Fraunhofer **Institut
Nachrichtentechnik
Heinrich-Hertz-Institut**

Overview

DRIVING THE DIGITAL FUTURE
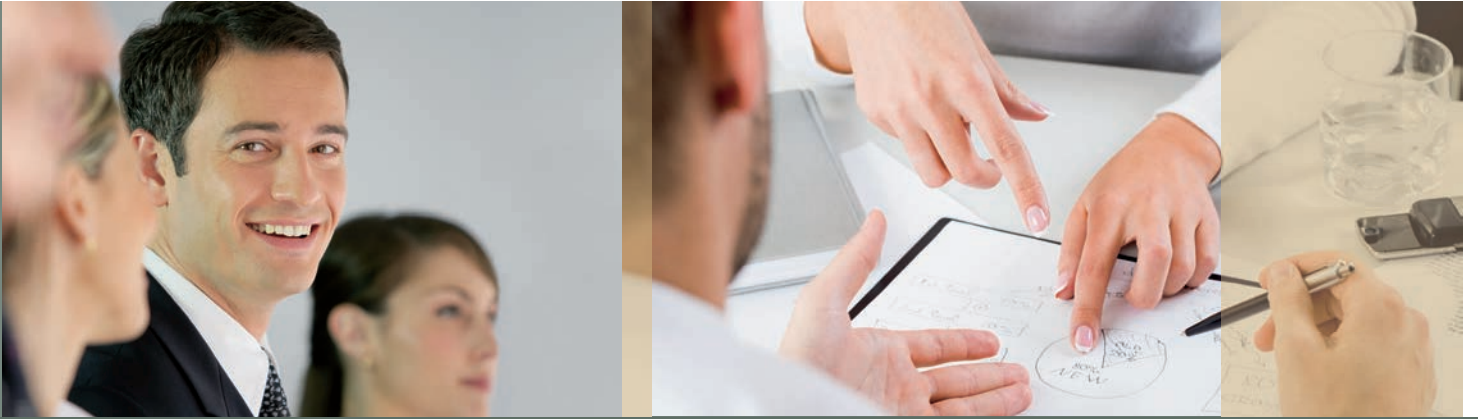
DRIVING THE DIGITAL FUTURE

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Preamble

The importance of telecommunications and mediated applications and services for the economy is also reflected in the high development dynamics in these areas. It is one of the main objectives of the Heinrich Hertz Institute (HHI) to deliver relevant development contributions and to act as a competent partner of the economy in a leading position. This goal has been achieved in the reporting years with successfully implemented measures. The perception of the HHI as a solution partner in the fields of telecommunications and multimedia has been reflected in a significant increase in industrial orders. The longitudinal study of the past few years shows a steady expansion of profits from such orders. Recently, with approximately 30 percent of total revenues from industry earnings with at the same time rising operating budgets, the HHI has been able to meet the requirements demanded by the Fraunhofer Society regarding institute-specific income structures. It is thus one of the HHI's major organizational tasks to shape a sustainable future – despite and especially because of increasingly difficult general conditions – and thereby to cope with the substantial significance of areas of knowledge presented in this report. A motive for the strengthening of organizational structures in marketing and sales was the improvement of customer and market proximity. It is here that specialized marketing officers work together with the department heads to initiate orders or projects within public R&D programs as well as with new or established customers, to prepare participations in trade fairs and to foster customer relationships. In addition, the establishment of business areas as necessary interfaces to the market has been pushed consistently since 2007. As one of the business areas, the field of medical technology

could be successfully positioned. After the establishment of a strategic research partnership with a leading manufacturer, the extension of the solutions offered abroad will be necessary to ensure that the HHI's solutions will be available to the players of these regions.

Overall, the implementation of these structural conditions supports the general goal of the HHI, to establish lasting and strategic cooperative partnerships with stakeholders from various areas.

The long-term success of implementing such market-specific structures is always based on the presence of an innovative and vibrant research setting. It is therefore a priority goal, to ensure and to further promote new approaches and the evaluation of appropriate applications. The research efforts of the HHI of recent years could be considerably broadened. Thus, the HHI has succeeded in winning a number of EU projects which will, because of their thematic orientation, help the HHI to be seen increasingly as an opinion leader in the relevant knowledge areas in the years to come.

One example to mention here is the HHI's partici-pation in national and international collaborative projects in the areas of 3-D content creation, coding, transmission and representation (PRIME, funded by the BMWi, 3DMEDIA, 3D4YOU, MOBILE3DTV, 3DPRESENCE, all funded in the framework of EU FP7).

The objective of this effort is to establish the HHI as a global competence center in this sector. Furthermore, the participation in the project THESEUS of the BMWi (Federal Ministry of

Economics) must be pointed out, in which the HHI has taken on the leadership of the Core Technology Cluster.

Last but not least: The HHI is striving to intensify the cooperation with partners in the region Berlin-Brandenburg. In addition to the multitude of research collaborations, for example funded by the PROFIT program of the federal state of Berlin, the participation in the regional cluster initiative "Secure Identity" must be highlighted. Here, new approaches for the secure identification of individuals are being developed in collaboration with companies.

The HHI sees itself as a regionally rooted research institute and feels obliged to make the knowledge areas dealt with at the institute visible to the outside world. Thus, all regular colloquia have been open to the public for a long time now and have been published in the corresponding media. Another approach is the participation in the „Lange Nacht der Wissenschaften" (Long Night of Sciences), which gives citizens an insight into the institute's work. Furthermore, the HHI has participated in the initiative "Girls' Day", which familiarizes girls of the various branches of school with job opportunities in engineering. It also has to be mentioned that the HHI offers apprenticeships in the fields of IT, management and technology. Finally, the participation in the competition „365 Orte im Land der Ideen" (365 Landmarks in the Land of Ideas) has to be pointed out, in which the HHI was chosen as landmark in the land of ideas 2009 from 2,000 candidates.

But the increasing attention in the recent past has mainly been due to the excellence of the scientists active at the institute.

A particular highlight was the bestowal of the Leibniz Prize 2008 to Prof. Dr.-Ing. Dr. rer. nat. Holger Boche, Director of the HHI, for his work on the mobile networks of the future.

He has also become a member of the Leopoldina.

Furthermore, the Primetime EMMY Award in the category Technology 2008 was awarded to the Joint Video Team (JVT) for the development and establishment of the video coding standard H.264/MPEG-4 AVC.

Thomas Wiegand received the EMMY together with the other award winners in Los Angeles on August 23, 2008.

Additionally, the Day Time EMMY Award in the category Technology was awarded to the video experts of the ITU-T and ISO/IEC for the same achievements. Thomas Wiegand received the award together with the other video experts in Las Vegas on January 7, 2009.

We are also delighted to announce that Professor Dr.-Ing. Thomas Wiegand has accepted a professorship in the department of Image Communications at the Institute for Telecommunication Systems at the Technical University of Berlin (TUB) since the summer term 2008.

The institute expresses its sincere congratulations to all award winners and to all those who have been honored and appointed.

▶ Prof. Dr.-Ing. H.-J. Grallert

▶ Prof. Dr.-Ing. Dr. rer. nat. H. Boche

So what is next? Of course the HHI has to face the conditions of the global economy, which, due to the financial crisis, are accompanied with lower growth forecasts than recently expected. It seems inevitable that certain industries and companies that are structurally out of alignment, will, together with their suppliers and also with their external competence partners, be under considerable pressure to adapt, which will also lead to an implementation of savings measures in research and development services by third parties. Even though a significantly difficult course of business can be expected, the HHI sees itself in a good starting position.

Concerning the alternative scenarios regarding the future economic development of the HHI, a further consolidation without any significant collapse of orders can be positively assumed.

Finally, I would like to thank all staff members who have contributed to the positive development of the institute with their outstanding commitment and who have given an important stimulus to the development of new solutions for our partners from economy, research and politics.

Spring 2009

Prof. Dr.-Ing. Hans-Joachim Grallert,
Managing Director of the institute;

Prof. Dr.-Ing. Dr. rer. nat. Holger Boche,
Director of the institute

1. Challenges

Through the developments in information and communications technology in the recent past, this area has become one of the main drivers of the economy. This can be stated for specific sectors, such as industry and services, but is also a phenomenon that applies to all social fields of activity, such as schools and education, work and leisure as well as entertainment. The development dynamics described here will continually grow in the future.

The bandwidth demand is growing faster than the network capacity. In the past years it has been observed that network traffic (in fixed and wireless networks) has increased continuously between 30 percent and 50 percent because of a growing use of IP-based services for more than ten years. An end to this trend is not in sight. Rather, peer-to-peer services and applications such as IPTV, Second Life, YouTube or Joost will significantly add to the increase. According to forecasts, the number of mobile phones will have doubled up to five billion users by the end of 2015 and the transmitted amount of data will have centupled, which corresponds to an increase of approximately 60 to 70 percent per year. According to expert opinions, it can be assumed that the present bandwidths and the bandwidths available in the next few years will not be sufficient to cover the immensely growing data transfer needs in the fixed and mobile networks. Multimedia is one of the key components in information technology, as images, videos, language, sound and additional data are used for an increasing number of services in the office, at home and in public areas.

The vision of having multimedia services available for everyone anywhere and at any time is also the driving force behind the R&D activities of the HHI experts.
In addition, exogenous determining factors will affect and accelerate further development.

Convergence of media. The "Internet Protocol" (IP) is the technical basis for the consolidation of formerly separate media. This applies to the different infrastructures, the imparted services and the necessary devices and means that with new transmission facilities contents can be sent and received that will not be media-specifically limited to certain technical conditions when transferred. Along with this and taking into account the increasingly complex services, usage forms will be possible, which give rise to expectations of the creation of new markets and services. These are the major motivators for focusing on new research topics related to multimedia.
In addition to the technical management of increased efficiency, the future will be about putting the achieved technical improvements in terms of benefits for users in the context of the application potentials and to show their added value.

Penetration of different areas of life. The importance of telecommunications is reflected in the high speed with which solutions for a wide variety of usage situations are adapted.
The role of the original "addressee" of this development is of less importance in this case. If a technology for the compression of images and videos was developed for mass communication today, at the same time there would arise feasible application scenarios in professional

areas, for example in the fields of medical technology and safety monitoring

Differentiated service offers. The provision of efficient infrastructures as well as multi-functional devices has significantly enlarged the range of usable offers. Furthermore, with the emergence of so-called peer-to-peer services, such as MySpace, Friendster, YouTube, etc., offers have evolved besides the conventional point-to-multi-point approach for the traditional mass communication services on the web, which were not feasible a few years ago. This has a direct influence on the nature and extent of the usage of existing bandwidths. In addition, services and business processes can be decoupled from each other and recombined individually. The singular added value processes can vary according to the needs and wishes of different target groups and can be adjusted independently according to time and place.

Explosion of data volumes. The amount of worldwide transmitted and stored data is growing disproportionately. According to expert opinions, the global volume of data will grow to about 1,000 exabytes in 2010. Storage space is viewed as a so-called commodity, similar to broadband connections. However, such amounts of data are only useful if adequate bandwidths and intelligent tools are available. This trend will be aggravated by adding a new group of actors, namely all the users who produce and exchange their own content.
The so-called user-generated content creates a usage scenario which eludes the usual economic categories and understands the web as a platform for socially driven networks.

2. Approaches and Examples

In this context, solutions are required that allow users to have access to the desired content in the required quality and speed at any time and at any place and to make this content available to others.

The HHI does therefore not only use its expertise to develop hardware for improving transfer rates. Likewise, the content and services which are to be transferred must be packed and compressed so effectively that highly complex images and videos reach users on time and with high quality – via fixed as well as mobile channels. With the coming of 3-D internet, especially 3-D services and devices move to the center of attention.

The HHI is currently one of the few facilities able to depict 3-D stereoscopic images in the highest, almost holographic technical quality without the help of special glasses for viewers and to have expertise in the entire 3-D technology from capture to playback.
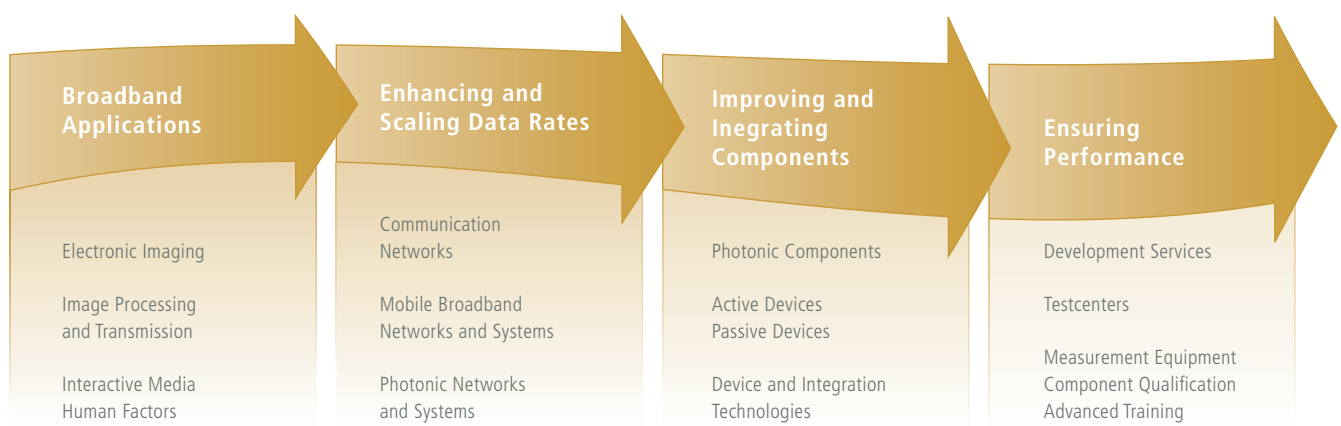
The institute has been adapted to the changing markets and customer groups by several measures in the past years. To reach congruence between the constitutive departments of the institute and the competencies demanded by the market, fields of competencies have been structured to develop and provide solutions for business partners from the industry, the service and public sector:
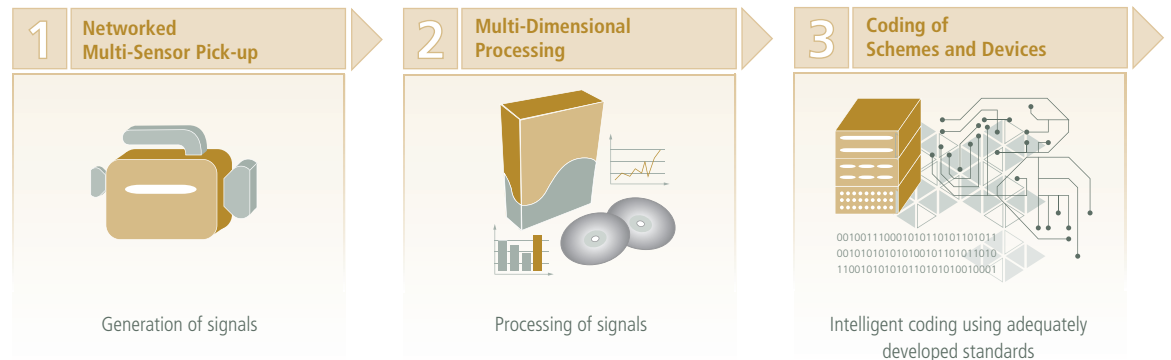▶ Electronic Imaging
▶ Communication Networks
▶ Photonic Components
▶ Development Services

Here the individual levels of the different value chains are displayed almost completely, as exemplified by Electronic Imaging.

This means that the entire process chain from the
▶ generation of signals (in this example: multi-camera system) to
▶ processing,
▶ to the intelligent encoding using accordingly developed standards,

Broadband Applications	Enhancing and Scaling Data Rates	Improving and Inegrating Components	Ensuring Performance
Electronic Imaging	Communication Networks	Photonic Components	Development Services
Image Processing and Transmission	Mobile Broadband Networks and Systems	Active Devices Passive Devices	Testcenters
Interactive Media Human Factors	Photonic Networks and Systems	Device and Integration Technologies	Measurement Equipment Component Qualification Advanced Training

1 Networked Multi-Sensor Pick-up	**2** Multi-Dimensional Processing	**3** Coding of Schemes and Devices
Generation of signals	Processing of signals	Intelligent coding using adequately developed standards

▶ **Graphic 1:** Development and research focus in the area of Electronic Imaging

- ▶ to the transmission over high-performance infrastructures (wired and wireless),
- ▶ to the reception using hardware- and software-based solutions and to
- ▶ the representation of (video) signals on future-proof displays (here: 3-D and immersive presentations)

can plausibly be presented with the required quality when developing new solutions or when existing approaches are being improved within the HHI.
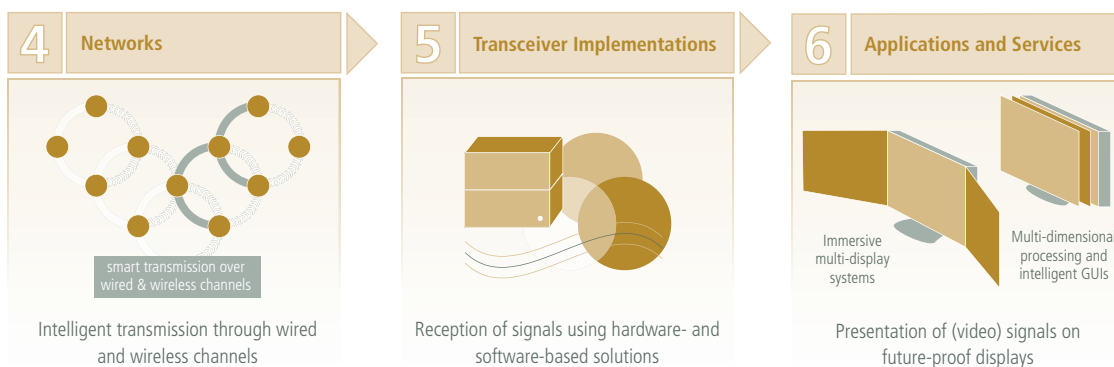
Examples of Solutions (selection)

The following examples should only give a small insight into the variety of different developments realized by the HHI.

Example I: Development of a Highly Efficient Video Coding Standard (H. 264/AVC)

The H.264/AVC (Advanced Video Coding) method represents the latest technology in terms of standards for video coding. It allows a much improved compression performance (with savings in bitrates of more than 50 percent compared with an MPEG-2 video with the same quality). The Fraunhofer HHI has contributed significantly to the development of H.264/AVC.

4	Networks	5	Transceiver Implementations	6	Applications and Services

smart transmission over wired & wireless channels

Intelligent transmission through wired and wireless channels

Reception of signals using hardware- and software-based solutions

Immersive multi-display systems

Multi-dimensional processing and intelligent GUIs

Presentation of (video) signals on future-proof displays

Example II: Virtual Mirror Allows New Experiences

The Virtual Mirror simulates different variants of garments on a model of the beholder. Touching the screen is enough to change the design of the outfit as desired. Additional features: The Virtual Mirror improves the visualization of customer-specific consumer goods such as clothes, shoes, jewelry, etc. The solution uses sophisticated 3-D image processing techniques. A camera captures the real world and shows its mirror image on a large display (including the tracking of the 3-D movements).

Example III: Contactless Control of Presentations (iPoint Presenter)

With the development approaches of the HHI it will be possible to control machines (here: presentation tools) without touching them. Meanwhile, the research and development team has developed that approach to such an extent that the tool is able to detect almost all fingers and thus a wide range of gestures. The features in detail:

▶ "multi-point"-interaction
▶ fully contactless (non-invasive)
▶ interactions in 3-D
▶ real-time tracking with multiple fingers
▶ innovative human-computer interactions
▶ simple, pleasant and sterile usage

Example IV: Optical Wireless Transmission

With this solution it is possible to transfer data in situations and environments, in which one is dependent on additional transmission methods (for example in aircrafts) or where the use of radio frequencies is not permitted (for example in operating rooms).

Another promising application area for free-space optical communication is communication between vehicles (car-to-car communication), for example, by using LED taillights and LED daytime running lights.
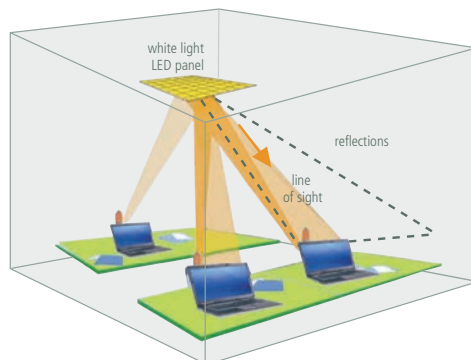
Example V: Rapid Laser Diodes for Communication in Space

Outer space is free of attenuation and dispersion, which makes it an almost ideal medium for the optical transmission of data between far-off satellites with relative velocities of about 26,000 km/h.

This leads to extreme demands on the alignment and tracking of the laser beam – comparable to the task of tracking and hitting the window of a high-flying airliner successfully from the ground. The HHI has developed special reception diodes for this purpose, which were put into orbit on board two satellites. Since then, their performance, even under the local operating conditions, has been completely reliable..
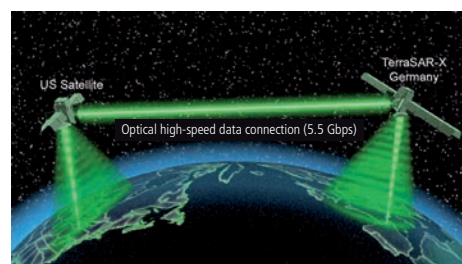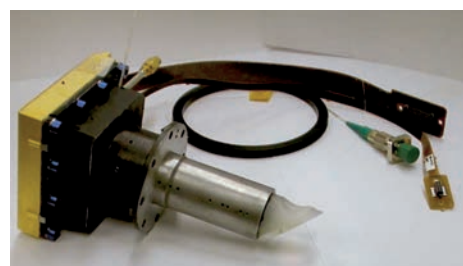
3. Connection of Development and Research Skills with Market Requirements: Business Areas as Interface to the Customer

As part of the restructuring of the last years, important prerequisites within the HHI have been created to better cope with market demands. The Business Development department has been created which aims at presenting the potential of the solutions offered by the HHI. In this department, marketing officers specialized in all fields work together with the heads of the specialty departments to attract funding from new and existing customers as well as from public R&D programs for contracts or projects, to prepare the participation in trade fairs and to foster customer relationships. Through the use of professional marketing, the customer orientation has been intensified. Another element in the repertoire of the market-oriented approach is the structuring of the problem solving skills of the HHI by business areas. This is regarded as an important solution model for improving the interfaces to the market and customers. An essential condition in this respect is that solutions of a general nature can be subsumed for the specific requirements of single markets. Another important prerequisite is that these solutions are made available to the business partners not only at the moment but also in the short and medium term to emphasize that they will benefit the HHI's future developments. This corresponds to the overall goal of the HHI to establish long-lasting and strategic partnerships with stakeholders from a variety of areas. Another criterion for the structuring of business areas is the probability of the services provided by the HHI receiving positive market responses which would
- ▶ allow a satisfactory volume of projects,
- ▶ create stimuli for new developments close to the markets' needs

▶ as well as adequate returns, which in turn secure the basis for investments in the respective fields of knowledge.

From today's perspective, this can be expected for a number of business areas:

Promising business segments	Example solutions
Medical technology	Touchless control in operating rooms
Safety & Security	Supervision/distribution centers
Network operators	FTTX system consultation
Entertainment industry	Cinema of the future
Education	Innovative blackboards
…	…

The successful implementation of the business area approach is supported by the formation of a new "Strategic Marketing" department. Here, experts with marketing and research skills work closely together to lastingly ensure the anticipation of future-oriented topics for the work at the HHI (scouting function). From 2009 on, a newly created "Corporate Communications" department will strengthen the positioning of the institute, its visions, goals and services internally, in the media and in the political sphere, promote networking and ensure the development of the staff's communicative competencies.

In another target area it is imperative to develop key customers out of contract relations who recognize the possibilities of cooperation with the HHI as a major source of innovations for developing competitive advantages or for achieving increased efficiency and who aspire a strong and close partnership with the HHI. To reach this goal,
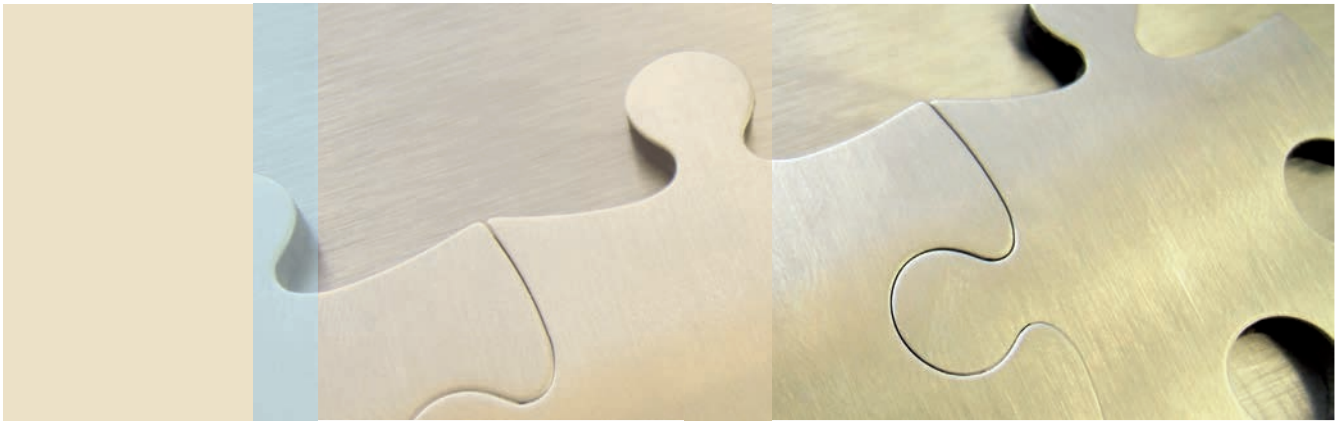
a sequence of process steps is performed together with the customer which simultaneously offers the opportunity for an exchange of ideas as well as mutual respect and understanding. Based on an increasingly better perception of the clients' problems – whether they are individual and/or market-specific custom-fit solutions can be developed and optimized on the basis of evaluations carried out systematically.

How to Meet the Customers' Needs

A	**Attention:** making customers aware (most important: publications, journals, internet)
I	**Interest:** providing a better understanding of the provided solutions ("Technology-Day", customers' visits, fares and conferences, 400 visitors to the HHI in 2007)
D	**Desire:** specifying the customers' requirements (based on complex R&D contracts, normally connected with licensed-based agreements)
A	**Action:** development of prototypes (incl. evaluation and adjustions) or small volumes of products (certified quality, ISO 9001)

Example: Medical Technology

Medical technology is one of the fastest growing and most dynamic areas of the economy. On the one hand this is due to the growing need for expedient technical solutions and on the other hand it is a result of the high degree of innovation seen in this industry.

The need for medical services will grow in all areas in the future: The average age of the population is increasing as well as the general expectations of the quality of health care. This is contrasted by the need to reduce costs in the health care system. In this respect, new solutions are required which conciliate both these extremes. This results in an increased need for appropriate development and research efforts. In this context, the HHI sees itself as a suitable partner for the medical technology industry to codevelop such solutions. The HHI offers the chance of optimally linking together technological know-how and application orientation. The areas of development of innovative solutions in medical technology can be found in the following spheres of competence:
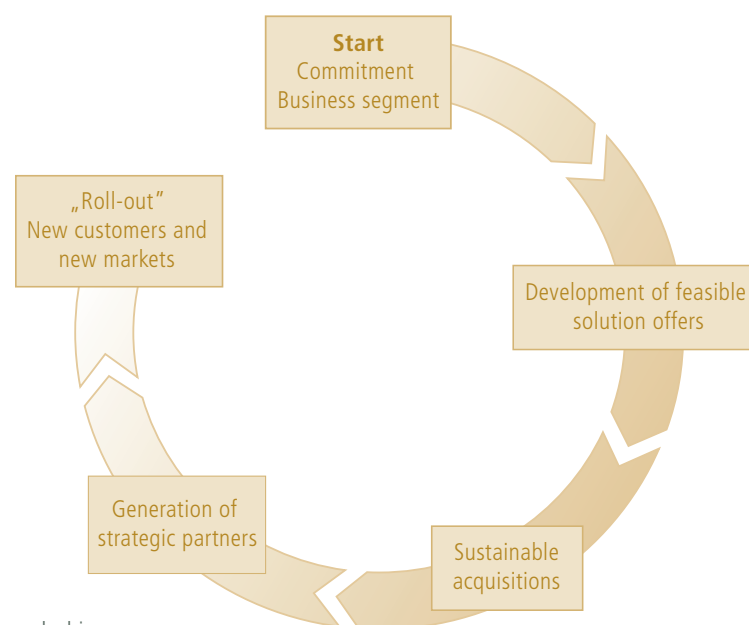
▶ image processing (modeling, coding, HD representation, storage and analysis)
▶ communication networks (wired and wireless)
▶ innovative interfaces (usability, man-machine control and high-quality 3-D)
▶ photonic components
▶ photonic sensor systems

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        ┌──────────────┐
        │    Start     │
        │  Commitment  │
        │Business segment│
        └──────────────┘

┌──────────────┐              ┌──────────────────┐
│  „Roll-out"  │              │Development of feasible│
│New customers and│            │  solution offers │
│ new markets  │              └──────────────────┘
└──────────────┘

   ┌──────────────┐         ┌──────────────┐
   │ Generation of│         │ Sustainable  │
   │strategic partners│      │ acquisitions │
   └──────────────┘         └──────────────┘
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▶ **Figure 1:** Business segment development system

Especially the connection of the different areas of competence leads to innovative solutions with a high application value. For example:

▶ video retrieval and analysis (IT-based comparison of individual clinical pictures with typical phenomena to verify diagnostic statements)
▶ electronic endoscopies
▶ contactless and wireless control of devices within the operating rooms
▶ sensor network (e. g. to record vital bodily diagnostic patient data directly)
▶ optical sensors as subunits of compact lab-on-a-chip systems

During the reporting years of 2008/2009, the HHI's solutions have been intensively communicated. The HHI participated in the leading trade fairs of the medical technology industry with its own booth (Medica and others) the feedback has been extremely positive and hence has been a motivation for the continuation of this commitment. More recently, this approach has been adapted on an international scale so that contacts with leading suppliers abroad can be improved.

Furthermore, in 2008 a research partnership with a leading manufacturer of medical technology has been established. Areas of cooperation include gestural user interfaces, user-friendly interactive information systems for operating rooms and stereoscopic endoscopy. In this context the HHI not only contributes its technical skills in areas such as image processing and imaging (especially 3-D/stereoscopy), but also its social science competencies in the areas of user-centric design and ergonomics/usability. The contactless man-machine interaction developed by the HHI will, among other things, make it possible in the future to easily control surgical devices and applications

needed in
the operating room
(for example the presentation of information before any surgical interventions are carried out on a large screen) even in sterile areas. This allows existing products to be complemented by innovative solutions, but also completely new products can be developed (including a contactless operating room information system). It is intended to establish long-term research partnerships so that the partner companies will benefit of the HHI's new research results.

4. The Departments at a Glance
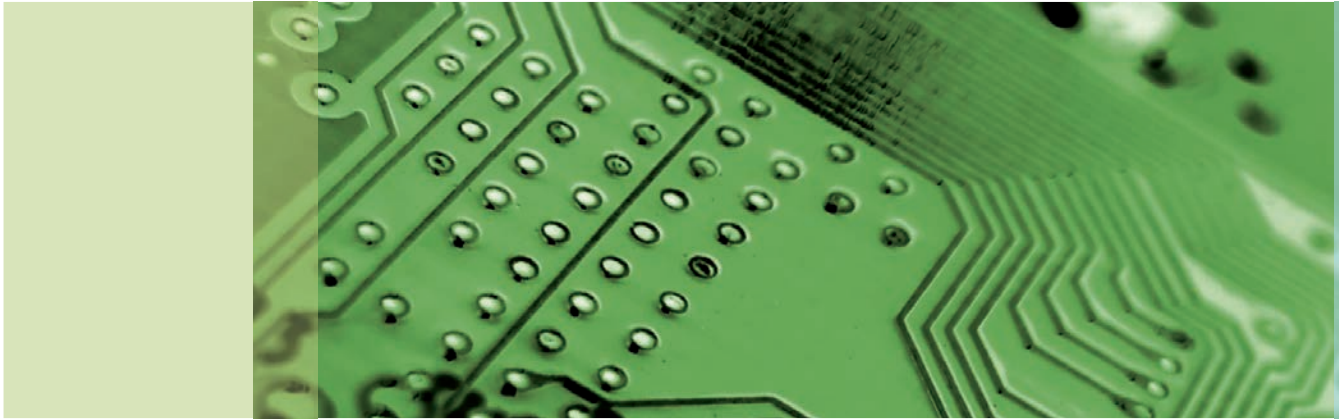
4.1 Image Processing (IP)

The vision of having multimedia services available for everyone anywhere and at any time is also the driving force behind the R&D activities of the Image Processing department. It has core competencies and an internationally acclaimed reputation in the following areas:
▶ image and video coding
▶ multimedia transmission (internet, mobile, DVB)
▶ 3-D image and video processing
▶ image and video analysis, computer vision
▶ image and video synthesis, computer graphics
▶ software development for multimedia systems
▶ hardware design and Implementation of multimedia systems (video, audio, graphics)
▶ IP design for aSICs, FPGas and "embedded" processors

These issues are dealt with in four business areas of the department:
▶ Multimedia Communications
▶ Image and Video Processing Systems
▶ Immersive Media
▶ Hardware and Embedded Systems for Multimedia

Furthermore, the worldwide trend toward 3-D both in cinemas as well as in the domestic area has been taken into consideration by the IP department regarding projects.
IP has taken these international developments into account by participating in a total of six national and international collaborative projects in the areas of 3-D content creation, coding, transmission and presentation (PRIME, funded by the BMWi, 3D MEDIA, 3D4YOU, MOBILE3DTV, 3DPRESENCE, all funded under the EU FP7).

The objective of this effort is to establish HHI as a global competence center in this sector. In addition, participation in standardization activities in the area of video coding and transmission continues to be the department's center of activities.

This concerns the Moving Pictures Experts Group (MPEG) of ISO/IEC as well as the Video Coding Experts Group (VCEG) of ITU-T, but also increasingly the Internet Engineering Task Force (IETF), the DVB Forum, WorldDMB and the SMPTE. DVB and IETF have mainly focused on applications for the SVC extension of the video coding standard H.264/AVC, mainly developed by the HHI. SVC (Scalable Video Coding) allows the generation of a scalable video streams from which substreams can be extracted and decoded, which results in a video with low local and/or temporal resolution and reduced quality.

Following the worldwide successful launch of the H.264/AVC, which is currently the most efficient video coding standard in all application fields from mobile TV to HDTV, including storage media such as Blu-ray and the internet (Adobe Flash, MS Silverlight), the next step in video coding is in preparation. H.265 will halve the datarate while retaining the same image quality. One of the very promising strategies includes analysis synthesis coding for which HHI has already presented initial results.

Other key activities include:
- ▶ T-DMB and DVB-H encoders for mobile TV
- ▶ video streaming methods for arbitrary IP- or MPEG-2 TS-based networks
- ▶ development of the immersive telepresence sector (for example high-resolution projection systems, digital cinema, 3-D video conference systems)
- ▶ 3-D modeling (such as the Virtual Mirror)
- ▶ hardware developments (intra-only implementation of H.264/AVC on FPGA platform, also available for ASIC design, for example for the automotive sector and applications in medical technology)
- ▶ high-datarate transmission (maskless lithography)

One of the key sectors in which HHI is involved is the project THESEUS – a research program initiated by the Federal Ministry of Economy and Technology (BMWi) aimed at developing new internet-based knowledge infrastructure so that knowledge placed in the internet can be better utilized.

The IP department has been participating in the THESEUS Use Case CONTENTUS and the Core Technology Cluster (CTC).
CONTENTUS is developing digitization and restoration procedures of video material as well as the generation of so-called metadata, which facilitate the search for video content.
CTC is researching basis technologies for image and video analysis, video encoding and determining the video quality.
IP is also responsible for the management of the overall CTC.

4.2 Photonic Networks and Systems (PN)

Since the 1970s, HHI has been intensively researching and developing photonic transmission systems and networks in cooperation with industry and network operators. It is hence one of the few institutions world-wide to have been actively involved in this field from the very beginning of research in this area and to have contributed greatly towards progress in this field. HHI, for example, still holds the transmission world record of 2.56 Tbps on one wavelength over a 160 km long transmission line.

New techniques allow the better utilization of optical-fiber transmission systems and the boosting of the performance of photonic networks in order to be able to fulfill the requirements outlined above. All network levels are considered, from long-distance to access networks to the in-house area.

This involves projects in a wide range of areas covering high-capacity wavelength multiplex systems with transmission rates of 40 Gbps up to 1 Tbps per wavelength channel right through to in-house systems based on optical polymer fibers and free-space optical communications. The HHI was, for example, involved in the product development of terrestrial 40-Gbps transmission systems and submarine systems on behalf of industrial customers.

Ethernet technology will have a special role to play, constituting a very promising, cost-effective alternative to existing system technologies. The 10 GB Ethernet technology has meanwhile

become well established. The focus now lies on the 100 GB Ethernet technology which is to be standardized by 2010. Within the scope of the Celtic project 100GET, the corresponding technologies and systems for the 100 GB Ethernet are being developed by ADVA, Alcatel-Lucent, Ericsson, Nokia Siemens Networks and other enterprises in cooperation with the HHI.

Higher transmission rates are also increasingly in demand for satellite communications which can only be achieved by photonic transmission. The HHI can contribute its expertise in photonics in this area. Other R&D activities address the use of optical transmission methods for high-capacity inter-machine and intra-machine communications (M2M communications) with total forecasted datarates of a few Mbps to several Tbps. This also includes a smart-metering functionality for remote electricity, gas, water, etc. metering.

Besides R&D on the physical layer of photonic networks, other studies and developments are geared towards the design and management of photonic networks as well as interaction between the protocol layers and the physical transport layer. Special simulation tools are used here.

Excellently equipped laboratories are available for R&D work, which allow experiments to be performed up to the current physical and technical limits.

Freely configurable WDM loop testbeds enable system and network studies with up to 120 wavelength channels in several wavelength bands (S, C and L band) and a data rate of up to 160 Gbps per channel. A high-speed laboratory

enables studies and transmission tests in the direction of several terabits per second on one channel. The studies are accompanied and supported by computer simulations using complex simulation tools.

4.3 Photonic Components (PC)

To avoid the costly installation of new fibers, multiplication of equipment or additional regeneration stations in long-distance links, a new set of optics is required with significantly better performance – a trend which is opening up excellent opportunities for technologically-driven companies or institutions. The HHI has always been at the forefront of optical component technologies. Over the past two years, the HHI has introduced the world's first 100 Gbps detector, improved the performance of the company-internal 40 to 80 Gbps modulator and achieved preliminary results with direct modulation of a semiconductor laser at 40 Gbps.

The department has not only presented their latest products and results at scientific conferences, but also to industrial standardization committees such as the IEEE High Speed Study Group for 100 Gbps. The PC also introduced the latest photo detector at the ECOC '08, together with an American manufacturer of measuring instruments. The department (together with the PN department) has again been certified according to DIN EN ISO 9001:2000 standards, not only regarding research and development, but also technology. To develop optical components with provably stable long-term behavior, investments in facilities for aging and burn-in processes and qualification measurings will continue.

In addition, very promising initial results on the aging of our polymer platform and the optical functions implemented on it could be achieved.

The terahertz spectrum has opened up new possibilities: Telecom technologies will bring a typical THz setup from the lab table to the briefcase. The department has initiated work here, with promising initial results on the receiver side at 1.5 µm. The collaboration with non-telecom customers, focusing on single mode lasers with up to 700 mW output power between 1,300 and 1,550 nm, and on DFB lasers for sensor applications, has also been strengthened.

4.4 Interactive Media –
Human Factors (IM)

The classical and rather passive media consumers are continually being replaced by interacting, consuming and even content-providing users. This development increases the frequency and complexity of interaction and hence the meaning of easy to use interfaces between humans and computers. The research department IM of the HHI develops interactive solutions, which adjust technical systems to human capabilities and human communication behavior – and not vice versa. Through the use of ergonomic and technical facilities, the human-machine dialogue should be as "humane" as possible today. Innovative technology becomes almost imperceptible as users focus on the actual goals they want to achieve. The visual information output is thus able to mimick almost perfectly our visual impression of the real world: Stereoscopic displays allow the viewer to experience the spatial depth of a scene without bothersome devices such as stereo glasses or markers.
This can on the one hand be achieved by using so-called beam splitters, which separate the image information for the left and right eye almost perfectly – and therefore minimize crosstalk. On the other hand, the observer's eye position is tracked, so that image output can be adapted to any change of position without delay. This results in an almost perfect 3-D image in the viewer's visual center.

In addition, the accommodation-convergence conflict (the contradiction between the focusing of the human eye on the screen and their convergence to an object shown in front of the screen) could be resolved: Using a special technique, a stereo image is projected within the user's reach. Realistic vision, natural grasping and interacting become possible without strain on the eyes.

Potential application areas are medical and geological data examinations, CAD and architecture, as well as virtual worlds and simulations.

Equally consistent, the HHI orients itself to the natural human experience of the world in its search for interaction methods. Tools such as the computer mouse and pen will be replaced by direct control using hands and fingers. The technological part of the solution lies in techniques for image recognition which continuously analyze camera images of the user's hands and translate them into inputs in real time. Thus it is possible to use a great number of applications while standing freely in front of a display or a projection screen which otherwise would typically have been operated by mouse and keys. Already this solution has opened up completely new fields of application such as vandalism-safe information systems in public spaces or gesture-based control of operating room equipment by an aseptic physician during the operation. But this approach will go even further. For the hand detection, for instance, stereo cameras are used. They cover all three space coordinates and can use these for input operations. 3-D objects can be enlarged and reduced by changing the distance between the hand and the screen. This way, also different input modes can be realized. Several people can use the system simultaneously since the detection procedures are able to trace and interpret up to ten finger positions without any delay. The HHI has interlinked this contactless procedure in a system called "iPoint Presenter"

with information systems and games and has already won several international awards. Another problem has been solved by the technical approach to the capabilities of man. In extensive amounts of picture and video data similar image content is quickly and accurately identified. What is similar is defined by visual features which are represented by the software through efficient image descriptors. Currently this search is completed by a robust face recognition in order to determine whether people are depicted on a certain image. Using this technology in private photo archives is as equally conceivable as its application in security and surveillance areas of airports or on train platforms. In the field of eGovernment the HHI is pursuing the approach of delivering services to citizens instead of the current procedure of sending the citizens to the service points. Almost all services of local public offices can be offered using a "mobile citizen's briefcase" in shopping malls or retirement homes. Many cities in Germany already offer this service and in the framework of the EU project CIDRE the HHI has promoted the extension on a European level. The question of if the user's expectations could be met with this user-oriented approach and if a high usability could be achieved, is currently being analyzed in the "Human Factors Test Center" of the HHI. There, with the help of representative probands, usability tests of prototypes or finished products are being conducted. This gives the assurance that the solution is in accordance with human cognitive and physiological capabilities.
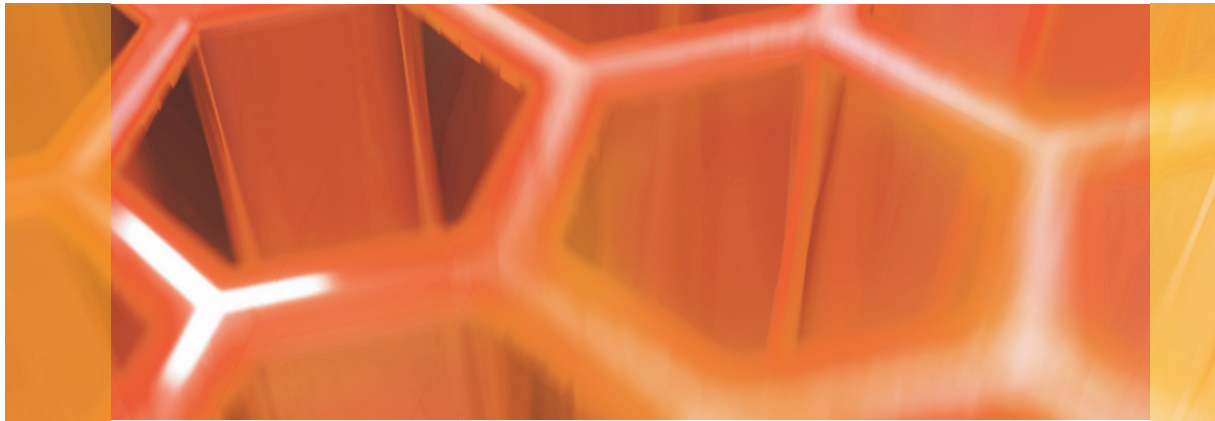
4.5 Broadband Mobile Communi-cation Systems (BM)

In the strategic business field of mobile broad-band networks and systems, solutions are being developed within the entire range of information theory, spanning from channel measurement, design of detection algorithms, system and network simulation right through to the imple-mentation of algorithms in real-time demonstra-tors with focus on the following elements:

▶ multi-antenna systems (MIMO) up to 1 Gbps
▶ 3 GPP LTE testbed @ 2,6 GHz
▶ multi-hop techniques for coverage and through-put enhancements for LTE advanced
▶ resource management for cellular and WPAN systems up to 60 GHz
▶ new cross-layer optimization approaches for QoS enhancement
▶ wireless ad-hoc networks
▶ car-to-car communications
▶ multi-standard baseband signal processing platform
▶ heterogeneous access management
▶ meshed networks and wireless sensor systems
▶ cognitive radio

MIMO systems are an important main topic. One key advantage for multi-user MIMO systems is the fact that the downlink transceiver optimization problem can be reformulated and solved as a virtual uplink problem due to the duality theory.

Another research focus is on cooperative commu-nication strategies for distributed antennas. The introduction of active cooperation between several distributed antennas offers advantages from the spatial structure of the wireless propaga-tion medium. Significant increases in spectral efficiency can be achieved, especially by active reduction of inter-cell interference. The HHI has hence developed a theory for modeling and optimizing interference-coupled ratio networks. Multi-cell MIMO channel measurements then enable the determination of how large gains will be in reality.

Within a joint research project with the Deutsche Telekom AG (DTAG) real-time key functionalities will be implemented on prototypical platforms. The resulting performance will be investigated within the framework of a field test, using a 3 GPP LTE air interface under realistic constraint conditions.

In a joint project, Nokia Siemens Networks, Fraunhofer HHI and IAF GmbH have developed transmission concepts for the 3 GPP LTE of UMTS. The base system with orthogonal frequency-divi-sion multiple-access (OFDMA) in the downlink and single-carrier (SC) FDMA in the uplink was pre-sented at the GSMA Mobile World Congress (formerly 3GSM World Congress) 2007 and 2008 in Barcelona with features such as link adaptation and channel and service aware multi-user scheduling.

Broadband millimeter-wave transmission in the 60 GHz range is another main topic which is seen to be a promising method of meeting the demanding requirements of future WPAN systems with regard to increasing datarates.

One immediate application is, for example, wireless multimedia supply in aircraft cabins. In this respect, the properties of the broadband 60 GHz indoor channels are being investigated
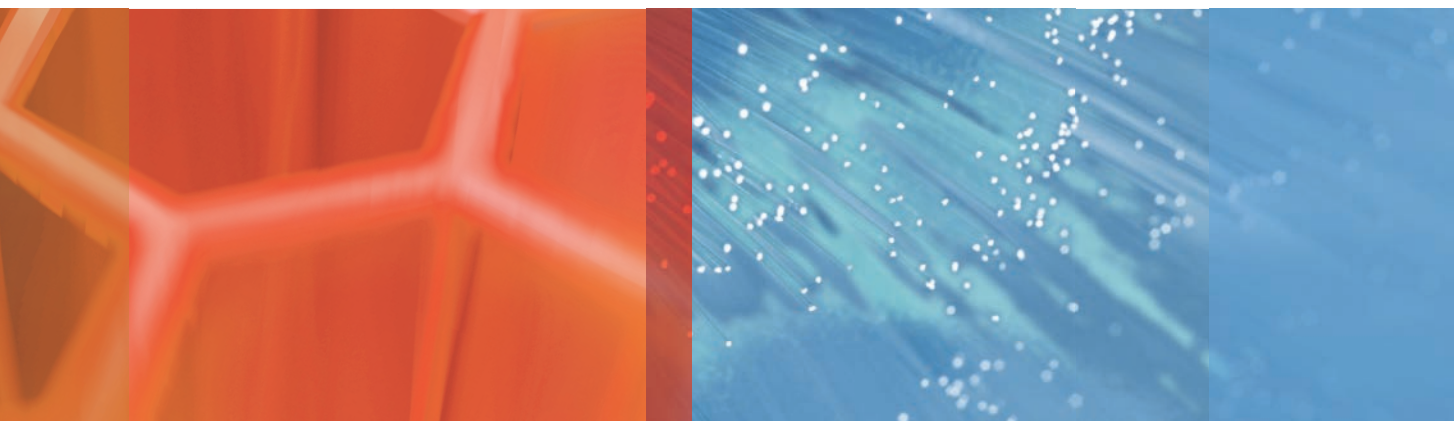
and a system concept is being developed and evaluated on an experimental system under realistic conditions.

In the field of wireless ad hoc networks, research activities include work on distributed coding for correlated sources and the development of energy-efficient communication algorithms and protocols.

Facing an increasing penetration of the usable radio spectrum with different active air interfaces, interference is increasingly becoming a limiting factor. A promising solution, taking into account the current spectral use and the spatial interference situation, are so-called radio transmission techniques (cognitive radio).

We are investigating radio transmission techniques using local knowledge of spectral occupation and the implications on the applied standards. Even in an actively-used spectrum of a primary radio system, cognitive signal processing techniques allow another secondary radio system into this spectrum. At the same time the secondary system keeps the interference load for the primary radio system below an agreed level.

4.6 Fiber Optical Sensor Systems (FS)

The Goslar-based department for Fiber Optical Sensor Systems was established in 2009 and maintains close connections to the department for Applied Photonics at the Institute of Physics and Physical Technologies at the Technical University Clausthal (TUC). It also cooperates interdisciplinarily with the Laser Applications Center at the TUC and the Energy Research Center for Lower Saxony (EFZN), likewise in Goslar. The department is under the management of Prof. Dr. rer. Nat. Wolfgang Schade.

The department has access to the facilities of its cooperation partners in Goslar (including a variety of laser sources, laser diagnostics, spectroscopy, plants for three-dimensional material processing with high-femtosecond laser pulses and nano-meter spatial resolution and plants for the manufacturing and characterization of zinc oxide nanowires). This equipment allows industrial users to test customized sensor concepts in the form of experimental models and small batch runs in prototype plants jointly with the users.

The FS' core competencies lie in the development and production of innovative, miniaturized and fiber optic sensors and sensor networks, nanophotonic solution strategies for industrial applications in process control, process optimization for use in safety engineering, and intelligent sensorics in offshore wind energy plants and power cables.

Current R&D priorities:
Miniaturized fiber optic photoacoustic sensors
for highly sensitive gas diagnostics and gas analytics
and the controlling of industrial processes (for
example, for the early detection of fires or
methane detection in mines), safety engineering
(e. g. highly sensitive and selective detection of
volatile explosive substances and acetylene
detection in high-performance transformers) and
bio-med analyses (e. g. analysis of respiratory gas,
measuring of oxygen or acetone) using photo-
acoustic spectroscopy (PAS), cavity ring-down
spectroscopy (CRDS) and multi-pass absorption
spectroscopy (MAS).

**Intelligent cables through fiber-optic sensor
systems** for controlling load on wind energy
plants and power cables, in order to forecast any
possible outages at an early stage. For example,
by means of optical processes, variables in cables
such as spatially resolved temperate profiles,
mechanical load and ozone concentrations are
measured continuously as dimensions for corona
discharge and then evaluated via the sensor
network.With the creation of the PS (Photonic
Systems) department, the HHI has expanded its
business expertise to the area of fiber optical
sensor networks and systems while, at the same
time, meshing with the scientific expertise of the
University of Clausthal and the Energy Research
Center of Lower Saxony located in Goslar, both
contemplary to the HHI's own expertise. In this
way the basis is laid for the development of new
concepts and functions for innovative and specific
fiber-optical sensor systems which will be particu-
larly economically important for SMEs.

5. Highlights 2008/2009

5.1 Prizes, Awards and Vocations

Prof. Dr.-Ing., Dr. rer. nat. Holger Boche Receives Leibniz Prize

New impetus for mobile communications – for his work on the mobile networks of the future, Prof. Holger Boche, head of the Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute HHI, has been awarded the prestigious Leibniz Prize 2008.

Prof. Boche's special field is data transmission for mobile communications. This is however not concerned with simple cellular phone calls where only comparatively small amounts of data (9,600 bits per second) are transferred. For researchers data transmission only becomes exciting when tens of billions of bits per second are involved: The technical challenge lies in sending these data packets as space-saving as possible while guaranteeing optimal reception at the same time. Everyone wants to access data, whether in the form of images, text, audio files or movies at any time and from any place; however, this only works if the data transfer is coordinated. To achieve this, the base stations must optimally work together. This is not easy if the users constantly move and switch back and forth between the different stations. All stations try to contact the mobile device, trying to send or receive data. The larger these packets are, the faster the base stations reach their capacity limits. Each improvement of the transmission channels has therefore, according to Holger Boche, a considerable influence on the resources of mobile communications and in this respect has a great influence on the national economy. Hence, he develops, amongst other things, new mathematical methods that help to optimize the transmission.

The jury justified the award by stating: "Several key developments in the expansion of the mobile phone networks in recent years have been due to Holger Boche. On the basis of his theoretical work, Boche has advanced the understanding of complex mobile communication systems and at the same time has put his insights into practice in the technology used to standardize new mobile telephone systems." The prize winners 2008 were selected by the committee from 158 nominations.

Prof. Dr.-Ing. Thomas Wiegand Receives EMMY for the H.264 Standard

Both the Primetime and the Daytime EMMY Award 2008 in the category "technology" went to the video experts of the ITU-T and ISO/IEC for the development and establishment of the H.264 MPEG-4 AVC video coding standard.

Thomas Wiegand, together with the other heads of the video group, accepted the respective EMMY awards on August 23, 2008 in Hollywood and on January 7, 2009 in Las Vegas.

Generally television shows, which are aired during the daytime hours, are awarded the Daytime Award. The Primetime Award in contrast is awarded to television shows aired in prime time. For the first time in the history of the EMMY, one and the same technology received both awards.

After many awards and honors, the highly effective and efficient video compression technique H.264 (with the official name ITU-T Recommendation H.264|ISO/IEC 14996-10 MPEG-4 AVC) was honored by both the Academy of Television Arts and Sciences and the National Academy of Television Arts and Sciences. The video teams which are jointly funded by the standardization organizations ITU (International Telecommunication Union), ISO (International Organization for Standardization), and IEC (International Electrotechnical Commission) were also honored. The three leaders of the Joint Video Team, Thomas Wiegand of the HHI, Gary Sullivan of Microsoft and Ajay Luthra of Motorola, were awarded the Primetime Technology EMMY together with Malcolm Johnson, the Secretary General of the ITU-T and Scott Jameson, the head of the JTC1 of the ISO/IEC.

The Daytime EMMY award in the category technology was received by the video experts of ITU-T and ISO/IEC, Thomas Wiegand (HHI), Gary Sullivan (Microsoft), Ajay Luthra (Motorola) and Jens-Rainer Ohm (RWTH, Aachen) on January 7, 2009.

The Technology & Engineering EMMY Awards are presented once a year for outstanding technical achievements. Technical developments that allow consumers to use various media platforms more efficiently are honored.

Thomas Wiegand as the editor of the now award-winning standard has drafted the extensive H.264 specification. In addition, Thomas Wiegand's team at the Heinrich Hertz Institute has also contributed significantly to the technical content of H.264 and therefore to its success. The work carried out at the HHI was in many areas sponsored by the Federal Ministry of Education and Research. Furthermore, the HHI is in charge of the standard's reference software and has contributed to its establishment in many working areas. The improvements achieved through H.264 have contributed to the success of new video applications like HDTV, Blu-ray Disc, internet and mobile TV, video iPods and iPhones. It is important for the users at which speed and quality the videos are transferred to the respective end devices. With H.264, typically less than half of the bits for a video are required than with the previous standards.

Thomas Wiegand Appointed Professor at the TU Berlin

Beginning summer semester 2008, Prof. Dr.-Ing. Thomas Wiegand was appointed to a professorship at the Image Communication department at the Institute for Telecommunication Systems at the Technical University of Berlin (TUB) in the Faculty IV Electrical Engineering and Computer Science.

5.2 HHI: "Place in the Land of Ideas"

In 2009, out of some 2,000 candidates, the HHI was selected as a landmark in the context of the "Land of ideas" initiative.

▶ **Figure 1:** Virtual Mirror

The Virtual Mirror was selected as an outstanding example of future worlds of experience. The HHI's Virtual Mirror allows a user to personally experience virtual realities. Users can for example watch themselves wearing different clothes than those they are in fact wearing. Thereby a multitude of variants can be "tried on". Pressing a button on the touch screen is enough and the design of the garments is changed as desired. While in front of the mirror, the viewer is always able to move around freely. This solution, which considerably enhances the presentation quality, can develop itself to be a standard for smart POS (point of sale) systems.

Besides the "Cinema of the future" has been highlighted: This is a cooperation together with the Fraunhofer IDMT, where high-definition cinema projections in combination with three-dimensional sound are demonstrated. By combining a high-quality 180-degree video projection with the IOSONO surround sound technology, the recipient experiences a significantly improved overall perception and feels almost "right in the middle".

"365 places in the land of ideas" is a competition of the initiative „Deutschland – Land der Ideen" realized in cooperation with the Deutsche Bank.
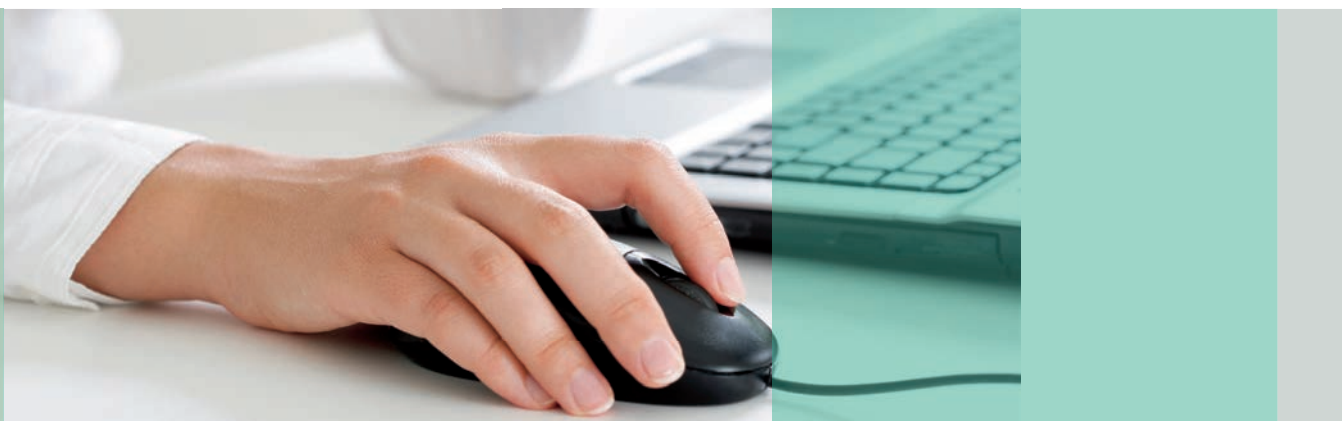
5.3 Redesign of the HHI's Web Presence

In order to position the HHI with its strengths and development potentials on a global level, the internet and the layout of a website are crucial factors. After a systematic review in 2007, it turned out that a number of features (design, handling, technology and background processes) had to be improved to underline the "pole position" of the institute on the web. The essential characteristics considered to be target-oriented for the HHI are:

▶ the HHI as a place of innovation ("amazing"),
▶ the HHI as an enabler for the acquisition of new technological trends and as a solution partner of the industry ("helpful"),
▶ the HHI as an international know-how guide ("inspiring"),
▶ the HHI as an important network partner for politics and society ("connecting"),
▶ the HHI as a "Career Center" (students, junior and exchange scholars),
▶ the HHI as an expert partner in the Berlin-Brandenburg region ("relevant").

These characteristics have to be reflected in the internet presentation and have to be made perceptible through appropriate content and resources. For this purpose it was necessary to address meta-topics away from the demanding presentation of scientific details with technical jargon, in order to concisely point out the significance of the HHI for the target groups outside the scientific community. The new layout of the website took into consideration the specific needs of the different types of users. While addressing the scientific community concerning the quantity of the pages presented was a less urgent design task, the other target groups were not at all or only rudimentarily represented with adequate content. In particular the addressing of business customers, of players from public and political domains as well as of job seekers was completely redesigned. The result is a web presence offering various "entrances" adapted to the interest of the different user groups. These "entrances" differ regarding their content and form (using wording/visuals, topic selection and use of multimedia elements). In the future, the website of the HHI will be developed and adapted further to the users' needs.
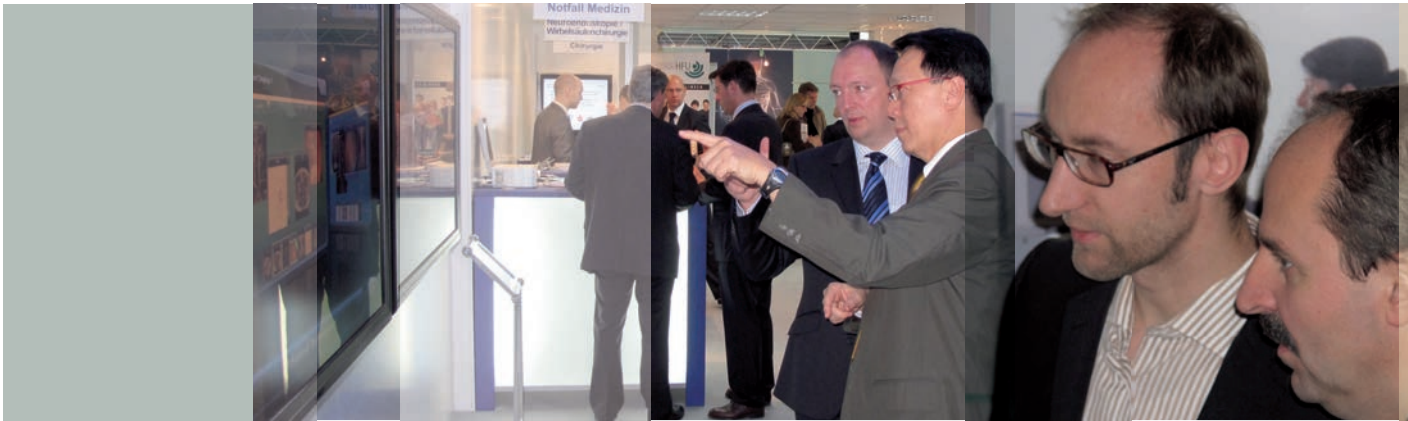
5.4 Participations in Trade Fairs 2008/2009

The HHI was involved in a multitude of industry sector and theme-oriented trade fairs. The larger fair commitments for example, the CeBIT from March 4 to 9, 2008 in Hanover (with the presentation of the iPoint Presenters), the IFA from August 29 to September 3, 2008 (with the presentation of the Virtual Mirror) and Medica (November 19 to 22, 2008 in Düsseldorf with the exhibits "Mixed Reality Workstation" and "video coding").

In addition, the HHI participated for the first time and with great success in the FOE, the Fiber Optics Expo, January 16 to 18, 2008 in Tokyo. Some further participations in international trade fairs should be mentioned that took place in cooperation with business development institutions from Germany: The participation in CONNECTIONS, one of the leading events in the United States on the topic "Digital Living", June 24 to 26, 2008 in St. Clara, California. The HHI participated as a cosponsor, together with "Invest in Germany" and provided one of the key notes.

An overview of the trade shows taking place in 2009 is presented below:

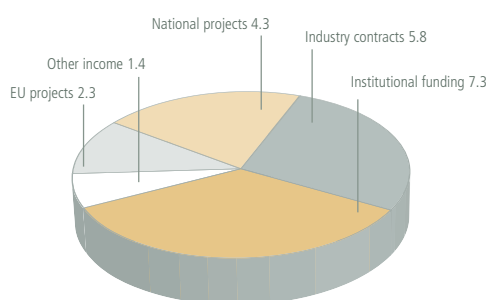|	
IMA 2009	01/13/2009 – 01/16/2009 Düsseldorf, Germany
FOE 2009	01/21/2009 – 01/23/2009 Tokyo Big Sight, Japan
Photonics West 2009	01/24/2009 – 01/29/2009 San José, California, USA
Arab Health Congress 2009	01/26/2009 – 01/29/2009 Dubai, UAE
GSMA Mobile World Congress 2009	02/16/2009 – 02/19/2009 Barcelona, Spain
CEBIT 2009	03/03/2009 – 03/08/2009 Hanover, Germany
OFC 2009	03/24/2009 – 03/26/2009 San Diego, California, USA
ANGA Cable 2009	05/26/2009 – 05/28/2009 Cologne, Germany, Fair Grounds, Hall 10
IEEE ICC	06/14/2009 – 06/18/2009 Dresden, Germany
IFA	09/04/2009 – 09/07/2009 Berlin, Germany
IBC	09/10/2009 – 09/14/2009 Amsterdam, Netherlands
ECOC 2009	09/21/2009 – 09/23/2009 Vienna, Austria
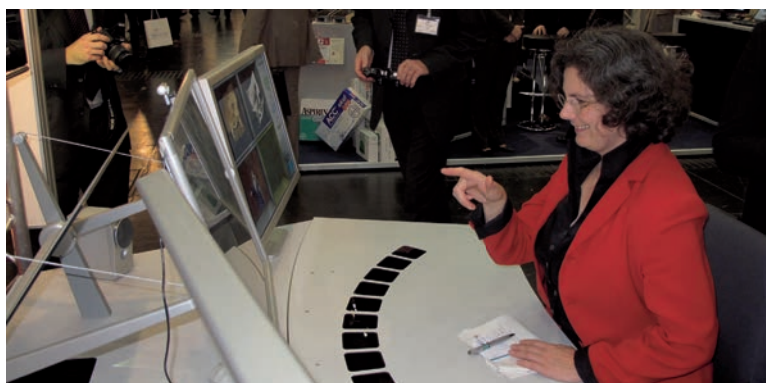
▶ **Figure 1:** Visit of the Secretary of State for Economic Affairs, Technology and Women, Ms. Almuth Nehring-Venus at the HHI booth at Medica 2008
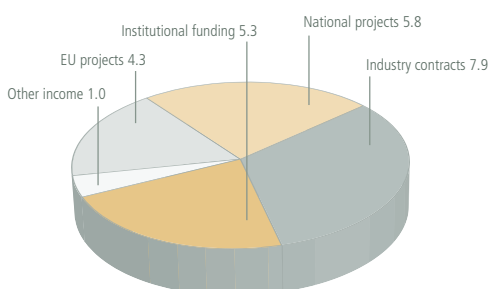
6. HHI: Facts and Figures

6.1 Operating Figures and Course of Economic Development 2008

The institute's operating budget (capital excluding investments) was 23.1 million Euros in 2008. In addition, there is a volume of 2.2 million Euros for the "German-Sino Lab for Mobile Communications" (MCI) (Deutsch-chinesisches Labor für mobile Kommunikation).

A total of 224 employees (+ 22 MCI) and 70 student assistants (+ 10 MCI) were employed. The consolidation process of the last years has been successfully continued. Thus, the HHI's income from projects with industry partners in the years under review has significantly improved.

This positive development is also illustrated in the longitudinal comparison (2005–2008)

▶ **Figure 3:** Development 2005–2008 (in million Euros)

The successful business development in the last few years can be illustrated by the development of the rho values (Share of the different kinds of income to cover the operating budget).

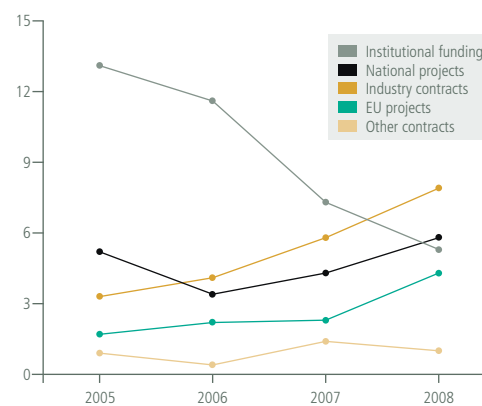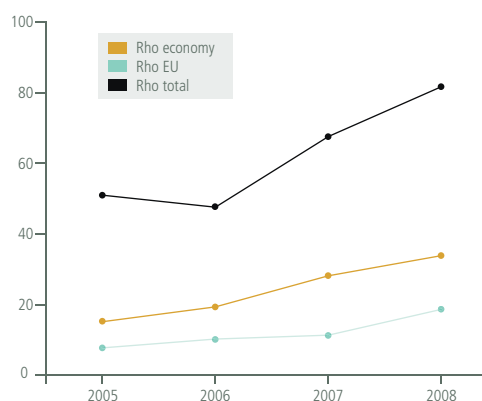▶ **Figure 4:** Development of Rho values (2005–2008) (Profit share of the operating budget) in percent.

▶ **Chart 1:** 2007, income from the various areas (in million Euros)

▶ **Chart 2:** 2008, revenue from the various areas (in million Euros)

This pleasing development of the business has also been also reflected in the quality of customer orders: With the rapidly increasing industrial contracts, customer loyalty to the HHI increases – newly acquired clients increasingly conclude follow-up orders and orders with higher volumes with the HHI.

In regards to the development of its workforce, after the phase of consolidation, the HHI is in a period of growth due to an increase in project contracts. In 2007 and 2008, a number of new positions have been filled at the HHI.

The HHI is also offering apprenticeships – with apprentices in the fields of IT, administration and technology.

6.2 Board of Trustees

The institute is supported in its work by a Board of Trustees with representatives from politics, industry and science. The last meeting of the Board of Trustees was held April 2, 2008 in the HHI.

Members of the Board of Trustees:

Professor Dr.-Ing. Jörg Eberspächer
Chairman of the Board of Trustees
Technical University of Munich

Dr. Erich Zielinski
Vice Chairman of the Board of Trustees
Alcatel-Lucent Germany AG

Dr. Andreas Bereczky
Zweites Deutsches Fernsehen
(Second German Television)

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Dr. Volkmar Dietz
Federal Ministry for Education and Research

Dr. Rainer Fechner
Alcatel-Lucent Germany AG

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Federal Ministry of Economics and Technology

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Dr. h. c. Hartmut Raffler
Siemens AG, CT, IC

Dr. Roland Raschke

Gerhard Schaas
Loewe AG

Dr. Mario Tobias
BITKOM

Dr. Fiona Williams
Ericsson GmbH, Eurolab R&D

6.3 Quality Management

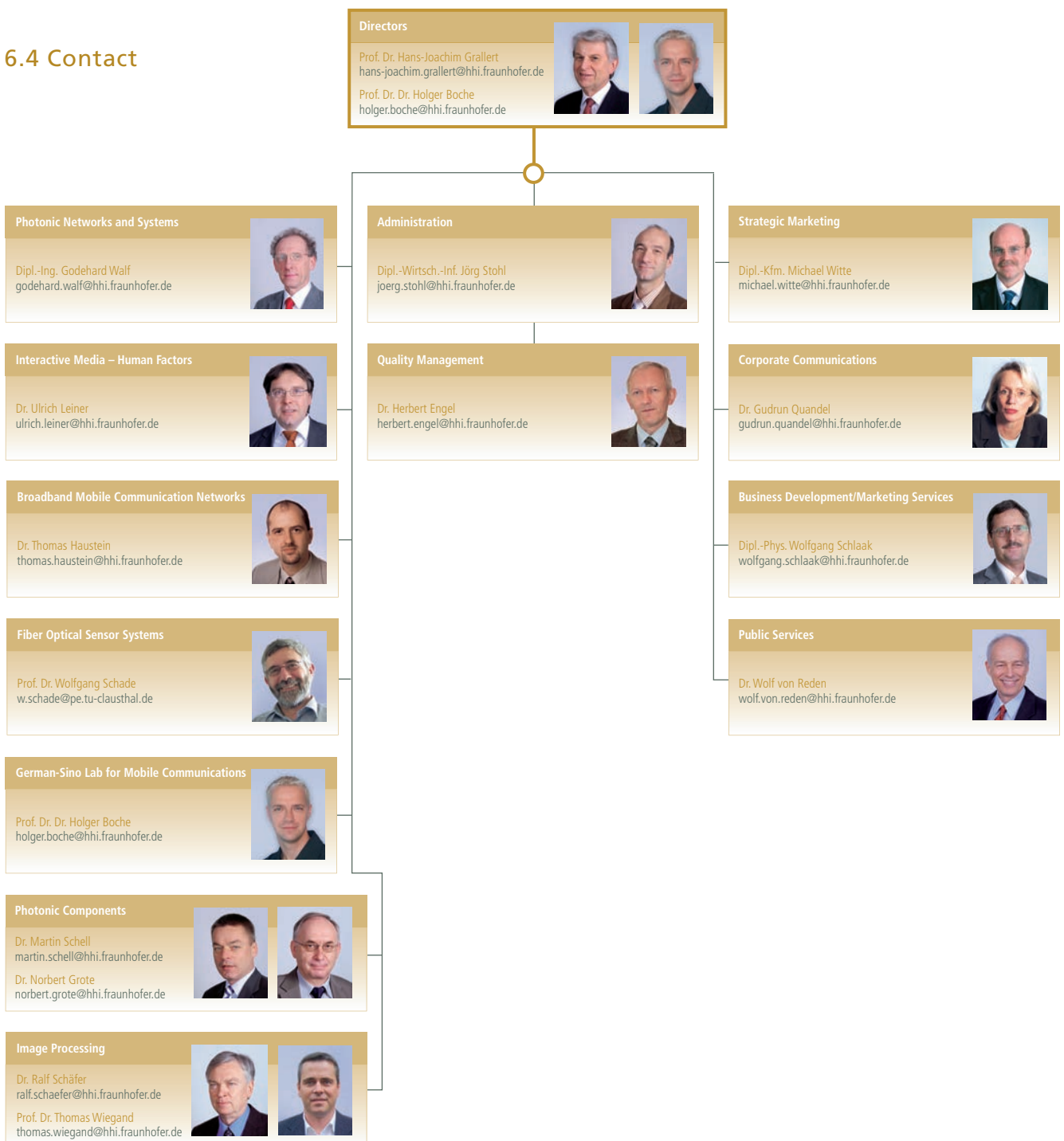The HHI has established and maintains a quality management system according to DIN EN ISO 9001:2000 in the sectors research, development and production in the field of photonics in all business functions at the Berlin site, Einstein-ufer 37. The fulfillment of the standard require-ments has been assessed by a quality audit.

The certificate was issued April 2, 2007 and is valid until April 1, 2010.

6.4 Contact

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- Fiber Optical Sensor Systems
- Mobile Broadband Networks and Systems
- Interactive Media – Human Factors
- Image Processing

Further information from other fields of expertise

HHI is divided into six specialized departments. Each of them has its own brochure which offers further information about the department's respective work and projects.

You can order any brochure(s) free of charge under the following contact details:

Gudrun Quandel
Tel   +49 30 31002-400
gudrun.quandel@hhi.fraunhofer.de