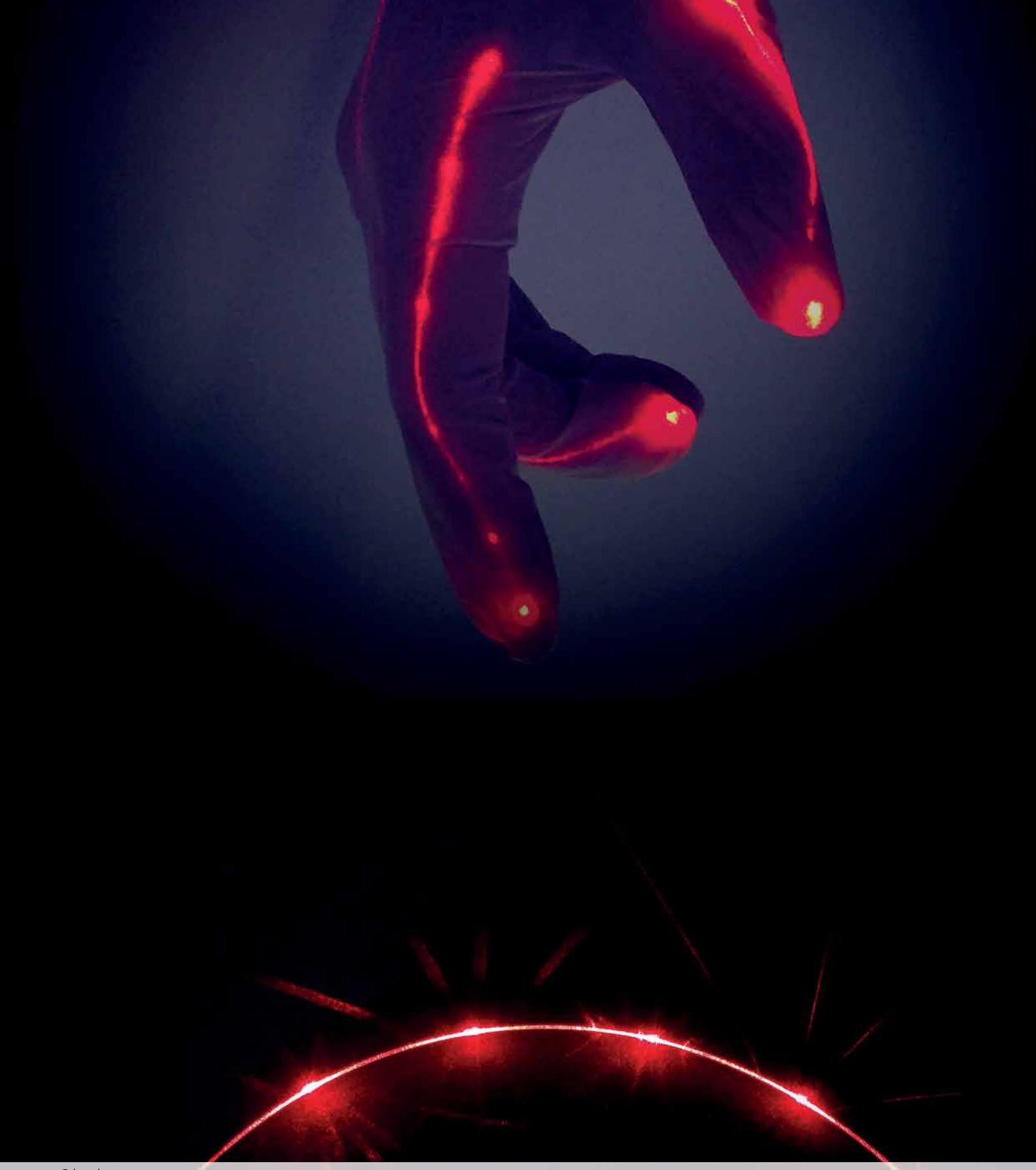
FOMACS: The mobile, miniaturized fiber optical measurement and control system (FOMACS) enables the precise recording and evaluation of fiber optical sensor signals. These data can be transmitted to a higher-level system in a customer-specific format per broadcast.

Material processing and assembly using ultra-short pulse technology

Ultra-short laser technology is used for the functionalization of surfaces on various materials, making them suitable for battery electrodes or to produce hydrogen using excess electrical energy. They can also be used in such a way for the passive cooling of electronic components and the structuring of PMMA plates for innovative LED lighting. Fraunhofer HHI is planning a pilot production line for large-area material processing to support this application.

Battery and Sensor Test Center

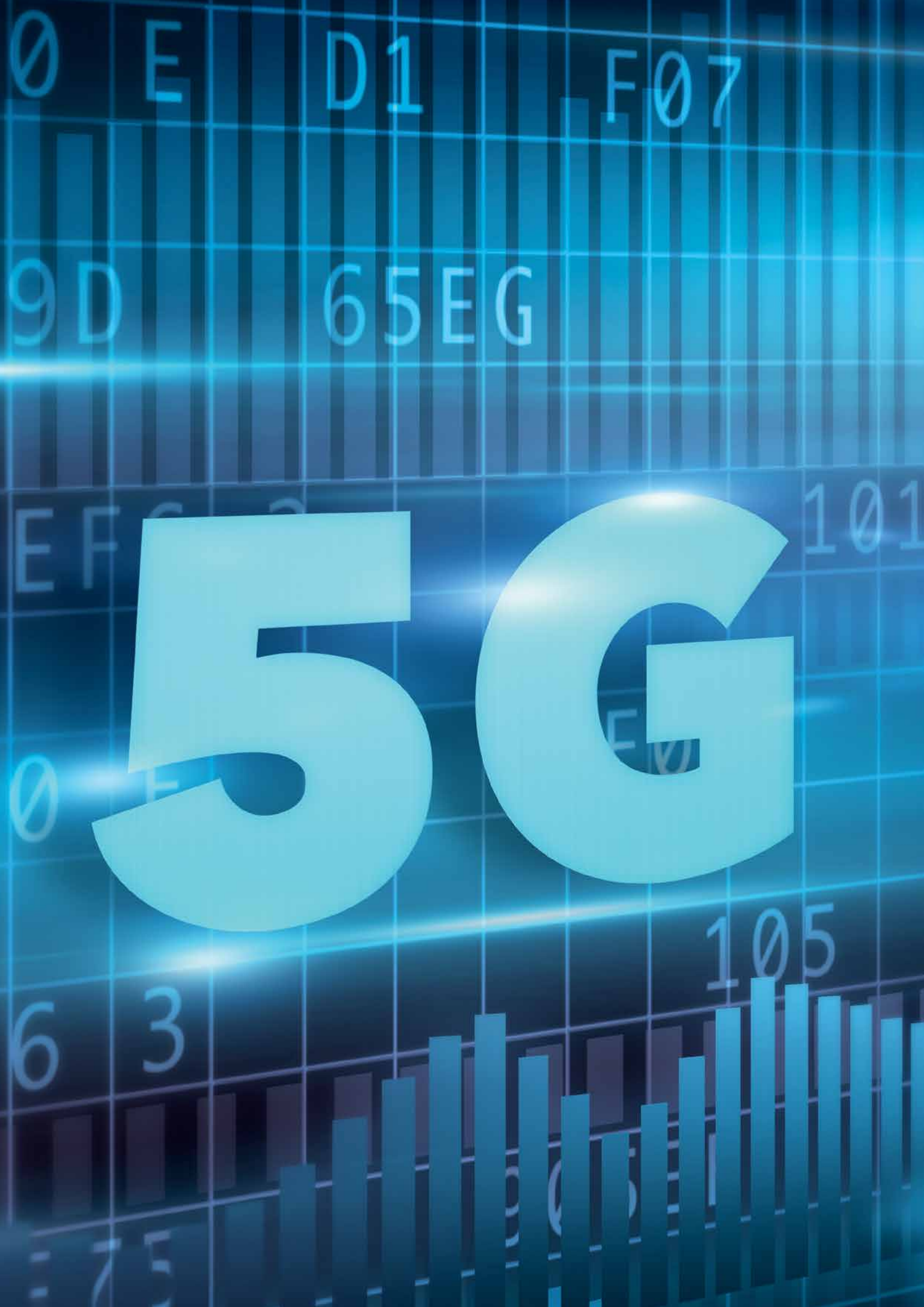
A Battery and Sensor Test Center was also opened at the Goslar site in 2015. New and innovative concepts for expanded battery safety are developed and reviewed here. Lithium ion storage systems that are tested with expanded, both passive and active safety systems in the extreme range take center stage. In addition to single cells, entire battery storage systems are investigated for both stationary and mobile applications. A climate container and several battery test stands with an output up to 1.2 MW are available in addition to two test furnaces. This equipment supports battery abuse tests up to full combustion including gas analysis.



Cyberglove

RESEARCH AND DEVELOPMENT

- Fiber optical micro sensors
- 3D-waveguide processing with ultra-short laser pulses
- Material processing and assembly using ultra-short pulse technology


5G

WIRELESS COMMUNICATIONS AND NETWORKS

The Wireless Communications and Networks department researches on technology and develops solutions for radio-based information transmission. In close cooperation with numerous companies, the researchers make extensive contributions to the theory, concept development and technical feasibility of radio systems. Services offered by the department include scientific studies, simulations, and evaluations at the link and system levels, field measurements, and the development of hardware prototypes.

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WIRELESS COMMUNICATIONS AND NETWORKS

Research for the future of mobile data transmission

Wireless networks are an essential foundation of the digital infrastructure for society, industry, traffic, and medicine. The Wireless Communications and Networks department conducts research on the issues of the future in this field to provide technical solutions that meet the enormous demands for increased data rates, low latency and access to many distributed data sources.

The researchers together with European partners from government, industry, and science have set the direction for important aspects of 5G mobile networks. Future 5G application cases and their requirements were defined. Concepts and technical approaches to solutions were subsequently developed. The results form an input to the foundation for the framework program "5G PPP" (private-public partnership). Currently researchers are working on overcoming fundamental technological challenges for the successful introduction of 5G wireless networks. The department is also making essential contributions to 5G channel measurements and 5G channel models for massive MIMO systems and the frequency range between 6 and 100 GHz.

Also, within the 5G PPP framework, the researchers are investigating new millimeter wave technologies for mobile wireless networks in the areas of wireless access as well as fronthaul and backhaul.

Novel waveforms for new applications

Researchers are investigating novel waveforms for wireless data networks. The goal of this research is an efficient wireless connection for sensors and machines that only transmit small amounts of data sporadically. The researchers investigate and develop new (wireless) waveforms and access methods for uncoordinated and asynchronous transmission for this purpose, meeting the requirements for machine-based communication.

Efficient radio-based communication for industrial processes

The scientists explore radio systems for reliable real-time applications in automation technology. A cognitive distributed learning system was developed for this purpose by the department, delivering robust forecasts of the link and system states based on partial and faulty measurements of the wireless environment. Link failures can therefore be prevented through timely system configuration, improving the reliability and real-time capability of the overall system. This is of major importance for the control of radio-based industrial processes.

Research continues within the area of Industry 4.0. Here the scientists develop an overall concept for high-reliability data transmission with latencies of less than one millisecond for the wireless networking of sensors, actuators, and machines in factory automation.

EVOLUTION OF WIRELESS COMMUNICATIONS

1G
Analog voice services
(car phone)

Revolution
analog - digital

2G
Digital voice services + text messaging
(available globally)

Evolution
Integration of data services

3G
Language *(connection-based)*
+ Data *(packet-based)*

Evolution
IP-based + higher data rates

4G
IP-Data
(voice, email, web, audio/video streaming)

Evolution & Revolution
integration of vertical industries

5G
Control & Management
(Machine Type Communications, Internet of Things + Augmented Reality, Virtual Reality, Ambient Assisted Living)

128-element, dual-polarized cylindrical Massive MIMO antenna consisting of 16 columns each with eight antenna elements.

RESEARCH AND DEVELOPMENT

- Future mobile networks (5G)
- Reliable industrial communication with low latency
- Car-to-car communication
- Multi-antenna systems (MIMO, Massive MIMO)
- Millimeter wave technologies
- Cognitive radio systems and networks
- Software-defined radio
- Machine learning for mobile networks

VISION AND IMAGING TECHNOLOGIES

The Vision and Imaging Technologies department is researching technologies and developing solutions for the entire video processing chain from content creation to final playback. A special focus is on complex 2D/3D analysis and synthesis methods in media, medical and industrial fields of application and in computer vision. Complex solutions for immersive and interactive systems are also developed for this purpose with corresponding innovative camera, sensor, display and projection systems.

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Temporally consistent wide baseline facial performance capture

OmniCam-360

3D Human Body Reconstruction for Virtual Reality.

RESEARCH AND DEVELOPMENT

- 2D- and 3D-image processing
- 3D-capturing and -rendering
- High resolution audio-visual systems
- Human-machine interaction
- System solutions for immersive media

VISION AND IMAGING TECHNOLOGIES

OmniCam-360 delivers content for VR glasses and the Deutsche Bahn Noise Control Information Point

The OmniCam-360 is a camera system developed by Fraunhofer HHI that consists of a special mirror system with ten HD cameras. Their individual images are seamlessly stitched in real time into a UHD video panorama with a spatial resolution of 10,000 x 2,000 pixels. This allows live events to be experienced interactively in a 360 degree video panorama using a tablet, smart phone, and also Virtual Reality (VR) glasses. The viewer feels immersed into the events on site. A 3D-capable extension for cylindrical and spherical panoramas is being actively researched. This technology is used in various applications including the demonstration of noise control measures by Deutsche Bahn. For that, the sounds of passing trains were recorded and realistically presented with a special 3D sound system. This demonstration is called the "Noise Control Information Point".

Video analysis and human-machine interaction in medical technology

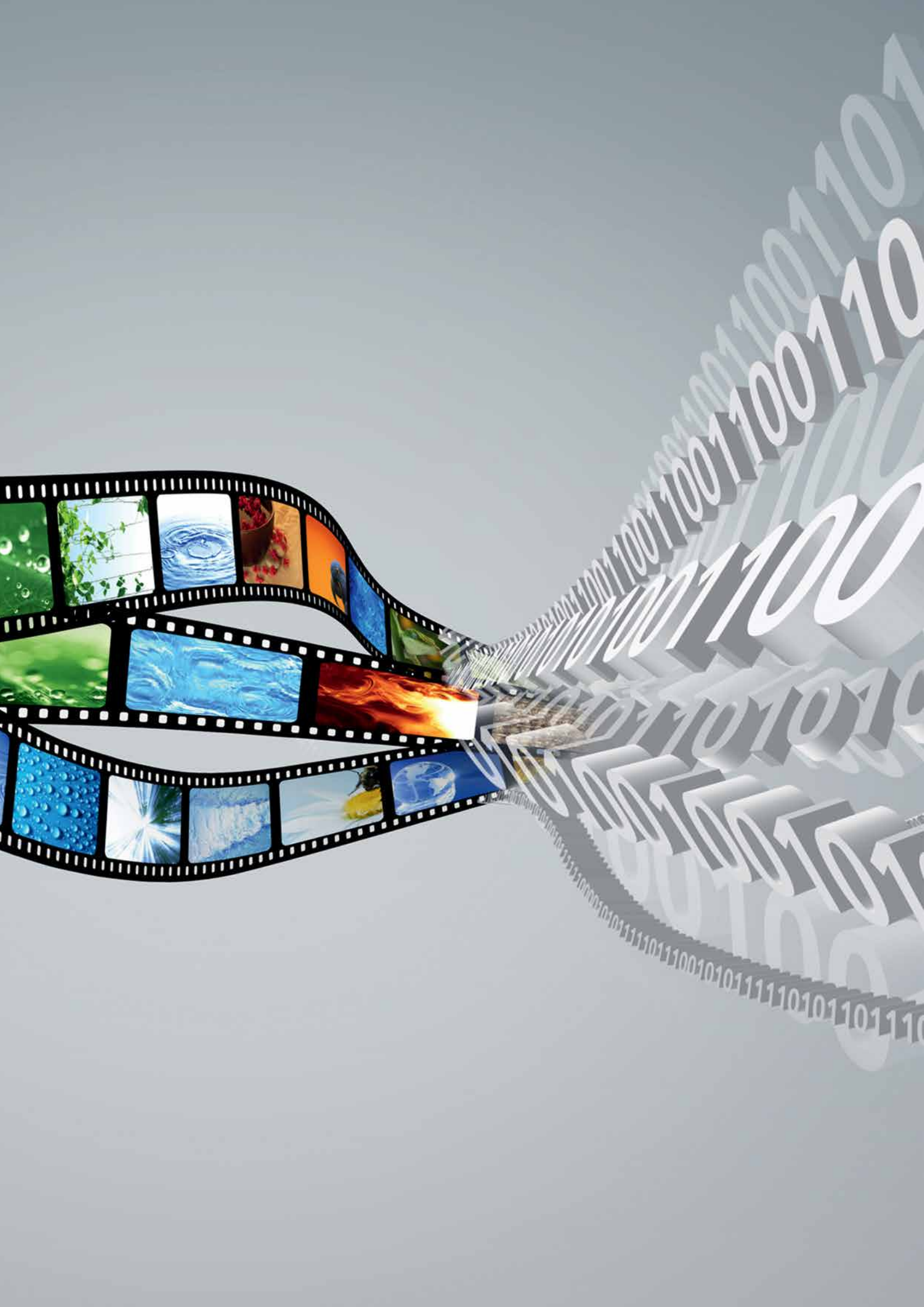
To effectively improve the hygiene situation in the critical intensive care unit environment and simultaneously offer relevant information as intuitively and comprehensively as possible, a contactless control unit for user-adaptive image data visualization was realized for medical applications. In addition, video analysis methods for operating room microscopy and 3D endoscopy are being developed. They support the control of 3D quality for fatigue-proof stereo presentation and also permit the extraction of depth information for special medical applications (such as tympanoplasty in ENT surgery). Methods were also developed for the 3D recording and presentation of laser scan microscopy data of the skin.

3D reconstruction of persons, objects and environments for VR applications

New applications in the media sector such as interactive TV shows and video streaming as well as presentations on a second screen or with VR glasses require innovative solutions from computer vision. Creating interactive 3D models of persons, objects, and environments is the objective here. Hence, Fraunhofer HHI has developed new techniques for the real-time representations of persons with high-quality photorealistic models by combining computer graphics with an image-based rendering process. They can be integrated into virtual or real scenes. Semantic adaptations are possible as well – for example changing viewing direction, establishing eye contact or the animation and correction of movements.

Tools and plugins for digital post-production

Current work in the field of digital post-production involves the development of tools for high-precision tracking of deformable surfaces. These techniques are used for temporal consistent correction and retouching of image regions, or to add entirely new assets under consideration of lighting and shading. Depth-based processing methods have also been developed to create new virtual views from two or more, also very different camera views. This for example permits the calculation of virtual stereo pairs with a changed basis or the calculation of new virtual views for auto-stereoscopic 3D displays. Tools for the evaluation, control, and improvement of stereo quality were developed as well. All of the tools mentioned here were made available as plugins for common software platforms such as Nuke or After Effects.



VIDEO CODING AND ANALYTICS

The sum of all types of digital video signals, whether TV, video-on-demand, Internet video or peer-to-peer will increase from the current 70 percent of global data traffic by 2019 up to 80 to 90 percent. Therefore, the importance of efficient coding, transport, processing, and analysis of video signals is ever-increasing. The Video Coding and Analytics department deals with all relevant aspects of the related research areas. With its significant contributions to the video coding standards H.264/MPEG-AVC and H.265/MPEG-HEVC, the department helped to provide the key technologies for the increasing use of digital video in our daily lives.

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VIDEO CODING AND ANALYTICS

Contributions to video coding standards and corresponding implementations

H.264/MPEG-AVC is the most widely used video coding standard worldwide. More than 50 percent of all bits on the Internet and several billion devices are using H.264. Researchers from Fraunhofer HHI were significantly involved in its development. Also, the successor standard H.265/MPEG-HEVC (High Efficiency Video Coding) has been designed from the outset with substantial contributions of the department.

After the completion of the first version of the HEVC standard in April of 2013, the second and third version was adopted in October 2014 and April 2015, respectively. These HEVC versions provide specific extensions for professional applications (Range Extensions - Rext), scalable coding (Scalable Extensions - SHVC) and for multiple views or 3D video (Multiview Extensions - MV HEVC or 3D Extensions - 3D HEVC). For all these extensions of HEVC the department has made significant contributions through technical proposals and administrative support. In addition, the department developed and implemented an HEVC-conforming real-time software-based encoder for 4K/UHD, which was already in use for testing purposes in several successful live television productions and is currently being marketed in partnership with industry.

Estimation of perceived quality using machine learning

Video encoding methods can introduce visual artifacts, which are perceived as annoying by the viewer. A general model of human perception of visual quality, which could be integrated into the coding algorithm, does not yet exist. Hence, scientists at Fraunhofer HHI explore new possibilities of direct and indirect visual quality measures. For this purpose methods of machine learning were used to "learn" a model from many annotated examples, which can predict the perceived quality for images more accurately. New ways have been found in order to derive the visual quality of sensations by measuring the brain activity directly. These EEG studies show that the direct measurement of quality for images and 3D visualizations is possible.

Machine learning

The work in the area of machine learning is expanded in many directions. In the basic research on machine learning at Fraunhofer HHI, the inversion of Deep Neural Networks for explaining classification results are analyzed among others. In addition, various topics are being explored in a series of collaborations with Max Planck institutes and universities, including the field of medical diagnostics.

Video encoding and streaming for Virtual Reality

With Virtual Reality (VR) glasses there is a new device category that allows an immersive experience of audio-visual content. Corresponding panoramic video content for these devices must be transferred over the Internet using resources efficiently. This represents a challenge to the existing infrastructure and transport mechanisms. A new technique, which was developed in the department, allows the stitching of individual tiles of such encoded content customized for the individual user. Thus, the available data rate can be better utilized.

Formats for video coding in the Virtual Reality.

Soccer live transmission in 4K/UHD resolution with HEVC real-time encoder by Fraunhofer HHI.

EEG-based measurement of visual quality perception.

RESEARCH AND DEVELOPMENT

- Image and video coding
- Multimedia communications
- Embedded systems
- Machine learning
- Image and video understanding

MEET US

The experts from Fraunhofer HHI on tour

Our scientists are year-round to be found at various fairs and events worldwide. They present the latest results and prototypes of research and development at Fraunhofer HHI. We are regularly attending the following fairs:

- SPIE Photonics West
- GSMA Mobile World Congress
- Embedded World Exhibition & Conference
- Optical Fiber Communication Conference and Exhibition (OFC)
- Fiber Optics Expo (FOE)
- National Association of Broadcasters Show (NAB Show)
- LASER World of PHOTONICS
- CeBIT
- Internationale Funkausstellung (IFA)
- International Broadcasting Convention (IBC)
- European Conference on Optical Communication (ECOC)

We are also organizing several workshops and panel discussions:

- 5G: More speed or quality or both?
- Future broadband – workshop and parliamentary evening
- Photonics academy for young students by the German Federal Ministry of Education and Research
- Co-hoster of the IT capitol tours
- Go Digital! Chances of digitalization for SMEs
- Challenges and opportunities of Virtual Reality
- eBusiness Lotse Berlin: Linked Data – Making more of your company's data
- eBusiness Lotse Berlin: Strategies for company founders
- Webinar: HEVC in a real-world environment (with Rhode & Schwarz)

In addition, we were present in the past few years at the following exhibitions and events:

2013:

- Medica
- ITU Telecom World
- Cars 2013 – Computer Assisted Radiology & Surgery
- ISE – Integrated Systems Europe
- Lange Nacht der Industrie

2014:

- Laser Optics Berlin
- Analytica
- Metropolitan Solutions
- ILA Berlin Air Show
- Medica
- Federal government: Open-door day

2015:

- Micro Photonics – Preview Event
- Science in three minutes – Digital Science Match
- TiME Lab at Avant Premiere (as part of the Berlinale)
- International Motor Show (IAA)

The mirror-based OmniCam-360 on tour at various trade fairs.

Presentation of research results at the LASER World of PHOTONICS.

Getting the most out of UHD content with UHD Zoom by Fraunhofer HHI.

The research results of Fraunhofer HHI are always worth a look.

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