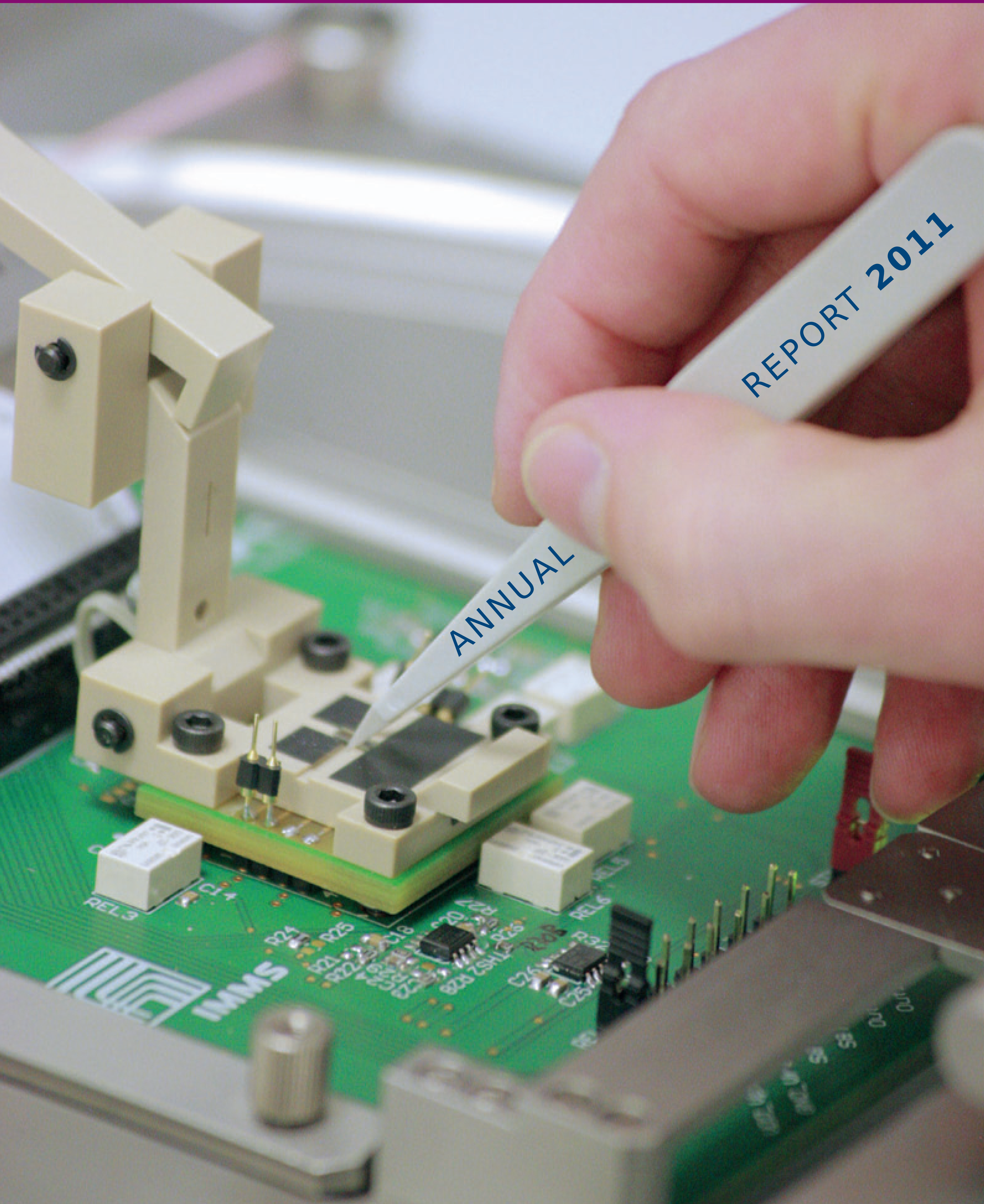
IMMS

ANNUAL REPORT 2011



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Socket for application-specific
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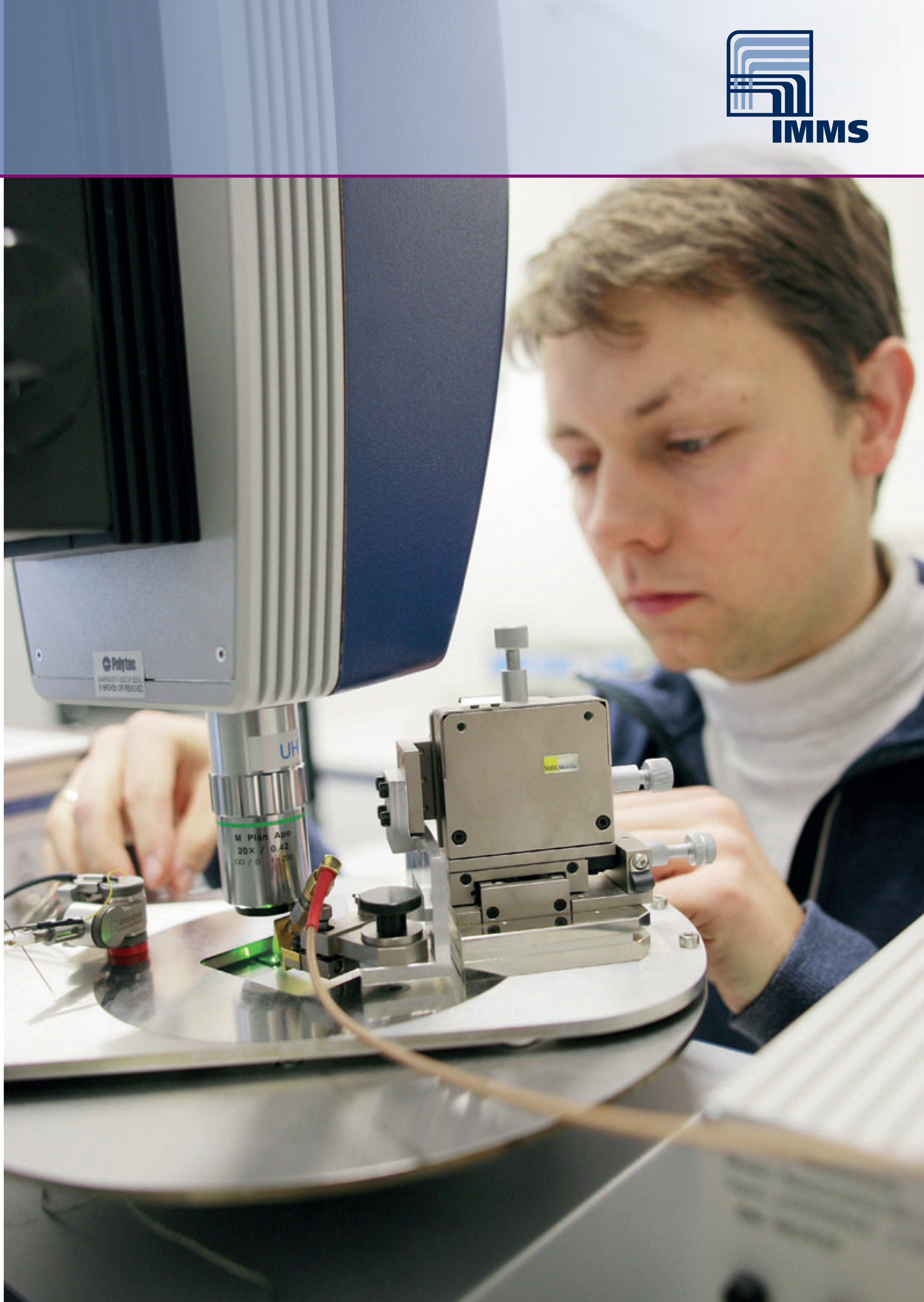

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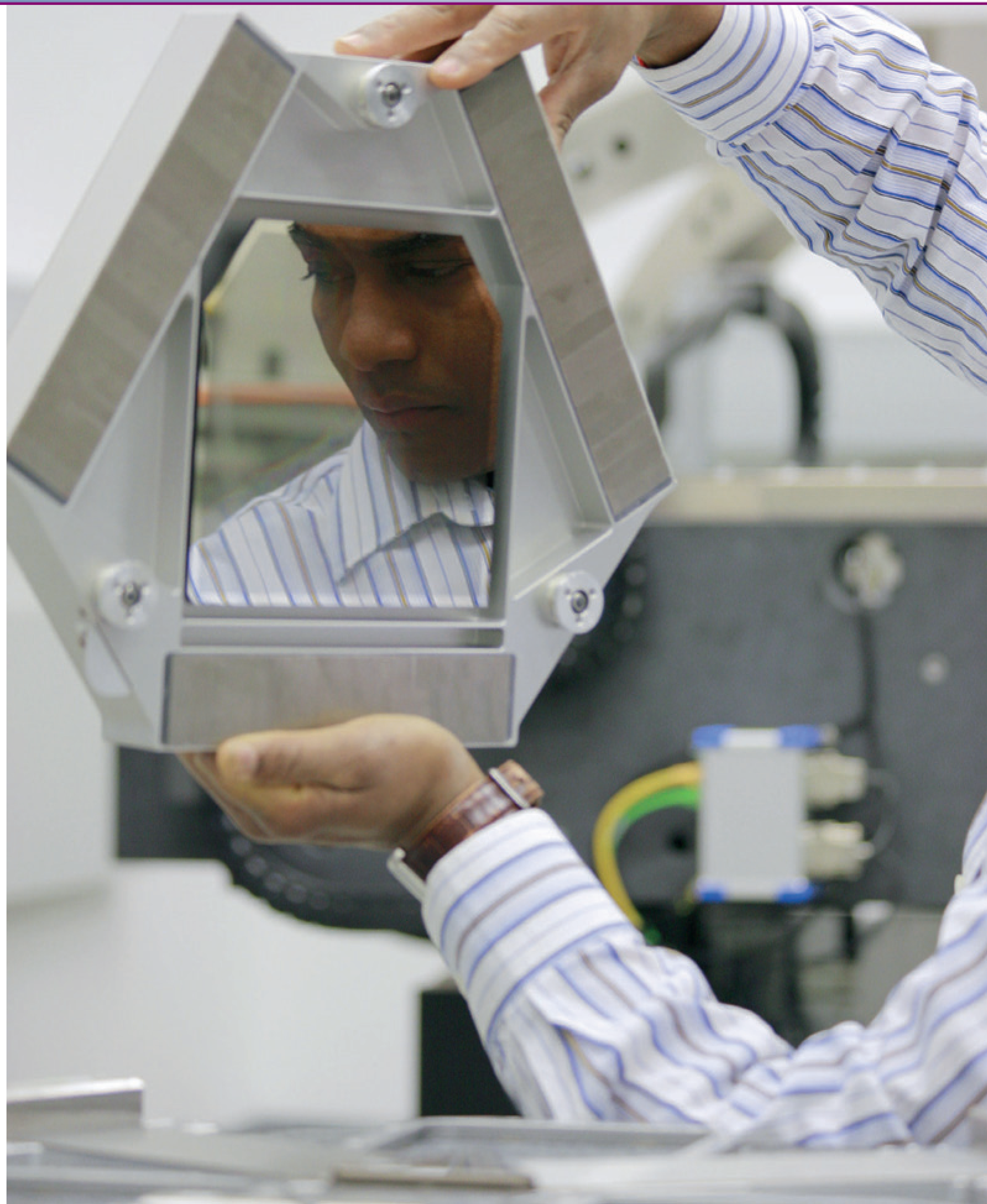

Page 5:
Free floating slider of the Mag6D system with 6D scale on reflective panel for precise positioning (compare page 22).

Preamble

The research strategy of the Institute for Microelectronic and Mechatronic Systems non-profit limited company (IMMS GmbH) focuses on applications, aiming for solutions that eventually yield products. In close cooperation with the Ilmenau University of Technology and partners from the industry, the institute deepens, distributes and implements research results, concentrating on application-oriented proactive research and development in microelectronics and systems engineering as well as in mechatronics. It is IMMS's goal to reinforce synergies among these fields and to work interdisciplinarily, acquiring comprehensive experience and knowledge potentials. This coincides with the German federal government's High-tech Strategy, which demands competences in the design of systems as a whole.

At the same time, the institute focuses on key issues of Thuringian policies and has been aligning its research for years to make important contributions to, e.g., the development of sustainable (“green”) production technologies and consumption processes as required in the funding program “Thüringen GreenTech” under the keywords “Energy Efficiency” and “Resource and Material Efficiency”.

For example, IMMS develops cost- and energy-efficient hardware and software solutions for multi-modal smart sensors. These are multi-sensors with embedded digital signal processing, consisting of microelectronic circuits and embedded system and micro-system components. Further topics of research also include innovative communication protocols for optimizing informational throughput and power consumption as well as for enabling self-organizing, complex, high-density wireless sensor networks (“sensor clouds”); optimal energy harvesting solutions for an energy-autarkic operation of wireless sensors in difficult-to-access locations or for cost-sensitive applications; and the characterization and calibration of energy-autarkic multi-modal smart sensors with a particular focus on material and resource efficiencies. This universal know-how developed at the institute can be used in various strategic areas of application, such as environmental monitoring, green building, green mobility or disaster prevention. Having been major issues at IMMS for a long time, these topics are promoted immensely by the “ Green Sense” research group established in 2011. This research, which has now become interdisciplinary, focuses on making multi-modal smart sensors more efficient, to unite them in one modular technology platform and to open them up for a wide spectrum of future application scenarios.

Supporting Young Scientists

IMMS is heavily engaged in its duty to support young scientists and academics. It supervises promotions and many research projects in cooperation with the Ilmenau University of Technology and other German and international universities and colleges in undergraduate works, such as internships, research assistances, bachelor and master theses. The institute offers an internationally-competitive infrastructure according to industry standards in design support and lab technology for electronic and mechatronic systems, which is supplied for research and necessary prior qualifications. The last year in particular has led to a major increase in the number of students at the Ilmenau University of Technology, which proves the intensive efforts in basic education worthwhile.

This way, and to our delight, highly-motivated students with extraordinary accomplishments find their way to IMMS. In some areas, the institute even reached its capacity limits. In order to both back up and challenge young academics, a weekly “Scientific Seminar” has been introduced. There, students and postgrads introduce their works and issues, so that they can then be discussed profoundly. The intensive communication initiated there expands the boundaries of their individual subjects, leading to new connections and ideas.

In 2011, new ideas and projects have been brought forward by the staff of almost 90 employees, to

make innovative developments for the industry ready to market. This allows for surgical stents to be produced in a highly precise and easier manner, enables the blind to see, monitors material decay in aircraft wings and analyzes emissions of engines or biogas plants. This report illustrates the research that has been necessary for these and numerous other R&D results of the institute.

But first of all, we would like to thank the Federal State of Thuringia in the name of the IMMS team. It is the state's funding that makes our work possible. We thank the Board of Directors and the Academic Board of IMMS for their support and consulting on all issues. We would like to thank the Ilmenau University of Technology for our extraordinary co-operation, which not only enormously enriches our work, but creates many synergies by connecting research topics of both institutions. We would also like to thank all our business partners and supporters, friends and people supporting us in our work. But our most important assets are our creative and engaged minds. We would like to thank them, our staff and our students, for promoting our Institute and shaping our common future through their specialist expertise and personal competences, constructive and trusting cooperation.

Dipl.-Ing.
Hans-Joachim Kelm

Prof. Dr.-Ing.
Ralf Sommer

Cooperation with the Ilmenau University of Technology

Due to its position as an affiliate institute of the Ilmenau University of Technology, IMMS as well as the university take advantage of research and scientific networking of both partners. In 2011, IMMS has cooperated in more than 13 research projects with 28 departments in Electrical Engineering and Information Technology, Mechanical Engineering, Information Technology and Automatization, Mathematics and Media and Communication Sciences. The key aspects were on highly precise positioning and measurement machinery, biomedical technology, sensorics for process monitoring at high temperatures and high-frequency technology for satellite navigation. From IMMS' networking with the industry emerged invaluable practical impulses for the research of the institute and for the Ilmenau University of Technology.

Also in 2011, IMMS scientists engaged strongly in supporting young academics. They teach students of the Ilmenau University of Technology theoretically fundamented knowledge of methods and early combine this with its practical implementation in applications. In addition, the institute offers trainings and company visits. In 2011, 46 students have worked as interns or student assistants at IMMS or wrote their bachelor, master or diploma thesis here. For young academics, the close relationship between the institute and the industry offers practical research topics and result-oriented working.

Cooperation Highlights 2011:

Magnetically Floating Platform for Nanometer Positioning

Mag6D is a highly precise drive system which makes the platform float solely using magnetic powers, positioning it in 6 coordinates. The prototype system was implemented by IMMS, the Ilmenau University of Technology, Department of Mechatronics, and PI – Physik Instrumente GmbH.

Close cooperation in the Research Groups GreenSense and PORT

The goal of the IMMS research group GreenSense is the research and development of a modular technology platform to allow the energy-efficient setup and operation of highly complex, closely coupled, energy-self-sufficient, multimodal smart sensor networks for a wide sprectrum of future application scenarios, especially for monitoring and controlling industrial production, transport and operation processes. There is also a close cooperation with the PORT research group. Both research groups make important contributions to set up "green" production technologies and consuming processes as are funded in the program "Thüringen GreenTech" under the key words "Energy Efficiency" and "Source and Material Efficiency",

Cooperation of Doctorate Program Mobicom and IMMS on the Way

In December 2011, a cooperation in mobile wireless communication was agreed upon by Prof. Dr. Mitschele-Thiel and IMMS. It is the goal of this cooperation to transfer information from autarkic sensor networks in superior IT infrastructures, without being permanently connected to a base station. A sensor network developed at IMMS will be integrated into scenarios on desaster management in the Department of Integrated Communication Systems of the Ilmenau University of Technology. Joint tests and further activities are planned.

Networked, Mobile, Smart – Building Blocks of Tomorrow's Innovation

“Networked, mobile, smart” – this was the slogan of the 6th National IT Summit on December 6th, 2011, in Munich. Intelligent information and communication products (IKT) strongly influence business, workplace and our social life. Existing infrastructures are increasingly being equipped with modern IKT solutions, they are networked. In the process of digitalization of business and society, these smart technologies are the key to growth and prosperity. They are the foundation of promoting the infrastructure to so-called intelligent networks. These allow innovative, efficient and sustainable infrastructures, in areas such as energy, transport, logistics, automation, administration and health care. The Internet becomes increasingly powerful and mobile. Intelligent networks are used in such ways that energy is used more efficiently, patients are better cared for, traffic is optimized and made safer. Such complex tasks as “Smart Grid” or “Smart Traffic” (Figure 1) can only be solved through close cooperations among research and industry from various sectors. Is IMMS ready for these new challenges? How can our skills be integrated in major projects like these? The institute has found an answer in its partners: For years, IMMS's specialists have done research in the future technology of “sensor networks.” These collect data in real-time that can be used by the operators of different application scenarios, e.g., to route more traffic across a certain crossroads. The resulting application-specific solutions and services are open and user-friendly. They can be seamlessly integrated in the system environments of our customers.

Figure 1: Smart Traffic; Source: IMMS

To implement the innovations of tomorrow, it is absolutely necessary to deal with cross-industrial views requiring to put all specialist skills together. In addition to technology, it is vital to consider standards, regulations and legal questions. Intelligent solutions drive interdisciplinary approaches. Here, IMMS is getting involved with all its knowledge and skill.

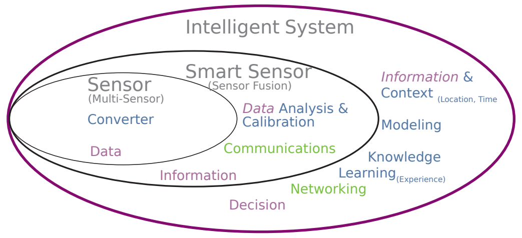

Figure 2: From the sensor to the intelligent system; Source: IMMS

The following activities contribute to promoting IMMS's knowledge, to call attention to new research activities and results, and to usefully translate them into applications:

- Active participation in standardization processes for Ambient Assisted Living and in roadmapping
- Use of the SatNat Saxony network to put together competencies in navigation applications, geo-information, information and communication technology, traffic telematics and autonomous systems in Saxony and Thuringia
- Preparation and realization of future-oriented events, such as “Sensors for regenerative energy and energy efficiency” (Figure 2) or “Cyber-Physical Systems” (CPS).

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Testimonials

Univ. Prof. Dr.-Ing. habil. HANNES TÖPFER, Head of Department of Advanced Electromagnetics, Ilmenau University of Technology

At the Department of Advanced Electromagnetics at the Ilmenau University of Technology, we work on research topics concerning the development of highly sensitive electromagnetic sensors. In the DFG research training group "Electromagnetic Flux Measurement and Eddy Current Examination Using the Lorentz Force," foundations for innovative procedures for non-destructive material tests are developed. These can be applied to non-ferromagnetic conductor materials like aluminum or conductive composite materials. Lab experiments and numeric simulations have already proved that material defects in electric conductors can be detected at much greater depths than with conventional eddy current examinations.

For this development, the cooperation with IMMS in 2011 was essential as they combine research competence and focus on applications in an outstanding way. Especially the cooperation with the mechatronics department contributed significantly to ensuring the practical applicability of the material testing procedures.

As a result, there are going to be solutions whose application orientation has been established in close dialogue right from the beginning. This example illustrates the advantageous effects of the cooperation of fundamental and applied research. Speaking for the department at the Ilmenau University of Technology, I would like to extend this kind of cooperation also to other research topics.

Prof. Dr. CHRISTIAN BRECHER, Director of the Institute WZL of the RWTH Aachen, Research Area Machine Tools, and Chairman of the IMMS Scientific Advisory Board

Having been a member of the Scientific Advisory Board for years and as of recently also its head, I am delighted to actively follow the development and strategic direction of IMMS. Due to its long-standing research and development, the institute has acquired extensive know-how with comprehensive competencies and expertise in microelectronics, mechatronics, system design and measurement technology. These four fields are joined in two research programs for microelectronics and mechatronics in an almost unique combination with numerous synergy effects, creating a unique position for the institute.

The synergistic combination of different fields of research is constantly gaining importance. "Integrativity" is the key competence for mastering tomorrow's challenges and describes the holistic, inter-professional and interdisciplinary understanding of complex problems.

Due to their heterogeneous structures, the systems of tomorrow will only be possible to design in integrated ways. For example, a sensor-actuator system involves mechanics, magnetics, fluidics and microelectronics. With the goal of the optimal system in mind, these systems cannot be designed in separate domains and put together later on. As the individual systems are increasingly being connected to form larger networks, aspects of higher-level communications are gaining importance as well.

Mastering such integrated, cross-domain design processes is one of the long-term strategic goals of IMMS. To accomplish this, the institute as an interdisciplinary team cooperates with strong partners, such as the Ilmenau University of Technology. Companies of a wide variety of industries, many of them from Thuringia, find a suitable partner in IMMS to sustainably close the gap between novel scientific insights and the development of innovative products.

Page 10:
Testing a wafer using a prober.

Univ.-Prof. Dr. rer. nat. habil. MATTHIAS HEIN, Head of Department of Information Technology at the Ilmenau University of Technology and Member of the ThIMo Specialist Team

In my view as Head of Department of Information Technology and member of the specialist team in the Innovation Center for Mobility of Thuringia (ThIMo) at the Ilmenau University of Technology, the cooperation with IMMS is vital for strategic networking and cluster development. In addition to the universitary joint-department Research Institutes for Micro and Nano Technologies and for Automotive and Production Technologies, this is especially true for linking with industrial applications in Thuringia and Germany (e.g., Automotive Cluster Eastern Germany, Silicon Saxony, SatNav Saxony).

Furthermore, IMMS contributes to a coordinated teaching strategy and the promotion of young researchers at TU Ilmenau, for example in Information and Communication Technology.

Research and development tasks in cooperation with my department focus, i.a., on a federal initiative for developing a radio interface for robust satellite navigation with a holistic view on antenna system, front-end and signal processing as well as on the ThIMo research groups on sensor technologies (PORT and greenSENSE). Based on a joint application, the DFG research group MUSIK (Multiphysical Synthesis and Integration of Complex HF Circuits) is going to be established at the Ilmenau University of Technology in 2012, a fact about which I (as designated spokesperson) am particularly happy.

IMMS's specialist expertise stands for microelectronics, mechatronics and microelectromechanics, microelectronical circuits and design methodology as well as for embedded systems and sensor technologies. From my point of view as a member of the academic board of IMMS, I recommend to strengthen competences through concentration and to maximize synergy benefits.

Prof. Dr.-Ing. habil. EBERHARD MANSKE, Head of the Precision Measurement Technology Department at the Faculty of Mechanical Engineering at the Ilmenau University of Technology and Spokesperson of SFP 622

The Collaborative Research Centre SFB 622, "Nanopositioning and Nanomeasuring Machines", set up by the German Research Foundation (Deutsche Forschungsgemeinschaft, DFG) at the Ilmenau University of Technology, focuses on developing the scientific-technical foundations of design and implementation of highly precise nanopositioning and nanomeasuring machinery (NPM machines). They allow positioning, measuring, touch, modification and manipulation of three-dimensional objects with nanometer-precision.

Due to its expertise in precision drive systems, IMMS makes a highly valuable contribution to our research. Especially in the field of air-guided NMP systems, new solutions clearly exceed the capabilities of conventional systems by far. The results achieved by IMMS impressively prove the ability of the developed direct drive systems to position exactly "down to the nanometer" and are an excellent starting point for their application in large driving areas. According to the DFG experts, "In the field of nanopositioning and nanomeasuring technology, the world standard … is also set in Ilmenau."

Promotion of young academics at IMMS

At IMMS, the promotion of young academics is given highest priority. Therefore, students are intensively integrated into developing practical solutions and individually supervised. Prospective engineers in Biomedical Technology, Electrical Engineering, Automotive Engineering, Applied Computer Science, Mechanical Engineering, Mathematics, Mechatronics and Physics can acquire knowledge in practically solving attractive scientific tasks as research fellow or intern and write bachelor or master thesis.

Dipl.-Ing. Gerrit Kropp

Gerrit Kropp

During my industry internship, in October 2008, "Industrial Electronics and Measurement Technology (IEM)“ has been my first step at IMMS. After that I became a research fellow in the fields of Circuit Design and PCB Design. From August 2009, I finished my studies in Electrical Engineering writing a diploma thesis on "Conception, Set-Up and Application of a Modular Test System for Quality Assessment in the Semiconductor Industry". After defending the thesis with very good results under supervision by Prof. Sommer and Ingo Gryl, since April 2010, I have been a research assistant at IMMS. In this position, I am also responsible for hardware development for modular testing systems.

For me, there are many reasons to stay at IMMS: On the one hand, the topics in industrial electronics and measurement technology (IEM) are roughly the same as my personal interests. On the other hand, chances are that I can advance professionally and systematically. This for sure is an advantage for my professional career. Furthermore, the close relationship of research and industrial applications provides an important connection of my work to practical issues. But the most important reason for me is: Working in this team is simply fun!

Felix Neumann

I first heard about IMMS during Prof. Sommer's lecture. After a first internship from April 2010 until June 2011, I have worked at IMMS at the industrial IKT2020 cooperation project SyEnA (Synthesis Driven Design of Analog Circuits). During my master thesis at IMMS, I have extended my intercultu-

M.Sc. Felix Neumann

ral competences in their international team. The creative project work at the institute, always with new research aspects, provided many different and interesting aspects for my everyday work. For technical problems, productive solutions are being discussed in a motivating environment, often help is offered. In addition, IMMS is very family friendly: Neither family nor work has to take a backseat, but are easily coordinated. Since the beginning of the year, I am a research assistant in the reserach group "PORT" at the Ilmenau University of Technology in the Electronic Circuits and Systems department, working at my doctorate. Due to the close scientific cooperation of the department and IMMS, I will stay closely related to the institute. This environment provides me with a foundation to realize scientific ideas, thus always improving the world a little bit.

X-Fab Grants Scholarship to a Young Ilmenau Academic

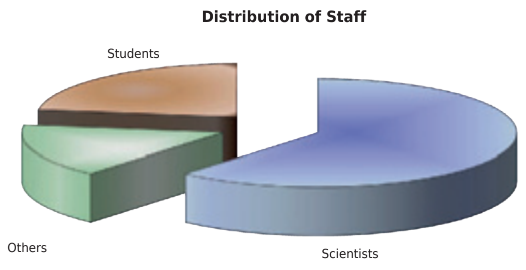
The X-FAB Semiconductor Foundries AG is one of the leading enterprises worldwide specialized in producing mixed analog-digital microchips. X-FAB is a close partner of IMMS. It has granted Eric Schäfer, one of the best students of the year, a scholarship for his outstanding results to support scientific work in microelectronics. Also as a student, Mr. Schäfer has worked intensively in joint research and development projects at IMMS and in Prof. Sommer's department. Since the beginning of 2011, he is working as a research fellow in the microelectronics department. At IMMS, he specializes in system and circuit design and verification in the projects "Compact Adaptive Terminal Antenna for Noise-Free Satellite Navigation" (KOMPASSION). This scholarship allows him to research within his promotion in design methods for CMOS-integrated HF systems.

With this scholarship, X-FAB again supports the combination of industry, research and specialist staff promotion in electronic technology and microtechnology in Thuringia. Dr. Jens Kosch, board member of X-FAB AG, emphasizes: "Research, education, industry and business are elements of the society that need to be connected – as for the chip production – to be successful in international competition."

With granting this scholarship to a young Ilmenau academic, the close cooperation of IMMS and X-FAB has once again proved worthwhile.

Page 15:
Test of packaged devices using a modular test system

IMMS in Numbers



In 2011, 90 people were employed by IMMS. Of these, 54 were scientists and 21 students as full-time employees in research and development, which is about 82% of all IMMS staff.

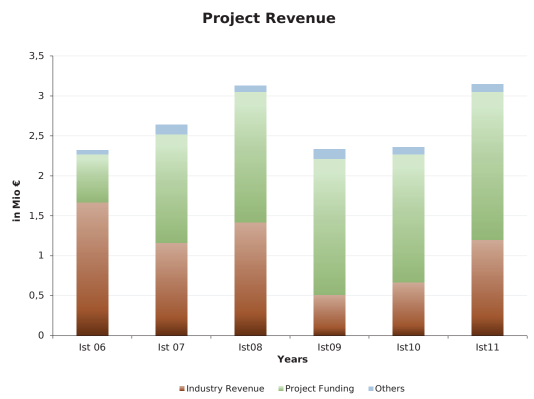
As in the years before, many students (a total of 42) have accepted IMMS' offer to improve and complement their education with practical research: 21 students worked as interns; 2 diploma thesis, 6 bachelor thesis and 5 master thesis have been supervised. 7 staff are currently registered at a university for a doctorate degree. [Kel]

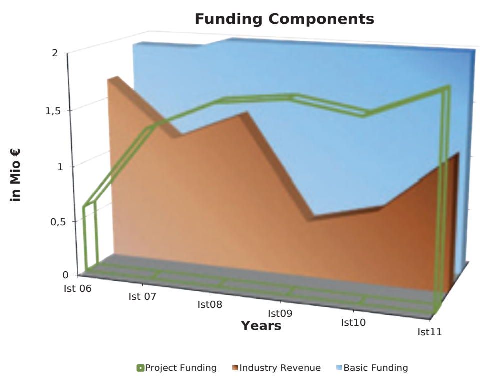
In 2011, the revenue from contract research increased by 30% again, the revenue from public funding by approx. 25%. However, the absolute revenue from contract research has not yet reached the level it had before the global economic crisis. The economic situation in 2011 has stabilized on the level of the previous year though. Spirits in the economy are still on a high. This gives hope for a future increase of industrial contract research. Strategically, IMMS has consequently focussed its research on future topics energy and environment, mobility, communication and safety. The goal is a sustainable and dynamic development of research transfer to our industry customers.

The positive development of project funding proves the acceptance of IMMS as a research partner. Nearly all these projects are cooperations. IMMS' networking clearly improved the project activities. A great challenge is to secure project funding on a high level and to increase the revenue from contract research also in the next year. Earnings from these activities are used for financing publicly funded projects in deficit.

IMMS strongly engages in student education. This way, it attracted a sufficient number of graduates to sustain the numbers and qualification necessary for our scientific staff. This allows the institute to deal with the increasing number of publicly funded research projects.

The Free State of Thuringia provided also in 2011 reliable conditions by supplying a stable institutional allowance. This has especially supported the cooperation with small and medium enterprises.





Events and Life at IMMS

15 Years IMMS – Future is Now

Honorary guests at IMMS' 15th anniversary: Prof. Dr.-Ing. habil. D. Schipanski, Founding Member; Christoph Matschie, Thuringian Minister of Education, Science and Culture; Gerd Schuchardt, Head of MDR Administrative Council; Source: IMMS

On May 5th, 2011, IMMS celebrated its 15th anniversary with 150 guests, among them partners, supporters and friends. Minister Christoph Matschie complimented IMMS in his speech on the comprehensive initiatives bridging fundamental research and practical application. On IMMS EXPO, guests could learn about innovative products and developments IMMS has created in cooperation with its partners from industry and science. As a scientific highlight of the celebrations, under the motto "Technology versus Application: Changes in Economic and Scientific Challenges", IMMS' innovative achievements with relation to applications were presented in lectures. This was followed by a lively panel discussion with Prof. Scharff, Rektor of the Ilmenau University of Technology, and further representatives from science, politics and industry.

Celebrations were concluded by a staff party in the TU Ilmenau refectory, where the day was finished with excellent food, a glass of wine and live music by the Second Unit Jazz Band.

To mark this 15th anniversary, an exhibition of images of life at IMMS was presented. The motifs portrayed staff and showed a glimpse of the working environment at IMMS, products and also leisure activities. The photo series are on display in the building of the IMMS head quarter.

Sports Competitions

In 2011, IMMS took part in the BVMW Luge Cup on August, 27th, 2011, at the Ilmenau Summer Luge Track. In the singles, Bianca Leistritz finished third, the IMMS team came in fourth place. At the RUN business run on June 6th, 2011, in Erfurt IMMS came in 128th and 197th of 207 male teams. Their times of 1:42:09 and 2:00:27 are an incentive for the next start in 2012.

IMMS team "Precision in any Position" at BVMW Luge Cup. Source: IMMS

Workshops

In cooperation with OSADL eG, IMMS organized a workshop in the **Embedded Linux** series, which was successfully continued this way, on September 27th and 28th, 2011. In special technical lectures on chances, practical approaches and legal aspects of Open Source and in a practical course,

Final "SMARTIEHS" project meeting with representatives of all partners from France, Switzerland, Norway, Poland and Germany. Source: IMMS

the participants learnt about programming with real-time embedded Linux on an embedded system. This was the foundation for them to create first real-time applications for an industrial embedded system themselves. Especially the practical examples and trainings received a very positive response from the international participants. Due to this excellent feedback, this series is going to be a fixed part of joint events of IMMS and OSADL eG. It is planned to offer this workshop twice a year. The next date is set for spring 2012.

Under the scientific direction of Prof. Dr.-Ing. Hannes Töpfer, in February 2011 the qualification seminar **"Embedded Systems – Towards the Smart Sensor"** took place at IMMS. In its second year, it has been a fixed part of the qualification offer by the AMA Association for Sensor Technology. It focussed basically on the development, inital operation and programming of embedded systems and on Open Source approaches, further on illustrations how these systems can be programmed and tested using available PC infrastructure. The translation into realistic scenarios and the implementation in sensor networks using established bus systems and local area radio technologies have been explained using various practical examples. The participants gathered new knowledge and ideas and gave a positive feedback.

One part of the **Technology Days 2011**, started by Polytec GmbH in Waldbronn, was an event at IMMS under the topic "Ultrasound, Micro and Nano Technology: Capturing and Visualizing Vibrations up to 1.2 GHz." In cooperation with Polytec and leading research institutes, IMMS presented modern trends in vibrometer measuring technology. Among other typical applications, one topic was the identification of material stresses in thin membranes. Guided tours in the mechatronics lab and the measuring labs of IMMS complemented the specialist lectures and sparked intensive discussions among the 25 visitors.

On the occasion of the **11th MEMUNITY Workshop** hosted by IMMS on "RF-MEMS and Other Advanced Components", more than 40 international experts from the industry and research community met to discuss current developments on the MEMS market. Specialist lectures outlined the requirements for the MEMS test and indicated new solutions. Among others, the parallel test of MEMS realized within the EU project SMARTIEHS (SMART InspEction system for High Speed and multifunctional testing of MEMS and MOEMS) was presented in the lab. More information on the principle of this testing system and on IMMS' role in this project are included in the corresponding article in this annual report.

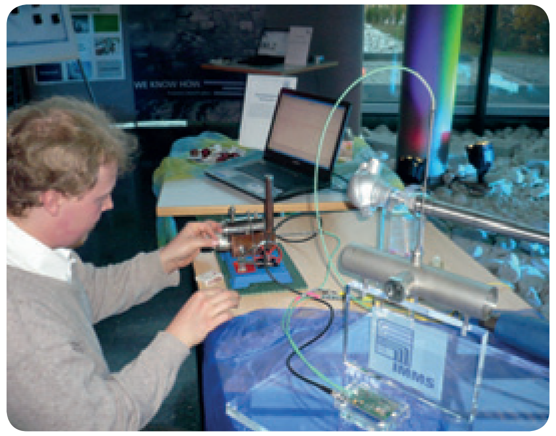
Long Night of Sciences in the Thuringian Capital

Impressive, scientific and interesting scenario

On November 4th, the third Long Night of Sciences took place in Erfurt. There was a vast offer of events shaped by the scientific research of the local universities and colleges, the clinical center and the many examples of applied sciences at local companies. The visitors were spoilt for choice when arranging an interesting route for this evening. The institute welcomed approximately 400 interested visitors with an impressive play of colored light in the entrance area leading up to different demonstrators from various fields of research. From demonstrating our Foucault's Pendulum and different exhibits of sensors for everyday life, visitors could learn about application opportunities for microelectronics, mechatronics and embedded systems in talks and presentations.

Above all, many different applications for sensors were on display. One exhibit demonstrated, how sensors can monitor temperature, carbon dioxide concentration and brightness in rooms, this way allowing automated building control. Another test setup presented, how sensors measure temperatures in very hot places, e. g. in the turbines of a power plant or in car engines. In connection with the precise analysing electronics developed by IMMS and by using new high-temperature technologies, such sensors can help to save energy and to protect our environment. Real measurements were carried out using a high-temperature sensor demonstrated at the example of a small steam engine.

Our conclusion: An evening worthwhile for visitors and hosts. We are looking forward to the next one!



Student Christian Thierfelder at the Demonstrator "High Temperature Sensor", Source: IMMS.

Andre Richter from IMMS demonstrates the practical use of sensors for CO_2, temperature and light. Source: IMMS

Trade Fairs

embedded world 2011
Trade fair for producers and developers of hardware and software, embedded tools and services and information overview on state-of-the-art embedded technologies, Nuremberg, March 1st – 3rd, 2011

SENSOR + TEST 2011
International trade fair for sensorics and measurement technology, "Low-Cost/Low-Power Sensor Frontends for Energy-Autonomous Sensor Systems", Nuremberg, June 7th – 9th, 2011

INOVA 2011
Recruitement and career networking fair on campus of the Ilmenau University of Technology, ELMUG joint stand, Ilmenau, October 18th, 2011

Innovationstag Thüringen (Day of Innovation, Thuringia)
ELMUG joint stand, Erfurt, November 24th, 2011

ELMUG-Branchentag (ELMUG industry exhibition)
Industry trade fair of the ELMUG industry cluster, "Electronic Measurement and Equipment Technology Thuringia on Track to the Future with the ELMUG Specialist Groups", Erfurt, December 12th, 2011

Conference participations

TuZ 2011
23rd GI/GMM/ITG Workshop "Test Methods and Reliability of Circuits and Systems", Passau, February 2011

DATE'11
Design Automation and Test in Europe, Grenoble, France, March 2011

Specialist Information Event of TMWAT
Energy efficiency by process optimizing, technological aspects of measurement-aided consulting, March 2011

Silicon Saxony Day 2011
"Department of Applications", Dresden, March 2011

edaWorkshop'11
Design Technology Conference Hannover, May 2011

DASS 2011
Working conference on circuit and system design, Dresden, May 2011

CDNLive! EMEA 2011
Cadence Designer Network Conference, Munich, May 2011

Industrial Days at Jena University of Applied Sciences
"Intelligent Perspectives", May 2011

Leibniz Conference 2011
11th Conference of Advanced Science – Solar Age 2011, Lichtenwalde, May 2011

elmug4future 2011
Technology conference, Suhl-Ringberg, July 2011

56th IWK Ilmenau
International Scientific Colloquium at the Ilmenau University of Technology, "Innovation in Mechanical Engineering – Shaping the Future", Ilmenau, September 2011

21st IWK Mittweida
International Scientific Conference, Mittweida, October 2011

ASPE 2011
26th Annual Meeting of the American Society for Precision Engineering, Denver, USA, November 2011

Analog 2011
12th GI/GMM/ITG specialist conference "Design of Analog Circuits with CAE Methods", Focus: Design of embedded sensor systems, Erlangen, Fraunhofer Institute IIS, November 2011

5th RFID Symposium Dresden
Topic: "Internet of Things", Dresden, December 2011

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Function test of a measurement and recording unit

Magnetic 6D Direct Drive Mag6D

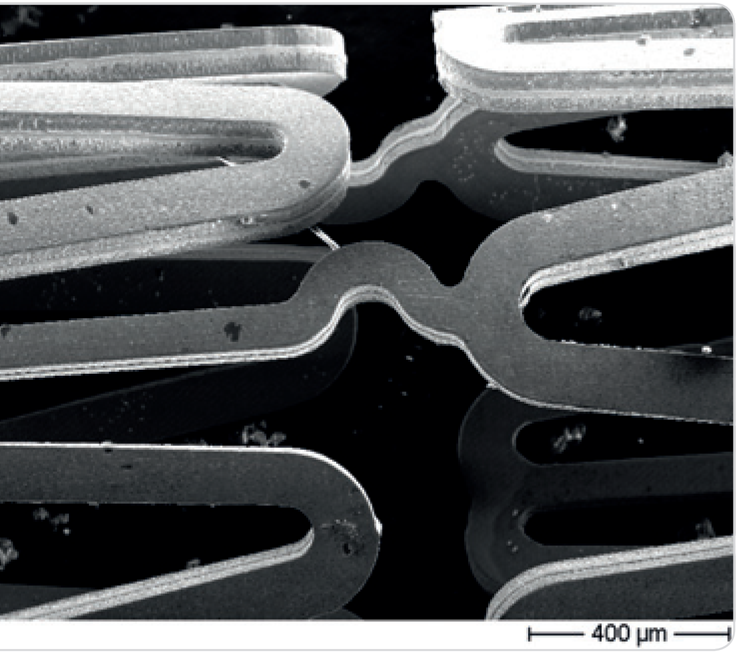

Figure 1: Stent Structure. Source: LLT

How can one make a finite mass body float magnetically stable? This is being worked on worldwide. What works in the macroscopic world, e.g. for a magnetic suspension train drive, shall also be used for highly precise moving and positioning of objects, e.g. in semiconductor production. In processes like wafer structuring and wafer inspection, by now air-guided positioning systems are preferred. For applications though, that make working in vacuum or additonal positioning variance necessary, magnetically driven systems are a real alternative, e. g. also in microscopy as well as in Life Science and Biotech applications. This technology can be used to produce very small structures – like those needed for stents (see fig. 1).

For 15 years, IMMS has been developing drive solutions for air-guided precision systems with driving areas of 20 x 20 up to 400 x 400 mm2. They are mostly used in machines for laser structuring with applications in precision technology, medicine technology and laser dicing of wafers. In 2011, a new magnetic-driven 6D direct drive system has been developed in our institute (see fig. 2). It is based on the structure of an IMMS air-guided planar direct drive (fig. 3).

The Challenge

According to the Earnshaw theorem, a static magnetic field can not steadily balance objects. This has been proved by Samuel Earnshaw in 1842. For a magnet in a magnetic field, this means that it always moves straight towards another magnet causing the field.

But since we know floating magnets on superconductors, even floating graphite slices on magnetic arrays from various "toy applications" – may be Earnshaw was not right after all? Certainly not, but his theorem is only valid for macroscopic, static fields. This approach does neither describe quantum-mechanical effects nor dynamic fields. So there are a lot of opportunities to steadily float magnets.

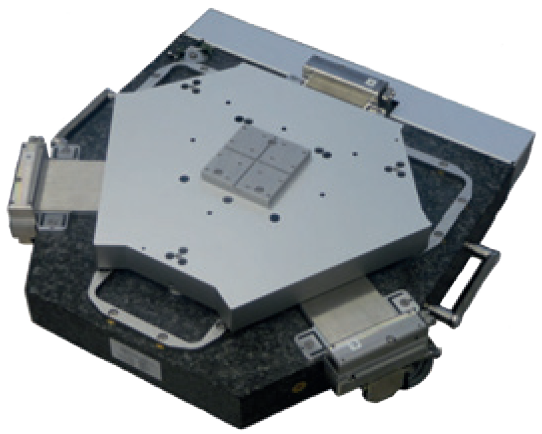

Figure 2: Mag6D Direct Drive, Source: IMMS/PI/TUI 2011

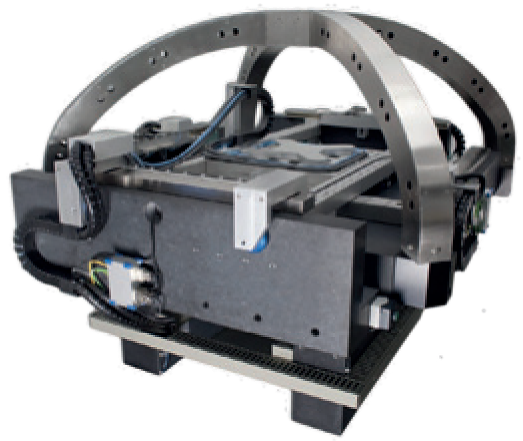

Figure 3: Air-guided 3D Direct Drive, Driving Area 400 x 400 mm2, Source: IMMS 2009

Actively Controlled Floating Solves the Problem

Many common solutions for planar magnetic guides, as in the example in figure 5, use an array of coils and magnets in stator and slider. In a simple way, enlarging the array allows the extension of the driving area or an adaption to the actual payload. But the necessary effort for controlling the inductor array is immense. According to the position of the runner element, every one of the by now 27 coils has to be commutated individually. In addition, none of the common approaches allows to couple a 6D measurement system efficiently to such guides.

Therefore, the researchers at IMMS wanted to find a motor structure that significantly reduces the control effort, at the same time allowing the integration of a high-resolution 6D measurement system.

The prototype of this highly precise driving system is called Mag6D. It makes a slider float solely using magnetic powers and positions it in 6 coordinates. Mag6D is the result of a cooperation of IMMS, the Mechatronics department of the Ilmenau University of Technology and the Physik Instrumente (PI) GmbH. It provides a driving area of 100 x 100 x 0.12 mm^3 in translatory coordinates.

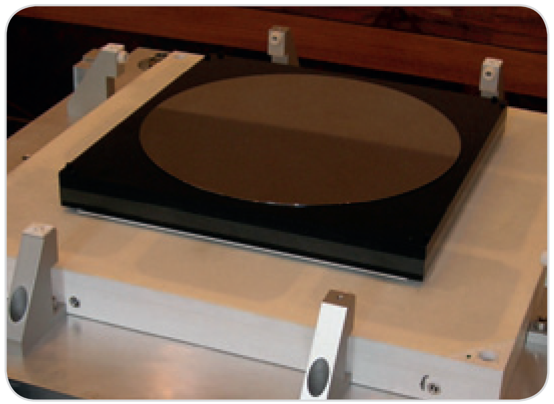

Figure 4: Philips Maglev, IMMS 2006

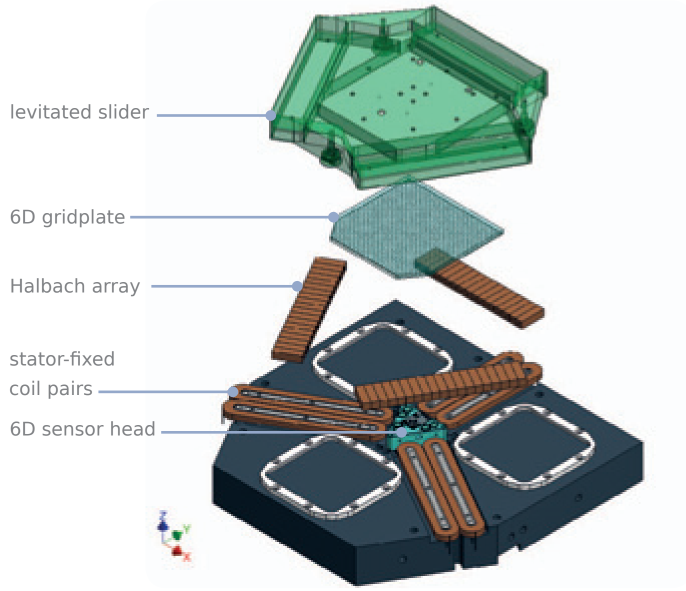

Figure 5: Working Principle of the 6D Positioning System. Source: IMMS

Only 6 planar motor coils are necessary to carry the slider's weight including a payload of 500g and to move it in 6 freedom degrees. Also, the runner works completely without feed line.
A new, compact integrated sensor head – consisting of optical and capacitive sensor elements – allows positioning and control of the slider in all 6 degrees of freedom.

When positioning on a set point, a standard deviation of < 6 nm is currently measured in the translatory axis, in the tilting axis of < 250 nrad. The system features a very simple structure, a close-to-object integration of a compact 6D sensor system and high efficiency of the actor tempering. Carrying just the load of the runner causes the actor coil temperature to increase by approx. 1 K. Perpectively, this difference is further going to drop. First approaches to impement this technology into a customer's application have started already,

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MEMS/NEMS – Simulation and Test

Micro- and nanoelectromechanical systems (MEMS/NEMS) mostly are structures with a size of only a few micrometers, consisting of sensors, actors and control electronics on a substrate or a chip. MEMS are increasingly used in places where miniaturizing and improved functionality are essential. They are an important foundation for innovation. MEMS trigger airbags, are used for stability control in vehicles and as blood pressure sensors in intensive care facilities.

Nondestructive Indirect Parameter Identification

If, for example, the gyroscope sensor for position detection of a smart phone and its microphone are tested, both are quality checked at the earliest to minimize the reject rate of assemblies or even complete phones. The tiny MEMS structures of a gyroscope or a microphone, which are only a few micrometers in size, are too delicate towards mechanical touching and would be destroyed by such a check-up. Therefore, recently IMMS has developed a procedure for nondestructive indirect parameter identification. It checks production relevant geometry and material parameters and has been used for beam and membrane structures. Before taking further production steps, the procedure checks directly on the wafer. It is based on a vibrometric measurement of resonance frequencies of test structures. On the other hand, in a finite elements simulation, the functional relationship between resonance frequency and the parameters to be measured is described.

Currently, IMMS is taking part in the USENEMS project, further developing this procedure. It can nondestructively identify the mechanical characteristics of new materials and can be integrated into production processes.

Going beyond silicon technology, modern high performance materials like group III nitrides, nano laminates, or graphene will be the base for ultra-sensitive integrated MEMS and NEMS in the near future. IMMS' research focuses on easing their development significantly. For sensor and actor units, it is important to recognize, monitor and targetedly influence mechanical characteristics like anisotropic elasticity and in-/ homogeneous stress. For this, IMMS and its project partners have designed optimal indicator structures, as for example doubly-clamped beams, as shown in figure 3. Parameter identification is used on these structures to identify their material characteristics.

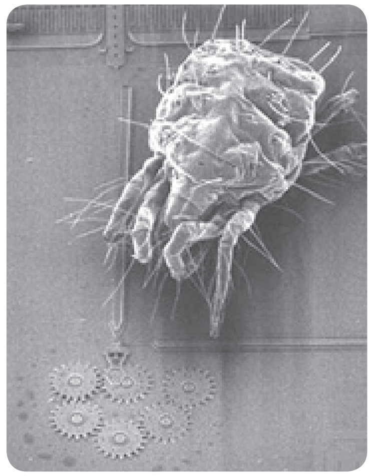

Figure 1:

Comparison of the Sizes of a Mite and a Micro System.

Source: Sandia National Laboratories

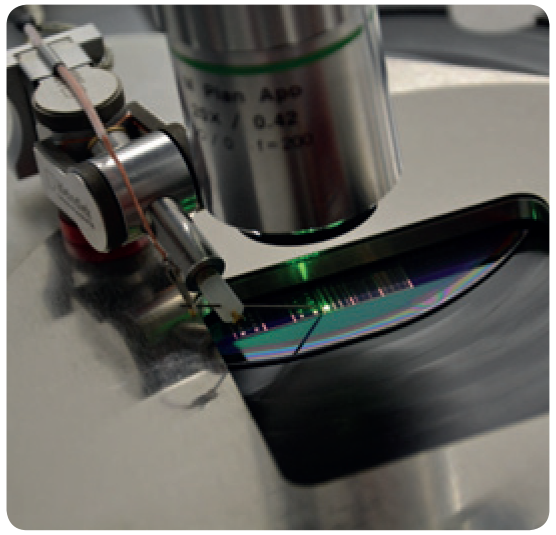

Figure 2: Electrostatic Excitation of Test Structures using a Probe Needle for Vibrometric Measurement, Source: IMMS

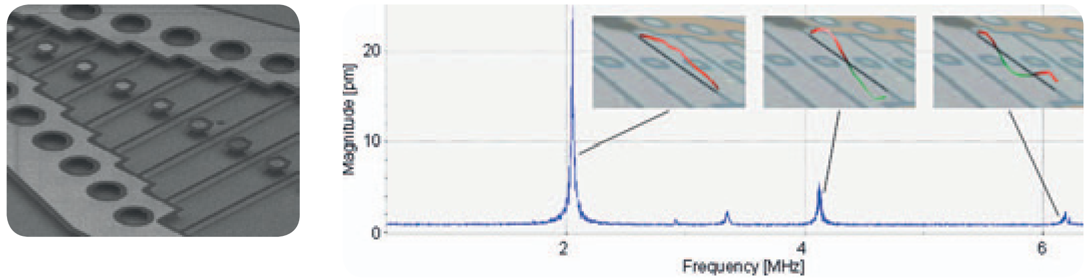

Figure 3, left: SEM micrograph of doubly spanned beams from aluminum nitride with lengths of 35 – 255 µm (Source: Ilmenau University of Technology, Institute for Materials Engineering/Institute of Micro-and Nanotechnologies). Right: Results of a doppler vibrometric measurement: Frequency response and inherent forms of the first three bending vibrations (Source: IMMS).

Piezo-Electrically Coupled MEMS Resonators

The use of vibrating quartzes that control the clock signal of computers, could soon be a story from the past. Vibrating quartzes cannot be produced together with microprocessors, but must be integrated later on. Therefore, MEMS are about to be used as clock generators in future. To implement this, IMMS is involved in the PRIMOS project, developing piezo-electrically coupled MEMS resonators. Already at frequencies up to 125 MHz, they are a real alternative to conventional vibrating quartzes. In addition, they can be integrated into production processes, are really tiny and lower in cost. To significantly extend the frequency spectrum and to make such resonators available for new applications, the institute attempts to create HF clock generator frequencies from 200 MHz up to GHz values. As HF local oscillators, they become the core of mobile devices for telecommunication, near field radio technology and ultrafast bus systems. For that, multifrequency oscillators are necessary. Their multifrequency character is caused by different longitudinal modes. In cooperation with the Ilmenau University of Technology, IMMS created design guidelines and an optimal design process using finite elements simulations of the structures. In addition, the institute has automatized the well known Assurance Criterion Method for recognition of longitudinal modes, thus allowing a much higher work efficiency. Based on this method, scientists have researched the influence of different boundary conditions on the resonator. To validate the results of this calculation, measurements are carried out at the test structures using a laser doppler vibrometer. The analysis allows a successive improvement of the simulation model and the development of an optimal resonator design. Apart from this, with the results of the finite elements simulations, parameters can be identified and optimized to accomplish certain characteristics of components.

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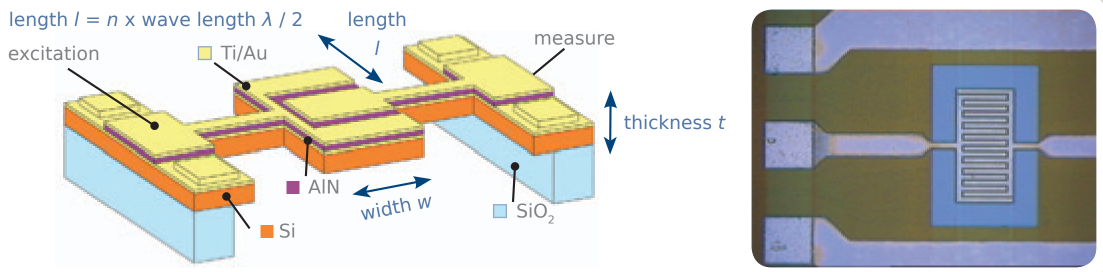


Figure 4: Model of a MEMS resonator (left, source: Ilmenau University of Technology, Institute for Information Technology, RF and Microwave Research Laboratory) and processed structure with a length of 240 microns (right, source: project PRIMOS).

ASIC Development and Test for a Retinal Implant

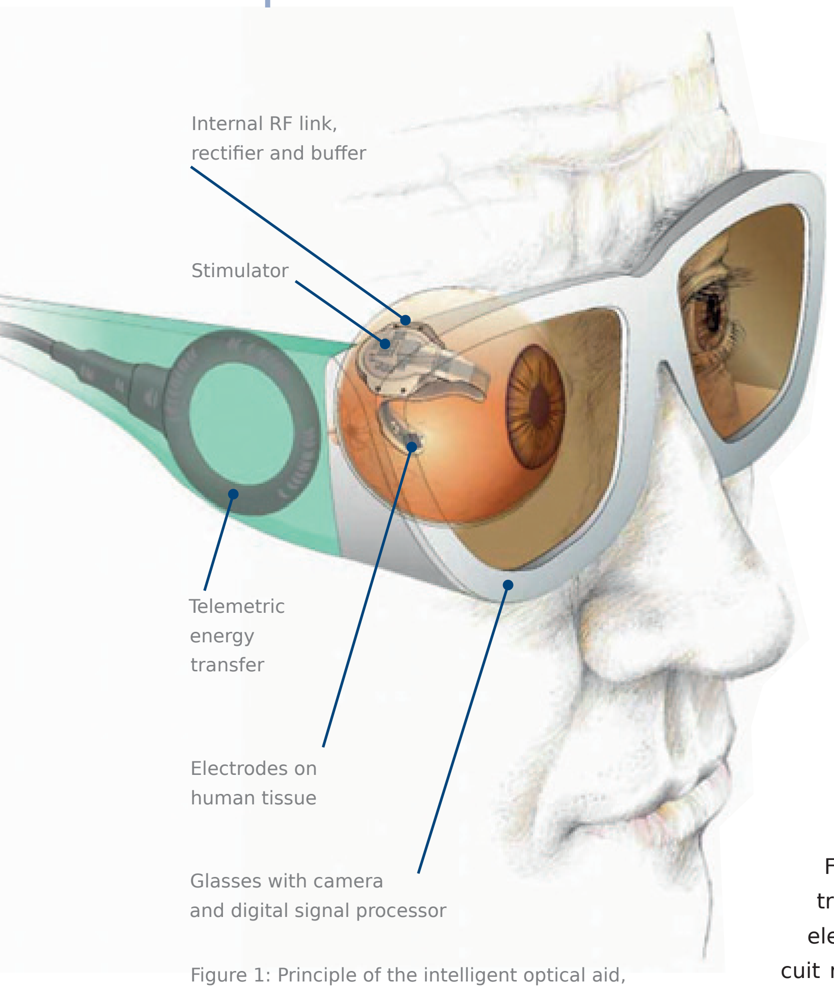


Figure 1: Principle of the intelligent optical aid,
Sources: www.imidevices.com, Ortmanns JSSC 07

A dream could come true: to make the blind see again. A vital IMMS contribution to this is the development of an ASIC[1] used in an intraocular implant. Based on the circuit specification of our research partner IMI Intelligent Medical Implants GmbH, the institute designed and tested within minimum time. At present, it is further developed to extend the range of functions.

This intelligent optical aid helps patients with retinal degeneration to partially see again. This is allowed by a modular system consisting of three main components: Visual Interface, Pocket Processor and Retina Stimulator. A camera integrated into spectacles records images of the environment, which are transfered by a processor into stimulation signals for the optical nerve. An optical interface, reaching from the spectacles via the pupil into the inner part of the eyeball, transfers the information to the Retina Stimulator. There, the data is handed over to the optical nerve. This way, the patient can learn to recognize structures in his environment.[2]

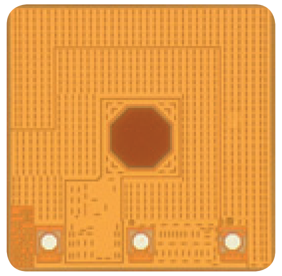
The ASIC developed at the institute is implanted into the inner eyeball and translates the incoming information from the optical interface into a current signal which is transferred to the stimulator ASIC. Essential elements for implementing this functionality are the photodiode, a rectifier for energy supply, the control circuit for signal detection and the output driver.

For this, the photo diode is the sensor element transferring the incoming optical signal into an electrical data stream. The following control circuit recognizes, whether the data stream is a parasitary or system relevant signal. Depending on this, the output driver is activated or remains in passive mode. In a human body, the energy supply for circuits cannot be realisied by a DC voltage. Therefore, IMMS has developed an energy supply for the ASIC using AC voltage. It is transformed by the rectifier into an internal DC voltage exclusively used in the hermetically sealed circuit.

Figure 2:

ASIC with photodiode in the center.

Source: IMMS



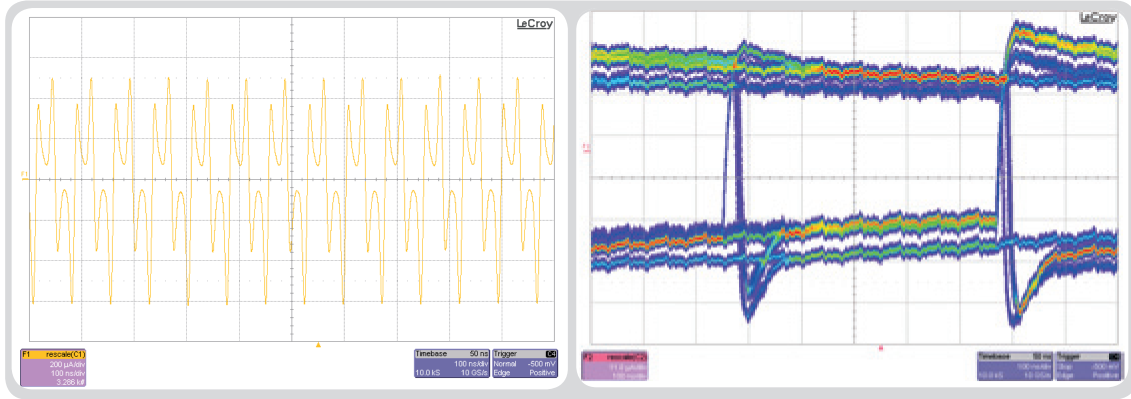


Figure 3: According the supply current (top) and the eye diagram of the output current (bottom), it is verified that the transmission reliability of the data transfer between spectacles and Retina Stimulator is ensured. Source: IMMS.

After design and circuit production, the institute in realtime verifies the functionality of the system by testing it with its wafer prober. For this, circuits on the wafer are tested using probe needles. Also the wafer test for the ASIC is carried out by IMMS. Here, we focus on the characteristics of the output signal, but at first a defined input signal is vital. The setup of the wafer measuring station for opto-electrical tests allows the input of an optical data signal through a microscope. Here, the signal can be influenced in its intensity as well as in its position. This allows the use of an optical input signal with known size, performance and position.

The parameters of the output signal are derived from an eye diagram, especially jitter, pulse width and output current are evaluated using histograms. Here, the focus is on identifying detection errors.

In contrast to standard circuits with DC voltage power supply, the ASIC has to be supplied with a defined AC voltage with a frequency of 13.56 MHz. For this reason, the evaluation of the supply current cannot be realized using standard measurements. Therefore, IMMS has developed an especially adapted measuring method.

The ASIC specification considers a maximum value of the supply current. Measuring this parameter challenges the measuring setup, since the function of the circuit must remain uninfluenced by this. The use of an inductive current probe proved most suitable here. For this, a prober needle is put through a ferrite ring recording the magnetic field of the supply current and transferring it into a secondary coil. Passing a resistor, the induced current ICs was transferred into a voltage representing the timing of the supply current. The histogram analysis then allows a statement on the RMS[3] value of the current I_{AC}.

The functional reliability of the implant can for example be impaired by eye movements of the patient. Therefore, in a future redesign of the ASIC, the permitted voltage tolerance is extended by approx. 40%, and a monitoring of this supply voltage will be implemented. Further developments like this are designed to make the system more robust.

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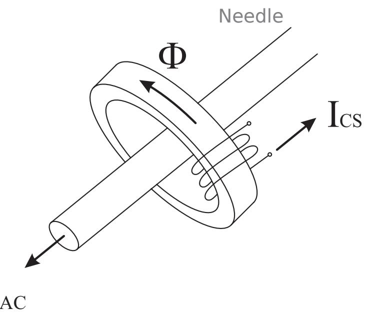
Figure 4: Inductive current probe for measuring the supply current I_{AC}. Source: IMMS



[1] ASIC – application specific integated circuit
[2] Compare http://www.imidevices.com /de/imi-retina-implantat-system.html
[3] RMS – root mean square

SMARTIEHS Sets New Standards for MEMS Tests on Wafer Level

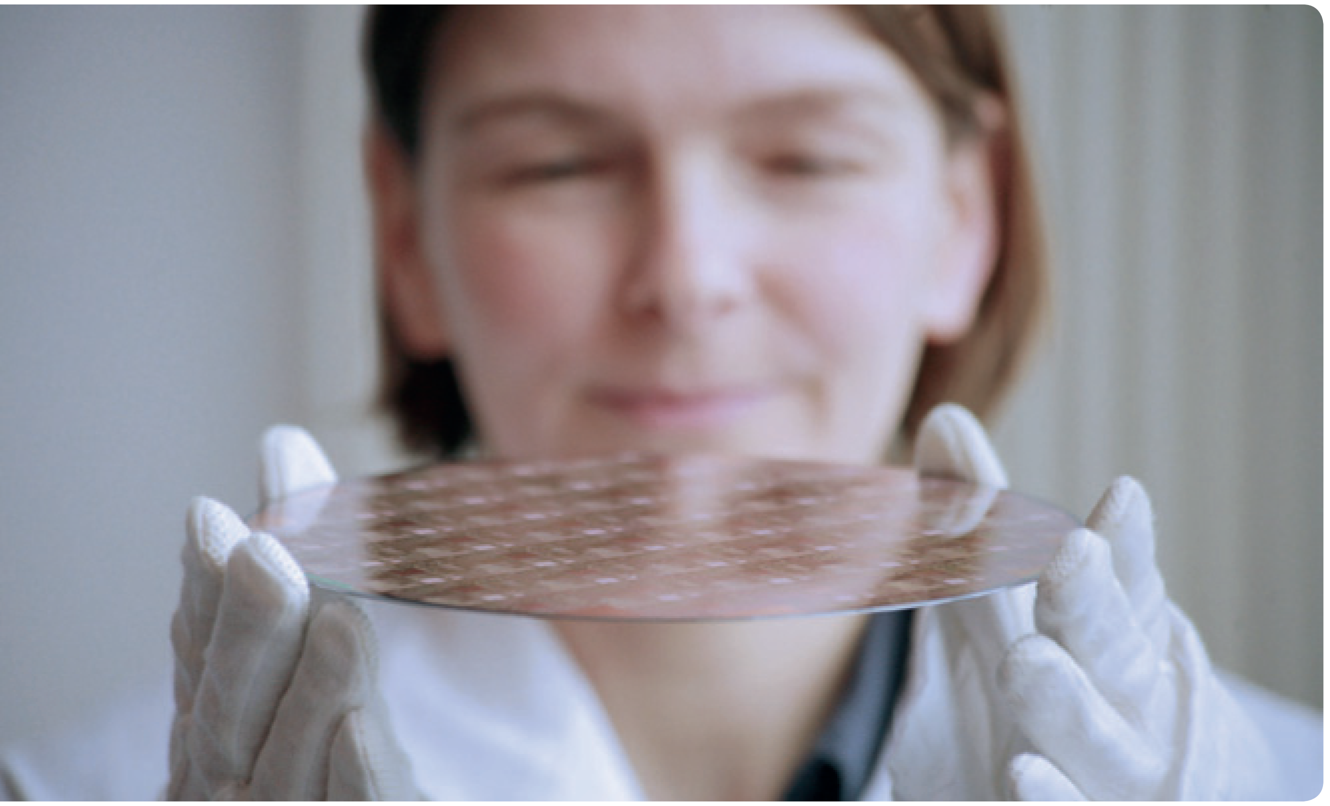


Figure 1: On 8 inch wafers, an average of 10,000 structures is placed. It is the goal of the SMARTIEHS project to test these structures faster. Source: IMMS

Micro-(Opto-)Electro-Mechanical Systems (M(O)EMS) detect the fall of a laptop to park the read head of the hard disk in time, control inkjet printing heads or warn in car tyres in case of a sudden pressure drop. Therefore, M(O)EMS are a vital driving force of developing innovative products. With a size of only some millimeters, they unite sensors, actors and control electronics in a compact setup on one chip. All these elements are created directly on the wafer using procedures, some of which are established in the semiconductor process already and have been further developed for M(O)EMS production. Worldwide, about 6 billion M(O)EMS are produced per year. According to estimates of the market researcher Yole Développement, this number is going to double within 5 years. At the same time, the microsystems become more and more complex, as well as their reliability requirements. To succeed in competition, this means that the production costs have to be reduced continuously.

The MEMS production requires a number of tests securing quality and performance parameters. In general, M(O)EMS elements are being tested at the earliest stage in the production process. This way, in case of a defect element, the following steps like separation, contacting and housing can be omitted. The trend towards larger wafer diameters and smaller elements leads to a higher number of units that have to be tested per wafer. In addition, the rising quality requirements demand a 100% test of all elements. All these requirements cannot be efficiently met with the currently applied test methods, since by now, single elements are measured sequentially. This is very time and cost intensive. Therefore, the test methodology has to be improved significantly.

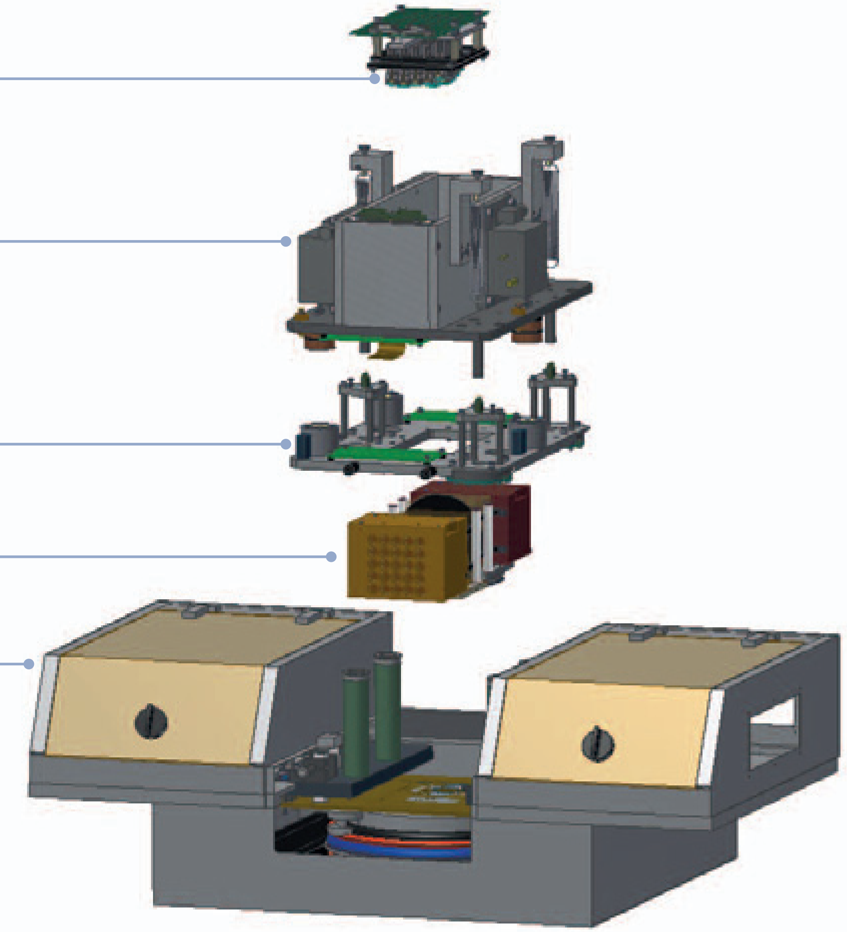


Figure 2: Exploded view of demonstrator at work. Source: IMMS

With this motivation, the SMARTIEHS project was established, funded by the European Union (SMART InspEction system for High Speed and multifunctional testing of MEMS and MOEMS, code FP7-ICT2007-2, project ID 223935). After three years, it was sucessfully finished in October 2011 and united research groups from 6 European countries. IMMS was leading the implementation of the whole inspection system. The project resulted in a scalable, parallel measurement system able to test 25 M(O)EMS structures on a wafer at the same time in the first run. An extension to up to 100 test units is possible. This is realized by microoptically processed interferometer matrices. These consist of two different groups of miniature interferometers aligned in a 5x5 matrix. Dynamic parameters like modal frequencies and mode forms are measured with a laser interferometer (LI) in Twyman-Green Configuration. A low coherence interferometer (LCI) in Mirau configuration measures topography and distorsion. Smart pixel cameras, developed especially for this purpose, also aligned in a 5x5 matrix, allow the efficient processing of all these signals on pixel level already. From such measuring values and from simulation data, MEMS parameters like material stress, are identified non-destructively in an indirect procedure.

On the one hand, IMMS was responsible for test procedures, on the other hand for the implementation of the whole inspection system. The institute developed hardware and software components to process the data of the smart pixel cameras with 3 giga bits per second. The inspection system platform constructed at IMMS united all developed mechanical and optical assemblies of all project

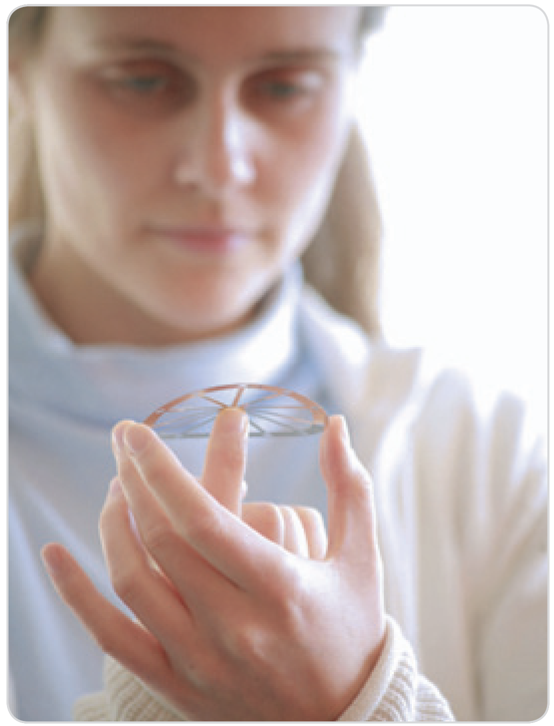


Figure 3: The vertical motion of the smart pixel camera is stabilised by three membrane springs. Source: IMMS

partners in a full working demonstrator. The justification of the different optical and mechanical components towards each others within micrometers was especially challenging. For example, 25 electrodes of the electrostatic actor unit in form of a wafer had to be positioned within a distance of only a few micrometers parallel to the wafer to be tested. The demonstrator was based on a wafer prober PA200, with which the inspection system can test a complete wafer with all elements automatically. IMMS developed a software program that controls and synchronizes the system components and coordinates the data stream between them. Topography measurements are carried out to test the sensor quality. This requires scan movements of the measuring head. For this, IMMS developed a high-precision drive with a precision of 10 nm and better, with a homogeneous movement with less than 1 % offset at a speed of 0.1 to 1 mm/sec.

During the remaining 9 project months in 2011, the institute carried out an intensive function and application test on the SMARTIEHS system. To meet all the parameters required by the industry, first, IMMS optimized the hardware and software of the test setup using a special testwafer solely developed for the project. In the application tests, the institute then carried out measurements at an industrially produced MEMS wafer and compared the results with the ones of commercial test hardware. A good compliance could be reached and finally validated by an industrial partner. The results acknowledge the system's absolute singularity due to the parallel concepts, as well as potential for a number of further industrial applications.

After finishing the SMARTIEHS project, IMMS hosted a Final Review Meeting in mid-October to present the project results to all project partners and experts of the European Union. At the same time, the institute organized the 11th Memunity Workshop, at which the SMARTIEHS system was introduced to a specialist audience in a lecture and a presentation of the demonstrator.

In the project, IMMS has successfully applied and extended its know-how in design and optimization of complex systems. In addition, the institute gathered experiences in controlling precision drives and modelling and has applied parameter extraction of MEMS elements on new sensor systems. The research on non-destructive indirect parameter extraction of MEMS by measuring their modal frequencies is currently continued at IMMS in the UseNEMS project. In cooperation with our industry partners we want to apply this procedure in quality assurance in the future.

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Energy Management of Wireless Sensor Nodes

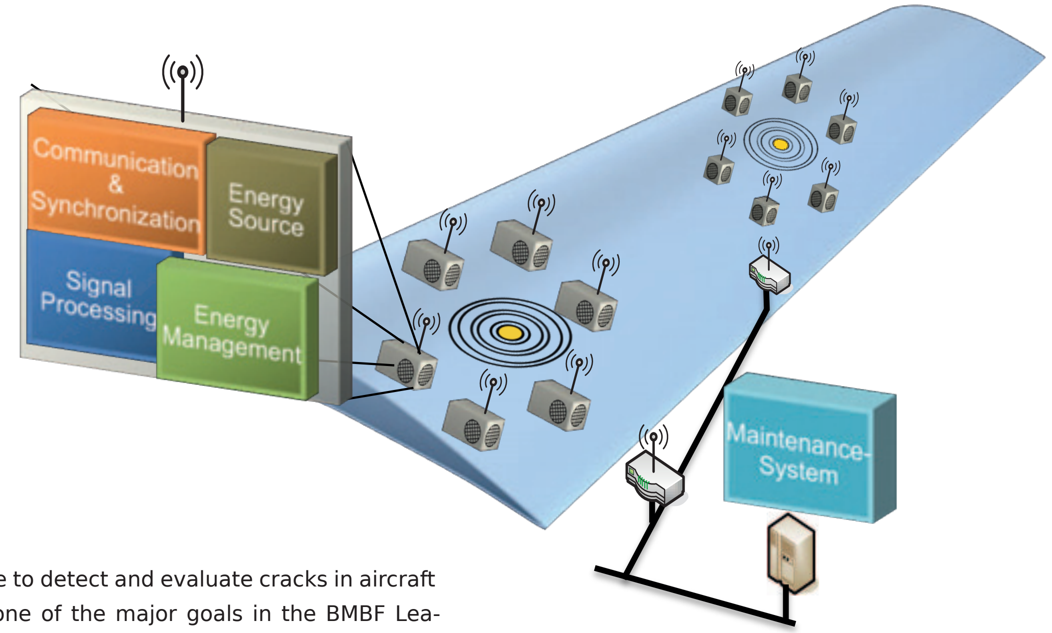

Figure 1: Monitoring of aircraft wings; source: IMMS

Being able to detect and evaluate cracks in aircraft wings is one of the major goals in the BMBF Leading-Edge Cluster “Cool Silicon”. IMMS cooperates in the “CoolConSens” sub-project (code 13N10401) in order to gradually approach this goal. Aircraft wings are made of composite materials. If wireless sensor nodes were to be used inside them to detect cracks, they would have to be operated in an energy-autarkic manner throughout their operational lifetime. IMMS researches suitable energy management solutions for wireless sensor systems for acoustic condition monitoring in buildings as an example. The results of this research are later to be applied to sensor nodes in aircraft wings.

With its test setup, the institute has detected and characterized noise sources and carried out acoustic measurements. Using energy harvesting, such a system is able to collect energy from its environment and store it in accumulators. However, this represents a rather unreliable energy source compared to the high-performance sensor and radio systems employed. Numerous system parts have to cooperate to fulfill a overall measurement and control task. Scheduling and communication of the subsystems are essential in this. Managing the available energy as efficiently as possible is both complex and challenging: each subsystem has to be efficient in itself yet at the same time interoperate seamlessly with other components. This is not only true for hardware and software, but also and particularly for wireless communications. A large number of parameters influence the energy budget, thus determining a system's lifespan.

The sensor system analyzed by IMMS for acoustic condition monitoring of buildings consists of a central unit, a maintenance system and a variable number of wireless sensor nodes. The most important functional units of the sensor nodes are the sensor subsystem, the communications subsystem and the power supply including energy management. The sensor subsystem comprises the acoustic sensors and actuators as well as a high-performance data processing unit for pre-processing the audio data. The communications subsystem and energy management each have their own control units. The subsystems are able to communicate with each other and report their status via dedicated signal lines. Later on, the subsystems for monitoring the wings are to interact with each other according to the same principle.

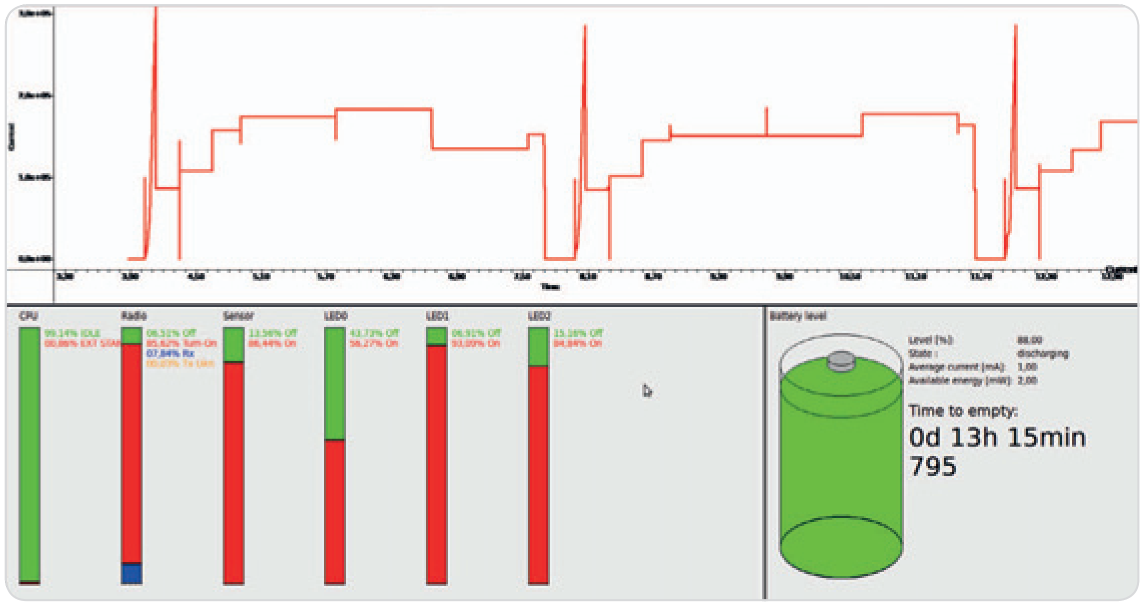

Figure 2: Visualization of the energy consumption of discrete modules. Source: IMMS.

For an efficient management of the available energy, the system condition and behavior as well as the energy consumption of the subsystems have to be characterized exactly. For this, the institute has recorded and analyzed an energy profile of the wireless sensor system for buildings. Recording the energy consumption conventionally using a measuring shunt or a clamp-on ammeter proved difficult due to the large measuring range and limitations of measurement resolution. Therefore, IMMS used highly-precise power analyzers and additionally recorded the condition down to function and command levels using in-system analysis features. Based on the measured values and other available analysis features, the institute has developed an energy management.

At its core, the concept is to optimize the energy consumption during specific tasks and reduce it to a minimum when the system is idle. Presuming that due to scheduling, energy-intensive subsystems, such as sensor and radio transceivers, are switched off most of the time and the control unit of the energy management system is also active rather rarely, the energy consumed in the idle state becomes the dominant part of the total energy requirement. The present system is therefore designed to cover at least this requirement via energy harvesting. Experiments with a compact solar cell used in the typical environment of a room in a building at diffuse daylight produced about 0.54 mW, much more than the energy needed for idle state. Thanks to this novel energy management, which has so far been tested with first prototypes in buildings, about 18 % of energy could be saved compared to traditional systems. IMMS has thus provided a basis for a system of wireless sensor nodes for monitoring aircraft wings.

The energy management developed is an essential aspect of the reliable operation of the nodes throughout the lifetime of the system. This way, the time-consuming and error-prone visual inspection of wings might be omitted in the future.

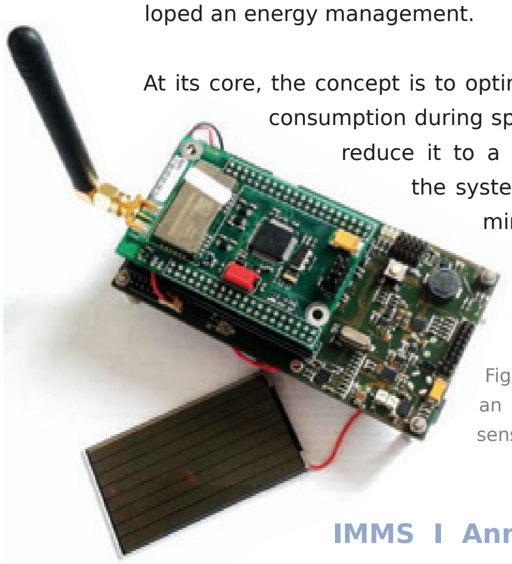

Figure 3: Prototype of an acoustic wireless sensor. Source: IMMS

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IMMS Enables New Applications for Wireless Sensor Networks

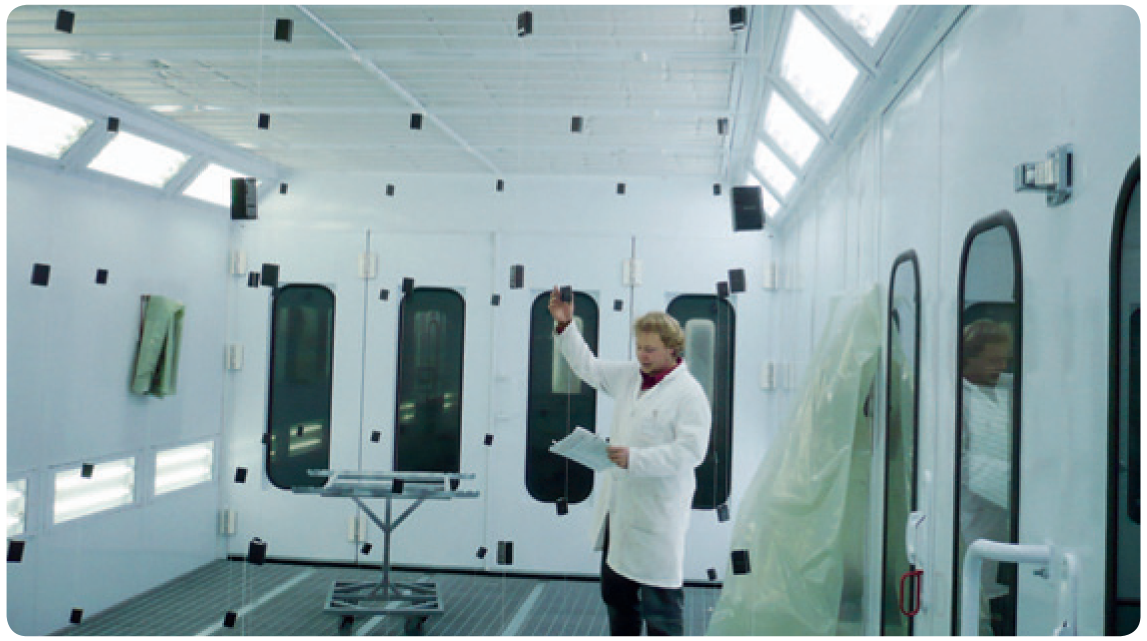
The Machine Stop

Imagine a company with total assets of 5 Million Euro and an annual profit of 130,000 Euro. The enterprise acts as a supplier for the automotive industry, certified according to ISO/TS 16949, which is important in this sector. Their business activities include spray-painting of body components. Automakers require highest quality, the varnish providers give detailed handling directions. To meet these requirements, the company makes an investment of 500,000 Euro. The acquired spray booth is to optimize the production process and to make sure all required parameters are met exactly. The company assumes that the cabin is going to be fully utilized according to the order situation, so the investment will have paid off after a short time. After several months of extensive tests and adjustments, it turns out that the error rate of the new facility cannot be brought below 40% – despite its correct setup according to the paint provider's directions.

Defect notices to the producer of the cabin amount to nothing. The manufacturer refers to the flawless state of the cabin upon delivery and insists on the user's responsibility for all configurations. Pressure of time and cost are increasing. They decide to outsource the varnishing in order to meet the automaker's quality requirements and deadline. The costs for that have not been planned for.

IMMS Searching for Clues

IMMS has a solution for such scenarios, which has led to the successful identification of the cause of the faulty processing inside the booth. The modular hardware and software platform for wireless sensoric networks developed at IMMS includes a multi-sensor system which can be configured flexibly. Due to the open source operating system approach employed in the project, this can furthermore be adapted for specific application purposes and environments. IMMS has used this system to analyze the production conditions inside the spray booth, including the equipment within. In the course of this, scientists measured the temperature distribution using a large number of wireless nodes with appropriate sensors during a limited period of time.



Analysis of production conditions inside a spray booth with wireless sensor networks. Source: IMMS

This represents a particular challenge for electronic systems in general as the smart sensor components developed at the institute comprise not only the actual sensor element but also a processing unit, energy supply and management as well as a communications interface – all having to cope with the operational conditions. Tests on this matter have proved that the IMMS solution can (with the components used) operate safely at temperatures ranging from –30°C to +80°C.

Measurements such as these are an excellent foundation to analyze the given production process. Based on these data, the company obtained proof that the temperature displayed at the control panel of the spray booth did not match the actual temperature at the body components: there was an average difference of up to 30 degrees. The fact that the cabin stopped further heating after reaching the supposedly-correct temperature explained the faulty result of the hardening of the varnish.

Also, the temperature control in the booth was assessed as to whether the process parameters could be kept stable during varnishing over a longer period of time. Using long-term measurements, the technology enables the recording of processes and operation conditions. In the case of the spray booth, it was recorded how precise the required processing temperatures could be met. The use of sensor networks for simultaneous data collection in several places is also a promising strategy when searching for optimization potentials. For this, the cabin was equipped with a three-dimensional grid of 5x5x4 sensors. Further sensor units monitored the conditions in the environment as well as in the air inlet and outlet ducts. Using these measurements, IMMS has identified clues for further optimizations.

This example illustrates the importance of quality assurance for the commercial viability of products. Apart from documenting the production conditions using wireless sensor networks, these data can help to understand processes in existing facilities in much more detail and optimize their control. Above all, in the future, measurement data like these are meant to also help optimize the energy requirements of processes. The more sensors are needed for this, the bigger are the challenges with regard to complexity and data evaluation.

From Machine Monitoring to Environmental Monitoring

Scientists of IMMS have adopted the highly-scalable IPv6 networking technology for sensor networks, integrating it with the wireless sensor networking platform developed at the institute. This lowers the platform's barrier towards integration with standard IT infrastructures. While former research and development works focused on wireless sensor networks for use in building automation, further areas of application have recently been opened up in machine health and environmental monitoring, e.g., to monitor biogas plants. As a part of the modular hardware and software design, easy integration of new sensors into the overall system has been a primary concern. Sensors for a plethora of physical parameters have already been integrated into the sensor networking solution, enabling, i.a., temperature, acceleration, humidity, air pressure, gas concentrations (CO_2), illuminance, magnetic fields, electric field strengths and changes in capacity to be measured simultaneously. In addition, sensors can detect whether objects are moving in their surroundings or where other wireless sensors nodes are located.

IMMS continues its research and development in this field and is able to offer services accordingly, for example in metering and automation.

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Tool Framework for Technology Transfer of Analog Circuits

Microelectronic analog circuits in mixed analog-digital systems are usually designed for a certain semiconductor technology and specification, then tediously manually transferred for being re-used in a different environment. By now, there is no system allowing a fully automatized technology transfer of analog circuits. Therefore, IMMS took part in the research project SyEnA[1] .

It designed semi-automatic tools covering the whole design chain from specification to layout. One component is the Tool Framework EDADB (Electronic Design Automation Data Base) developed at IMMS and working independently from commercial design tools. Its modular structure supports the circuit designer with a variety of features (fig. 1). A speacial focus is the support for the transfer of designs with intelligent algorithms controlled by an easy to use graphical user interface.

As a result, a sized circuit complying with most specifications is created that can be instantly further developed and optimized using commercial tools. The tool replaces old process design kits (PDK) as well as original symbols and models. It adopts the circuit diagram to new pin setups and symbol sizes, translates parameters, carries out a rule-based feasibility analysis and calculates an initial sizing. With the new tools, several circuits have been successfully ported. Using the IMMS software, the transfer of a Folded-Cascade operational amplifier from a 0.6 µm technology of X-FAB Semiconductor Foundries AG (XB06) into a 0.35 µm technology (XH035) took only a few hours. A manual porting would have taken two days.

Figure 1: Reticles like this are used in semiconductor production to transfer circuit structures to the photo layer of a wafer. These structures are based on the circuit design. Source: X-FAB AG/Michael Voigt.

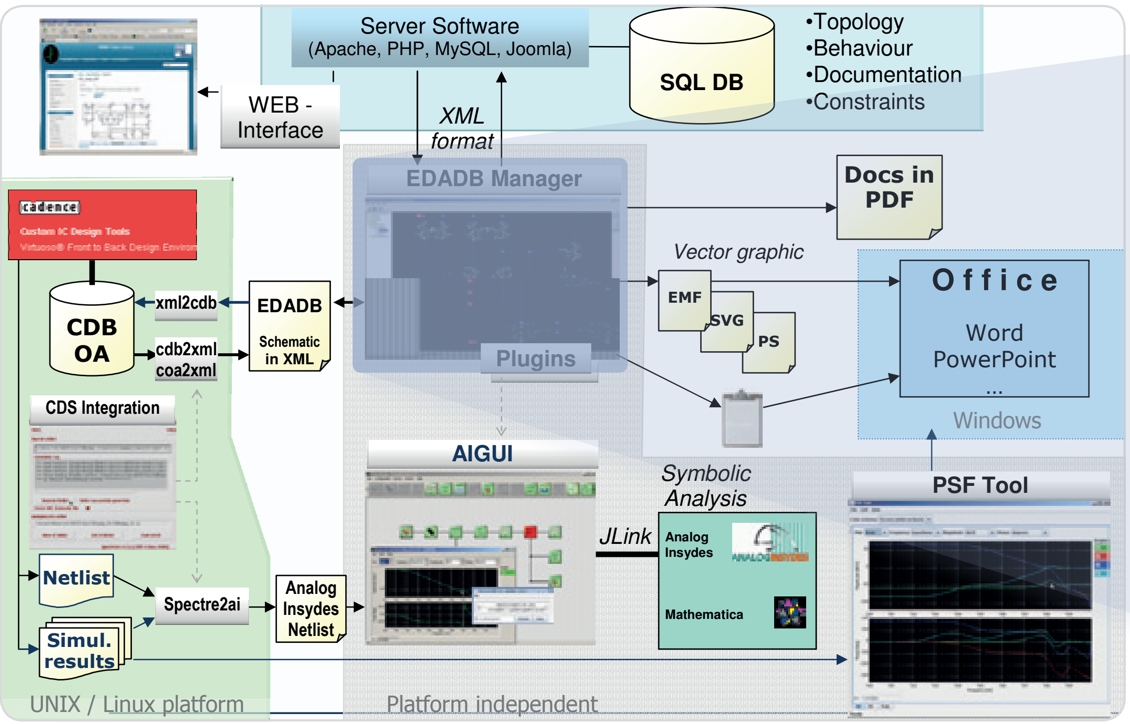

Figure 2: Scheme of the Module variety of the EDADB Manager. Source: IMMS

Circuit Porting for a Technology Migration

Schematic Expander for Symbol Replacement

During the library exchange, the library symbols are replaced by the corresponding ones from the new PDK. If these have different sizes or connectors, a formal replacement causes errors by wrong or missing connections, as indicated in figure 3. Correcting the circuit diagram manually takes time and is prone to further errors.

The EDADB Manager recognizes problem areas and automatically enlarges the diagram using a schematic expander. The new symbols are placed centrally in the gap and connected correctly with the circuit, as shown in figure 3.

Adapter Symbols at Changed Pin Set-Up

If the pins of the new symbols are arranged in a different way, also the corresponding connections have to be newly arranged. To insert new symbols into the original schematic, new adapter symbols are used. Figure 4 demonstrates how these can be designed from a symbol graphics with original pin set-up and how the pins of the new symbol are connected with the correct lines.

Feasibility Analysis

For analog circuits, a technology transfer always causes changes in operation and device parameters changing the characteristics of the circuits or even leading to total failure. Only after several runs, simulation or optimization tools deliver information on whether a reused circuit can work with the adopted parameters in a new environment. Therefore, the EDADB Manager carries out a feasibility analysis. This calculates a voltage interval for every node in the circuit, in which the necessary conditions (constraints) are fulfilled for all functions. In case of conflicts, the analysis finds the source of problems without time-consuming simulation runs. This way, one can decide quickly, whether a circuit can be realized at all.

Initial Dimensioning

Based on the voltage intervals determined before the parameters of all components are sized in a way that their operating points are in valid ranges. For this, every node is assigned a voltage within the interval so that all voltage contraints can be fulfilled with maximum reserve. For calculating the geometry of the MOS transistors, look-up tables of a SyEnA cooperation partner, TU Dresden, are used. They contain the simulation results for several measuring points allowing a prompt identification of different parameters. The values between the measuring points are interpolated using special interpolation methods for the given conditions.

This leads to an initial sizing of an analog block within a few seconds, e. g. of an OTA with approx. 20 transistors.

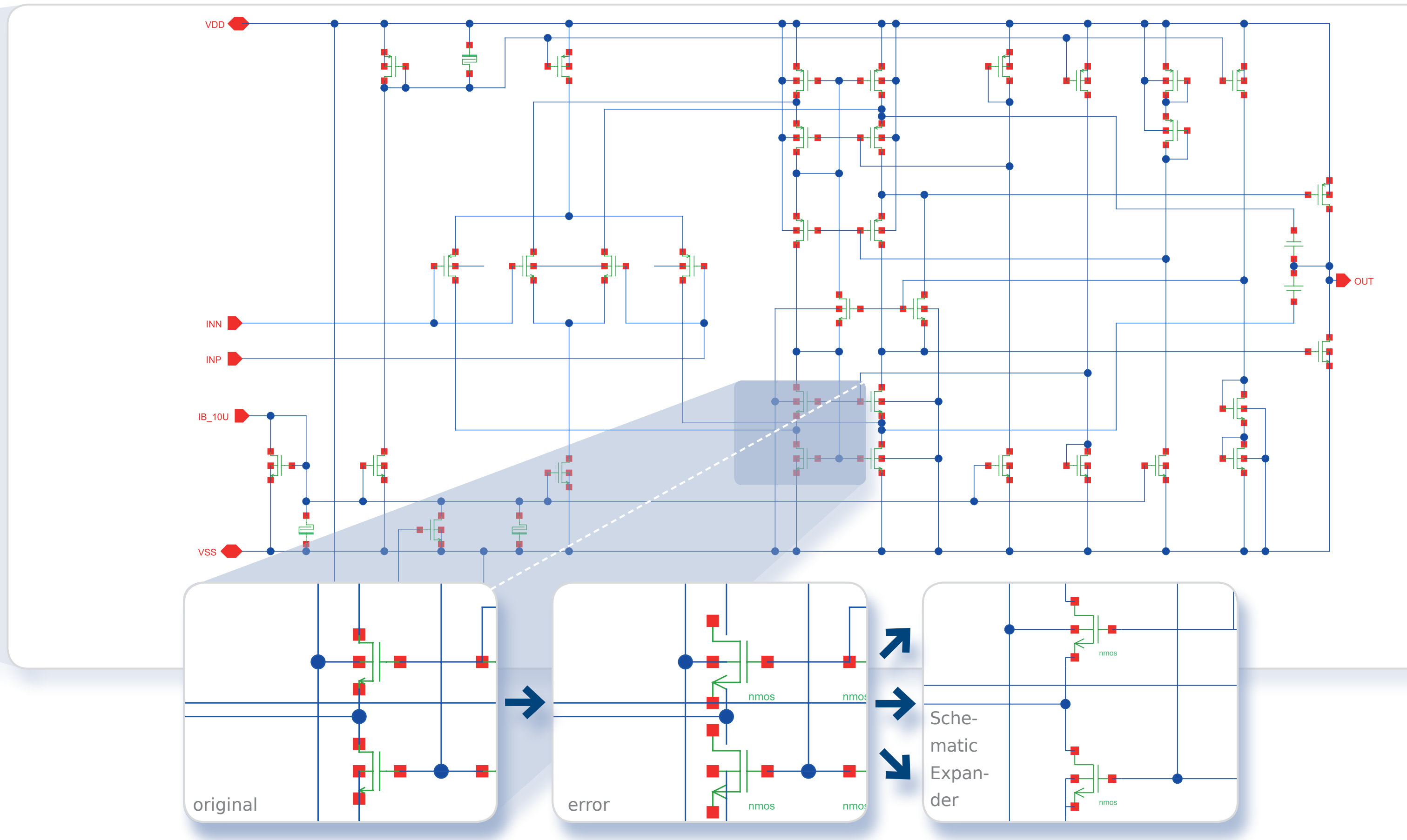

Figure 3: Formal symbol replacement can cause errors. Correction by Schematic Expander. Source: IMMS

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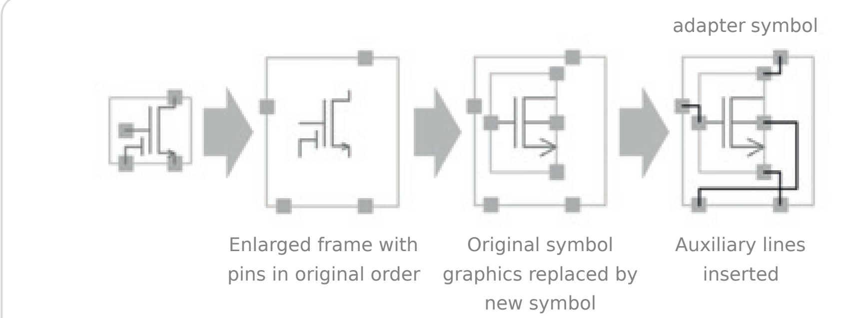
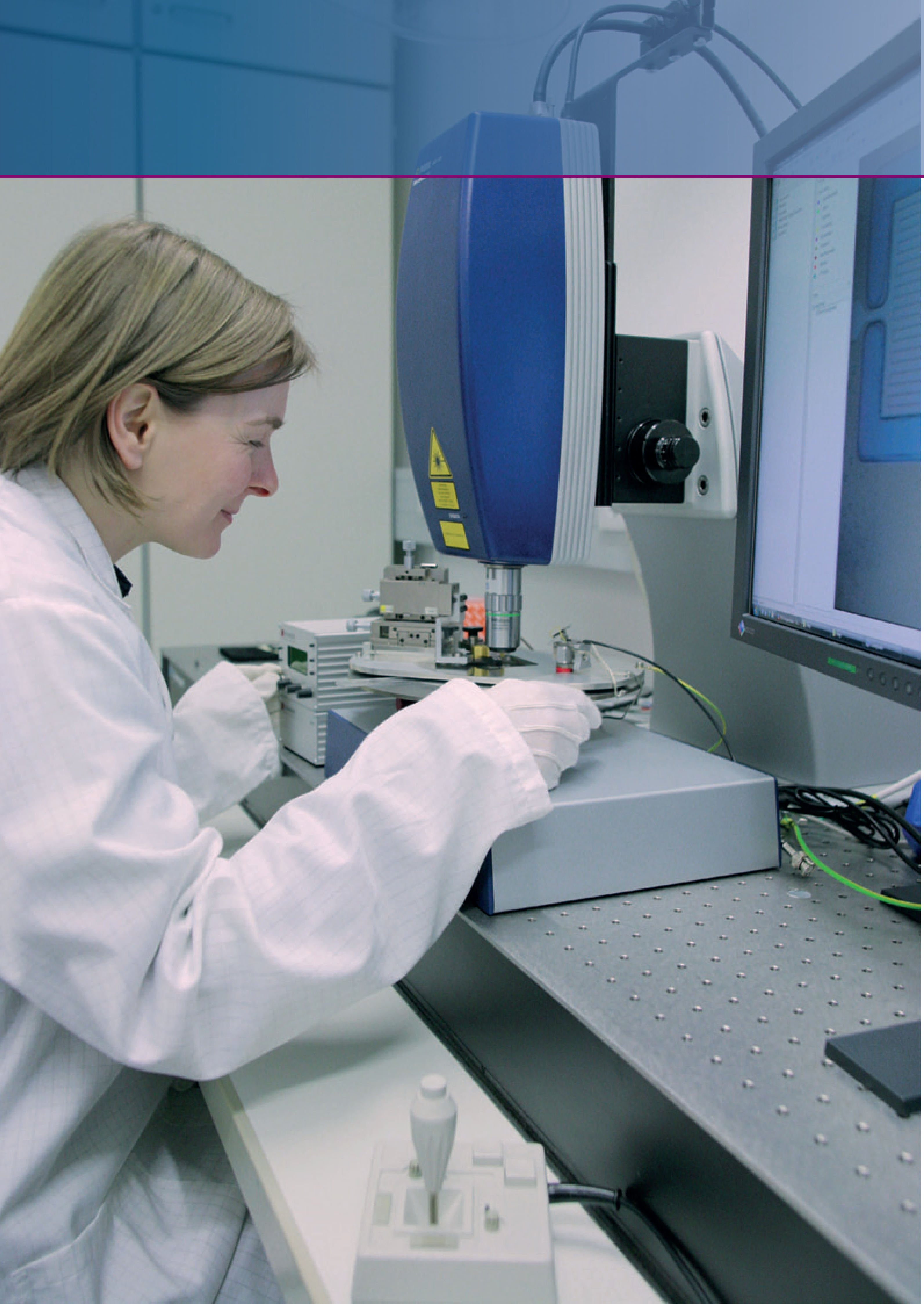
[1] SyEnA wird unter dem Förderkennzeichen 01 M 3086 im Förderprogramm IKT 2020 teilweise durch das BMBF gefördert.

Figure 4: Example of an adapter symbol, Source: IMMS





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Vibrometric measurement of resonance frequencies of test structures for a nondestructive indirect parameter identification (compare page 24).

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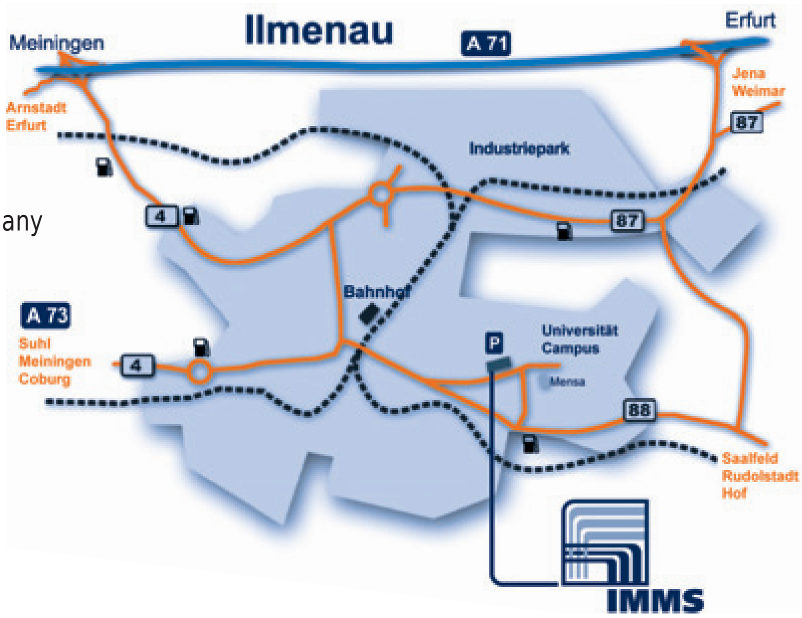

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