Fraunhofer IPMS

Fraunhofer Institute for Photonic Microsystems IPMS

Annual Report 2021/2022

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 improved quality of life 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

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

another eventful year lies behind us. We are all hoping for an end to the pandemic and a return to "normality". The times are unfortunately still highly dynamic. But every crisis also offers opportunities. And Fraunhofer IPMS has demonstrated extraordinary resilience over the past two years. We have learned that partnerships and collaboration can be successfully established and maintained also digitally. We have found an agility that will enable us to offer you – our customers and partners – even more tailored solutions. At this point we would like to thank you: For your sustained loyalty to our institute and our research. We are proud to have had a successful 2021 financial year and are once again positioning ourselves as a leading research & development service provider for electronic and photonic microsystems.

The pandemic acted as a kind of burning glass for vulnerabilities in many places, including microelectronics. The issue of chip shortages is currently on everyone's minds. There are many reasons for this. But one thing is clear: The demand for microelectronics and microsystems technology research and development will continue to grow steadily. In the context of the German and European goals of regaining technological sovereignty in microelectronics, we see great opportunities to expand our technological offering and to tap into new collaboration partners and customer groups. Specifically, we hope that the second "Important Project of Common European Interest" (IPCEI) will soon come into being and that the growth plans of the entire semiconductor industry will be implemented. We are therefore devoting a special section of this annual report to the technology sovereignty of Germany and Europe.

In 2021, microelectronics in Dresden turned 60 years old. The fact that there are sufficient ideas and demand for another 60 years is shown by the possible settlements of large semiconductor companies in Saxony, which are currently being discussed. We would be pleased to inform you about current developments and our contribution to how we can continue to support the competitiveness of companies through our services and innovation impulses.

The fact that we are already doing this successfully today is shown by numerous highlights from 2021, which are presented in this annual report. As a result, we were able to launch many exciting projects in next generation computing. In quantum computing, we leverage our expertise in industry-grade, CMOS-compatible manufacturing methods to develop scalable technologies for semiconductor qubits. In Neuromorphic Computing, we research materials, technologies, and hardware solutions for an "intelligent computing" of the future. We also support efforts to make future generations of electronic systems reliable with research and development work on trusted solutions at the level of manufacturing, components, circuits, and entire systems.

Prof. Dr. Harald Schenk
Executive Director of the Institute

Prof. Dr. Hubert Lakner
Institute Director

We are also focusing on intelligent sensor technology. By integrating edge-based AI methods, applications in various industries can benefit. In general, we are currently experiencing a leap forward in the digitalization and data communications that drive our world. “Green” and particularly energy-efficient electronics is a defined goal that we want to drive with our research.

We would also like to highlight the human moments of 2021. The motivation of our junior staff to get involved in social issues makes us extremely proud. Our trainees developed a feel-good traffic light that visually represents the noise level in rooms. The traffic light was handed over to the Bremerhaven-based association “Rückenwind für Leher Kinder e.V.” in October 2021 and now ensures a pleasant coexistence for children between the ages of six and twelve, who receive free care, leisure, and support services there.

As we look ahead to 2022, a number of highlights await us. The Innovation Campus Electronics and Microsensorics Cottbus (iCampµs)” enters its second phase after a successful positive interim evaluation. In the spirit of “What Comes after Coal? Future Opportunities through Microelectronics and Digitalization!”, our Cottbus institute branch “Integrated Silicon Systems” is researching innovative technologies for Smart Health, Environmental Sensors 4.0, and Industry 4.0. Our expressed thanks go to the Federal Ministry of Education and Research, which is funding the project and thus the structural change in Lusatia with € 20 million. We also thank the Federal State of Brandenburg – in particular the Ministry of Science, Research, and Culture – for their support.

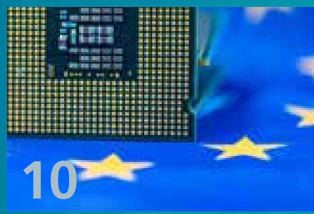
This summer, we celebrate the opening of the Center for Advanced CMOS and Heterointegration Saxony. Here we are expanding our Center Nanoelectronic Technologies business unit together with the “All Silicon System Integration Dresden” branch of Fraunhofer IZM (IZM-ASSID). The only 300 mm center in Germany for state-of-the-art semiconductor technologies, it will be a beacon for research and development in Europe offering top-level microelectronics and strengthening the innovative power of Germany.

In 2022, the Fraunhofer Society and thus also Fraunhofer IPMS will celebrate its 30th anniversary in Dresden. What a beautiful occasion to look positively and excitedly into the future together. We look forward to continuing to work successfully with you as customers, sponsors, and partners, developing solutions for industry and society, and bringing innovative ideas to application.

Harald Schenk

Hubert Lakner

Contents



Technology Sovereignty

Quantum Technology

Neuromorphic Computing

Trusted Electronics

Sustainability and Health

Next Generation Sensor Technology

Digitalization & Data Communication

Spotlight

Fraunhofer IPMS at a Glance

»

In Germany, we need a strong semiconductor industry that can hold its own internationally.«

Jörg Amelung
Deputy Director of the Institute

On June 1, 2021, Fraunhofer IPMS welcomed a new addition to its institute management. Since then, Dr. Wenke Weinreich, Division Director of the Center Nanoelectronic Technologies, has been deputy to Institute Director Prof. Dr. Hubert Lakner. Jörg Amelung, Division Director of Active Micromachined Systems is deputy to Institute Director Prof. Dr. Harald Schenk. In an interview, they talk about the successes of the institute over the past year, its goals for 2022, and how they have grown together as a team at Fraunhofer IPMS.

What do you think are the greatest successes for Fraunhofer IPMS in 2021?

Amelung — I am quite proud that we managed to achieve an excellent financial result despite all the adversities of the pandemic. All our regular customers have remained loyal to us. I see this as a sign that we are quite well positioned – in terms of both personnel and technology.

Weinreich — That's right – it was an outstanding year from an economic point of view. I also think it's great that we were able to establish ourselves strongly in strategic future topics last year. Be it in quantum computing, neuromorphic computing, or trusted electronics – we have positioned ourselves quite well and launched numerous new projects. We have grown together in the internal management circle and have found a common set of values. I find it absolutely fantastic that, despite the limited personal contacts, the cooperation worked so well and that we came together as a team.

What were your personal highlights in 2021?

Weinreich — Of course, I would first like to mention the area that I head, the Center Nanoelectronic Technologies. Moving our clean room to the new location is my absolute highlight. The fact that we have arrived here, set up the offices, and filled up the clean room. At the beginning of the year, we were still standing in a 4,000 m² empty room. And by the end of the year, the systems were built and running. That is simply remarkable and an incredible achievement.

Amelung — My personal highlight is the stable customer relationships that we were able to build on again in 2021. We have recently been placing great emphasis on establishing stable and strategic collaborations. This also includes the fact that we were able to solve all the technological challenges facing us in our projects in 2021. This makes us a strong research partner for our customers and contributes to their value creation. To be able to finish the year with this good feeling is a real highlight for me.

What specific goals do you have for 2022?

Weinreich — My goal is to drive forward the aforementioned strategic topics for the future and, above all, to transfer them to industrial applications. We have already formed many partnerships in the public projects and are so far advanced in development that we can support the industry with the new technologies. With neuromorphic computing, the first thing I see is the potential. Second, scientific excellence and visibility of Fraunhofer IPMS in the scientific space is quite important for me. I therefore see it as a great goal to continue to focus on publications in journals and at conferences and to stay consistent with that.

Amelung — After all, we're talking about not only 2022 here. These topics will be with us for years to come and will generate many innovations. And this is where we want – and need – to position ourselves as innovators and drivers. I also look forward to continuing to work with our customers in a spirit of trust in our established research topics. The direct connection to industry and the transfer of our results to industry are particularly important to me.

Jörg Amelung

Dr. Wenke Weinreich

What will change at Fraunhofer IPMS in 2022?

Amelung — The aspiration to devote ourselves to socially relevant issues of the future has clearly increased. This is what we want to address. One example is climate neutrality 2030, which the Fraunhofer Society as a whole – but also we as an institute – hope to achieve. We initially conducted an environmental analysis for one of our clean rooms together with Fraunhofer IZM in order to assess where we stand. This year, there will be many measures that we will implement together.

Weinreich — I can think of another topic. The conversion of the ERP system of the Fraunhofer Society to SAP will change a wide range of processes. We may not be able to define these precisely at the moment. However, I am convinced that we will have to act here in the course of the year. This also applies to the new MES system in the clean room. We intend to use this jointly in connection with Research Fab Microelectronics Germany.

Amelung — The clean rooms of the Fraunhofer Society are increasingly growing together. As a result of the new clean room strategy in the Fraunhofer Group for Microelectronics, we will experience greater use of our clean room as one of the main sites. This is a challenge – but also a great opportunity – and definitely an important change for us.

The semiconductor industry and its status in Europe is currently the subject of much discussion – keyword “chip shortage”. What is your position on this?

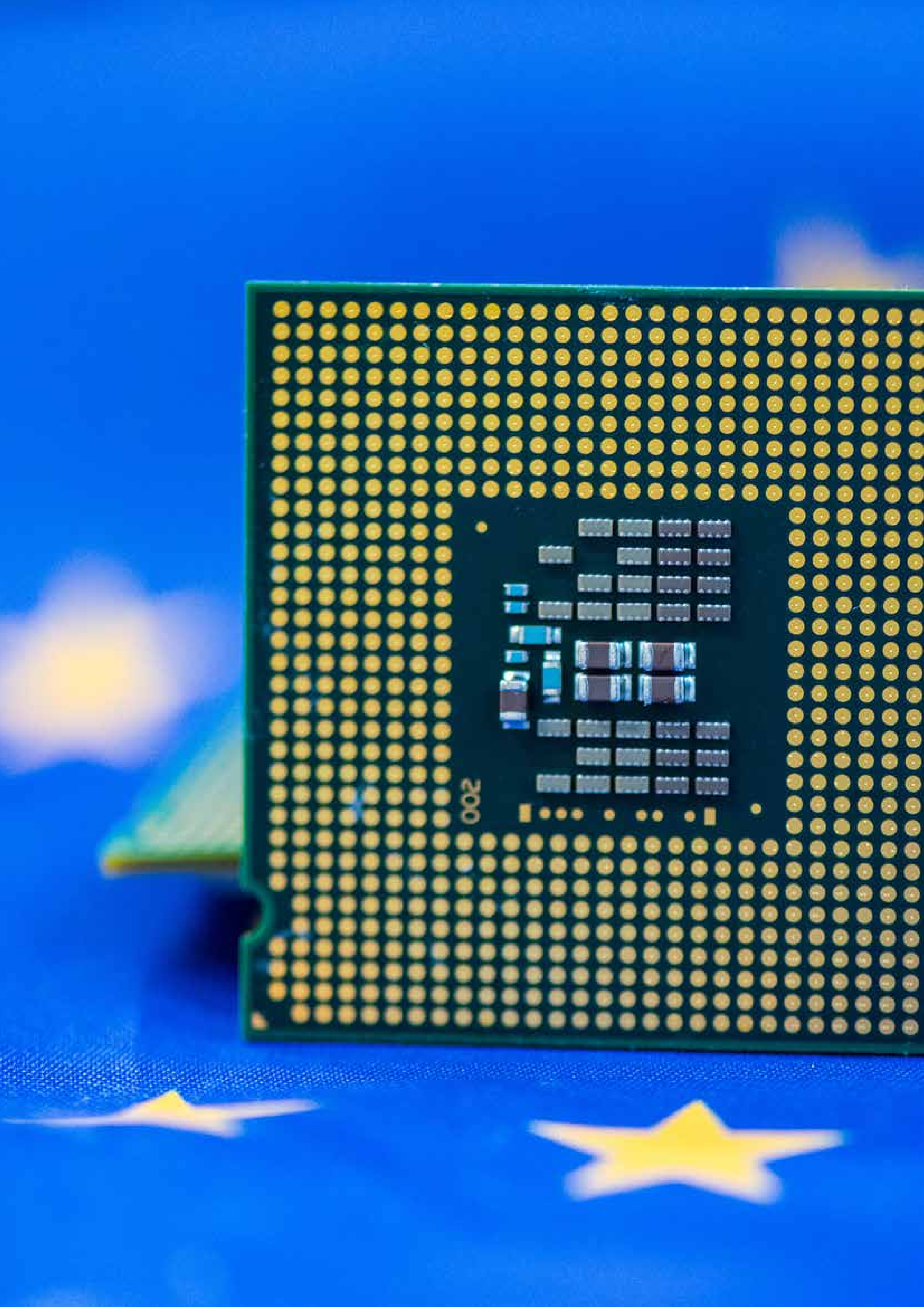
Amelung — I prefer to talk about technology sovereignty here because that is the real core of the discussion. In Germany, we need a strong semiconductor industry that can hold its own internationally. We don’t have to map the entire semiconductor industry. But for the core industries in Germany – such as the automotive industry – we must be able to confidently serve the entire value chain. However, this will work only if the circuit from Germany does not cost more than the one from Asia.

Weinreich — In the discussion, it should not be forgotten that the semiconductor industry is highly diverse. Of course, the main topic of discussion at the moment is the chip shortage for the automotive industry. But which chips are we talking about exactly? Which technologies are needed now or later? What about high-frequency electronics, power electronics, sensor technology, packaging, and storage? There is little or no talk about this – even though storage technologies are the be-all and end-all for any modern computing application. I see the challenge more in figuring things out: What technologies do we want and need in Europe?

Amelung — What I would also like to address is the absolute shortage of skilled workers and the promotion of young talent. We are already noticing this quite clearly in our institute. No matter what we establish technologically, we have to train young people and get them excited about microelectronics in order to remain efficient.

Weinreich — I absolutely agree with that. We have just discussed that the demand for research to deal with socially relevant topics is increasing and that climate protection and environmental awareness play a major role in this. Of course, the semiconductor industry is not exempt from this. But in perspective, microelectronics will provide many energy-efficient solutions. I believe that by communicating more strongly and contributing to a clean future through our research, we can convince young people of our work and attract new professionals.

Find more information at
s.fhg.de/reinforcement



Technology Sovereignty

Suddenly it was everywhere: The keyword "Technology sovereignty". The semiconductor shortage has clearly shown how important a strong microelectronics industry is in Germany and Europe. To mark the current occasion, we are presenting national and international voices on this topic here.

We will also show you how the Fraunhofer Group for Microelectronics is positioning itself with a new clean room strategy in order to be able to act even more effectively.

And if you'd like to hear and see more from us on the topic of chip crisis and technology sovereignty, we have some tips on that too. We hope you enjoy reading.

On Everyone's Minds

The chip shortage has shown how important technology sovereignty in microelectronics is for the German and European economy. Read here what leading politicians have to say about it – and why they think Saxony is a great semiconductor location.

»

The European Chips Act will be a game changer for the global competitiveness of Europe's single market.

In the short term, it will increase our resilience to future crises, by enabling us to anticipate and avoid supply chain disruptions. And in the mid-term, it will help make Europe an industrial leader in this strategic branch. With the European Chips Act, we are putting out the investments and the strategy. But the key to our success lies in Europe's innovators, our world-class researchers, in the people who have made our continent prosper through the decades.

Ursula von der Leyen
President of the European Commission

We want to make Germany the global location for the semiconductor industry.

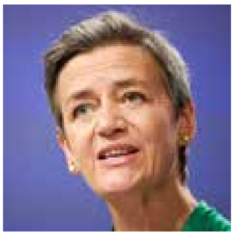
To this end, the German semiconductor industry is to receive adequate financial support along the entire value chain in order to secure, strengthen, and expand this key technology in Europe for the future.

Olaf Scholz
Chancellor of the Federal
Republic of Germany

» Oil was once considered the lifeblood of an economy. But today, we are more in need of semiconductors than ever before.

We lead on manufacturing equipment and we are at the forefront of research and innovation. […] European industry needs reliable access to a wide spectrum of chips, to meet today's demand, and in order to power tomorrow's revolution in connected cars and devices. And we need energy efficient semiconductors. Lowering energy intensity remains key to success.

Margarethe Vestager
EU Commissioner for Competition



» I would like Germany to become the great driver of innovation in Europe.

Chips are becoming increasingly smaller. However, their importance is growing – for our economy as well as for almost all areas of life. Microelectronics is the basis for almost every promising technology of the future: for AI applications and quantum computing as well as for autonomous and connected driving. Reason enough to work toward greater expertise and sovereignty and less dependence in this key technology, which microelectronics undoubtedly is. In this way, we will not only make Germany (and Europe as a whole) more crisis-resistant but also create new opportunities for growth and prosperity, sustainable jobs, and social security.

Angela Merkel
former Chancellor of the Federal Republic of Germany

» Europe has important strengths to bring to the table.

Just as smart phones have fundamentally changed our everyday lives – the way we live, the way we work, and the way we communicate with each other today – advances in AI, in microelectronics, and in quantum computers will open up entirely new perspectives. For example, how we can detect and cure diseases, how we can get the best products out of our machines, and how we can effectively protect the climate. We must – and want to – be in a position to understand these technologies, to manufacture them, and to sell them worldwide because this will ensure our prosperity.

Anja Karliczek
former German Federal Minister for Education and Research

Saxony will become one of Europe's main and most advanced industrial and technological semiconductor centres. Our capacity to produce the most advanced chips will contribute to our industrial leadership and geopolitical weight. It's time for Europe to play its cards.

Thierry Breton
EU Commissioner for Internal Market;
here during his visit to Fraunhofer IPMS in November 2021

European Chips Act

On February 8, 2022, the European Commission proposed the European Chips Act. This package of measures is designed to ensure the security of supply, resilience, and technological leadership of the EU in semiconductor technologies and applications.

The desired outcome is a thriving semiconductor ecosystem from research to production and a resilient supply chain. Overall, the market share of the EU is expected to increase from 10 to 20% by 2030.

Fraunhofer IPMS looks forward to playing its part with its research strength.

Encore

If you want to hear and see more from us on the topic of technology sovereignty, take a look here:

Prof. Dr. Hubert Lakner,
Institute Director of
Fraunhofer IPMS

»I think that despite all the countermeasures, the chip shortage will keep us busy for another two to three years.«

CNBC Europe Interview: “Dresden is the number one place for chips production in Europe”

Prof. Dr. Hubert Lakner talks about the semiconductor shortage and Dresden as a successful center of Silicon Saxony in an interview with the European business channel CNBC.

s.fhg.de/CNBC-interview

Next Generation Computing

The next generation of computing technologies will be driven by the highest levels of parallelis, "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,**
- **neuromorphic computing**
- **trusted computing.**

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.

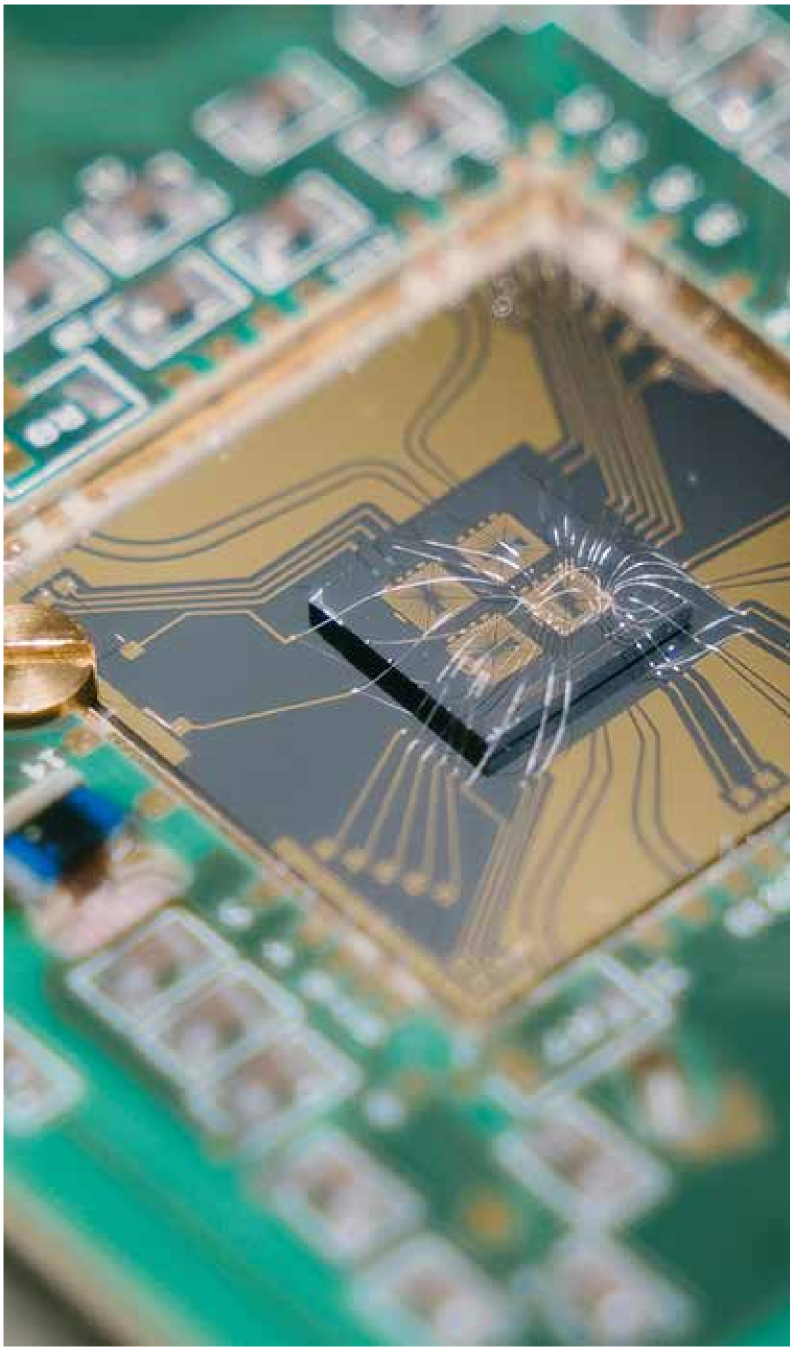
QUASAR – On the Way to the Quantum Processor "Made in Germany"

Quantum computers have the potential to far outperform conventional supercomputers on certain problems. For example, when it comes to controlling traffic flows in metropolitan areas or simulating materials at the atomic level. Germany has long been a world leader in basic research. In the joint project QUASAR, Fraunhofer IPMS is developing scalable concepts for quantum computing at the wafer level together with Forschungszentrum Jülich, Infineon in Dresden, and the Leibniz Institute for Innovative Microelectronics IHP. This lays the foundations for the industrial production of quantum processors "Made in Germany".

Semiconductor qubits are a promising approach to this because they scale well; this is critical for industrial manufacturing. Electron spin qubits in silicon exhibit comparatively stable quantum properties for this purpose and are much smaller in structure than superconducting quantum bits. However, until now, it was not possible to scale them as easily as classic computer chips because of geometric limitations. The qubits must be close to each other in order to couple them. One possible solution is a quantum bus. These are special interconnect elements that efficiently bridge distances of up to 10 micrometers between individual qubits. The quantum bus makes it possible to trap the electrons on the quantum dots and transport them in a controlled manner without losing the quantum information. This approach, which has already been successfully tested in the laboratory, is now being adapted to industrial manufacturing processes in the QUASAR project.

Fraunhofer IPMS is contributing its expertise from CMOS manufacturing to the project. Based on its many years of experience in electron beam lithography and in close cooperation with Infineon, it will be involved in producing the complex "Gate 1" quantum logic gates. In the end, optimized device structures with the highest possible homogeneity at the substrate level should be made available. In terms of structure scalability, this would not be achievable with proven laboratory methods such as lift-off processes in the quality and quantity required.

s.fhg.de/QUASAR-en



Semiconductor quantum chip of the JARA cooperation of Forschungszentrum Jülich and RWTH Aachen University

QLSI – Scalable Silicon Qubits for Quantum Computers

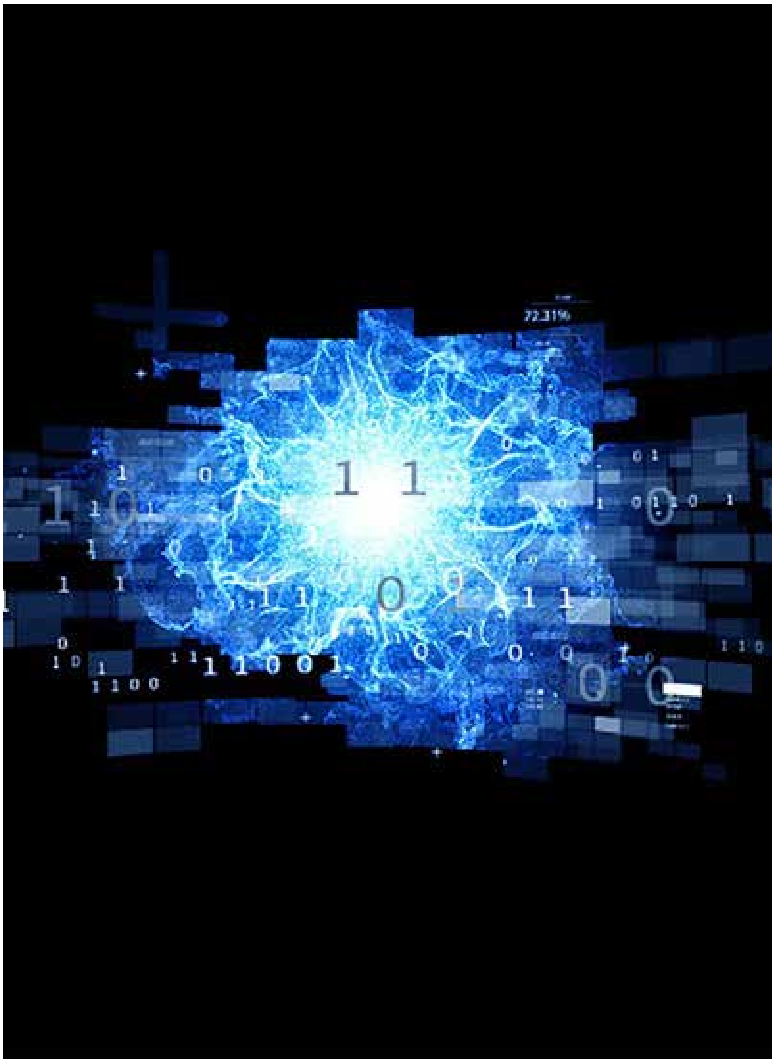
The race for the quantum computer is well underway. In order to take Europe a major step forward, Fraunhofer IPMS is developing a 16-qubit chip with 18 European partners as part of the QLSI – Quantum Large-Scale Integration with Silicon – project. This lays the foundation for the industrial implementation of semiconductor quantum processors in Europe.

The chip is based on silicon qubits, which can be driven and read out quickly and are ideal for quantum computing because of their small size, high Q-factor, and compatibility with industrial manufacturing processes. Silicon qubits have already been successfully demonstrated; the project is now about developing a scalable technology for later industrial implementation and manufacturing a 16-qubit chip.

Fraunhofer IPMS contributes its expertise in state-of-the-art, industry-compatible CMOS semiconductor production at the 300 mm wafer standard. This will create the infrastructure to enable highly scalable quantum processors in the first place. This concerns manufacturing processes for nanostructuring as well as material development and electrical control from the CMOS area.

The QLSI project is part of the ambitious Quantum Flagship program of the EU: a 10-year, € 1 billion research initiative launched in 2018. The overall goal is to consolidate and extend the scientific leadership and excellence of Europe in quantum computing, to launch a competitive European industry for quantum technologies, and to make Europe a dynamic and attractive region for innovative research, business, and investment in this field.

s.fhg.de/QLSI



Contact partner

Dr. Benjamin Lilienthal-Uhlig
Head of Business Unit
Next Generation Computing
+49 351 2607-3064
benjamin.lilienthal-uhlig@
ipms.fraunhofer.de

QSolid – Quantum Computer in the Solid State

The construction of a complete quantum computer based on cutting-edge technology from Germany is the goal of the joint project QSolid. Together with 24 German research institutions and companies and under the coordination of Forschungszentrum (FZ) Jülich, Fraunhofer IPMS is developing a quantum computer with improved error rates. The aim is to make Germany a world leader in quantum technology and to open up numerous new applications for science and industry. The first demonstrator will be operational in mid-2024 and will enable the testing of applications as well as benchmarks for industry standards.

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

Fraunhofer IPMS contributes its expertise in state-of-the-art, industry-compatible CMOS semiconductor production in the 300 mm wafer standard. This will enable scalable quantum processors that build on the achievements and advantages of silicon-based semiconductor manufacturing. Among other things, this concerns manufacturing processes such as deposition and nanostructuring or electrical characterization at the wafer scale. Together with GLOBALFOUNDRIES and Fraunhofer IZM-ASSID, an interposer technology that focuses on high-density superconducting interconnects and thermal decoupling through advanced packaging is being developed. In addition, the cryogenic characterization of the CMOS technology of GLOBALFOUNDRIES will be performed for scalable control.

s.fhg.de/QSolid-en

Cryogenic setup and control of a superconducting quantum computer at Forschungszentrum Jülich

Contact partner

Dr. Benjamin Lilienthal-Uhlig
Head of Business Unit
Next Generation Computing
+49 351 2607-3064
benjamin.lilienthal-uhlig@ipms.fraunhofer.de

PhoQuant – Photonic Quantum Computer

With the sufficiently high interconnectivity of many computational units (qubits) in a system, quantum computers can achieve higher computational speed than classical computers. At this scale, the photonic approach, which uses light particles (photons) as qubits, offers considerable advantages. This is because the functions required for computing operations can be produced on a single chip using advanced semiconductor manufacturing processes. Fraunhofer IPMS is therefore researching a photonic quantum computer together with partners.

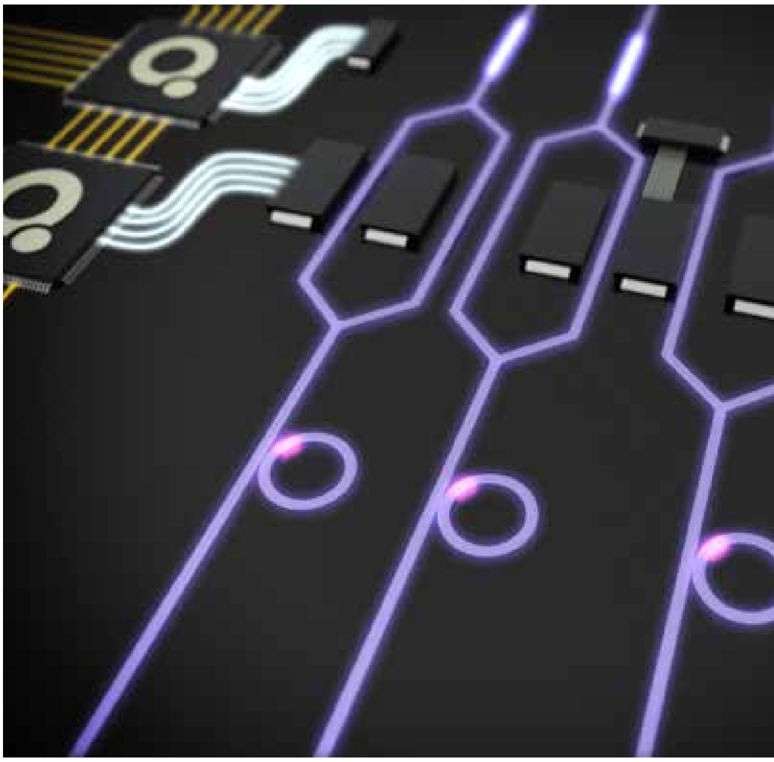
The goal is to provide an advantage for the computation of industrially relevant applications. A first example is the real-time optimization of schedules at airports in the case of unforeseen delays. For this purpose, the consortium, consisting of university research, start-ups, and industry, is developing a new photonic computer architecture, which will enable a quantum computer with up to 100 qubits in the course of the project.

The project is based on a method of the coordinator Q.ANT, which can be used to create extremely powerful quantum computer chips. By creating highly specialized optical channels on silicon chips, this photonic chip process is able to transport, control, and monitor quanta with almost no loss – even at room temperature. This means that the chips can be used in conventional mainframe computers as well.

In the project, the integrated (monolithic) design of this architecture is combined with scalable manufacturing processes from the semiconductor industry. This promises the possibility of further developing the system beyond 100 qubits. Tailored to this new architecture, optimized algorithms for special problems as well as algorithms for universal quantum computing will be developed and made available to the public via cloud connection.

In two and a half years, the project partners plan to present a first prototype; in five years at the latest, a quantum computer chip capable of performing large-scale computations should be created.

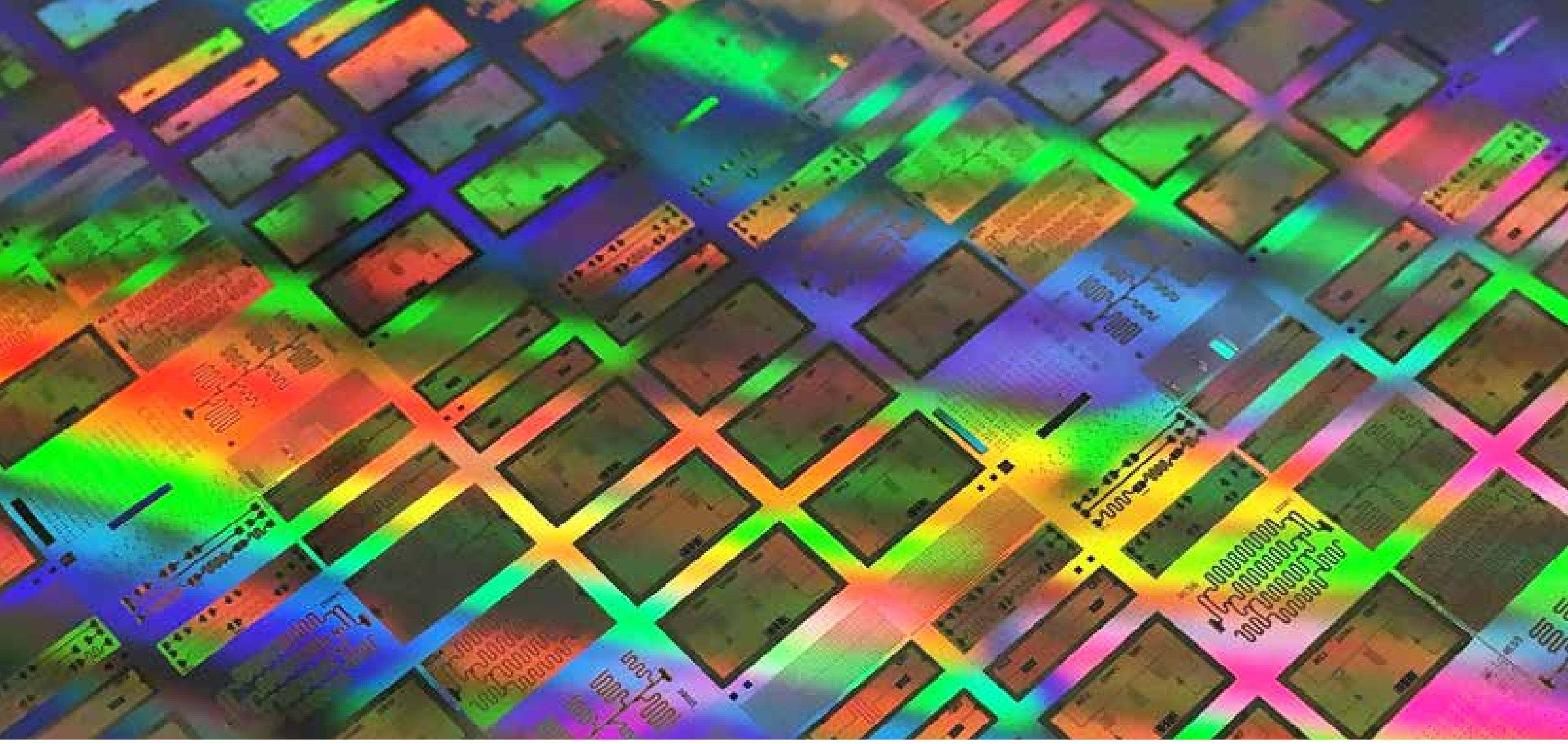
s.fhg.de/PhoQuant-en



Graphical representation of a photonic quantum computer with ring resonators as quantum light sources (purple circles), waveguides (purple lines), and electrically modulatable Mach-Zehnder interferometers (diamonds) as well as electrical contacts (black boxes), chip control (black ICs with the Q logo), and wiring (gold and white lines).

Contact partner

Dr. Frank Deicke
Head of Business Unit
Wireless Microsystems
+49 351 8823-385
frank.deicke@
ipms.fraunhofer.de



Test chip with superconducting qubits based on 300 mm wafer technology

MATQu – New Materials for a European Value Chain in Quantum Computing

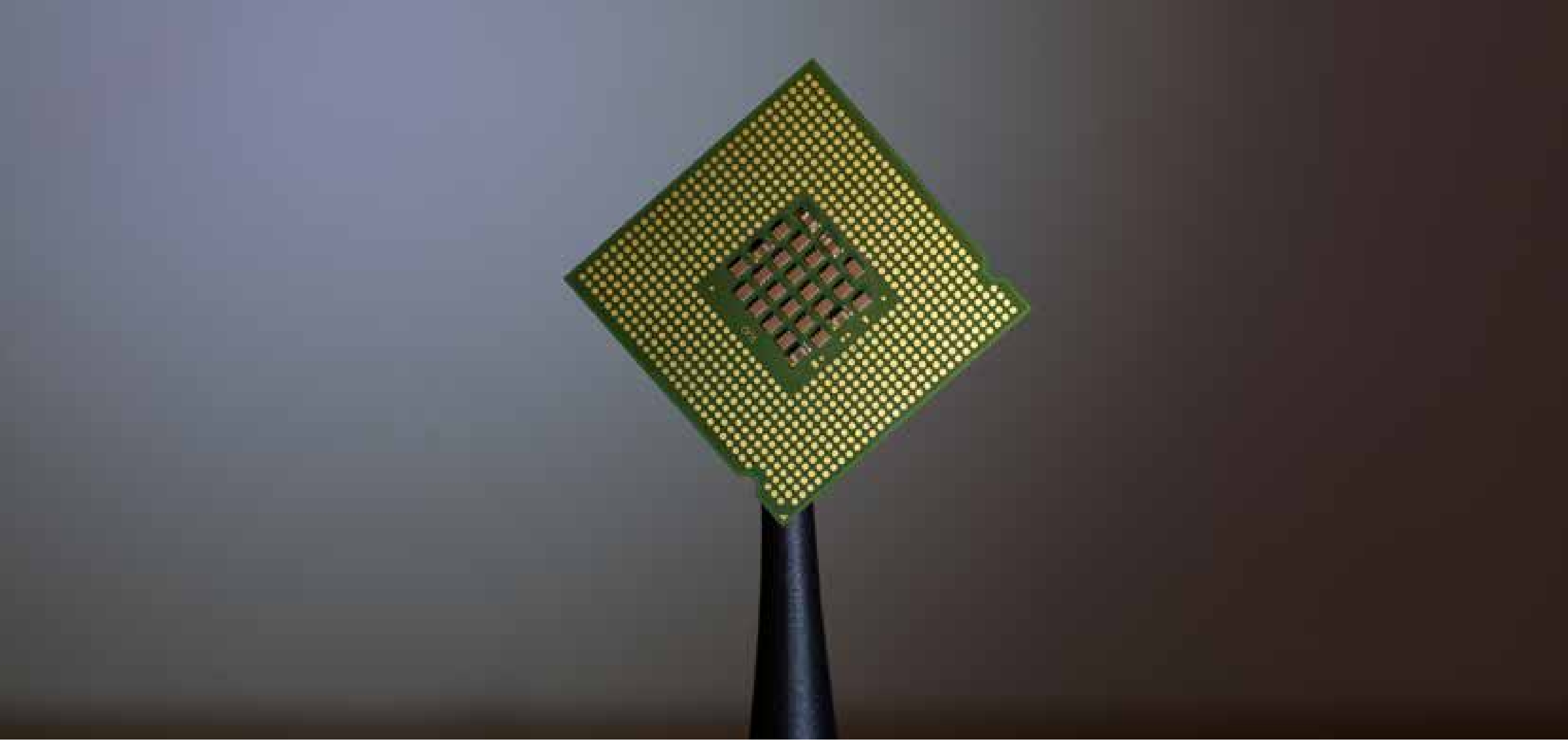
The (computational) performance of quantum computers depends heavily on the central hardware element: the qubit. There are several approaches to realizing qubits. However, there is a lack of stable, scalable manufacturing methods in order to achieve a breakthrough in industrial use. In the MATQu project, Fraunhofer IPMS and partners aim to expand existing European expertise in materials and production processes. This should pave the way for European industry to solid-state based quantum computers.

The goal is to establish a European supply chain for materials and processes for solid-state qubits through close collaboration between leading European research institutes and industry and application partners. Superconducting qubits are among the most promising devices to realize a large-scale quantum computer. However, their performance depends on the quality of the substrates and materials used as well as the reproducibility of the manufacturing processes. A stable and established value chain is therefore key to improving these parameters. The main technical goal of the MATQu project is thus the improvement and transfer of materials and technologies from the laboratories to the market.

The focus of Fraunhofer IPMS in the project is to bring the existing concepts and technologies from the laboratory to industrial production. The institute is drawing on its expertise in 300 mm production, which already serves as the industry standard for CMOS computing platforms. New insights into the material and process influences for the production process of superconducting qubits, especially in the area of deposition, patterning, and integration of superconducting layers, are now expected. In addition, Fraunhofer IPMS will advance the manufacture of devices for quantum computing on a European scale through novel manufacturing processes and testing at cryogenic temperatures.

A second focus is to work with industry and research partners to provide European SMEs and start-ups with access to state-of-the-art manufacturing facilities and expertise to considerably increase the maturity of superconducting qubit technology and strengthen the European quantum technology ecosystem. The project is coordinated by Research Fab Microelectronics Germany and Fraunhofer IAF. In addition to imec and CEA-Leti, 15 other partners are involved.

www.matqu.eu



HalQ – Semiconductor-Based Quantum Computing

For future German and European technological sovereignty – also in hardware – the development of proprietary technologies for the production of scalable and industry-compatible quantum computing chips is crucial. In the HalQ project, Fraunhofer IPMS is therefore evaluating concepts for various integration technologies of qubits into an overall system. In particular, the strengths of microelectronics for the realization of highly scalable quantum computers will be considered, and the corresponding technologies will be further developed.

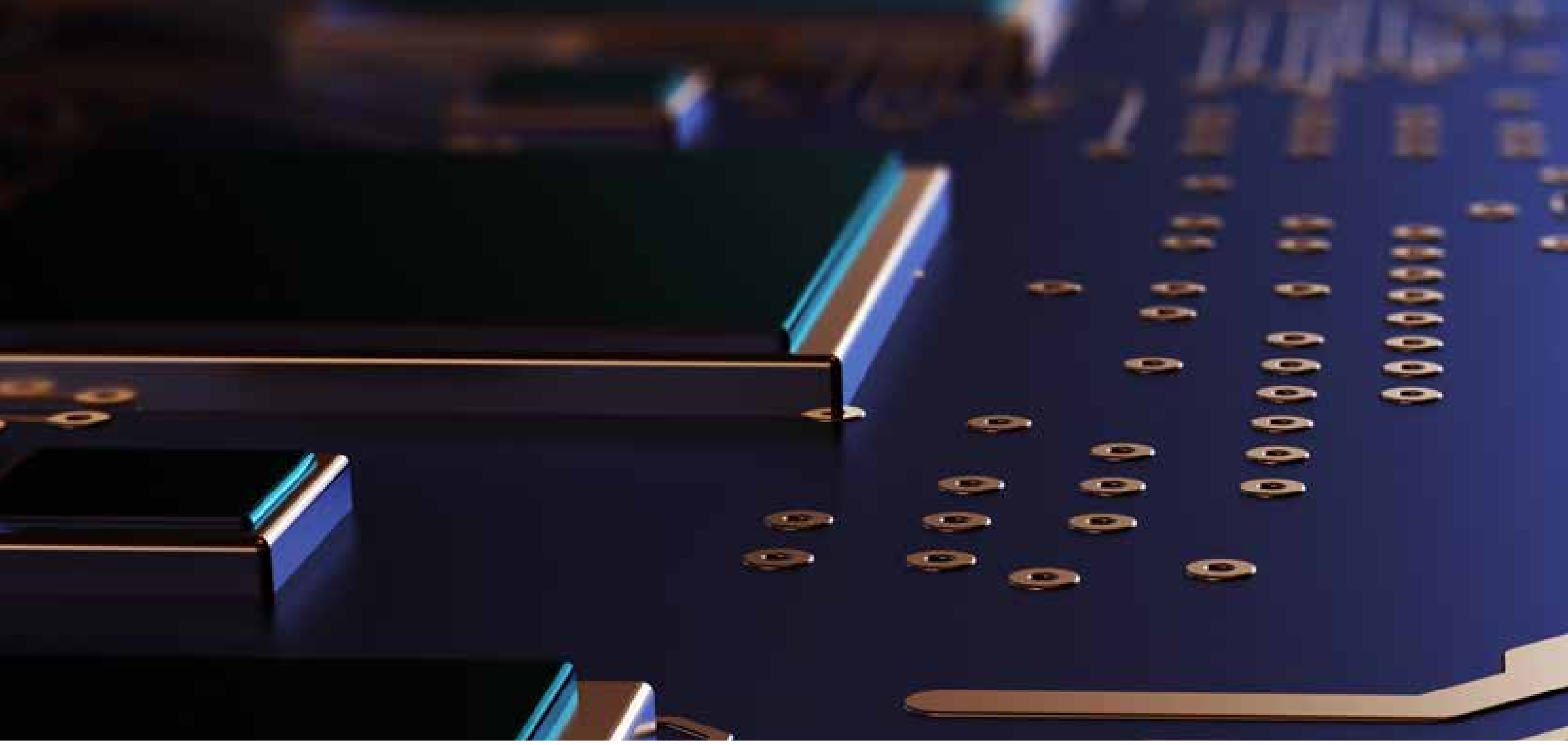
The focus of the project is on the production of qubits and the electronic interfacing of these. Specific approaches in the production of qubits that have high potential for near-industry scalability include Si/SiGe, Si-MOSFET and superconducting as well as color center and MEMS ion trap-based qubit technologies. In addition to the actual qubits, an effective and integratable control (readout and manipulation) must be realized. In addition, communication between the qubits as well as fast processing and feedback of the read signals with specially tuned digital signal processing in real time is necessary. This must be done at both the design and technology levels. Equally important is the development of new and optimized materials, processes, and integration concepts for cryoelectronics and superconducting packaging technology.

The HalQ project, which is coordinated by Fraunhofer IPMS, is dedicated to this holistic view with the goal of creating an overarching platform within microelectronics for the evaluation and integration of qubit concepts that build on existing technologies in microelectronics and enable the qubit count required for quantum computing with error correction. Specifically, the manufacture of physical qubits (quantum dots, superconducting qubits) will be addressed for the areas of materials development, integration, and process development. Here, Fraunhofer IPMS contributes its expertise in CMOS and RF technology as well as FDSOI and electrical characterization. The modern 300 mm clean room environment of Fraunhofer IPMS offers optimal conditions for this.

s.fhg.de/HalQ-en

Contact partner

Dr. Benjamin Lilienthal-Uhlig
Head of Business Unit
Next Generation Computing
+49 351 2607-3064
benjamin.lilienthal-uhlig@
ipms.fraunhofer.de



FMD-QNC – Research Fab Microelectronics for Quantum and Neuromorphic Computing

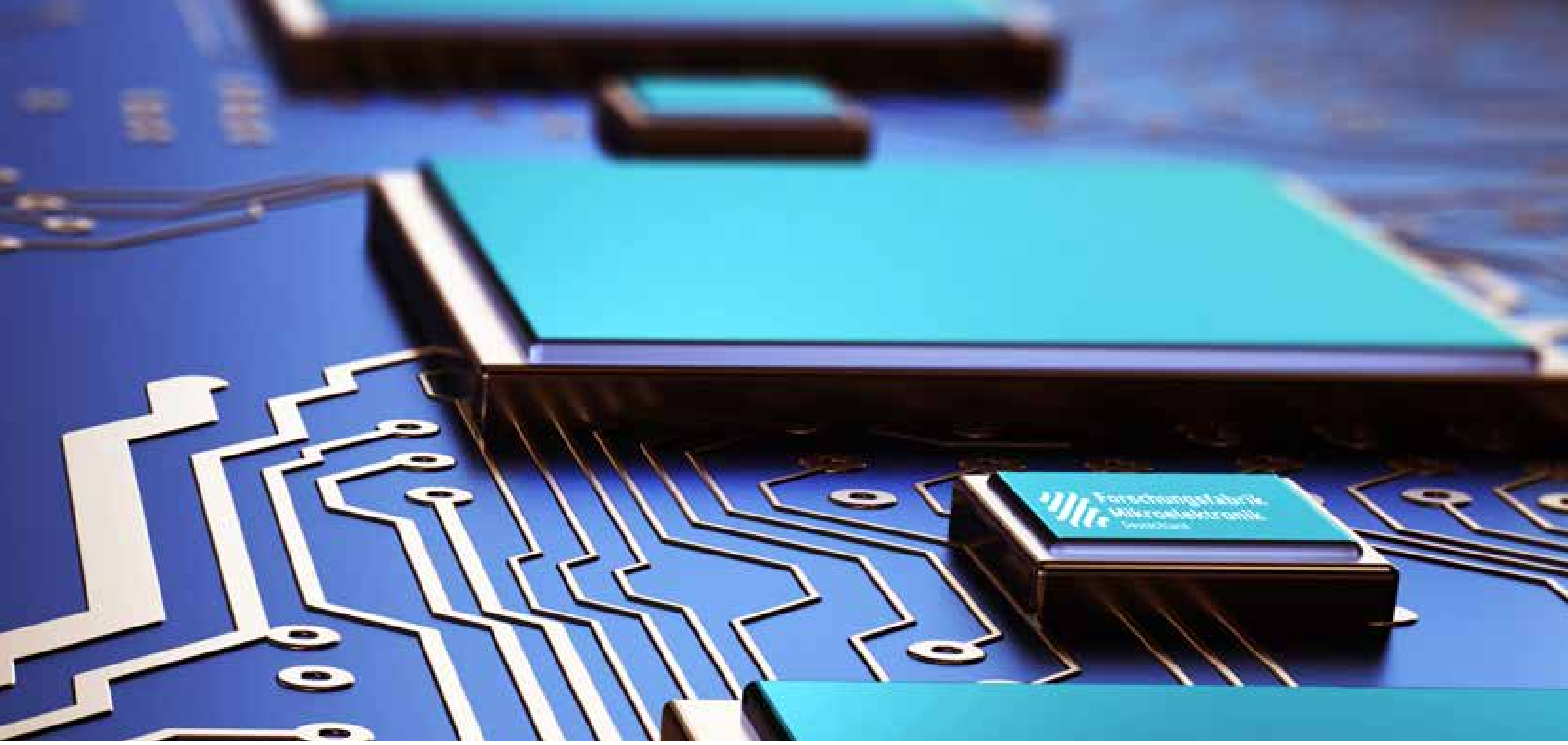
Quantum and Neuromorphic computing are the essential foundations for next generation computing technologies. Without these, many competition- and safety-critical applications could not be realized. By creating a central point of contact for scientific research and industrial application, the technologies currently under development in Germany can be greatly accelerated in their practical implementation. Especially for these highly complex topics, such low-threshold access to manufacturing technologies is essential in order to be able to realize new ideas from start-ups and small and medium-sized enterprises (SMEs) in timely demonstrators and prototypes. For this reason, Research Fab Microelectronics Germany (FMD) and its partners are applying to the German Federal Ministry of Education and Research (BMBF) for a corresponding expansion of their equipment infrastructure.

The existing Research Fab Microelectronics Germany developed from a project funded by the Federal Ministry of Education and Research and has now become a successful "one-stop shop" for scientific and industrial research. It has established and professional organizational structures, a strong clean room network, and extensive expertise in microelectronics manufacturing. The FMD-QNC – the Research Fab Microelectronics for Quantum and Neuromorphic Computing – will build on this and create the instrumental and structural conditions for research at the highest level in quantum and neuromorphic computing. In order to meet the complex challenge of content, the range of expertise is being expanded by involving Fraunhofer IMWS, IOF, IPM, and ILT as well as RWTH Aachen, TU Munich, Forschungszentrum Jülich, and AMO GmbH.

The proposed FMD-QNC project will address the major currently identifiable needs of quantum and neuromorphic computing research. In quantum computing, these include color centers and superconductors as well as neutral atom, ion trap, and electrostatically defined qubits. In total, the technology offering of FMD-QNC covers four areas. These include

- Design, simulation, and modeling
- Assembly and interconnection technologies / integration
- Test, characterization, and reliability
- Pilot production at the wafer level

A flexible access model allows customers to enter where needed. For example, in joint research projects, the development



of demonstrators, rapid prototyping, or pilot production. In addition, the FMD-QNC also focuses on young talent: An integrated academy provides training for highly qualified specialists and junior staff through continuing education, PhD and post-doc programs, and a teaching and conference program. Over 50 research partners from industry have already expressed interest in using the FMD-QNC.

Fraunhofer IPMS is looking forward to being a strong partner in the FMD-QNC with its technological expertise in quantum and neuromorphic computing.

Contact partner

Jörg Amelung
Deputy Director
+49 351 8823-49691
joerg.amelung@
ipms.fraunhofer.de

Lighthouse Project NeurOSmart – Sensors Learn to Think

For many manufacturers of smart sensor solutions in Europe, Industry 4.0 is an important driver. Autonomous mobile robots and driverless guided vehicles are increasingly being used in factory and logistics automation in particular. Forecasts predict that the necessary computing capacity of the sensor periphery of such devices will have to match that of a current supercomputer in less than 10 years. In the Fraunhofer lighthouse project NeurOSmart, Fraunhofer IPMS has joined forces with four other institutes in order to develop particularly energy-efficient and intelligent sensors based on neuromorphic architectures for the next generation of autonomous systems.

In order to work autonomously, mobile robots are packed with sensors and electronics that enable them to perceive their surroundings handle unforeseen situations independently. The more complicated the task, the more intelligent and agile the machine must be. However, this trend is accompanied by a considerable increase in energy consumption. In order to find a solution, Fraunhofer IPMS is developing a neuromorphic in-memory accelerator in the NeurOSmart project together with four other institutes. This accelerator is to be tailored to the respective sensor. The energy-efficient human brain serves as a model.

Data processing (i.e., thinking) is realized by a novel analog computer memory technology, which is also capable of performing arithmetic operations when data is newly recorded in the system. In practice, this is used to detect objects and their behavior accurately and in real time. Until now, this mode of operation has required several separately developed components in computers and particularly energy-intensive communication between them.

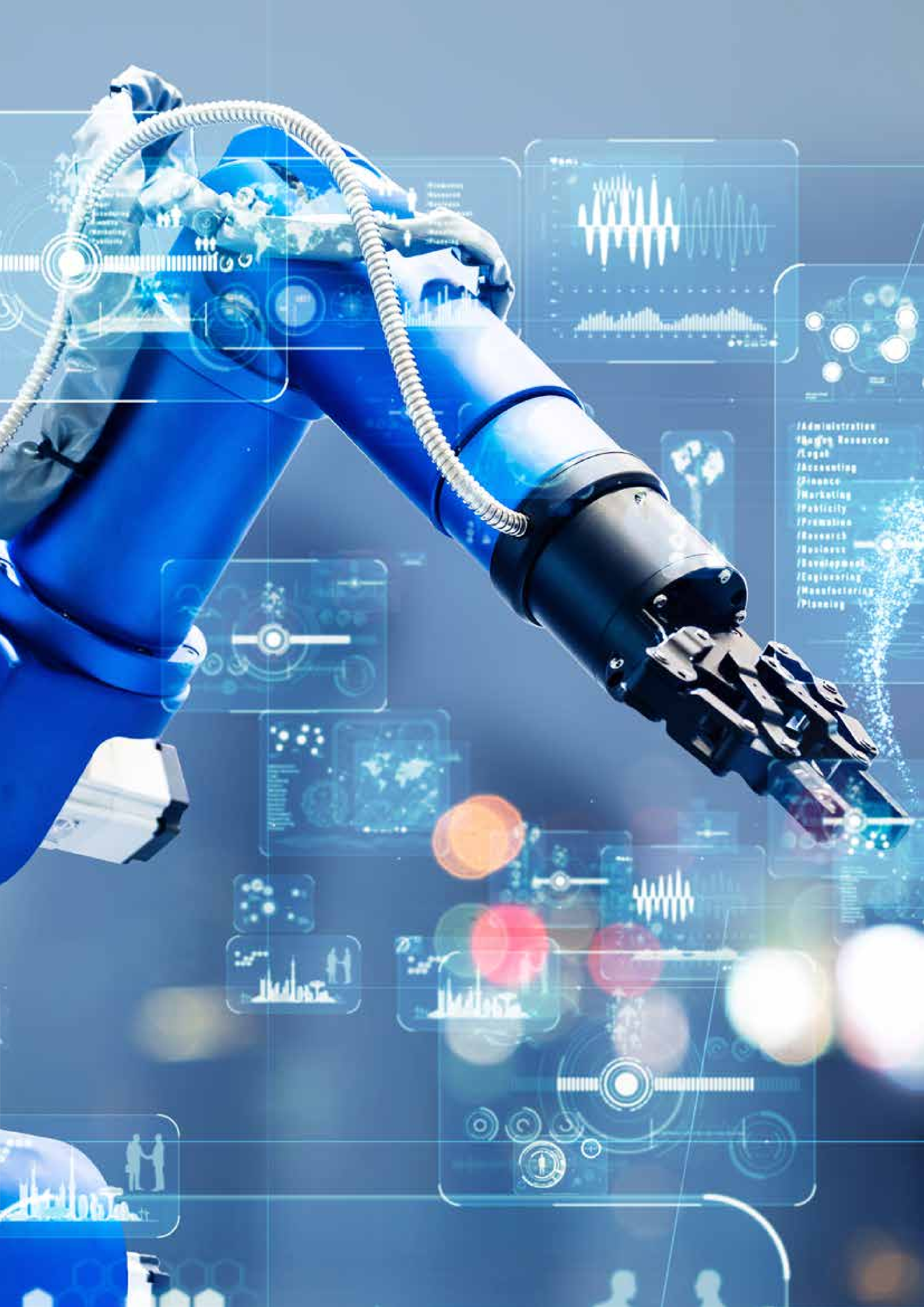
Within the project, Fraunhofer IPMS develops and trains the circuitry of the neuromorphic accelerator. Its core enables the mapping of complex digital computations for AI models to energy-efficient memory operations in the circuit. For the internal control of the data flows, the RISC-V processor core 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. In this context, research into a software-programmable system architecture will enable the flexible use of the circuit in a wide range of applications.

Furthermore, Fraunhofer IPMS is involved in the research of the neural network model for LiDAR data analysis. The goal here is the automated mapping on the available hardware topology as well as the transfer of this to a circuit design. Here, communication between the pre-processing (FPGA) and accelerator circuitry takes place via a real-time capable high-speed Ethernet interface. Finally, Fraunhofer IPMS is part of the validation of the new memory cell approaches for future accelerator implementations.

www.neurosmart.fraunhofer.de/en.html

Contact partner

Dr. Wenke Weinreich
Division Director Center
Nanoelectronic Technologies
+49 351 2607-3053
wenke.weinreich@
ipms.fraunhofer.de


/Administration
/Legal
/Accounting
/Finance
/Marketing
/Publicity
/Promotion
/Research
/Business
/Engineering
/Planning

MEMION – Memristive Redox Transistors for Neuromorphic Architectures

In order to set completely new standards in electronic data acquisition and processing, alternative computer architectures – especially neuromorphic computing – are increasingly coming into focus. The goal is to design architectures that represent the functionality of a brain as faithfully as possible and enable a high degree of plasticity. In the MEMION project, the development goal is energy-efficient transistors with multilevel switching behavior that can be used in neuromorphic computing networks.

The most important basic elements of a neuromorphic computing system are electronic synapses. Neuromorphic architectures based on resistive memories (RRAM) are particularly promising. Here, much higher information densities can be achieved thanks to the multi-stage switching characteristics. Because the resistance of such elements depends on their own history, such elements are often called memristors.

Compared with classical RRAM elements for which the conductivity of the channel is changed by the formation of filaments (controlled breakdown), electro-chemical or redox transistors allow much higher densities of states with better accuracy. In the MEMION project, a lithium-based synaptic transistor is manufactured and characterized at Fraunhofer IPMS using semiconductor technologies processes. The concept is based on a battery-like layer stack with solid electrolyte on silicon substrate, which is easily integrable and scalable. Low energy consumption and simple structures are essential for the realization of highly integrated memories.

The goal is a device that can be switched between voltage states with extremely low power consumption. For this purpose, nanoscopic test structures were designed and manufactured using the structuring methods and materials available at the institute. The lamella array provides a pattern width of 50 nm to enable resistance measurements with high signal-to-noise ratio. The adjustable change in material properties as a function of the lithiation state of lithium titanate was successfully demonstrated using the example of ionic conductivity.

s.fhg.de/MEMION-en

Contact partner

Sascha Bönhardt
Group Low Power Functions
+49 351 2607-3026
sascha.boenhardt@
ipms.fraunhofer.de

SEC-Learn – Sensor Edge Cloud for Federated Learning

Complex information systems and digital technologies are essential factors for the economic growth and competitiveness of Europe. As a result of ongoing digitalization, the amount of sensor data to be collected and evaluated is growing rapidly; this is accompanied by high demands on software and hardware. Conventional computing technologies are reaching their limits in terms of speed, performance, and energy efficiency. Fraunhofer IPMS is therefore pursuing novel approaches from neuromorphic computing in the SEC-Learn project. For example, in order to be able to realize computationally intensive tasks even in applications such as mobile devices or vehicles in which energy and memory capacities are limited.

Many processes that require the evaluation, categorization, and presentation of huge amounts of data now rely on AI. On one hand, the large number of data records generated as a result are accompanied by increased energy requirements; on the other hand, the data are stored centrally. This entails risks from the point of view of data protection and data security. New approaches that combine both energy efficiency and safety aspects are therefore desirable. In the SEC-Learn project, Fraunhofer IPMS is conducting research with 10 other Fraunhofer institutes in order 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 across multiple devices or servers. In contrast to classic cloud-based machine learning, the advantage is that sensitive data remains in local systems – a considerable gain in terms of data protection and data security. The platform developed in the SEC-Learn project will additionally use neuromorphic hardware accelerators that have several orders of magnitude lower power consumption. The developments are being tested on two use cases: speech recognition for voice assistants and image recognition for autonomous driving. In the project, Fraunhofer IPMS leverages its expertise in novel memory technologies, in particular embedded non-volatile memory (NVM) in advanced technology nodes. These enable local integration of logic elements and thus in-memory computing.

s.fhg.de/SECLearn-en

Contact partner

Dr. Thomas Kämpfe
Group Manager
Integrated RF & AI
+49 351 2607-3215
thomas.kaempfe@
ipms.fraunhofer.de

TEMPO – Technology and Hardware for Neuromorphic Computing

Neuromorphic computing is a new approach to microelectronic chip design inspired by powerful and efficient biological neural networks. Neuromorphic chips are capable of acquiring, analyzing, and controlling data with ultra-low power consumption. However, in order to further develop the technology to meet the requirements of future products, research in terms of hardware design and algorithms is still needed. The TEMPO project therefore aims to greatly improve the energy efficiency of neuromorphic hardware in order to enable novel applications in industry, health care, and automotive.

Fraunhofer IPMS is involved in the technological implementation of microelectronic components with particularly low power consumption. These can also be used for applications in AI, IoT, and Edge Computing.

One partial aspect is novel memory concepts as well as the integration of additional functional modules made of ferroelectric capacitors. In addition, Fraunhofer IPMS is cooperating directly with industrial partners within the project in order to be able to ensure the subsequent industrial feasibility of the neuromorphic circuits and chips.

Nineteen European partners have joined forces in the project. Fraunhofer IPMS is conducting research on chips in 28 nanometer technology nodes of Globalfoundries in order to shrink the interconnect structure and reduce leakage currents and process variations. The chips will initially be used in image recognition systems (e.g., for autonomous driving or for processing sensor data in radar systems). The goal is to reduce power consumption by several orders of magnitude thanks to the neuromorphic chip design and adapted peripherals.

www.tempo-ecsel.eu

Contact partner

Dr. Thomas Kämpfe
Group Manager
Integrated RF & AI
+49 351 2607-3215
thomas.kaempfe@
ipms.fraunhofer.de

StorAIge – Innovative Storage Technology for Edge AI Applications

Artificial intelligence is being used in increasingly more applications and is considered a key technology for electronic components and systems. Current AI technologies are inefficient and expensive and often still suffer from low public acceptance. In the StorAIge project, Fraunhofer IPMS has joined forces with European partners in order to develop a platform for silicon-based AI chips that is high-performance, energy-efficient, and secure, thereby enabling competitive edge AI applications in the automotive, industrial, security, and consumer sectors.

Most AI systems are currently used for data analysis and data-driven decisions. Edge AI approaches in which intelligent data analysis is performed directly in the evaluation chip of the sensor offer major advantages in this regard: Decisions can be made faster (latency) without relying on network connections (lower bandwidth usage). In addition, large amounts of data do not have to be moved back and forth across a network (reduced data storage). This reduces the overall power consumption of the system. Because data is processed locally, security is increased. 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.

In order to enable this, Fraunhofer IPMS relies on ferroelectric field-effect transistors (FeFETs). These are implemented directly on the semiconductor chip. This will enable the institute to expand its experience in the integration, characterization, and optimization of ferroelectric storage technology.

s.fhg.de/StorAIge-en

storaige.eu

Contact partner

Konrad Seidel
Group Manager
Emerging Memories
+49 351 2607-3059
konrad.seidel@
ipms.fraunhofer.de

Velektronik – Trust is Better

A future-oriented society depends on electronic components in all relevant technical application domains – whether in critical infrastructures, in Industry 4.0, in the automotive sector, or even in medical devices. In order use electronics safely and reliably, it must be understood where they come from, what they do, and how they are built. There are already some technical solutions in the sense of trusted electronics. However, there is not yet an end-to-end methodology that sufficiently incorporates the entire value chain. This is where the Velektronik research project, which started in March 2021, comes in. Fraunhofer IPMS is investigating trusted manufacturing processes in the project.

Technological sovereignty means that, against the backdrop of highly internationalized value creation, we retain sovereignty over the specific properties of the electronic components in our products. Electronics are trusted when they meet all of our expectations for functionality but leave no back doors or vulnerabilities open to attackers and tampering. With this in mind, the Velektronik project is developing a platform solution that takes into account the complete value chain in order to provide specific concepts for trusted electronics. To this end, the partners are focusing on creating a technological overview, contributing to the necessary standardization, and building up the network of research and industry as well as the ultimate expertise.

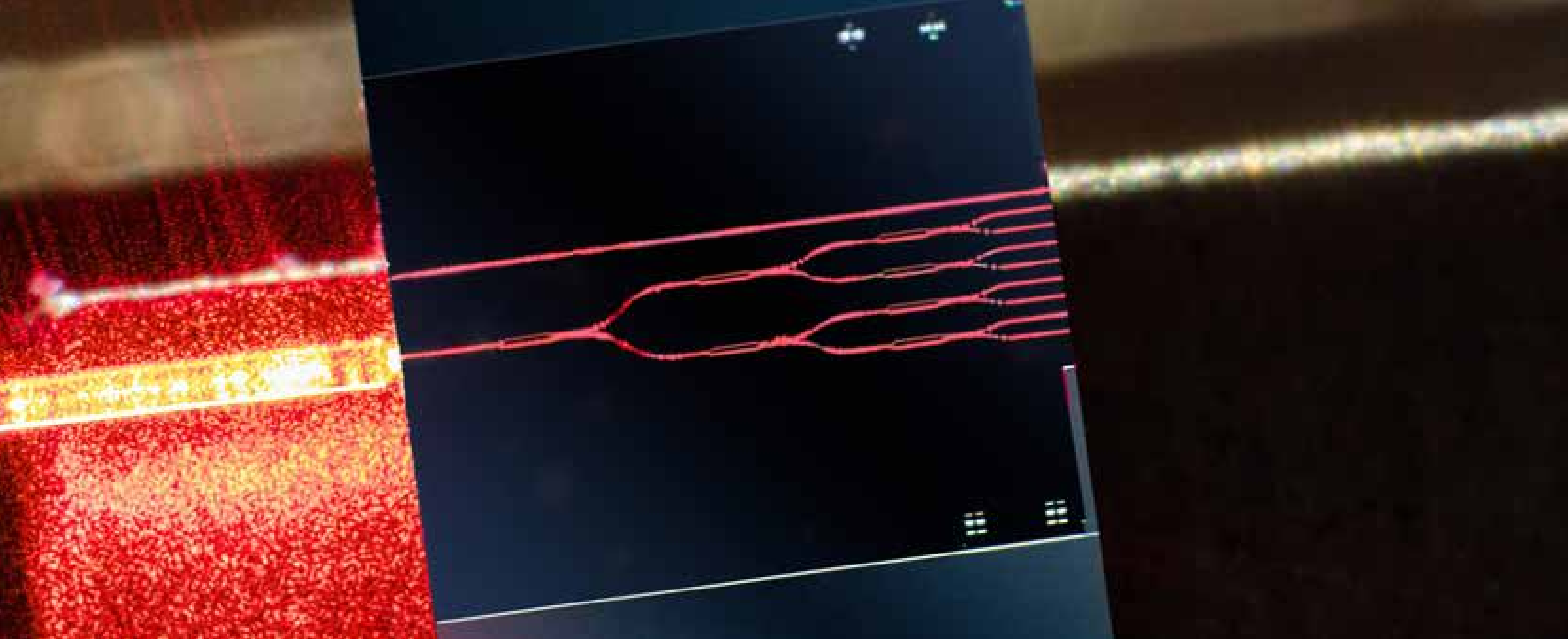
The Velektronik collaborative platform is coordinated by Research Fab Microelectronics Germany. Cross-cutting issues within the three pillars (design, manufacturing, and analysis) of the microelectronics value chain are addressed. For example, design methods, analysis procedures, and approaches for particularly trusted manufacturing processes for small series are being researched and compiled for this purpose.

Within the project, Fraunhofer IPMS deals with the production of electronic components at different manufacturing sites or "split manufacturing". This is the approach of having a chip processed and built by different foundries. For example, the CMOS backplane assembly can be detached from MEMS manufacturing. This is typically how it is found in international value chains. In terms of trusted electronics, it is important to protect the IP of the individual components, to maintain interfaces and functionalities, and to provide security features in hardware and software.

www.velektronik.de/en

Contact partner

Thomas Zarbock
Division Director Engineering, Manufacturing & Test
+49 351 8823-372
thomas.zarbock@
ipms.fraunhofer.de



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

Silhouette – Photonic Solutions 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 powerful, hardware-supported cryptographic algorithms are being used. But with ever-increasing communication speeds comes an increasingly negative cost and energy budget. One solution can be found in the expansion of silicon-based technologies to include photonic components. In the Silhouette project, Fraunhofer IPMS is developing a universal platform solution for the development of such hybrid systems. The essential core point is to consistently convert safety-critical electrical signals into optical signals, to further process or validate them, and 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 hybrid approach allows the use of existing third-party safety-critical components so that the current range of applications can ideally be maintained. The project covers the entire value chain: From the design of electrical and optical components 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 electro-optical platform solution will be located in the European economic area.

Fraunhofer IPMS contributes its experience in the integration of particularly energy-efficient components for IoT applications. Furthermore, three different concepts of a quantum cryptographically secure key generator based on cryptographic multi-mode interferometers (k-MMI) are evaluated with respect to their performance, security, and risks. With the most suitable concept, a k-MMI component is manufactured and its functional proof is provided by cryptographic analysis methods. In addition, the development of the open RISC-V peripheral components on the electronic side is implemented at the institute. The focus is on both digital and analog control and evaluation of the photonic extensions.

s.fhg.de/Silhouette-en

Contact partner

Marcus Pietzsch
Group Manager
IP Cores & ASICs
+49 351 8823-355
marcus.pietzsch@
ipms.fraunhofer.de

Trusted Chips Thanks to Tamper-Proof RFID Labels

Nowadays, the development and production of electronic components and systems takes place all over the globe. This makes the security aspect a central issue for both manufacturers and users. The proof that only trusted components were used in the manufacturing process is particularly important. Previous technical solutions failed because of cost and size. Fraunhofer IPMS has developed an RFID tag measuring just 1.5 mm² that can be integrated into each individual microelectronic chip as a tamper-proof label, thereby ensuring trustworthiness.

Nowadays, the manufacturing process of modern electronic components and systems can be traced only via accompanying documents and printed serial numbers. This carries the risk of deliberately introducing additional functionality in order to gain information about the system and thus bypass security. There can thus be no talk of trusted electronics.

Fraunhofer IPMS is pursuing a solution involving a tamper-proof RFID tag measuring just 1.5 mm^2 that can be integrated into each individual microelectronic chip in order to monitor its entire lifetime. The chip operates completely autonomously and has no electrical connection to its environment, thereby making it tamper-proof. Energy harvesting principles are used to supply energy. The data traffic is secured via cryptographic procedures.

The project will improve the technical parameters in order to achieve broader applicability. For example, the read distance between the reader and the authentication chip is increased tenfold to about 5 cm, the chip area is reduced to less than 1 mm², and the authentication speed is reduced to less than 100 ms. This is achieved by using millimeter-wave frequency bands at above 60 GHz (which allows the antenna to be made smaller) and state-of-the-art CMOS technology in order to enable the system to operate without batteries via energy-harvesting devices with an extremely low supply voltage (0.4 V). Furthermore, the application of the technology is being validated in other industries (logistics, proof of authenticity of medicines, asset tracking).

s.fhg.de/Trusted-Electronics

Contact partner

Dr. Frank Deicke
Head of Business Unit
Wireless Microsystems
+49 351 8823-385
frank.deicke@
ipms.fraunhofer.de

TRAICT II – Trusted Resource Aware ICT

The TRAICT II project combines the two cutting-edge research areas of trusted and sustainable electronics by addressing the following questions: How can the reliability and trustworthiness of critical electronic components and systems be guaranteed in globally interwoven supply and value chains? And how can resources be conserved and the energy efficiency of electronic components and systems be increased? Information and communications technology is uniquely suited to answering these questions.

In our modern, networked world, information and communications technology (ICT) is considered one of the most important critical infrastructures – for both end users and industry. As such, the ICT essentially relies on the availability of microelectronic components and systems that are both trusted in order to protect data and particularly efficient in order to keep the ever-increasing amounts of data manageable from the perspective of energy efficiency. Fraunhofer IPMS and its partners are therefore researching trusted and energy-efficient hardware and software components for modern 5G communication technology in the TRAICT II project.

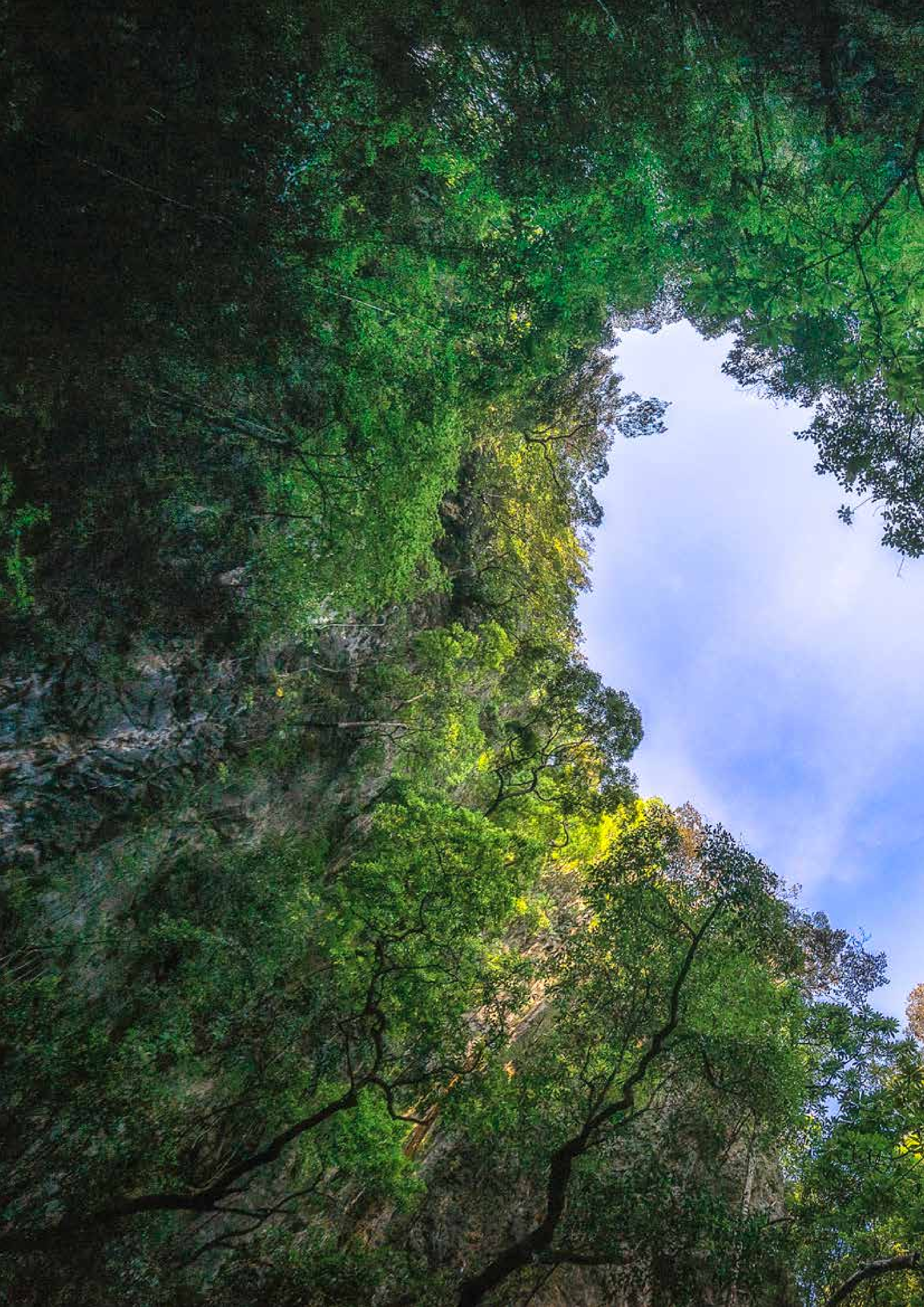
The project investigates trusted system architectures and components. This involves analyzing 5G hardware components from the assembly to the transistor level using new test methods and reverse engineering – and from this, developing a new methodology for testing. Fraunhofer IPMS contributes its expertise in the RISC-V platform and works on integrated, functionally safe RISC-V subsystems for real-time communication: a dynamically reconfigurable embedded platform for software / hardware co-designs for industrial and automotive communication. Also demonstrated is a prototype RISC-V-based security module that enhances the security of critical network components and smart sensor applications.

System energy optimization is realized locally in components, subsystems, and assemblies as well as in distributed computing and in the system using AI-based models. Novel semiconductor materials for microelectronic components in edge and sensor devices enable considerable energy savings compared with existing technologies.

s.fhg.de/TRAICT2-en

Contact partner

Marcus Pietzsch
Group Manager
IP Cores & ASICs
+49 351 8823-355
marcus.pietzsch@
ipms.fraunhofer.de



Sustainability and Health

The buzzwords sustainability and health were particularly relevant in 2021. Climate change is progressing unstoppably, and the Corona pandemic has changed our lives.

At Fraunhofer IPMS, we are researching sustainable electronics – in the area of particularly energy-efficient components – as well as new concepts for using clean materials and saving energy as early as the manufacturing process.

And we want to contribute to public health with intelligent medical technology. For example, we have developed new technologies for the early detection of diseases.

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

Green ICT – On the Way to Sustainable Microelectronics

In our highly digitalized society, the total energy consumption of information and communication technology is continually increasing. There is a goal of reducing CO_2 emissions worldwide. This presents microelectronics with the challenge of reducing the resources required for both manufacturing and operating electronic systems and pursuing more sustainable solutions. In the "Green ICT @ FMD" project, a competence center is to be established under the leadership of Research Fab Microelectronics Germany (FMD). This will make a major contribution to the implementation of the Green ICT mission of the German government.

The aim of the Green ICT Competence Center is to act as a central point of contact for industry, politics, and science in Germany and Europe. The aim is to offer cross-technology Green ICT solutions up to a high level of technical maturity from a single source for partners in industry and science. The center is guided by the various evaluation dimensions of green ICT systems – such as low energy consumption in nominal operation, avoidance of toxic materials, or even improvement of the recycling capabilities of microelectronic systems. Other offerings such as a student academy and a comprehensive training and qualification program for industry on green technologies and systems are being established as flanking measures to contribute to improved transfer of expertise and train specialists in green ICT.

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/Green-ICT

Contact partner

Jörg Amelung
Deputy Director
+49 351 8823-4691
joerg.amelung@
ipms.fraunhofer.de

Environmentally Friendly Cleaning Technologies in Microelectronics

Many individual process steps are necessary before a chip is created in microelectronics. In this process, it is always necessary to clean wafers or to remove existing layers either completely or partially. This is usually done using aggressive chemical cleaning processes. At Fraunhofer IPMS, an alternative technology is being developed in collaboration with intelligent fluids GmbH. This is more efficient, more cost-effective, and, above all, more environmentally friendly.

The phase fluid based technology sets new standards in terms of environmental friendliness, occupational safety, and equipment compatibility and represents a major step towards green fab in semiconductor production. In addition, process flows can be simplified, thereby resulting in savings in production time and consumables and enabling new application scenarios in process integration.

In contrast to conventional processes in which photoresists are dissolved using aggressive solvents (and sometimes toxic chemicals) and then disposed of at great expense, phase fluids infiltrate the corresponding layers, fragment them, and "lift" them off the wafer surface without defects. The phase fluid and the detached photoresist are then rinsed off with deionized water and removed without leaving any residue. Since no chemically aggressive dissolution of contaminations or coatings takes place, even sensitive substrates and surfaces are not attacked and consequently protected.

The technology for front-end photoresist removal for industrial use in 300 mm production lines is being qualified by the Leipzig-based technology company intelligent fluids GmbH in collaboration with Fraunhofer IPMS. This creates an environmentally friendly cleaning technology that can be integrated into next generation semiconductor manufacturing.

s.fhg.de/cleaning-technologies

Contact partner

Dr. Wenke Weinreich
Division Director Center
Nanoelectronic Technologies
+49 351 2607-3053
wenke.weinreich@
ipms.fraunhofer.de

KODIAK – Components and Modules for Improved Optical Point-of-Care Diagnostics

Lab-on-chip (LOC) diagnostics is now the state of the art in various laboratory diagnostic procedures. It enables the automated processing and evaluation of samples. Diagnostic results can thus be provided faster, earlier, and more cost-effectively than with conventional analysis in a medical laboratory. However, lab-on-chip systems are not available for all applications. Together with partners, the Fraunhofer Center MEOS is therefore developing new components and modules for LOC diagnostics in cytokine release syndrome.

Cytokine release syndrome (CRS) can occur with various diseases and therapies (e.g., immunotherapy, sepsis, and infectious diseases such as COVID-19). In a CRS, cytokines are produced as part of the body's immune response, thereby activating more immune cells. These migrate to the site of inflammation and produce cytokines that trigger an excessive immune response. This does not subside automatically – as is usually the case – but rather continues to intensify. Because this serious side effect can be fatal, it must be diagnosed and treated as soon as possible.

In order to ensure rapid analysis of CRS, various biomarkers in the blood that are typical of an inflammatory response must be detected rapidly and with high sensitivity. This can be detected and quantified via fluorescence- or luminescence-based assays on a microfluidic chip. Currently, diagnosis is symptomatic (i.e., delayed, nonspecific) and via blood tests (i.e., invasive). Online monitoring that immediately detects the occurrence of CRS would be desirable.

This is where the KODIAK joint project comes in. In addition to the biological assay, electronic, optical, and fluidic components and associated integration techniques will be developed and their utility demonstrated on a lab-on-chip system for CRS diagnostics.

The employees of Fraunhofer IZI working at the MEOS center are developing the luminescence assay for CRS detection as part of KODIAK. The detection is performed in optically transparent microfluidic cavities to which SPAD (Single Photon Avalanche Diode) sensors of the project partner IMMS are attached for optical detection.

The necessary optical design comes from Fraunhofer IPMS. Overall, the new technology is expected to help detect serious disease processes earlier, use clinical capacities more effectively, and strengthen medical care for patients.

s.fhg.de/KODIAK-en

M³Infekt: Mobile Monitoring of COVID-19 Patients

The Fraunhofer cluster project M³Infekt started in 2020 in order to develop a monitoring system that enables rapid intervention in the case of sudden medical condition deterioration in the context of a COVID-19 infection – and does so in a modular, multi-modal, and mobile way in normal wards as well as out-of-hospital settings. At the end of the 2021 project, with the participation of Fraunhofer IPMS, two sensor technologies were developed to a high level of maturity and successfully tested in measurements in a hospital environment. The systems can thus help to mitigate the course of disease, shorten the duration of therapy, and make flexible use of intensive care units.

As part of the project, systems in body-worn sensor technology, non-contact vital sign acquisition, and breath analysis were developed. Parameters of the cardiovascular system (including heart rate, ECG, oxygen saturation, blood flow situation) and respiration (including respiratory rate/volume, breath analysis) were measured. In order to facilitate diagnosis, AI-based methods were chosen as the basis for evaluation.

On the technological side, Fraunhofer IPMS was primarily concerned with two topics in the project: ultrasound-based breath analysis and ion mobility spectrometry (IMS) for biomarker detection. An ultrasonic spirometer was developed to record physical respiratory parameters (e.g., respiratory volume and respiratory rate). This consists of a reusable system for electronics and data processing and a disposable module for sensor technology. The newly gained knowledge about the individual components of the spirometer, the technical challenges of these, and the feedback from the clinical study as well as discussions with clinical professionals revealed great potential for the further development of the system.

Regarding ion mobility spectrometry, a sampling system for breathing air was established at the MEOS center together with Fraunhofer IZI. For this purpose, the patient must exhale into a Tedlar® Bag: This is done either via a tube and an optional mouthpiece or a nose adapter. Both systems were tested within the project on reference devices as well as in the clinic in order to record and evaluate the respective advantages and disadvantages. Complementing this approach, a functional laboratory demonstrator based on a MEMS filter device enabling Field Asymmetric Ion Mobility Spectrometry (FAIMS) was developed.

The M³Infekt consortium, which was led by Fraunhofer IIS and the Fraunhofer Center MEOS, consisted of 10 Fraunhofer institutes and four medical partners. The sensor modules were developed by the end of the project in September 2021. The clinical testing and system integration of these will take place subsequently.

Contact partner

Dr. Michael Scholles
Head of Fraunhofer Center MEOS
+49 361 66338-151
michael.scholles@ipms.fraunhofer.de

Confocal Microscope for Rapid Detection of Tumor Boundaries During Surgery

Every year, approx. 500,000 people in Germany are diagnosed with cancer. Diagnostics and treatment are continually evolving. However, it is still almost impossible for physicians to quickly determine the success of a tumor resection during surgery. For example, after the surgical removal of a tumor, it is still today customary to take a tissue sample from the wound margin and have it pathologically examined in the laboratory in order to ensure that all tumor cells have been removed. This process can take up to 20 minutes. A method that can be used quickly, reliably, and directly on site in the operating room would be desirable. Employees of Fraunhofer IPMS and Fraunhofer IZI have therefore jointly developed a new confocal microscope for intraoperative tumor diagnostics in the Fraunhofer Center MEOS.

It is not often easy to distinguish between healthy tissue and tumorous tissue. The goal of tumor surgery is to create tumor-free resection margins while preserving the surrounding healthy tissue. This is currently hindered by the fact that three-dimensional imaging of the tumor margin is not possible with current technical solutions. Histological analysis during surgery is generally feasible. However, it is time-consuming and not feasible for all tissue types (e.g., bone). There is thus a great need for an easy-to-use optical method that differentiates healthy tissue structures from tumor tissue intraoperatively and within a short period of time.

At the Fraunhofer Center MEOS, employees of Fraunhofer IPMS and Fraunhofer IZI have jointly developed a MEMS-based laser scanning microscope and a fluorescence marker method of tumor cells. The goal is to localize tumor boundaries as best as possible in order to ensure complete preservation of brain cells and arteries during neurosurgical procedures. In the first step, the tumor margin must be stained. Here, a special method for the specific staining of tumor cells is used. This was developed by Fraunhofer IZI and entails using fluorescence-labeled antibodies at the cell culture level. An image of the cut surface is then captured through the confocal microscope. At the heart of the microscope is a scanning mirror developed at Fraunhofer IPMS. This allows light to be deflected in the x- and y-directions, thereby generating an image virtually in real time. A lateral resolution < 1.0 µm can thus be achieved in the fluorescence image with an image field size of 200 × 200 µm² (960 × 960 pixels). For sectional images, the system is equipped with a z-shifter with a maximum path length of 2000 µm and 5 nm minimum step size.

In 2021, a demonstrator of the microscope was set up and successfully tested at the Fraunhofer Center MEOS in Erfurt. For this purpose, tissue samples were provided by the application partner, the Helios Clinic in Erfurt. Future work will focus on the use of AI for the automated detection of tumor resection margins, robotics to create an assistance system for surgical staff, and system adaptations for transfer to a clinical setting.

s.fhg.de/LSCOnco-en

Contact partner

Dr. Peter Reinig
Group Chemical Sensors
+49 351 8823-103
peter.reinig@
ipms.fraunhofer.de


Fraunhofer
LSC-Onco
MEOS


N
K
P

Next Generation Sensor Technology

As the basis for miniaturized, intelligent, and networked sensors and actuators, microelectronics is a key technology and enabler for digitalization, IoT, and Industry 4.0.

We are therefore researching ways to make sensors more powerful, more energy-efficient, and more intelligent. Through approaches such as edge computing in which data processing takes place directly at the sensor, we also help to increase the trustworthiness of the systems. In several projects, we have developed platform solutions with partners through innovative technologies so that SMEs can also benefit from our developments.

You can get an impression of our current research projects on optical, electrical, chemical, and ultrasonic sensors on the following pages.

NextNIR – Miniaturized MEMS-Based Near-Infrared Spectral Analysis

Miniaturized NIR spectrometer developed by Fraunhofer IPMS

Spectroscopic methods are already being used for non-destructive optical material testing in many areas. The near-infrared (NIR) spectral range with wavelengths from 900 to 1900 nm is particularly suitable for the analysis of plastics, foodstuffs, and agricultural products. Here, an increasing demand is developing for compact, mobile systems for fast and cost-effective on-site NIR analysis. The applications for this are manifold: the stringent monitoring of supply and process chains, incoming goods inspections, and environmental monitoring. Such mobile and compact MEMS-based systems are being developed by Fraunhofer IPMS in collaboration with its industrial partner Hiperscan GmbH.

The goal of the NextNIR project, which was completed in 2021, was to research and test spectroscopy systems in the long-wavelength NIR for high-performance, flexible, and cost-effective analyses. Innovations in the areas of functionality, miniaturizability, and mobility have resulted in new powerful and flexible optical NIR analysis systems. In addition to the established pharmaceutical incoming goods inspection of the project partner, new applications and markets, (e.g., in the food, textile, and recycling industries) can thus be developed.

Fraunhofer IPMS developed several demonstrators for MEMS-based monochromators for NIR spectral analysis and highly miniaturized NIR systems for use in smart phones. In addition, MEMS developments for longer wavelengths have been carried out in order to address the long wavelength NIR region (1400–2500 nm) with suitable diffraction gratings. This will enable more precise and trusted analyses than ever before.

Fraunhofer IPMS has achieved a special milestone in the development of a highly miniaturized NIR spectrometer based on MEMS grating chips. With a size of only 13 × 12 × 6 mm³, the module has a free spectral range of 900–1850 nm and a spectral resolution < 12 nm (FWHM). This allows the spectrometer to be integrated into the standard housings of mobile devices such as smart phones and tablets. This is promising for future applications. The project was funded by the Sächsische Aufbaubank (SAB) as part of the ERDF technology funding program.

s.fhg.de/NIR-en

Contact partner

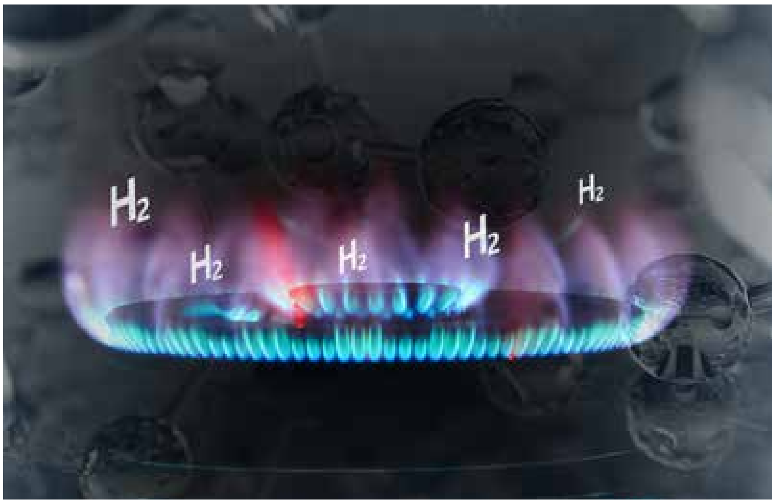
Dr. Peter Reinig
Group Chemical Sensors
+49 351 8823-103
peter.reinig@
ipms.fraunhofer.de

MUT4H2 – Characterization of the Hydrogen Content in Natural Gas Systems

The use of hydrogen as an energy carrier is an essential building block for the energy transition. In addition to production, transport and distribution are important aspects for green hydrogen. Among other things, existing natural gas pipelines will be used for this. However, in order for end users on site to use gas mixtures safely and effectively, an accurate knowledge of the gas mixture is essential. Fraunhofer IPMS is therefore developing a new technology for measuring gas mixtures based on micromachined ultrasonic transducers (MUT) within the MUT4H2 project. These enable compact and inexpensive analysis as well as the decentralized monitoring or control of local systems.

Gaseous systems are now characterized mainly via gas chromatograph (as in the case of hydrogen in the natural gas system). However, this method is too expensive, especially for smaller gas systems at end users. There, bellows gas meters, rotary meters, and turbine meters are still used for flow measurement. However, if hydrogen-natural gas mixtures are still to be used in the future, an accurate measurement capability is needed in order to ensure the suitability of existing heating systems at end users. Here, existing systems are suitable up to an H_2 admixture of 10% by volume; above this, the systems must be adapted.

The novel measurement system being developed in the MUT4H2 project is based on ultrasonic measurements by means of MUT. This enables inexpensive and uncomplicated measurement of gas fractions and flow velocity (e.g., of the hydrogen content in natural gases at the customer's site). Fraunhofer IPMS is developing a multi-sensor system consisting of a flow sensor, a hydrogen sensor, a pressure sensor, and a temperature sensor. The flow sensor will be based on the technology for capacitive micromachined ultrasonic sensors (CMUT) for non-corrosive gases. For the hydrogen sensor, the institute relies on a NED-MUT-based sensor for non-corroding binary gases based on a sound velocity measurement.



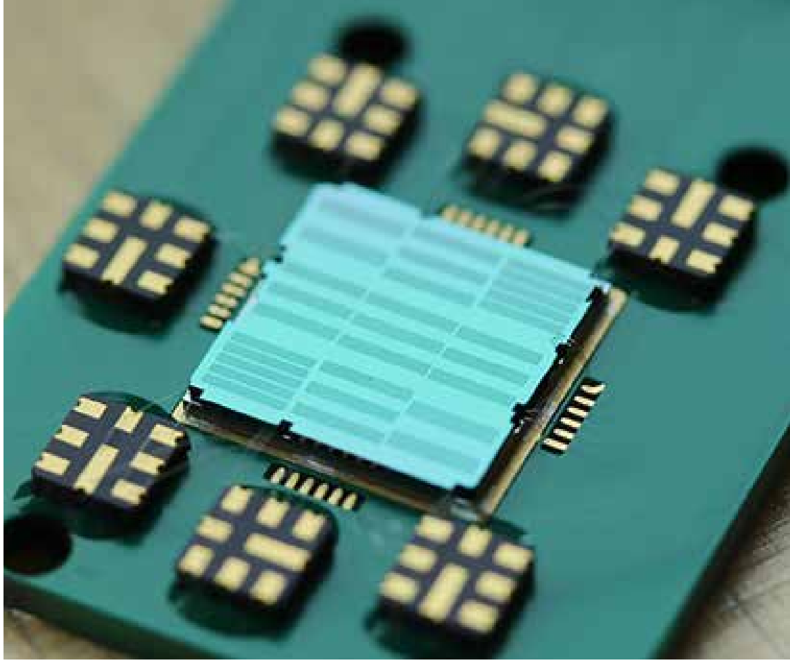
The integration of all individual sensors into a compact measuring system places high demands on the stability of the platform. The project aims at a compact and low-cost integration technology (< 50 cc) that includes a pre-processed digital interface for direct connection to a control unit. The demonstrator is thus intended to form the basis of a multi-sensor system for the characterization of gas mixtures in the industrial, home, and mobility sectors.

s.fhg.de/MUT4H2-en

Contact partner

Jörg Amelung
Division Director Active Micromachined Systems
+49 351 8823-4691
joerg.amelung@ipms.fraunhofer.de

Innovative Ultrasonic Sensors for SMEs



NEDMUT of Fraunhofer IPMS

Many current monitoring, measurement, and characterization tasks in industry are based on classic ultrasonic sensors. Micromachined ultrasonic transducers (MUT) represent an innovative and effective further development in this context. This can open up new areas of application thanks to the compact design and power efficiency. However, the investment costs for developing such MUTs are too high for many SMEs. Therefore, Fraunhofer IPMS and its partners established an application platform that also enables SMEs to use MUTs. In a first phase of the platform, different application areas of MUTs were evaluated through collaborations with industrial partners.

Whether distance measurement and micropositioning, gesture control and collision sensing, or endoscopy and sonography – ultrasonic sensors have formed the basis in industry, medicine, and mobility for many years. These application-specific sensors are currently developed and manufactured by the SMEs themselves. The use of modern MUTs allows the realization of highly compact systems and an increased sensitivity as well as the efficient use of array functionalities such as imaging and directivity. In addition, materials that are harmful to health and the environment can be avoided. However, this is offset by the additional, usually high, cost of developing these semiconductor based MUTs. This is where Fraunhofer IPMS, together with Fraunhofer ISIT and Fraunhofer ENAS, provides a remedy in a joint project.

The three Fraunhofer institutes (IPMS, ISIT, and ENAS) develop different technologies in order to offer solutions for a wide range of applications in the entire frequency range from 20 kHz to 20 MHz. Fraunhofer IPMS focuses on capacitive (CMUT) and electrostatic (NED) solutions, while Fraunhofer ISIT concentrates on piezoelectric (PMUT) ultrasonic transducers. Fraunhofer ENAS is developing both capacitive (CMUT) and piezoelectric (PMUT) ultrasonic transducers. From design to manufacturing, characterization, assembly, and interconnection technology to system integration, the institutes can offer development services along the entire value chain.

The modular platform approach allows innovative ultrasound systems to be quickly and efficiently adapted to specific applications and developed for SMEs. As part of the development of the MUT platform three central research fields were primarily addressed: production technology, human-machine interaction, and medical technology.

In order to steer developments in a targeted manner, joint workshops were held with interested industry partners early on in the project. Thus, potential opportunities and requirement profiles for MUTs were jointly derived. These laid the foundation for further feasibility studies and joint development projects. In the project, feasibility studies for the use of MUTs were carried out within four clusters with industrial partners for various fields of application. The aim was to demonstrate good integrability of the MUTs into existing systems and to make them directly applicable for SMEs. The project supported the successful launch of the platform, which will be continued in 2022.

s.fhg.de/KMUMUT-en

Contact partner

Jörg Amelung
Division Director Active Micromachined Systems
+49 351 8823-4691
joerg.amelung@ipms.fraunhofer.de

Object and Surface Monitoring with Ultrasound

CMUT Evaluation Kit of Fraunhofer IPMS

Grasping and placing objects and detecting surface properties are fundamental tasks in industrial robotics (machine loading, parts transfer, and grip-in-the-box) as well as service and assistance robotics (laboratory, agriculture, and hospital). For this purpose, standardized automation and gripper solutions are used in clearly structured processes. However, these are unsuitable when objects and surfaces with high variability or unknown properties need to be processed or when the environment is unstructured. In order to cope with the increasing diversity of objects and surface properties to be investigated as well as the action complexity in human-machine collaboration, the ProTaktilUS project has successfully developed ultrasound based miniaturized sensor systems with high spatial resolution.

As part of the project funded by the Fraunhofer Society, Fraunhofer IPMS together with Fraunhofer IKTS, EMFT, and IFF developed a system platform for ultrasound-based object and surface monitoring. Fraunhofer IPMS participated with its capacitive micromachined ultrasonic transducers (CMUTs). On one hand, these have been optimized for high-resolution contactless distance measurements in the megahertz frequency range and protective structures for air applications. On the other hand, they were successfully adapted and validated for use as sensitive, capacitive tactile sensors.

In order to test the ProTaktilUS platform in application, a demonstrator consisting of a robot with an adaptive two-finger gripper was set up at Fraunhofer IFF. Ultrasound based distance sensors in the gripper jaws detect an intervening object via 3D scanning (in-gripper scanning) and thus obtain a three-dimensional image in the form of a point cloud. The ultrasonic signals are also used to dynamically monitor the object position during a gripping process and thus ensure that the object is safely gripped by the robot (adaptive grasping). The next step is to use AI based evaluation algorithms to detect the surface shape and counteract the dynamic behavior of the object during transport (slip detection).

With the help of these new developments, various different gripping capabilities are now made possible. These are highly useful in industrial as well as assistance and service robotics: adaptive planning of the gripping and releasing process, grip validation, sensitive gripping, position and contour recognition, and object classification in the gripper. In addition, the high-resolution airborne ultrasonic sensor technology of Fraunhofer IPMS offers further application potential (e.g., in contactless topology analysis and gas flow measurement).

In order to enable customers to evaluate the ultrasonic transducers quickly and easily in their application, Fraunhofer IPMS also developed a fully functional test setup for CMUTs in the project. Users can thus convince themselves of the technical advantages of CMUT technology with little effort and evaluate the sensor technology for various application scenarios (e.g., close-range monitoring, acoustic spectroscopy, and flow measurement) in which there is a need for miniaturization with increased sensitivity.

s.fhg.de/CMUT-eval-kit

Contact partner

Dr. Sandro Koch
Group Manager
Ultrasonic Components
+49 351 8823-239
sandro.koch@
ipms.fraunhofer.de

iCampμs Cottbus – Microsensors from Lusatia

The Innovation Campus Electronics and Microsensors Cottbus – iCampμs – 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 iCampμs, Fraunhofer IPMS with its Cottbus branch is researching technologies in the areas of environmental sensor technology, Industry 4.0, and Smart Health.

Ultrasound Camera for Smart Health

Fraunhofer IPMS is pushing ahead with the development of an ultrasound camera, including the subsequent AI evaluation. In this process, the data received is analyzed by an AI-supported, adaptive network and can subsequently be used to control another system (e.g., alarm indicators).

Applications can be found in motion detection and object recognition in the security sector, surface scanning in industry, and status monitoring of sick people in hospitals and nursing homes. The latter enables the detection of not only the movements of sick persons at night but also vital parameters (respiratory cycles) thanks to the increased sensitivity and resolution.

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.

www.icampus-cottbus.de

Contact partner

Dr. Sebastian Meyer
Head of Branch Integrated Silicon Systems
+49 351 8823-137
sebastian.meyer@ipms.fraunhofer.de

Pilot Line for Smart Catheters

CMUT chips on a wafer

Approximately 10% of the Western population will be taken to a catheter lab at some point in their lives for angioplasty surgery (stent placement) in order to treat an arrhythmia or replace a heart valve. These procedures are supported by various smart, imaging, and sensory catheters that are the surgeon's "eyes and ears" directly at the point of intervention. However, the technology behind it has been developed only slightly over the past 10 years. At the same time, the demand for smaller, less expensive instruments with better functionality is increasing. In the Position II project, Fraunhofer IPMS and its partners are therefore developing a platform solution that will enable innovations with a high production volume to be marketed with little effort and at low cost.

One of the technologies used in smart catheters is MEMS-based ultrasonic sensors. There are many manufacturers for them in Europe; these are based on a number of different basic technologies, which differ greatly in the manufacturing processes, the addressable sensor properties, and the possible system integration. This makes it impossible to objectively assess which technology best meets the requirements for catheters or other specific applications.

In the Position II project, Fraunhofer IPMS in cooperation with partners developed a benchmarking of micromachined ultrasonic transducers from leading suppliers for piezoelectric (PMUT) and capacitive ultrasonic transducers (CMUT) in order to pave the way for further and innovative new developments based on the findings.

In order to achieve an objective comparability of different technology approaches, performance and operating parameters, and technology maturity levels, the specifications and chip layout for the MEMS chips to be compared were specified to be as similar as possible. Based on this, test structures were manufactured and compared with each other.

As a result, CMUTs such as those developed by Fraunhofer IPMS achieved the best performance as well as the highest level of technological maturity. The combination of max. generated sound pressure and high bandwidth receive sensitivity make this technology promising beyond the medical application of smart catheters.

Based on the benchmark, a demonstrator with integrated test chip was built at Fraunhofer IPMS. The modules consisting of housing, printed circuit board, and integrated preamplifier electronics are suitable for all chips created within the project. This means that customers can immediately select a suitable chip from the portfolio and set it up in the demonstrator. These much shorter development cycles from requesting a MEMS system to testing it in an application enable much faster development of new ideas and reduce the gap between research results and the path to market.

www.position-2.eu

Contact partner

Marco Kircher
Group Ultrasonic Components
+49 351 8823-361
marco.kircher@ipms.fraunhofer.de

Digitalization & Data Communication

Every day, we generate vast amounts of data. In 2018, there were 33 zettabytes – 33,000,000,000,000,000,000,000 bytes – worldwide. For 2025, 175 zettabytes per year are predicted (source: Statista). Progressive digitalization is bringing us into an age of knowledge characterized by digital technologies and innovations.

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.

We are also committed to making high tech accessible to SMEs, the backbone of German industry. Here we are working with partners on flexible and cost-effective platform solutions.

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

T-KOS – Terahertz Technologies

In our digitalized, high-tech world of life and work, the availability of communications and data connections is a basic requirement. The increasing mobility of users, the flexible use of broadband multimedia content (e.g., entertainment, medicine, logistics), and the adoption of technologies such as the Internet of Things (IoT) or autonomous driving are increasing both the volume of data in mobile networks and the demands on the communications networks themselves. One promising option for increasing data capacity and usable bandwidth is the additional use of terahertz technologies. In the joint project T-KOS, Fraunhofer IPMS is developing high-frequency front-end solutions from 60 to 500 GHz as well as an energy-efficient AI accelerator based on in-memory computing.

Although terahertz radiation is predestined for a wide range of applications (e.g., in security technology, quality assurance, and materials testing) industrial introduction has so far failed because of the lack of availability of inexpensive, fast, and high-resolution systems with optimized, AI-based image recognition algorithms.

In the joint project T-KOS, 10 Fraunhofer institutes are now working to synergistically develop terahertz technology for wireless radio transmission, non-destructive testing, spectroscopy, and non-contact in-line measurement technology. Together, they are developing three demonstrators that address the future fields of high-frequency electronics, terahertz photonics, and wireless, high-bit-rate communications.

A special focus is on building a German value chain to terahertz radio links (e.g., for high-bit-rate communication in industrial production and in-line monitoring of production processes with AI-based and real-time imaging processing for resource-efficient production). Industry-ready terahertz communication and sensing will also be demonstrated for the first time by combining scalable electronic and photonic concepts.

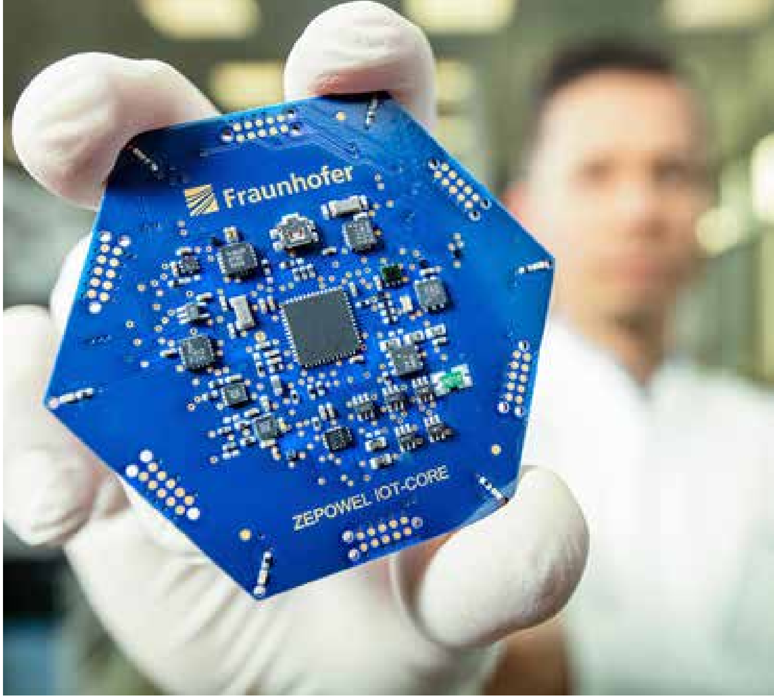
In the project, Fraunhofer IPMS focuses on RF/millimeter-wave front-end solutions with high output power in the frequency range of 60–500 GHz. In addition, energy-efficient AI accelerators based on in-memory computing are designed in technology nodes such as 28 nm HKMG as well as 22 nm FDSOI. Building on transceiver systems already developed at 240 GHz and 480 GHz in SiGe BiCMOS technology, a solution is being developed for 300 GHz with increased transmit power dynamics. Furthermore, an FPGA implementation is developed as a precursor to an in-memory computing ASIC core in order to establish an optimal bitwise computing architecture for terahertz data classification requirements.

s.fhg.de/TKOS-en

Contact partner

Dr. Thoms Kämpfe
Group Manager
Integrated RF & AI
+49 351 2607-3215
thomas.kaempfe@
ipms.fraunhofer.de

ZEPOWEL – Power Electronics for Economical Radio Communication



Energy self-sufficient sensor node

Today, increasingly more devices are connected wirelessly with the help of intelligent sensors. But as the number of devices in the growing IoT increases, so does the power demand. In the Fraunhofer lighthouse project Zero Power Electronics (ZEPOWEL), hardware that makes the sensors not only energy-efficient but energy-saving was developed. The result is two sensor nodes for different application scenarios: for harsh industrial conditions and for data acquisition in an urban environment. Fraunhofer IPMS developed the technologies for energy harvesting for energy management and storage.

Whether it's protecting your home from burglars or keeping an eye on the machines in a factory, sensors for monitoring and control are on the rise. Sensors that report when a window is suddenly opened or those that register that a machine is idling and wasting energy. However, these sensor nodes still consume large amounts of energy themselves because of their high numbers.

Fraunhofer IPMS therefore worked with seven other institutes to develop particularly efficient solutions: a self-sufficient "smart city" sensor node that independently supplies itself with energy and collects environmental data (e.g., on air quality) and an intelligent sensor node that records the operating status of machines, motors, or pumps in order to drastically reduce their energy requirements.

The "SmartCity" node is characterized by the fact that enters an energy-saving deep sleep mode when it is not needed. In this state, it consumes only a few nanowatts, which can also be provided via energy harvesting. Only when it is activated via radio does it start up – for example, in order to measure fine dust and send the measured values via radio. Because of its small size and maintenance-free and low-cost manufacturing, it can be used in many places in order to establish fine-mesh measurement networks. Fraunhofer IPMS focused primarily on the areas of energy harvesting and energy storage.

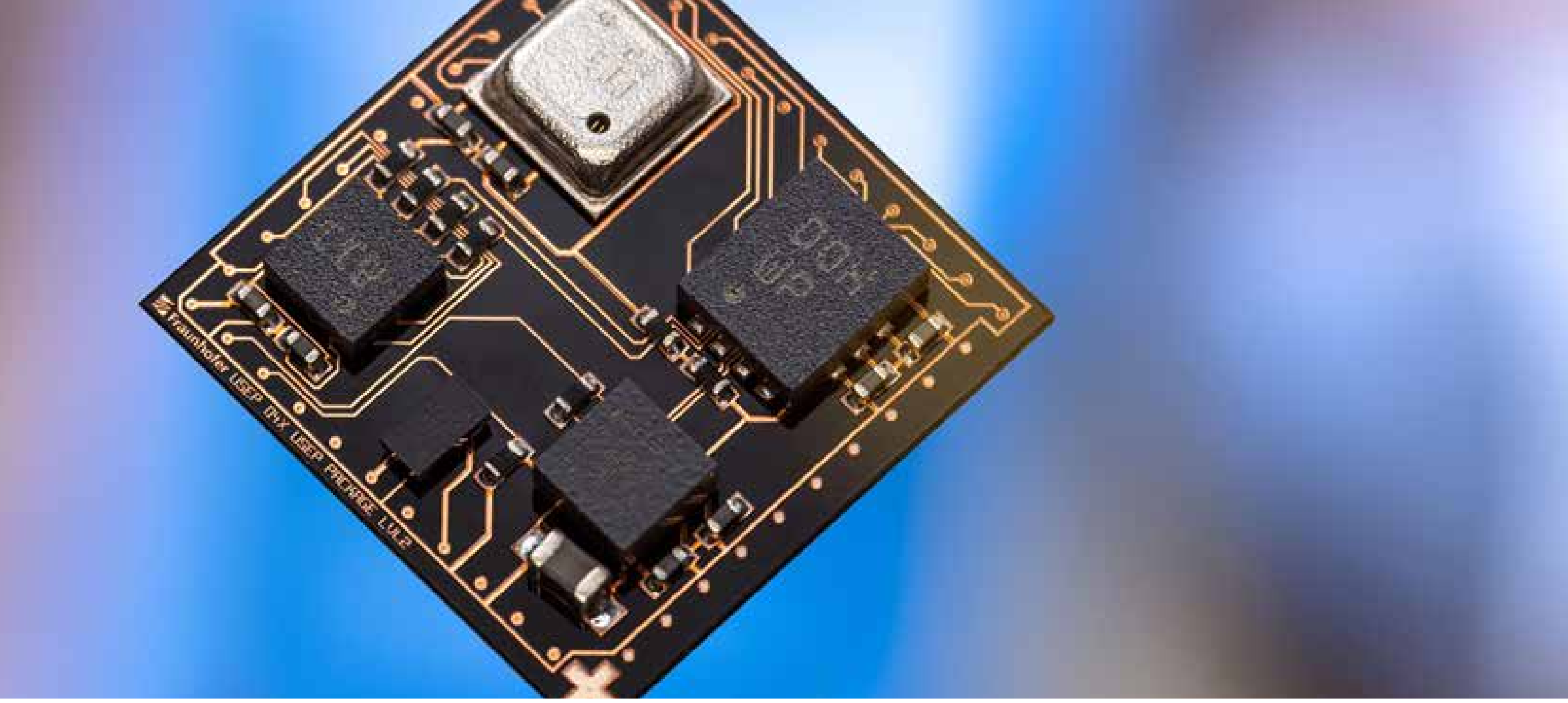
Concepts for integrated circuits for energy harvesting and energy management were researched and integrated into self-designed chips (ASICs). These were then combined with Fraunhofer IPMS integrated energy storage systems and successfully tested.

The sensor node for industrial applications has been especially optimized for harsh environments. This applies to both the requirements for communication and data exchange in heavily occupied and possibly disturbed frequency bands and stresses caused by ambient temperatures, vibrations, and dust. In contrast to the "SmartCity" demonstrator, the technologies for energy harvesting here are much more specifically tailored to the place of use. For example, a harvester that can extract energy from rotating or vibrating parts was developed. Because of the high number of sensors, the connection to the electrical supply and its maintenance becomes the driving cost factor. On the road to Industry 4.0, alternative, wireless energy supply is an essential building block.

s.fhg.de/ZEPOWEL-en

Contact partner

Sascha Bönhardt
Group Low Power Functions
+49 351 2607-3026
sascha.boenhardt@
ipms.fraunhofer.de



USeP – Universal Sensor Platform for SMEs

How can we develop a highly integrated, multi-channel sensor solution for mechanical engineering? Or a networked sensor system for building automation? For SMEs, the development of smart systems tailored to requirements, miniaturized, and adapted to individual specifications is often a complex and expensive undertaking. Fraunhofer IPMS has therefore developed a sensor platform with collaborative partners that can be used to create individually configurable IoT and edge computing solutions. This means that, for the first time, small and medium-sized suppliers can now produce particularly powerful, energy-efficient, and highly integrated systems at low cost.

The sensor platform offers an energy-efficient and high-performance system-on-chip design. Thanks to its flexible modules and the associated software environment, it enables the uncomplicated integration of different physical sensors, which can thus be perfectly adapted to the requirements of the respective customer. The central computing and control unit is based on a powerful 32-bit RISC-V processor with nine cores. This open-source processor architecture is considered forward-looking – not least because of its openness and flexibility – and provides the ideal basis for secure and trusted electronics.

The universal sensor platform has already passed its first practical test. Within a cooperation of Globalfoundries Dresden with five other companies from the hardware and software sector, it was the core of an edge AI pilot solution. With the help of these, the companies were able to develop an initial product version (minimum viable product) for the predictive maintenance of ultra-pure water valves in chip production within just three months.

In the meantime, the project has even grown into an independent company: The start-up Sensry in Dresden not only offers its customers the opportunity to tailor highly integrated sensor electronics modules using the Universal Sensor Platform but can also provide interested SMEs with the expertise of USeP development partners. This gives them a supply chain with which they can efficiently implement their ideas and visions: Concept development, system design, processors, sensor technology, and data transmission as well as the simulation and testing of your planned system are supported comprehensively and sustainably.

s.fhg.de/USeP-en

Contact partner

Dr. Frank Deicke
Head of Business Unit
Wireless Microsystems
+49 351 8823-385
frank.deicke@
ipms.fraunhofer.de

RISC-V Core for Functional Safety in the Vehicle

Safety-relevant applications can be found everywhere in the world: in drive controls, automation technology, and vehicles. Safety standards such as IEC 61508 guarantee that electronic systems meet the latest safety requirements. This also applies to processors used in such systems. Fraunhofer IPMS has now launched the first ISO 26262-certifiable RISC-V processor core for safety-critical functions in vehicles: the EMSA5-FS.

The embedded RISC-V processor core developed by Fraunhofer IPMS for applications in the context of functional safety is a 32-bit, in-order, single-issue, five-stage pipeline processor. With the fault-tolerant design and included safety documents, users can more easily and quickly achieve ISO 26262 certification up to ASIL-D, the highest automotive safety integrity level.

The RISC-V core is therefore suitable for use in safety-critical systems in vehicles. Thanks to the support of multiple IDEs, the processor core enables efficient and professional software development for complete systems. Available FPGA-based development kits and sample designs also facilitate certification, evaluation, and rapid prototyping.

Developers using the EMSA5 FS processor core can use open-source RISC-V development environments (IDE) and test tools and libraries, including the GNU tool chain and the comprehensive Eclipse IDE with OpenOCD debug support. Fraunhofer IPMS is also working with commercial third-party compiler and software tool vendors in order to enable support for EMSA5-FS through safety-ready development tool sets. For example, using IAR Embedded Workbench enables end-to-end IEC 61508 and ISO 26262 compliant development. This allows companies to simplify their own certification process, increase the quality of their own design process, and save costs throughout the product life cycle.

The EMSA5-FS processor core of Fraunhofer IPMS can be made available for any FPGA platform. Integration into customer-specific ASICs for any foundry technologies is also possible. Fraunhofer IPMS also provides services to extend the IP core with customer-specific modules.

s.fhg.de/EMSA5-en

Contact partner

Marcus Pietzsch
Group Manager
IP Cores & ASICs
+49 351 8823-355
marcus.pietzsch@
ipms.fraunhofer.de


-CONTACTS
-MESSAGES
-PEOPLE
-FORUMS
-MAIL
-SHOP
-BUY
-SALE
NEWS

On-Board Networking with Lowest Latency for the Modern Vehicle

Digitalization is also making its way into vehicles. Numerous sensors for condition monitoring, comfort functions, infotainment applications, drive and driver assistance systems – even today, more than 70 ECUs are used for this purpose. These signals must be prioritized and transmitted via communication protocols. Important for this is a high-performance vehicle network such as Automotive Ethernet, which offers advantages such as standardization, scalability, and support for IP protocols. Fraunhofer IPMS is developing platform-independent IP core controllers with low latencies for this purpose.

Modern vehicles generate and transmit data continuously in order to get passengers safely and comfortably to their destinations. Numerous sensors for condition monitoring, comfort functions, infotainment applications, drive and driver assistance systems – even today, more than 70 ECUs are used for this purpose. These signals must be prioritized and transmitted via communication protocols. The data traffic that can no longer be provided by classic systems is correspondingly high. Time Sensitive Networking (TSN) is a key technology for deterministic automotive Ethernet networks with guaranteed bandwidth and low latencies.

The automotive industry is moving away from the use of many individual ECUs connected via comparatively slow classic bus systems such as CAN or LIN to centralized computing units networked with high bandwidths and low latencies. The demands of energy efficiency, safety, and economy can thus be reconciled. Open solutions that are standardized worldwide for compatibility reasons (e.g., IEEE 802.1/.3 Ethernet) are coming to the fore.

Building on these standards, Fraunhofer IPMS is developing platform-independent IP cores for in-vehicle communication. The automotive IP cores are suitable for integration in both FPGAs and ASICs. Pre-certification according to ISO 26262 up to ASIL-D greatly reduces the development and approval process of the overall system because all functions, including the necessary safety features, are fully implemented and tested. This guarantees maximum functional safety in the vehicle; costs and time spent on system development are also minimized.

The IP portfolio currently consists of a CAN Controller Core (CAN 2.0, CAN FD and CAN XL), various TSN Cores, a LIN Controller Core, and a Low Latency Ethernet MAC Core. In addition, customer-specific design adaptations are also made, or systems are developed based on special customer requirements.

s.fhg.de/Automotive-IP-en

Contact partner

Marcus Pietzsch
Group Manager
IP Cores & ASICs
+49 351 8823-355
marcus.pietzsch@
ipms.fraunhofer.de

SURPRISE – Spatial Light Modulators for Space Applications

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

The main goal of the project is to develop a demonstrator. Core parameters include spectrally broadband operating range – in the 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. Compressive Sensing also 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 are the most suitable solution for this task because 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 developed 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 manufacture of spatial light modulators in order to find the best solution for the specific requirements in the project. The biggest challenges here are the space capability of all components and the coverage of a broad spectral range from visible to mid-infrared.

Fraunhofer IPMS leads the activities in the project regarding the spatial light modulators. The main tasks are to contribute to demonstrator development and to prepare a feasibility study and development road map for a first space-qualified spatial light modulator (SLM) developed entirely in Europe.

www.h2020surprise.eu

Contact partner

Sara Francés González
Group Light Modulator
Product Development
+49 351 8823-472
sara.frances-gonzale@
ipms.fraunhofer.de

Range Optimization of Wireless Sensor Networks

In many sparsely populated regions, only a weak mobile communications infrastructure can be found. This makes the digitalization of measuring points a major challenge – be it for flood protection, monitoring of groundwater / water, forest fire, structure, infrastructure, and terrain, as well as in digital agriculture. Especially the radio interface for networking sensors with cloud applications or centralized monitoring stations is range-limited in many cases; this makes coverage in highly distributed scenarios particularly difficult. Fraunhofer IPMS and its partners are therefore researching energy-efficient sensor technology with a long range.

The main challenges for mobile communications infrastructure in rural environments are the distances to be covered as well as the efficient use of limited battery capacity in remote locations without a central power supply. In many cases, decentralized energy generation (e.g., with the help of photovoltaic cells) can ensure self-sufficient operation in the long term. But especially in industrial use, there are many applications where solar energy or other sources are not available in sufficient quantities or size and weight limitations prohibit concepts for energy generation. There is thus a great need for purely battery-powered wireless sensor nodes that nevertheless guarantee a long runtime. The individual measuring points are also often widely distributed, thereby resulting in high energy requirements for transmission and reception.

To address these challenges, Actemium BEA GmbH, TU Hamburg, and Fraunhofer IPMS have joined forces in order to develop MEMS-based parametric amplifiers for the range optimization of wireless sensor networks. Because the radio interface has the highest energy demand of all components, this is the focus of the project. The basic idea is to generate energy for the amplifier from a high-frequency electromechanical excitation. This is to be made possible by a mechanical MEMS oscillator being developed at Fraunhofer IPMS. Furthermore, an energy-efficient sensor node is being created in the project. To this end, a microsystem is being manufactured in silicon at Fraunhofer IPMS; this will be integrated as an efficiency-optimized amplification element in the receiver at TU Hamburg. This solves the two biggest challenges – energy consumption and range. The application partner Actemium BEA GmbH will demonstrate the use of this system on its automation systems and machines or on decentralized measuring points.

Other possible sectors of economic utilization include digital agriculture and mineral resource extraction as well as the environmental monitoring and equipping of white goods (e.g., refrigerators, dishwashers, washing machines) with the novel and efficient radio and signal processing platform. This platform can be integrated into almost all applications in which large amounts of data are to be generated and transferred. If required, even the sequence control of downstream sensor technology can be taken over.

s.fhg.de/Sensor-networks-en

Contact partner

Dr. Christine Ruffert
Staff of Deputy Director Jörg Amelung
+49 355 69-4763
christine.ruffert@ipms.fraunhofer.de

Spotlight

Innovative Modeling Approach for Micro Loudspeakers

The Internet of Things and especially the Internet of Voice requires energy-efficient and high-quality audio devices. In-ear headphones pose a particular challenge in this regard. These battery-powered miniature devices are designed to cover an ever-increasing range of functions. An innovative loudspeaker technology developed by Fraunhofer IPMS represents an important development push thanks to its small component volume and high energy efficiency. In 2021, the institute presented its latest research results in the renowned "Nature Journal Microsystems & Nanoengineering".

The novelty of the loudspeaker technology developed by Fraunhofer IPMS is the silicon-based transducer principle, which no longer has a conventional membrane but rather works with bending bars. When an audio signal voltage is applied, these are excited to oscillate and produce audible sound waves. By integrating all components directly into the silicon chip, these sound generators are potentially much smaller and more energy-efficient than conventional loudspeakers. This will allow various other functionalities to be integrated into in-ear headphones. For example, they allow smart hearable applications such as instant translation, payment functions, and other Internet services – all voice-controlled and without the need to look at your smart phone. These multi-talents could even take over all Internet communication.

In 2021, Fraunhofer IPMS published its latest research results in the renowned "Nature Journal Microsystems & Nanoengineering". The paper "Coulomb-actuated micro-beams revisited: experimental and numerical modal decomposition of the saddle-node bifurcation" describes the further development of reduced-order models of electrostatically deflected micro-beams by numerically and experimentally investigating the modal contribution of Euler-Bernoulli modes to the static deflection. The findings allow the creation of reduced-order models based on the projection onto the Euler-Bernoulli zero mode, thereby enabling an accurate representation of the deformation of micro bars over a single degree of freedom.

Arioso Systems GmbH, which was spun off from Fraunhofer IPMS in 2019, is responsible for marketing the innovative research results. The potential of the novel micro loudspeakers is currently being evaluated in discussions with interested industrial customers. At the same time, the team is already patenting and implementing further ideas.

s.fhg.de/microspeaker-paper

Contact partner

Dr. Anton Melnikov
Group Monolithic Integrated Actuator and Sensor Systems
+49 351 8823-4635
anton.melnikov@ipms.fraunhofer.de

You Think it's Impossible to Visualize Noise? Think Again!

The Bremerhaven-based association "Rückenwind für Leher Kinder e.V." offers children from the Lehe district free care, leisure, and support services. The children find various activities here and learn to abide by rules. Nevertheless, it sometimes gets loud. Too loud. In order to ensure appropriate noise levels in various situations, a trainee project at Fraunhofer IPMS was dedicated to developing a feel-good traffic light to visualize the volume in rooms.

The feel-good traffic light uses clever technology to visually display the noise level in enclosed spaces. Comparable to a traffic light circuit, the feel-good traffic light lights up green when there is calm. If the ambient volume increases, the colors gradually change from green to yellow to red and finally to a flashing red signal. If the traffic light is in flashing mode for more than 5 s, an acoustic warning call will sound.

The feel-good traffic light can also be adjusted to the ambient volume. The noise thresholds are adjustable in three different levels. Level 1 can be used for silent work or rest periods. In this level, the feel-good traffic light comes on even for quiet noises. If Level 3 is set, a conversation is possible at the normal volume; the traffic light gives an "alarm" only when the noise level is loud. The feel-good traffic light is powered by a power bank, which allows mobile use for up to about 14 hours. If the battery is empty, the feel-good traffic light can be charged via an accompanying USB-C cable and used at the same time.

Trainees Sophie Kupke and Markus Kraetzig (see photo on top) are proud of their achievement. In the project, they were able to learn about the process, content, and management of a project and work independently. Teamwork, organization, and discipline were particularly important to them in order to successfully complete the project. And they succeeded: The feel-good traffic light was ceremoniously handed over to "Rückenwind für Leher Kinder e.V." in Bremerhaven on October 26, 2021.

s.fhg.de/noise-indicating-lamp

Contact partner

Dr. Olaf R. Hild
Group Manager
Chemical Sensors
+49 351 8823-450
olaf.hild@ipms.fraunhofer.de

Fairs and Events 2021

International Conference on IC Design and Technology (ICICDT)

September 15 – 17, 2021

Today, the mutual optimization of design and technology offers a decisive advantage in the highly competitive semiconductor market. Traditionally, in the production of integrated circuits, the design and technology were considered and developed separately. With a view to the future, this is no longer appropriate today. The IC development requires a deeper understanding of the interactions between design and technology options in order to ensure maximum product optimization.

ICICDT is a global conference for IC design and technology. It offers interested parties from research, engineering, and industry a forum for exchanging information on current trends in design as well as process technology in product development.

In 2021, Fraunhofer IPMS organized the ICICDT and created a successful online conference for about 90 participants with presentations, tutorials, and an extensive networking program. The unique workshop style of the conference provided technologists and product designers the opportunity to share breakthrough ideas and collaborate effectively.

The one-day tutorial program on plasma-induced damage, GaN power devices, neuromorphic computing for edge AI, and large-area silicon photonic MEMS switches was followed by two days of technical presentations and workshops. Topics that require close interaction and collaboration from all design, technology, and process fields in order to achieve improvement in product development and manufacturing were addressed.

Because the guests were unfortunately unable to be present in Dresden due to the pandemic situation, Fraunhofer IPMS also filmed a virtual city tour in order to introduce the site.

s.fhg.de/ICICDT-conference

s.fhg.de/city-tour

60 Years of Microelectronics in Dresden
October 2, 2021

On October 2, 1961, the "Arbeitsstelle für Molekularelektronik Dresden", founded by Werner Hartmann, started its work. Fraunhofer IPMS celebrated its 60th anniversary with the symposium "60 Years of Microelectronics in Dresden" at the Technische Sammlungen Dresden with around 100 participants. In lectures, contemporary witnesses report on the beginnings of the Dresden-based chip industry as well as its restructuring and transformation up to the present day.

MST Congress
November 8 – 10, 2021

Fraunhofer IPMS was represented at the joint booth of Research Fab Microelectronics Germany at the MST Congress in Ludwigsburg. In lectures and poster sessions, the institute presented current results and developments in intelligent MEMS-based sensor and actuator technology.

s.fhg.de/MST-Congress-2021

Workshop with HTW Dresden
October 15, 2021

Under the motto "From Sensor to User Interaction", representatives of HTW Dresden and Fraunhofer IPMS met to exchange views on current research priorities and to explore opportunities for cooperation. For example, they discussed how students can gain an early insight into practical work. The university representatives were very interested in formats such as showroom tours, cleanroom tours and – especially for higher semesters – hands-on teaching of skills in the laboratories of Fraunhofer IPMS. A follow-up to the workshop is planned for 2022 to further discuss the implementation of the ideas.

Semicon Europe
November 16 – 19, 2021

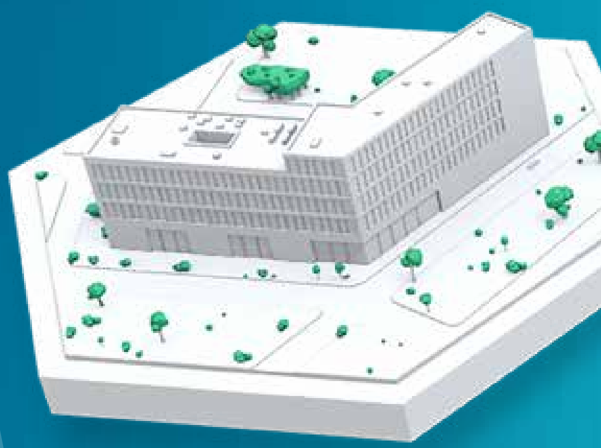
Fraunhofer IPMS presented an exciting mix of topics from the fields of semiconductors, sensor technology, Internet of Things, automotive, and medical technolog in the area of 200 and 300 mm research and development at Semicon Europa at the Silicon Saxony joint booth in Munich.

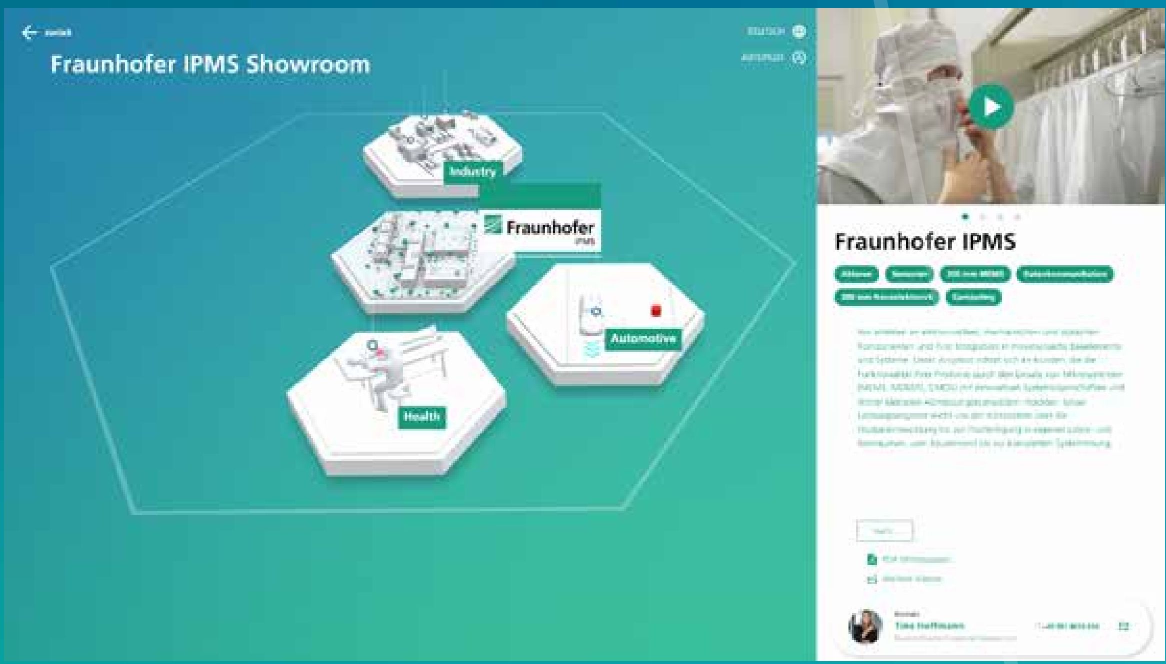
s.fhg.de/Semicon-Europe-2021

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. Enjoy!

www.showroom.leistungszentrum-mikronano.de





Contact partner

Dr. Anne-Julie Maurer
Head of Marketing &
Communication
+49 351 8823-2604
anne-julie.maurer@
ipms.fraunhofer.de

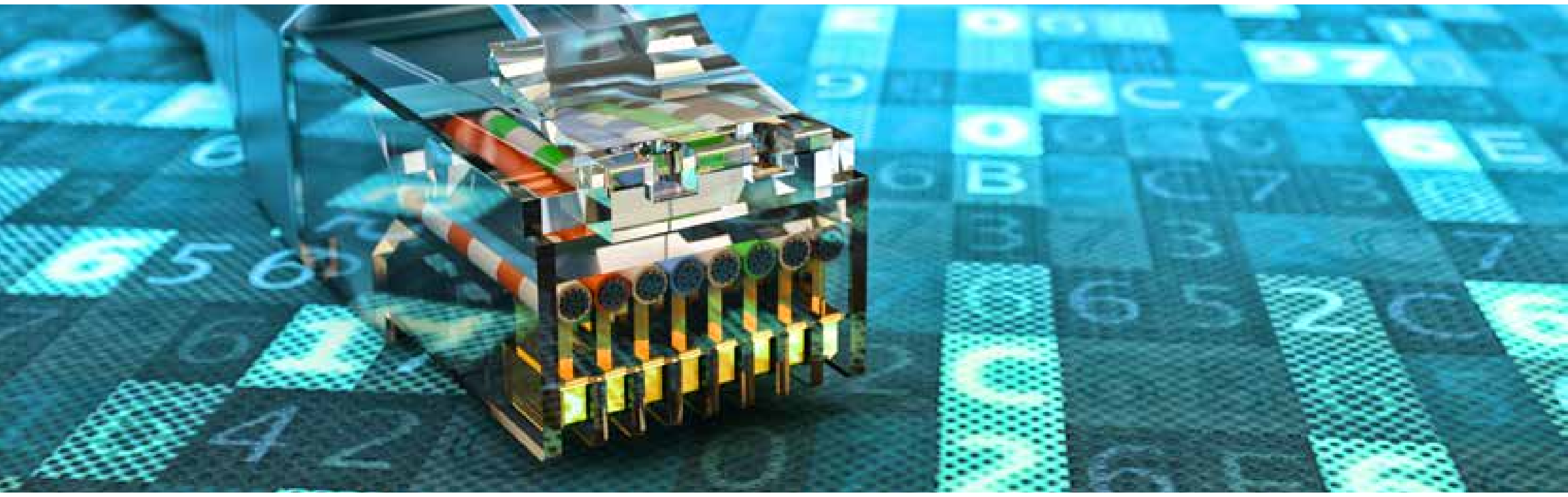
Fraunhofer

30 Years of Fraunhofer in Dresden

In 2022, the Fraunhofer Society will celebrate its 30th anniversary in Dresden. 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, the institute now has more than 500 employees and a budget of over €50 million. Follow us on social media throughout the year for more highlights from our exciting history.

Our Whitepapers

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

TSN Implementation Based on Intel FPGAs

The further development of TSN is intended to increase the degree of determinism in switched Ethernet networks according to IEEE 802.1 and 802.3. This means implementing Ethernet networks with guaranteed end-to-end latencies for real-time critical traffic, transmission of (time) critical and non-critical data over a convergent network, low packet loss, and low latency fluctuations (jitter). This whitepaper discusses possible implementations of TSN based on Intel FPGAs.

s.fhg.de/TSN-whitepaper2

TSN Ethernet Switched Endpoint Controller

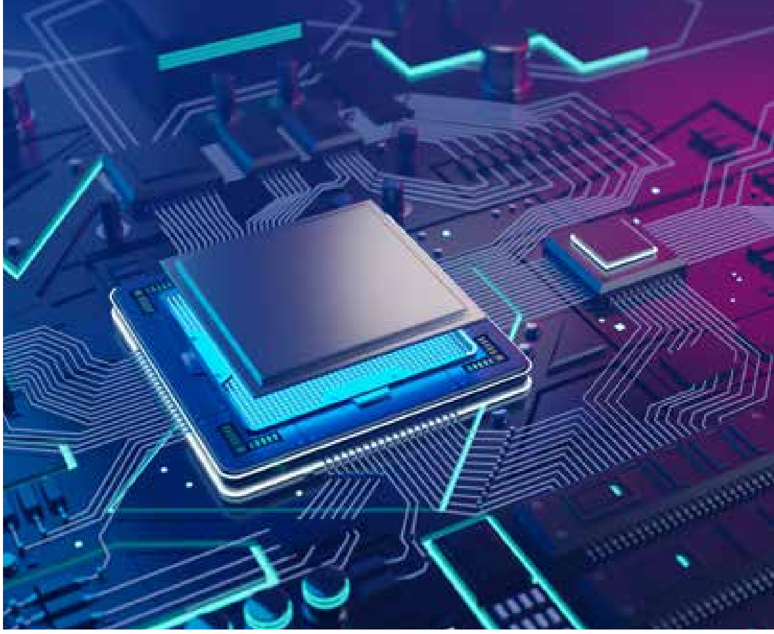
Time-Sensitive Networking (TSN) is the functional extension of IEEE 802.1 Ethernet networks currently under development by the IEEE. The set of standards is intended to enable time-critical and non-time-critical data to be transmitted simultaneously on a connected network. This whitepaper explains in detail the TSN Ethernet Switched Endpoint Controller and introduces potential use cases.

s.fhg.de/TSN-whitepaper3

Latency-Optimized TSN networks

Time sensitive networking (TSN) allows different protocols to share a common infrastructure across the network by optimizing critical real-time traffic and non-critical traffic to simultaneously enable real-time characteristics and optimal performance of data transmission. The whitepaper examines what advantages and disadvantages arise in practice with TSN from the use of different operating systems.

s.fhg.de/TSN-whitepaper6



CAN IP Core Design

Novel driver assistance systems as well as vehicle-to-vehicle networking and user-centric infotainment applications integrate a multitude of sensors and applications in automobiles. Some of these require high bandwidths and guaranteed low latencies for the transmission of user data. CAN as one of the dominant bus protocols – perhaps even the leading serial bus system worldwide – is ideally suited for these tasks. In the whitepaper, the CAN history is examined in detail, and the exemplary use in a customer-specific Fraunhofer IPMS subsystem is presented.

s.fhg.de/CAN-IP-Core-Whitepaper-en

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

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

Benchmarking of Ultrasound Technologies

Micromachined ultrasound transducers (MUTs) are suitable for use in medical imaging because they can be manufactured inexpensively and in large quantities using standard semiconductor technologies and enable 3D imaging. This white paper compares and benchmarks various European technologies. This allows customers to find the right technology for their application quickly and easily.

s.fhg.de/Ultrasound-Benchmarking

Find and download all of our whitepapers at:
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:

Multimodal, Modular and Mobile Sensor System for Improved Patient Monitoring

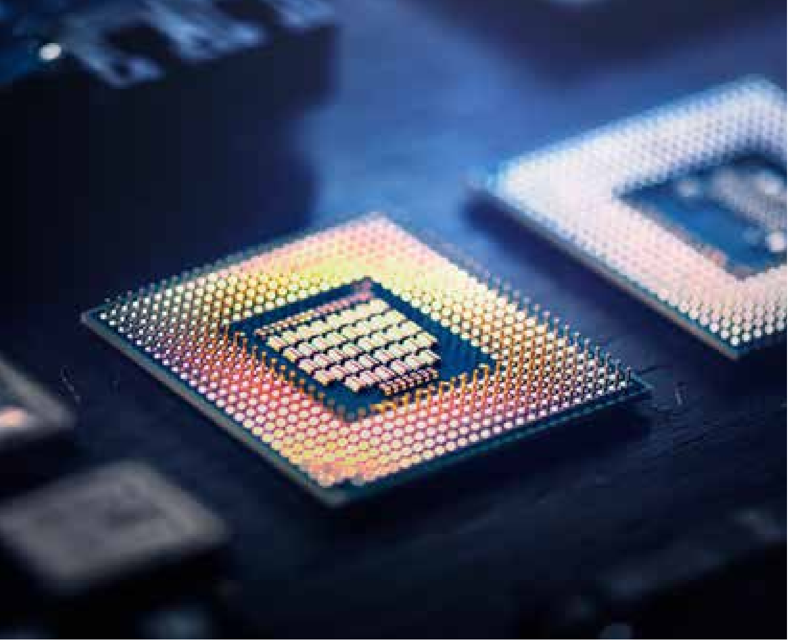
Analysis using compact chemical sensing systems based on a MEMS ion mobility spectrometer can provide methods for rapid testing. Optical sensor technology for mobile point-of-care diagnostics uses optimized components such as micro-ring resonators with functionalized surfaces. The docking of antibodies to the surface changes the optical properties of these devices, thus making them suitable for high-sensitivity, high-throughput detection. In addition to device and system development, the design of surfaces and their characterization are also part of the work.

s.fhg.de/patient-monitoring-webinar

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



Advanced Technology and Hardware for Next Generation Computing

Fraunhofer IPMS conducts applied research on 300-mm wafers for microchip producers, suppliers, equipment manufacturers, and R&D partners. We offer technology development and services at Ultra Large Scale Integration (ULSI) level in FEoL and BEoL. In this webinar, you will get a short introduction about our services. We will also give you an outlook on the research fields in this area for the next few years.

s.fhg.de/NGC-webinar

Material Development for MRAM and FRAM Stacks

Data is now the lifeblood that disrupts many industries. The vast majority of this data is stored in the form of non-volatile magnetic bits in hard disk drives. This technology was developed more than half a century ago and has reached fundamental scaling limits that prevent further increases in storage capacity. New approaches are thus needed.

The webinar will present FRAM (Ferroelectric Random Access Memory) and MRAM (Magnetoresistive Random Access Memory) as two promising concepts for future ultra-low power memory technologies. Special attention will be paid to material development and production on state-of-the-art industrial equipment for 300-mm wafers.

s.fhg.de/material-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

Enjoy all webinars in our media hub at **s.fhg.de/IPMS-Webinars**

Awards

Alica Lehmann

Tina Boehme

Jennifer Born

Alica Lehmann, who trained as an office management assistant at Fraunhofer IPMS, was honored as **one of the best 20 trainees in 2021**. Her instructors Tina Böhme and Jennifer Born also received awards.

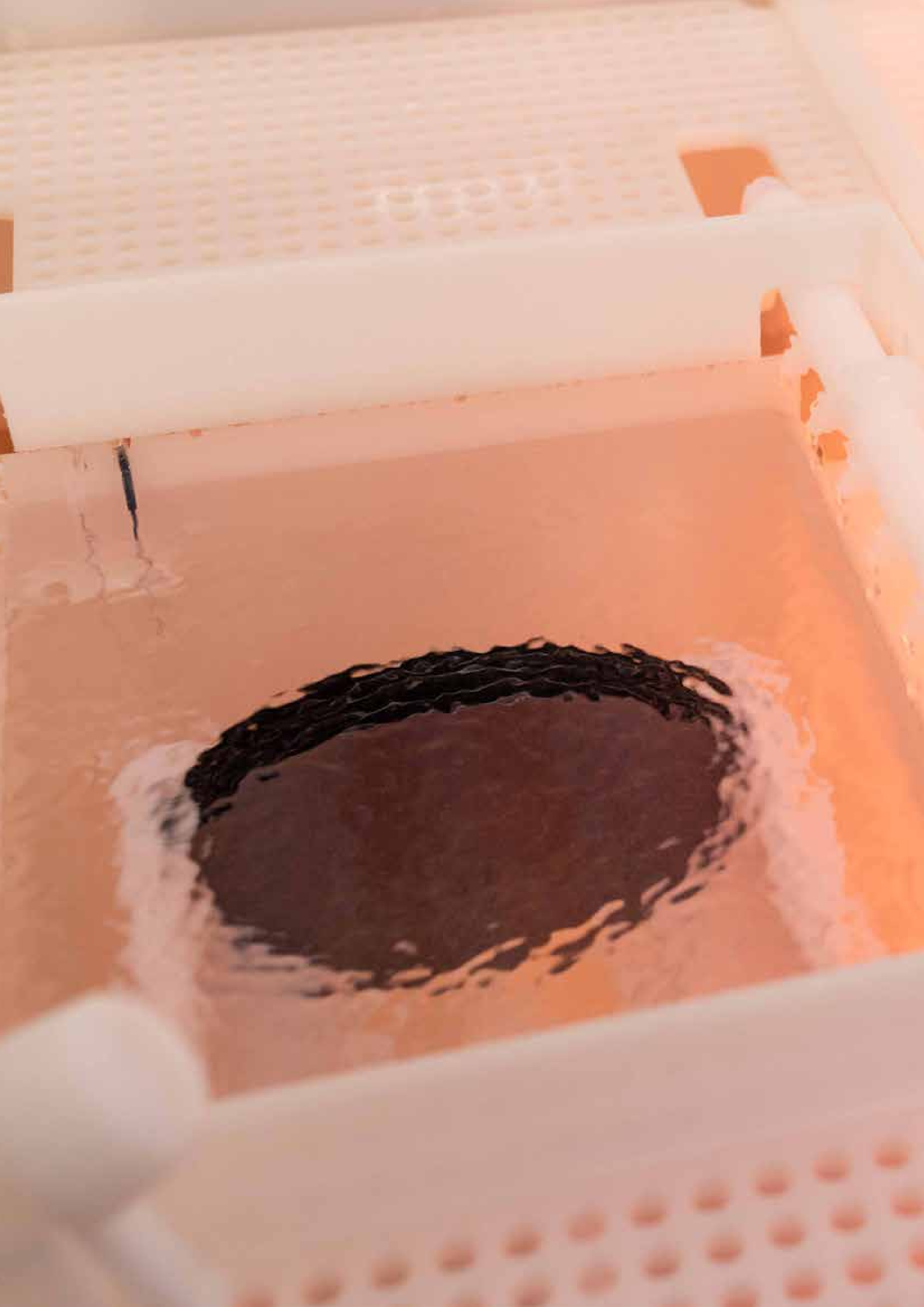
Franz Müller, PhD student at Fraunhofer IPMS, won the **Best Student Paper Award**at the VLSI "Technology, Systems and Applications Symposium" (VLSI-TSA) with his paper "Current percolation path impacting switching behavior of ferroelectric FETs".

Sören Köble

Severin Schweiger

At the IEE conference ISSE - "International Spring Seminar on Electronics Technology" – there were two reasons to celebrate. Sören Köble and Severin Schweiger were recognized for their excellent posters/papers. Sören Köble received the **"Excellent Poster Award for Junior Scientist"** for the poster "Capacitive Micromachined Ultrasonic Transducers (CMUT) Utilized as Tactile Sensors". Severin Schweiger received the **"Excellent Paper Award for Junior Scientist"** for the paper "Two-Photon Lithography Substrate Reflection and Absorption Compensation for Additive Manufacturing of Metamaterials on MEMS".

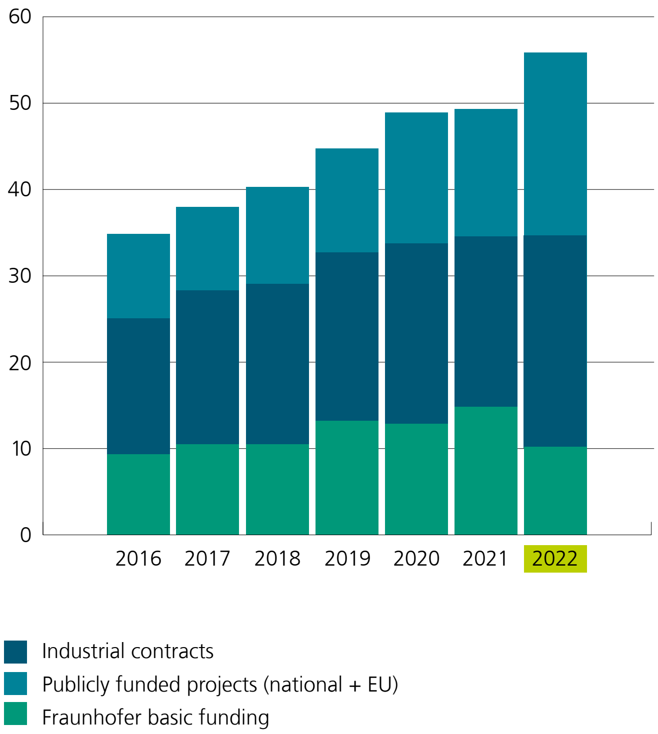

Fraunhofer
Beste Auszubildende 2021
Alica Lehmann



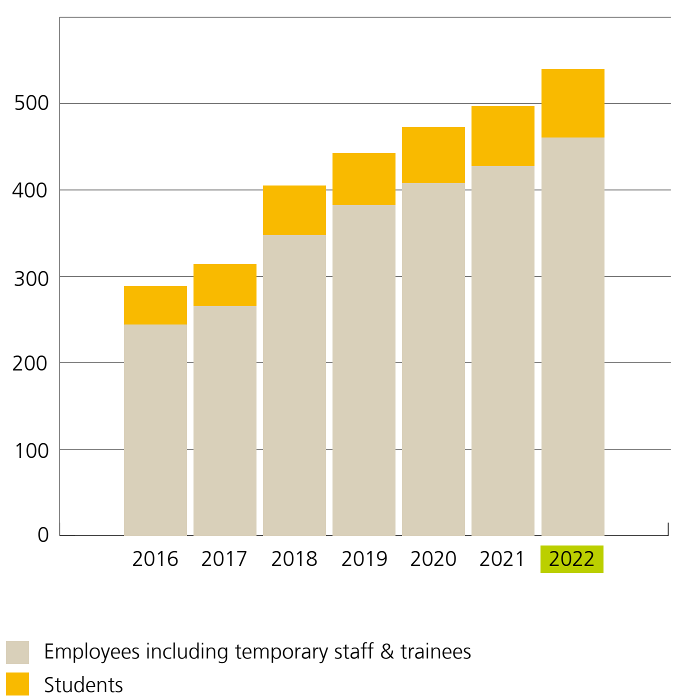
Fraunhofer IPMS at a Glance

Fraunhofer IPMS in Figures

Budget (in million Euros)



Employees



At a Glance

	2016	2017	2018	2019	2020	2021	2022
Industry in %	51	48,5	47	42.7	43.5	40.8	43.9
Public funds	22.1	24.6	27.3	27.1	31.1	29.9	36.5
Total revenue in %	73.1	73.2	74.3	69.8	74.6	70.7	80.4
Employees (number)	289	314	405	443	473	497	540

Plan

Advisory Board 2021

The following persons were members of our Advisory Board in 2021:

Industry Representatives:

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

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

Prof. Dr. Jörg-Uwe Meyer
MT2IT GmbH & Co.KG, General Manager

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

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. Alex Dommann
EMPA Swiss Federal Laboratories for Materials Science and Technology, Head of department "Materials meet Life"

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. Ronald Tetzlaff
TU Dresden, Faculty of Electrical and Computer Engineering, Dean

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

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

Services

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.

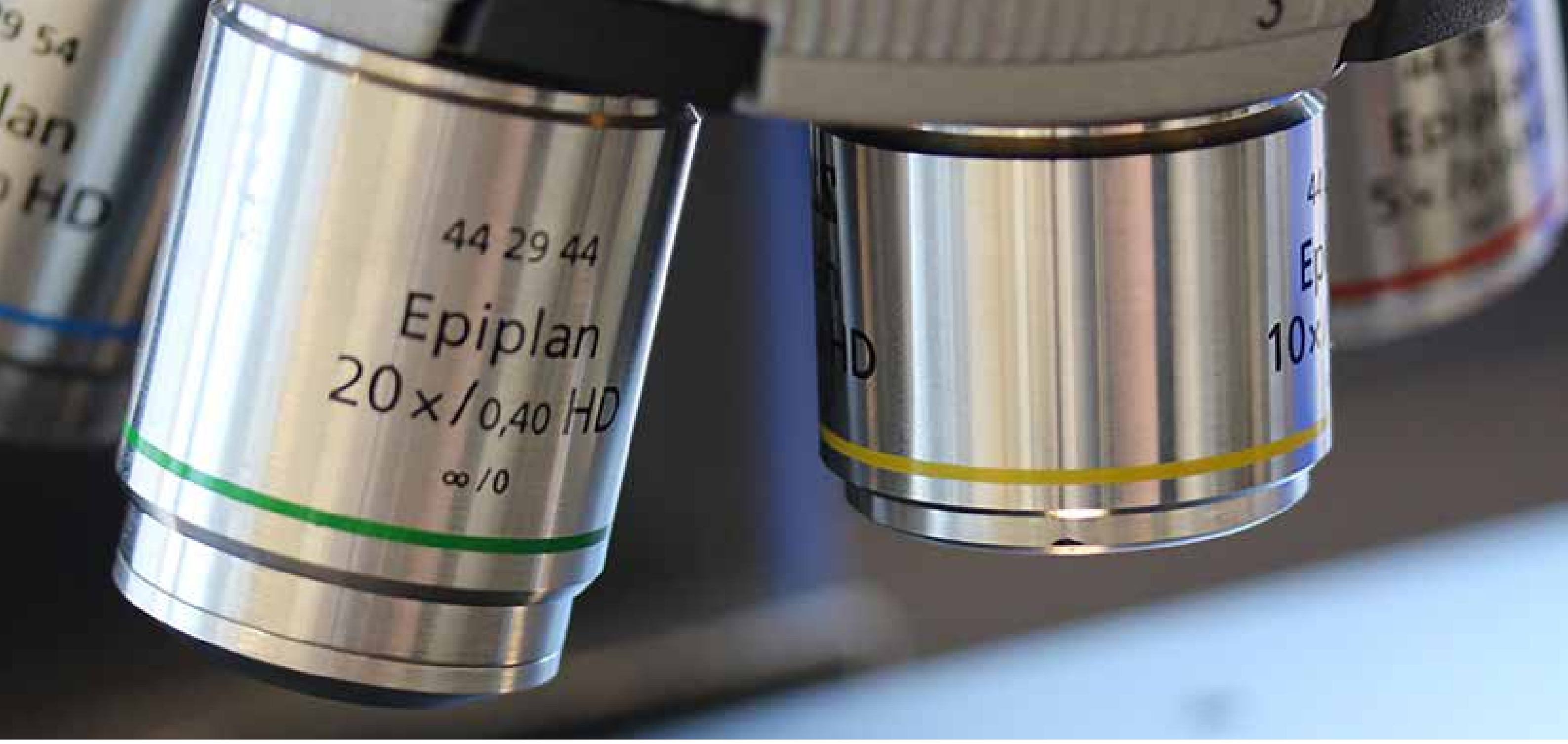
s.fhg.de/MEMS-Technologies-Dresden

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



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

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

You can find more information at:
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

The “QSDrive Scan Kit” evaluation kit allows small and medium-sized companies in particular to operate MEMS scanners from Fraunhofer IPMS according to specifications without the need for costly in-house development of drive electronics. The evaluation kit consists of a ResoLin device – a gimbal MEMS scanner with a linear axis and an optional, orthogonally oriented resonant axis – and drive electronics. The component is supported by a scan head, which is also included in the scope of delivery. Thanks to its special design, it can be easily integrated into common optical experimental setups.

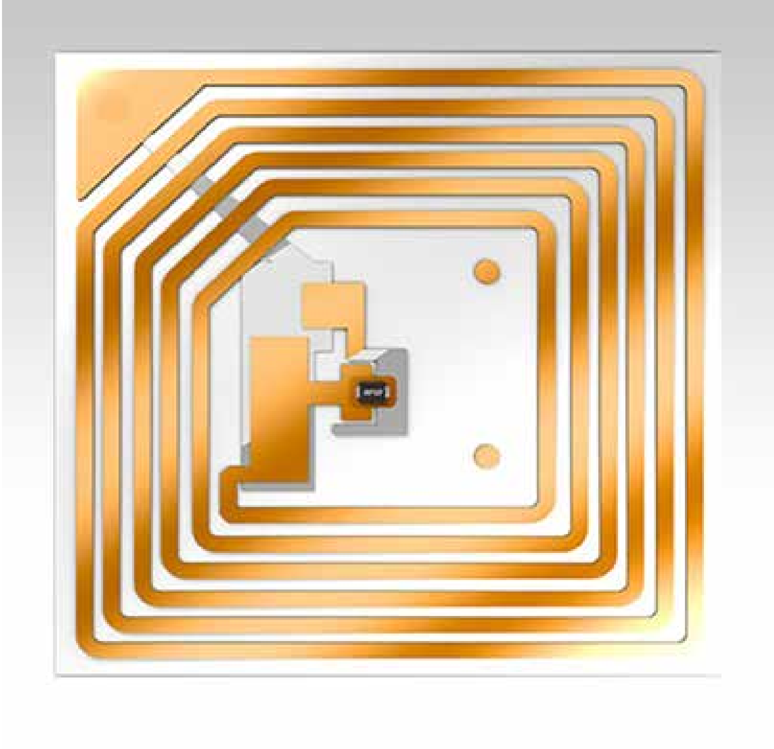
s.fhg.de/MEMS-eval-kit

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

s.fhg.de/Gigadock-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

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

RFID

This evaluation kit includes commercial and in-house developed RFID transponder ASICs for different frequency ranges. Thanks to an agile interface concept, we are able to flexibly integrate analog and digital sensor technology. In addition, our evaluation kits contain a software solution as middleware. Communication with any readers, identification and sensor transponders in the various frequency ranges (LF, HF, UHF and NFC) and from different manufacturers can be implemented in a uniform manner.

s.fhg.de/RFID-eval-kit

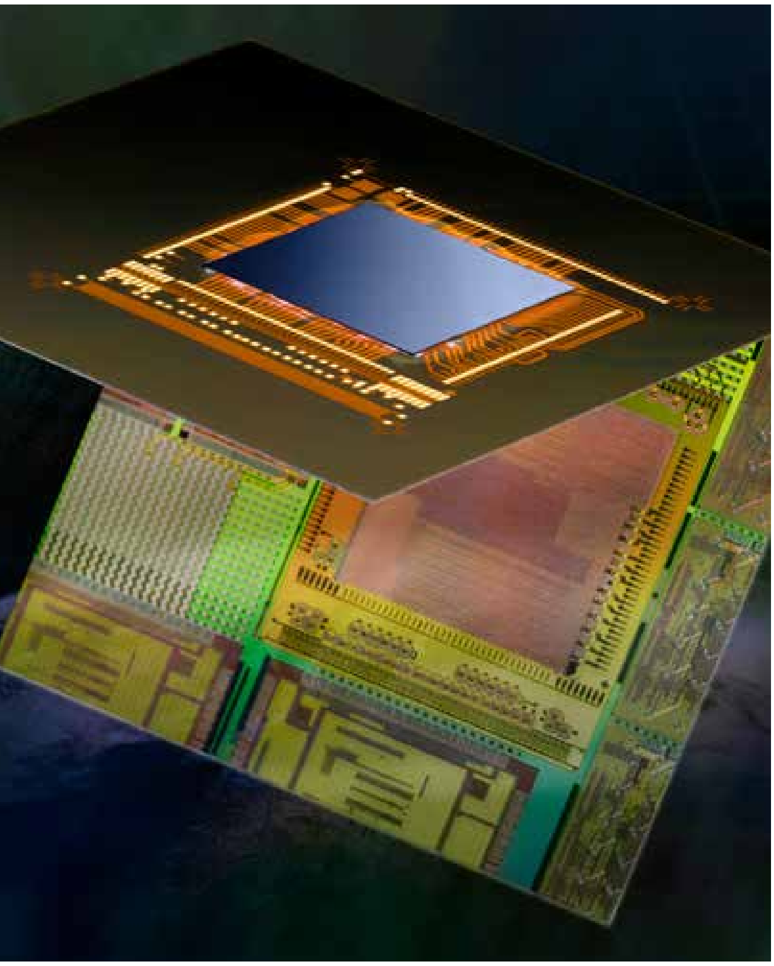
Ethernet Time Sensitive Networking (TSN)

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

For more information please visit our website at **s.fhg.de/IPMS-eval-kits**

Networks and Cooperations



High Performance Center Micro / Nano – From Research to Transfer

The task of a high performance center is to transfer research results from the participating institutes as directly as possible to industrial partners and thus into application. In the high performance center "Functional Integration for Micro- and Nanoelectronics" (High Performance Center Micro/Nano), Fraunhofer IPMS, IIS-EAS, ENAS, and IZM-ASSID work together with institutes of TU Dresden, TU Chemnitz, and HTW Dresden on new technologies for microelectronics and microsystems technology as well as their application (e.g., in the industrial IoT).

Throughout the Fraunhofer Society, there are 20 high performance centers with different thematic focuses and regional locations. In 2021, the Fraunhofer Society decided to continue the high performance center format on a success-based basis. For example, all performance centers will receive € 1 million per year from the Board of Management from 2022 to 2024.

In 2024, all high performance centers will be evaluated with the perspective of follow-up funding for the next three-year period if the evaluation results are positive.

The successful transfer from preliminary research to industrial implementation is the core objective of the high performance center. This is based on the technology platforms jointly created by the participating institutes; these allow attractive scientific and technical offers for both new and existing customers. One example from 2021 is the conclusion of another long-term cooperation agreement with the company Endress+Hauser with which Fraunhofer IPMS has already been working for several decades. Endress+Hauser is a leading international supplier of industrial measurement and control technology.

In particular, in order to attract new partners and customers to the technology offer, the High Performance Center Micro/Nano has created a digital transfer platform: A virtual showroom was set up; this presents the research offers and developments interactively and in 3D. Take a look for yourself and let yourself be inspired:

www.showroom.leistungszentrum-mikronano.de

Contact partner

Dr. Frank Benner
Coordinator
High Performance Center
+49 351 8823-418
frank.benner@
ipms.fraunhofer.de

iCampμs Cottbus – WhatComes after Coal? Future Opportunities through Microsensor Technology and Digitalization!

The energy turnaround is a major challenge, especially for regions in which the economic strength is closely linked to coal production. Up to 25,000 industrial jobs in Lusatia alone depend directly and indirectly on lignite. In order for structural change to succeed, future prospects are needed. This is where the "Innovation Campus Electronics and Microsensorics (iCampμs Cottbus)" comes in. Through research and development on microsensors and digitalization, four non-university research institutes – including Fraunhofer IPMS – together with the Brandenburg University of Technology Cottbus-Senftenberg are creating a broad range of technical services, especially for SMEs and thus a perspective for skilled workers as well as the economic power in the region. The focus of developments is on Smart Health, Environmental Sensor Technology 4.0, and Industry 4.0.

The German Federal Ministry of Education and Research (BMBF) is funding the second phase of iCampμs Cottbus with € 20 million from 2022 to 2026. In the first phase from 2019 to 2021, the BMBF had supported the consortium partners with € 7.5 million from the emergency program for implementing the recommendations of the "Growth, Structural Change and Employment" Commission. The second phase is now building on the research results achieved here; economic utilization is being increasingly addressed. At the start, 44 letters of intent were received from companies in the region; direct cooperation on projects is now underway with 11 of them.

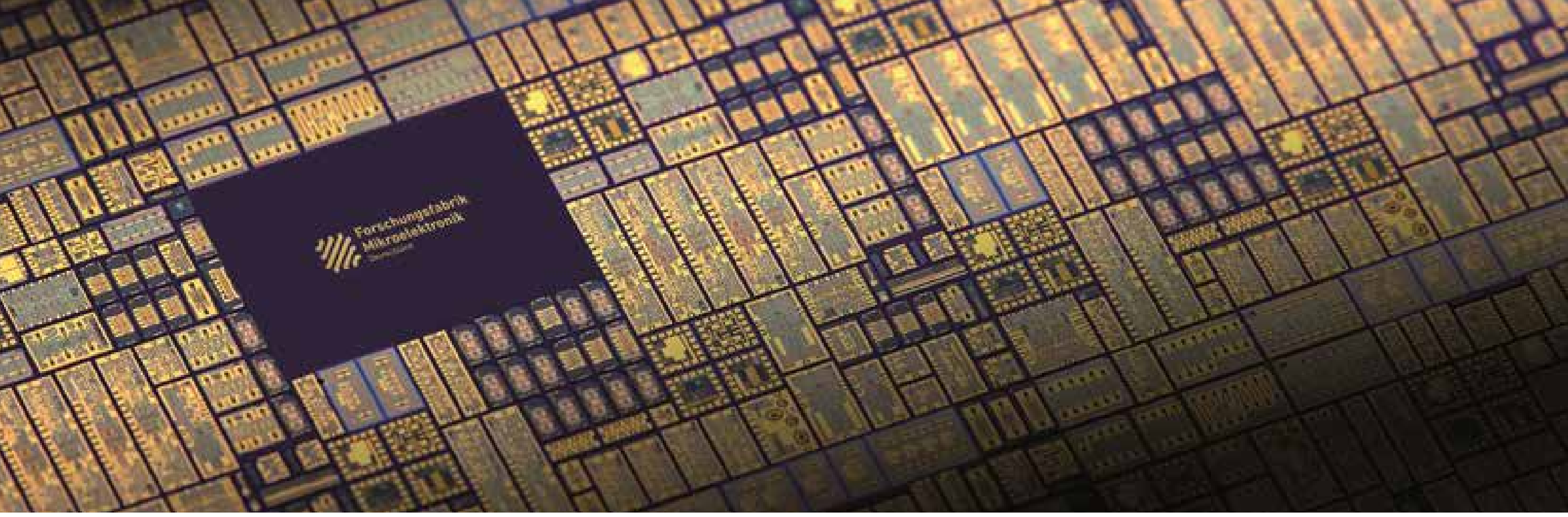
The declared aim of the iCampμs is to build bridges to the regional economy with research and development and to accelerate the transfer of knowledge and findings. Demonstrators or prototypes can be developed for SMEs; these range from the creation of individual solutions to small series production capable of handling large numbers of units. The broad competencies of the six partners enable them to offer technical solutions from the fields of optics and photonics, ultrahigh-frequency technology, MEMS technology, and application-oriented AI evaluation. Fraunhofer IPMS is researching an ultrasound camera for Smart Health, NIR sensors for Industry 4.0, and MEMS varactors for 5G mobile communications as part of iCampμs – read more on page 54.

Funding is provided under the 2021 to 2024 framework program "Microelectronics. Trusted and Sustainable. For Germany and Europe" of the German government with funds from the Structural Development Act for coal-mining regions. Project partners are the BTU Cottbus-Senftenberg, the Fraunhofer Institute for Reliability and Microintegration (IZM), the Ferdinand-Braun-Institut gGmbH, Leibniz Institute for Highest Frequency Technology (FBH), the Leibniz Institute for Innovative Microelectronics (IHP), and Thiem-Research GmbH.

www.icampus-cottbus.de

Contact partner

Dr. Sebastian Meyer
Head of Branch Integrated Silicon Systems
+49 351 8823-137
sebastian.meyer@
ipms.fraunhofer.de



Research Fab Microelectronics Germany

Since 2017, Fraunhofer IPMS, together with eleven institutes of the Fraunhofer Group for Microelectronics and the two Leibniz Institutes FBH and IHP, has formed the cross-site Research Fab Microelectronics Germany, or FMD for short. With more than 2,000 scientists, the FMD is one the world's largest R&D network of its kind. With its unique diversity of expertise and infrastructure at the institutes, it is helping Germany and Europe to further expand their leading position in research and development.

Transition to regular operation

Until the end of 2020, the FMD was in its start-up phase. The extensive investments of the Federal Ministry of Education and Research (BMBF) in the modernization of the institute´s infrastructure could be completed by the end of 2020 / beginning of 2021, with the exception of a few minor delays caused by the Covid19 pandemic.

At the beginning of 2021, the FMD started steady operations with the merger of the two offices of the Fraunhofer Group for Microelectronics and Research Fab Microelectronics Germany and the new head of the joint office, Dr. Stephan Guttowski. This transition was marked by the digital conference "Impulsgeber FMD: Angebot & Potenzial - Köpfe & Know-how" on April 22, 2021. This model of interdisciplinary and interorganizational cooperation in the German research landscape is already bearing its first fruits and it may serve as a role model at the European level in the future.

Networking and cooperation for technological sovereignty

In the meantime, the FMD is considered a role model when it comes to setting up the competencies of different R&D institutions with a joint strategy and a bundled offer to industry. With its cross-location, cross-technology and cross-competence collaboration, FMD ensures that technological sovereignty is maintained and expanded along the entire value chain.

The Berlin office represents the FMD institutes and acts as a central point of contact for all issues related to micro- and nanoelectronic research and development in Germany and Europe.

Versatile cooperation opportunities

In addition to the range of services for its customers from industry, FMD also offers a wide variety of cooperation opportunities for its partners in science and education. These are aimed directly at cooperative processing of research questions, such as collaborative work in joint projects and the operation of joint laboratories. A major opportunity for cooperation lies the testing of special concepts and solutions from basic research on the facilities of the FMD institutes to gain a better understanding of their suitability in more application-oriented environments.

Trustworthy and sustainable microelectronics systems for innovative strength

A future-oriented society depends on electronic components in all relevant technical application domains – whether in critical infrastructures, in Industry 4.0, in the automotive sector or even in medical devices. People must be able to rely on these in order to build trustworthy products, systems and infrastructure with them.

The cross-technology competencies needed to meet these challenges are being developed by the institutes of Research Fab Microelectronics Germany in large-scale projects such as "TRAICT" or "Velektronik". In the TRAICT (Trusted Resource Aware ICT) project, for example, eight FMD institutes worked together with another ten Fraunhofer institutes until the end of 2021 to develop framework conditions to ensure that information and communication technology is trustworthy and compliant with data protection requirements, and can be used in a self-determined and secure manner.

In order to shed light on the entire value chain and create end-to-end concepts for trustworthy electronics in Germany and Europe, a platform for trustworthy electronics – "Velektronik" for short – was launched in March 2021. Within the project, corresponding standards, norms and processes based on a national and European chip security architecture are to be developed and brought into application.

www.forschungsfabrik-mikroelektronik.de/en.html

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 Leibnitz 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.

Starting in 2022, it is planned to expand the current sensor technology to 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 depth of penetration, reduces costs, and improves recovery prospects through the treatment 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.

Test stand of the HybridEcho project

s.fhg.de/Hybridecho

s.fhg.de/Hybridecho-Video

Contact partner

Dr. Sandro Koch
Group Manager
Ultrasonic Components
+49 351 8823-239
sandro.koch@
ipms.fraunhofer.de

»

In building a **strong quantum industry in Europe**, the Fraunhofer Institute for Photonic Microsystems IPMS is a key player with its outstanding, industry-oriented research on scalable technologies for quantum computing and its close links to the microelectronics and semiconductor manufacturing industries.

With its state-of-the-art 300 mm semiconductor infrastructure and extensive expertise in large-scale qubit production and technology integration, Fraunhofer IPMS is a key partner in the Quantum Business Network QBN for collaborative innovation and is making a considerable contribution to the development of the first useful quantum computers.«

Johannes Verst
CEO, Quantum Business Network QBN

Fraunhofer and CEA-Leti are Europe's two major research technology organizations. They share a common mission: bridging the gap between research and industry.

Fraunhofer IPMS and CEA-Leti coordinate a large number of European projects leveraging their scientific excellence. They fuel their respective microelectronics ecosystems with top-notch research, with differentiating solutions using 200 and 300 mm wafer technologies. The two RTOs collaborate on a regular basis with cross cleanroom visits, complementing one another.

From engineering staff to executive management, Fraunhofer IPMS and CEA-Leti teams share the same vision and best practices. Through the HTA alliance, we discuss roadmaps and strategies to support our French and German semiconductor leaders, such as STMicroelectronics, Soitec, Infineon, Bosch, GlobalFoundries, among others.

Recently, CEA-Leti and Fraunhofer IPMS tackled together quantum computing, as well as edge computing to support the deployment of edge AI within several ECSEL projects, including TEMPO, ANDANTE and MATQu. New materials as well as new non volatile memories are being developed, with the goal of integrating them into neural network architectures.

We would like to thank our Fraunhofer IPMS colleagues for being always supportive and provide constructive collaboration, a strong team for success. The Chip Act has put both FhG-IPMS and CEA-Leti in the spotlight. We are living through an historic moment to reinforce Europe's economic sovereignty, and I am sure our knowledge-sharing culture will be fruitful.

Dr. Laurent Clavelier,
Division Manager Silicon Technologies, CEA-Leti

Photo, left to right: Martin Landgraf, Dr. Manuela Junghänel, Prof. Dr. Hubert Lakner (Fraunhofer); Dr. Laurent Clavelier, Dr. Yannick LeTiec & Dr. Fabrice Nemouchi (CEA-Leti); and Dr. Wenke Weinreich (Fraunhofer) during a visit at Fraunhofer IPMS in September 2021.

Patents

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 274 issued patents. 237 patent applications are still pending.

s.fhg.de/IPMS-Patents

Publications

Fraunhofer IPMS conducts top-quality research. This is substantiated by the numerous publications that were published by scientists from Fraunhofer IPMS in 2021.

A highlight in 2021 was a publication on innovative in-ear speakers in the renowned Nature Journal Microsystems & Engineering. Here, Fraunhofer IPMS presented new devices that represent an important development push due to their small volume and high energy efficiency. The paper ”Coulomb-actuated microbeams revisited: experimental and numerical modal decomposition of the saddle-node bifurcation” can be read free of charge through Open Access at: www.nature.com/articles/s41378-021-00265-y
Find more information on this topic on page 68.

You can find all of our publications at:

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. Since 2021 you can also virtually visit our laboratories at BTU (in German):

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 “iCampμs Cottbus” project (pp. 54, 91).

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

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. 90).

Science Gallery of 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 of Applied Sciences (HTW)

Cooperation with HTW Dresden in the area of Industry 4.0 and Industrial IoT began in 2015 via Fraunhofer IPMS' Business Unit Wireless Microsystems.

In order to strengthen cooperation in other areas as well, joint workshops have been held since 2021 to exchange research topics and project ideas (p. 72). 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, Fraunhofer IPMS would like to offer guest lectures and enable students of HTW Dresden to gain practical insights at the institute through excursions.

Find all of our networks at:
s.fhg.de/Collaborations

Theses

Bachelor Theses

Bannies, Karen Margaretha
Konzeption eines Beschaffungscontrollings am Fraunhofer IPMS – Ableitung eines Geschäftsprozesses Beschaffungscontrolling inklusive Definition zugeordneter KPIs
HTW Dresden; Supervisors: Prof. Dr. oec. Publ. Wolfgang Sattler, Dipl.-Ing. Grit Walther

Hertel, Johannes
CMOS-kompatibles Rutheniumsilizid für die thermoelektrische Anwendung
HTW Dresden; Supervisors: Prof. Dr. Grit Kalies; Dr. Maik Wagner-Reetz

Peuckert, Lea
Charakterisierung von Silizium-basierten thermischen Emittern mittels Fourier-Transform-Spektroskopie
Berliner Hochschule für Technik; Supervisors: Prof. Dr. Ralf Ahlbrink; Dr. Heinrich Grüger

Diploma Theses

Bachmann, Lukas
Entwicklung eines Software Tools zur computergestützten Auswertung von Transceiver Profilen auf Basis Neuronaler Netze für die Prozessqualifizierung
TU Dresden; Supervisor: Tobias Schneider

Luo, Yuxi
Untersuchungen zum Ladungsträgertransport und -injektion in organischen Halbleitermaterialien mit Hilfe von organischen Feld-Effekt-Transistoren und vergleichende Analyse für verschiedene Metall-Kontakte und Präparationsmethoden der Transistorstrukturen
TU Dresden; Supervisor: Dr. Olaf R. Hild

Reinhardt, Jonas
Development of a feedfoward overlay parameter model for the exposure of the FEOL of a 0.35 µm CMOS technology
TU Dresden; Supervisor: Prof. Hubert Lakner

Schneider, Julius
Miniaturisierte Kopfelektronik für MEMS-Scannerspiegel
HTW Dresden; Supervisor: Dr. Markus Schwarzenberg

Shen, Yukai
Low power circuit implementation of ReRAM-based STDP network for neural spike sorting
TU Dresden, Supervisor: Prof. Hubert Lakner

Wills, Alexander
Untersuchung von RISC-V-Architekturen für batterielose RFID-Sensorsysteme
HTW Dresden; Supervisor: Dr. Andreas Weder

Master Theses

Akkal Devi, Prashanth
Modal Analysis of Nanoscopic Electrostatic Drive based Micro-Positioning Systems
BTU Cottbus-Senftenberg, Supervisor: Dr. Christine Ruffert

Gogoi, Eshanee
Electrochmical chlorination of silver electrides for miniaturized sensor applications
TU Chemnitz; Supervisor: Dr. Conrad Guhl

Haller, Gwendolyn
Transport simulation of single and multidomain ferroelectric HfO2 - an abinito study
ETH Zürich; Supervisors: Dr. Thomas Kämpfe, Maximilian Lederer

Huang, Chao-Yi
Investigation and improvement of the nanopatterning process window for e-beam exposure and reactive ion etching processes
TU Dresden; Supervisor: Dr. Varvara Brackmann

Mahanta, Trideep
Investigation of High Electric Field Degradation Effects on Nanoscopic Electrostatic Drive Actuators (NED)
TU Chemnitz; Supervisor: Michael Stolz

Sünbül, Ayse
Electrical Characterization of Hafnium Zirconium Oxide Based Ferroelectric Tunnel Junctions
Christian-Albrechts-Universität zu Kiel, Supervisor: Tarek Ali

Dissertations

Eckhardt, Nora
Entwicklung einer Methodik zur Vorhersage von Prozesskenndaten für das chemisch-mechanische Polieren in der Halbleiterindustrie
TU Dresden; Supervisor: Prof. Dr. Hubert Lakner

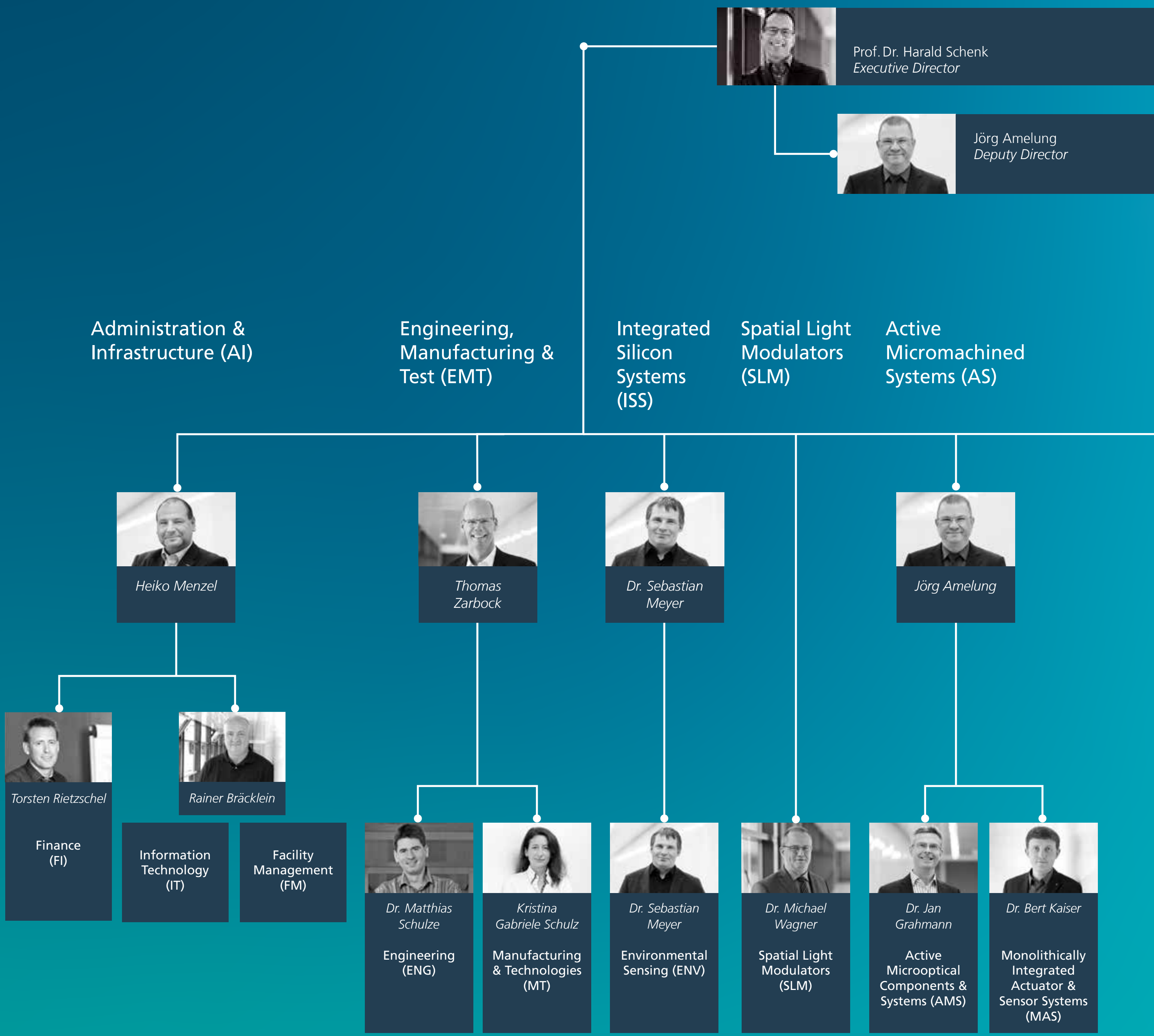
Kirrbach, René
System zur optisch drahtlosen Hochgeschwindigkeitskommunikation über mittlere Distanzen mit hohem Abdeckungsgrad
TU Dresden; Supervisor: Prof. Dr. Wolf-Joachim Fischer

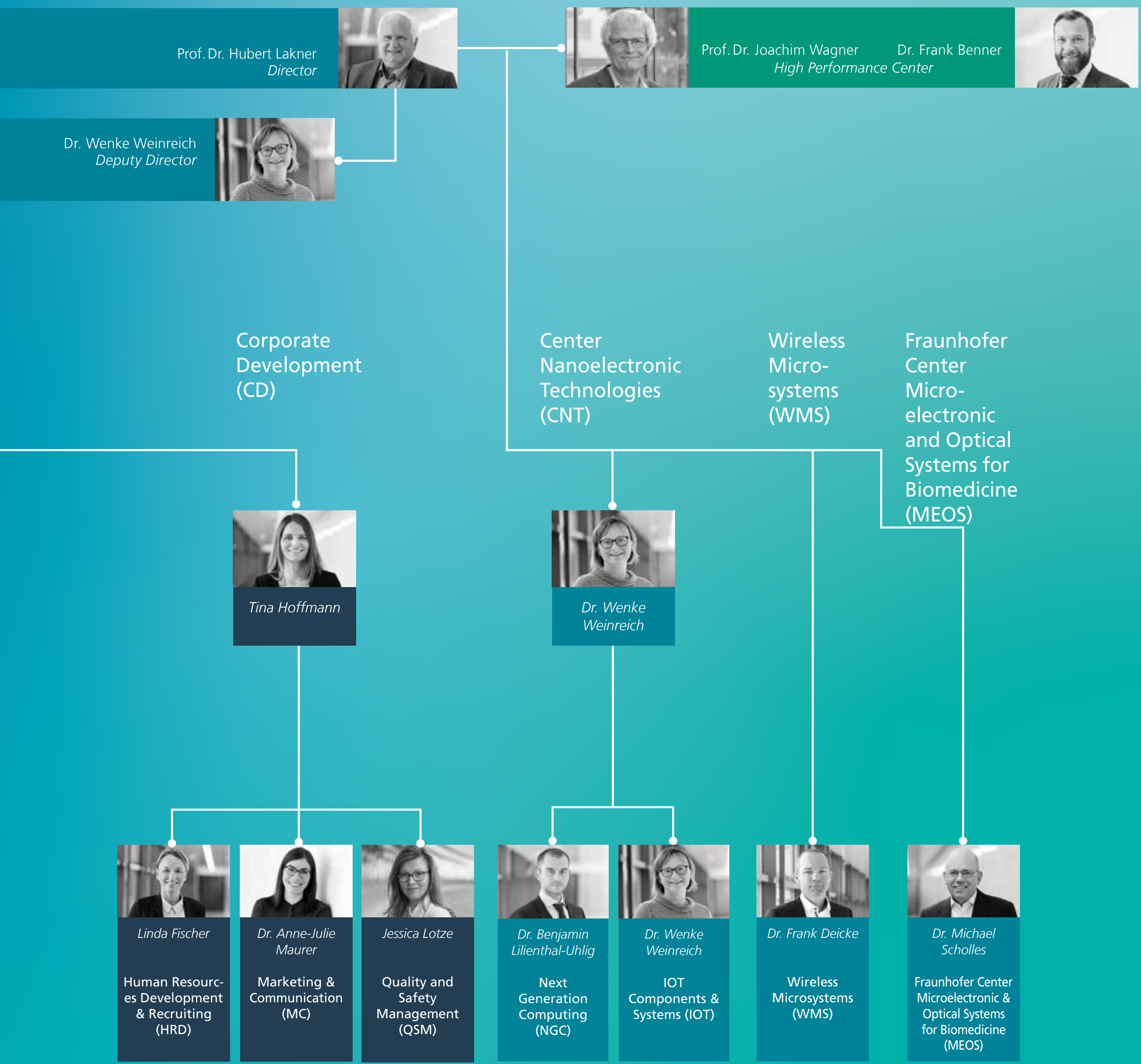
Mart, Clemens
Pyroelectric and electrocaloric effects in doped hafnium oxide thin films
TU Dresden; Supervisor: Dr. Wenke Weinreich

Fraunhofer IPMS

Fraunhofer Institute for Photonic Microsystems IPMS

Organigram





As of March 2022

Contact Partners

Prof. Dr. Harald Schenk | +49 351 8823-154 | harald.schenk@ipms.fraunhofer.de

Heiko Menzel | +49 351 8823-244 | heiko.menzel@ipms.fraunhofer.de

Thomas Zarbock | +49 351 8823-372 | thomas.zarbock@ipms.fraunhofer.de

Dr. Sebastian Meyer | +49 351 8823-137 | sebastian.meyer@ipms.fraunhofer.de

Jörg Amelung | +49 351 8823-4691 | joerg.amelung@ipms.fraunhofer.de

Tina Hoffmann | +49 351 8823-430 | tina.hoffmann@ipms.fraunhofer.de

Torsten Rietzschel | +49 351 8823-425 | torsten.rietzschel@ipms.fraunhofer.de

Rainer Bräcklein | +49 351 8823-342 | rainer.braecklein@ipms.fraunhofer.de

Dr. Matthias Schulze | +49 351 8823-335 | matthias.schulze@ipms.fraunhofer.de

Kristina Gabriele Schulz | +49 351 8823-436 | kristina.schulz@ipms.fraunhofer.de

Dr. Michael Wagner | +49 351 8823-225 | michael.wagner@ipms.fraunhofer.de

Dr. Jan Grahmann | +49 351 8823-349 | jan.grahmann@ipms.fraunhofer.de

Dr. Bert Kaiser | +49 351 8823-150 | bert.kaiser@ipms.fraunhofer.de

Linda Fischer | +49 351 8823-303 | linda.fischer@ipms.fraunhofer.de

Dr. Anne-Julie Maurer | +49 351 8823-2604 | anne-julie.maurer@ipms.fraunhofer.de

Jessica Lotze | +49 351 8823-1700 | jessica.lotze@ipms.fraunhofer.de

Prof. Dr. Hubert Lakner | +49 351 8823-111 | hubert.lakner@ipms.fraunhofer.de

Prof. Dr. Joachim Wagner | +49 351 8823-369 | joachim.wagner@ipms.fraunhofer.de

Dr. Frank Benner | +49 351 8823-418 | frank.benner@ipms.fraunhofer.de

Dr. Wenke Weinreich | +49 351 2607-3053 | wenke.weinreich@ipms.fraunhofer.de

Dr. Benjamin Lilienthal-Uhlig | +49 351 2607-3064 | benjamin.lilienthal-uhlig@ipms.fraunhofer.de

Dr. Frank Deicke | +49 351 8823-385 | frank.deicke@ipms.fraunhofer.de

Dr. Michael Scholles | +49 361 66338-151 | michael.scholles@ipms.fraunhofer.de

Sites

Fraunhofer Institute for Photonic Microsystems IPMS
Maria-Reiche-Str. 2
01109 Dresden, Germany
+49 351 8823-0
+49 351 8823-266
info@ipms.fraunhofer.de
www.ipms.fraunhofer.de/en

Fraunhofer IPMS – Center Nanoelectronic Technologies CNT
An der Bartlake 5
01109 Dresden, Germany
+49 351 2607 0
+49 351 2607 30 05
info@ipms.fraunhofer.de
www.ipms.fraunhofer.de/en

Fraunhofer IPMS – Integrated Silicon Systems ISS Branch
Fraunhofer IPMS at the
BTU Cottbus-Senftenberg
Konrad-Zuse-Str. 1
03046 Cottbus, Germany
+49 355 69 24 83
info@ipms.fraunhofer.de
www.ipms-iss.fraunhofer.de

Fraunhofer Center for Microelectronic and Optical Systems for Biomedicine MEOS
Herman-Hollerith-Str. 3
99099 Erfurt, Germany
+49 361 66338 150
meos@ipms.fraunhofer.de
www.meos.fraunhofer.de/en

Follow Us on Social Media

LinkedIn

Our press releases and events are always visible on the world's largest business network.

www.linkedin.com/company/fraunhofer-ipms

Twitter

A brief summary of all news from Fraunhofer IPMS and from our project partners on the most successful microblogging service.

twitter.com/fraunhoferipms

Facebook

Current job offers, public events and information about Fraunhofer IPMS.

www.facebook.com/fraunhoferipms

Youtube

Exciting interviews with our scientists and technical animations of technologies from Fraunhofer IPMS.

www.youtube.com/user/fraunhoferipms

Xing

Our press releases and events are always visible on the business network for the German region.

www.xing.com/pages/fraunhoferipms

Editorial Notes

Editors

Fraunhofer IPMS, Dr. Anne-Julie Maurer

Photos

Page 6, top © EU, 2021
Page 10/11 © EU, 2021
Page 12 © EU, 2019
Page 13 © Thomas Trusteschel Phototek
Page 14 © Merkel u. Karliczek: CDU / Laurence Chaperon; Vestager: EU, 2021
Page 22 © JARA
Page 24 © FZ Jülich
Page 25 © Fraunhofer IOF
Page 26 © IMEC
Page 27 © Brian Kostiuk – unsplash
Page 28/29 © shutterstock – spainter_vfx
Page 33 © Fraunhofer IDMT
Page 37 © Fraunhofer IZM
Page 39 © Fraunhofer IDMT
Page 59 © Fraunhofer IZM
Page 60 © Fraunhofer IZM
Page 70, photo of Dresden, © Mediaserver Dresden
Page 90 © Fraunhofer
Page 92 © Frauhofer IAF
Page 93 © EKFZ
Page 97 © Innovation Hub 13, Alexander Retsch
Page 99 © HTW Dresden, Peter Sebb
Page 103 photo of IPMS-ISS © BTU

In relation to grammar, masculine references to people apply equally to people of other genders, where appropriate.

Cover image: View of our virtual showroom, where you can experience our technologies interactively and in 3D. Experience a world full of innovation at:

www.showroom.leistungszentrum-mikronano.de

Fraunhofer Institute for
Photonic Microsystems IPMS
Maria-Reiche-Str. 2
01109 Dresden, Germany
+49 351 88 23-0
info@ipms.fraunhofer.de
www.ipms.fraunhofer.de

Fraunhofer IPMS is a leading research and development service provider for electronic and photonic microsystems in the fields of intelligent industrial solutions, medical & health technologies and improved quality of life. In all major markets – such as ICT, consumer, automotive, semiconductors, measurement and medical technology – you will find innovative products based on technologies developed at Fraunhofer IPMS.