


# Annual Report 2022/2023

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We do research for the people.  
Application-orientated, innovative and  
professional.

With over 500 employees, Fraunhofer IPMS develops innovative, customer-specific solutions in the fields of intelligent industrial solutions, medical & health technologies and mobility at four sites in Dresden, Cottbus and Erfurt.

Our research focuses on miniaturized sensors and actuators, integrated circuits, wireless and wired data communication, customer- and application-specific micro-electro-mechanical systems (MEMS) as well as leading-edge 300 mm technologies for future applications in digital, neuromorphic and quantum computing.

As a reliable and competent research partner, we provide our customers with complete solutions from the initial concept and technology development to the model and pilot production on 200 mm wafers in our own cleanroom using qualified, industry-orientated processes. The development of processes and materials on 300 mm wafers completes our range of services.

# Foreword

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## **Dear friends and partners of the Fraunhofer Institute for Photonic Microsystems,**

In 2022, the Dresden institutes of the Fraunhofer-Gesellschaft, and thus also Fraunhofer IPMS, celebrated a very special anniversary: for 30 years, they have been contributing as strong partners in close scientific networking to make the Saxon state capital a globally recognized research hotspot. In these three decades, much has already been achieved and science and research in Dresden is still expanding steadily. Fraunhofer IPMS was also able to successfully conclude the year 2022 once again and continue to grow. In the meantime, as a leading research and development service provider for electronic and photonic microsystems with four locations, we have increased the number of our employees to over 500.

Our special highlight of the year was the opening of the new Center for Advanced CMOS and Heterointegration Saxony. It is Germany's only 300-mm center for cutting-edge semiconductor technology and is being built jointly with Fraunhofer IZM's All Silicon System Integration Dresden branch and our Nanoelectronic Technologies Center business unit. It offers microelectronics at the highest level and strengthens Germany's and Europe's innovative power.

The importance of national semiconductor research is also made clear by the European Chips Act, in which Fraunhofer IPMS is playing a major role. In the context of the German and European goals to regain technological sovereignty in microelectronics, we see great opportunities to expand our technological offering and to develop new cooperation partners and customer groups. In concrete terms, we hope that the second "Important Project of Common European Interest" (IPCEI) will soon come into being and that the German government's research funding plans will be implemented.

The innovative strength of Fraunhofer IPMS is also reflected in the successful sales of the two spin-offs Arioso to Bosch Sensortec and HiperScan to Fagron last year. Arioso Systems emerged from Fraunhofer IPMS and research work at BTU Cottbus-Senftenberg in 2019 and is one of the world's most innovative suppliers of MEMS-based micro loudspeaker technology. It is a peculiarity that a new technology goes so quickly from concept to spin-off and now already to an acquisition by such a renowned company as Bosch. HiperScan is also a spin-off of Fraunhofer IPMS and the German market leader for reliable and safe identification of starting materials in pharmacies. The innovative scanning grating technology developed at Fraunhofer IPMS forms the basis for the near-infrared spectrometers developed by HiperScan. As part of





*Prof. Dr. Harald Schenk*  
*Executive Director of the Institute*

the Belgian company Fagron, new markets are opening up for HiperScan's technology to further enhance safety and drive the future of personalized medicine.

In terms of interpersonal relationships, 2022 brought relaxation for our employees and customers in the pandemic. We were once again able to be present at trade fairs and events, and to resume the personal exchange that we value so highly.

Despite all these positive signs, new challenges have come and continue to come our way. Material shortages and unstable supply chains, war and the energy transition bring the hope for a sustainable, peaceful and healthy life into focus in these uncertain and dynamic times. As a part of the Fraunhofer-Gesellschaft, which pursues the mission of creating innovations for the benefit of society, we see it as our duty to develop viable solutions to address these new conflicts and tasks. With our groundbreaking research, we want to help shape a positive future. In particular, we focus on the topics of climate neutrality ("Green ICT") including energy and resource efficiency. Other future topics in our digital world that Fraunhofer IPMS is researching deal with energy-efficient electronics, AI-based sensor systems, neuromorphic as well as quantum computing. Bio & health tech, which continues to be so important for all of us, also remains a focus of our work.



*Prof. Dr. Hubert Lakner*  
*Institute Director*

However, fulfilling these goals and tasks requires that we also manage the energy crisis. Due to our high energy costs in the clean room, we face a particularly big challenge here and expect costs to increase dramatically. We are therefore grateful for the Federal Government's electricity and gas price brake, which will limit the impact of the cost increase in 2023. This will allow us to continue to conduct our research at a top level in 2023. However, we anticipate permanently higher energy prices, which pose a genuine challenge for us.

We would like to especially thank you as customers, sponsors and partners for your many years of loyalty to our institute and our research. We are certain that together we will also successfully master these challenging times. In times of crisis and uncertainty, innovations pave the way for the future, and we look forward to treading this path with you.

First, we would like to review a successful past year with you. We hope you enjoy reading this report!

Harald Schenk

Hubert Lakner

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# Strategy process – actively shaping the future

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Fraunhofer IPMS has been undergoing a strategy process since 2022 – a methodology that has been anchored in the Fraunhofer-Gesellschaft for over 15 years. The strategy development serves a sustainable positioning of the institute in competition. In 2023, the strategy of Fraunhofer IPMS will be audited by external experts from science and industry. On this page we would like to give you an insight into how we want to actively shape the future and how the strategy process helps us to do so.



**Developing a  
dedicated strategy  
makes us competitive  
in the long term.«**

With the strategy, we lay the foundation for the future direction of Fraunhofer IPMS. We talk about our research topics, processes, structures, resources and the institute culture. In the turbulent times we are currently experiencing, it is all the more important to agree on a common goal. The fact that we succeed in this at the institute makes us successful – and a strong research partner for our customers. .



**Tina Heinz,**  
Division Director  
Corporate Development

To achieve this, we rely on an atmosphere of appreciation, flexible working time models, development opportunities and a trusting working environment. Our values – we are innovative, courageous, reliable and a team – guide our collaboration. For a successful future, we want to leverage internal competencies, expand career paths and attract international professionals.



**Linda Fischer,**  
Head of Human Resources Development & Recruiting



**We want our employees  
to be able to develop  
their competencies in a  
values-based and productive  
work culture.«**





**The future of microelectronics will be determined by a balancing act between high-performance computing, increasing communication range and low power consumption.«**

This can only be realized through intensive system heteroin-  
tegration. There is not one transistor technology that can do  
everything, even though scaling in the logic area will progress  
continuously. Therefore, interdisciplinarity will be the biggest  
challenge, but also the biggest opportunity, and a new para-  
digm of microelectronics. I'm looking forward to treading this  
path at Fraunhofer IPMS..



**Dr. Wenke Weinreich,**  
Deputy Institute Director

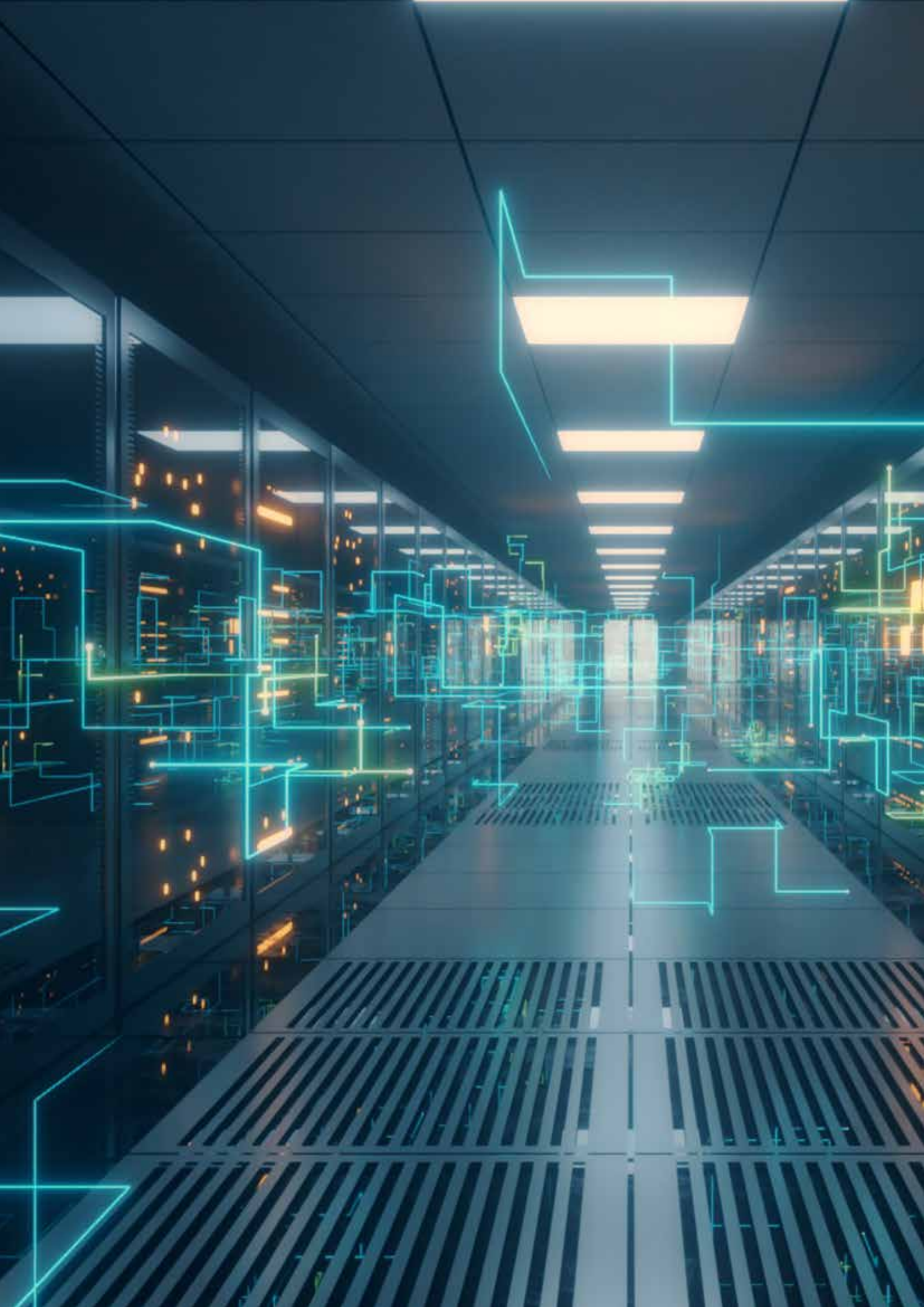


**Quantum technologies and AI are on the verge of further breakthroughs – here I expect exciting contributions from Fraunhofer IPMS.«**

In addition, Europe's geopolitical positioning in the semiconductor sector should be massively supported. The strategy of IPMS should clearly high-  
light the chosen focal points, enable them to be communicated and thus provide customers and employees with a clear guideline for their daily activi-  
ties. Good strategy development and implementation today is characterized by inclusion, measurability of goals and agile adaptation.



**Prof. Dr. Frank Schönefeld,**  
CTO T-Systems MMS and Speaker of the  
Auditors in the strategy process in 2023







# Next Generation Computing

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The next generation of computing technologies will be driven by the highest levels of parallelism, “quantum supremacy” and high energy efficiency with high performance as well as trustworthiness and security against interception.

These three approaches are widely known under the keywords

- **quantum computing and -cryptography,**
- **neuromorphic computing and**
- **trusted electronics.**

We carry out research with national and international partners on new materials, concepts, devices, and systems in Next Generation Computing. On the next pages, we present our projects.

## Quantum cryptography

# Secure optical data communication using quantum cryptography and Li-Fi

Modern quantum technology opens up many new areas of application. But it also harbors risks. Due to their enormous computing power, quantum computers, could undermine even the most modern data encryption methods. To forestall this scenario, Fraunhofer IPMS together with partners is developing a new approach to secure optical data transmission in wireless networks using light and quantum keys.

Previous research has focused on long-distance secure data communication for applications in the global data infrastructure, for networking government or military facilities, or for information exchange with satellites. However, the connections to the end user on the last kilometer have so far still been served by classical technologies and thus remain vulnerable to attack. To prevent this in the future, the project "QuINSiDa - Quantum-based Infrastructure Networks for Safety-critical Wireless Data Communication" was launched.


Li-Fi technology allows users to network with each other over short distances using optical signals. Compared to the familiar Wi-Fi technology, which is based on radio waves, the optical signals do not penetrate walls and can thus be designed for a defined area. In quantum key distribution (QKD), quantum states in the form of light are prepared and exchanged between participants in the network when the keys are generated. When the quantum states are received, they are measured and post-processed to produce keys that are identical on both sides but secret to an attacker.

The QuINSiDa project is the first to combine both technologies into a "QKD over Li-Fi" system. In contrast to radio-based approaches, the use of an optical communication network offers the advantage that every participant who registers in the optical wireless communication channel (Li-Fi channel) is also visible to the quantum channel. This ensures that secure key exchange can occur. Different wavelengths of light are used to separate the Li-Fi channel and the quantum channel. This separation can be optimized by the receiver by using appropriate optical filtering against interference.



The presented concept of a quantum-based infrastructure network for safety-critical wireless data communication is a completely new interdisciplinary approach that has not yet been presented in scientific publications or in current market solutions.

At the end of the project, a corresponding demonstration of the overall system is planned. The interdisciplinary networking between the different communities (QKD, optics, telecommunication, security) leads to a seamless integration of the novel technologies into existing security technologies. This makes it easy for end users to adopt the technology into existing infrastructure.

 [s.fhg.de/QuINSiDa-project](https://s.fhg.de/QuINSiDa-project)



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## Quantum cryptography

# Quantum-secure digital identities

Access to online services and network databases is regulated by means of digital identities. In order to transmit these securely over the network, asymmetric encryption methods are used. In the future, however, quantum computers will be able to crack these classic encryption methods. The project "Secure Quantum Communication for Critical Identity Access Management Infrastructures (Quant-ID)" aims to explore end-to-end solutions for reliable digital identities using post-quantum cryptography.

The widely used "Identity Access Management" architecture, which restricts access to certain predefined data in today's networks, will be used for this purpose. This will facilitate the transition from classical encryption algorithms to quantum-secure methods. A quantum-secure "single sign-on" approach will also be developed, allowing access to different services with a single central login. A modular approach will enable network administration to integrate either the entire system or only partial aspects.

At the end of the project, the digital identities and quantum-secure authorization will be tested in a demonstrator in a realistic application using existing network protocols. The capabilities of the developed system will be compared with classical methods.

The concept development in Germany strengthens sovereignty with regard to the security of national information technology systems. Against this background, the project solution has a particularly high market potential in highly sensitive areas and critical infrastructures such as banks, insurance companies, healthcare companies, public authorities and government institutions. These market participants in particular are dependent on meeting high security standards, as they are often exposed to increasingly complex attack structures. To support the exploitation of the quantum random generator, certification by the German Federal Office for Information Security (BSI) is also being sought..



[s.fhg.de/Quant-ID-project](https://s.fhg.de/Quant-ID-project)



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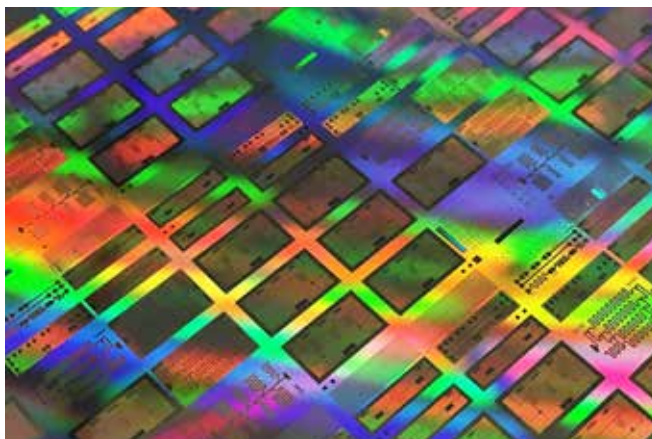
# Quantum computing

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## MatQu – New materials for quantum computing

In the MATQu project, Fraunhofer IPMS and partners aim to expand existing European know-how in the field of materials and production processes. This will pave the way for European industry to solid-state-based quantum computers. The aim is to establish a European supply chain for materials and processes for solid-state qubits through close cooperation between leading European research institutes, industry and application partners.

The focus of Fraunhofer IPMS in the project is to bring existing concepts and technologies from the laboratory to industrial manufacturing. In doing so, the institute invokes its expertise in 300 mm fabrication, which already serves as the industry standard for CMOS computing platforms. In addition, Fraunhofer IPMS will advance the fabrication of devices for quantum computing on a European scale through novel fabrication processes and testing at cryogenic temperatures. The project is coordinated by FMD and Fraunhofer IAF. In addition to imec and CEA-Leti, 15 other partners are involved.



*Test chip with superconducting qubits*

## PhoQuant – Photonic quantum computer

With sufficiently high networking of many computing units (qubits) in a system, quantum computers can achieve higher computing speeds than classical computers. It is precisely at this scale that the photonic approach, which uses light particles (photons) as qubits, offers enormous advantages. This is because the functions required for the computing operations can be produced on a single chip using sophisticated semiconductor manufacturing processes. Therefore, Fraunhofer IPMS is researching a photonic quantum computer together with partners.

The project goal is to provide an advantage for the computation of industry-relevant applications. A first example is the real-time optimization of schedules at airports in case of unforeseen delays. For this, the consortium, consisting of university research, startups and industry, is developing a new photonic computing architecture that will enable a quantum computer with up to 100 qubits over the course of the project. The project partners aim to present a first prototype in two and a half years.



*Graphical representation of a photonic quantum computer.*



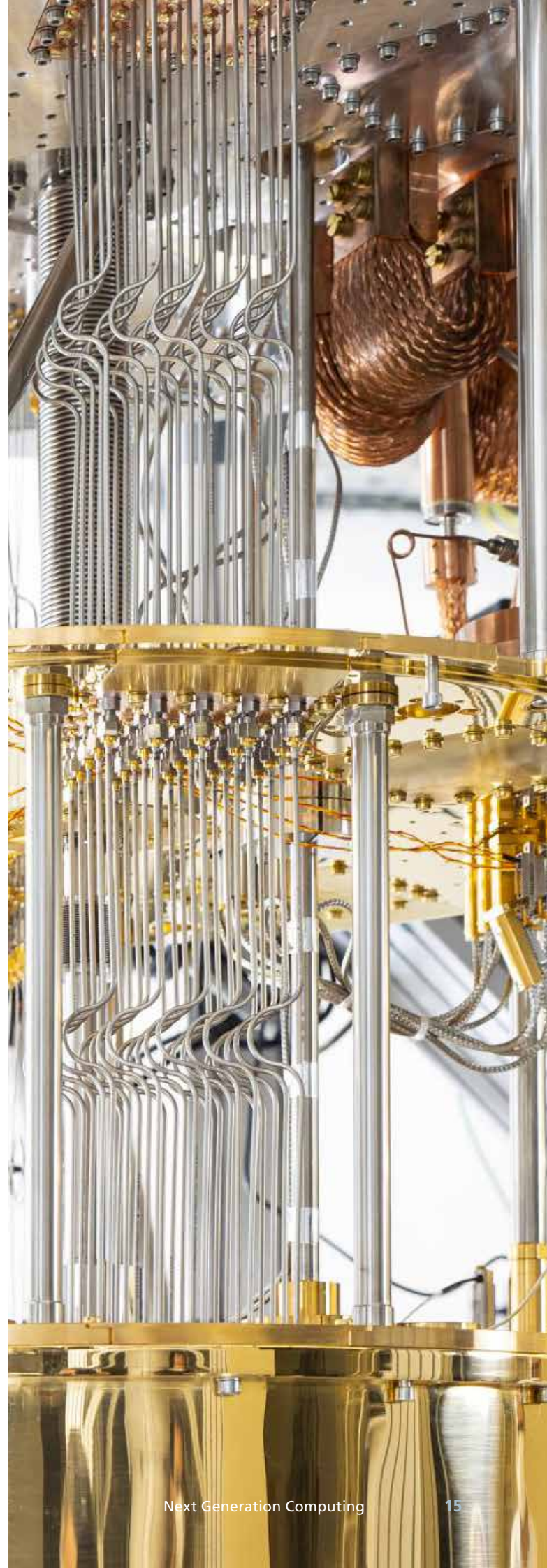


## QSolid – Quantum Computer in the Solid State

Together with 24 German research institutions and companies and under the coordination of the Research Center (FZ) Jülich, Fraunhofer IPMS is working on a quantum computer with improved error rates. The aim is to make Germany a world leader in the field of quantum technology and to open up numerous new applications for science and industry. The first demonstrator will go into operation in mid-2024 and make it possible to test applications as well as benchmarks for industry standards.

Fraunhofer IPMS contributes its expertise in state-of-the-art, industry-compatible CMOS semiconductor fabrication in the 300 mm wafer standard. This concerns, for example, manufacturing processes such as deposition and nanostructuring or electrical characterization on wafer scale. Together with GlobalFoundries and Fraunhofer IZM-ASSID, an interposer technology is being developed that focuses on high-density superconducting interconnects and thermal decoupling through advanced packaging. In addition, cryogenic characterization of GlobalFoundries' CMOS technology for scalable control will be performed.

The project focuses on qubits of very high quality, i.e. with a low error rate. A system is envisaged that contains various quantum processors based on superconducting circuits with a reduced error rate. The approach is considered a world leader and is also being pursued by Google, IBM and Intel, among others. The multiprocessor machine at FZ Jülich will run at least three different quantum chips in parallel: a "moonshot system" whose computing power surpasses classical supercomputers, an application-specific designed system that is already suitable for industrially useful quantum computations, and a benchmarking platform that is primarily focused on the development of digital twins and industrial standards.





# Neuromorphic computing

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## StorAlge – New storage technology for Edge AI

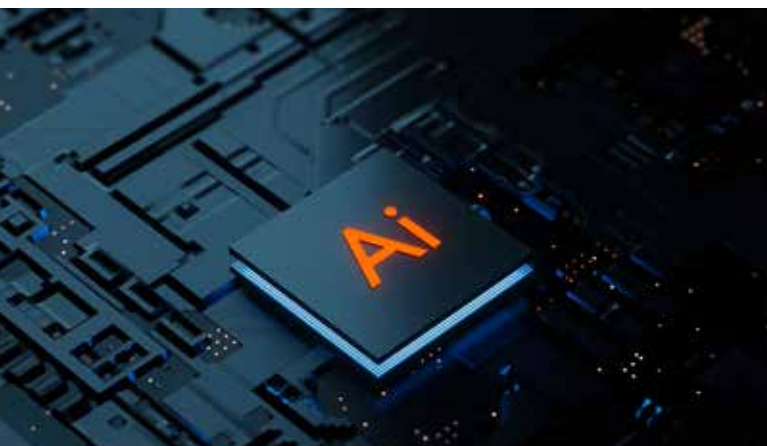
Artificial intelligence (AI) is being used in more and more applications today. Today's AI technologies are inefficient, expensive and often still suffer from low public acceptance. In the StorAlge project, Fraunhofer IPMS has joined forces with European partners to develop a platform for silicon-based AI chips that is high-performance, energy-efficient as well as secure and enables competitive edge AI applications in the automotive, industrial, security and consumer sectors.

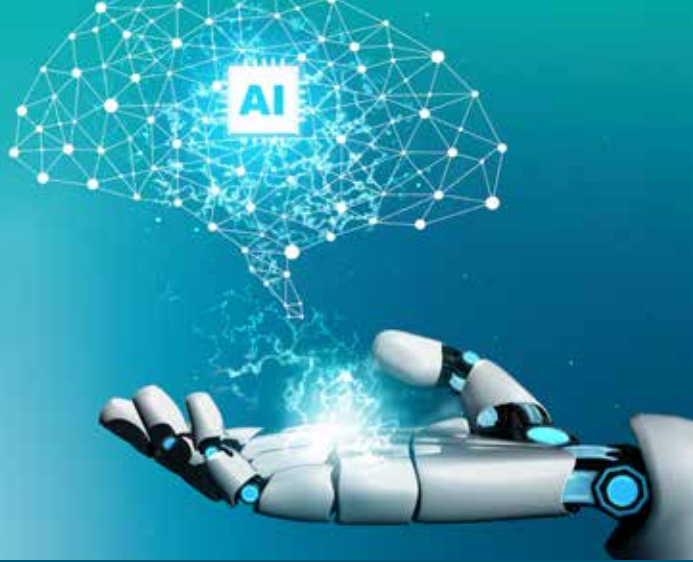
The key challenge of the project is to develop the design of complex systems-on-chip for smarter, safer, more flexible, low-power and lower-cost applications. To make this possible, Fraunhofer IPMS relies on ferroelectric field-effect transistors (FeFETs). These are implemented directly on the semiconductor chip. This allows the institute to expand its experience in the integration, characterization and optimization of ferroelectric memory technology.

## SEC-Learn – Sensor edge cloud for federated learning

Many processes that require the evaluation, categorization or presentation of huge amounts of data nowadays rely on artificial intelligence (AI). On the one hand, the many data sets generated as a result go hand in hand with increased energy requirements, and on the other hand, the data is stored centrally, which entails risks from the point of view of data protection and data security. In the SEC-Learn project, Fraunhofer IPMS is conducting research with ten other Fraunhofer institutes to develop a neuromorphic computing architecture for federated learning.

Federated learning refers to an approach in which AI algorithms are trained to store data in a distributed manner on multiple devices or servers. Unlike traditional cloud-based machine learning, the advantage is that sensitive data remains in local systems. The platform developed in the SEC-Learn project will additionally use neuromorphic hardware accelerators, which have a power consumption that is several orders of magnitude lower.





## Lighthouse project NeurOSmart – Sensors learn to think

Autonomous robots are packed with sensors and electronics to perceive their environment and also handle unforeseen situations autonomously. This is accompanied by a significant increase in energy consumption. This is why Fraunhofer IPMS, together with four other institutes, is developing a neuromorphic in-memory accelerator in the NeurOSmart project, which is tailored to the respective sensor. The human brain serves as a model.

Fraunhofer IPMS develops and trains the circuitry of the neuromorphic accelerator within the project. For the internal control of the data flows, the RISC-V processor core EMSA5 developed by Fraunhofer IPMS is implemented with direct interfaces to the analog accelerator board and higher-level systems as well as error protection mechanisms.

Furthermore, Fraunhofer IPMS is involved in the research of the neural network model for LiDAR data evaluation. The goal here is the automated mapping on the available hardware topology as well as its transfer to a circuit design. The communication between pre-processing (FPGA) and accelerator circuitry takes place via a real-time capable high-speed Ethernet interface.

All neuromorphic  
computing projects

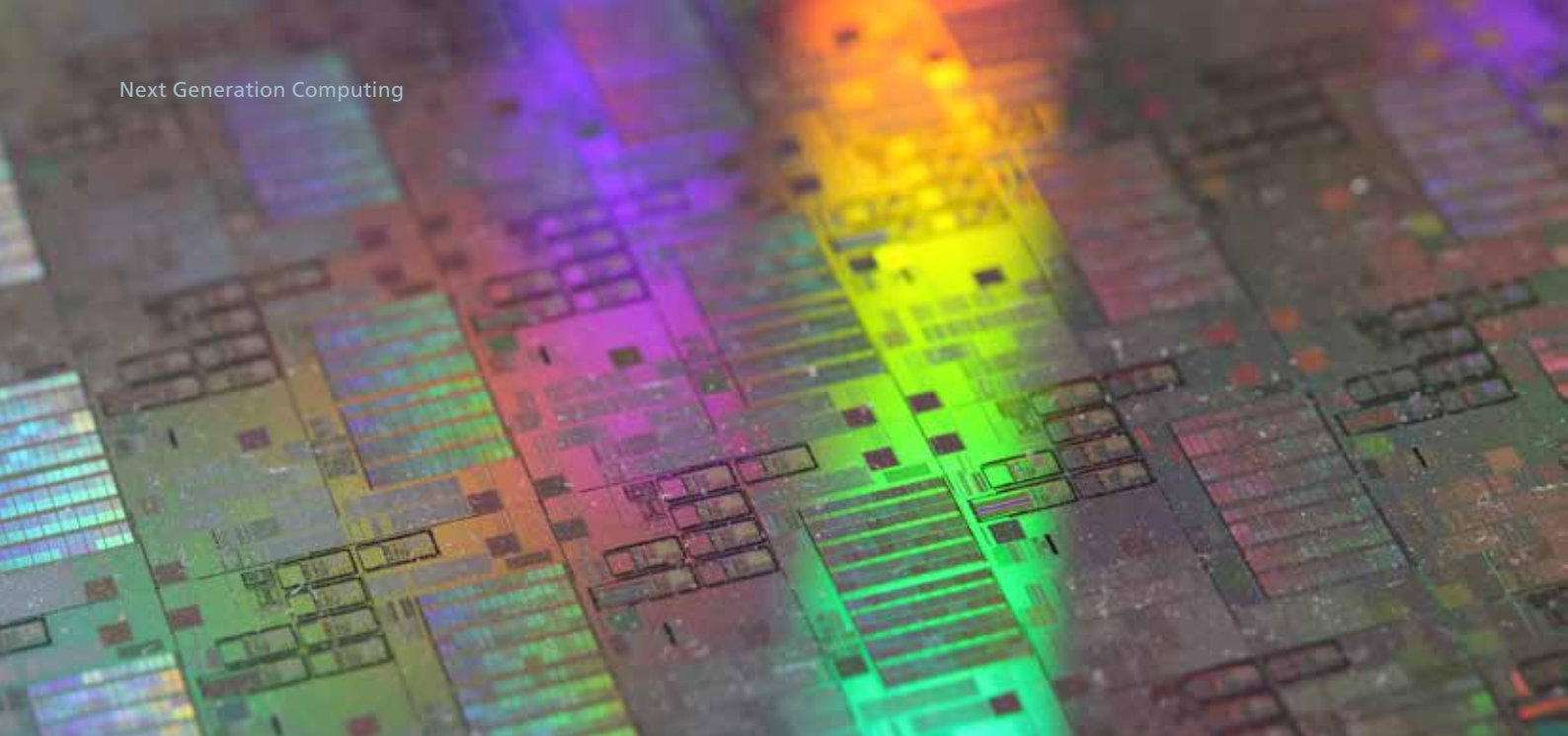


## TEMPO – Technology for neuromorphic computing

In the TEMPO project, Fraunhofer IPMS is working on the technological development of microelectronic components with particularly low power consumption that can be used for applications in the field of artificial intelligence, IoT and edge computing. One aspect is novel memory concepts as well as the integration of additional functional modules made of ferroelectric capacitors. Direct cooperation with industrial partners should ensure the subsequent industrial feasibility of the neuromorphic circuits and chips.

A total of 19 European partners have joined forces in the project. Fraunhofer IPMS is conducting research on chips in GlobalFoundries' 28 nanometer technology node in order to make the interconnect structure smaller and reduce leakage currents and process fluctuations. The chips will initially be used in image recognition systems, for example for autonomous driving or for processing sensor data in radar systems. The aim is to reduce power consumption by several orders of magnitude due to the neuromorphic chip design and the adapted peripherals.





## Neuromorphic computing

# Technology platform for neuromorphic chips

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Neuromorphic computers are modeled on the structure of a biological nervous system. The tasks of the neurons are performed, for example, by CMOS memristors which - as in the brain - are connected to each other via synapses. Neuromorphic systems for edge AI applications show enormous potential in pattern recognition, pattern analysis and pattern prediction and have a high application potential in areas such as medical diagnostics or speech pattern recognition and promise to enable these extraordinary performances with the lowest possible energy requirements compared to current architectures..

To enable industry to turn these technologies into commercial products and innovations as quickly as possible, they must be transferred from basic research into commercial applications and the necessary development and pilot production infrastructure must be established. The PREVAIL project - Partnership for Realization and Validation of AI hardware Leadership - aims to provide a technical platform capable of designing, manufacturing and testing prototypes for advanced neuromorphic chips for edge AI applications.

## Strengthening national and international collaboration

In the project, four Fraunhofer institutes - in addition to the coordinator Fraunhofer IPMS, these are the institutes IZM, IIS and EMFT - are contributing their advanced 300 mm manufacturing, design and testing capabilities. Together, they will create a "Hardware for Edge AI" platform for 300-mm technology. The platform will be expanded over the long term in collaboration with CEA-Leti, imec and VTT, the leading European research organizations (RTOs).

The project started in December 2022. In the first project phase of three and a half years, the focus will initially be on closing gaps in the tool parks of the participating partners and improving selective processes as well as, for example, coordinating business processes and contamination management in such a way to create the prerequisites for joint demonstrator offerings.

In a planned second phase, the platform will then actively provide pilot production capacities, especially for the European R&D market. This will enable companies, start-ups and research institutions to commission demonstrators, prototypes and small series in advanced designs for which there was previously no production option.

Through this collaboration, the partners aim to develop chips that go well beyond the state-of-the-art in the future. Currently, the RTOs operate their cleanrooms according to their respective national missions in regular collaboration, but on a project basis. The PREVAIL project clearly demonstrates the joint effort to work together in a permanent and coordinated manner, to bundle competencies and to complement each other.





### Bringing the European Chips Act to life

In early 2022, the European Commission adopted the proposal for new legislation on semiconductors, the so-called European Chips Act. In addition, individual member states are also currently developing national strategies to expand their industrial and production capacities and reduce dependencies. The PREVAIL project aims to promote the framework for aligning national initiatives with the European Chips Act by establishing a distributed technology platform with multiple nodes from the main European semiconductor RTOs.

The virtual AI hardware platform being created in the project will ensure that the availability of energy-efficient, high-performance, and trustworthy AI components (such as AI processors) and technologies can be permanently guaranteed in Europe. This will make a significant contribution to maintaining technology sovereignty in Germany. Edge computing in particular plays a crucial role in the digitization of industrial processes and in the successful implementation of the German Industry 4.0 strategy.

### Competitive worldwide

Worldwide, in addition to the research facilities of the European 3 RTO Alliance (imec, CEA-LETI, Fraunhofer Microelectronics), only the USA (Albany NanoTech Center) and Japan (AIST) have microelectronics research centers with similar equipment based on 300 mm. In this respect, the research capacities of the project partners are also of great importance for the microelectronics industry beyond Europe. In total, their 300 mm infrastructures comprise more than 10,000 m<sup>2</sup> of clean room space in Leuven, Grenoble and Dresden. The facilities are closely linked to industry and, thanks to their industry-standard equipment and established protocols, can exchange wafers and transfer processes quickly.

The Research Fab Microelectronics Germany (FMD) serves as a model for PREVAIL for a virtual, decentralized fab for the development of highly complex chips. By creating a European AI platform, PREVAIL is now directly contributing to advancing the transformation of microelectronics into an important enabling technology for meeting climate and sustainability goals in Germany and Europe.

The PREVAIL project is co-financed with funds from the European Union and the German Federal Ministry of Education and Research (BMBF) under the funding code 16ME0834. On a national level, the project is complemented by the BMBF project "Forschungsfabrik Mikroelektronik Deutschland - Modul Quanten- und neuromorphes Computing" (FMD-QNC), which started simultaneously on December 1, 2022. In this project, FMD together with four other Fraunhofer institutes, Forschungszentrum Jülich and AMO GmbH bundle their competences and technical equipment with regard to quantum and neuromorphic computing.



[prevail-project.eu](https://prevail-project.eu)



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# FMD-QNC – Research Fab for quantum and neuromorphic computing

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In order to consolidate and expand the existing microelectronic research and development in Germany regarding quantum and neuromorphic computing, the FMD launched on December 1, 2022, a joint project together with four other Fraunhofer institutes, the Jülich Forschungszentrum and AMO GmbH: The Research Fab Microelectronics Germany — Module Quantum and Neuromorphic Computing (FMD-QNC). The German Federal Ministry of Education and Research is funding the equipment and structural setup required for the project.

The performance limits of classical digital computers are increasingly being challenged by compute-intensive technologies and applications such as artificial intelligence (AI), edge computing, and the optimization of complex systems. Evidence of this can be found, for instance, in simulations used in chemistry and pharmaceuticals to speed up the development of new medications and vaccines, in the process optimization of complex production lines, as well as in the area of traffic and freight transport. A promising approach to solving this challenge is offered by quantum computing (QC) and neuromorphic computing (NC). They are considered the essential foundations for Next Generation Computing, i.e. for novel computing technologies essential for the realization of many competitive and safety-critical future applications.

## Contributing to the development of the future hardware foundation for novel computing technologies with the FMD-QNC

In Germany, several fundamental research projects are currently working on QC and NC. Nevertheless, there are still insufficient opportunities for application-oriented testing of the hardware developments that are required for the highly complex computing technologies, as well as for a rapid implementation of the results in prototypes and small series.

In order to provide researchers and industry with optimal support in the development of customized microelectronics as well as with scalable manufacturing and integration processes for the new computing technologies, the Research Fab Microelectronics Germany (FMD for its acronym in German) will be expanded to include the module Quantum and Neuromorphic Computing (QNC). To that purpose, the Fraunhofer institutes IMWS, IOF, IPM, and ILT, together with the Jülich Forschungszentrum and AMO GmbH, are cooperating to enhance the facility parks and diverse production lines of the participating partners, as well as the entire spectrum of expertise of the 13 FMD institutes.

## Customized microelectronics solutions along with scalable manufacturing and integration processes for QC and NC

Based on the cross-organizational and cross-site expertise generated within the FMD, it will be feasible to implement the envisaged FMD-QNC project in a target-oriented and efficient manner. Aiming to create a high-level holistic research structure for novel computing technologies, the cooperating partners will be gradually equipped over the next three years with design tools, measurement and characterization techniques as well as manufacturing facilities required for application-oriented research into highly complex QC and NC technologies.

The research structures will be interconnected to achieve industry-oriented research and pilot lines, among others for superconducting and memristive circuits, 3D system integration and highly integrated beam sources. As a result, it is intended to develop solutions for the — often extreme — operating environments, such as vacuum, cryogenic temperatures or electromagnetic shielding. This will set the process and technological requirements for design, fabrication and characterization of chips for neuromorphic computing as well as various QC technologies (superconducting, neutral atom, trapped ion, and quantum dot based).

### Industry-relevant research framework and low-threshold access to research infrastructure

In addition to the research activities and the application-oriented testing of the developments, the "QNC operator model" and a "Microelectronics Academy" are two further components of the overall FMD-QNC project. The Microelectronics Academy envisaged here aims to raise the awareness of the upcoming generation of specialists in the field of microelectronics at an early stage, as well as to provide basic training and continuing education for experts who are already active in the field.

"The so-called QNC operating model intends to comprise a flexible and low-threshold access model for partners from both science and industry enabling them to react agilely to the ongoing new developments and the requirements from research and development as well as to accelerate the transfer into the industry. For this purpose, three specific project corridors will be created: technology development, pilot production and preliminary research. Furthermore, it is planned to reinforce networks with diverse user groups along with selected complementary research activities to integrate the technologies into the research structures. This includes a QNC space for testing special manufacturing methods, the so-called multi-project technologies as simplified access to chip manufacturing runs, and an open design platform," explains Dr. Oliver Pyper, project manager of FMD-QNC.

### Networking among European research organizations to address current and future challenges in electronics research

At the European level, the FMD-QNC is complemented by the PREVAIL project (Partnership for Realization and Validation of AI hardware Leadership; see previous page), which started on December 1, 2022 as well.

The PREVAIL project is bringing together four European research organizations — CEA-Leti, Fraunhofer, imec and VTT — to establish a networked 300 mm technology platform for the fabrication of chip prototypes used in advanced artificial intelligence and neuromorphic computing applications. The national part of PREVAIL is constituted by the four Fraunhofer institutes EMFT, IIS, IPMS and IZM, which as part of the FMD are broadening their 300 mm fabrication, design and test facilities as well as deploying them in a complementary way to the 300 mm technology of their European research partners.

The intended project activities within PREVAIL and FMD-QNC will be synergetically interconnected and represent an essential preparatory work for the technological foundation of the European Chips Act. The European Commission's set of measures aims to boost the development of semiconductor technology to a new level and to increase Europe's innovative strength in microelectronics. Fraunhofer IPMS looks forward to making a significant contribution to this with its research and development.

The FMD-QNC project is funded by the German Federal Ministry of Education and Research.



[s.fhg.de/FMDQNC](https://s.fhg.de/FMDQNC)



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# Trusted Electronics

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## Using split manufacturing for trusted electronics

The increasing relocation of integrated circuit manufacturing to non-European regions increases the vulnerability to the introduction of malware and espionage functions into components supplied by foundries. At the same time, the risk of intellectual property theft of the circuit design by third parties increases. The T4T project aims to provide domestic industry with tools to access secure supply chains and trusted electronics. Subcomponents adapted to these requirements can still be sourced through existing supply chains (split manufacturing), but the assembly and encoding of the systems will take place in a trusted environment in Germany.

Within the project, Fraunhofer IPMS will address two main topics. On the one hand, the interface between classical front-end (wafer fabrication) and back-end (heterointegration) will be developed and optimized in terms of contamination management, defect density and process quality in the spirit of split manufacturing. In addition, modern post-quantum cryptographic methods using non-volatile memories are to be investigated and tested.



## Trusted electronics manufacturing

The Velektronik research project is concerned with trustworthy manufacturing processes. The aim is to create a platform solution that takes the entire value chain into account in order to deliver concrete concepts for trustworthy electronics. The project aims to create a technological overview, produce contributions to the necessary standardization and establish the network of research and industry. The collaborative platform Velektronik is coordinated by the office of the Forschungsfabrik Mikroelektronik Deutschland.

Within the project, the Fraunhofer IPMS deals with the production of electronic components at different manufacturing sites, the so-called split manufacturing. Here, for example, the assembly of the CMOS backplane can be detached from the MEMS manufacturing, which is typically the case in international value chains. In terms of trustworthy electronics, it is important to protect the IP of the individual components, to maintain interfaces and functionalities, and yet to provide security features in hardware and software.





## Photonics for tap-proof communication

Work is underway worldwide to improve the security of networked devices in order to protect sensitive data from misuse by third parties. Increasingly strong, hardware-supported cryptographic algorithms are being used. In the Silhouette project, Fraunhofer IPMS and partners are developing a universal platform solution for the development of hybrid electro-optical systems. The essential core point is to consistently convert safety-critical electrical signals into optical signals, to further process or validate them and finally to convert them back. This is because photonic transmission channels alone offer the advantage of being both virtually impossible to manipulate and tap-proof.

The project covers the entire value chain: from design to manufacturing, assembly and interconnection technology to testing and inspection methodology. In order to be able to guarantee technological sovereignty and trustworthiness in the design and manufacturing process as well, the envisaged electro-optical platform solution will be located in the European economic area.

Fraunhofer IPMS contributes its experience in the field of integration of particularly energy-saving components for IoT applications. Furthermore, three different concepts of a quantum cryptographically secure key generator based on cryptographic multimode interferometers (k-MMI) are evaluated with regard to their performance, security and risks.

*Test kit for high-precision self-aligned assembly technology for integrating light sources and detectors with photonic integrated circuits.*









# Medical and Health

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For many years, Fraunhofer IPMS has been researching technologies for improved prevention, diagnostics and therapy in the medical field. This includes, for example, MEMS-based innovative imaging techniques as well as new technologies for the early detection of diseases.

We welcome you to learn more about our research on the following pages.

# Laser scanning microscope improves tumor cell detection

Distinguishing between tumor and healthy tissue during surgery is of great importance but can be challenging. Optical methods for precise in-situ tumor delineation that are easy to use would be helpful to support surgery. To this end, a novel MEMS-based confocal laser scanning microscope has been developed at the Fraunhofer Center for Microelectronic and Optical Systems for Biomedicine (MEOS) in Erfurt, Germany. This makes it possible to determine much faster than before whether a tumor has been completely removed while still in the operating room.






Employees of Fraunhofer IPMS and Fraunhofer IZI have jointly developed a MEMS-based laser scanning microscope and a fluorescence marker method of tumor cells to localize tumor margins most effectively. In the first step, the tumor margin is stained for this purpose. Here, a special method using fluorescence-labeled antibodies at cell culture level is used, which was developed by Fraunhofer IZI. Subsequently, the confocal microscope is used to take an image of the cut surface.

The core of the microscope is a scanning mirror developed at Fraunhofer IPMS, which allows the light to be deflected in the x- and y-directions, thus generating an image practically in real time. This allows a lateral resolution of  $< 1.0 \mu\text{m}$  to be achieved in the fluorescence image with a field size of  $400 \times 400 \mu\text{m}^2$  ( $960 \times 960$  pixels). For sectional images, the system is equipped with a z-shifter with a maximum path length of  $2000 \mu\text{m}$  and  $5 \text{ nm}$  minimum step size.

A demonstrator of the microscope at the Fraunhofer Center MEOS in Erfurt has already been successfully tested. The application partner Helios-Klinikum in Erfurt provides tissue samples. Future work will focus on the use of artificial intelligence (AI) for automated detection of tumor resection margins, robotics to create an assistance system for surgical staff, and system adaptations for transfer to a clinical environment.

A project video provides an impressive visualization of the current status of the work:

-  [s.fhg.de/LSCOnco-Video](https://s.fhg.de/LSCOnco-Video)
-  [s.fhg.de/LSCOnco-en](https://s.fhg.de/LSCOnco-en)
-  [doi.org/10.1117/12.2608547](https://doi.org/10.1117/12.2608547)



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# Technology hub for cell-based therapeutics

The MEOS Innovation Center for Precision Analysis of Cell Therapy Products, or MIC-PreCell for short, is being established at the Fraunhofer Center for Microelectronic and Optical Systems for Biomedicine (MEOS) in Erfurt. Funded with 750,000 euros from the Free State of Thuringia, new analysis methods for quality assurance and process control for the manufacture of cell-based therapeutic products will be developed here by summer 2023.

With MIC-PreCell, infrastructure and know-how are brought together to narrow the currently still existing gap between innovative technologies for the analysis of quantitative, cell-related parameters, and their broad application in the context of the production of cell-based therapeutics. Cell-based therapies, such as chimeric antigen receptor T-Cells (CAR-T), are usually personalized to the individual patient receiving the treatment, and are still very expensive due to the very complex and lengthy manufacturing processes. Moreover, for people in the critical stages of cancer, timely manufacturing is often crucial to survival. Within the framework of MIC-PreCell, modern, innovative methods of integrated quality assurance are therefore to be established, with which the manufacturing processes can be monitored in real-time and any production errors can be detected considerably earlier, thus improving success rates of the final product.

In doing so, the project team is focusing on the broad use of innovative quality assurance methods in cell production, such as optomechanical profiling, which can be used to determine mechanical cell properties immediately and without labeling. The Fraunhofer researchers also plan to use a gas chromatograph-ion mobility spectrometer to analyze VOCs, volatile organic compounds emitted by cell cultures to the outside air, which act as metabolic fingerprints. In addition, devices for micromanipulation of cells and cell clusters or organoids will be used, allowing direct and detailed real-time information on the state and potency of therapeutic cell products.

 [s.fhg.de/MICPreCell](https://s.fhg.de/MICPreCell)



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# Detecting diseases by breath analysis

Rapid diagnosis of disease has been of great interest in recent years. The COVID-19 pandemic and the detection of antibiotic-resistant bacteria show that there is an urgent need for portable devices that allow for point-of-care diagnosis. The Fraunhofer Center MEOS is working on a solution by combining different approaches with a strong focus on interdisciplinary collaboration.



A particular focus for point-of-care (POC) devices is the analysis of gaseous components. It is known that diseases change the metabolism in the human body. This has an impact on the composition of urine and breath, for example. Common marker substances belong to the group of volatile organic compounds (VOC). The basic requirement for entering this attractive market for POC devices is (1) reliable and highly accurate detection of individual VOCs and (2) linking the measured data to diseases to enable reliable diagnosis. Compact and cost-effective systems in doctors' offices or care facilities that enable quick and easy diagnosis are conceivable.

A range of interdisciplinary competencies is required for the associated development. The sensor is a sophisticated component for future devices for medical diagnostics. Conventional laboratory methods (e.g. gas chromatography with mass spectrometry coupling) exhibit high sensitivity and certainty of results. However, the entire analysis chain is time-consuming and costly. This limits the widespread use for POC applications.

The use of miniaturizable sensor concepts such as ion mobility spectrometry (IMS) overcomes these limitations and provides an attractive basis for the development of portable devices. Fraunhofer IPMS is pursuing an adaptable chip concept and has developed a microsystem based on it. The core is an IMS chip consisting of a special FAIMS-based ion filter including detector and manufactured in silicon-based microtechnology. In combination with the required electronics, this has resulted in a laboratory demonstrator that can detect typical VOCs. Together with other experts in the field of biomedical analytics, application scenarios are currently being investigated and evaluated in terms of performance with the specially developed IMS setup. The overall goal is to move towards product development together with companies.

 [s.fhg.de/VOC-analytics](https://s.fhg.de/VOC-analytics)



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*Ultrasonic spirometer consisting of mouthpiece and tube with ultrasonic sensors as well as an easy-to-understand graphical user interface for evaluation.*



## Early detection of diseases by means of ultrasound breath analysis

Chronic and acute respiratory diseases such as asthma, COPD and COVID-19 pose a challenge to healthcare systems due to an aging, disease-prone society and the rapid spread of pathogens. Early detection of severe disease progression improves the chances of cure. By recording physical parameters such as respiratory rate and volume, signs of disease can be detected earlier than usual and, above all, non-invasively and thus particularly gently. Fraunhofer IPMS has developed an ultrasound-based spirometer for this purpose.

The spirometer records physical respiratory parameters (e.g. respiratory volume and frequency) based on the measurement of respiratory gas flows in a tube using ultrasonic waves. At the core of the system are capacitive micromechanical ultrasonic transducers (CMUTs) developed by Fraunhofer IPMS. These components, manufactured using microsystems technology, offer high precision combined with small size. In contrast to common piezo transducers, micromechanical manufacturing enables ultrasonic transducers in repeatable quality without post-processing.

A first demonstrator for airflow measurement and respiration analysis has already been successfully built. It consists of a tube equipped with ultrasonic transducers and a control unit, accessible via a graphical user interface, which allows the extraction of sensor data for physical respiratory parameters.

The functionality of these system modules has been clinically verified. Thus, for the first time, a portable CMUT-based ultrasound spirometer enables precise measurement of physical respiratory parameters. The integration of the CMUT elements into the disposable mouthpiece and the miniaturization of the overall system into a compact handheld in combination with the interface to virtual monitoring systems enable an improvement of treatment in the field of respiratory diseases.

 [s.fhg.de/Spirometer](https://s.fhg.de/Spirometer)



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# Sensors and AI

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We are researching ways to make sensors more high-performance, more energy-efficient and smarter. Through approaches such as edge computing, in which data processing takes place directly at the sensor, we are also helping to increase the trustworthiness of systems. In a number of projects, we have succeeded in opening up new applications by combining sensor technology with artificial intelligence.

On the following pages, we would like to give you an impression of our current research projects.




# AI-powered microsensing and actuation for gesture recognition

In everyday life, digital helpers – such as smart apps or cars that think for themselves – are already firmly integrated. Currently, however, the processing of data is mostly done on large, external servers. Embedded artificial intelligence (edge AI) should change this and enable the processing of data and algorithms directly on the end device. Fraunhofer IPMS is therefore researching innovative solutions to integrate machine learning algorithms into everyday devices.

Fraunhofer IPMS is increasingly combining its expertise and developments from different research areas. For example, in an internal institute project, findings from microsensor and actuator technology were combined with the latest technologies in nanoelectronics, wireless communication and processor developments. The resulting synergy effects now offer customers tailored complete solutions for hardware-related, AI-controlled microsensors and actuators.

In this context, sensor- or actuator-related signal preprocessing is enabled by means of AI-based methods (focus: TinyAI/ Embedded AI). The advantages here are both low latency in processing and more secure data processing without network connectivity. Furthermore, the edge AI solution enables re-learning in the field to optimize the system for specific on-site boundary conditions. Especially for edge AI sensor/ actuator solutions, the existing RISC-V computing platform EMSA5 at the institute was extended by an AI functionality (based on Tensorflow Lite).

A first demonstrator shows the developments in an application for non-contact, three-dimensional detection of distance, motion and gesture for communication with robots as well as in surgical areas and household systems. Based on an ultrasonic transmitting actuator and three distributed MEMS receiving microphones, the gestures are measured at a repetition rate of 150 Hz. To analyze the gestures, the system uses Long Short-Term Memory (LSTM) networks optimized for use on hardware platforms for wearable applications, such as the RISC-V processor IP core EMSA5 from Fraunhofer IPMS. In the demonstrator, the network was trained with approx. 10,000 gestures to ensure reliable recognition. During operation, the system enables continuous training to allow easy adaptation to user-specific gestures.

 [s.fhg.de/AI-microsensors](https://s.fhg.de/AI-microsensors)



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# Predictive maintenance using AI-powered sensors

Machine damage and failures are often associated with high costs and usually lead to considerable economic losses. Common methods of machine monitoring are limited to the detection of damage that has already occurred or the prevention of consequential damage on the basis of a few measured variables and simple features. It would be desirable to have predictive sensor technology that detects damage before it occurs. Therefore, Fraunhofer IPMS is researching smart, MEMS-based sensors with AI-based data evaluation for predictive maintenance applications.

The goal is a measurement sensor that combines novel, MEMS-based sensors such as accelerometers, capacitive micromechanical ultrasonic transducers and electrostatic bending transducers in a system-on-a-chip solution. All components can be manufactured as semiconductor devices based on CMOS technology and will be integrated on a compact printed circuit board.

The CMOS processes used can achieve a significant reduction in costs and energy consumption. Thus, considerably more machines and machine components can be equipped, where the use of systems for machine diagnostics was previously not possible due to space, weight or cost reasons. In addition, in terms of the Internet of Things, the use of sensor networks, i.e. several connected measuring sensors, for close-meshed monitoring of machines even in previously inaccessible places becomes profitable.

In data evaluation, the targeted fusion of measurement data from multiple sensors using AI algorithms is particularly important. Fraunhofer IPMS uses its expertise in the field of RISC-V IP cores here. This enables embedded AI, edge computing as well as real-time data transmission. A corresponding demonstrator was created at Fraunhofer IPMS in 2022 and can be viewed in the video:

 [s.fhg.de/Predictive-Maintenance-Video](https://s.fhg.de/Predictive-Maintenance-Video)



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# Characterization of hydrogen-natural gas mixtures with ultrasonic sensors

In a few years, hydrogen will be fed into the German gas pipeline network as a mixture with natural gas to enable its use in industry and in the private sector. The content of hydrogen in this mixture must be closely monitored at the various stages of the distribution process, as it has a lower calorific value and higher diffusivity than the carrier medium natural gas. This monitoring is intended in particular to ensure that the prescribed safety limits for the hydrogen concentration are met, but also to provide consistency in industrial processes and ensure that you receive what you pay for.

Fraunhofer IPMS contributes to the energy transition away from fossil fuels to more climate-friendly energies by providing sensor technology that detects and monitors the hydrogen content in pipelines, but also at potential leakage points. At the same time, volume measurement is performed.

End users benefit from being able to monitor the gas mixture themselves with this sensor technology. This contributes to

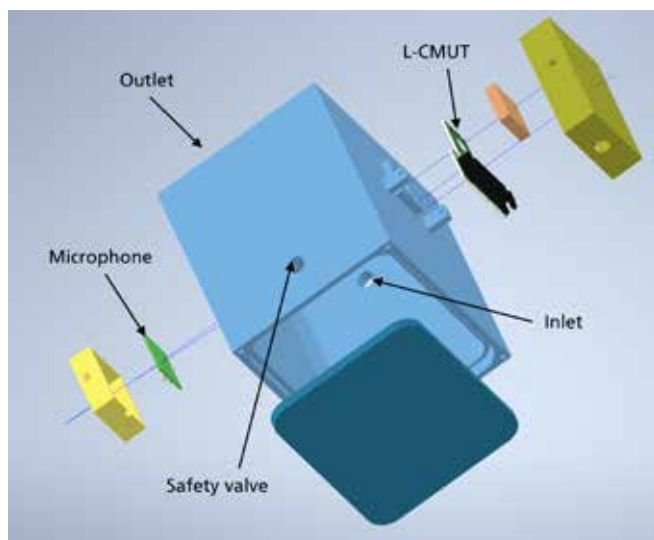
safety, because the hydrogen content must comply with prescribed limits. The quality can also be determined, because the  $H_2$  content influences the calorific value. In terms of economy, transparency is created for consumers, since the price should be directly related to the  $H_2$  content. In the field of industrial applications, it is also important to have an accurate, timely estimate of the  $H_2$  content for control purposes.

## Ultrasonic sensors for measuring hydrogen-natural gas mixtures

Ultrasonic sensors can provide a direct, integrated measurement of the hydrogen content in a binary mixture. The measurement principle is based on the time-of-flight measurement of an ultrasonic signal: If the composition of a binary mixture changes (whereby a component can also consist of different gases, as long as the individual concentrations do not vary), the partial pressures of the gas components and the overall density of the mixture also fluctuate. This in turn leads to a change in the speed of sound in this medium. The transmission of ultrasonic pulses and measurement of the transit time enables a calculation of the composition-dependent sound velocity in the gas mixture.

By emitting ultrasonic pulses along a fixed path, the measurement of the signal transit time allows a calculation of the speed of sound in the medium, which correlates directly with the hydrogen concentration. For path lengths in the centimeter range, the expected signal transit time corresponds to a few tenths of a millisecond. Capacitive micromechanical ultrasonic transducers (so-called CMUTs) form the basis for the measurement.

CMUTs are capable of transmitting or detecting pressure waves by changing the electric field between a fixed and a flexible electrode. In transmit mode, an oscillating voltage





is applied between the two electrodes, causing the flexible electrode to periodically displace a volume of air, generating ultrasonic waves. In receive mode, the incident ultrasonic waves cause the flexible electrode to oscillate, which can be measured as a pressure-dependent capacitance.

### **Demonstrator of Fraunhofer IPMS for gas concentration measurement**

The prototype for gas concentration measurement developed at Fraunhofer IPMS in 2022 comprises two different CMUT configurations suitable for different frequency bands: The out-of-plane CMUT is based on a membrane that oscillates longitudinally for wave propagation. The frequencies used are in the MHz range where the membrane resonates.

The in-plane CMUT (lateral CMUT or L-CMUT) is based on a micro-cantilever made of silicon, which oscillates transversely to the direction of wave propagation. This requires acoustic chambers through which air can be directed to the front and back of the chip. The resonant frequency is currently in the range of a few 10 kHz.

The CMUT units are implemented in the demonstrator in the two operating modes transmit and receive, while the L-CMUT units are operated only as transmitters and a commercial MEMS microphone is used as a receiver.

In order to bring the development to market, discussions with potential users and an exchange with the Lusatian hydrogen network "Durch<sub>2</sub>atmen" (BreatH<sub>2</sub>ing) are taking place in parallel with the evaluation of the measurement system.



[s.fhg.de/MUT4H2-en](https://s.fhg.de/MUT4H2-en)



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# Intelligent sensor solutions for Industry 4.0

The industry of the future will become more digital, more efficient and more automated. For this purpose, Fraunhofer IPMS develops MEMS-based sensors, optical components as well as actuators that capture the environment and make interaction safe. Applications are found in scanning imaging, laser scanning microscopy, endoscopy, LiDAR sensor technology for autonomous driving or in head-up displays, head-mounted displays and AMR displays.

Fraunhofer IPMS has many years of experience in the development and manufacture of customized, highly miniaturized MEMS scanners. The devices feature large scan angles and high scan frequencies and show excellent long-term stability. A CMOS-compatible bulk micromachining process is used to manufacture 1D and 2D microscanners in small and medium quantities..

New in the portfolio of MEMS micro-scanners of Fraunhofer IPMS are hybrid 2D vector scanner modules with an electro-magnetic drive. Here, Fraunhofer IPMS builds on many years of experience in the fabrication of gimbaled, monolithic 2D MEMS-scanners and combines this with the existing know-how of MEMS micro-assembly technologies. This new approach significantly expands the parameter space of previous monolithic scanners. At the same time, we retain the established advantages of Fraunhofer IPMS' MEMS-scanner technology - high optical planarity and decoupling of the scan axes through gimbal suspension as well as the fatigue-free nature of the spring elements. The new components allow 2-dimensional quasi-static deflection with larger mirror apertures as well as a high vectorial positioning speed.

The module also provides the mirror position as analog signals in order to be able to realize a controlled system. The well-known additional features such as the application of a customized, highly reflective dielectric mirror coating or the realization of the mirror plate as a diffraction grating are also feasible for these components. In order to exploit the full performance of the scan module, Fraunhofer IPMS provides



*2D vector scanner module of Fraunhofer IPMS*

suitable control electronics. The required algorithms, which are finely adapted to the mechanical properties of the module, were developed at Fraunhofer IPMS and can be transferred to the digital control of the customer's system electronics (FPGA or microcontroller). In addition, compact control electronics with a precise analog driver stage and input stages for the position signals are available. It can be addressed both analog and via a digital interface.

Further research work at Fraunhofer IPMS addresses the detection of the environment using quantum cascade laser spectroscopy. The miniaturized quantum cascade lasers developed jointly with the Fraunhofer Institute for Applied Solid State Physics IAF cover a large wavelength range and a broad spectral tuning range at a high scan rate. The micromechanically fabricated diffraction grating developed at Fraunhofer IPMS serves as an external resonator of the variable frequency quantum cascade laser. It allows to tune the laser wavelength with selectable speed or to choose a wavelength and hold it for selectable periods of time. Spectral ranges can also be scanned without mode hopping and enable therefore a very high resolution.

 [s.fhg.de/MEMS-scanners](https://www.s.fhg.de/MEMS-scanners)



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# On-site freshness testing of food

Anyone who has ever salted a cake knows that the correct identification of visually similar substances such as sugar and salt has major implications in food preparation. Complex compositional analyses can also provide information about the quality, ripeness or freshness of products. Therefore, Fraunhofer IPMS researches and develops smallest energy-efficient scanner systems, which enable contactless and mobile freshness testing on site.

In the field of analysis of materials in general, but especially in the case of food and its freshness, near infrared (NIR) spectral analysis is a proven method in laboratory use. Highly accurate instruments are able to provide precise information about the condition of the product at the time of measurement. However, it becomes problematic if the sample changes in the period between sampling and measurement in the laboratory or if the results are needed quickly.

The use of MEMS devices enables highly compact systems that can be manufactured cost-effectively in large quantities. The quality of the measurements is competitive for many important applications despite the small size. The acquired data are chemometrically analyzed on site or online and specific characteristics are extracted from them. This makes it possible, for example, to make direct statements about the ripeness and freshness of food. Other applications such as checking correct mixing ratios in food processing, rapid incoming and outgoing goods checks or selection in recycling or reuse processes can also be addressed..

Current work at Fraunhofer IPMS combines a simple technology for the MEMS component with a large addressable spectral range of the system and a high degree of modularity. At the core is a MEMS scanning mirror that deflects the incident collimated light beams onto a grating mounted in the system. A selection of different spectral diffraction gratings is possible, which can be optimized and used for specific applications.

Das aktuelle Demonstrationssystem adressiert den bewährten Spektralbereich von 950 nm bis 1900 nm mit einer spektralen Auflösung von 10 nm. Aktuell erreicht das System ein The



*Miniaturized NIR spectrometer of Fraunhofer IPMS.*

current demonstration system addresses the proven spectral range from 950 nm to 1900 nm with a spectral resolution of 10 nm. Currently, the system achieves a build volume of up to less than 1 cm<sup>3</sup>. However, further miniaturization is possible. In the context of the evaluation of quality parameters of foodstuffs, it was shown that pressure and damaged spots can be detected at a very early stage, using apples as an example, so that suitable selection allows recovery with the highest possible value added and avoidable destruction is minimized. Quantitative analyses are also possible using appropriate mathematical models..

Integration into a host system, for example a handheld, tablet or, in the future, even a smartphone, also benefits from numerous synergy effects. For example, the processor, memory and energy supply of the host system can be used and access to database information important for the evaluation can be made possible. Image evaluation by means of a camera could be used to narrow down the object to be measured and thus increase the precision of the results..

 [s.fhg.de/NIR-en](https://s.fhg.de/NIR-en)

 [s.fhg.de/NIR-video](https://s.fhg.de/NIR-video)



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# Digitalization and data communication

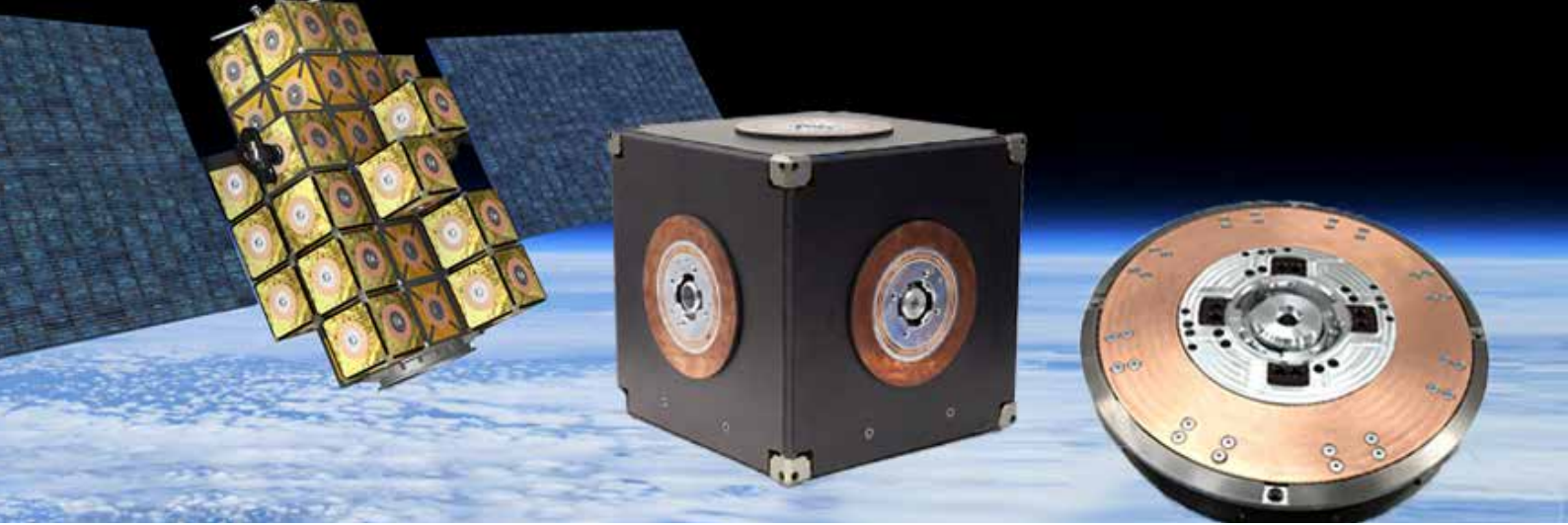
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Every day, we generate vast amounts of data. In 2020 there were 64 Zettabyte – 64.000.000.000.000.000.000 bytes – worldwide. For 2025, 181 zettabytes per year are predicted (source: Statista).

With this amount of data, it is clear that we need to pay particular attention to two aspects: We need to generate, transmit, and store data as efficiently as possible in order to minimize the environmental footprint. We also need to design the data capacity and bandwidth of our technologies in such a way that we transmit as much data as possible over as long a distance as possible in as short a time as possible – which also saves energy. We are looking into both approaches at Fraunhofer IPMS.

On the following pages, we present our projects in data communication and digitalization.





# Li-Fi technology on the ISS space station

Humans cause too much waste not only on Earth. Space debris is also becoming an ever greater problem. To make satellite systems more sustainable, they should be created in a modular system in the future so that individual components can be replaced, thus extending the service life of the satellites. To ensure a problem-free interface between the components, the Fraunhofer Institute for Photonic Microsystems IPMS has developed a transceiver that guarantees data transfer between the components. This was integrated into the iBOSS GmbH interface and has been on board the ISS (International Space Station) for testing purposes since February 2022.

There is international consensus in the space industry regarding the modularity of future satellite systems. In the future, such systems should be able to be flexibly disassembled and reassembled as in a modular system. The advantage of modular plug & play systems is that defective components can be replaced, thus significantly increasing the service life and function of a satellite. At the end of their lifetime, satellites either burn up in the earth's atmosphere or remain in earth orbit. The new generation of satellites will therefore replace the traditional architecture with a more sustainable and modular concept.

In order to be able to flexibly attach and detach modules directly in space, easy-to-couple and standardized components are particularly important. In addition to the mechanical coupling of the individual modules, it is essentially a matter of ensuring the transfer of data and energy between the individual modules so that satellites can be combined as required. For this reason, RWTH Aachen University applied for a patent years ago, which has now been brought to market by the spin-off iBOSS GmbH as iSSI® (intelligent Space System Interface) and forms a standard interface for such systems.

Part of the interface is a development of Fraunhofer IPMS and also known as Li-Fi GigaDock®. The core of the technology is an optical wireless transceiver, a highly integrated device that enables contactless full-duplex and bidirectional data transmission with a data rate of up to 5 Gbps. The possible transmission distance of the optical data interface is five centimeters. The component can also be used for rotor-to-stator transmission, as the transceiver functions perfectly even at high speeds. In addition to space travel, the component can be found in industrial communication systems, in medical technology as well as in docking applications.

In February, the interface flew into space for testing and demonstration purposes and was mounted by a robot for the first time on the Japanese part of the ISS. The module is to remain there until mid-December and prove its operational capability under vacuum conditions and the influence of radiation..

 [s.fhg.de/LiFi-ISS](https://s.fhg.de/LiFi-ISS)



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# Light modulators for space applications



Earth observation data are becoming increasingly important for our understanding of the planet and for addressing socio-ecological challenges – for example, in the area of environmental monitoring. Currently, methods for data acquisition and processing from space are limited by long acquisition times (up to several days per measurement), low spatial resolution (about 1 km), and the usable spectral range (mainly in the visible). Novel camera systems based on spatial light modulators can remedy this situation, which are being realized and tested for the first time within the EU project SURPRISE. Fraunhofer IPMS contributes with its long-standing expertise in the field of spatial light modulators and plans the development of a space-qualified spatial light modulator.

The main goal of the project is the development of a demonstrator. Core parameters are spectral broadband working range – in visible (VIS), near infrared (NIR) and mid infrared (MIR) – improved performance in terms of ground resolution and innovative on-board data processing and encryption functionality. Innovative Compressive Sensing (CS) technology is used for this purpose. It allows a two-dimensional image to be captured using a single-pixel detector. This is particularly interesting for the mid-infrared, because no suitable 2D detectors are available in this spectral range. At the same time, CS offers advantages in processing large amounts of data as well as native data encryption.

The special CS imaging technology used in the project for Earth observation requires special components. Spatial light modulators represent the most suitable solution for this task, since variable image patterns can be generated at high speed. These patterns are overlaid with the observation scene and recorded by single pixel detectors. The spatial light modulators (SLM) used by Fraunhofer IPMS consist of thousands or even millions of individual movable mirrors, each only a few micrometers in size.

Fraunhofer IPMS uses its extensive experience in the development and production of area light modulators to find the best solution for the specific requirements of the project. The main challenges are the space capability of all components and the coverage of a wide spectral range from visible to mid-infrared.

2022, an SLM of the latest technology generation from Fraunhofer IPMS successfully completed a test under space conditions. The 256 x 256 pixel device was evaluated particularly with regard to temperature (from -40 °C to 80 °C), vacuum (< 10<sup>-5</sup> mbar) and vibrations in the X, Y and Z axes. Not a single pixel failed.

These experimental findings, together with the simulation results, confirm the robustness of the Fraunhofer IPMS spatial light modulators and encourage further activities for the development of a space-specific SLM technology..



[www.h2020surprise.eu](http://www.h2020surprise.eu)



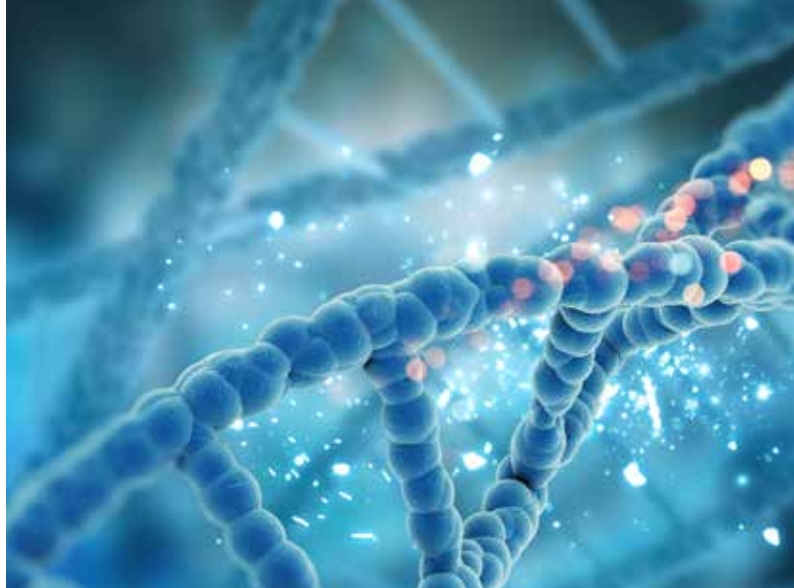
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# DNA as mass data storage of the future



**A new type of microchip platform for efficient cell-free and digitally controllable biosynthesis will be developed within the project "Modular high-throughput micro-platform for future mass data storage from synthetic biology", which is funded by the Fraunhofer-Gesellschaft in an internal program. Together with three other institutes, Fraunhofer IPMS is researching the fundamentals for the mass data storage devices of the future with extremely high storage density.**

DNA is known as a basic medium for storing genomic information. However, DNA can also be used to store (binary) data – a future technology that has so far been the subject of basic research in Europe. This involves transferring microbiological processes from nature to artificial data systems. Writing DNA on microchips is still a major challenge, but also a huge opportunity. For example, information can be stored in very high density directly on a microchip through the specific three-dimensional and digitally controllable arrangement of base pairs.

The project therefore combines the know-how of four Fraunhofer institutes with the aim of significantly improving DNA synthesis. This is achieved by a universal microchip platform for DNA / RNA / peptide writing. Previous synthesis approaches (including ink-jet) are not very efficient in generating long DNA segments. Moreover, they generate numerous inaccuracies, which are time-consuming and expensive to correct. In addition, the corresponding equipment technology is large and cost-intensive.

In the project, a platform for writing software-defined nucleotide sequences (DNA, RNA or peptides) based on conventional microchip manufacturing technologies will be presented. This will then enable the highly parallel and high-throughput production of mass data storage devices in the future by duplication in the volume production processes of the microelectronics industry. In a microplatform designed and fabricated using microelectronics methods, micrometer-level miniaturized reaction cells with picoliter-scale reaction volumes for cell-free

synthesis will be integrated into a freely programmable active matrix array assembly. Suitable thermal and photonic components as well as surface functionalization per reaction cell will be used for transport, immobilization, activation and monitoring of process conditions and results.

The task of Fraunhofer IPMS is to develop the "thermo" layer for the microchip platform. The heating function to set the temperature for biological synthesis is performed by structures in surface micromechanics following the technology of capacitive micromechanical ultrasonic transducers (CMUT). Fraunhofer IPMS is also contributing simulation expertise for thermal functionality.

The project is accompanied by a circle of renowned consultants from industry, science and users as well as with experts from the University of Marburg, XFAB, Infineon, the Federal Archive and Hybrotec. Initial results will be presented to the public for the first time at a user workshop at the end of 2023.

 [s.fhg.de/Biosynth](https://www.s.fhg.de/Biosynth)



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# New controller IP core for secure data

Data security is one of the most important issues in today's digital age. Increasing system attacks and cybercrime make it necessary to secure data in new ways. For this purpose, the Fraunhofer Institute for Photonic Microsystems IPMS developed the MACsec Controller IP-Core, which implements the latest Ethernet security standards. It provides authentication, integrity and encryption of data between different nodes of a Local Area Network (LAN).

MACsec (Media access control security) is a security standard specified by IEEE 802.1AE and is used for authentication and encryption of data packets between network devices.

MACsec protects Ethernet connections at the second layer of the OSI model by using a combination of authentication, encryption, and integrity protection to ensure that only authorized nodes communicate on the network, that traffic remains confidential, and that data integrity is ensured. The latest controller IP core Media Access Control Security (MACsec) implements the Layer 2 security standard specified in IEEE 802.1AE and is used for authentication and encryption of data packets between network devices. It ensures that only authorized nodes on the LAN are allowed to communicate with each other. It provides confidentiality by encrypting the transmitted data and provides cryptographic mechanisms that ensure data integrity.

The MACsec can be used with Fraunhofer IPMS' LLEMAC IP core, as well as any other Ethernet MAC IP core, and in standalone mode. Due to the platform independence an easy system integration is possible, so that the MACsec can be integrated on every FPGA as well as ASIC.

Fraunhofer IPMS has been developing and licensing IP cores to companies from a wide range of industries around the world for 20 years. Increasing digitalization and the resulting growing danger of cyber-attacks make it necessary to continuously adapt and further develop IP cores. This is the only way to ensure data security in the future.



[s.fhg.de/MACsec](https://s.fhg.de/MACsec)



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# Award-winning, edge AI enabled RISC-V processor core

IP modules can be used to quickly adopt complete functional areas in standard products such as SoCs, microcontrollers, FPGAs and ASICs, thus significantly reducing development times and costs. The EMSA5 from Fraunhofer IPMS is the first RISC V processor core available on the market that can be certified according to ISO 26262. In the latest release, the institute has ported Tensorflow lite to the EMSA5 RISC-V. As a result, the EMSA5 RISC-V processor core is now ready for use in edge AI applications, for example for sensor data evaluation, gesture control or vibration analysis.

Especially applications with low latency requirements benefit from edge computing, as there are no delays due to transmission to the cloud. The system is able to work even with unstable Internet connections and is not dependent on processing the data in the cloud - a major advantage for mobile or stand-alone applications.

The Fraunhofer IPMS EMSA5 processor core can be made available for any FPGA platform. Integration into customer-specific ASICs for any foundry technologies is also possible.

Developers using the EMSA5 processor core can leverage open-source RISC-V development environments, test tools and libraries, including the GNU toolchain and the comprehensive Eclipse IDE with OpenOCD debug support. Fraunhofer IPMS also collaborates with commercial third-party compilers and software tools such as IAR Embedded Workbench to enable software development in the context of Functional Safety.

Since 2022, the TRACE32® toolset from Lauterbach, the world leader in hardware-based debugging tools, has also supported the EMSA5-FS.

The fact that these developments are well received by customers is shown by a special milestone from 2022: The EMSA5-FS, as the first fault-tolerant embedded RISC V processor core according to functional safety, was awarded Product of the Year 2022 in the automotive sector by the trade journal Elektronik.

 [s.fhg.de/Risc-V-edge-KI](https://s.fhg.de/Risc-V-edge-KI)



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# Greater safety in electronic vehicle systems

Modern vehicles have a large number of electronic systems that are networked together. Because these systems are vulnerable to cyberattacks, Fraunhofer IPMS has developed a CANsec IP core that makes vehicle systems more secure. The IP core is already being evaluated in a demonstration by partner Renesas Electronics Corporation, a leading semiconductor company that supplies embedded processors along with analog and power products.

Vehicle electronics are becoming more and more extensive due to the growing number of sensors and actuators, driver assistance systems and additional control units. This leads to increasing complexity in the communication control of vehicle networks, which require deterministic, low latency and higher bandwidths.

At the same time, the potential for cyber attacks on vehicle networks is also increasing. These can cause both financial, but more importantly functional damage, which in the worst case can affect the safety of vehicle occupants. For this reason, the automotive industry is using various network technologies to meet the different technical, but also economic requirements of a vehicle.

One of the most commonly used data transmission protocols is the CAN protocol (CAN bus). The latest variant CAN XL allows higher data transmission rates and also a scalable user data length, which makes it possible to include additional safety information.

Based on this, Fraunhofer IPMS has developed the CANsec Controller IP-Core "CAN-SEC". This can be used directly between the host processor and a CAN-XL IP core. It builds up the CANsec structure in the buffers of the CAN-XL core directly before transmission or directly after reception of the frame. Furthermore, it can be used together with the CAN controller IP core of Fraunhofer IPMS as well as with IP cores of other manufacturers. Like all other IP cores of Fraunhofer IPMS, it can be used platform-independently in all FPGAs and foundry technologies.

The IP-Core of Fraunhofer IPMS is already under evaluation at the partner Renesas, a worldwide operating semiconductor company.



[s.fhg.de/CANsec](https://s.fhg.de/CANsec)



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# Competence center Green ICT @ FMD

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Aiming to contribute to the reduction of the digital technologies' footprint via research and development, the Fraunhofer and Leibniz institutes cooperating within the framework of the Research Fab Microelectronics Germany (FMD for its acronym in German) are jointly establishing a cross-location competence center for resource-conscious information and communication technology (Green ICT @ FMD). The project, launched on August 1, 2022, is receiving 34 million euros in funding from the German Federal Ministry of Education and Research under the Green ICT initiative. The latter is in turn part of the German government's Climate Action Programme 2030.

Significant advances in microelectronics and power electronics, including their manufacturing processes, are required in order to reduce resource consumption in the Internet of Things, in AI applications and in data centers. Besides the central data processing infrastructures (cloud), modern networked information and communication technology systems increasingly have the capacity to collect and process information at the network edge. Consequently, there is increased flexibility in optimizing the systems between resource consumption in the cloud and the edge, as well as data transmission between them. The development of electronics for resource-saving information and communication technology (ICT) in conjunction with edge cloud solutions may leverage the German government's climate goals.

Based on the portfolio, structures and expertise created by the FMD, the projected competence center can be targeted in an efficient manner. Under the label Green ICT @ FMD, the application-oriented research in the field of microelectronics is to be progressively expanded over the next 3.5 years in line with demand in terms of resource conservation and a significant reduction of the CO<sub>2</sub> footprint in the further development of ICT applications and infrastructures.

## FMD as One-Stop-Shop for Green ICT system and modeling expertise

To ensure that information and communications technology is designed to be eco-friendly and to make efficient use of resources throughout its entire life cycle, the reciprocal interaction between functionality, reliability, and ecology must be considered, analyzed, and structured. In the process, the entire hardware life cycle throughout the entire system level must also constantly be taken into account.

Within the newly launched Green ICT @ FMD competence center, specific Green ICT issues can now be coordinated and addressed as a whole, while comprehensive cross-technological ICT solutions up to a high level of technical readiness are offered to partners in industry and research under a single roof. Therefore, as established framework for cross-location cooperation between different R&D centers, the Research Fab Microelectronics Germany provides a two-fold opportunity: On the one hand, to perform a comprehensive systemic examination and further development of Green ICT issues with its partner network. On the other hand, to leverage the technological expertise of its Fraunhofer and Leibniz institutes to ensure the necessary technical depth in overall system analysis.

## Solution approaches for sustainable digitalization

The Fraunhofer and Leibniz institutes' portfolio within the Green ICT framework will be broadened with an application-oriented approach that is closely aligned with current commercial and business demands. In Erlangen, Dresden and Berlin, new application-oriented and system-oriented Green ICT hubs will be opened to complement the existing FMD institutes' research projects and as a basis for further research work.

These hubs combine the full expertise of the FMD institutes on key issues regarding future ICT applications. Moreover, the hubs are the first point of contact for project partners from both industry and academia, thus providing a particularly low-threshold range of services. In addition to the central office, the Green ICT hubs are the key interfaces to the thematically bundled technology competencies and testbeds. These Green ICT hubs will be implemented in the thematic focus fields of sensor edge cloud systems, communication infrastructures, as well as materials and processes for the so called Green Production, topics of particularly high relevance for industrial partners in Germany and Europe.

Parallel to bringing together the diverse research projects and the already existing know-how in the field of Green ICT in Germany, developing them further in line with requirements and making them usable for the industry. The overall project Green ICT @ FMD likewise comprises accompanying measures for a sustainable digitalization. The latter address both an early raise of awareness among the upcoming generations of professionals (Academic Young Professionals Program – Digital Green Camp) and at providing ongoing training for experts already working



in this field. Furthermore, the specific requirements of working with start-up companies are addressed in a separate subproject – The Hub for Green-ICT Start-ups – to enable emerging businesses to develop their product ideas using environmentally friendly and resource-efficient methods right from the outset..

### Fraunhofer IPMS in the project

Within the overall project, Fraunhofer IPMS is concentrating on new hardware concepts for the energy optimization of intelligent sensor systems (sensor edge cloud systems). On the other hand, offers for the development of energy-saving communication infrastructures (e.g., by using the particularly efficient and low-radiation optical LiFi data transmission technology) are provided.

Another focus is on the optimized use of resources within the manufacturing processes. In addition to the reduction of resource requirements, processes with alternative material types are to be evaluated and offered. Because the clean room infrastructure represents a major factor with regard to the environmental impact of electronic systems, Fraunhofer IPMS is also optimizing the control of the infrastructure technology (e.g., air circulation technology) and the use of recovery elements (cooling energy recovery or combined heat and power). In this way, the institute would also like to take a step towards green microelectronics at its own site.

 [s.fhg.de/GreenICT](https://s.fhg.de/GreenICT)



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An abstract geometric pattern on the left side of the page, featuring overlapping hexagons, triangles, and lines in shades of gray, white, and orange. Some elements are semi-transparent, creating a layered effect. A prominent red diagonal band runs through the lower half of the pattern.

# Highlights

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## Spin-off Arioso Systems acquired by Bosch Sensortec

Bosch is expanding its expertise in MEMS (micro-electro-mechanical systems) micro speakers and strengthening its market position as leading provider of sensing solutions for consumer electronics with an acquisition. Arioso Systems, based in Dresden, Germany, is to become part of the Bosch Sensortec GmbH. Agreements to this effect were signed by Bosch and Arioso Systems. It has been agreed that any project details such as the purchase price will not be disclosed.

Arioso Systems, which emerged from Fraunhofer IPMS and research activities at BTU Cottbus-Senftenberg in 2019, is one of the world's most innovative providers of MEMS micro speaker technology.

Arioso Systems developed a novel audio transducer technology, where sound is generated through movement of vertically oriented lamellas inside a silicon chip. Unlike conventional membrane, Arioso Systems technology uses the chip volume rather than surface. Therefore, it is possible to build a miniaturized MEMS micro-speaker to generate up to 120 dB SPL (sound pressure level) out of 10mm<sup>2</sup> active area. Thanks to the electrostatic actuator of all-silicon MEMS and thanks to its very low capacitance, the Arioso Systems technology allows to save battery for new sensor application in demanding hearable devices such as TWS as well as in other wearables devices.

The internet of tomorrow will be mobile and audio based, both speaking and listening. Components for smart in-ear devices must be increasingly small, light, efficient and scalable to meet the market's needs. More and more functionalities demand for smaller form factors and expanded battery run time. Market experts are predicting strong growth in micro speaker applications in the years ahead.

The unique and innovative technology concept from Arioso Systems combined with the long-lasting experience from Bosch Sensortec to develop a technology to high-volume consumer electronics market maturity is expected to shape the emerging global MEMS micro speaker market. Manufacturers of TWS (true wireless stereo) earphones and other hearable devices will benefit from a sound generation with significant less power consumption and a smaller form factor, which means an expanded battery run time and easier system integration.

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*Dust-tight, multifunctional and ready-to-use solution for pharmacy laboratories with integrated, validated substance database for identity verification within seconds.*

## Fagron acquires majority share of spin-off HiperScan

**Fagron, a leading global company active in pharmaceutical compounding, announced on April 14th the acquisition of HiperScan, the German market leader for reliable raw material identification in pharmacies. HiperScan is a spin-off of Fraunhofer IPMS and the German market leader for reliable and secure identification of starting materials in pharmacies.**

HiperScan, a Dresden-based technology company, is a specialist in near-infrared (NIR) spectroscopy and emerged in 2006 as a spin-off of the Fraunhofer Institute for Photonic Microsystems IPMS, developing innovative analysis systems for pharmacies and other industries. With its Apo-Ident analysis system, which is specially designed for the identification of raw materials and is used in over 5,500 pharmacies, HiperScan has become the leader in this market segment in Germany.

The innovative scanning grating technology developed at Fraunhofer IPMS forms the basis for the near-infrared (NIR) spectrometer developed by HiperScan. The analytical systems make it possible to significantly reduce investment costs to make NIR-analytics affordable even to small companies.

As early as 2004, Dr. Alexander Wolter, then a scientist at Fraunhofer IPMS and now managing director of HiperScan, approached Fraunhofer with his spin-off idea. The spin-off took place in 2006 and Fraunhofer acquired a stake in the company in 2007. Additional Fraunhofer funding with the goal

of further management expansion followed. The company was financed by the High-Tech Gründerfonds (HTGF) and the Technologiegründerfonds Sachsen (TGFS), among others. In addition to other shares, Fagron now takes over all Fraunhofer shares.

Fagron is a leading global company active in pharmaceutical compounding, which is focused on delivering personalized medicine to hospitals, pharmacies, clinics and patients in 35 countries around the world. Founded in 1990, the company has more than 3,000 employees.

By joining the Fagron family, new markets may open up for HiperScan's technology to further increase safety in order to accelerate the future of personalizing medicine.



[s.fhg.de/HiperScan](https://s.fhg.de/HiperScan)



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# Contactless touch – Semiconductor research meets German oceanographic museum



*Marco Kircher uses his gestures to control a virtual penguin on the demonstrator in the OZEANEUM Stralsund.*

The many innovations resulting from the applied research of the Fraunhofer Gesellschaft have so far mainly benefited industrial companies. In the future, Fraunhofer IPMS intends to make its research increasingly available to cultural institutions and thus to the public community. Accordingly, a pilot project was launched with the German Oceanographic Museum. In the future, visitors to the OZEANEUM Stralsund will be able to feed virtual penguins contactless thanks to a Fraunhofer IPMS development.

How do semiconductor research and Culture and Arts fit together? Normally, large industrial customers are the clients of research institutes. However, it is an important goal for Fraunhofer IPMS to inform the public about current research results and, in the best case, to involve them as well. The opportunity for technology transfer from research to culture is offered by the project "museum4punkt0".

Since the beginning of 2022, the Fraunhofer IPMS in Dresden and the German Oceanographic Museum with its OZEANEUM site in Stralsund have been working together. Within the joint project "museum4punkt0 - Digital Strategies for the Museum of the Future", the OZEANEUM wants to create interaction possibilities with its visitors in order to reinvent itself both digitally and culturally. This is because the pandemic necessitated the permanent disinfection of all operating elements in the museum – whether touchscreens, levers or buttons – which made it clear just how many surfaces are touched in the first place. In its search for contactless interaction possibilities, the OZEANEUM in Stralsund became aware of the ultrasonic components of Fraunhofer IPMS, which are already being used in a wide variety of commercial systems for gesture control.

However, they can only be used more widely in museums if control technologies are developed that function reliably even under difficult lighting conditions or in confined spaces, while at the same time enabling intuitive and hygienic operation. Fraunhofer IPMS therefore developed a demonstrator that allows museum visitors to control a penguin in search of food for its chick with a single hand movement. The ultrasound-based technology developed at the institute implements familiar gestures as control commands without contact to a surface.

 [s.fhg.de/gesturecontrol](https://s.fhg.de/gesturecontrol)



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# A cleanroom tour in 360 degrees

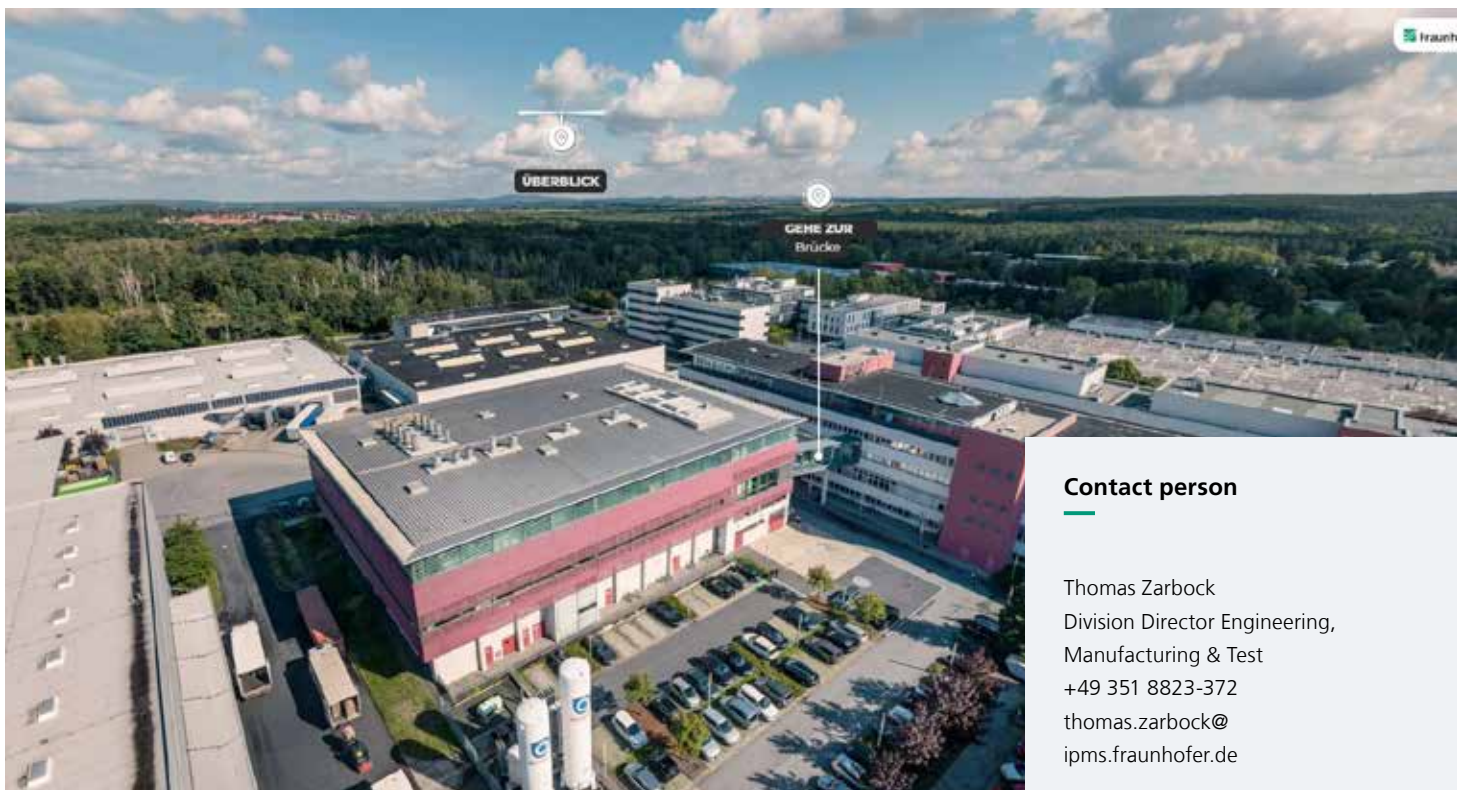
Many people have heard of a cleanroom, but far fewer have visited one. For anyone interested, this can now change with the virtual cleanroom tour of Fraunhofer IPMS. A mouse click gives access to the foyer, the changing room and finally the cleanroom, where equipment and processes can be explored.

Why do you have to change clothes before entering the clean room? How do you go through the airlock? What happens in lithography? And what equipment does the Fraunhofer IPMS have for 200 mm technology?

For all curious people there is a quick and easy answer to these questions: Start the virtual cleanroom tour and find out for yourself! In the different areas you will find a lot of information about the facilities and the technologies of Fraunhofer IPMS.

If you prefer to personally dive in, you might have the opportunity to take part in the physical cleanroom tour on site during a visit to Fraunhofer IPMS in the scope of a project meeting. The physical tour was also redesigned in 2022.

 [s.fhg.de/IPMS-virtual-cleanroom](https://s.fhg.de/IPMS-virtual-cleanroom)



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## Trade fairs and events 2022

### Opening of the Center for Advanced CMOS and Heterointegration Saxony

Juni 7, 2022

At the beginning of June, Dresden celebrated a beacon of semiconductor research with international reach. With the establishment of the "Center for Advanced CMOS & Heterointegration Saxony", Fraunhofer IPMS and Fraunhofer IZM-ASSID are pooling their expertise. In the future, they will offer the complete value chain in 300 mm microelectronics and thus the prerequisite for high-tech research for future technologies. Around 120 guests from industry, science and business attended the opening ceremony, including Saxony's Prime Minister Michael Kretschmer and the President of the Fraunhofer-Gesellschaft, Prof. Reimund Neugebauer.

With the Fraunhofer IZM-ASSID and Fraunhofer IPMS, Center Nanoelectronic Technologies CNT, two unique research facilities in the field of microelectronics are located

in Saxony. Today, they are the only two German research centers for applied microelectronics research based on 300 mm wafer industry standard equipment. With the bundling of competences and the foundation of the center, excellent perspectives arise to attract semiconductor companies, system users as well as material and equipment manufacturers worldwide and to bind them to Silicon Saxony. In addition to outstanding personnel and know-how, equipment with a modern pool of devices and systems is crucial for industrial and research contracts.

The joint center with a clean room of 4000 m<sup>2</sup> size enables a close cooperation and interlocking of the scientific-technical competences of both research institutions. This creates an outstanding R&D technology platform as well as an increase in efficiency and completion of the value chain, which at the same time opens up new fields of research.

 [s.fhg.de/Center-opening](https://s.fhg.de/Center-opening)





### Girls' Day

April 28, 2022

On Girls' Day, four schoolgirls from the fifth grade onwards took the opportunity to immerse themselves in the world of micro- and nanotechnology at Fraunhofer IPMS and take a look behind the scenes at the institute. After a visit to the showroom, they were able to take a closer look at the technologies in various laboratories and the gray room. We are already very much looking forward to more visitors next year!



### LASER World of Photonics

April 26 – 29, 2022

Fraunhofer IPMS was represented at the Fraunhofer joint booth and presented current research results and developments from the fields of sensor technology, spectroscopy and medical technology. The Fraunhofer Center MEOS was also on site. Here you can see the joint project LSC-Onco of Fraunhofer IPMS & Fraunhofer IZI (more on p. 26).

 [s.fhg.de/Laser-2022](https://s.fhg.de/Laser-2022)



### analytica

June 21 – 24, 2022

From analytics and quality control to biotechnology, life sciences, bioanalytics and diagnostics to laboratory technology – "analytica" is the leading trade fair for the fields of laboratory technology, analytics & biotechnology. Fraunhofer IPMS presented the latest technologies for near-infrared spectroscopy (picture above). In addition, developments in the field of ultrasound, electrochemical analytics and biosensor technology were presented.

 [s.fhg.de/analytica-2022](https://s.fhg.de/analytica-2022)



### Lange Nacht der Wissenschaften

July 8, 2022

Experiencing science up close, trying it out for yourself and talking to researchers - all this awaited the public on July 8, 2022, from 5 p.m. to midnight. After two years of pandemic, Fraunhofer IPMS was happy to present its research to a broad audience. There was also something for the little ones: For example, micro and nanotechnologies could be explored in a playful way at the children's quiz.

## Trade fairs and events 2022



### **MEMS & Imaging Sensors Summit**

September 6 – 7, 2022

In Grenoble, Fraunhofer IPMS showed its range of 200 mm clean room technologies in the field of MEMS/MOEMS at the booth. At the same time, there was an exciting presentation on "Fast Characterisation of Hydrogen-Natural Gas Mixtures With Micromachined Ultrasonic Sensors".

 [s.fhg.de/MEMS-2022](https://s.fhg.de/MEMS-2022)



### **all about automation**

September 28 – 29, 2022

In Chemnitz this year, everything revolved around process & quality monitoring for chemical and pharmaceutical analysis using infrared spectrometry as well as a new MEMS-based micropositioning platform based on an innovative ultrasonic actuator.

 [s.fhg.de/aaa-2022](https://s.fhg.de/aaa-2022)



### **Medica**

November 14 – 17, 2022

Medica connects the entire medical industry in one place. Fraunhofer IPMS presented the latest ultrasound developments in the field of medical technology. developments in the field of medical technology, for example a spirometer for breath analysis and ultrasound imaging for medical diagnostics. In addition, the novel laser scanning microscope for rapid tumor detection was presented, which was developed in the Fraunhofer Center MEOS through a collaboration between Fraunhofer IPMS and Fraunhofer IZI (read more on page 26).



### **HTW Workshops**

July 8, 2022 & November 11, 2022

After the successful start in 2021, HTW Dresden and Fraunhofer IPMS met in 2022 for two in-depth workshops. The focus was on intensified cooperation in the context of occasion- and project-related joint research activities, teaching and the supervision of student (final) theses. In addition, there was lively discussion of cooperation on promising issues in order to jointly build up relevant competencies (preliminary research) and then jointly address the needs of industry.



## Electronica

November 15 – 18, 2022

There was a lot to see at the Fraunhofer IPMS booth in Munich: In addition to MEMS scanner technologies, one focus was on optical communication via LiFi. IP core modules such as CAN and LIN, TSN networks and the institute's latest developments around the RISC-V processor rounded off the portfolio.

 [s.fhg.de/electronica-2022](https://s.fhg.de/electronica-2022)



## Semicon Europa

November 15 – 18, 2022

Fraunhofer IPMS presented everything around the 200 and 300 mm technologies at Semicon in Munich, the world's leading trade fair for semiconductors, sensor technology, MEMS and MOEMS. At the joint booth of Silicon Saxony there was a lively exchange with visitors about the research and development services of Fraunhofer IPMS.

 [s.fhg.de/Semicon-EU-2022](https://s.fhg.de/Semicon-EU-2022)



## Photonix

December 07 – 09, 2022

After 2 years of absence due to the pandemic, Fraunhofer IPMS was finally able to present itself again in Tokyo. Photonix as an international laser and photonics fair consists of three different exhibitions, which focus on laser processing, optics and optical metrology/analytics. Here, Fraunhofer IPMS showed latest developments for high-precision guiding, controlling and shaping of light by means of spatial light modulators (SLM).

 [s.fhg.de/Photonix-2022](https://s.fhg.de/Photonix-2022)

Find all of our trade fairs and events on our website:  
**[s.fhg.de/IPMS-Events](https://s.fhg.de/IPMS-Events)**



# Guests

In 2022, Fraunhofer IPMS was once again pleased to welcome a large number of visitors from science, industry and politics. In a joint exchange, the institute informed about current developments and future-oriented research topics.



On January 14, 2022, the President of the Fraunhofer-Gesellschaft, Prof. Reimund Neugebauer, visited Fraunhofer IPMS. He informed himself about the new location of the Center Nanoelectronic Technologies and the planned further research and development work in the field of neuromorphic and quantum computing. In April, Prof. Neugebauer also visited the Fraunhofer Center MEOS and learned about the LSC Onco-Microscope (see p. 26).



"Ways to a climate-friendly transformation of the Brandenburg economy" was the motto of the Brandenburg Energy Day on May 12, 2022. Dr. Christine Ruffert presented current developments of Fraunhofer IPMS in the field of micromechanical ultrasonic transducers for hydrogen sensor technology to the Brandenburg Minister for Economic Affairs, Labor and Energy, Prof. Jörg Steinbach.



How Saxony can be further developed innovatively is the core question of the Saxony Innovation Advisory Council. At the 5<sup>th</sup> meeting at the end of April, the focus was on next-generation microelectronics and the European Chips Act. The day before, some members met for a practical excursion at the Center Nanoelectronic Technologies.



Representatives of the State Chancellery of Brandenburg visited the iCampus at BTU Cottbus-Senftenberg on August 8, 2022 in the course of the summer tour of the Digital Representative State Secretary Dr. Grimm. As a partner of the iCampus, Fraunhofer IPMS showed its test and qualification laboratory for high-frequency sensor technology.



What Saxony is to Germany, Flanders is to Belgium. It is *the* region for microelectronics. To enable the two regions to get to know each other better and exchange ideas, a Flanders delegation visited Dresden, Chemnitz and Leipzig in September 2022 and also stopped off at Fraunhofer IPMS. Here they were given insights into the institute's research topics as well as a showroom tour.

In late September, 19 students from the "Invent a Chip" classes of 2021 and 2022 visited Fraunhofer IPMS.

## Invent a chip

is an annual competition launched in February by VDE and sponsored by BMBF to get young people interested in chip design. At Fraunhofer IPMS, the students experienced technologies up close in the showroom as well as during a tour around the 200-mm clean room.



On April 6, Dr. Peter Dröll, Acting Director Research and Innovation EU, visited Fraunhofer IPMS with a delegation of his Directorate General and the Saxon State Ministry for Science, Culture and Tourism. Dr. Dröll informed himself about the semiconductor location Dresden and microelectronics research at the Center Nanoelectronic Technologies.



On November 22, the partners of the EU-ECSEL project MATQu ("Materials for Quantum Computing") met at Fraunhofer IPMS. This was followed by a clean room tour at the Center Nanoelectronic Technologies of Fraunhofer IPMS with 10 partners from imec, IQM, BEIS, smartchem-SMAC, DelftCircuits and Fraunhofer IAF.

# Awards



## Applied Photonics Award

Dr. René Kirrbach

Dr. René Kirrbach won the Applied Photonics Award 2022 of Fraunhofer IOF with his dissertation "Investigations on linear optical-wireless front-ends and application-specific free-form lenses for optical-wireless communication".



## Best Paper Award

Hanying Wen

At the 45<sup>th</sup> International Spring Seminar on Electronics Technology, Hanying Wen won the Best Paper Award for Young Scientist. The award was given for her publication entitled "Improved Nearinfrared Photoresponse of Si-based Schottky Diode by Nanophotonic Structures".



## Product of the year 2022 in the automotive sector

Monika Beck for the DCC division

There was great cause for celebration on April 26, 2022, at the award ceremony for the Products of the Year of the trade journal "Elektronik".

The RISC-V core EMSA5-FS developed by Fraunhofer IPMS is the first RISC-V processor core that can be certified according to ISO 26262. This convinced the readers, who voted it 1<sup>st</sup> place for Product of the Year 2022 in the "Automotive" category. Monika Beck attended the award ceremony in Munich.

The magazine "Elektronik" belongs to WEKA Fachmedien GmbH, which is one of the largest publishers in the ICT, electronics and automation sector with a total circulation of around 5.5 million.





**Fraunhofer Communication Award**  
Dr. Anne-Julie Maurer

Dr. Anne-Julie Maurer achieved 3<sup>rd</sup> place at the Fraunhofer Communication Award with the virtual showroom of the Micro/Nano Performance Center (see following page). The prize is awarded annually. The 1<sup>st</sup> and 2<sup>nd</sup> place are awarded by an external jury; the 3<sup>rd</sup> place is voted on by the communication staff of all Fraunhofer institutes.



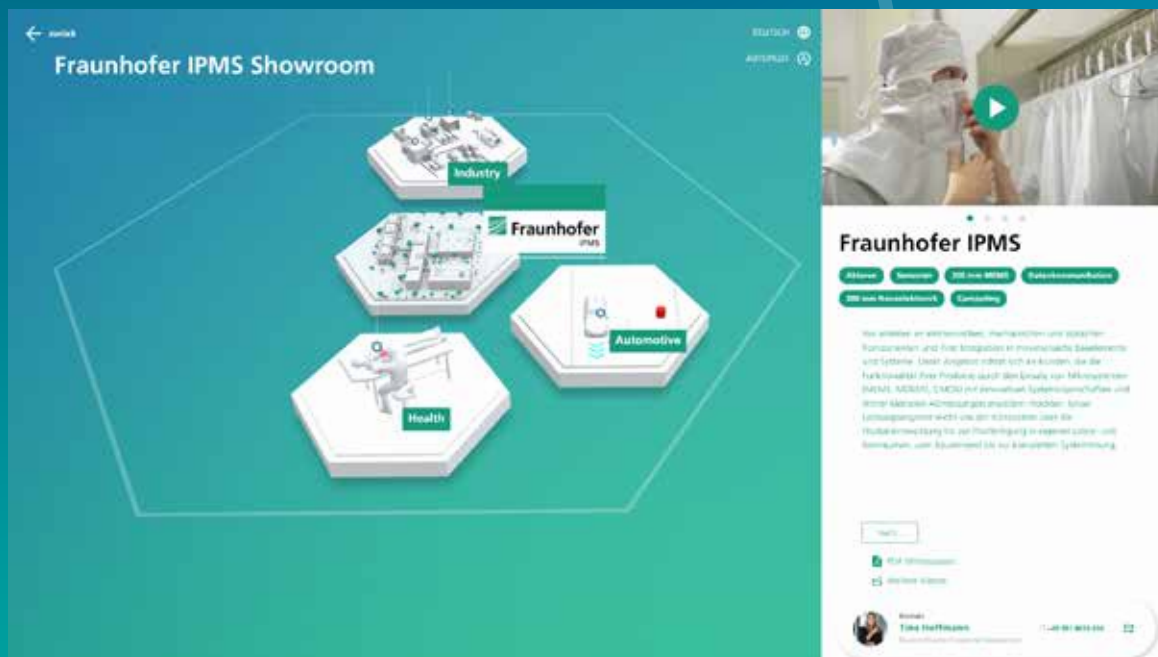
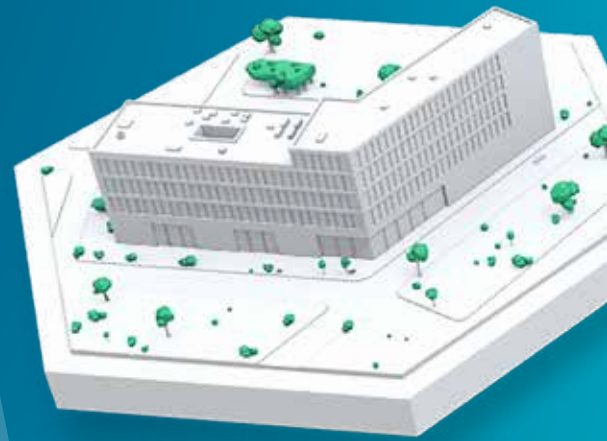
**Excellent Paper Award**  
Sukhrob Abdulazhanov et. al

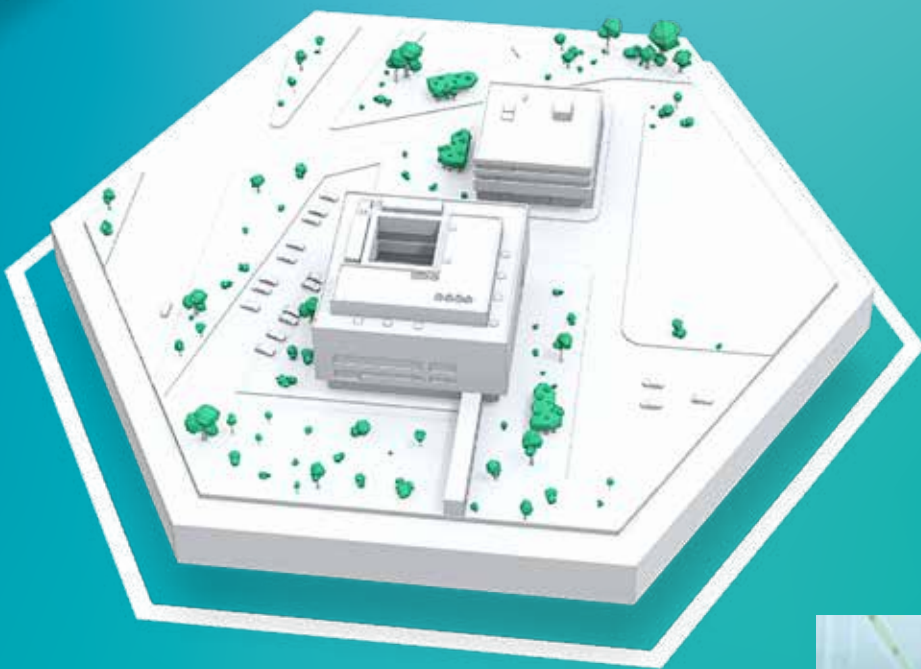
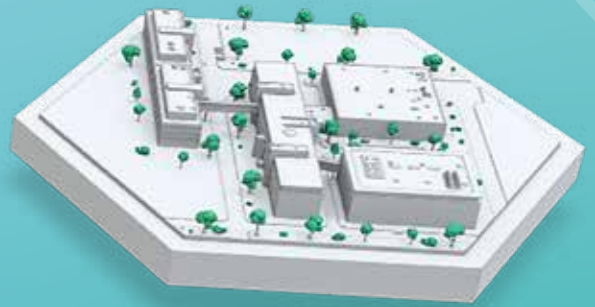
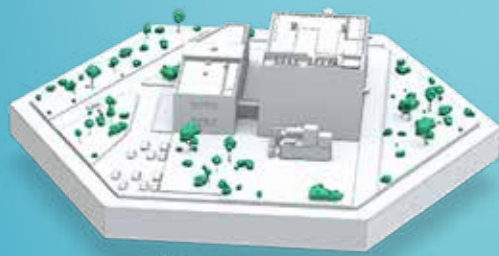
An Excellent Paper Award was given for the paper "Investigation of BEoL Integrated Ferroelectric Thin-Film HfO<sub>2</sub> for mm Wave Varactor Applications" at the IEEE International Symposium on Radio-Frequency Integration Technology 2022 in Busan, Korea.

# Virtual Showroom

In the virtual showroom you can experience our technologies interactively and in 3D. Take a look around and discover our demonstrators and application videos! Have fun!

 [www.showroom.leistungszentrum-mikronano.de](http://www.showroom.leistungszentrum-mikronano.de)





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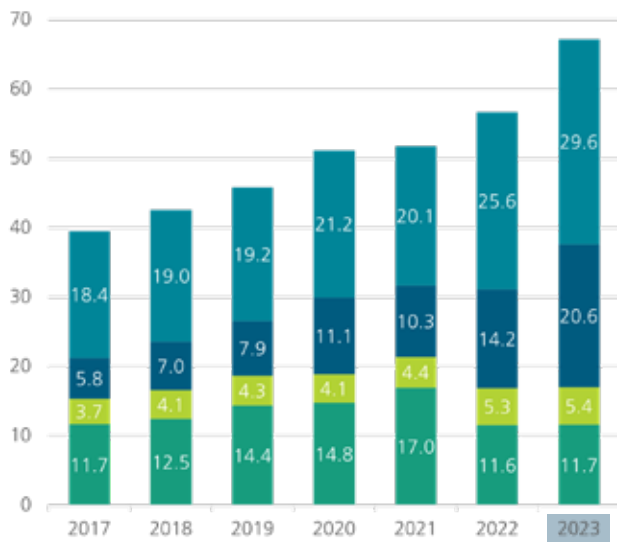


# Fraunhofer IPMS at a glance

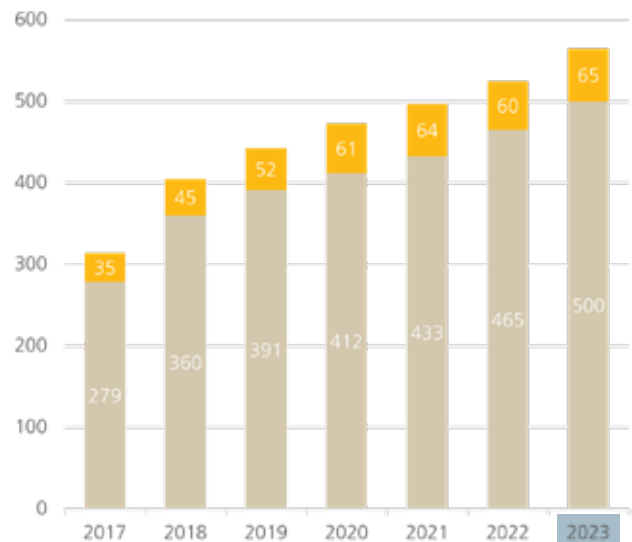
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# Fraunhofer IPMS in figures

## Budget (in million Euros)



## Employees



- Industrial contracts
- Publicly funded projects (national)
- Publicly funded projects (EU/other)
- Fraunhofer basic funding

- Employees including temporary staff & trainees
- Students

## At a glance

	2017	2018	2019	2020	2021	2022	2023
Industry in %	48.6	47.1	43.0	43.5	40.8	48.1	44.0
Public funds (national) in %	15.3	17.3	17.6	22.7	20.9	26.7	24.8
Public funds (EU/other) in %	6.9	4.9	3.0	2.0	3.1	5.0	8.0
Total revenue in %	73.5	74.7	70.2	74.6	70.7	84.8	82.7

■ Plan



# Advisory Board 2022

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The following persons were  
members of our Advisory Board in 2022:

## Industry Representatives

**PD Dr. Ingeborg Hochmair-Desoyer**  
MED-EL Medical Electronics, CEO

**Dr. Jens Kosch**  
X-FAB Semiconductor Foundries GmbH, CTO

**Dr. Axel Preuße**  
GlobalFoundries Dresden, Module One LLC & Co. KG, GF Fellow

**Björn Sass**  
GlobalFoundries Dresden, Module One LLC & Co. KG,  
Principal Member Of Technical Staff

**Dr. Ronald Schnabel**  
VDE/VDI Gesellschaft Mikroelektronik, Mikrosystem- und  
Feinwerktechnik (GMM), Managing Director

**Prof. Dr. Frank Schönefeld**  
T-Systems Multimedia Solutions GmbH, Member of the Board

**Dr. Johannes Schumm**  
Sensirion AG, Vice President Research & Development

**Rutger Wijburg, PhD**  
Infineon Technologies Dresden GmbH & Co. KG,  
Vice President & Managing Director

## Scientific Representatives

**Prof. Dr.-Ing. Karlheinz Bock**  
TU Dresden, Faculty of Electrical and Computer Engineering

**Prof. Dr.-Ing. Jürgen Czarske**  
TU Dresden, Chair of Measurement and Sensor System Technique,  
Director of Institute of Circuits and Systems

**Jörg Doblaski**  
X-FAB Global Services GmbH, CTO

**Prof. Dr. Gesine Grande**  
Brandenburg University of Technology (BTU)  
Cottbus-Senftenberg, President

**Prof. Dr. Wilfried Mokwa**  
RWTH Aachen, Institute of Materials in Electrical Engineering

**Prof. Dr. Wolfgang Osten**  
University of Stuttgart

**Prof. Dr. Katja Schenke-Layland**  
University of Tübingen, Director Natural and Medical Sciences  
Institute

**Prof. Dr. Ulrike Wallrabe**  
University of Freiburg, Department for Microsystems Engineering

## Public Sector Representatives

**Dr. Lutz Bryja**  
State Ministry for Higher Education, Research and the Arts,  
Head of Division

**Dirk Hilbert**  
State Capital of Dresden, Mayor

**MDgin Barbara Meyer**  
Saxon State Ministry for Economic Affairs, Labour and Transport,  
Head of Division

**Dr. Inge Schlotzhauer**  
Brandenburg Ministry of Sciences, Research and Cultural Affairs,  
Head of Division

**Dr. Eike-Christian Spitzner**  
VDI/VDE Innovation + Technik GmbH, Head of Department  
Electronics and Microsystems

**Dr. Tina Züchner**  
German Federal Ministry of Education and Research, Advisor




# Networks and cooperations

## High Performance Center Micro/Nano – bundled competence in research and development for microelectronics in Saxony

In the past two years, the importance of microelectronics for industry in Germany and Europe has been impressively demonstrated. In order to ensure secure supply of micro-electronic chips and to be prepared for new challenges, e.g. in the area of security of critical infrastructure, it is imperative to establish technological sovereignty in research and development in addition to the expansion of production capacities in Europe. Saxony, the largest microelectronics location in Europe with a focus on Dresden and Chemnitz, is particularly important in this regard.

This is precisely where the High Performance Center "Functional Integration for Micro/Nanoelectronics" (LZ Micro/Nano) comes into play as a local exchange and transfer platform with clearly defined focal points in terms of content. The LZ Micro/Nano bundles the competences of the four microelectronics institutes of the Fraunhofer-Gesellschaft IPMS, ENAS, IIS/EAS and IZM-ASSID. These are complemented by the relevant expertise of universities and colleges in Dresden and Chemnitz. Thus, the performance center creates a broad offer for technologies of microelectronics and micromechanics. This is aimed both at the major players in the microelectronics industry and specifically at small and medium-sized enterprises (SMEs). By providing flexible technology platforms, these companies are offered a low-threshold opportunity to benefit from high technology without having to develop the investment-intensive platforms themselves.

By resolution of the Executive Board of the Fraunhofer-Gesellschaft, the LZ Micro/Nano will be funded with € 1 million annually from Fraunhofer funds in the years 2022 – 2024 to strengthen its transfer activities. It will be evaluated on an ongoing basis with the prospect of follow-up funding for continuation for a next three-year period. In 2022, a strategy process defined the orientation and focus of the LZ Micro/Nano for the years 2023 and 2024. The focal points are the further expansion of digital formats such as the virtual showroom, the multimedia presentation of the LZ Micro/Nano at conferences, the further development of the "universal sensor platform" and the establishment of demonstrators, evaluation kits and application laboratories. Furthermore, a joint continuing education program and, with a focus on 2024, a special cooperation program with SMEs will be developed.

 [www.showroom.leistungszentrum-mikronano.de](http://www.showroom.leistungszentrum-mikronano.de)



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## Innovation Campus Electronics and Microsensors Cottbus – iCampus

The Innovation Campus Electronics and Microsensors Cottbus – iCampus – is a research cooperation for the development of innovative sensors on the basis of which SMEs from the region can be introduced to high-tech topics such as microsensors, AI-supported algorithms, and 5G data transmission. As a member of the iCampus, Fraunhofer IPMS with its Cottbus branch is researching technologies in the areas of environmental sensor technology, Industry 4.0, and Smart Health.

### Schottky photodiodes for automated processes

Low-cost sensors with an extended near-infrared (NIR) spectral range represent an important building block in the future automation of processes. Superimposing images can deepen information content and improve decision making. With the rapid advances in silicon (Si) photonics, there is a lot of interest in Si-based Schottky photodiodes as they offer significant advantages in terms of cost, speed and compatibility with CMOS technology.

### Near Infrared (NIR) Sensors for Industry 4.0

Automated and autonomous systems rely on a wide range of sensors that constitute their sensory organs. More powerful sensors can provide additional information that contributes to the safe use of the systems. The aim of the developments at Fraunhofer IPMS is the validation and optimization of NIR sensors and a further development towards a camera. A holistic concept that extends to the integration of sensor components in pixels in a sensor matrix is pursued.

## MEMS RF Varactor for 5G Mobile Communications

Capacitive MEMS tuning elements – varactors – are used in many areas (e.g., in measurement technology, telecommunications, Industry 4.0, Internet-of-Things (IoT), and RF sensing). The nanoscopic electronic drive (NED) actuator technology implemented at Fraunhofer IPMS makes it possible to map particularly large frequency ranges – as required for 5G mobile communications. In the project, the technology is being further developed for use at frequencies > 15 GHz. The goal is to produce a universally applicable micromachined varactor that can be easily integrated thanks to its broad parameters and CMOS compatibility.

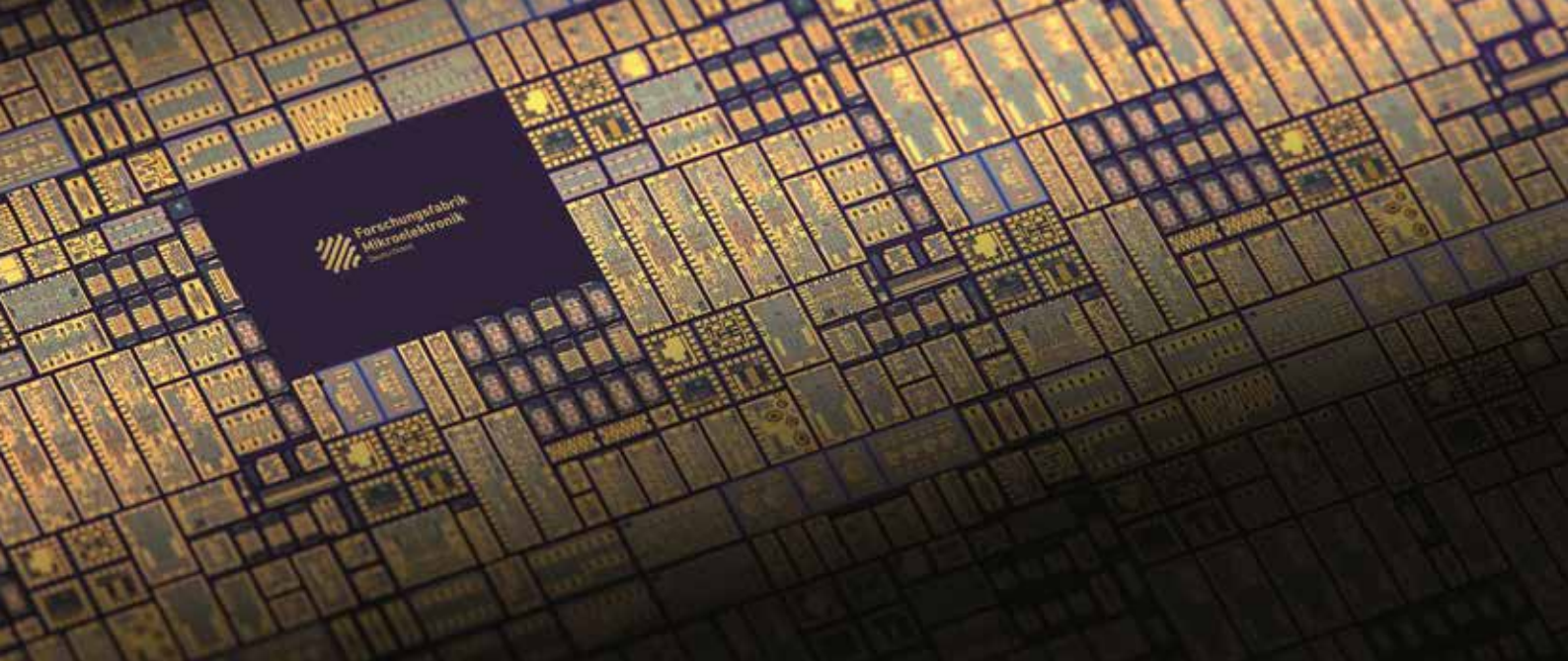
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## Research Fab Microelectronics Germany

Fraunhofer IPMS has been part of the Research Fab Microelectronics Germany (FMD) since 2017. As a cooperation of the Fraunhofer Group for Microelectronics and the Leibniz Institutes FBH and IHP, the FMD is the central contact for all questions concerning micro- and nanoelectronics in Germany and Europe. As a pioneer for cross-location and cross-technology cooperation, the FMD is actively addressing the current and future challenges of electronics research, providing key impulses for the development of elementary innovations for the world of tomorrow.

In 2022, the FMD has further grown. Currently, more than 4,500 employees contribute their expertise to the research and development of micro and nanosystems. The FMD is thus one of the largest R&D associations of its kind in the world.

### Major projects launched for sustainable electronics and new computing technologies

Building on the competences, structures and services created within the framework of the FMD, two new major projects – the "Green ICT @ FMD" and the "FMD-QNC" – were launched in 2022.

As part of the Green ICT @ FMD project, the Fraunhofer and Leibniz Institutes cooperating in the Research Fab Microelectronics Germany, together with the Fraunhofer ISI, are setting up a cross-location competence center for resource-conscious information and communication technology (ICT). Within this framework, Green ICT-specific issues can be addressed in a bundled manner and cross-technology ICT solutions up to a high level of technical maturity can be provided to partners in industry and research – all from a single source. This project, launched in August 2022, is funded by the German Federal Ministry of Education and Research (BMBF) under the Green ICT Initiative, which in turn is part of the Federal Government's Climate Action Program 2030.

Furthermore, to bring together and expand the existing microelectronic research and the developments related to quantum and neuromorphic computing carried out in Germany, the FMD together with four further Fraunhofer institutes, the Research Center Jülich and AMO GmbH launched a joint project in December 2022: The Research Fab Microelectronics Germany - Module Quantum and Neuromorphic Computing (FMD-QNC). FMD-QNC is a nationwide collaboration aimed at supporting researchers and companies in developing customized microelectronics and scalable manufacturing and integration processes for new computing technologies. The equipment and structural setup required for this is being funded by the BMBF.

### Increasing the innovative strength of microelectronics in Europe

To ensure that Germany and Europe remain key players in the global value chain, the FMD undertook crucial preparatory work for the technological foundation of the "European Chips Act" in 2022.

For instance, the FMD-QNC is being complemented at the European level by the PREVAIL project (Partnership for Realization and Validation of AI hardware Leadership). This project brings together four European research organizations, CEA-Leti, Fraunhofer, imec and VTT, to create a networked 300-mm technology platform for manufacturing chip prototypes used in advanced artificial intelligence and neuromorphic computing applications. The national part of PREVAIL constituted by four Fraunhofer institutes EMFT, IIS, IPMS and IZM, which as part of FMD are broadening their 300-mm fabrication, design and test facilities to complement the 300-mm technology of their European research partners.

 [www.forschungsfabrik-mikroelektronik.de](http://www.forschungsfabrik-mikroelektronik.de)

 [fmd-insight.de/showroom](http://fmd-insight.de/showroom)

## Towards top-level training quality: The FMD starts setting up a Microelectronics Academy

By establishing the Microelectronics Academy, the Research Fab Microelectronics Germany (FMD for its acronym in German) is laying the foundation for modern training programs in the field of micro and nanoelectronics aimed at counteracting the shortage of skilled workers in Germany. In cooperation with educational institutions and industry partners, the academy intends to work out a set of practice-based modules during a one-year design phase and subsequently test them over the next three years. Funding for this project is provided by the Federal Ministry of Education and Research as part of the Federal Government's Framework Programme for Microelectronics.

The Microelectronics Academy aims to develop and test new contents and formats for training specialists in the fields of micro and nanoelectronics. Whether as extension to university education or as further qualification for employees: The underlying concept of the Academy entails training and development for professionals in the field of microelectronics as well as for the upcoming generation of experts. To enable modern and, especially, hands-on learning and training opportunities, the Microelectronics Academy strives for a close cooperation with educational institutions, along with ongoing projects for the promotion of young talent as well as with industry.

In three thematic pillars, the high degree of specialization required in the field of microelectronics should be enabled at an excellent scientific level, while the skilled workforce demand should be optimally met. In terms of the thematic scope, the Academy is structured as follows: The first two pillars, Resource-conscious ICT and Practice-oriented semiconductor engineering and technology (both derived from the Green ICT @ FMD and FMD-QNC projects), are rounded off by a third pillar, design of microelectronic circuits and systems. Over the long term, the aim is to actively shape and drive forward areas such as climate protection, sustainability, novel computing technologies, as well as trustworthiness in semiconductors and chips.

The overarching goal is to improve the quality of the training of skilled workers in the field of microelectronics. Therefore, alongside close collaboration with industry and research partners, cooperation with educational institutions and established training and continuing education initiatives will be pursued. In this way, numerous synergies will arise, as well as the opportunity for a comprehensive transfer of theory and practice. At the same time, the cooperation of the stakeholders involved in the academy should be broadened throughout Germany and, in the long term, to Europe, leading to a close-meshed network of knowledge transfer.



*The Research Fab Microelectronics Germany (FMD) is laying the basis for modern education and training programs in the field of micro and nanoelectronics with the establishment of the Microelectronics Academy.*

By providing certification and qualification courses, the Microelectronics Academy intends to enable accessibility to the subject of microelectronics for interested parties with varying degrees of prior education. Furthermore, the promotion of young talents through an extensive and practical learning and training program will also constitute a central focus of the academy. Finally, the academy will provide access to hands-on design environments as well as state-of-the-art manufacturing infrastructures and test beds.

 [s.fhg.de/Mikroelektronik-Akademie](https://s.fhg.de/Mikroelektronik-Akademie)



## Lausitz Science Network



*V.l.n.r.: Michael Hübner (BTU), Thomas Büsse (IAP), Günther Tränkle (FBH), Karin-Irene Eiermann (FBH), Mario Ragwitz (EIG), Lars Enghardt (DLR), Harald Schenk (Fraunhofer IPMS), Andreas Peter (DLR), Gesine Grande (BTU), Uwe Riedel (DLR), Gerhard Kahmen (IHP), Bernd Wenzel (KEI), Harry Lehmann (PtX), Andreas Otto (BBSR)*

On December 14, 2022, the Lusatia Science Network was founded in Cottbus. Within the framework of this association initiated by the Brandenburg University of Technology Cottbus-Senftenberg, the research institutions involved in Cottbus and Senftenberg cooperate with the aim of jointly strengthening the research location. Fraunhofer IPMS is one of the founding members with its Integrated Silicon Systems ISS branch in Cottbus.

In the future, the participants want to hold joint conferences, promote young scientists, initiate collaborative scientific projects and invest in attracting specialists and marketing the science location.

Prof. Dr. Gesine Grande, President of the Brandenburg University of Technology Cottbus-Senftenberg and elected Chair of the Board of the Lusatia Science Network: "With the Lusatia Science Network, we are taking the next important step in making Cottbus and Senftenberg a visible and strong science location. We are learning from other science regions that strong networks lead to cutting-edge research, international attractiveness and regional economic success. For the Lusatia Science Park, which we are planning together with the city, the state and WISTA Management GmbH, this association is the scientific backbone."

Brandenburg's Science and Research Minister Dr. Manja Schüle: "Lusatia is a successful energy and industrial region that is constantly reinventing itself. For example, with the Lusatia Science Park, in which science and industry join forces to form an innovation and technology booster. The driving force: the Lusatia Science Network, a dynamic network with the BTU, non-university research institutions and strong partners from business and society. I am convinced that this is the way to successfully develop the new science and technology park into a competence center with charisma: interdisciplinary, international, innovative. This is what successful structural change 'Made by future' looks like."

The most important project in the Lusatia Science Network is the planned Lusatia Science Park, which is to cover 420 hectares when completed. It will be built on the site of the former technology and industrial park, the so-called TIP site, on the northwestern outskirts of Cottbus in the direct vicinity of the main campus of the BTU. The BTU Cottbus-Senftenberg aims to sustainably bundle top-level research and transfer at an international level and thus develop an interdisciplinary innovation network as well as an excellent science and technology location.

According to estimates, the Lusatia Science Park holds a potential of at least 10,000 jobs - from students to specialists, from education to management. It offers space for 200 small and medium-sized companies, which will find attractive working conditions, a high-quality research environment and the best framework conditions for science and research, innovation and transfer here in the future. This will move excellently educated people to the region, but also help retain skilled workers in Lusatia.

 [www.b-tu.de/lausitz-science-park](http://www.b-tu.de/lausitz-science-park)



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*Project meeting of the HybridEcho project in May 2022*



### **Else Kröner Fresenius Center for Digital Health: Promoting Research. Helping People.**

The Else Kröner Fresenius Center for Digital Health (EKFZ) is a joint cross-faculty initiative of the TU Dresden, the University Hospital Carl Gustav Carus Dresden, and five Fraunhofer Institutes – including Fraunhofer IPMS – as well as the Leibniz Institute for Polymer Research and the Helmholtz Center Dresden-Rossendorf. The goal is to bring innovative, digital medical technologies from the laboratory to patients. Fraunhofer IPMS is conducting research in the HybridEcho project to drastically improve medical imaging thanks to the use of highly sensitive MEMS-based ultrasound transducers.

As a radiation-free, mobile technology, ultrasound is widely used and has long been established in medicine. Ultrasonic transducers in the medical field are currently mostly based on piezoceramics and composites. These emit sound waves, and the returned echo is recorded to form an image. However, the reception quality of piezo-based ultrasonic transducers is so low that the spatial resolution is limited to 1–2 mm at a depth of 10 cm. Modern MEMS-based ultrasonic transducers offer a solution here: They allow the use of higher frequency bandwidths, thereby enabling higher image resolution and offering a more compact design.

In the HybridEcho project, Fraunhofer IPMS, together with the University Hospital Carl Gustav Carus Dresden, TU Dresden, Fraunhofer IKTS, and Contronix GmbH, combines these advantages with state-of-the-art evaluation algorithms. The “massive MIMO” (multiple input, multiple output) approach known from 5G mobile communications technology is used for this purpose. This bundles the transmission power and greatly increases transmission efficiency and data throughput. This results in a considerably increased image quality of the ultrasound.

The overall system consists of a multi-channel hybrid transmitter and receiver unit made of piezoelectric and MEMS-based ultrasonic transducers. Fraunhofer IPMS contributes its capacitive micromachined ultrasonic transducers (CMUTs) and successfully integrates them with the piezo sensor technology on a common substrate. In 2021, a test bed was set up by TU Dresden in order to test the imaging algorithms on this system.

2022 saw the expansion of existing sensor technology to include multi-channel systems, higher bandwidth and greater receiver sensitivity with packaging suitable for imaging. The improved technology promises early diagnosis of diseases (e.g. cancers) through higher resolution imaging at greater penetration depth, reduces costs and improves recovery prospects through the therapy of diseases in their early stages.

In addition, Fraunhofer IPMS is very interested in intensifying its cooperation with the EKFZ in 2022. Entirely in the spirit of Else Kröner-Fresenius: Promoting research. Helping people.



[s.fhg.de/Hybridecho](https://s.fhg.de/Hybridecho)



[s.fhg.de/Hybridecho-Video](https://s.fhg.de/Hybridecho-Video)



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## Patents

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Whether it's MEMS-based bending actuators, IP Cores or Spatial Light Modulators (SLM) with individually movable tilting mirrors, which are unique on an international level, Fraunhofer IPMS stands for innovations in the field of optical sensors and actuators, ASICs, microsystems and nanoelectronics.

Fraunhofer IPMS currently has 263 issued patents. 236 Patent applications are still pending.

 [s.fhg.de/IPMS-Patents](https://s.fhg.de/IPMS-Patents)

## Publications

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Fraunhofer IPMS conducts top-quality research. This is substantiated by the numerous publications that were published by scientists from Fraunhofer IPMS in 2022.

A highlight in 2022 was a publication on innovative in-ear speakers in the renowned Nature Journal Microsystems & Engineering. Here, Fraunhofer IPMS presented a novel push-pull principle for loudspeaker concept, which in tests confirmed high volume and excellent sound quality coupled with excellent energy efficiency. The paper "The push-pull principle: an electrostatic actuator concept for low distortion acoustic transducers" can be read free of charge through Open Access:

 [www.nature.com/articles/s41378-022-00458-z](https://www.nature.com/articles/s41378-022-00458-z)

You can find all of our publications at:

 [s.fhg.de/IPMS-Paper](https://s.fhg.de/IPMS-Paper)



# Scientific collaboration

## Brandenburg University of Technology Cottbus-Senftenberg (BTU)

Through the professorship for micro- and nanosystems of Prof. Dr. Harald Schenk on the one hand and the institute's branch "Integrated Silicon Systems" on the other hand, Fraunhofer IPMS is particularly closely linked to the Brandenburg University of Technology (BTU) Cottbus-Senftenberg. The cooperation ranges from the joint use of laboratories and premises to the provision of attractive study focuses in graduate education and further education in the field of photonic microsystems to joint research and development work. You can also virtually visit our laboratories at BTU (in German):

 [s.fhg.de/ISS-Labore](https://s.fhg.de/ISS-Labore)

In addition, the research activities of BTU Cottbus-Senftenberg, Fraunhofer IPMS and other non-university research institutions are combined in the "iCampus Cottbus" project (p. 69).

Like Fraunhofer IPMS, BTU Cottbus also focuses on transfer. This is how the "Science Gallery" came into being, which offers a vivid and entertaining presentation of technological innovations in a showroom. The Science Gallery is open to the public and also presents two exhibits of Fraunhofer IPMS, an ultrasonic sensor and a micropositioning system (in German).

 [innohub13.de/showrooms/sciencegallery](https://innohub13.de/showrooms/sciencegallery)

## Dresden University of Technology (TU Dresden)

Since its foundation, Fraunhofer IPMS has maintained a close partnership with TU Dresden. This applies in particular to the Faculty of Electrical Engineering and Information Technology, whose deans traditionally advise Fraunhofer IPMS in the Advisory Board. Through the professorship for Optoelectronic Devices and Systems of Prof. Dr. Hubert Lakner, there is an intensive exchange with students. The joint research work is reflected in regular joint public project proposals, publications, trade fair participations and patent applications.

Cooperation in the field of developing innovative components and manufacturing technologies was further intensified with the High Performance Center Micro / Nano (p. 68).



*Science Gallery der BTU Cottbus*

TU Dresden and Fraunhofer IPMS also present themselves jointly to the outside world. Under the brand "DRESDENconcept", TU Dresden has joined forces with partners from science and culture, among them Fraunhofer IPMS, to make the excellence of Dresden's research visible and to coordinate its science strategy.

## HTW Dresden - University for Applied Sciences

To strengthen cooperation, joint workshops have been held since 2021 to exchange research topics and project ideas (see p. 56). From sensor technology, human-machine interaction, edge AI to modern manufacturing processes, there is a range of topics that can be jointly shaped.

In the future, the Fraunhofer IPMS will also offer guest lectures and enable students of the HTW Dresden to gain practical insights at the institute through excursions.

Find all of our networks at:  
[s.fhg.de/Collaborations](https://s.fhg.de/Collaborations)



# Theses

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## Bachelor Theses

Meisel, Tenia  
**Optimierung der Richtcharakteristik von MEMS-Ultraschallwandlern durch passive Strukturen**  
BTU Cottbus-Senftenberg, Supervisor: Prof. Dr. Harald Schenk

Le, Tung Son  
**Datenerfassung und KI-basierte Datenauswertung von Ultraschallsensoren zur vorausschauenden Wartung**  
HSB Hochschule Bremen, Supervisor: Dr. Marcel Jongmanns

## Diploma Theses

Song, Mingying  
TU Dresden, Supervisor: Prof. Dr. Hubert Lakner

## Master Theses

Godkhindi, Sampada Janardhan  
**Layout dependency of dielectric deposition for integration in semiconductor fabrication**  
TU Dresden, Supervisor: Prof. Dr. Hubert Lakner

Günther, Marcel  
Hochschule Anhalt, Supervisor: Konrad Seidel

He, Dongzhe  
**Lifetime Measurement for NED-Micropositioning System**  
TU Braunschweig, Supervisor: Dr. Christine Ruffert

Karakus, Firat  
**Analysis of Novel Diffusion Barriers for Interconnects**  
TU Chemnitz, Supervisors: Prof. Dr. Stefan E. Schulz, Dr. Maik Wagner-Reetz

Kini, Ganesh Rathnakar  
**Design of a multi-purpose CMOS oscillator for next generation automotive radar and aviation telecommunication millimetre wave solutions**  
TU Dresden, Supervisor: Prof. Dr. Hubert Lakner

Mangadahalli Siddaramu, Shanmukha  
**Investigation of temperature-dependent behavior of STT-MRAM devices**  
Ernst-Abbe-Hochschule Jena, Supervisors: Dr. Jyotirmoy Chatterjee, Dr. Maik Wagner-Reetz

Pourjafar, Amir  
**The effect of co-doping on the electrical performance, oxygen vacancy distribution, and crystallographic properties of ferroelectric hafnium oxide**  
TU Dresden, Supervisors: Prof. Dr. Hubert Lakner, Konrad Seidel

Prabhu, Aditya  
**Fabrication and Electrical Characterization of Metal-Ferroelectric-Metal based capacitors for Laminated  $\text{HfO}_2$ - $\text{ZrO}_2$  and Hybrid Ferroelectric-Antiferroelectric stacks**  
TU Dresden, Supervisors: Prof. Dr. Hubert Lakner, Konrad Seidel, Dr. David Lehninger

Valiappan, Manikandan  
**Parametric Study of the Nano E-Drive Mechanism in Clamped-Clamped Beams**  
TU Bergakademie Freiberg, Supervisor: Jorge Mario Monsalve Guaracao



## Dissertations

Ali, Tarek

**Novel Fluorite Structure Ferroelectric and Antiferroelectric Hafnium Oxide-based Nonvolatile Memories**  
TU Dresden; Supervisor: Prof. Lukas Eng, Konrad Seidel

Haruyanyan, Armen

**Passive und aktive RFID-Tags im 60-GHz-Band**  
TU Dresden; Supervisor: Prof. Wolf-Joachim Fischer

Kirbach, Sven

**Piezoelektrische Eigenschaften Silizium-dotierter Hafniumdioxid Dünnschichten**  
TU Dresden; Supervisors: Prof. Dr. Hubert Lakner, Dr. Wenke Weinreich

Lederer, Maximilian

**Material development of doped hafnium oxide for non-volatile ferroelectric memory application**  
TU Dresden; Supervisors: Prof. Lukas Eng, Konrad Seidel

Schulze, Tim

BTU Cottbus-Senftenberg; Supervisors: Prof. Dr. Harald Schenk, Prof. Dr. Georg von Freymann

Schumann, Erik

**Percolated Si:SiO<sub>2</sub> Nanocomposite: Oven- vs. Laser-Induced Crystallization of SiO<sub>x</sub> Thin Films**  
TU Chemnitz; Supervisor: Prof. Dr. Sybille Gemming

Uhlig, Sebastian

**Silizium-basierte Mikropumpen mit dem lateralen nanoskopischen elektrostatischen Antrieb**  
BTU Cottbus-Senftenberg; Supervisor: Prof. Dr. Harald Schenk

## Habilitations

Dr. Kämpfe, Thomas

**Electron Devices Based On Ferroelectric Hafnium Oxide Thin Films**  
TU Dresden; Supervisor: Prof. Gerald Gerlach

*Theses with a blocking notice are listed without a title.*

Our job advertisements for theses:  
[s.fhg.de/Bachelor-Master](https://s.fhg.de/Bachelor-Master)  
[s.fhg.de/IPMS-dissertation](https://s.fhg.de/IPMS-dissertation)



Safety systems are a **key field of computing innovation**, powering advances in life critical applications including aviation, automotive and manufacturing.

We are delighted to see Fraunhofer IMPS delivering processors to enable critical applications, with their EMSA5-FS enabling system developers to readily achieve ASIL-D the highest level of ISO26262 certification. RISC-V powered processors like this will enable amazing new experiences for people around the world.«

**Calista Redmond**  
CEO, RISC-V International





*From left to right: Dr. Helmar Rendez (LEAG AG); Martin Landgraf (Fraunhofer IPMS); Hannes Koch (Advisor to the Saxon State Chancellery); Prof. Dr. Wolfgang A. Herrmann (Chairman of the Innovation Advisory Board); Jörg Mühlberg (Managing Director of the Saxon Agency for Structural Development (SAS) GmbH); Dr. Katrin Leonhardt (Chairwoman of the Board of Sächsische Aufbaubank – Förderbank – SAB); Prof. Dr. Harald Schenk (Fraunhofer IPMS), Cornelia Quennet-Thielen (Former State Secretary at BMBF), Dr. Wenke Weinreich (Fraunhofer IPMS)*



At the new location of the Center for Nanoelectronic Technologies CNT, Fraunhofer IPMS offers **ideal conditions for application-oriented, practice-oriented research** with its industry-compatible clean room and the latest semiconductor process equipment.

In the direct vicinity of the semiconductor plants of Bosch and GlobalFoundries, a research infrastructure unique in Germany has been created. It gives Saxony a further unique selling point in the European innovation landscape in the field of microelectronics.«

**Dr. Katrin Leonhardt,**  
Chairwoman of the Board of Management of  
Sächsische Aufbaubank - Förderbank - (SAB), shown  
here in the center during a visit of the Innovation  
Advisory Board Saxony in April 2022.

# Our whitepapers

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With our free whitepapers, you are always informed about current standards and our technology developments. You can see a selection here.

## Time Sensitive Networking – An Introduction

Ethernet has become popular in both computer and automation networks. However, Ethernet was not originally developed for the requirements of automation technology. This mainly concerns requirements for guaranteed and real-time communication. However, Industry 4.0 applications will require increasingly more end-to-end Ethernet networks. Using the traditional structure, these be created only with great effort. This is now to be changed with Ethernet TSN.

 [s.fhg.de/TSN-whitepaper1](https://s.fhg.de/TSN-whitepaper1)

## RISC-V Processor Core for Functional Reliability

Unlike many other instruction set architectures, RISC-V is free to use as an open source license, making it possible for anyone to develop RISC-V cores and processors without paying royalties. Fraunhofer IPMS RISC-V processor EMSA5-FS for embedded functional safety is a 32-bit processor with a five-stage pipeline that supports the open standard RISC-V instruction set architecture (ISA). This is presented in this white paper.

 [s.fhg.de/RISCV-whitepaper](https://s.fhg.de/RISCV-whitepaper)



## MIMUTs – Ultrasonic Transducers

Ultrasonic transducers are used in a wide range of applications – from medical imaging to non-destructive testing and parking sensors. Mechanically interconnected micromachined ultrasonic transducers (MIMUTs) are a new development that takes advantage of the benefits of conventional ultrasonic transducers while overcoming their limitations. This whitepaper provides an overview of these developments.

 [s.fhg.de/MIMUTS-whitepaper](https://s.fhg.de/MIMUTS-whitepaper)

Find and download all of  
our whitepapers at:  
[s.fhg.de/IPMS-Whitepapers](https://s.fhg.de/IPMS-Whitepapers)


# Our webinars

Our free tech webinars offer you an exciting insight into current research topics and technology applications. In our webinar series, you are sure to find a topic that interests you. Here is a selection:




## Spatial Light Modulators – Status and Potential for Holography

Spatial light modulators (SLM) play a central role in various applications such as image projection, wavefront control, and light beam control. There are both liquid crystal and MEMS-based modulator types. The webinar will present three different talks by SLM experts covering different complementary SLM variants. Special attention will be paid to the perspective of using SLMs for computer-generated holography applications up to true 3D holographic displays without negative physiological side effects. The introductory talk will be given by an outstanding and well-known expert in augmented, virtual, and mixed reality displays.

 [s.fhg.de/Holography-webinar](https://s.fhg.de/Holography-webinar)

## Two-photon polymerization 3D printing for high-resolution rapid microfabrication


The two-photon lithography system of Fraunhofer IPMS allows three-dimensional additive manufacturing of micro- and nanostructures in a photosensitive polymer. In the webinar you will learn more about the technical possibilities and the applications.

 [s.fhg.de/two-photon-webinar](https://s.fhg.de/two-photon-webinar)

## Neuromorphic Computing for Edge AI

Neuromorphic computing technology is brain-inspired sensing and processing hardware for more efficient and adaptive computing. It promises a low-energy implementation of human cognition, (e.g., interpretation and autonomous adaptation). Although the communication pathways in the brain and other neural systems cannot be directly translated into electronic circuits, these mathematical models form the basis for implementation. Various hardware realizations are currently being discussed. These include mixed-signal analog/digital CMOS circuits, asynchronous and event-based communication and processing schemes, and memristive, phase-change, ferroelectric or spintronic devices, and other nanotechnologies.

This webinar will discuss the benefits and challenges of various technical solutions in order to achieve the goal of efficient neuromorphic computing hardware for edge intelligence systems.

 [s.fhg.de/Neuromorphic-computing-webinar](https://s.fhg.de/Neuromorphic-computing-webinar)

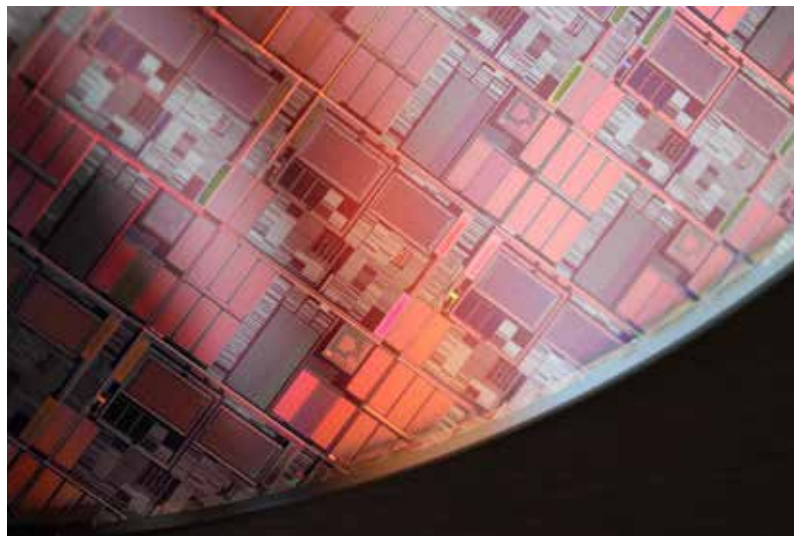
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# Services

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Fraunhofer IPMS offers you  
a selection of services:



## **MEMS Technologies Dresden**

Fraunhofer IPMS offers its customers a complete service for the development of micro-electro-mechanical systems (MEMS) and micro-opto-electro-mechanical systems (MOEMS) on 200 mm wafers.

Technological development of MEMS technologies and support in this area, from individual processes to technology modules to complete technology, as well as process-related support using equipment in the clean room, is provided by our team of over 90 engineers, operators and technicians.


At the customer's request, we handle pilot production following successful development or we support the technology transfer. We thus cover technological maturity levels (TRL) from 3 to 8.

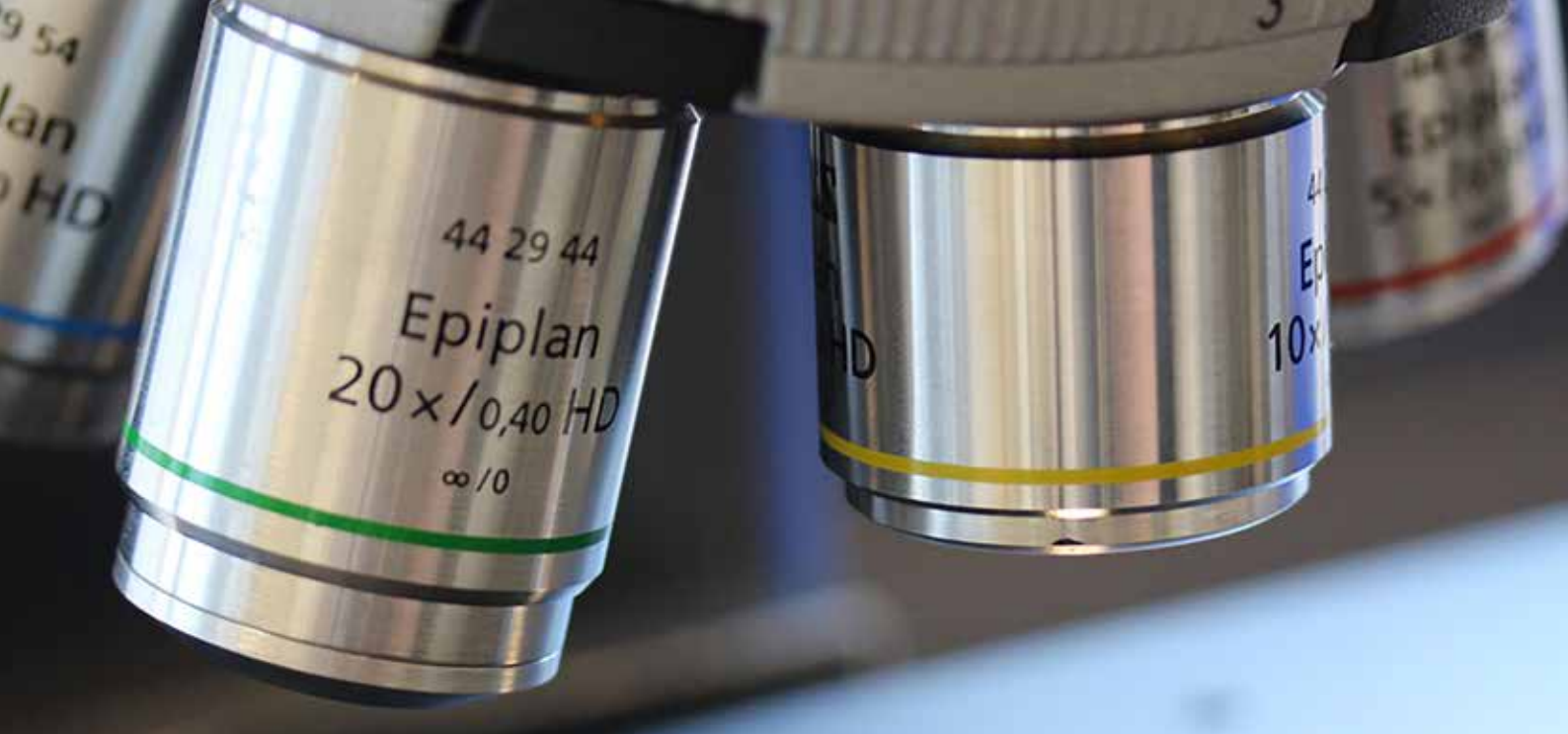
 [s.fhg.de/MEMS-Technologies-Dresden](https://www.s.fhg.de/MEMS-Technologies-Dresden)

## **300 mm Semiconductor Processes & Screening Fab**

We provide technology development and services in the fields of FEoL and BEoL. For series production of semiconductor devices, such as microprocessors, each individual process step is important for evaluation and optimization. Test vehicles and test wafers are essential for testing developments and new materials under production conditions and enabling a rapid response to process changes as well as a transfer of chemicals or processes from "lab to fab."

In the "Screening Fab", we offer screening and evaluation services for materials, processes, chemicals as well as consumables from laboratory to production scale, under industrial conditions and in a state-of-the-art 300 mm clean room.


 [www.screeningfab.com](https://www.screeningfab.com)



## Analytics and Metrology

We have various analytical characterization methods available in our physical failure analysis laboratories. The focus is on wafer characterization using various X-ray techniques as well as Raman spectroscopy and ToF-SIMS. In addition, high-resolution electron microscopy and grain analysis with appropriate preparation techniques are available. Atomic and piezoelectric force microscopy as well as chemical etching of wafer surfaces complete the portfolio. In addition, a complete electrical characterization is possible here.

With our in-line metrology, we can determine physical and chemical properties of structures on 300 mm wafers. All of our wafer-level analysis equipment is housed in a Class 1000 (Class 6 ISO 14644-1) clean room environment that meets industry standards.

 [s.fhg.de/300-mm-Analytics](https://s.fhg.de/300-mm-Analytics)

## RF Characterization

At Fraunhofer IPMS, RF/mm-wave characterization can be performed either in coaxial / waveguide measurement environments or at the wafer level. In both cases, special measuring equipment and application-oriented setups are required. In particular, an advanced semi-automated probe station enables the automated on-wafer S-parameter characterization of 2-port devices up to 170 GHz and 4-port devices up to 67 GHz. In addition, the vector load-pull measurement setup up to 65 GHz and the scalar load-pull measurement setup up to 110 GHz are available for the nonlinear characterization of active devices. In addition, the extraction of noise parameters up to 170 GHz is performed using the source-pull technique.

 [s.fhg.de/Characterization](https://s.fhg.de/Characterization)

You can find more  
information at:  
[s.fhg.de/IPMS-Services-en](https://s.fhg.de/IPMS-Services-en)

# Evaluation Kits

With our evaluation kits you get a fully functional experimental setup and can immediately test our technology for your application.



## **MEMS scanner for quasi-static or resonant operation**

The evaluation kits "QSDrive Scan Kit" (for quasi-static scanners) and "Simple MEMS Driver" (for resonant scanners) allow especially small and medium sized companies to operate MEMS scanners of Fraunhofer IPMS according to specification without the complex in-house development of drive electronics.

The evaluation kit for quasi-static scanners consists of a ResoLin device - a gimbal MEMS scanner with a linear axis and an optional, orthogonally oriented resonant axis - as well as control electronics that enable operation of the devices with a supplied optimized trajectory. Depending on the design of the MEMS device, closed-loop operation of the device and synchronized operation of the resonant axis are also possible. Function control is performed by software that communicates with the electronics via USB.

The resonant scanner kit contains a 1D or 2D resonant device - a cardanic MEMS scanner with one or optionally with two orthogonally oriented resonant axes - as well as the Simple MEMS drive electronics, which enables the operation of both axes with the respective resonant frequency. Depending on the design of the MEMS component, synchronized operation of the resonant axes is also possible. Function control is provided by software that communicates with the electronics via USB.

Both evaluation kits include a scan head that holds the device. Thus, thanks to its special design, the evaluation kit can be easily integrated into common optical experimental setups.

 [s.fhg.de/MEMS-eval-kit](https://s.fhg.de/MEMS-eval-kit)





## CMUT

The “CEK CMUT” evaluation kit offers interested developers and users of ultrasonic sensors the possibility to build a fully functional experimental setup for evaluating miniaturized capacitive micromachined ultrasonic transducers (CMUT). It consists of either one or two CMUT sensor modules, adapted control electronics, and software as a web application that controls the CMUT via plug-and-play.

 [s.fhg.de/CMUT-eval-kit](https://s.fhg.de/CMUT-eval-kit)

## RISC-V Processor IP Core

Our EMSA5 demo platform is an ideal tool for evaluating the RISC-V processor IP core EMSA5. It includes an Artix®-7 35T FPGA arty evaluation board with implemented EMSA5 IP core. Thanks to the included peripherals and expansion interfaces, the kit is ideal for numerous applications. It is programmable via JTAG and includes Quad-SPI flash, a JTAG port, 10/100 Mb/s Ethernet and a USB UART bridge, four Pmod connectors, and an Arduino Shield expansion connector.

 [s.fhg.de/RISCV-eval-kit](https://s.fhg.de/RISCV-eval-kit)



## LiFi Hotspot & Gigadock

In the LiFi area, we offer two evaluation kits with different focuses. LiFi GigaDock® is suitable for an optical, wireless, bidirectional point-to-point data link in full duplex mode over short distances in the cm range. Different versions offer data rates from 1 to 5 Gbit/s. For medium distances in the meter range, our evaluation kit LiFi Hotspot is a good choice. It supports data rates up to 1 GB/s at a distance of up to 5 m. With our evaluation kits, users can learn about the technical advantages of LiFi technology with little effort and test them in their own network or environmental conditions.

 [s.fhg.de/Hotspot-eval-kit](https://s.fhg.de/Hotspot-eval-kit)

 [s.fhg.de/Gigadock-eval-kit](https://s.fhg.de/Gigadock-eval-kit)

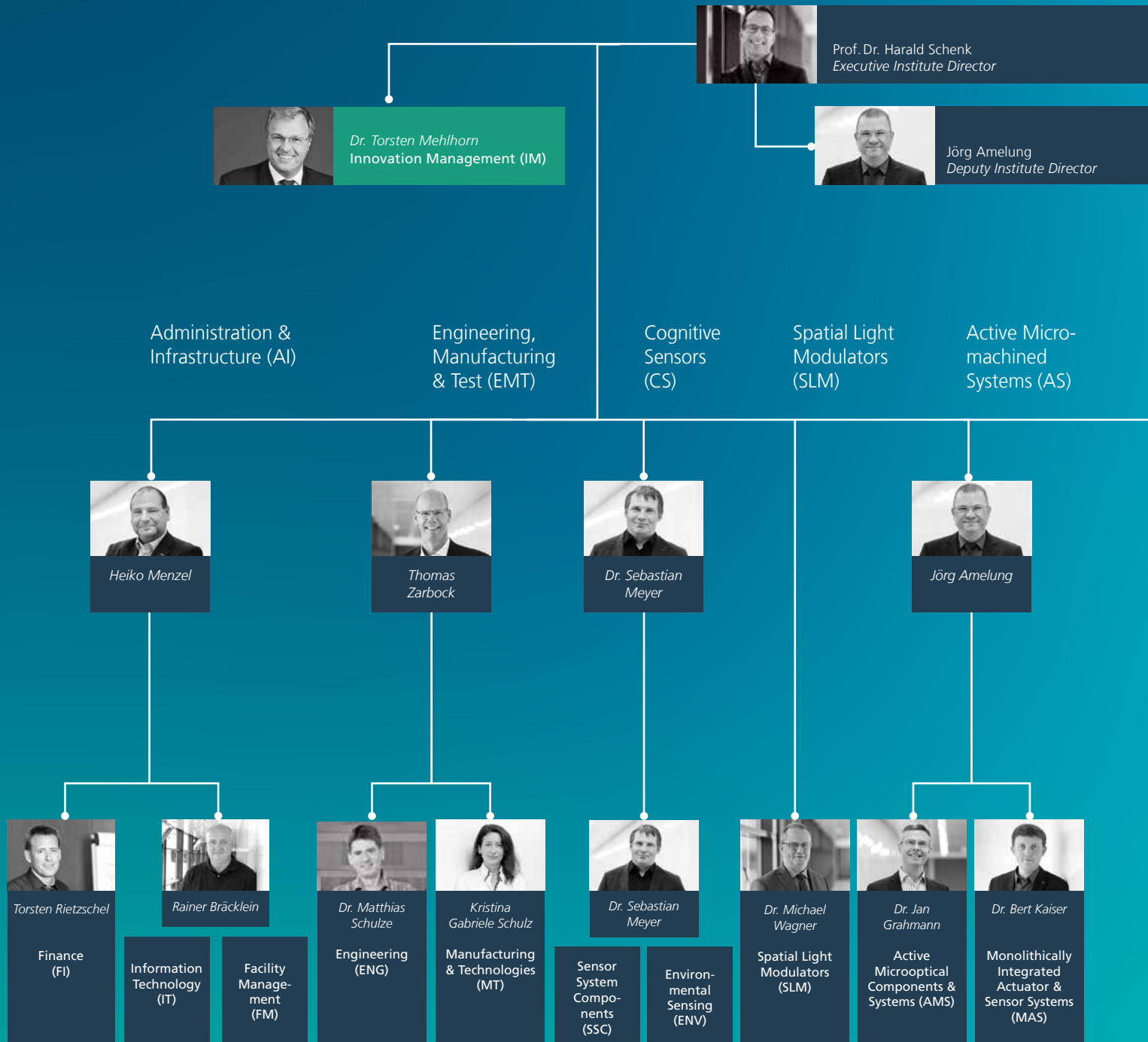
## Ethernet Time Sensitive Networking (TSN)

The evaluation kit consists of either a Smartzync board (Xilinx) or a Netleap board (Intel/Altera) with an optionally implemented IPMS TSN-IP core for endpoint applications (TSN-EP), switched endpoint applications (TSN-SE), or switch applications (TSN-SW). Linux drivers with application examples as well as RTOS test applications and TSN network configuration examples are also available.

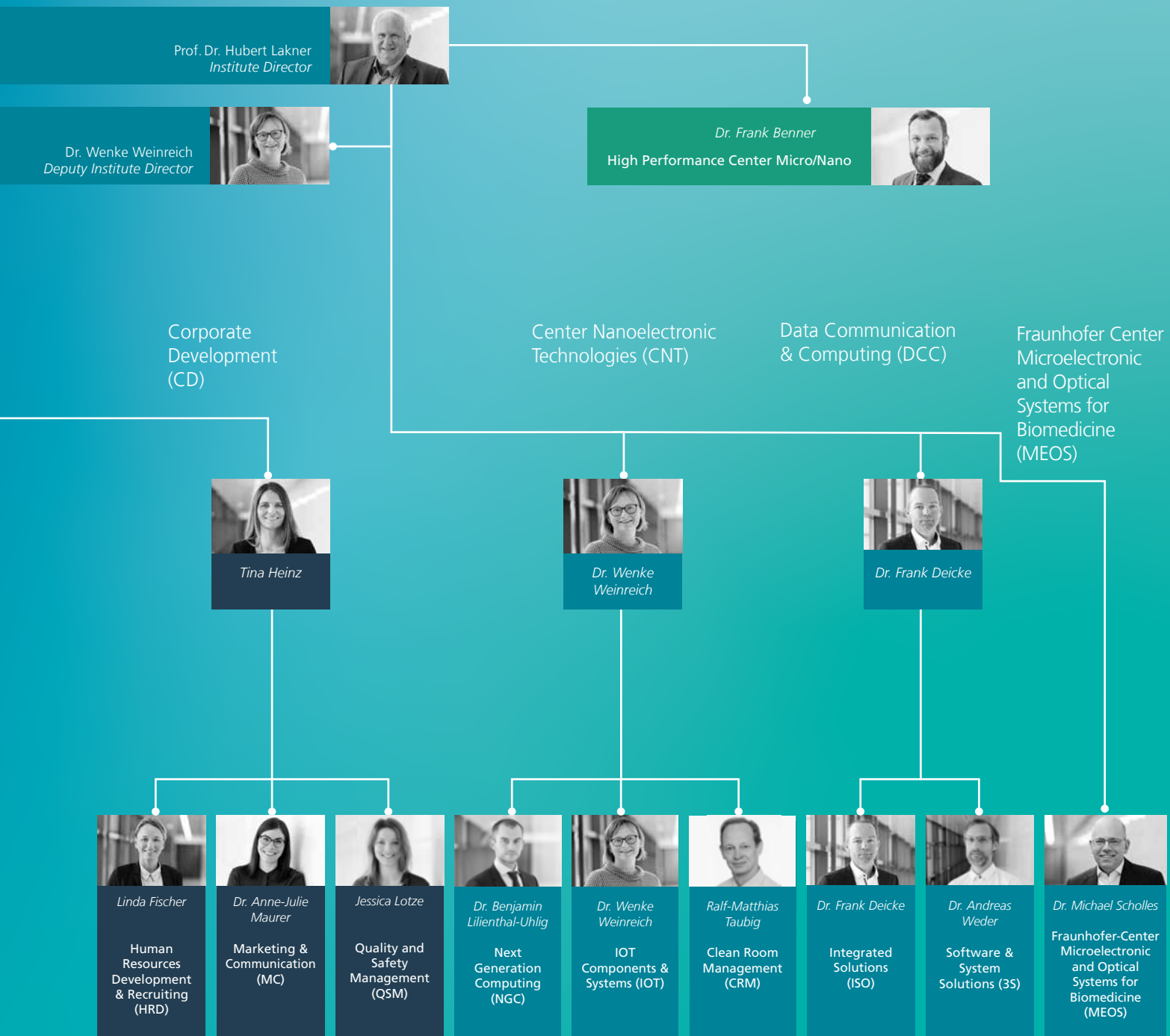
 [s.fhg.de/TSN-eval-kit](https://s.fhg.de/TSN-eval-kit)

For more information  
please visit our website at  
[s.fhg.de/IPMS-eval-kits](https://s.fhg.de/IPMS-eval-kits)

# Organigram



As of March 2023





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www.ipms.fraunhofer.de/en



## Fraunhofer IPMS – Center Nanoelectronic Technologies CNT

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+49 351 2607 0  
info@ipms.fraunhofer.de  
www.ipms.fraunhofer.de/en



## Fraunhofer IPMS – Integrated Silicon Systems ISS Branch

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## 30 years of Fraunhofer in Dresden – 30 years of Fraunhofer IPMS

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In 2022, the Fraunhofer-Gesellschaft celebrated its 30th anniversary in Dresden. The Fraunhofer IPMS started as a branch of the Fraunhofer IMS Duisburg and became an independent institute in 2003. From 150 employees and a budget of €13 million, it has now grown to more than 500 employees and a budget of over €50 million. Take a look at 30 successful years with us!



 [s.fhg.de/30-Jahre-Fraunhofer-IPMS](https://s.fhg.de/30-Jahre-Fraunhofer-IPMS)



## Editorial notes

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### Editors

Fraunhofer IPMS, Dr. Anne-Julie Maurer

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