



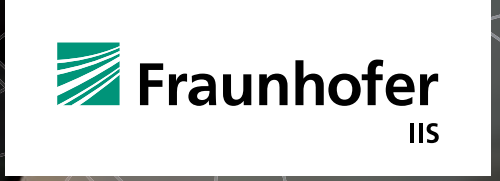
**Cover image**

Fraunhofer IIS audio technologies are shaping the future of sound – whether in radio, telephony, television, or music and movie streaming. And they are already solving everyday challenges. MPEG-H Dialog+ is an AI-supported technology that improves the intelligibility of television dialogue – for example in the ARD Mediathek. Thanks to artificial intelligence, it can separate the dialogue and background of existing film sound, enabling a new, more intelligible mix. This means that future technology from Erlangen is already ensuring accessible movie experiences today, while at the same time helping with the seamless transition to Next-Generation Audio technologies.

**Fraunhofer IIS**

The Fraunhofer Institute for Integrated Circuits IIS in Erlangen is one of the world's leading application-oriented research institutions for microelectronic and IT system solutions and services. Today, it is the largest institute of the Fraunhofer-Gesellschaft.

Research at Fraunhofer IIS revolves around two guiding topics: "Audio and Media Technologies" and "Cognitive Sensor Technologies." Applications for the research results are found in connected mobility, in communication and application solutions for the Internet of Things, in the digitalization of human sensing, in product and material monitoring and in business analytics in supply chains.



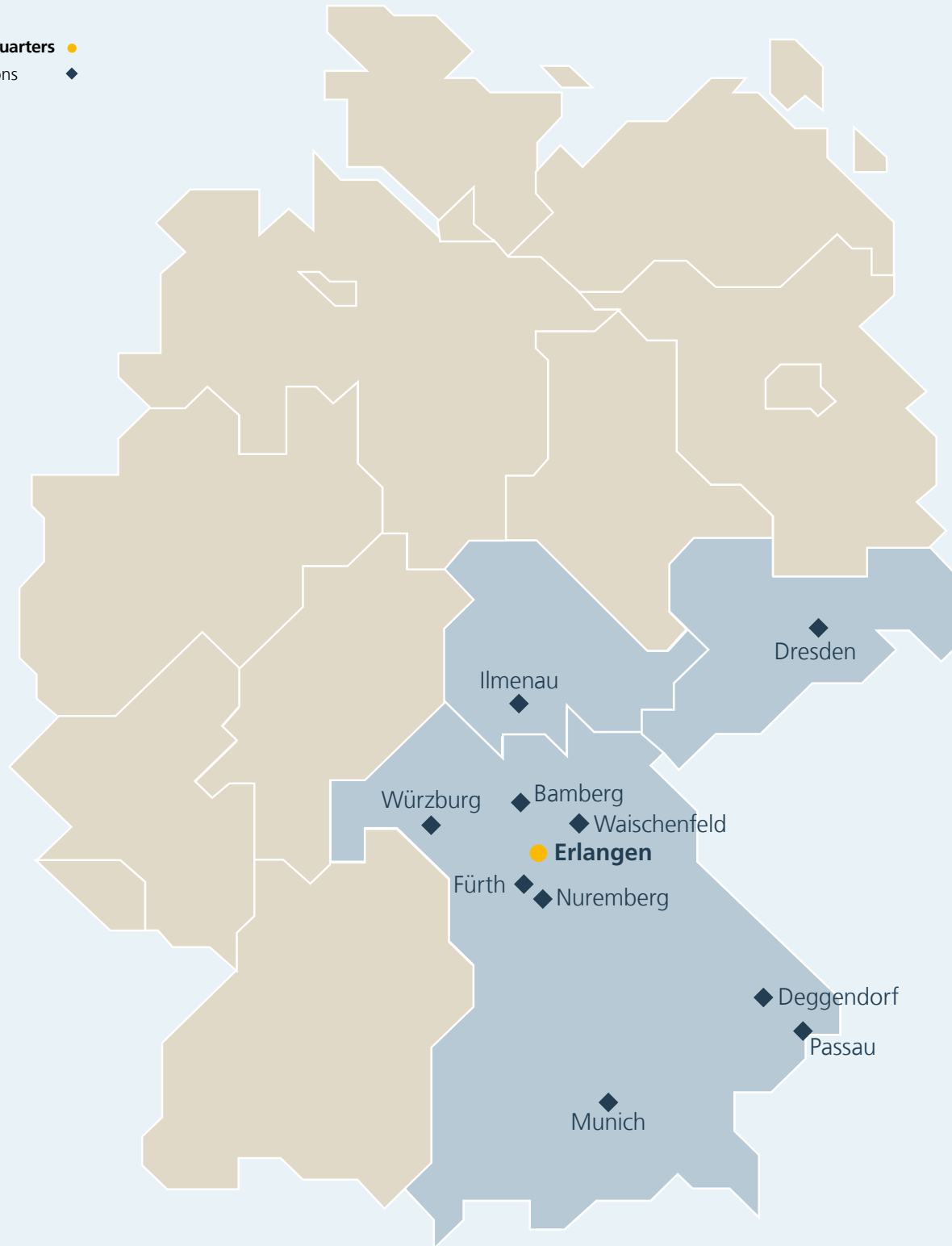
Fraunhofer Institute for Integrated Circuits IIS | Highlights 2022 | Annual Report

Annual Report

Highlights 2022

#WeKnowHow

Headquarters ●  
Locations ◆



You can find the online version of the Annual Report along with further information and multimedia content at

[www.iis.fraunhofer.de/annualreport](http://www.iis.fraunhofer.de/annualreport)

 Link to further information about the topic

 Link to multimedia content

## Profile of Fraunhofer IIS

The Fraunhofer Institute for Integrated Circuits IIS, headquartered in Erlangen, Germany, conducts world-class research on microelectronic and IT system solutions and services. Today, it is the largest institute of the Fraunhofer-Gesellschaft.

Research at Fraunhofer IIS revolves around two guiding topics: "Audio and Media Technologies" and "Cognitive Sensor Technologies."

Audio and media technologies from Fraunhofer IIS have been shaping the audio and film industry for over 30 years: starting with mp3 and AAC and continuing down to the fourth generation with MPEG-H Audio, LC3/LC3plus and xHE-AAC, which can be found in all new cellphones and in the offerings of leading global music and video streaming services. The institute also played a significant role in the digitalization of cinema.

In addition, Fraunhofer IIS has been working on speech technologies for over 20 years. The institute had a big hand in developing the EVS standard, which is mandatory for all 5G voice services. Today, it is expanding its activities in the direction of voice signal processing and voice assistance systems.

In the sphere of cognitive sensor technology, the institute researches technologies for sensor technology, data transmission technology, data analysis methods and the exploitation of data as part of data-driven services and their accompanying business models. This adds a cognitive component to the function of the conventional "smart" sensor. Applications for the research results are found in connected mobility, in communication and application solutions for the Internet of Things, in the digitalization of human sensing, in product and material monitoring and in business analytics in supply chains.

More than 1170 employees conduct contract research for industry, the service sector and public authorities. Founded in 1985 in Erlangen, Fraunhofer IIS now has locations in 11 cities: Erlangen (headquarters), Nuremberg, Fürth and Dresden, as well as Bamberg, Deggendorf, Ilmenau, Munich, Passau, Waischenfeld and Würzburg. 72 percent of the budget of 189,7 million euros a year is financed by contract research projects. Institutional funding from the Fraunhofer-Gesellschaft covers 28 percent of the budget.

Last updated: February 2023

 [www.iis.fraunhofer.de/en](http://www.iis.fraunhofer.de/en)

You can see the organizational structures of the individual locations in the organizational chart on pages 12 and 13.

Annual Report



# Highlights 2022

# Foreword

---



Prof. Alexander Martin,  
Prof. Albert Heuberger,  
Prof. Bernhard Grill  
(from left to right)

## Shaping a livable future together

### Dear reader,

Despite difficult political and economic conditions, 2022 was another good year for Fraunhofer IIS. Our Annual Report provides you with an overview of the diverse range of research projects carried out last year as well as their practical applications.

The challenges of the current energy crisis coupled with the pressing need for climate action are shifting the focus of our work even more toward creating resource-efficient digital technologies. By increasing the sustainability of information and communication technologies and reducing the complexity of value chains in semiconductor production, we are making major inroads into saving energy and lowering CO<sub>2</sub> emissions. Our Green ICT @ FMD competence center, for instance, is a key point of contact for green microelectronics. Turn to page 56 to learn more.

Other highlights featured in this report include AI-driven facial recognition, quantum-safe data transmission, sustainable agriculture, 5G technology and AI technology for clear TV dialogue.

We hope you enjoy reading the report.

Prof. Albert Heuberger

Prof. Bernhard Grill

Prof. Alexander Martin

Directors of Fraunhofer IIS

# Contents

Interpreting expressions with AI



20

Quantum-safe data transmission made in Saxony



26

Preparing for climate change with sensor technology



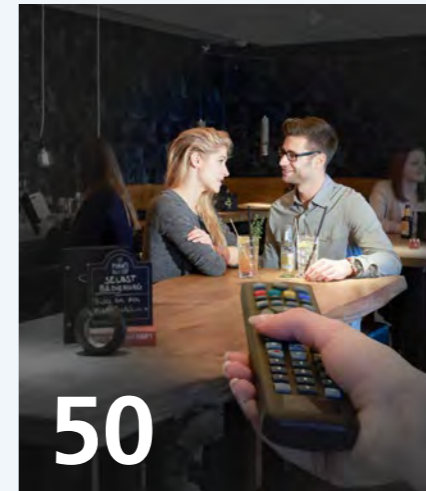
34

Professional mobile communications applications with global appeal



44

AI technology for clear TV dialogue



50

## #WeKnowHow

**We:** Emphasizes the **diversity** of researchers and all employees who provide solutions across countries and disciplines.

**Know:** Fraunhofer defines fields of research, turning **knowledge** into technology for lead markets – which in turn adds value for society as a whole.

**How:** With an attitude between thirst for **action** and the spirit of research, the Fraunhofer-Gesellschaft tackles even seemingly unsolvable problems – for the world of tomorrow.

## We

- 6 Knowledge meets play: The new Fraunhofer IIS AI showroom | The Long Night of the Sciences at Fraunhofer IIS | United by diversity
- 10 Awards, prizes and appointments 2022 – A selection | RFicient® – Wireless, efficient, sustainable
- 12 Organizational Chart | Research Fab Microelectronics Germany (FMD)
- 16 Facts and figures | Members of the Advisory Board | The Fraunhofer-Gesellschaft

## Know

- 20 **#WeKnowHow: Smart Sensing**  
IMAGO – Image-based cell sorting | Bavarian Chip Design Center strengthens the economy | Chips that increase sovereignty in cybersecurity | Trustworthy artificial intelligence
- 26 **#WeKnowHow: Adaptive Systems**  
AI to optimize welding processes in shipbuilding | Standards-based chiplets on Samsung's 5 nm process technology
- 32 **#WeKnowHow: Communication**  
5G for tomorrow's mobility | New simulation platform available
- 34 **#WeKnowHow: X-ray**  
The final secrets of encryption machines | PCBcycle – Recycling printed circuit boards | For5G – Digitally twinning cherry trees

## Know

- 40 **#WeKnowHow: Digital Transformation**  
Knowledge graphs for Industry 4.0 | Process mining of material flows | Promoting intermodal transportation | Optimal inventory planning under uncertainty | Making cash supplies more resilient | How digital eagle eyes find brownfields | Technologies and data pave the way for a circular economy
- 44 **#WeKnowHow: Positioning**  
Smart and sustainable | Digital technology meets inpatient care | Qubits for industrial applications
- 50 **#WeKnowHow: Audio**  
Global demand for audio codecs from Erlangen | AI-driven speech technologies | Enveloping sound at home and on the go | JPEG XS for professional all IP video production

## How

- 56 Resource-efficient technologies for sustainable, global value creation
- 58 In the name of sustainability
- 60 DFG SFB / Transregio 154 enters phase 3 | Fraunhofer IIS projects in phase 4 of the Leistungszentrum Elektronische Systeme (LZE) | The InSignA High-Performance Center | Outlook: AI-accelerated neuromorphic computing
- 64 Publishing notes

Fraunhofer IIS AI showroom, Augustinerhof, Nuremberg

Opening hours:  
Wed to Fri 12 noon – 7 p.m.  
Sat to Sun 10 a.m. – 5 p.m.

# Knowledge meets play: The new Fraunhofer IIS AI showroom

Artificial intelligence (AI) is gaining more and more ground in everyday life, but very few people actually know what it's really all about. Fraunhofer IIS has come up with a special way to shed light on this important topic: a "showroom" that considers many different aspects of AI – and is open to everyone. Presenting the institute's own AI research methods, expertise and use cases in ways accessible to the general public, the AI showroom also gives visitors the opportunity to playfully engage with AI and even co-create it. The AI showroom was officially opened with a ceremony attended by representatives of industry, politics and society on May 17, 2022.

## In honor of Joseph von Fraunhofer

The new AI showroom location in the Augustinerhof in the heart of Nuremberg puts it in respectable company – namely the Future Museum, a branch of Munich's Deutsches Museum. Visitors can learn about all kinds of future topics and then go next door to the new showroom and immerse themselves in the world of AI. Covering a total area of 60 m<sup>2</sup>, the showroom is divided into four sections. As soon as they enter, visitors are met with a series of four colored glass panels. These recall the namesake of Europe's largest applied research organization, Joseph von Fraunhofer, and his pioneering work on the spectral absorption lines of sunlight. The panels present his research biography and the operational scope of Fraunhofer IIS.

## Interactive AI knowledge transfer

Next stop is the AI exhibition, which provides the basic content required to understand the technology as well as a selection of Fraunhofer IIS research topics. These include a topic that is particularly relevant at the moment: the sustainable handling of data throughout its life cycle – from collecting, analyzing and publishing to archiving and reusing it. The exhibition takes a multimedia approach, with information boards and interactive screens presenting text, stills and videos – including about sample use cases from Fraunhofer IIS research.

Armed with all this fascinating knowledge, it's time for visitors to get involved: in the center of the room, an interactive gaming table stands ready for talented players to demonstrate their skills. The goal of Metro Driver – a subway game based on a joint research project between VAG Verkehrs-Aktiengesellschaft Nürnberg and Fraunhofer IIS – is to guide subway trains through multiple stations as energy-efficiently as possible. Together, the trains are not allowed to cause any load peaks and must remain on schedule. Quite a challenge – that is, without the help of AI!

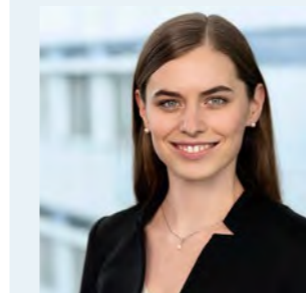
## It all began with mp3

The fourth section, Audio and Media Technologies, features a large light installation based on US singer Suzanne Vega's classic earworm track "Tom's Diner." The a cappella version of the song played a key part in vastly improving a predecessor to the mp3 coding algorithm. The content of the exhibition ranges from the history of mp3 across all four generations of audio codecs to current research topics such as AI-driven audio signal processing and digital speech assistants.

## Networking in the lounge

With their eyes and ears still buzzing from the reds and blues of the light installation and Vega's "da da da da," visitors can round out their time at the AI showroom by relaxing on the comfortable sofas in the networking lounge. For those who are fascinated by AI and want to learn more, there is a monitor showing nuggets of Fraunhofer IIS knowledge as well as job opportunities at the institute. Meeting rooms located on the lower level can be booked to accommodate larger group discussions. And for those who still haven't had enough, there's another highlight to visit right next to the AI showroom: the JOSEPHS® open innovation lab, a spin-off of Fraunhofer IIS and Friedrich-Alexander-Universität Erlangen-Nürnberg. This is where innovations can be tested and feedback given, all of which helps shape the development of tomorrow's products and services.

We look forward to your visit!



### Contact

#### Agnes Pelzl

Fraunhofer Institute for Integrated Circuits IIS  
Deputy Head of Corporate Communications

Phone +49 9131 776 1644  
agnes.pelzl@iis.fraunhofer.de

Top: Mayor of Nuremberg Marcus König (2nd from right) with the three Directors of Fraunhofer IIS – Prof. Albert Heuberger (2nd from left), Prof. Bernhard Grill (3rd from left) and Prof. Alexander Martin (right) – and guests at the opening of the AI showroom in May

# The Long Night of the Sciences at Fraunhofer IIS



At the showroom, the focus was on AI, here for energy-efficient subway operation

## Following a prolonged break due to the pandemic, guests were once again able to experience research face to face in the tri-city area of Nuremberg, Fürth and Erlangen

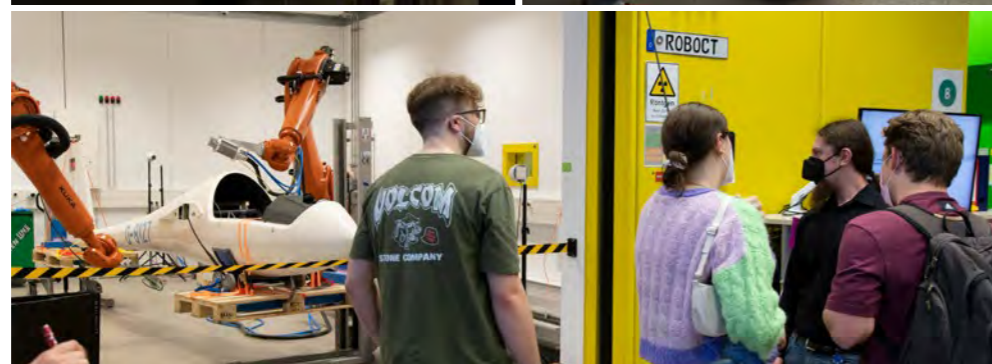
On May 21, 2022, the Long Night of the Sciences gave knowledge-hungry adults and the next generation of scientists the chance to experience research up close and learn more about the trends that will shape the future. It was the tenth time that state and city institutions and associations joined universities, institutes and research-focused companies in opening their doors to the public. Visitors got to look over researchers' shoulders and gain insights into their day-to-day work. Fraunhofer IIS took part in the event at three locations: New on the program was the recently opened AI showroom in Nuremberg's Augustinerhof, where guests could learn more about artificial intelligence through a wide range of exhibits and interactive

experiences.

Fraunhofer IIS headquarters in Erlangen-Tennenlohe presented highlights including smart screw connections, an escape game, a driving simulator that detects when the driver is overtaxed, and audio technologies that are popular the world over. And visitors to the Development Center X-ray Technology in Fürth got to take a look inside both tiny and massive objects – from crop plants to sections of aircraft.



Center left: Visitors to the Erlangen location were treated to a great many exhibits and presentations



Center right: The next generation of scientists was also taken with the smart screw

Bottom: In Fürth, an aircraft was inspected for material faults with the help of RoboCT

# United by diversity



## How Fraunhofer IIS is promoting diversity

At Fraunhofer IIS, diversity is both supported as a matter of course and a pillar of our success. Indeed, we celebrated Germany's Diversity Day in May under the banner of "Diversity Connects." Through a wide range of keynotes, discussions and workshops, participants were able to learn about topics such as unconscious bias and intergenerational collaboration, explore using sign language, and take language and culture courses in Hindi and Persian.

We also support and develop our employees by offering a wide range of targeted training opportunities, both in German and English.

[www.iis.fraunhofer.de/talenta-en](http://www.iis.fraunhofer.de/talenta-en)

Diversity is very much alive at Fraunhofer IIS through its multinational, interdisciplinary workforce made up of people of different genders and generations – which is reflected in the institute's management and work models. This includes dual leadership positions, flexible work models and the promotion of young talent. We help young women build careers in the still male-dominated field of science. A prime example of this is the josephine® mentoring program, in which female STEM students and mentors work together to plan their professional development. Another is TALENTA, the comprehensive career and development program for female scientists and managers.



Diversity is integral to Fraunhofer IIS culture. We need the brightest minds from all over the world.«

Dr. Peter Dittrich  
Deputy Director of  
Fraunhofer IIS



# Awards, prizes and appointments in 2022 – A selection

## Living Lab innovation prize

The Fraunhofer IIS Mobile Health Lab is one of 13 consortium partners for the TEAM-X project, which was awarded the Living Lab innovation prize by the German Federal Ministry for Economic Affairs and Climate Action on May 31, 2022. TEAM-X aims to pave the way for forward-looking health and nursing care provision.

## EurAI Fellow

Prof. Ute Schmid, head of the Comprehensible AI group at Fraunhofer IIS and Professor of Applied Computer Science focusing on cognitive systems at the University of Bamberg, was named one of four new EurAI Fellows.

## Best Poster Award – Scientific Conference

**Autism Spectrum (WTAS)**  
Martina Simon of our Center for Applied Research on Supply Chain Services and her co-authors won the Scientific Conference Autism Spectrum (WTAS) Best Poster Award for their work titled “Acceptance of Robot-Assisted Therapies for Children on the Autism Spectrum and Assessment of Associated Ethical and Social Aspects.”

## AES Fellow

Sascha Dick from the Audio and Media Technologies division was made an AES Fellow in recognition of his work on a new kind of educational

website about audio coding artefacts.

## Best Paper Award – First Workshop on Ever Evolving NLP

Jann Goschenhofer, who works at our Center for Applied Research on Supply Chain Services, and his coauthors received the First Workshop on Ever Evolving NLP Best Paper Award for their paper “CC-Top: Constrained Clustering for Dynamic Topic Discovery.”

## Dissertation Prize – University of Passau

As part of the University of Passau’s Dies academicus on November 11, 2022, Dr. Thomas Lang from our Development Center X-ray Technology was among those awarded the Dissertation Prize for his outstanding work titled “AI-Supported Interactive Segmentation of 3D Volumes.”

## Best Paper Award Winner at CadenceLIVE Europe 2022

Andy Heinig and Gunjanben Limbachiya from our Engineering of Adaptive Systems EAS division received the Best Paper Award at CadenceLIVE Europe 2022 for “Development of Radar Algorithm for the Tensilica Processor.”

## Funding through the Reinhart Koselleck program

Prof. Meinard Müller and his team were awarded 1.25 million euros in funding from the German Research Foundation (DFG) as part of the Reinhart Koselleck program of projects. The funded project on music data analysis is being carried out at the International Audio Laboratories.

## Best Paper Award Winner at IEEE Wireless Communications and Networking Conference

Sebastian Kram, Christopher Kraus, Maximilian Stahlke, Dr. Tobias Feigl, Prof. Jörn Thielecke and Dr. Christopher Mutschler from the Positioning and Networks division won the Best Paper Award at the IEEE WCNC for “Delay Estimation in Dense Multipath Environments using Time Series Segmentation.”

## Best Presentation Award – ION-GNSS+

Johannes Rossouw van der Merve and his co-authors Inigo Cortes Vidal, Dr. Fabio Garzia, Alexander Rügamer and Dr. Wolfgang Felber received the Institute of Navigation Best Presentation Award for their paper “Exotic FMCW Waveform Mitigation with an Advanced Multiparameter Adaptive Notch Filter (MPANF).”

## EURASIP Best PhD Award

Dr. Maja Taseska won the European Association for Signal Processing (EURASIP) Best PhD Award for her thesis on “Informed Spatial Filters for Speech Enhancement.”

## Best Paper Award Winner at ETRA

Marie Eckert, Thomas Robotham, Prof. Emanuel Habets and Olli Rummukainen received the Best Paper Award at the ACM Symposium on Eye Tracking Research & Applications (ETRA) 2022 for their work titled “Pupillary Light Reflex Correction for Robust Pupillometry in Virtual Reality.”

## Graduate prizes – SIEMENS AG

Anna Leschanowsky and Luca Resti from our Audio and Media Technologies research area were honored by Siemens AG’s Corporate Technology department for their outstanding academic performance in information and communications technology.

# RFicient® – Wireless, efficient, sustainable

## Fraunhofer IIS development team wins Joseph von Fraunhofer Prize

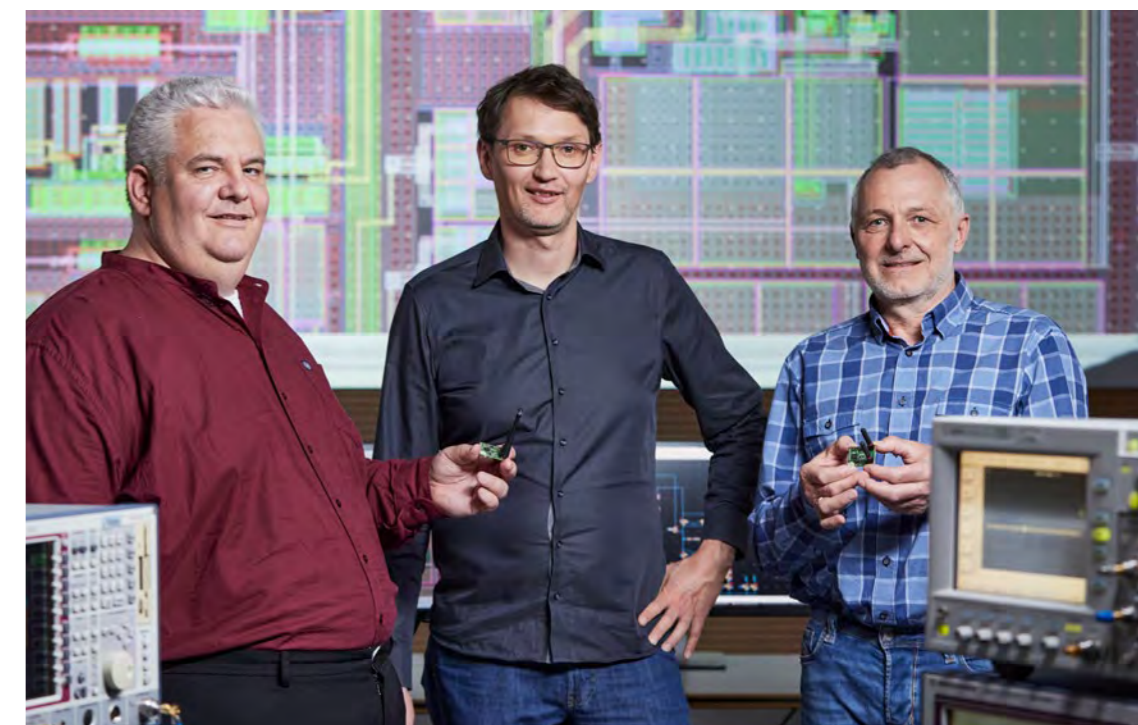
The Internet of Things, IoT for short, connects devices so that they can exchange data with each other. In both private and industrial contexts, the number of such wirelessly connected devices is growing all the time. This consumes a lot of energy, and constantly having to change the battery leads to higher resource consumption.

The solution is the RFicient® chip, which successfully combines sustainability with economic efficiency. It adds a wake-up receiver to conventional sensor nodes and transfers all connected components from sleep mode into active mode as needed. Short switch-on times reduce power consumption by up to 99 percent. This increases the life span of conventional batteries from just one month to up to ten years. At the same time, the sensor node remains constantly receptive and requires only 30 milliseconds to respond to a signal. Real-time responses are guaranteed. This means that IoT receivers are always reachable, respond quickly and remain maintenance-free for extended periods.

The many years of work performed by Dr. Frank Oehler, Dr. Heinrich Milosiu, Dr. Markus Eppel and their development team earned them the Joseph von Fraunhofer Prize 2022.

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

[youtu.be/ttacNG3OqmU](https://youtu.be/ttacNG3OqmU)



The RFicient® development team (from left): Dr. Heinrich Milosiu, Dr. Markus Eppel and Dr. Frank Oehler



# Organizational Chart

<b>Management of the Institute</b> Prof. Dr. Albert Heuberger (executive), Prof. Dr. Bernhard Grill, Prof. Dr. Alexander Martin		
<b>Deputy Directors</b> Prof. Dr. Randolph Hanke, Dr. Peter Dittrich		
<b>Administration and Research Management</b>   Dr. Peter Dittrich		
<b>IT Service</b>   Florian Freund <b>Staff</b>   Matthias Rose <b>Administration Erlangen</b>   Sonja Ludwig <b>Administration Fürth</b>   Colett Reißmann		
<b>Audio and Media Technologies</b> Prof. Dr. Bernhard Grill <b>ER</b>	<b>Development Center X-ray Technology EZRT</b> Dr. Norman Uhlmann <b>FÜ</b>	<b>Smart Sensing and Electronics</b> Dr. Jens-Uwe Garbas Dr. Denise Müller-Friedrich <b>ER</b>
<b>Audio</b> Johannes Hilpert	<b>Conversational AI Research</b> Prof. Dr. Emanuel Habets	<b>Application-specific Methods and Systems</b> Alexander Ennen, Dr. Stefan Gerth
<b>Audio for Embedded Systems</b> Dr. Nikolaus Färber	<b>Media Systems and Applications</b> Harald Fuchs	<b>Contactless Test and Measuring Systems</b> Dr. Peter Schmitt
<b>Audio for Communications</b> Manfred Lutzky	<b>Patents and Licensing</b> Stefan Geyersberger, Martin Dietz	<b>CT in Metrology</b> Prof. Dr. Simon Zabler <b>DEG</b>
<b>AudioLabs-IIS</b> Dr. Frederik Nagel	<b>Semantic Audio Processing</b> Oliver Hellmuth	<b>Magnetic Resonance and X-ray Imaging</b> Dr. Karl-Heinz Hiller <b>WÜ</b>
<b>Moving Picture Technologies</b> Prof. Dr. Siegfried Föbel	<b>Staff Audio and Media Technologies</b> Matthias Rose	<b>Production Monitoring</b> Dr. Steven Oeckl
<b>Business</b> Marc Gayer		

<b>Administration Nürnberg</b>   Regina Kühn <b>Administration Dresden</b>   Franziska Vogel, Sophie Prieß			
<b>Communication Systems</b> Prof. (Univ. Navarra) Michael Schlicht <b>ER</b>	<b>Positioning and Networks</b> Dr. Günter Rohmer <b>N</b>	<b>Center for Applied Research on Supply Chain Services</b> Prof. Dr. Alexander Pflaum <b>N</b>	<b>Engineering of Adaptive Systems EAS</b> Prof. Dr. Peter Schneider <b>DD</b>
<b>Broadband and Broadcast</b> Bernhard Niemann	<b>Self-Powered Radio Systems</b> Josef Bernhard	<b>Analytics</b> Dr. Christian Menden	<b>Efficient Electronics</b> Andy Heinig
<b>Electronic Measurements and Signal Processing</b> Prof. Dr. Giovanni Del Galdo, Dr. Markus Landmann <b>IL</b>	<b>Precise Positioning and Analytics</b> Thomas von der Grün, Dr. Christopher Mutschler	<b>Data Spaces and IoT Solutions</b> Prof. Dr. Andreas Harth	<b>Design Methodology</b> Dr. Roland Jancke
<b>Radio Communication Systems</b> Dr. Gerd Kilian	<b>Satellite Based Positioning Systems</b> Dr. Wolfgang Felber	<b>Innovation and Transformation</b> Dr. Nadja Hoßbach-Zimmermann	<b>Distributed Data Processing and Control</b> Dr. Dirk Mayer
<b>RF and SatCom Systems</b> Rainer Wansch	<b>Distributed Systems and Security</b> Karlheinz Ronge	<b>Risk and Location Analysis</b> Dr. Roland Fischer	

**ER | Headquarters Erlangen**  
Am Wolfsmantel 33  
91058 Erlangen  
Phone +49 9131 776-0

**N | Location Nürnberg**  
Nordostpark 84 und 93  
90411 Nürnberg  
Phone +49 911 58061-0

**FÜ | Location Fürth**  
Flugplatzstraße 75  
90768 Fürth  
Phone +49 911 58061-7500

**DD | Division Engineering of Adaptive Systems EAS**  
Münchner Straße 16  
01187 Dresden  
Phone +49 351 45691-0

**DEG | Application Center for CT in Metrology**  
Dieter-Görlitz-Platz 2  
94469 Deggendorf  
Phone +49 991 3615-678

**WÜ | Magnetic Resonance and X-ray Imaging Department**  
Am Hubland  
97074 Würzburg  
Phone +49 931 31830-60

**IL | Electronic Measurements and Signal Processing**  
Am Vogelherd 90  
98693 Ilmenau  
Phone +49 3677 69-4280

Last updated: April 2023

# Research Fab Microelectronics Germany FMD

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

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

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

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

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

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

computing technologies. The equipment and structural setup required for this is being funded by the BMBF.

## Setting up a Microelectronics Academy

As part of the Green ICT @ FMD and the FMD-QNC projects, a Germany-wide microelectronics academy will be established over the next three years. In December 2022, the kick-off of the conceptualization phase took place and with it, the establishing of the Academy and the enabling of modern training opportunities in the field of micro and nanoelectronics. Regarding its thematic foundation, the Academy is structured in three thematic pillars. The first two pillars, Resource-conscious ICT and Practice-oriented semiconductor engineering and technology (both derived from the Green ICT @ FMD and FMD-QNC projects), are further complemented by the third pillar focusing on design of microelectronic circuits and systems. In the process of setting up the Microelectronics Academy, the FMD is not only assuming the organizational management, but also taking responsibility for the three thematic pillars. The overarching goal is to improve the quality of the training for skilled workers in the field of microelectronics as well as, in the long term, to actively impact and drive forward areas such as climate protection and sustainability, new computing technologies and trustworthiness in the semiconductor and chip sector.

## Increasing the innovative strength of microelectronics in Europe

To ensure that Germany and Europe remain key players in the global value chain, the FMD undertook crucial preparatory work for the technological foundation of the "European Chips Act" in 2022. For instance, the FMD-QNC is being complemented at the European level by the PREVAIL project (Partnership for Realization and Validation of AI hardware Leadership). This project brings together four European research organizations, CEA-Leti, Fraunhofer, imec and VTT, to create a networked

300-mm technology platform for manufacturing chip prototypes used in advanced artificial intelligence and neuromorphic computing applications. The national part of PREVAIL constituted by four Fraunhofer institutes EMFT, IIS, IPMS and IZM, which as part of FMD are broadening their 300-mm fabrication, design and test facilities to complement the 300-mm technology of their European research partners.

For more information about the FMD, visit

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

Check out also our 3D virtual showroom at

<https://fmd-insight.de/showroom>



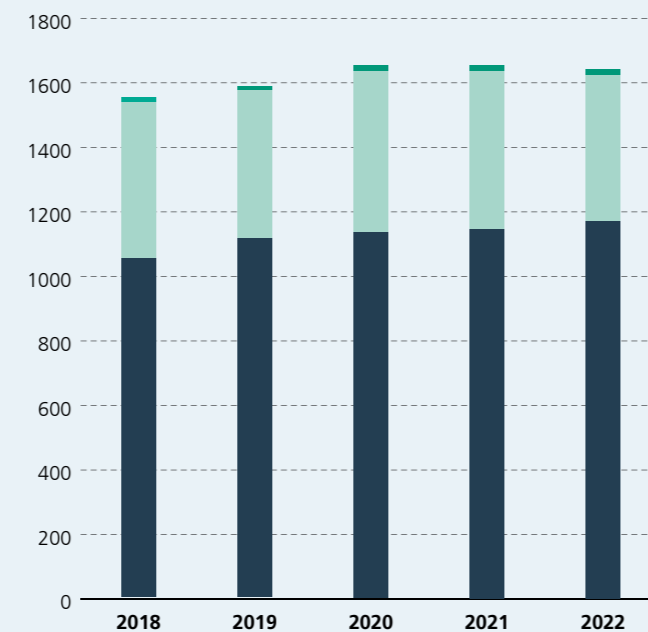
# Facts and figures



**1173**  
salaried employees

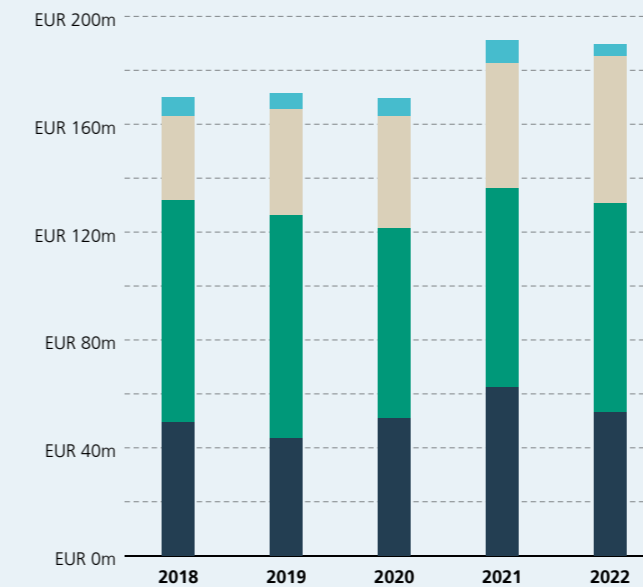
Fraunhofer IIS has a workforce of 1173 salaried employees. The number of staff on the books rose slightly year over year. In addition, 452 students and 18 trainees work at the institute.

## Personnel development



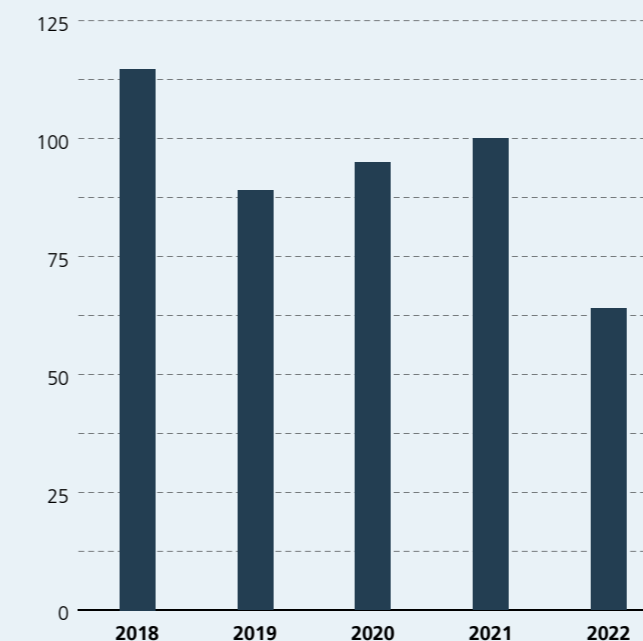
- Salaried employees
- Student assistants
- Trainees

## Funding development\*



- Institutional funding (incl. base funding)
- Industrial revenue
- Public-service revenue
- Other revenue

## Invention disclosure development



**189,7 Mio. €**  
funding

Fraunhofer IIS had a balanced budget in 2022. The institute received 41 percent of its funding from business and industry, 29 percent from public-service revenue. A total of 28 percent came from institutional funding (incl. base funding) through the Fraunhofer-Gesellschaft. Other revenue, including from foundations and other research institutions, accounted for 2 percent of the budget.



**64**  
invention disclosures

In 2022, Fraunhofer IIS employees submitted 64 invention disclosures. The majority of the invention disclosures related to audio and communication standards and came from the research areas Audio and Media Technologies and Communications Systems.

\* Projection as of January 2023

# Members of the Advisory Board

The Advisory Board advises the institute's directors and helps to forge contacts with industry and other organizations

<b>Dr. Annerose Beck</b>	Saxon State Ministry for Science, Culture and Tourism
<b>Marco-Alexander Breit</b>	German Federal Ministry for Economic Affairs and Climate Action
<b>Eckard Eberle</b>	Siemens AG
<b>Dr. Bernd Ebersold</b>	Thuringian Ministry for Economic Affairs, Science and Digital Society
<b>Dr. Astrid Elbe</b>	Aviat Networks
<b>Prof. Kai Fischbach</b>	University of Bamberg
<b>Prof. Joachim Hornegger</b>	Friedrich-Alexander-Universität Erlangen-Nürnberg
<b>Dr. Walther Pelzer</b>	German Aerospace Center (DLR)
<b>Dr. Heike Prasse</b>	German Federal Ministry of Education and Research
<b>Dr. Heike Riel</b>	IBM Research
<b>Dr. Dietmar Schill</b>	Sony Europe B.V.
<b>Dr. Isabel Thielen</b>	Thielen Business Coaching GmbH
<b>Dr. Dirk Tielbürger</b>	German Federal Ministry of Defence
<b>Dr. Manfred Wolter</b>	Bavarian Ministry of Economic Affairs, Regional Development and Energy
<b>Ulrich Zwölfer</b>	SICK AG

Last updated: December 2022

# The Fraunhofer-Gesellschaft

The Fraunhofer-Gesellschaft based in Germany is the world's leading applied research organization. Prioritizing key future-relevant technologies and commercializing its findings in business and industry, it plays a major role in the innovation process. A trailblazer and trendsetter in innovative developments and research excellence, it is helping shape our society and our future.

 [www.fraunhofer.de/en](http://www.fraunhofer.de/en)



Last updated: January 2023

Overview of the institutes and research facilities of the Fraunhofer-Gesellschaft in Germany

# Interpreting facial expressions with AI

Most people can tell at a glance if someone looks sad, angry or happy. Researchers at Fraunhofer IIS in Erlangen used artificial intelligence to teach a software to do the same. SHORE®, the facial recognition and emotion analysis software, is now 15 years old and has been upgraded with additional functions, including heart rate recognition.

While most people can recognize and interpret facial expressions right away, children with autism frequently find this difficult. Moreover, they can often have a hard time finding the correct facial expression for what they themselves are feeling. As part of the ERIK project, therapists want to use a robot to teach autistic children how to read people's facial expressions with a view to understanding others' feelings.

The technology behind this work is provided by SHORE®, the facial recognition and emotion analysis software developed by Fraunhofer IIS. "SHORE® is a software

library for real-time facial recognition and expression analysis using artificial intelligence methods," says Dr. Dominik Seuß, head of the Facial Analysis Solutions group at Fraunhofer IIS. "SHORE® can recognize a person's face and use what it sees to identify their age, sex and emotions." The idea to incorporate facial recognition technology into therapies for autistic children came from a number of parents who wanted to make their child's day-to-day life easier. The Fraunhofer IIS development team received a number of such inquiries.



## At a glance

- 1 | SHORE®, the facial recognition and emotion analysis software developed by Fraunhofer IIS, celebrates its 15-year history.
- 2 | To mark this milestone, SHORE® was given several new features: contactless camera-based detection of heart rate and remote analysis directly in a web browser.
- 3 | This is relevant for applications including driver monitoring systems for cars and trucks.

In collaboration with Humboldt University of Berlin and with funding from the German Federal Ministry of Education and Research (BMBF), the team got to work. The result was a white, humanoid robot with a display on its chest showing sample facial expressions that the children are invited to interpret. The robot speaks to the children, offering advice, praise, encouragement and explanations. For instance, it will tell them that a hallmark of a happy face is when the corners of the mouth are raised. Then it's the children's turn to imitate the expression they've just seen. This method appears to be effective: the participating children are finding it easier and easier to interpret other people's facial expressions.

### Keeping an eye on ethical aspects

When it comes to projects like ERIK that involve research on or with people, Fraunhofer IIS researchers always take into account the ethical, legal and social implications, or ELSI for short. They include users in the process and gain the approval of an ethics commission as a matter of course. Artificial intelligence (AI) is trained using large data sets. In the case of children's facial expressions, the researchers train the AI using videos of people making a range of facial expressions with a view to making the training as nuanced as possible. "For every new research method, we get confirmation that what we're doing is ethically tenable," Seuß says. SHORE® has also held a data privacy seal for more than five years.

### Emotion recognition in advertising?

Applications for facial expression recognition are by no means limited to therapies. Take advertising: Does the key message resonate with the target group? At what point do viewers experience positive feelings, and when should the manufacturer's or product's logo then appear? To help answer these and similar questions, German market research company GfK also used the SHORE® facial recognition software. "GfK visited people at home and showed them a series of advertising spots on a computer and got their permission to be filmed while watching. This new footage was transmitted to the GfK offices, where it was analyzed using SHORE®," Seuß says.

### An upgraded version of SHORE® at 15

To mark the 15th year of SHORE®, a new version of the technology was released. It's now possible to analyze data directly in a browser, which means that videos no longer have to leave the computer they are saved on. Instead, only the metadata, in other words the results of the analysis, are transmitted.



"Now that we have a WebAssembly version, the software library can also be used in web applications. This has the enormous benefit of no longer having to transmit video material," Seuß says.

Another enhancement is that the facial analysis can now determine heart rate. This is because each heartbeat sends a pulse wave through the body, subtly altering the color of the skin. Although these changes are imperceptible to the naked eye, the camera picks them up due to its much more finely tuned color detection. The AI is thus in a position to determine a person's heart rate based on pulse-controlled changes to their skin tone. Potential applications here include driver monitoring systems: camera-based – and thus contactless – facial recognition can be used to capture vital parameters. Fraunhofer IIS researchers plan to develop SHORE® so that it can be used to detect even more biosignals in addition to heart rate. "To this end, we're working closely with our neighboring Digital Health Systems department as well as with other experts whose expertise dovetails with our own," Seuß says.

In addition, the SHORE® research team is making inroads into crowd analysis. "We want to use SHORE® to detect, say, the moment when the mood of a large crowd suddenly shifts," Seuß says. The conditions the technology supports could hardly be better: SHORE® can already detect and

simultaneously analyze any number of faces featured in an image. The researchers have shown that they are open to tackling other potential applications: they have a number of ongoing projects that require them to tailor SHORE® to the needs of industry partners.

- [www.iis.fraunhofer.de/shore](http://www.iis.fraunhofer.de/shore)
- [youtu.be/Gg6b-tRuoLc](https://youtu.be/Gg6b-tRuoLc)

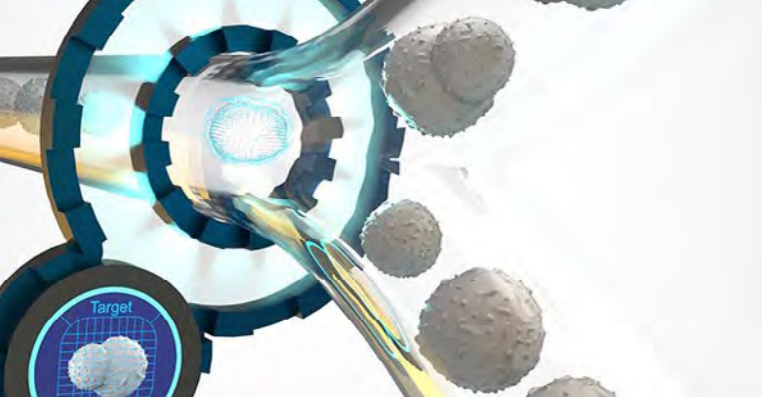


#### Contact

**Dr. Dominik Seuß**

Smart Sensing and Electronics

Phone +49 9131 776-5164  
dominik.seuss@iis.fraunhofer.de



Schematic illustration of image-based sorting of cell pairs  
© Fraunhofer IZI-BB

## IMAGO – Image-based cell sorting

### Sorting cells according to their microscopic appearance using smart image analysis

A key technology in modern biomedicine is segregating heterogeneous cell populations. The IMAGO research project is taking cell sorting to a whole new level: in the future, it will be possible to sort cells according to spatially resolved characteristics. This is about characteristics that describe a cell's inner appearance, such as the position of cell organelles or the distribution of proteins.

IMAGO uses smart image analysis methods as well as neural networks that learn the cell characteristics upon which sorting decisions will be made. If successful, this could overcome the previous limitations of conventional cell sorting methods and open new doors in biomedical research – for example in the field of immunotherapy.

At Fraunhofer IIS, the working group on Medical Image Analysis is responsible for developing the AI that makes the sorting decision. This group is developing a user-adaptable AI that will work for many sorting use cases as well as an application software for future users. As part of Fraunhofer's PREPARE program, IMAGO is to achieve market readiness in collaboration with the Bioanalytics and Bioprocesses (BB) branch of the Fraunhofer Institute for Cell Therapy and Immunology IZI, the Fraunhofer Institute for Applied Optics and Precision Engineering IOF and the Charité university hospital in Berlin.

[www.iis.fraunhofer.de/imageanalysis](http://www.iis.fraunhofer.de/imageanalysis)



The aim of the Bavarian Chip-Design-Center is to promote technology transfer in business and enhance the training of highly qualified chip designers

## Bavarian Chip-Design-Center strengthens the economy

### Funding from the State of Bavaria strengthens the competitiveness of microelectronics particularly among SMEs

Together with the Fraunhofer Institute for Applied and Integrated Security AISEC and the Fraunhofer Research Institution for Microsystems and Solid State Technologies EMFT, we have been awarded just under one million euros in funding for the preliminary project for the Bavarian Chip-Design-Center, or BCDC for short. The funding notification was presented by Bavaria's Minister of Economic Affairs Hubert Aiwanger. The preliminary project will focus on establishing the organizational structure, setting up networks and initiating the first topic-based research projects to pave the way for a joint BCDC. In the long term, it is hoped that the BCDC will expand Bavaria's expertise in IC design, establish a chip design ecosystem and provide SMEs in particular with easy access to application-specific ICs at minimal risk. What's more, it should expand access to manufacturing capacity, expedite the training and qualification of designers and pave the way for faster innovation rollouts. Also on the agenda is the education and training of the next generation of chip designers.

Fraunhofer IIS is providing the project with the benefits of its cutting-edge research into microelectronic and IT system solutions and services as well as of the innovative and integrated digital and mixed-signal systems it develops. The focus here is on designing chips for a wide range of applications and on establishing design solutions for increasingly complex electronic systems. Above all, what we are doing is bringing the entire development process together under one roof – from generating ideas to resolving supply chain issues to acting as an interface to semiconductor manufacturers.

[www.iis.fraunhofer.de/bcdc-en](http://www.iis.fraunhofer.de/bcdc-en)

## Chips that increase sovereignty in cybersecurity

### Better security in the digital age thanks to the Trusted Electronic Center Bayern

As the world becomes more digital, it is becoming increasingly important to protect electronic devices from outside attacks. Trusted electronics and data security are the basis for all secure, digital and connected systems, for the Internet of Things and for AI. Providers and integrators of microelectronics therefore need to be able to trace their development and manufacturing and inspect their functions for both hardware and software.

Together with Fraunhofer AISEC and Fraunhofer EMFT, we are working on precisely these solutions as part of the Trusted Electronics project.

Through the planned Trusted Electronic Center Bayern (TrEB) and the corresponding expansion in research infrastructure, we will be taking a major step forward in the development of tailored technology and system solutions for reliable and trusted electronics. In turn, this will help us solve current and future challenges in microelectronics. The TrEB will serve as a point of contact particularly for Bavarian industrial companies and SMEs. It will offer straightforward access to trusted secure technologies as well as integrated analog and digital hardware complete with software, system protection solutions and state-of-the-art analysis labs.

The role of Fraunhofer IIS is to use innovative methods in design and testing to protect intellectual property along the value chain of microelectronic components and systems. In this project, our focus is on developing a secure design flow for circuit components and processors. In addition, we help implement solutions to create a secure element platform and secure neuromorphic hardware, and assist with the provision of IPs relating to functionally secure sensors for industrial plants, the automotive industry and medical engineering.

Prof. Kai Fischbach, President of the University of Bamberg; Jonas Glüsenkamp, Deputy Mayor of Bamberg; Prof. Ute Schmid, Head of the Project Group for Comprehensible Artificial Intelligence; Melanie Huml, Bavarian Minister of State for European and International Affairs; Johann Kalb, District Administrator for Bamberg; and Prof. Albert Heuberger, Executive Director of Fraunhofer IIS (from left)

## Trustworthy artificial intelligence

### Turning black into white: from black box AI decisions to a white box

When it comes to classifying large amounts of image data or analyzing a multitude of time series, there really is nothing better than artificial intelligence. But it does present certain challenges: since many applications are based on black box models, humans can have a hard time understanding how an AI system reaches decisions. How is it possible to ensure that the decisions made by AI are indeed trustworthy? The answer lies in the following five aspects: transparency, responsibility, privacy, fairness and reliability.

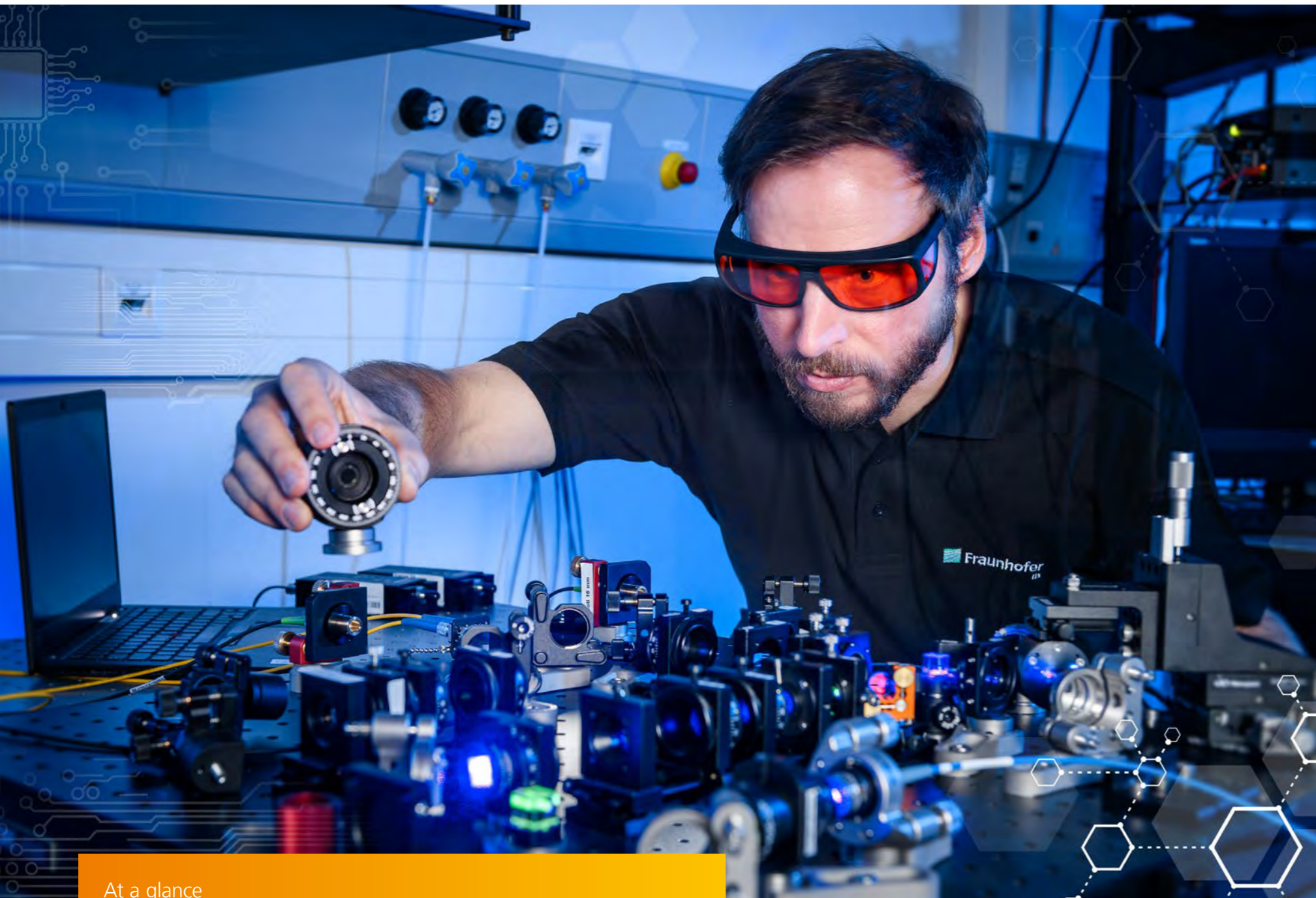
In addition to fairness and reliability, our research focus is on transparency: the Project Group for Comprehensible Artificial Intelligence (CAI) is developing methods of transferring the decisions made by such black box systems to a white box – thus making them understandable, and for a broad range of applications. For instance, where is AI's decision threshold for classifying a workpiece as a reject? When it comes to fairness, CAI researchers are developing – among other things – methods of establishing a fair data basis that integrates people of different genders, ages and ethnicities. The team achieves reliability and robustness especially through what are known as hybrid or neuro-symbolic approaches: integrating knowledge into the learning process helps prevent certain decision errors.

On May 23, 2022, Minister of State Melanie Huml and representatives from politics, industry and business attended the open day at the University of Bamberg to learn about the project group's latest findings.

[www.iis.fraunhofer.de/cai](http://www.iis.fraunhofer.de/cai)

[youtu.be/A08U4Ui2TQE](https://youtu.be/A08U4Ui2TQE)





# Quantum-safe data transmission made in Saxony

A new center for the practical application of quantum communication has been established at the Dresden branch of Fraunhofer IIS. Quantum communication is considered a technology of the future because it permits hack-proof data transmission between advanced high-performance computers. A demonstrator has been built for quantum-safe video communication.

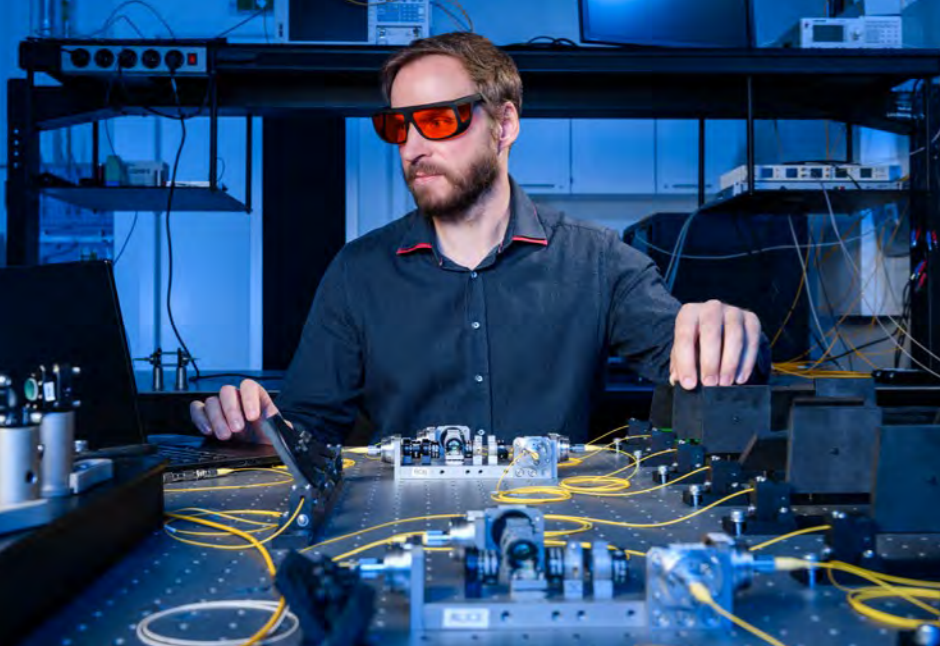
Due to rapid advances in quantum computing, many of the cryptographic encryption methods used today – for example, in online banking – will become vulnerable to attacks. This means that research into new methods for the secure transmission of data and information is crucial. Encryption techniques that can replace or usefully supplement today's methods already exist. They are based on a system whereby the sender and the receiver have a secret key known only to them. The advantage of quantum communication systems is that the exchange of keys is performed using quanta of light, and certain physical laws make it impossible to intercept quantum keys undetected. The quantum-encrypted data can then be securely transmitted via a conventional connection.

## At a glance

- 1 | Communication based on the quantum key exchange principle cannot be intercepted without being noticed.
- 2 | We have established an Application Center for Quantum Communication to support the practical development of electronic systems.
- 3 | The center plans to demonstrate highly secure signal transmission from Saxony to Thuringia and subsequently to Bavaria.

*Aligning an entangled photon pair source in the Application Center for Quantum Communication at Fraunhofer IIS/EAS*





The new application center will help shape key stages in the development of quantum technology.

### Innovation potential for high-tech industry

The Application Center for the Design of Scalable Electronic Systems for Quantum Communication – to give its full title – at the Engineering of Adaptive Systems (EAS) Division is working to cultivate this technological principle for practical application. Its goal is to nurture the innovation and application potential of the technology for the high-tech industries that are such a strong presence in the Saxon economy, such as micro- and nano-electronics. Since the summer of 2022, the center has been providing companies and researchers with flexible experiment and test environments for the development of electronics for quantum communication systems. One of the focuses of its work, for example, has been on microelectronic circuits based on chiplets. This approach not only makes it possible to produce electronics cost-effectively even in small batches, but also offers a way to implement very high-performance functional units using the optimum technology for each of the heterogeneous systems required.

“Quantum communication – that is, the exchange of data via qubits – will change our world forever. The prospect of hack-proof data transfer offers just a glimpse of the full potential of this technology. However, it will take many more technological innovations for this technology to become widespread in industry and administration and, ultimately, among the general public. This is where the new application center comes in. Working within a partner network, it will develop and test precisely these

applications in an effort to shape the key development stages of quantum technology,” says Saxony’s Minister of Science, Sebastian Gemkow.

### Demonstrator for quantum-safe video communication

An important milestone of the application center was achieved in 2022 with the successful creation of a prototype quantum communication system. “In a first stage, we did intensive testing of quantum-safe communication via fiber optics at our institute building on Münchner Straße,” reports Dr. Kay-Uwe Giering, head of the application center at Fraunhofer IIS/EAS. “As a result, we can now give other research institutes and companies access to a demonstrator as a practical testing environment for their own developments of electronic components and systems.” This experimentation environment is based on entangled photon pairs, which permit the allocation of a random key. The setups use individual photons and currently encode the key bit in the photon polarization or the photon phase. Furthermore, the test environment makes it possible to implement the design, validation and optimization of high-performance electronic circuits for quantum communication in modern semiconductor technologies. “The modern approach we’re pursuing here offers huge advantages for our partners,” Giering says. “As well as enabling miniaturized and cost-effective electronic modules, it also provides them with maximum performance capability and adaptability.”

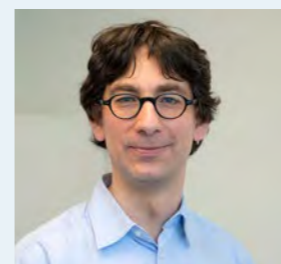
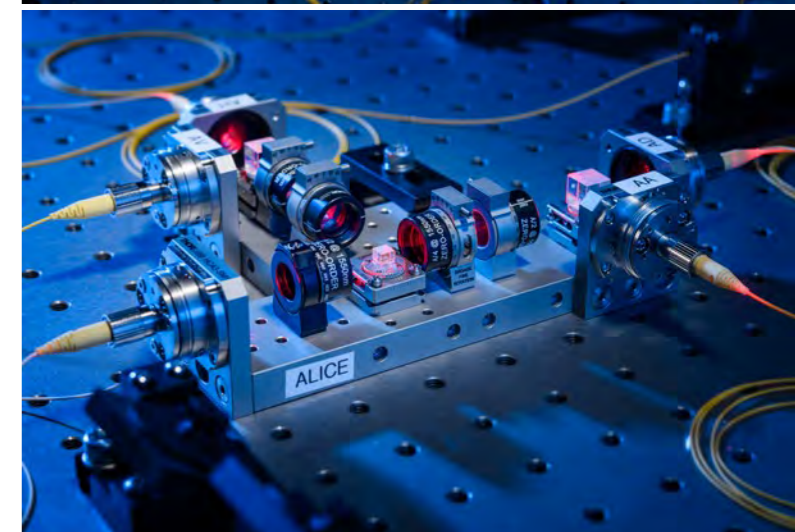
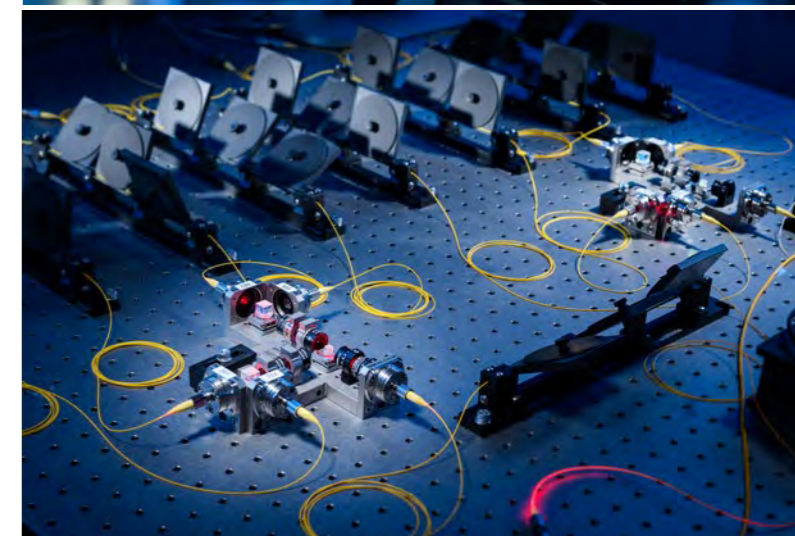
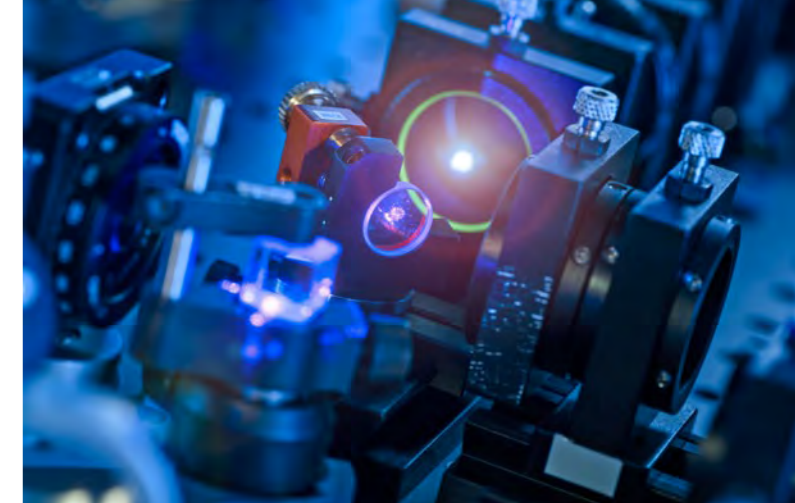
### Secure communication between three German states

It is planned to incrementally expand the distances for highly secure signal transmission – starting at the local and regional levels in Saxony and extending from there to Thuringia in 2024 and then further afield to Bavaria at a later point. After all, the center was specifically designed as research infrastructure for the establishment of quantum communication under the umbrella of an initiative between the three states. The states’ activities themselves complement the Germany-wide QuNET research initiative for the development of new key technologies for quantum communication, which is supported by the German Federal Ministry of Education and Research.

The establishment of the application center has received around eight million euros in funding from the Saxon Ministry of Science, Culture and Tourism in the context of the European Regional Development Fund (ERDF). This initiative is co-funded by taxation money allocated from the budget of the Saxon State Parliament.

[www.eas.iis.fraunhofer.de/quantum-communication](http://www.eas.iis.fraunhofer.de/quantum-communication)

[youtu.be/eHZQY1JIZX8](https://youtu.be/eHZQY1JIZX8)



#### Contact

**Dr. Kay-Uwe Giering**  
Engineering of Adaptive Systems EAS

Phone +49 351 45691-202  
kay-uwe.giering@eas.iis.fraunhofer.de

## About the KISSS project

The move toward smart systems and production methods will make it possible to tap the potential of maritime digitalization and strengthen resource-efficient production methods. Under the leadership of MEYER WERFT GmbH & Co. KG, project partners Laserline GmbH, SLV Mecklenburg-Vorpommern GmbH and the Engineering of Adaptive Systems EAS division of Fraunhofer IIS will collaborate to achieve the project's goals by 2025. The KISSS joint project is funded by the German Federal Ministry for Economic Affairs and Climate Action as part of the Maritime Research Program.

## AI to optimize welding processes in shipbuilding

### Manufacturing individual components with an innovative AI-based welding process

In many industrial sectors, welding is one of the basic processes for joining components together. The welding methods currently used in shipbuilding are particularly efficient when it comes to repeatedly prefabricating similar and flat components. But in the field of component manufacturing, more and more new, complex and even three-dimensional tasks are emerging – tasks today's welding robots are not designed for.

To avoid major time losses and an increase in the cost of manufacturing a ship, we and our partners in the KISSS research project (the German acronym stands for "AI-based manufacturing technology for autonomous laser welding of complex ship structures") are working on a new and robust laser welding process. Our goal is for this to form the

basis for significant productivity and quality improvements in component manufacturing for shipbuilding. The project will employ AI methods in different phases of the welding manufacturing process in order to make the high complexity of the application manageable.

By employing suitable AI methods, the project partners aim to draw up approaches that can help improve the entire planning of a sequence of welds. The partners will also apply these methods to find the optimal design for each individual weld seam in a new type of automated laser welding process that uses targeted heat input. Overall, this shortens lead times and reduces error rates while improving product quality.

 [www.eas.iis.fraunhofer.de/kiss-en](http://www.eas.iis.fraunhofer.de/kiss-en)

## Standards-based chiplets on Samsung's 5 nm process technology

### Design work supports introduction of chiplet technology, including for smaller batches of electronic products

Producing a chiplet interface from chip to chip nowadays is economical, especially for mass-produced applications. However, this largely excludes customer-specific implementation for product groups with smaller and medium batch sizes; for these, the use of chiplets is currently still too costly and unprofitable. The advantages of the technology, such as the greater degrees of freedom in selecting suitable manufacturing technologies for circuits, remain broadly untapped in this market segment.

To change this, we at the Engineering of Adaptive Systems EAS division are working on developing customizable chiplet-based solutions. However, making them safe and efficient calls for uniform standards, such as with regard to the die-to-die interface. This is the only way to successfully integrate circuits from different manufacturers, including for small production runs, and to avoid problems during chip assembly.

"We are delighted to work with Fraunhofer IIS/EAS on implementing their interface IP in our 5 nm process technology," says Kevin Yee, Senior Director of Marketing, Foundry IP and Ecosystem from Samsung Electronics. "As a leading IP partner in our SAFE™ ecosystem, and a provider of BoW-based interface IPs, which is also of interest to Samsung Foundry, we plan to work together and find ways of supporting our mutual customers and the industry."

To this end, the Fraunhofer design team used the Open Compute Project's BoW (Bunch of Wires) standard. "As part of this work, we even managed to implement a data rate of 16 Gbit/s per lane – the highest rate specified by the BoW standard. We believe this provides an excellent basis for implementing forward-looking solutions for our customers," adds Andy Heinig, chiplet expert at EAS.

 [www.eas.iis.fraunhofer.de/chiplet-interface-ip-project](http://www.eas.iis.fraunhofer.de/chiplet-interface-ip-project)

## Background: Chiplets

Chip packaging solutions based on chiplets allow various functional units, including with different technologies, to be incorporated onto a substrate or into a 3D stack. As a result, developers can use the most suitable manufacturing technologies to, say, concentrate functionalities requiring circuits with the latest semiconductor technologies into a few circuits instead of using them for the entire chip.

## 5G for tomorrow's mobility

### Testing 5G functionalities for connected driving in a real traffic environment

The new 5G mobile communications standard is putting connected driving within reach. Faster data connections, minimum latency and high reliability pave the way toward optimized traffic concepts that enable vehicles to communicate with their environment and be intelligently integrated into the traffic flow.

Companies can find out whether this also works smoothly in practice at our 5G Bavaria automotive test bed. Since May, companies have been able to give their 5G applications a "reality check" in the test bed sponsored by the Bavarian Ministry of Economic Affairs, Regional Development and Energy. In this way, applications can be put through their paces under various reception conditions before being launched on the market. The controlled and reproducible test environment south of Rosenheim is ideal for this purpose due to its heterogeneous road area.

The automotive test bed is of particular use to developers who want to test new connectivity solutions in a real road network. The focus

is on testing transmission technology and evaluating specific transmitter and receiver components. Essential performance parameters such as latency, reliability and throughput provide valuable insights into a given application's quality of service and user experience. Connected driving introduces new functions that can be evaluated on the area's test routes just as comprehensively as the quality of the data connections between the vehicle and the wireless network and among the vehicles themselves.

Connected car scenarios can also be expanded to include infrastructure components such as stationary traffic monitoring systems with object recognition. A local multi-access edge computing server can help test numerous applications in cases that require short response times, need to avoid cloud processing due to privacy concerns, or where local processing is preferred to reduce network traffic.

[www.iis.fraunhofer.de/5g-testbedautomotive](http://www.iis.fraunhofer.de/5g-testbedautomotive)  
[youtu.be/qk-orVwRexM](https://youtu.be/qk-orVwRexM)

Testing connected automotive applications with 5G



## New simulation platform available

### Virtually testing connected driving with 5G on C-V2XSim, our web-based simulation platform

Since summer 2022, companies have been able to access our web-based simulation platform free of charge and virtually test a wide variety of traffic and communication scenarios. In this way, C-V2XSim facilitates and supports the development of vehicle functions for connected driving based on the 5G mobile communications standard.

After registering, users can access a wide range of options for intuitively configuring the traffic and mobile communications environment in which the simulation is to take place. Once the simulation has been run, C-V2XSim generates a helpful report containing detailed KPIs on the network's performance in the modeled scenario.

The tool visualizes weak points in mobile coverage or data transmission in the form of, for example, heat maps based on real map material. This makes it possible to see at a glance whether a planned application can be implemented safely at any point in the environment in question.

We're continuing to develop C-V2XSim so that we can offer companies even more functionality. In addition to extended options for configuring traffic, mobile communications and result parameters, upon request we also provide an interface that can be used to link external simulators or entire development environments with C-V2XSim.

This is how we, in a joint project with the company Elektrobit, have created an end-to-end simulation environment in which complex driving functions can be modeled, developed and then tested by means of simulation directly in the application context. This helps

developers quickly identify any problems that arise, correct the algorithms accordingly, and then put the driving functions to the (virtual) test again – all with just a single software tool. The actual code is generated and transferred to the vehicle only once the software-based validation has succeeded.

C-V2XSim is traffic simulator and 5G simulator in one



Previously common but costly intermediate steps, in which the software is transferred several times to the hardware and tested again and again in the vehicle, are no longer required. As a result, C-V2XSim helps significantly shorten software development cycles.

[www.iis.fraunhofer.de/c-v2xsim](http://www.iis.fraunhofer.de/c-v2xsim)  
[youtu.be/hWetNXp8Rdw](https://youtu.be/hWetNXp8Rdw)

# Preparing for climate change with sensor technology

The summer of 2022 made it clear once again: agriculture needs plants that are adapted to climate change. To help breeders select suitable varieties, Fraunhofer IIS develops high-performance optical and X-ray systems. Since 2022, these technologies have been further refined in the recently established Fraunhofer Center for Biogenic Value Creation and Smart Farming.

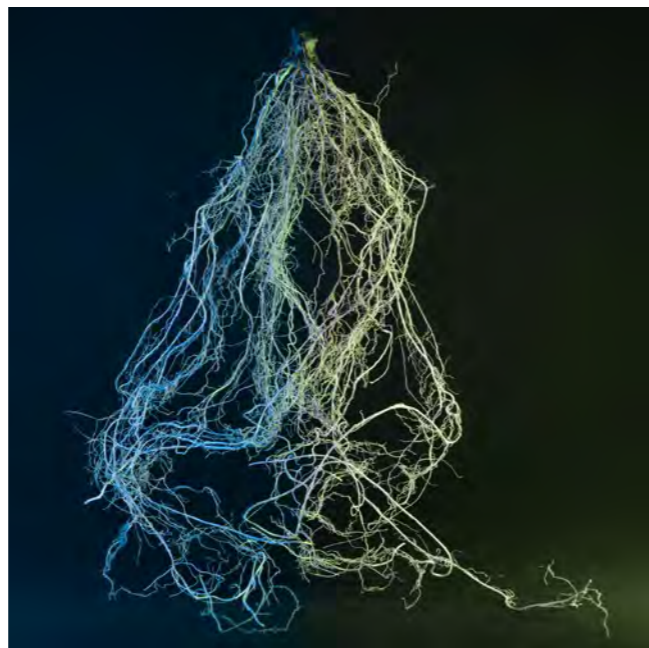
## At a glance

- 1 | The Development Center X-ray Technology EZRT develops technologies to objectively measure external characteristics of plants.
- 2 | Phenotyping results support breeders in selecting crops adapted to climate change.
- 3 | Fraunhofer IIS is establishing a new site in Triesdorf, a national center for agricultural research and teaching.



Top:  
X-rays let us look into the earth: potato tubers at an advanced stage of growth

Bottom:  
A corn plant's washed root structures (optical image)



No less a figure than Bavaria's Minister of Economic Affairs, Hubert Aiwanger, came to the kickoff meeting of the Fraunhofer Center for Biogenic Value Creation and Smart Farming in July 2022. His presence underscored the importance of the research network that is being established in Mecklenburg-Western Pomerania and Bavaria. Its objective is to develop innovative technologies for sustainable agriculture – from seeds to food processing technology to refined products.

In a Bavarian subproject, the Development Center X-ray Technology EZRT of Fraunhofer IIS starts with the seed. More specifically, with the process of breeding crops adapted to climate change. The new varieties have to cope with heat and drought, while also requiring as little fertilizer as possible and ideally no more pesticides. "People have been selecting crops based on external characteristics for thousands of years," explains Dr. Stefan Gerth, Head of Department at Fraunhofer EZRT. "We're developing technologies to objectively and reproducibly measure these traits and use the data to optimize breeding." The scientists consider factors such as leaf size, leaf position, root network and yield. Together, these characteristics determine the phenotype, i.e. the external appearance of a plant.

### Watching potatoes grow – without digging them up

When Dr. Gerth began X-raying potatoes ten years ago, he was one of the pioneers in the virtually unexplored field of nondestructive phenotyping of underground plant parts. Back then, he was studying potatoes suffering from heat stress. He wanted to track their growth without digging them up, so he cultivated the potatoes in flowerpots and constructed a computed tomography device with his team to X-ray the plants. "Regular X-rays allowed us to observe exactly how tuber formation is affected by heat and drought," Gerth says.

With this research, he laid the foundation for the construction of a special X-ray chamber for crops; this one-of-a-kind equipment exists only at Fraunhofer EZRT in Fürth. Pots of crops are arranged in neat rows on the narrow conveyor belt in front of the X-ray machine. The assembly line positions the plants one after the other in the device. After just five minutes, it's

the next plant's turn. "With this system, we can even record the delicate root architecture of wheat and observe how the plants react to heat or drought stress," Gerth explains. "Our device is the most modern and powerful X-ray system for underground plant parts."

In collaboration with Fraunhofer EZRT, Dutch company PhenoKey has developed a robust CT scanner for plant cultivation. Its customers also include big seed breeding companies, which have tens of thousands of plants in their greenhouses that need to be assessed. The CT images have enormously high resolution and measure some 40 gigabytes. To make these data volumes manageable for customers, algorithms analyze the data sets automatically and zero in on the important data.

### The whole plant in view

When evaluating the cultivated plants, the aboveground parts of the plant are of course measured as well. Here, other questions come to the fore: Does the plant raise its leaves to protect itself from the sun? Does it curl them up due to stress? Answers to these come mainly from optical 3D measurements that are recorded digitally.

By combining 3D images and X-rays, even more in-depth information can be obtained. The DeBiFix field robot shows how this works in practice. The high-legged vehicle rolls through wheat fields under remote control. As it makes its way through densely packed ears of wheat, it continuously takes X-ray images of the plants. At the same time, it generates 3D images using an optical system. With this data, the robot can essentially look inside the ears of wheat and determine whether the variety being cultivated will produce a good yield.



### New location at the Triesdorf Center for Agriculture

As part of the Fraunhofer Center for Biogenic Value Creation and Smart Farming, Fraunhofer EZRT is establishing a new plant phenotyping site in Triesdorf. The Bavarian town is home to agricultural teaching institutes and the Weihenstephan-Triesdorf University of Applied Sciences, making it a national center for agriculture. Fraunhofer EZRT is already working closely with the Center of Excellence for Digital Agriculture there. "The Triesdorf site is ideal for expanding contact with agriculture and driving technology transfer," Gerth says. "With our research, we want to support small and medium-sized plant breeding companies in particular."

At the same time, Fraunhofer IIS is stepping up its collaboration with the two other Fraunhofer Institutes active in the Center for Biogenic Value Creation and Smart Farming in Bavaria. The

Fraunhofer Institute for Process Engineering and Packaging IVV in Freising is working on projects for the sustainable, resource-conserving use of regional raw materials. The Fraunhofer Research Institution for Microsystems and Solid State Technologies EMFT in Munich contributes its expertise in the fields of sensor technologies, system integration and microactuators to the center. For example, a test field in Triesdorf is equipped with sensors to record climate and soil data in a fine grid. For Gerth, this collaboration offers excellent added value: "By combining the environmental data with our phenotyping data, we can provide breeders with even more precise information for crop selection."

[youtu.be/Jr-IR51gp5U](https://youtu.be/Jr-IR51gp5U)



#### Contact

**Dr. Stefan Gerth**

Fraunhofer Development Center for X-ray Technology EZRT

Phone +49 911 58061-7658  
stefan.gerth@iis.fraunhofer.de

## The final secrets of encryption machines

Thanks to powerful X-ray technology, the mysterious interiors of 60 encryption machines from the collection of the Deutsches Museum have been revealed

Their inner workings are among the best-guarded of secrets – after all, the machines themselves were all about secrecy. We are talking about encryption machines, with which the military and secret services but also banks encoded their messages. Last year, 60 of these encryption machines from the collection of the Deutsches Museum were studied using a particularly powerful X-ray machine. The Enigma machine used by the Nazis and its less well-known successor, Cipher Machine 41, were among the items scanned at the Development Center for X-ray Technology EZRT at Fraunhofer IIS in Fürth.

“We expect that this research project will yield new findings about the construction of the encryption machines and how they work,” says cryptography curator at the Deutsches Museum, Carola Dahlke. “The Enigma has been quite thoroughly researched, but other encryption machines simply cannot be opened without damaging them.” Machines from the early days of computers in particular have revealed a lot of mysteries. Their designers wanted of course to shield the inner workings of the machines from the eyes of unauthorized

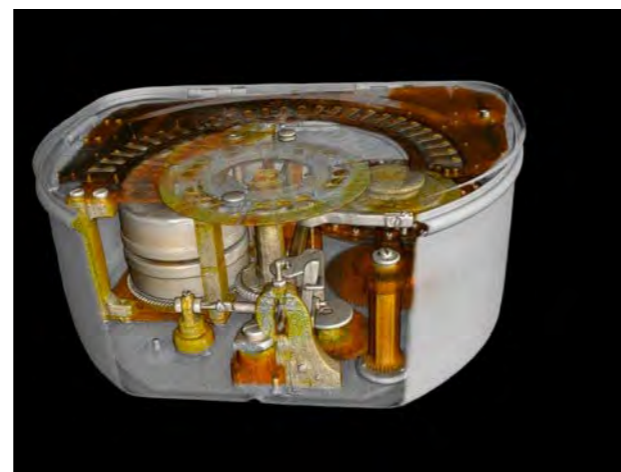
people. “Some encryption machines are welded shut or even filled with a mysterious substance that ensures that the inner workings of the machine are destroyed when the casing is opened,” Dahlke says. But thanks to state-of-the-art technology at Fraunhofer EZRT in Fürth, it is possible to study the inner workings of these devices nonetheless.

The XXL scanner at EZRT somewhat resembles a CT scanner in a hospital – except that the XXL scanner does not have a giant tube that rotates around a patient, rather the object is placed on a turntable that rotates while the X-ray source stays fixed in its place. And the X-ray source is also much stronger than in a medical device. “That’s necessary because the objects are largely made of metal and difficult to penetrate for conventional X-ray tubes,” explains Nils Reims, head of the 3D-Cipheram project at the Fraunhofer Development Center for X-ray Technology EZRT. This allows the last mechanical mysteries of the top-secret encryption machines to be brought to light.

Left: The encryption machines are carefully unpacked



Bottom: X-ray image of a Kryha cipher machine



## PCBcycle – Recycling printed circuit boards

An effective sorting system for waste electrical equipment

Printed circuit boards (PCBs) from waste electrical equipment are a valuable source of materials, containing raw materials such as gold, copper and palladium.

Consumer electronics and information and telecommunications technology are presenting the recycling industry with a problem: there is a lack of suitable methods for determining the exact value of a large volume of printed circuit boards with high precision and high throughput.

The goal of the PCBcycle project is to carry out a complete online evaluation of the PCBs followed immediately afterward by sorting. This results in a system and process for the automatic sorting of waste printed circuit boards (WPCBs). On the basis of the predicted value, it can be determined whether it is financially worthwhile to extract valuable components.

The system records dual-energy X-ray images of the PCBs on a conveyor belt. These images are pre-processed and fed into a deep neural network that recognizes individual components. The system calculates the value of each component in a PCB. An important advantage of X-ray images here is that they allow components to be recognized at the front and back simultaneously.

[www.iis.fraunhofer.de/pcbcycle-en](http://www.iis.fraunhofer.de/pcbcycle-en)

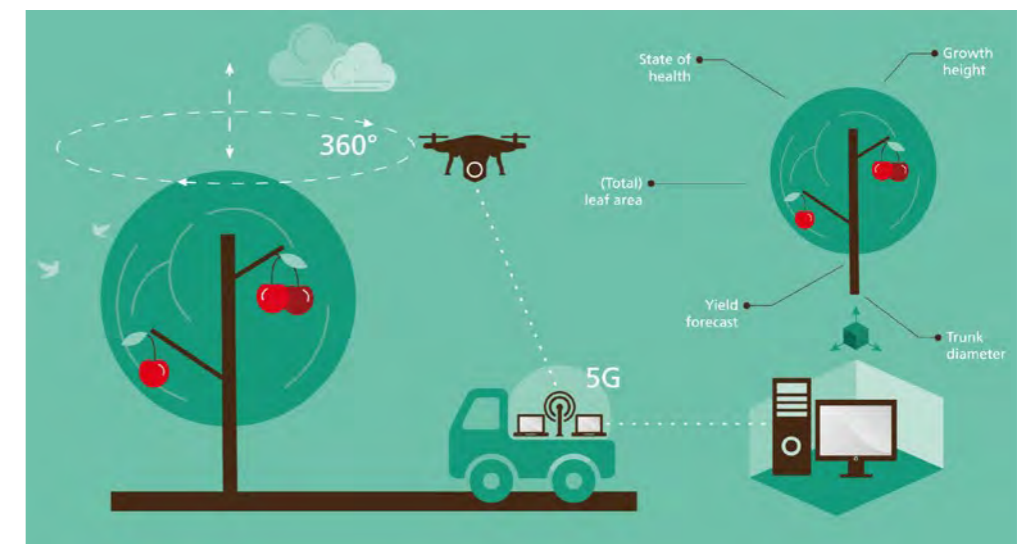
## For5G – Digitally twinning cherry trees

The heart of the For5G project is the generation and analysis of a digital twin for fruit trees

As part of the For5G project, a practical 5G application is being developed for cherry farming. The core of the project, which is located in the Franconian Switzerland region of Bavaria, is the generation and analysis of a digital twin for fruit trees via a 5G campus network. In the future, the insights obtained will then be transferred to other use cases. Fraunhofer IIS, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), the Weihenstephan-Triesdorf University of Applied Sciences (HWST) and its Horticultural Institute, and Forchheim District Council are collaborating on the implementation. The project has received funding of 1.4 million euros from the German Federal Ministry for Digital and Transport.

Widely cultivated in the region, the sweet cherry was selected as the first use case. The digital cherry tree twin is designed to support farmers in predicting harvests, recognizing when trees are stressed and in planning and implementing care measures, thus contributing to a more efficient and more sustainable orchard management.

The expertise brought together for the project in the areas of 5G and phenotyping (Fraunhofer IIS), robotics and visualization (FAU) and fruit cultivation (HWST / Forchheim District Council) complement each other ideally for the successful execution of the project.



## Knowledge graphs for Industry 4.0

### Using connected data to move toward smarter process analysis and more trustworthy electronics

Tomorrow's digital factory will be able to organize itself more and more independently and will also be increasingly automated or able to respond on its own to malfunctions. However, to become reality, this vision requires a wide range of machine-readable data in large quantities. To this end, our Center for Applied Research on Supply Chain Services is developing "knowledge graphs." These knowledge graphs use artificial intelligence (AI) to link data from different sources and pool it all together. With this AI-based technology, it is possible not only to represent data, but to conduct predictive analytics as well. For example, in such a data space, AI can analyze in advance what time is good for a repair so that upcoming orders can be processed in line with demand.

### AI-Nalyze – intelligent analysis of production processes in real time

Disruptions often occur at inopportune times. The AI-Nalyze project aims to create an intelligent process analysis solution that, using AI, can learn from previous failures and predict future ones in real time. Together with Trevisto AG, we are working to find opportunities for controlling and improving transparently mapped processes for the Siemens AG plant in Amberg, Germany. Data such as machine speed, power consumption or which workpieces are currently in use are automatically recorded – as are malfunctions. This smart factory data is applied to optimize processes in real time; for example, by having an AI suggest a suitable time for maintenance – before any damage occurs. The underlying knowledge graph makes it possible to link the various data sources and thus provides the system context for individual data points, which the AI can then take into account.

### Welelektronik – a wiki for electronics hardware without security gaps

In computing parlance, a backdoor is an unwanted access point built into electronic hardware that hackers use to bypass security systems so they can spy on, say, corporate networks. To ensure that trustworthy suppliers are reliably recognized by the German microelectronics industry, we are developing new software as part of a Fraunhofer-wide consortium project on

trustworthy electronics, called Welelektronik. With knowledge graphs as a database, we are building Welelektronik: an open, collaborative wiki for describing supply networks and analyzing them for trustworthiness. The data for this is obtained from public sources such as Wikidata or manufacturer websites, but can also be entered by supply chain participants themselves.

[www.scs.fraunhofer.de/en-ai-nalyze](http://www.scs.fraunhofer.de/en-ai-nalyze)  
[www.scs.fraunhofer.de/en-welelektronik](http://www.scs.fraunhofer.de/en-welelektronik)

## Process mining of material flows

### Verification of internal material flow processes in small-scale production operations

Wide ranges of variants, small batch sizes and flexibility: as manufacturing becomes more and more individualized, the tasks of in-house logistics are becoming increasingly complex. There is still plenty of potential for optimization in material flow control, but at SMEs especially, the corresponding physical processes are often insufficiently digitally mapped. It is also not always clear which processes have actually been executed, to say nothing of when and how. That's why in the ProCheck project, our Center for Applied Research on Supply Chain Services and the Positioning and Networks unit have been researching how to enable automated and continuous analysis plus optimization and verification of material flow processes, even in small-scale production operations. To do this, the team used process mining methods for these physical material flows. Missing data and information on cyber-physical systems (CPS) was collected to create a valid data basis.

The application partner was a manufacturing company with a corresponding requirements profile, such as spatially distributed machine and assembly stations as well as material and tool requirements related to ordering. Fraunhofer researchers installed the required CPS and, in parallel, applied process mining methods to the existing ERP data.

[www.scs.fraunhofer.de/en-procheck](http://www.scs.fraunhofer.de/en-procheck)

## Promoting intermodal transportation

### Regional shipping platform for CT terminals in peripheral locations

There's much to be said for shifting transport from road to rail. In practice, however, this shift quickly reaches the limits of feasibility. In central regions, the necessary rail networks or terminals of what's called combined transport (CT) are already almost at full capacity. Expansion is proving difficult due to a shortage of space. On the other hand, the CT terminals in peripheral locations usually still have untapped possibilities.

In a research project called "ReVeLa – Developing and evaluating a regional shipping platform for the use of CT terminals on the outskirts of metropolitan regions," our Center for Applied Research on Supply Chain Services past three years. They are looking into how CT can be supported as an environmentally friendly transport alternative in locations outside major metropolitan regions. The project focuses on the sustainable design of CT in peripheral locations through digitalization, promotion of data exchange and enhancement of the alternative's appeal.

At the end of the project, a newly developed solution concept for a digital CT information platform was ready for implementation.

[www.scs.fraunhofer.de/en-ReVeLa](http://www.scs.fraunhofer.de/en-ReVeLa)

*The two partners took the terminal in Schweinfurt, Germany, as an example, conducting their analysis in close cooperation with local players: CT stakeholders, regional organizations and associations as well as various information platform providers*



## Optimal inventory planning under uncertainty

### Optimizing inventory planning in wholesale with artificial intelligence

"Out of stock" has been a frequently heard refrain in recent times. Wood, bathroom fittings and toilet paper are not in stock when customers need them, while goods that are not in demand are taking up valuable space. This makes managing inventory levels a key challenge in the wholesale sector. In the OBER project, researchers at our Center for Applied Research on Supply Chain Services are combining forecasting models with mathematical optimization to create an artificial intelligence (AI) that also takes into account restrictions such as purchasing conditions, storage capacity and capital commitment.

While forecasts are already in use in some places, they often provide only a mean of previous sales and thus deliver point forecasts. Often, however, it is precisely the uncertainty factor that is critical in allowing statements to be made about how likely it is for a predicted sales volume to be exceeded or undercut. The Fraunhofer AI uses the latest forecasting models from research, quantifies this uncertainty factor and, on this basis, determines the best possible ordering strategy for dispatchers in terms of order quantity and timing. The project is funded by the Bavarian Ministry of Economic Affairs, Regional Development and Energy. Project partners are Trevisto, Eisen-Fischer and FIS Informationssysteme und Consulting.

[www.scs.fraunhofer.de/en-ober](http://www.scs.fraunhofer.de/en-ober)

*AI-based inventory planning in the warehouse: Use of the latest forecasting models from research to determine the best possible ordering strategy*



## Making cash supplies more resilient

### Ensuring the supply of cash in a crisis: Optimization algorithm for determining key cash withdrawal points in Germany as part of a new security framework

An intact cash cycle is important. What happens, however, if crisis situations disrupt the circulation of cash and today's widely adopted electronic payment methods cease to work?

In the Resilience of Cash Supply (BASIC) consortium project, the German Central Bank, commercial banks, trading companies, cash-/valuables-in-transit service providers and research institutions are developing the first ever holistic cash security framework that is designed for the long term and takes into account all the players involved and their needs. For specific scenarios, researchers at our Center for Applied Research on Supply Chain Services define the optimum cash delivery by means of mathematical optimization. They pinpoint which data needs to be available for an optimization in a given crisis situation. And based on the available data, they calculate the most relevant cash withdrawal points (ATMs and banks) in order to prioritize their supply or, for example, to equip them with crisis-proof emergency power generators. Moreover, the optimization algorithm can be adapted individually to the crisis setting through various parameters. This new, integrated approach will improve the supra-regional availability of cash in emergency situations.

[www.scs.fraunhofer.de/en-basic](http://www.scs.fraunhofer.de/en-basic)

## How digital eagle eyes find brownfields

### Detecting unused industrial and commercial sites using geodata and aerial and satellite images

Abandoned warehouses, empty industrial facilities, unused commercial properties – in Germany, there are many of these brownfield sites, which are often difficult to research. At the same time, there are many expanding businesses that are looking for industrial and commercial sites. In the ARGOS project (Reconnaissance of Reactivable Brownfield Sites Using Optical-Based Systems), researchers at our Center for Applied Research on Supply Chain Services are training AI to identify such sites. Brownfield sites have a lot of advantages: As well as being connected to supply networks, they are often in a central location with good infrastructure links and are accessible by truck.

### Detecting unused sites with AI

AI can be trained to recognize reactivatable brownfield sites using geodata and aerial and satellite images. This reveals the existence of potential industrial and commercial sites and enables new real estate projects, which is beneficial not only for commercial reasons, but also from a sustainability standpoint. After all, no new land has to be paved over and permanently sealed for new developments and company expansions. A preliminary study has already demonstrated the project's feasibility Germany-wide.

[www.scs.fraunhofer.de/en-argos](http://www.scs.fraunhofer.de/en-argos)

## Technologies and data pave the way for a circular economy

### Smart circular economy for more sustainability and resource conservation

Natural gas is becoming more expensive, there is a shortage of microchips, we are supposed to do without the fossil fuel oil in future and even timber is scarce. Global supply bottlenecks, rising raw material prices, dwindling resources and the German government's strict sustainability goals such as net zero by 2045 are making a circular economy, in which raw materials are continually reused, increasingly important.

In companies, there is still a lot of scope for the more efficient use of resources. But for the organization of value creation on a circular basis, businesses need data. And this data should be properly connected for optimal results: Where is a potential raw material located and what condition is it in? When is the next maintenance of a machine due and which parts of it are reusable, repairable or have to be recycled? To gain this information, technologies such as smart sensors can be used for the collection of data, or AI methods for the corresponding data analyses. As the way of using a resource also influences its life cycle – for example, when a device is used in salty air or in dry halls – such aspects must be taken into account additionally when it comes to possible implementation.

### Instruments and solutions for a smart circular economy

In the smart circular economy topic area, experts at the Center for Applied Research on Supply Chain Services are helping companies not only to use raw materials more effectively in their own cycles, but also to extend the service lives of assets through predictive maintenance and to reuse product components at the end of their life cycles. To this end, the researchers observe the possibilities available in the company and its environment and derive suitable recommendations for action. This work is done with the help of the Smart Circularity Transformation Navigator, a tool that was developed at Fraunhofer IIS. This resource navigator is used to analyze the respective maturity level of circular value creation in a company as the status quo, so that suitable measures can then be derived in a specially adapted transformation roadmap along with specific recommendations for action.

### Circular economies in the metal and electrical industries

Users include KME (Kompetenzzentrum Mittelstand GmbH) and the Employers' Associations of the Metalworking and Electrical Industries in Bavaria (bayme vbm), for which the Center for Applied Research on Supply Chain Services has produced a study on the use of digital technologies for the realization of circular economy solutions in the metal and electrical industries. This study systematically analyzes the benefits and potential of digital technologies for the sector and identifies fields of action for the implementation of circular value creation.

[www.scs.fraunhofer.de/en-smartCE](http://www.scs.fraunhofer.de/en-smartCE)



Smart circular economy: Using technologies and data to move away from linear value creation toward a smart circular economy



# Professional mobile communications applications with global appeal

Fraunhofer IIS has developed an unprecedented 5G offering that enables precise location of autonomous vehicles, products and tools on factory floors. The Fraunhofer IIS team demonstrated how this system works and what the 5G mobile communications standard can do for professional mobile users for the first time at the new, positively received 5G Connect symposium in its 5G Bavaria Industry 4.0 test bed in Nuremberg. At the event, attendees were able to learn more about 5G from automotive applications to satellite communications, experience localization in industrial environments, and dive into the world of private networks while learning about the opportunities of edge computing.



## At a glance

- 1 | Based on 5G, positioning with an accuracy of up to 50 centimeters is already possible today in complex production environments.
- 2 | The 5G Connect symposium proved to be an important event for professional mobile communications users.
- 3 | The Nuremberg 5G Bavaria Industry 4.0 test bed enables companies to test and further develop their 5G solutions and concepts independently of manufacturers.

When the topic of 5G comes up, the thing most people probably think of first is smartphones, greater bandwidth and shorter response times. In fact, however, 5G opens up completely new possibilities, especially for professional mobile communications applications such as in industry. In the future, it will be possible to link machines, control devices, cameras and sensors together even more effectively than before with 5G. This will make production more automated and, above all, more flexible. A far less well known fact is that the 5G standard is also suitable for a completely different industrial application – the precise localization and reliable control of, for example, autonomous transport vehicles or products in the manufacturing process. Fraunhofer IIS has been researching positioning technologies for around 20 years and has been working for some time with radio frequencies and signals that are now used in the 5G standard. It offers researchers a 5G test center and two 5G test beds. Manufacturers of 5G technology, network operators and, above all, companies can test applications, concepts and new developments here together with Fraunhofer experts. Fraunhofer IIS expertise has global appeal: this was evident at 5G Connect, the international symposium that the institute hosted for the first time on September 29, 2022.

### Hosting 200 professional mobile communications users from Europe and the US

Around 100 experts gathered at the Nuremberg test center to learn about the current state of research on industrial 5G applications, including experts from the United States, Canada and many European countries. Another 100 or so international participants used the online platform to take part. One of the highlights of the event was the 5G location of an industrial truck in a 5G campus network. “The vehicle is equipped with a commercially available 5G modem,” says Karin Loidl, a positioning and networks expert, who organized the symposium. “But we’ve enhanced our local 5G network with algorithms to be able to locate the vehicle in real-world environments to within about 50 centimeters. The development step to get there was enormous,” she stresses, “because tracking vehicles by radio normally requires additional technology that has to be installed and networked specifically. We, however, are using the 5G standard, which combines communication and localization in one system and will be available almost everywhere in the future, including most factory floors. We can get by with this without any additional technology at all; except, of course, for the laser scanners on board, which help to avoid collisions.” Accordingly, the guests at 5G Connect were thrilled when the small vehicle drove through the hall, Loidl says.

### Precise positioning in demanding environments

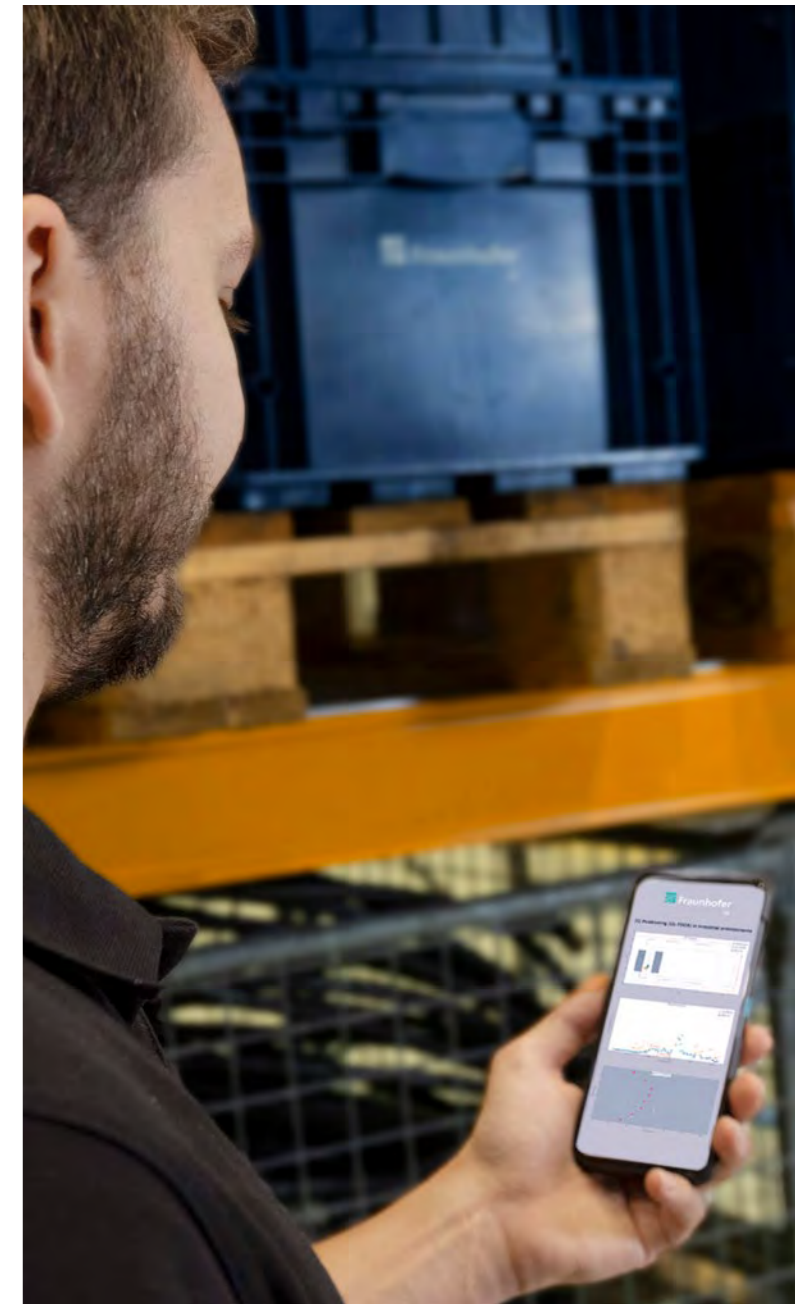
The 5G standard has been rolled out worldwide for a good two years. The fact that Fraunhofer IIS has already been able to present such powerful localization for use in enterprise solutions is primarily due to many years of development of the algorithms that process the radio signals. “Factories and production environments are full of obstacles and sources of interference that make signal processing difficult,” says Maximilian Kasperek, an expert in algorithm development. They feature a lot of metal, which can both reflect and shade radio signals. In addition, the environment changes frequently because material is temporarily stored close to production. This presents an enormously challenging environment for localization. The algorithms developed at Fraunhofer IIS are capable of correctly interpreting the 5G signals despite interference. But 5G isn’t everything. Fraunhofer IIS has expertise in a wide range of different radio standards and methods. These are used together on vehicles that travel both indoors and outdoors in the yard. For example, 5G is combined with satellite navigation. “Among other things, we use the signals from Europe’s Galileo satellite system,” reveals Jan Niklas Bauer, who is responsible for implementing localization in the 5G Bavaria Industry 4.0 test bed in Nuremberg. “Not only will this allow users to seamlessly switch between satellite and 5G navigation, but the technologies can also support each other to make localization more reliable overall.”



### Fraunhofer IIS as a neutral research partner

One strength of the Nuremberg 5G test bed is that interested parties can test technologies here independently of manufacturers. “We offer tests in very different system environments,” Loidl says. “This allows us to evaluate applications neutrally. That ensures our algorithms, e.g. for localization, aren’t oriented to specific providers. Everyone can benefit from the results, so they can develop new 5G-related offerings with us.” Since Loidl and her colleagues also participate in the international 5G standardization body 3GPP, Fraunhofer IIS can offer access to firsthand information. “It gives us a pretty good idea of what solution makes sense for our industry partners or what hurdles might come up.”

[www.iis.fraunhofer.de/5g-connect-conference](http://www.iis.fraunhofer.de/5g-connect-conference)



The 5G Bavaria Industry 4.0 test bed project is funded by the Bavarian Ministry of Economic Affairs, Regional Development and Energy



#### Contact

**Karin Loidl**  
Positioning and Networks

Phone +49 911 58061-9413  
karin.loidl@iis.fraunhofer.de

## Smart and sustainable

The Q-Bo® smart screw connection enables wireless, energy-efficient and reliable IoT sensor technology for condition monitoring 4.0

Screw connections are fundamental to the construction of machines, structures and vehicles. They secure bridges and buildings, keep flange connections tight and ensure that wheels and rotors are firmly positioned. But inspecting them as part of maintenance routines is complex and costly.

Making screws smart enough to report any problems at an early stage before any damage occurs was the aim of a research project on the Q-Bo® smart screw connection. This project was conducted by the cross-institute research team in the Fraunhofer Cluster of Excellence for Cognitive Internet Technologies CCIT, consisting of Fraunhofer IIS and the Fraunhofer Institutes for Surface Engineering and Thin Films IST, for Structural Durability and System Reliability LBF, and for Applied and Integrated Safety AISEC.



Top:  
The Q-Bo® smart screw connection secures e.g. structures and wind turbines

Bottom:  
Smart, robust, sensitive and self-powered: the Q-Bo® smart screw connection

### Smart and sensitive

A piezoresistive, pressure-sensitive thin film on a washer measures a screw connection's pre-tension at three points. Using three measuring points ensures that even a tilting of the screw connection will be detected. The measurement is then sent via a radio transmitter. An additional temperature reading on the washer takes into account and corrects any temperature effects on the measurement.

### Self-powered, robust and reliable

To enable many of these Q-Bo® smart screw connections to be energy-efficient or self-powered, the experts at Fraunhofer IIS integrated energy harvesting technologies into their radio transmitters. A thermoelectric energy converter generates sufficient current to operate the wireless sensor even when temperature differences are only small. The wireless sensor's energy requirements can also be met completely using small solar cells. This eliminates the need to replace or recharge batteries. The mioty® LPWAN technology, also developed at Fraunhofer IIS, can be used to reliably send data across several kilometers using the robust telegram splitting method. That means a base station can receive and forward more than 3.5 million data packets per day. The mioty® protocol is so resistant to interference that even if 50 percent of the transmitted data packets are lost, all relevant information will safely reach its destination. Thanks to cryptographic encryption, each screw's data transmission is tamper-proof.

Q-Bo® is already in the evaluation phase at several companies.

[www.cit.fraunhofer.de/smartscrew](http://www.cit.fraunhofer.de/smartscrew)  
[www.iis.fraunhofer.de/energyharvesting-en](http://www.iis.fraunhofer.de/energyharvesting-en)

[youtu.be/p\\_L9FCJfJzs](https://youtu.be/p_L9FCJfJzs)

## Digital technology meets inpatient care

The DiSPnet project is developing a networking technology for needs-based care

In the "Networking digital assistive sensor technologies in inpatient care" project, DiSPnet for short, the aim is to use digitally supported sensor technologies to make care easier and more efficient. From carers to the people in need of care, everyone involved stands to benefit. We are working on this together with moio GmbH, the Bavarian Red Cross and SRH University Wilhelm Löhe. Currently, the project is testing the use of mioty® technology for monitoring and thus preventive avoidance of pressure ulcers.

In contrast to usual WLAN or mobile solutions, mioty® technology makes it possible to operate compatible sensors in difficult building structures, for example in buildings made of reinforced concrete. Thanks to the special mioty® wireless protocol, all important data from several thousand sensors reaches the base station safely, reliably and simultaneously. Transmission is energy-efficient, which conserves sensor batteries and guarantees long runtimes.

With mioty®, we offer a digital networking technology that supports needs-based care. It speeds up the process of informing carers about the condition of the person in need of care and about any necessary measures. Other benefits of mioty® include its cost-efficient operation and retrofittability.

[www.iis.fraunhofer.de/telemetry](http://www.iis.fraunhofer.de/telemetry)

## Qubits for industrial applications

The QLindA project combines quantum computing with AI processes for industrial applications

Quantum physics is finding its way into technology developments that aim to make industrial applications more efficient using artificial intelligence (AI) and machine learning. In the QLindA project, we are researching how to combine quantum computing with AI technologies for what is known as reinforcement learning (RL). Our project partners are Friedrich-Alexander-Universität Erlangen-Nürnberg, OTH Regensburg and the companies Siemens and IQM. In this process, a system goes through trial-and-error cycles to independently learn the best strategy for achieving the goal. Together with users, the scientists are investigating how RL can be realized on quantum computers. Potential applications include optimizing control based on reinforcement learning in process manufacturing, implementing distributed automation systems in the smart factory, and optimizing production planning. The project got underway last year with funding from the German Federal Ministry of Education and Research. The content is the development of novel algorithms for operating quantum computers, the evaluation of methods, the creation of a library for use in industrial applications, as well as considerations of the potential and limitations of using the algorithms.

[www.iis.fraunhofer.de/qlinda-en](http://www.iis.fraunhofer.de/qlinda-en)

[youtu.be/rYHRsfEM4ww](https://youtu.be/rYHRsfEM4ww)

Using quanta to realize reinforcement learning for industrial applications



# AI technology for clear TV dialogue

Most TV broadcasters are familiar with viewers complaining that they find it difficult to make out what is being said. Our AI-based technology MPEG-H Dialog+ offers new opportunities for taking an existing audio mix and generating an alternative Clear Speech version with reduced background sounds and music. This version is offered to users as an additional soundtrack in the on-demand segment of German broadcaster ARD's Mediathek.

## At a glance

- 1 | The AI-based MPEG-H Dialog+ technology makes it easier to understand dialogue on television – for instance in the ARD Mediathek.
- 2 | Fraunhofer IIS's MPEG-H Dialog+ technology allows incremental transition to the media formats of the future.
- 3 | With automated workflows and cloud-based solutions, we facilitate cost-effective, scalable and future-proof investments.



A 1991 study by the BBC was the first to document regular complaints about hard-to-understand speech in movies. Loud background sound and music were identified as causing the difficulties in intelligibility. However, the results of the study weren't conclusive; only later did it emerge that personal preference and listening effort are very important for speech intelligibility. The study also pointed out that the broadcast system in use at that time was incapable of transmitting an additional soundtrack with speech at a higher volume. A lot has changed since then. As early as 2011, BBC and Fraunhofer IIS carried out a public field test during the Wimbledon Championships that allowed viewers to personalize the dialogue levels. This was the birth of dialogue enhancement as an "object-based" service facilitated by the broadcaster (see info box on next page).

Although object-based sound production is becoming increasingly important worldwide, most content today is still produced, transmitted and archived in channel-based formats. And up until a few years ago, traditional, model-based signal processing methods were used for dialogue separation in TV content. Today, these approaches are being roundly outperformed by deep neural networks (DNNs). MPEG-H Dialog+ also uses state-of-the-art DNNs to achieve dialogue separation and thus highest-quality personalization of dialogue, including for legacy material. Success has validated this approach. The technology was selected for the first national field tests in Germany in which DNNs permitted the dialogue personalization of TV content.

Object-based audio (OBA) such as the MPEG-H Audio technology from Fraunhofer IIS delivers the components of an audio mix to the consumer device as separate objects. This enables users to adapt audio contents to their personal taste – by selecting defined presets, for example, or adjusting individual elements within a framework defined during production. Because the final mix is created in the playback device, it can be perfectly adapted to the individual situation.

### High-performance training for networks

MPEG-H Dialog+ is a file-based dialogue separation technology that was developed at Fraunhofer IIS. At its core is a neural network that separates out the dialogue – in this case, a Deep Convolutional Neural Network. The network is trained using a specially prepared audio database that contains data derived from real broadcasting content supplied to Fraunhofer IIS by TV networks and production companies. The DNN training works on the basis of stems – that is to say, composite soundtracks. Two stems are prepared: one for dialogue and another for music and effects (M&E). These audio stems are edited manually to exclude all parts in which non-speech sounds are present in the dialogue stem or dialogue in the M&E stem. This prevents training errors whereby, for example, sounds could later be misinterpreted as speech and separated.

Having received the mix of the components as an input signal, the neural network automatically separates them so that they are available as individual elements at the output and can be remixed. The goal is for these elements to resemble the separate components as closely as possible. For the quality and robustness of the model, it is essential to have a very broad variety of training data covering the full spectrum of broadcasting contents. Both female and male speakers are represented in the data, which comes from all kinds of genres – from nature documentaries to sports programs to movies. The language of the training data has been predominantly German to date, but initial projects in other languages indicate that Dialog+ can also deliver good results there.

### It's all in the mix

Dialogue separation makes it possible to separate the dialogue and non-dialogue signals in existing mixes. But what do you do with the separated components to get a new audio mix that is easier to understand? This is where the automatic remixing of MPEG-H Dialog+ comes into play: it can combine static background noise reduction with dynamic, time-variant background noise reduction.

The static reduction lowers the level of the separated background sound by a set decibel value across the entire signal. This has several advantages: one is that the general sound design and music, which many people find intrusively loud, becomes more quiet; another is that it makes it possible to distinguish clearly and quickly between the original mix and the Clear Speech version. However, background noise reduction isn't strictly necessary in the absence of dialogue. Indeed, it can even spoil the esthetics and artistic intent or suppress sounds with narrative significance. In such cases, it makes sense to lower the background sound level only when the dialogue signal is present and to lower it only as much as is absolutely necessary. Helpfully, Fraunhofer IIS also has a solution for this: the Adaptive Background Attenuation algorithm, which automatically generates a dynamic new mix by means of a few easily adjustable parameters.

### Clear Speech for the ARD Mediathek

Is speech intelligibility really such a big problem? The short answer is: Yes! Many people complain about not understanding dialogue. For this reason, the German public broadcaster Westdeutscher Rundfunk (WDR) and Fraunhofer IIS cooperated in an online test in 2020. While watching content in the ARD Player, over 2,000 participants were able to switch between the original mix and a Clear Speech – as ARD calls it – version with reduced background noise. Afterward, the participants answered an online survey. It turned out that 68 percent of all participants have problems understanding TV dialogue either often or very often. This problem intensifies with age. A full 90 percent of participants over the age of 60 reported difficulty understanding TV dialogue. The option of switching to a Clear Speech mix appealed to 83 percent of participants – even those who said they had no or few problems with speech intelligibility. This shows that this is not a fringe concern, but that the desire for clearer speech, or at least for options, permeates the entire audience.

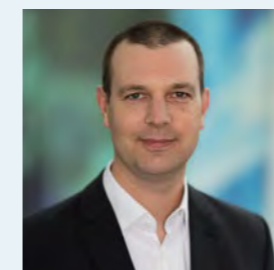
Subsequently, the Fraunhofer IIS partners WDR and Bayerischer Rundfunk (BR) carried out field tests with MPEG-H Dialog+, whereby Clear Speech soundtracks were produced and made available for various popular German TV shows. WDR transmitted Clear Speech via DVB-S as an additional audio signal, while BR provided Clear Speech via HbbTV and added it synchronously to the existing broadcast signal. Some of the WDR productions were then offered in the on-demand service in the ARD Mediathek, with the addition of further TV shows since. The provision of an additional Clear Speech soundtrack does not involve any significant additional cost or effort; it can be inserted directly into the current workflows of the existing media center content. The Clear Speech mix is generated automatically from the original mix and fed into the ARD Mediathek.

### Fit for the future of television

In the future, broadcasting and streaming will increasingly make use of object-based formats, known as Next Generation Audio (NGA). In addition to producing the channel-based Clear Speech stereo mix, MPEG-H Dialog+ can automatically generate a file that combines the separated audio objects and the metadata that are required for NGA. These files are suitable for use as a production format for NGA distribution processes and can be encoded directly into MPEG-H Audio. Such a workflow was implemented on a trial basis at WDR, including encoding and playback in an MPEG-H-capable app.

Film and TV production is making increasing use of cloud-based services. These facilitate the easy and rapid scaling of production workflows and can be consumed online by a broad range of users. They can also greatly reduce initialization and maintenance costs in the software-as-a-service domain. Fraunhofer IIS designed its NGA technologies to meet these requirements and for integration into state-of-the-art workflows. This means they are not only ready for immediate use, but also fit for the future.

 [mpeg.com/produce/#dialogplus](https://mpeg.com/produce/#dialogplus)



#### Contact

##### Christian Simon

Audio and Media Technologies

Phone +49 9131 776-6241  
christian.simon@iis.fraunhofer.de

## Global demand for audio codecs from Erlangen

Thanks to MPEG-H Audio, soccer fans in Brazil and South Korea experienced the World Cup with immersive, interactive sound. Windows and Xbox users enjoy the benefits of xHE-AAC.

xHE-AAC now enables uninterrupted streaming of audio content in two prestigious Microsoft products. With the support of Fraunhofer IIS, the tech giant has integrated the codec into Windows 11 and distributed it to all users worldwide as part of a service update. Microsoft's Xbox console also received an xHE-AAC decoder via an update.

At the 2022 World Cup, soccer fans in Brazil and South Korea experienced the benefits of MPEG-H Audio. Brazil's largest media corporation Grupo Globo broadcast the event in MPEG-H Audio on three of its five commercial channels. In addition, comprehensive tests were carried out before the launch of the TV 3.0 standard with MPEG-H Audio as the mandatory audio codec. SBS, one of South Korea's leading broadcasters, streamed the mega sporting event via an app in which viewers could choose between different audio presets.

In the domain of communication codecs, LC3 became the mandatory Bluetooth Low Energy profile earlier this year. Since then, it has been enhancing the listening experience of users of wireless devices. Meanwhile, LC3plus has been certified by the Japanese Audio Society for the prestigious Hi-Res Audio Wireless Logo program.

[www.audioblog.iis.fraunhofer.com](http://www.audioblog.iis.fraunhofer.com)

## AI-driven speech technologies

Reliable speech technologies have gained hugely in importance due to increased use of videoconferencing and voice-controlled devices

The Fraunhofer Institute for Intelligent Analysis and Information Systems IAIS and Fraunhofer IIS have globally unrivaled expertise in the field of speech technologies. Building on this, the institutes are partnering with German industry to develop a completely new voice assistance system. Because the resulting solutions are independent of US or Asian technologies, they can guarantee that data security complies with European standards. To pool their expertise, the two Fraunhofer Institutes are planning to establish a German Center for Speech Technologies, which will be at the center of an extensive ecosystem of start-ups, SMEs, industry and research.

Unlocking the power of AI to solve complex tasks is a particular challenge here. For example, neural networks and machine learning methods can detect the speech signal in a video recording and separate it from other sounds. The noises are efficiently suppressed as a result, which greatly increases speech intelligibility. And when it comes to speech output, AI can generate natural-sounding voices that very closely approximate the intonation and emotions of human speakers. Moreover, the AI-driven adaptability of speech characteristics can be used to reinforce brand identity – for example, with the voice of a well-known speaker.

[www.allinga.fraunhofer.de/en.html](http://www.allinga.fraunhofer.de/en.html)

## Enveloping sound at home and on the go

Audio processing technologies such as Cingo and upHear use intelligent algorithms to deliver enveloping 3D sound both from large soundbars and from miniature in-ear headphones

Audio processing is the term used to describe methods for enhancing the audio signal, such as 3D sound generation on stereo headphones. Fraunhofer Cingo makes stereo, multi-channel and immersive sound formats sound natural and spatial on headphones. Integrating new audio features and algorithms such as these into products can be challenging. The use of a flexible platform like Audio Weaver from DSP Concepts can accelerate product development while also reducing costs and providing must-have functions.

Fraunhofer's upHear Immersive Audio Virtualizer audio processing technology is also concerned with 3D sound playback, albeit on soundbars. This year, Sennheiser used this technology to launch the little brother of its successful AMBEO Soundbar MAX: the Sennheiser AMBEO Soundbar Plus. This enables users to adapt the immersive sound perfectly to the conditions of any given room. The upHear Immersive Audio Virtualizer generates high-quality surround sound, rendering obsolete the rear loudspeakers generally used in traditional surround-sound systems. This is achieved by means of sophisticated device-specific audio processing, developed by Fraunhofer experts.

[www.uphear.com](http://www.uphear.com)  
[www.fraunhofer-cingo.com](http://www.fraunhofer-cingo.com)

## JPEG XS for professional all-IP video production

Designed for production professionals, the JPEG XS Software Development Kit (SDK) 5 offers video transmission over Internet Protocol (IP) with speeds 25 percent higher than its predecessor for the encoding and decoding of HD/4K/8K images

JPEG XS is a compression codec that was developed to permit the transmission of high-quality videos of up to 8K over IP in production quality. The first edition of the ISO standard for JPEG XS was published in 2019, and the codec is now on the way to market readiness. Our video coding experts were able to demonstrate an initial JPEG XS system solution together with Japanese partner Astrodesign at the International Broadcast Convention 2022 and Inter BEE 2022. Under a cross-licensing agreement, we jointly offer JPEG XS-based solutions as an FPGA IP core or software solution.

The new JPEG XS SDK 5 developed by Fraunhofer IIS enables a 25 percent faster encoding and decoding of images. This reduces the required hardware resources on graphics cards and processors such as x86 CPUs, ARM CPUs and NVidia GPUs. Through code optimization and suggestions for parameterization, this can deliver a substantial boost to performance. This is a big advantage for all production workflows, which can now fully rely on IP-based transmission – from camera to post-production through to cloud connection.

[www.iis.fraunhofer.de/jpegxs](http://www.iis.fraunhofer.de/jpegxs)  
[vimeo.com/653681773](https://vimeo.com/653681773)



Left: LC3plus has been certified by the Japanese Audio Society for the "Hi-Res Audio Wireless Logo" program.

Middle: Using AI methods, unwelcome sounds can be eliminated from recordings.

Right: Cingo lets you enjoy immersive sound even over stereo headphones.

## Resource-efficient technologies for sustainable, global value creation

Powerful computers have become a fact of everyday life and the digital transformation is continually engendering new high-tech business models. While fulfilling our demand for quality of life, security and health, these advances consume a lot of energy. It is our conviction that forward-looking technologies for our economy and day-to-day lives must be in harmony with the needs of a sustainable world, which is why we see it as our mission to promote resource efficiency.



**Prof. Albert Heuberger**  
Executive Director  
Fraunhofer IIS

### Microelectronics can help bring about notable energy savings

**Albert Heuberger:** We are continuously developing and improving the performance of technologies and entire systems. While doing so, we strive to make the energy consumption of electronics as efficient as possible – through means such as energy-efficient AI processors. When it comes to microelectronics, we start with things like resource efficiency in sensor edge cloud systems, energy-saving communication infrastructures and resource-optimized electronics production.

### Resource-efficient electronics is the basis for a forward-looking economy

Industry 4.0, machine learning and artificial intelligence are making new demands in relation to energy consumption, data processing and data transfer times. For this reason, we are working to advance next-generation computing and developing quantum-based and neuromorphic computing as well as resource-efficient microelectronic components and systems.

### Green ICT @ FMD is a central contact point for green microelectronics

On August 1, 2022, we founded Green ICT @ FMD, a cross-location competence center for resource-conscious information and communication technology. The center has been awarded funding of 34 million euros by the German Federal Ministry of Education and Research (BMBF) as part of the Green ICT initiative within the German government's Climate Action Program 2030. Green ICT hubs will be opened with a focus on sensor edge cloud systems, infrastructures, materials and processes for green production. The Research Fab Microelectronics Germany (FMD) will function as a central point of contact for a wide variety of environmental questions in electronics – for industry, for politics, for individual customers, for young people and for students.



**Prof. Bernhard Grill**  
Director  
Fraunhofer IIS

### Efficiently implemented algorithms give competitive advantage

**Bernhard Grill:** For businesses to maximize their competitive advantage, they need to go beyond economical electronics. Resource-efficient technologies also require adapted, efficiently implemented algorithms for the respective platform. As such, companies need

to carefully choose the right techniques and continuously need to exploit relevant processor-specific optimizations.

### SPEAKER voice assistance system uses energy-efficient AI processors

In the domain of voice assistance systems in particular, the SPEAKER project has made significant progress in the use of energy-efficient AI processors. The project is funded by the German Federal Ministry for Economic Affairs and Climate Action as part of its AI Innovation Competition.

### AI-based algorithms efficiently process large amounts of information in real time

The implementation of efficient algorithms and the increasing performance capabilities of microelectronics are allowing us to develop new technologies and processes that also technically improve our products. A good example of this is Fraunhofer upHear Spatial Audio Microphone Processing. It provides spatial audio capturing with innovative and automatic noise suppression that eliminates interfering background noises: naturally, efficiently and in real time for very compact devices.

Moreover, advanced AI techniques are being used to synthesize natural sounding language from written text. These applications must efficiently process large amounts of information in real time. Fraunhofer IIS has made significant advances in this area with its Allinga Voice speech synthesis solution.



**Prof. Alexander Martin**  
Director  
Fraunhofer IIS

### Advancing Industry 4.0 through resource efficiency

**Alexander Martin:** In addition to resource-efficient hardware design, the resource efficiency of the algorithms that run on this hardware plays an important role. Algorithms, based on AI and mathematical optimization models, are a vital part of countless applications in Industry 4.0 today. Their reliability critically depends on the data quality, but also on the volume of data. The generation and storage of this data consumes huge amounts of energy. Handling data in a resource-conserving, sustainable manner in each phase of the data life cycle is therefore essential for the digitalization of tomorrow.

### Optimization algorithms permit energy savings

Beyond the energy-efficient design of the algorithms themselves, the solutions calculated using the algorithms can also enhance energy efficiency in a wide variety of industrial applications. Digitalization can therefore be an opportunity to make a significant contribution to energy savings and thus to the reduction of CO<sub>2</sub> emissions in many domains by means of the intelligent control and management of systems, processes and networks.

The goal here is not just enhancing the control of established energy networks and production processes, but also further developing energy systems and determining the optimal energy mix for the energy supply of the future.



## In the name of sustainability

The technologies developed at Fraunhofer IIS are an engine for greater sustainability.

**A globally digitalized and environmentally sustainable world – that is what all social actors must collectively strive for. With its climate action measures and climate protection technologies in research and development, Fraunhofer IIS is helping society on the road to more sustainability and resource efficiency.**

The Fraunhofer-Gesellschaft has set itself an ambitious climate objective: It has committed itself to making its scientific operations climate-neutral by 2030 and to reduce the emissions created by its headquarters and institutes to virtually zero by 2045. To this end, over 100 officers for climate neutrality and sustainability have been appointed across all Fraunhofer establishments. Their task is to develop and implement the institute's own climate strategy and to initiate and coordinate suitable measures and structures. Furthermore, Fraunhofer will of course continue to develop and advance technologies that help industrial enterprises and society implement sustainability.

Employees should also actively pursue the implementation of sustainable thinking in everyday situations. Indeed, Fraunhofer IIS's participatory energy saving initiative has proved to be a big success. All employees were asked to contribute their ideas on energy saving. The suggestions are collected in an action list on the intranet. This list is continually expanded. The aim is to underscore the message that sustainability begins with the individual. If, for example, every single one of the around 1,200 employees were to switch off their computer monitors when finishing up for the evening, that would have a big impact. An individual cannot make a difference?

Nothing could be further from the truth!

### Sustainability through research

The technologies developed at Fraunhofer IIS are an engine for greater sustainability. Intelligent digital controls for devices, systems, processes and networks make an important contribution to energy savings and therefore to the reduction of CO<sub>2</sub> emissions. On the other hand, the increasing use of sensors, electronics and artificial intelligence means more energy consumption. If microelectronics is to contribute to substantial energy savings, it is vital not only to consider the energy efficiency of every individual component but that of the overall networked system. We do this, among other places, at Green ICT @ FMD, a cross-location competence center for

resource-conserving information and communication technology, where we further develop corresponding applications.

The RFicient® chip developed by Fraunhofer IIS also represents a giant leap forward, facilitating power savings of over 99 percent (see Page 11). At a conservative estimate, more than 50 million IoT devices will benefit from this new sustainable technology over the coming years.

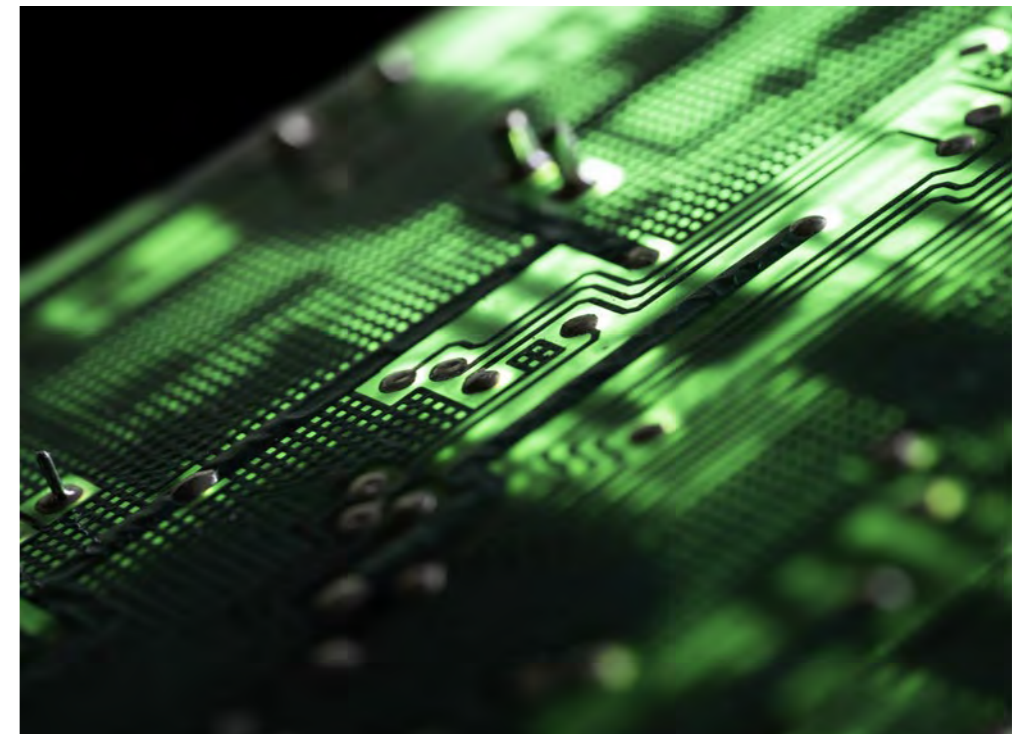
 [www.iis.fraunhofer.de/research-sustainability](http://www.iis.fraunhofer.de/research-sustainability)

*Left: The Fraunhofer Research Campus in Waischenfeld meets low-energy standards and was built by regional companies using local timber.*

*Right: The Green ICT @ FMD competence center promotes resource-conserving information and communication technology.*

### Climate action at Fraunhofer IIS

As the largest institute in the Fraunhofer-Gesellschaft, Fraunhofer IIS is actively transforming its scientific operations in the pursuit of greater sustainability. Dr. Peter Dittrich, Deputy Director of Fraunhofer IIS, is an officer with responsibility for implementing sustainability in everyday business at the institute. For example, he oversaw the installation of heat pumps at three of the institute's locations – Erlangen, Nuremberg and Fürth – and is organizing the installation of solar panels. New buildings at Fraunhofer IIS are also being designed with sustainability in mind. Take the Fraunhofer building in Waischenfeld, for example, which meets low-energy standards and was built by regional companies using local timber. "Fraunhofer IIS has long made sure that its construction activities obtain the 'silver' quality standard under the Assessment System for Sustainable Building (BNB)," Dittrich confirms.



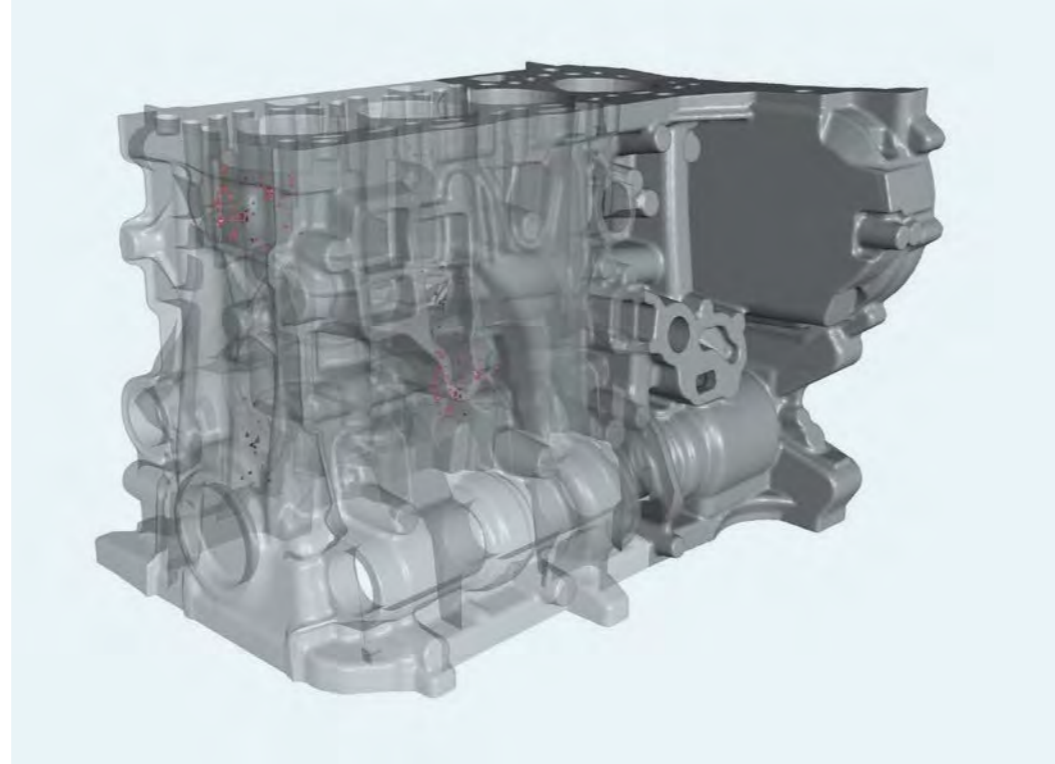


## German Research Foundation CRC/TRR 154 enters third phase

### Controlling gas networks by means of mathematical optimization

The focus of the German Research Foundation Collaborative Research Centre / Transregio 154 is on mathematical modeling, simulation and optimization using the example of gas networks. Its objective is to plan and control complex gas networks using a clever combination of mixed-integer and non-linear optimization concepts along with numerical analysis and simulation. In the third phase of TRR 154, the primary focus is on the switch to new energy sources, taking hydrogen as an example. One of the questions being addressed is whether and how the existing infrastructure can be used by the new energy source, which has some different physical properties compared to conventional sources.

The spokesperson for the project is Prof. Alexander Martin in his role as Chair of Analytics and Mixed-Integer Optimization at Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU). HU Berlin, TU Berlin, TU Darmstadt and WIAS Berlin are partners. In previous projects, the close cooperation between the Chair of Analytics and Mixed-Integer Optimization and the Analytics Department at the Center for Applied Research on Supply Chain Services at Fraunhofer IIS has led to a lively exchange of knowledge and personnel, which has benefited both basic research and work on application-related industrial projects.



Left:  
Transregio 154 is being funded by the German Research Foundation (DFG)

Top:  
At the X-ray factory, it is possible to investigate the inner structure of an object for hidden damage

Right:  
Prof. Jörg Robert, Deputy Head of Department, displays the LPWAN open-source module

## Fraunhofer IIS projects in phase 4 of the High-Performance Center Electronic Systems (LZE)

**The focus of the High-Performance Center Electronic Systems (LZE) is on implementing state-of-the-art technologies from research directly in products and making them quickly and easily accessible to business**

A joint initiative of the Fraunhofer-Gesellschaft, its Institutes for Integrated Circuits IIS and for Integrated Systems and Device Technology IISB, and the Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), the High-Performance Center Electronic Systems (LZE) has entered its fourth project phase. Fraunhofer IIS is represented in this phase by the following projects:

- Fraunhofer IIS is investigating the expectations of its customers in a novel manner. On behalf of Fraunhofer, LZE GmbH is **conducting a market test in the sphere of X-ray technology and running the corresponding X-ray factory**, from which interested customers can order various X-ray services.
- Screw connections in critical and safety-relevant installations such as bridges, wind turbines and industrial machines are constantly subject to high stresses. The **smart screw connection Q-Bo®**, a **wireless, self-powered monitoring**



## The InSignA High-Performance Center

### Collaborative project to pool research capabilities in Ilmenau

Initial pilot projects were launched at the Intelligent Signal Analysis and Assistance Systems – InSignA for short – High-Performance Center in 2022 following its foundation the previous year. The center was co-initiated by resident Fraunhofer Institutes – Fraunhofer IIS and the Fraunhofer Institutes for Digital Media Technology IDMT, for Ceramic Technologies and Systems IKTS, for Optronics, System Technologies and Image Exploitation IOSB and for Nondestructive Testing IZFP – which wanted to strengthen their collaboration and pool together their research capabilities for tackling joint projects. Other partners are TU Ilmenau and the IMMS Institute for Microelectronics and Mechatronic Systems.

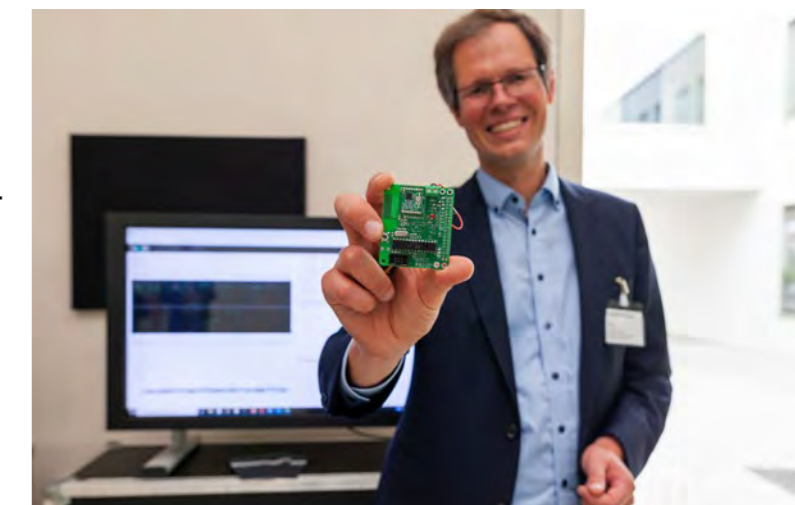
An example of a current collaborative project is the center's work with the Ilmenau public utilities company to digitalize the power grid. Fraunhofer IIS is contributing to the project by supplying know-how from its communication systems research field on subjects such as 3GPP standardization and LPWAN technologies.

InSignA provides digitalization support to SMEs which lack the financial resources to have their own research departments. A key goal of the high-performance center is to encourage companies to approach and collaborate with the research institutions. This will deliver lasting benefits to the technological innovation culture in the region.

[www.fraunhofer.de/en/institutes/cooperation/high-performance-centers/intelligent-signal-analysis-and-assistance-systems.html](https://www.fraunhofer.de/en/institutes/cooperation/high-performance-centers/intelligent-signal-analysis-and-assistance-systems.html)

**solution, allows permanent monitoring of the preload force of any kind of screw connections**, which enhances safety and reduces inspection costs (see Page 48).

- The RoboProd project is all about **X-ray computed tomography using cooperating robots** to enable the non-destructive testing of large or complexly shaped objects and high-resolution 3D analyses of object sections.
- An **open-source and developer platform** provided in the IoT4Scale project is designed to **give customers easier access to LoPAN/mioty® technology** from Fraunhofer IIS and allow them to conveniently try it out.
- The embeddif.[ai] software solution developed by Fraunhofer IIS makes it possible to **endow objects with intelligence and execute AI algorithms directly on embedded hardware in an energy-saving manner** – in areas such as cognitive tools, smart sports technology, seamless shopping and maintenance and repairs.



## Outlook: Neuromorphic computing as an AI accelerator

### Neuromorphic hardware and software for edge AI applications

Fraunhofer IIS is a world-class innovation driver in the field of neuromorphic computing. We develop chips whose architecture is based on biological neural networks.

In addition, Fraunhofer IIS is working on integrated circuits for convolutional neural networks (CNNs) and spiking neural networks (SNNs) in qualified CMOS technologies that are scalable and configurable depending on the use case. Using analog circuits, our low-power, low-latency neuromorphic processor units (NPU) for CNNs have higher parallel processing and lower on-chip data transfer requirements than von Neumann based solutions. The software tools we develop are used to train networks and to transfer the networks to the hardware.

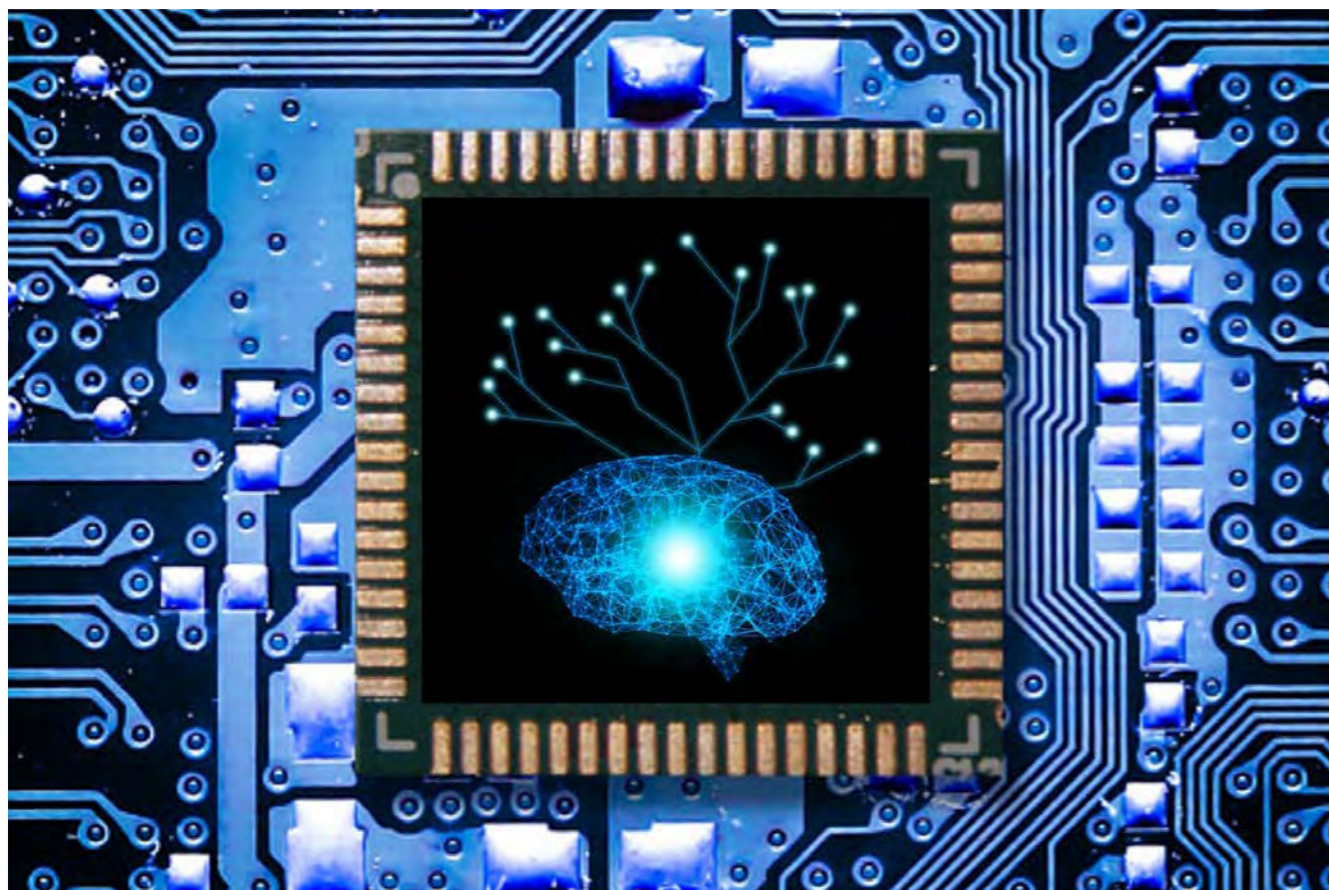
### Strategically important and sustainable research field

What makes Fraunhofer IIS's neuromorphic solutions special is that their hardware and software development is seamlessly intertwined, so that both components are coordinated from the outset. This particular hardware-software co-design flow permits the rapid development of highly complex designs, especially through our neural network (NN) synthesis generator tool.

To this end, we combine our expertise in low-power IC design, neural network (NN) algorithms, software tools, system and circuit architecture design with application-specific domain knowledge such as sensors, audio signal and image processing, message transmission and localization. By combining this expertise and domain knowledge, we can implement complete application-specific solutions that offer better system performance than generic solutions.

 [www.iis.fraunhofer.de/analog-ic](http://www.iis.fraunhofer.de/analog-ic)

*Neuromorphic computing:  
Chips whose architecture is  
based on biological neural  
networks*



Solutions for a  
smart world«

[www.iis.fraunhofer.de/en/magazin](http://www.iis.fraunhofer.de/en/magazin)



## Fraunhofer IIS Magazine

You can follow the topics featured in the Annual Report throughout the year in our online magazine. Here you will find current interviews with researchers and the institute's management, reports on technical innovations and successes, plus opportunities for collaboration. The newsletter for the magazine will always keep you up to date.

# Publishing notes

---

## **Publisher**

Fraunhofer Institute for Integrated Circuits IIS  
Prof. Albert Heuberger  
Prof. Bernhard Grill  
Prof. Alexander Martin

Am Wolfsmantel 33  
91058 Erlangen, Germany  
Phone +49 9131 776-0  
info@iis.fraunhofer.de  
www.iis.fraunhofer.de/en

## **Editors**

Agnes Pelzl (editor-in-chief), Thoralf Dietz, Saskia McDonagh,  
Patricia Petsch

## **Editorial team**

Dr. Janine van Ackeren, Christine Broll, Clara Conradt,  
Dr. Katja Engel, Mandy Garcia, Simon Hagen, Syndia Ioannidou,  
Jennifer Karbach, Thomas Kestler, Sandra Kundel,  
Angela Raguse-Föbel, Daniela Rembor, Tim Schröder,  
Diana Staack-Tettling, Lucas Westermann, Claudia Wutz

## **Layout and production**

Claudia Matthias

## **Translation**

Klein Wolf Peters GmbH

## **Proofreading**

Saskia McDonagh

## **Contact**

Fraunhofer Institute for Integrated Circuits IIS  
Corporate Communications  
Am Wolfsmantel 33  
91058 Erlangen, Germany  
Phone +49 9131 776-1631  
presse@iis.fraunhofer.de

## **Photo acknowledgments**

Cover, pages 6–8, 20–23, 25, 34–35, 36 (bottom), 44–47, 53:  
Fraunhofer IIS, Paul Pulkert  
Foreword, page 57: Fraunhofer IIS, Peter Roggenthin  
Page 9, 33, 37: Fraunhofer IIS, Franziska Köhler  
Page 11: Fraunhofer, Piotr Banczerowski  
Page 15: Fraunhofer Mikroelektronik  
Page 24: Fraunhofer IIS, Erik Rümpel (left),  
Fraunhofer EMFT (right)  
Page 26–29: Fraunhofer IIS/EAS and BLEND3 Frank Grätz  
Page 32: Fraunhofer IIS and Adobe Stock, candy1812  
Page 38 (rechts): Deutsches Museum and Fraunhofer EZRT  
Page 39: Fraunhofer IIS, Claudia Matthias  
Page 41: Bagszas Industrial Logistics (left), Adobe Stock, ban-  
nafarsai (right)  
Page 43: Adobe Stock, surasak  
Page 49: iStock, Fraunhofer IIS  
Page 50–51: David Hartfiel and Fraunhofer IIS  
Page 54: Fraunhofer IIS and Adobe Stock, magneticmcc (left),  
Fraunhofer IIS and F.M.Eckstein Fotografie (right)  
Page 55: Adobe Stock, Mediteraneo (right)  
Page 58: Fraunhofer IIS, Peter Roggenthin  
Page 59: Adobe Stock, Henk Vrieselaar (right)  
Page 60: iStock, Brazhyk (left), Fraunhofer EZRT (above)  
Page 61: Fraunhofer IDMT, Stefanie Theiß  
Page 62: iStock, tcareob72 and Adobe Stock, tampatra  
Page 63: Adobe Stock, metamorworks





All other images: © Fraunhofer IIS

All rights reserved.

Reproduction and publication is permitted only with written  
authorization from the editors.

## **Report period**

January 1 to December 31, 2022  
© Fraunhofer IIS  
Erlangen, February 2023

 facebook.com/FraunhoferIIS  
 @FraunhoferIIS  
 linkedin.com/company/fraunhofer-iis  
 xing.com/companies/fraunhoferiis  
 youtube.com/user/FraunhoferIIS