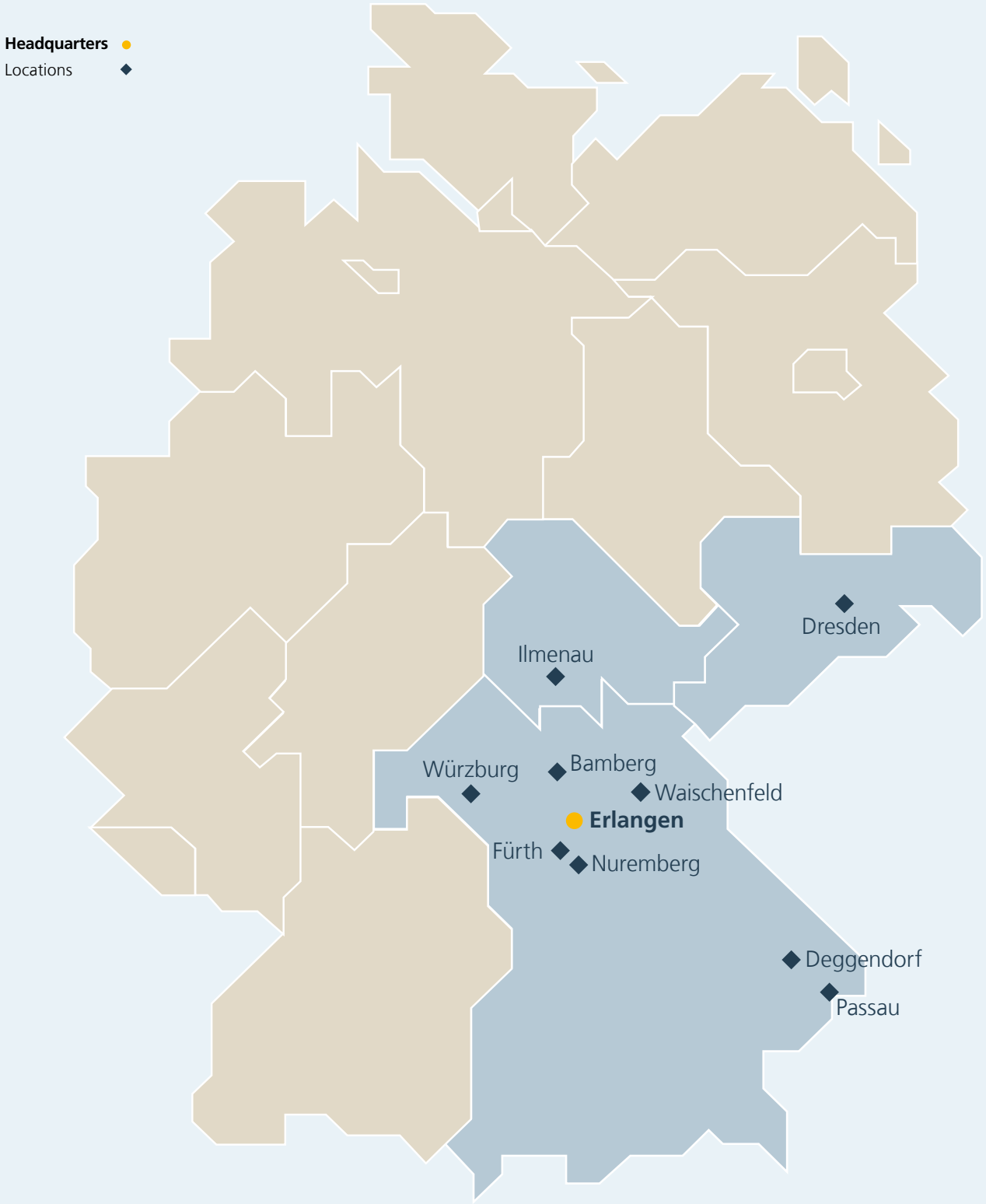
Fraunhofer IIS

Annual Report

Highlights 2021

#WeKnowHow



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

www.iis.fraunhofer.de/annualreport

Link to further information about the topic

Link to multimedia content

Annual Report

Highlights 2021

Foreword

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

Mastering challenges together – for a successful future

Dear reader,

The coronavirus pandemic dominated the year 2021, challenging people worldwide on an unforeseen scale. Despite the difficulties, we were able to ensure continuity in our research projects and pursue them with our usual performance. The highlight articles in the 2021 Annual Report showcase our successful research work and the projects and activities we developed and pushed ahead with, along with their practical implementation.

A crucial topic that will take center stage over the coming years is digital sovereignty. In particular, it will be the key to the innovation capability and competitiveness of the German economy. It will involve a wide variety of areas, ranging from the development of hardware to the use of artificial intelligence and its translation into applications. Strengthening digital sovereignty in Germany is a collective and comprehensive project to which Fraunhofer IIS is contributing with its broad know-how and proven expertise.

Meanwhile, important topics such as quantum technology, artificial intelligence and sustainable information and communications technology will remain on our agenda. It is our stated goal to strategically advance these subjects and develop practical uses to benefit our partners.

Enjoy the read!

Prof. Albert Heuberger | Prof. Bernhard Grill | Prof. Alexander Martin

Directors of Fraunhofer IIS

#WeKnowHow

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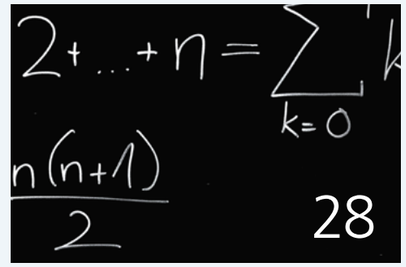
mioty® wireless technology: Award-winning and standardized



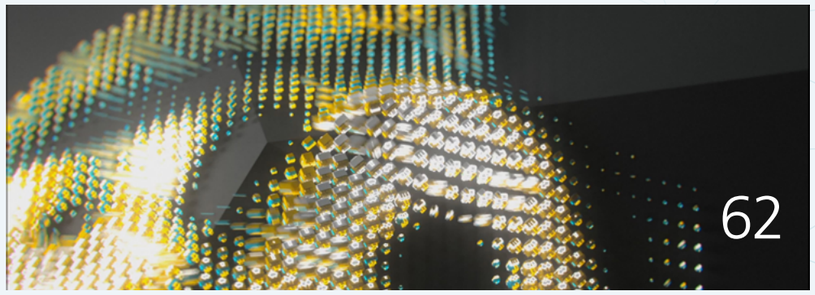
AI revolutionizes the supply chain

Golden opportunity to try out 5G

Switching and measuring with unique precision

New gold standard for industrial CT

Better audio experiences around the world



Quantum world: From research to application

mioty® wireless technology: Award-winning and standardized

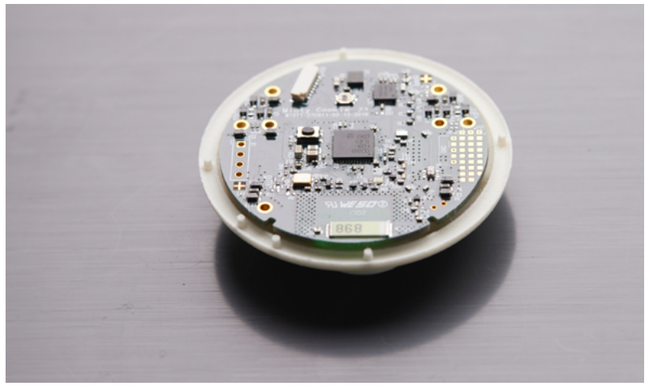
At a glance

1 | mioty® wireless technology is able to transmit data from over a hundred thousand sensor nodes via a single base station, with no loss of information.

2 | mioty® technology has been established as the standard, a patent pool has been set up and initial licensing agreements have been concluded.

3 | Dr. Gerd Kilian, Josef Bernhard and Prof. (Univ. Navarra) Michael Schlicht received the Fraunhofer Prize 2021 for the development.

Whether on factory floors or fields of crops: wherever people need to acquire and collect billions of tiny data packets on a decentralized basis – and need to do so efficiently, securely and cost effectively – mioty® wireless technology can help. No wonder, then, that the development has not only been standardized, but has won a prize.



Much of the talk about carbon neutrality tends to focus on renewable energy, hydrogen and electromobility. But making such a huge push toward a zero-emissions society calls for numerous technological building blocks. One such component is mioty®, which makes it possible to transmit data from several thousand – up to a hundred thousand – sensor nodes per square kilometer via a single collection point without loss of information. This paves the way for the efficient and reliable implementation of a great many condition monitoring and remote maintenance applications. Meanwhile, thirty patent families have been registered, a start-up has been initiated, the technology has been standardized internationally, an industrial alliance has been founded, a patent pool has been set up and initial licensing agreements have been concluded. On behalf of the 30-person development team, Dr. Gerd Kilian, Josef Bernhard and Prof. (Univ. Navarra) Michael Schlicht received the Joseph von Fraunhofer Prize 2021. In our interview, the researchers reveal what is behind the technology and what they see as the secret of its success.

mioty® allows small data packets to be transmitted with no loss of information. In what contexts is this important?

Michael Schlicht: The key phrase is the Internet of Things, or IoT for short. In a nutshell, this involves sensors recording small volumes of data, which are sporadically transmitted by radio to a central point, where they are evaluated. mioty® makes it possible for the first time to send several hundred data packets simultaneously. With a bandwidth of just 200 kilohertz, mioty® robustly transmits over three million data packets per day to a single collection point. And it does so with such energy efficiency that the batteries last for up to 20 years.

Josef Bernhard: Wherever many small objects have to be securely connected over many years in a way that saves energy, mioty® performs an invaluable service.

The mioty® technology used in these sensors is one of the first wireless communication solutions for IIoT applications, based on the ETSI standard TS 103357.

mioty® wireless technology has developed into the international standard, and initial licensing agreements worth millions of euros have been concluded – to name just two milestones. What is the recipe for this success?

Michael Schlicht: A very important principle for a project like this – and indeed for almost all Fraunhofer projects – is the following: we're never all alone in the world; rather, we're part of a value chain, part of an ecosystem. As an organization that can bring scientific excellence to partnerships, we make such ecosystems possible. In this case, we've done this also by awarding software licenses to device manufacturers and through the international "mioty alliance," which currently has 30 members including such well-known names as Texas Instruments and Diehl.

What qualities are needed to solve the challenges along the way when developing a technology like this?

Josef Bernhard: First and foremost, you need agility and determination. And everyone in our team brought these qualities to the table – otherwise, we wouldn't have been able to transform the initial idea into a marketable, licensable product.

Gerd Kilian: The most important thing with mioty® was and is the collaboration! Without the great team, none of this would have been possible, precisely because the topic is so diverse and complex. We had communications, HF technology and digital circuit engineers, software developers, business developers and project managers working on the project – and doing so at various Fraunhofer IIS locations.

You three have been awarded the Fraunhofer Prize for the development of mioty® on behalf of the whole team. What was it like for you to collaborate?

Gerd Kilian: On top of the many technical disciplines you need, marketing and standardization are also hugely important. Between us, we cover these three areas well. Michael is more involved in the marketing than the rest of us, Josef takes the lead when it comes to standardization, and I perhaps had more of a hand in the scientific aspects. But that being said, we're all scientists and we all talk collectively with potential customers …

Josef Bernhard: … and despite this division of labor, each of us is very well versed in the disciplines of the others.

What are you proud of?

Michael Schlicht: We're proud that our mioty® idea didn't languish in a drawer somewhere, but that we managed to develop it into a product family and that it even became an ETSI standard – that is, a standard of the European Telecommunications Standards Institute. In short, we're proud of developing the first standardized low-power-wide-area communication solution, based on our transmission method of telegram splitting, which ensures reliable data transmission. Although the original idea was ours, it was also motivated by the ecosystem – in other words, application was the mother of invention.

What social relevance does mioty® have?

Josef Bernhard: The variety of applications that the technology can serve is enormous: industrial applications, smart cities, sustainability, agribusiness, early warning systems, condition monitoring, the list goes on – in fact, the technology can be used in all vertical markets. What's most important of all is that we allow other people – beyond our own preconceptions – to be creative in terms of the applications they come up with. One promising application of mioty® is in agriculture, for example, especially in reducing the carbon footprint.

Gerd Kilian: Optimized irrigation is a nice example. On the one hand, you don't want the crops to dry out; on the other hand, too much irrigation consumes resources and washes away unused fertilizer. If you know what condition the soil is in, you can save large quantities of fertilizer and water. This is precisely what mioty® allows you to do.

Josef Bernhard: The trend toward digitalization is unmistakable. Communication topics, energy-efficient and energy self-sufficient solutions, and IoT platforms play an important role here. It will be very exciting to see how it all plays out over the coming years.

www.iis.fraunhofer.de/mioty_e

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Contact

Dr. Gerd Kilian
Communication Systems Division

Phone +49 9131 776-6327
gerd.kilian@iis.fraunhofer.de

Contact

Josef Bernhard
Positioning and Networks Division

Phone +49 911 58061-3300
josef.bernhard@iis.fraunhofer.de

Contact

Prof. (Univ. Navarra) Michael Schlicht
Communication Systems Division

Phone +49 9131 776-4050
michael.schlicht@iis.fraunhofer.de

Institute Director Dr. Bernhard Grill appointed honorary professor

Expert in audio coding boosts teaching line-up at Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU)

On January 21, 2021, Dr. Bernhard Grill was appointed honorary professor at the School of Business, Economics and Society at Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU). He brings decades of experience and successes in patent licensing to his teaching assignment. His lecture "Patenting for Innovation" addresses questions of intellectual property, in particular patents in research, development and innovation, as well as patent exploitation and international patent politics.

"Innovations need an environment with curious and passionate people who are thirsty for knowledge. So I'm delighted that Dr. Bernhard Grill is joining FAU as an honorary professor," said Prof. Joachim Hornegger, President of FAU, on awarding the certificate. Prof. Freimut Bodendorf, Chair of Information Systems, adds: "With his outstanding expertise, Bernhard Grill will greatly enrich our information systems teaching and our major research area of digitalization and innovation."

From as far back as 1988, Grill played a decisive role in the development of the mp3 and AAC technologies. Twelve years later, he received the German Future Prize – Federal President's Award for Technology and Innovation together with Karlheinz Brandenburg and Harald Popp, on behalf of the wider team at Fraunhofer IIS, for their research achievements as inventors of the mp3 process. With licensing revenues from the mp3 and AAC technologies far exceeding a billion euros, the Fraunhofer-Gesellschaft was able not only to create more than 1000 jobs over multiple decades, but also to found the Fraunhofer Future Foundation to promote innovations in Germany.

Grill became head of the Audio department at Fraunhofer IIS in 2001, while in 2011 he took over the reins of the Audio and Multimedia research area, which in its current incarnation as Audio and Media Technologies is recognized worldwide as a technological and scientific leader in many areas of audio signal processing. In 2016, he was appointed Institute Director of Fraunhofer IIS with responsibility for audio and media technologies.

Passing of baton in Smart Sensing and Electronics

Management duo bring strong expertise to role

On January 1, 2021, Dr. Denise Müller-Friedrich and Dr. Jens-Uwe Garbas became joint directors of the Smart Sensing and Electronics research division. They took over from Josef Sauerer, who had successfully headed the division since 2016.

Josef Sauerer goes into retirement

"Josef Sauerer has been at Fraunhofer IIS since the very beginning. For over 35 years, he has been instrumental in shaping our core competence of microelectronics and has played a major part in establishing Germany as a leader in this field," says Institute Director Prof. Albert Heuberger, praising the outgoing director's outstanding commitment. The Smart Sensing and Electronics research division employs approx. 140 people and has an annual budget of around 28 million euros. Josef Sauerer went into retirement at the end of March 2021.

Shared leadership

The new management duo bring their respective expertise to the shared leadership model. Prof. Albert Heuberger is happy about the appointment: "As joint directors, they will complement one another in personality and qualifications and will pilot the division to a successful future."

Electronics engineer Dr. Jens-Uwe Garbas is chiefly responsible for the overall strategy and personnel management: "We supply science and industry with first-class solutions encompassing everything from sensors for medical applications to developing AI software for image processing and IC design geared toward mass production. My goal is to leverage even more synergies between business units while building on the strengths of our existing research areas."

Dr. Denise Müller-Friedrich is responsible for the topics of organizational development, strategic and business processes, and finance. "Our research is driven by our vision for developing smart sensors, microelectronics and software that improve everyday life. We want to build on the technological and strategic successes of recent years, launch new initiatives, and create a perfect marriage between subject matter and the needs of people," explains Müller-Friedrich.

Dr. Jens-Uwe Garbas and Dr. Denise Müller-Friedrich have headed the Smart Sensing and Electronics division since January 1, 2021.

Research has many faces

Promoting diversity – benefiting from diversity

> The value of diversity in all its dimensions has always been self-evident to us as Institute Directors of Fraunhofer IIS.”
>
> **Dr. Peter Dittrich**
> Deputy Director of Fraunhofer IIS

Every day, 1149 employees, students and trainees from 53 countries on four different continents work at Fraunhofer IIS to create solutions for a smart future. However, this spectrum of nationalities is just one aspect of diversity at our institute. Diversity means that all employees, in all their individuality – that is, in all their differences of social and cultural origin, gender or age – belong to us and the culture of Fraunhofer IIS.

Diverse teams bring a variety of useful perspectives and are key to creativity, innovation capability and higher problem-solving ability. Decisions that are made in such teams are more viable, as they better incorporate different needs and application contexts in research and development. Fraunhofer IIS is committed to equal opportunity, work-life balance, inclusion and international HR. Our offer of childcare during the summer vacation, our Children’s Day on the “Buß- und Bettag” school holiday and the 30 language courses we offered in 2021 are just a few examples. Our goal across the Fraunhofer-Gesellschaft is to attract young women to careers in the STEM (science, technology, engineering and mathematics) fields. To this end, we systematically employ programs to attract and develop talented young women. The well-established josephine® mentoring program is just such an initiative. It is aimed at young female students in STEM disciplines, who are given the opportunity to discuss their individual potential and career options with an experienced female scientist as a mentor to provide them with invaluable guidance. A student who was a mentee in the first round of the program and is now an employee with us and herself a mentor describes her experience thus: “The conversations with my mentor and the seminars that were offered really helped me to become aware of and strengthen my abilities and to find the right career entry point for me.” In addition to a collective kick-off event, a networking get-together and the concluding event, the mentees also have access to exclusive workshops and seminars. Six new student employees and two new full-scale employees were brought into the Fraunhofer IIS fold in 2021 via josephine®. The fourth round of the program will take place in 2022.

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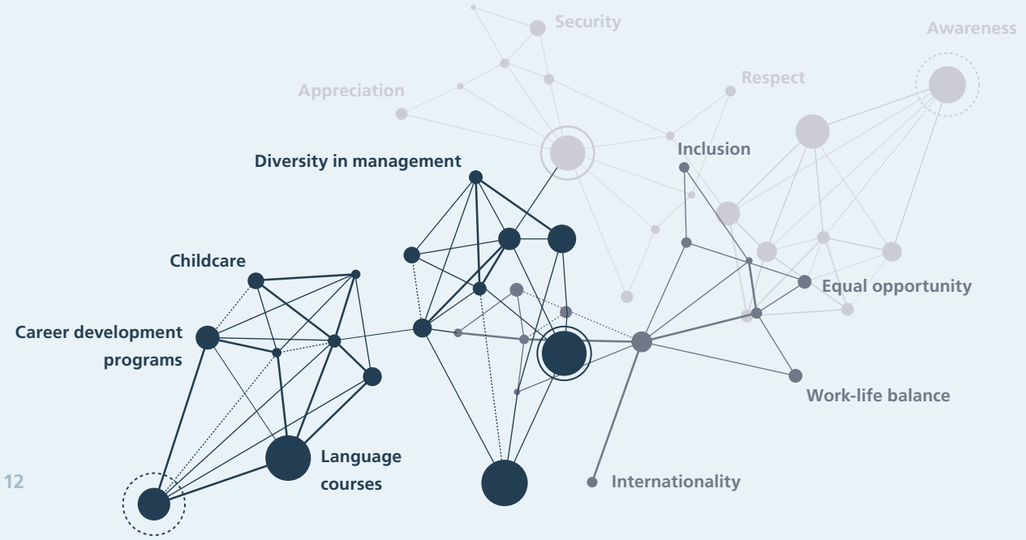


Nurturing early careers at research campus in Waischenfeld




Events to inspire talented young researchers

Idyllically situated in Franconian Switzerland, an upland in northern Bavaria, our research campus in Waischenfeld provides a stimulating location for hosting group events. The excellent research infrastructure facilitates effective, focused work as well as giving guests the opportunity to collectively recharge their batteries with team experiences and outdoor activities on the doorstep. In the pandemic-blighted year of 2021, this winning combination benefited the young participants of three events in particular.

From August 11–20, 2021, the Junior Academy Bavaria (JuniorAkademie Bayern) was held on the campus. Following a Bavaria-wide selection process, the coveted places were awarded to thirty high-school students who had excelled at their schools in their talent and enthusiasm for technology. Under the guidance of our scientists, the young technology enthusiasts explored topics ranging from the generation and perception of music to the creation of electromagnetic fields and color depths. Sport and creativity workshops provided variety and a holiday atmosphere.

Organized by the Fraunhofer Network for Science, Art and Design, the annual Fraunhofer Summer Camp was held in the second week of September 2021. True to the theme of the event – “Design & Research vs. Pandemics” – interdisciplinary teams of researchers and students searched for creative, practical solutions to pandemic-related research questions. This bringing together of diverse skills and expertise resulted in the development of three innovative prototypes.

The last of these three events for talented youngsters was the Talent School, which was held from November 2–5, 2021. A follow-up program to the Junior Academy 2019, the Talent School was designed to bring the same talented young people in STEM subjects back into contact with research and make them enthusiastic about pursuing a career in this domain. Two of our experts introduced the young people to topics such as the aesthetics of complex numbers and how to design a functional electrical circuit.

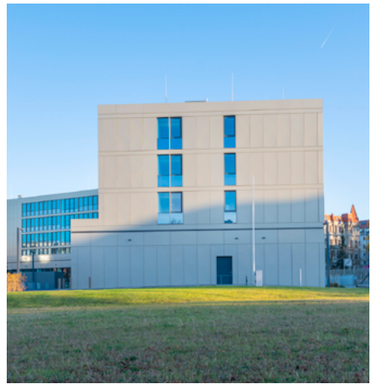
Left:
At the Fraunhofer Summer Camp 2021 at the research campus in Waischenfeld, students and researchers worked together on ways of combating side effects of pandemics.

Center left:
Leisure activities on the grounds of the research campus were also on the agenda at the Summer Camp.

Center right:
The participants of the Junior Academy could choose from a diverse program of main and creative courses.

Right:
The research campus in Waischenfeld.

Moving in to the new institute building in Dresden



More attractive working conditions and new laboratory spaces for the Engineering of Adaptive Systems EAS division

There is life in the new Fraunhofer IIS building in Dresden. The offices have been furnished and the laboratory spaces have been fitted out with numerous new testing and experimenting facilities. And since the summer of 2021, the employees of our EAS division have been working in the new building, which encompasses 4300 square meters of floor space on a site close to the Technische Universität Dresden. The division's previous home was no longer capable of meeting the growing demands of a challenging scientific environment, and it had also become too small for the number of employees working there.

In Saxony, the main focus of our research is on the implementation of complex electronic systems and intelligent sensor technology and on solutions for intelligent production. To place our research into these topics on a future-proof footing, we now possess not only sufficient office space, but also two large testing halls integrated into the building as well as numerous electronics laboratories, measuring rooms and a vehicle test bench. This allows us to respond even better to the needs of our partners. In addition, the building offers the ideal conditions for pursuing research into cutting-edge topics of the future, such as a new application center for quantum communication or a laboratory for testing and prototyping applications based on artificial intelligence.

And the concept of sustainability extends beyond our research to incorporate building design and energy use. The entire building is highly energy efficient thanks to technologies such as earth-air heat exchangers, thermal component activation and a photovoltaic power plant. The rear-ventilated aluminum façade not only has a long service life, low maintenance requirements and very good recycling characteristics, but also provides optimized thermal insulation.

And because successful research projects are made up of many individual components, the new location also offers ideal conditions for creative and professional exchange with its flexible communication areas, library, conference room and training room.

www.eas.iis.fraunhofer.de/new-building-dresden

Further education and training courses – a selection

Acquiring expertise – developing skills

Engineering of Adaptive Systems
"Webinar Wednesday": virtual courses on up-to-date topics such as:

- IC reliability – an overview
- SystemVerilog for verification
- On the way to the smart factory – wireless real-time connectivity in manufacturing
- AI in production engineering – how to mastermind successful application
- AI basic training and AI intensive training

Audio and Media Technologies
- Digital Media Weekly Specials: informative interviews on the latest topics from the Digital Media business area
- Further education and training from the KISS project, such as "Optimization and deployment of deep neural networks on heterogeneous systems" or "Compression of deep neural networks"
- MPEG-H audio webinar series in Brazil: advanced modules and live presentations
- AES workshops and webinars on MPEG-H audio production
- MPEG-H webinar at the German Association for Audio Professionals (VDT)
- Colloquium series: Virtual LiVe – virtualization of live events through audiovisual immersion

Development Center X-ray Technology
- ISAR expert workshop in person for customers of ISAR tire testing software

Positioning and Networks
- Webinar on 5G Bavaria Industry 4.0 test bed
- NIK event series "5G Dialog" as part of 5G Bavaria initiative: 5G in industrial communication – technologies and application scenarios
- Fraunhofer IIS Technology Compass: presentation of positioning and networking technologies, AI and energy systems
- IT security in wireless communication systems

Center for Applied Research on Supply Chain Services
- "Digital Transformation" knowledge snacks: e-learning webinars in cooperation with High-Performance Center Electronic Systems (LZE)
- "Leading Digital Transformation": training program for managers in cooperation with the Indian Institute of Management Bangalore and FAU Erlangen-Nürnberg
- Master's in logistics and SCM: master's degree in Logistics and Supply Chain Management at European Distance Learning University in Hamburg (Euro-FH Hamburg)
- SME 4.0 training courses:
  - initiative of SME 4.0 Competence Center Augsburg with focus on "Digital Business Models" for SMEs
  - SME 4.0 Mobile: exhibition room on wheels with Industry 4.0 demonstrators
- "LEAN LOGISTICS" training series in cooperation with industrial partner "trilogIQa – change to lean" with interactive educational games and business management simulations

Fraunhofer Vision
Seminars with application consulting, such as:

- "Quality assurance with industrial X-ray technology"
- "Optical 3D measurement technology for quality assurance in production"

Current offering

We would be happy to help with your individual further education and training needs. You can find offers and details on our website:

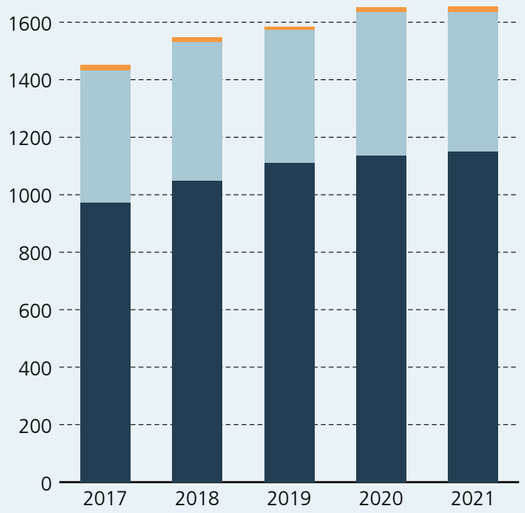
www.iis.fraunhofer.de/en/weiterbildungen

Facts and figures

A growing workforce

Fraunhofer IIS has a workforce of 1149 employees from four different continents. As in the preceding years, the number of staff on the books rose slightly. In addition, 488 students and 17 trainees work at the institute.

1149
salaried employees

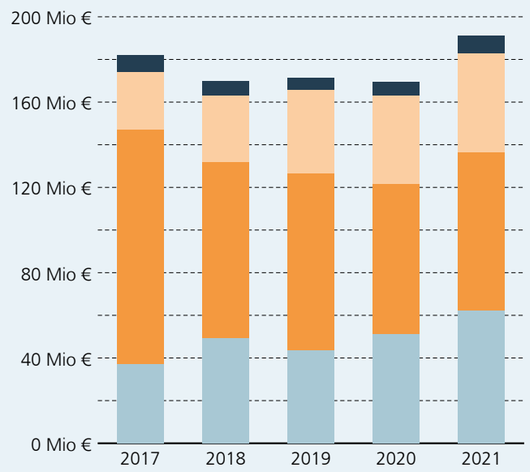


- Salaried employees
- Trainees
- Student assistants

40 percent industrial earnings

Fraunhofer IIS had a balanced budget in 2021. 40 percent of its funds came from industry and business. Base funding, provided by the German federal and state governments, amounted to 19 percent. 25 percent of the budget came from public-service revenue.

EUR 191m €
funding

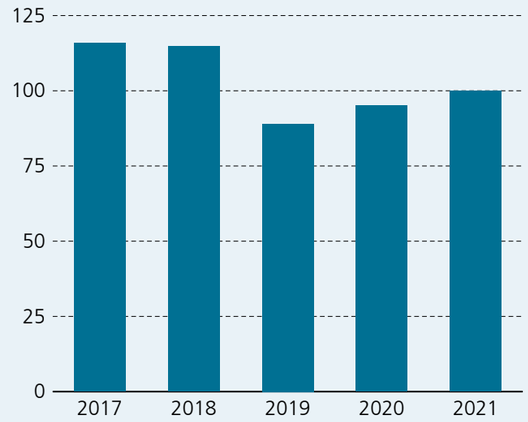


- Base funding, internal project funding FhG
- Industrial revenue
- Public-service revenue
- Other revenue

Number of invention disclosures increased

100 invention disclosures were submitted by employees of Fraunhofer IIS in 2021. The majority came from the "Communications Systems" and "Audio and Media Technologies" research divisions and related to the topics of 5G and audio.

100
invention disclosures



We I Facts and figures

Organizational Chart

Management of the Institute Prof. Dr. Albert Heuberger (executive), Prof. Dr. Bernhard Grill, Prof. Dr. Alexander Martin
Deputy Directors Prof. Dr. Randolf Hanke, Dr. Peter Dittrich

Administration and Research Management Dr. Peter Dittrich
IT Service | Florian Freund **Staff |** Matthias Rose **Administration Erlangen |** Sonja Ludwig **Administration Fürth |** Colett Rißmann **Administration Nürnberg |** Regina Kühn **Administration Dresden |** Franziska Vogel, Sophie Prieß

Audio and Media Technologies
Prof. Dr. Bernhard Grill
ER

- **Audio** — Johannes Hilpert
- **Audio for Communications** — Manfred Lutzky
- **Audio for Embedded Systems** — Dr. Nikolaus Färber
- **AudioLabs-IIS** — Dr. Frederik Nagel
- **Business** — Marc Gayer
- **Conversational AI Research** — Prof. Dr. Emanuël Habets
- **Media Systems and Applications** — Harald Fuchs
- **Moving Picture Technologies** — Prof. Dr. Siegfried Fößel
- **Patents and Licensing** — Stefan Geyersberger
- **Semantic Audio Processing** — Oliver Hellmuth
- **Staff Audio and Media Technologies** — Matthias Rose

Development Center X-ray Technology EZRT
Dr. Norman Uhlmann
FÜ

- **Application-specific Methods and Systems** — Alexander Ennen, Dr. Stefan Gerth
- **Contactless Test and Measuring Systems** — Dr. Peter Schmitt
- **CT in Metrology** — Prof. Dr. Simon Zabler — **DEG**
- **Magnetic Resonance and X-ray Imaging** — Dr. Karl-Heinz Hiller — **WÜ**
- **Production Monitoring** — Dr. Steven Oeckl

Smart Sensing and Electronics
Dr. Jens-Uwe Garbas
Dr. Denise Müller-Friedrich
ER

- **Sensory Perception & Analytics** — Stephan Gick
- **Digital Health Systems** — Dr. Christian Münzenmayer
- **Integrated Circuits and Systems** — Dr. Norbert Weber
- **Integrated Sensor Systems** — Harald Neubauer

Communication Systems
Prof. (Univ. Navarra) Michael Schlicht
ER

- **Broadband and Broadcast** — Bernhard Niemann
- **Electronic Measurements and Signal Processing** — Prof. Dr. Giovanni Del Galdo — **IL**
- **Radio Communication Systems** — Dr. Gerd Kilian
- **RF and SatCom Systems** — Rainer Wansch

Positioning and Networks
Dr. Günter Rohmer
N

- **Distributed Systems and Security** — Karlheinz Ronge
- **Precise Positioning and Analytics |** Thomas von der Grün, Dr. Christopher Mutschler
- **Satellite Based Positioning Systems** — Dr. Wolfgang Felber
- **Self-Powered Radio Systems** — Josef Bernhard

Center for Applied Research on Supply Chain Services
Prof. Dr. Alexander Pflaum
N

- **Analytics** — Dr. Christian Menden
- **Data Spaces and IoT Solutions** — Prof. Dr. Andreas Harth
- **Innovation and Transformation** — Dr. Nadja Hoßbach

Engineering of Adaptive Systems EAS
Dr. Peter Schneider
DD

- **Design Methodology** — Dr. Roland Jancke
- **Distributed Data Processing & Control** — Dr. Dirk Mayer
- **Efficient Electronics** — Andy Heinig

Last updated: July 2022

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

N | Location Nürnberg
Nordostpark 84 (SCS: 93)
90411 Nürnberg
Phone +49 911 58061-9500

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

Members of the Advisory Board

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

Dr. Annerose Beck	Saxon State Ministry for Science, Culture and Tourism
Eckard Eberle	Siemens AG
Dr. Bernd Ebersold	Thuringian Ministry for Economic Affairs, Science and Digital Society
Dr. Astrid Elbe	Aviat Networks
Prof. Dr. Kai Fischbach	University of Bamberg
Jörg Fürbacher	EURO-LOG AG
Klaus Helmrich	Siemens AG
Prof. Dr. Joachim Hornegger	Friedrich-Alexander-Universität Erlangen-Nürnberg
Anton Kathrein	
Prof. Franz Kraus	ARRI AG
Dr. Walther Pelzer	German Aerospace Center (DLR)
Dr. Heike Prasse	German Federal Ministry of Education and Research
Dr. Heike Riel	IBM Research
Dr. Dietmar Schill	Sony Europe B.V.
Dr. Alexander Tettenborn	German Federal Ministry for Economic Affairs and Climate Action
Dr. Isabel Thielen	Thielen Business Coaching GmbH
Dr. Dirk Tielbürger	German Federal Ministry of Defence
Norbert Michael Weber	
Jürgen Weyer	
MinDirig Dr. Manfred Wolter	Bavarian Ministry of Economic Affairs, Regional Development and Energy

Last updated: December 2021

Awards, prizes and appointments 2021 – a selection

AES Best Peer-Reviewed Paper Award

Thomas Robotham, Dr. Andreas Silzle and **Prof. Jürgen Herre** received the AES Best Peer-Reviewed Paper Award for their publication "Perceptual Evaluation of Interior Panning Algorithms Using Static Auditory Events."

AES President's Award for Outstanding Technical Achievement

Alessandro Travaglini, an employee in the Audio for Broadcast Applications research group, received the award for his contributions to Technical Document TD1008 "Recommendations for Loudness of Internet Audio Streaming and On-Demand Distribution" as a member of the TC-BOD drafting group.

ARD/ZDF Prize for Women in Media Technology

The second prize of 3000 euros went to sound engineer **Daniela Rieger** for her master's thesis "Object-Based Music Production – Development of a Combined Workflow for Dolby Atmos Music and 360 Reality Audio Based on an Existing Stereo Mix," submitted to Stuttgart Media University.

IEEE Industrial Innovation Award

Prof. Jürgen Herre received the IEEE Industrial Innovation Award in conjunction with Prof. Karlheinz Brandenburg and James D. Johnston for contributions to the standardization of audio coding technology.

Innovation competition: "Electronics for Energy-Saving Information and Communications Technology"

Fraunhofer IIS and Fraunhofer IAF, together with the University of Freiburg / INATECH, took second place in the innovation competition organized by the German Federal Ministry of Education and Research with their joint project "EdgeLimit – Evaluation of Power Electronics in Modern Edge Cloud Systems." The project consortium has been awarded funding to implement their solution for energy-saving mobile radio base stations.

Joseph von Fraunhofer Prize 2021

A team of researchers led by **Prof. (Univ. Navarra) Michael Schlicht, Josef Bernhard** and **Dr. Gerd Kilian** received a 2021 Joseph von Fraunhofer Prize for the new wireless transmission technology mioty® for massive IoT, which has been developed to market readiness. The prize is awarded to employees of the Fraunhofer-Gesellschaft for outstanding scientific achievement in solving application-oriented problems (see p. 6).

Pilot innovation competition: "Energy-Efficient AI System"

"What kind of chip is capable of detecting cardiac arrythmias and atrial fibrillation in ECG data with an accuracy of at least 90 percent while consuming the least amount of energy?" This challenge was answered with aplomb by a team from Fraunhofer IIS and FAU Erlangen-Nürnberg, whose energy-saving AI chip took first place in the pilot innovation competition organized by the German research ministry.

Professorships

Prof. Bernhard Grill, Institute Director of Fraunhofer IIS with responsibility for audio and media technologies since 2016, has been appointed honorary professor in the School of Business, Economics and Society at FAU Erlangen-Nürnberg as of January 21, 2021 (see p. 10).

Prof. Stefan Kasperl has been Professor of Physics at Nuremberg Institute of Technology since the winter semester 2021/22. At Fraunhofer IIS, he is Chief Scientist in the Development Center for X-ray Technology at the institute's Fürth location.

In appointing **Prof. Simon Zabler,** Deggendorf Institute of Technology has acquired an expert in imaging methods with a special focus on computed tomography. Professor Zabler will continue to head up the Fraunhofer Application Center for CT in Metrology within the Development Center for X-ray Technology, with locations in Deggendorf and Passau.

Prof. Jörg Robert has been Professor for Dependable Machine-to-Machine Communication in the Faculty of Electrical Engineering and Information Technology at TU Ilmenau as of February 1, 2021. At Fraunhofer IIS, he heads the Reliable M2M Communication research group.

Ron Halmshaw Award

Andreas Michael Stock received the award for his paper "Edge-preserving compression of CT scans using wavelets," published in the UK journal Insight. Together with his colleagues, Stock investigated how certain compression algorithms that use so-called wavelets behave in the case of industrial data.

Research Fab Microelectronics Germany (FMD)

The central partner for business and science, politics and society

Since 2017, Fraunhofer IIS, together with another ten institutes of the Fraunhofer Group for Microelectronics and the two institutes FBH and IHP of the Leibniz Association, has formed the cross-site Research Fab Microelectronics Germany.

For the first time, 13 institutes from the two research organizations, Fraunhofer and Leibniz, are combining their expertise under one virtual umbrella, thus creating a new quality to the research and development of micro- and nanosystems. With more than 2,000 scientists, the FMD is one the world's largest R&D network of its kind. With its unique diversity of expertise and infrastructure at the institutes, it is helping Germany and Europe to further expand their leading position in research and development.

Transition to regular operation

Until the end of 2020, the FMD was in its start-up phase. The extensive investments of the Federal Ministry of Education and Research in the modernization of the institute´s infrastructure could be completed by the end of 2020 / beginning of 2021, with the exception of a few minor delays caused by the COVID-19 pandemic.

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

Networking and cooperation for technological sovereignty

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

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

Versatile cooperation opportunities

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

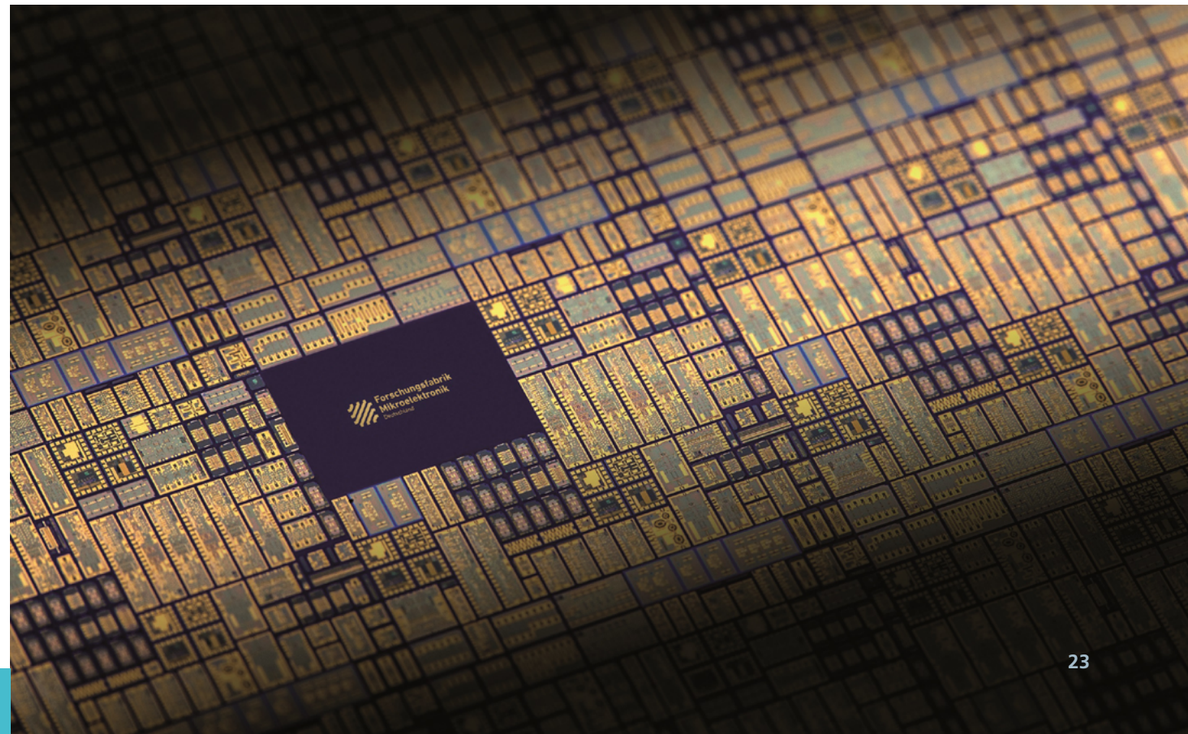
Trustworthy and sustainable microelectronics systems for innovative strength

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

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

In order to shed light on the entire value chain and create end-to-end concepts for trustworthy electronics in Germany and Europe, a platform for trustworthy electronics - "Velektronik" for short - was launched in March 2021. A total of 12 partners are involved - 11 institutes of the FMD as well as the edacentrum. Within the project, corresponding standards, norms and processes based on a national and European chip security architecture are to be developed and brought into application.

www.forschungsfabrik-mikroelektronik.de/en



The Fraunhofer-Gesellschaft

We I The Fraunhofer-Gesellschaft

The Fraunhofer-Gesellschaft worldwide

The Fraunhofer-Gesellschaft cooperates with legally independent Fraunhofer affiliates in Europe, North and South America and Singapore. Fraunhofer Representative Offices and Fraunhofer Senior Advisors worldwide form a bridge to local markets, and an office in Brussels acts as an interface between Fraunhofer and the European institutions. Numerous strategic collaborations with excellent international partners round off the Fraunhofer portfolio.

www.fraunhofer.de/en/institutes/international

Last updated: January 2022

The Fraunhofer-Gesellschaft currently operates 76 institutes and research institutions across Germany.

Last updated: January 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. It is a trailblazer and trendsetter in innovative developments and research excellence. The Fraunhofer-Gesellschaft supports research and industry with inspiring ideas and sustainable scientific and technological solutions and is helping shape our society and our future.

The Fraunhofer-Gesellschaft's interdisciplinary research teams turn original ideas into innovations together with contracting industry and public sector partners, coordinate and complete essential key research policy projects and strengthen the German and European economy with ethical value creation. International collaborative partnerships with outstanding research partners and businesses all over the world provide for direct dialogue with the most prominent scientific communities and most dominant economic regions.

Founded in 1949, the Fraunhofer-Gesellschaft currently operates 76 institutes and research units throughout Germany. Over 30,000 employees, predominantly scientists and engineers, work with an annual research budget of €2.9 billion. Fraunhofer generates €2.5 billion of this from contract research. Industry contracts and publicly funded research projects account for around two thirds of that. The federal and state governments contribute around another third as base funding, enabling institutes to develop solutions now to problems that will become crucial to industry and society in the near future.

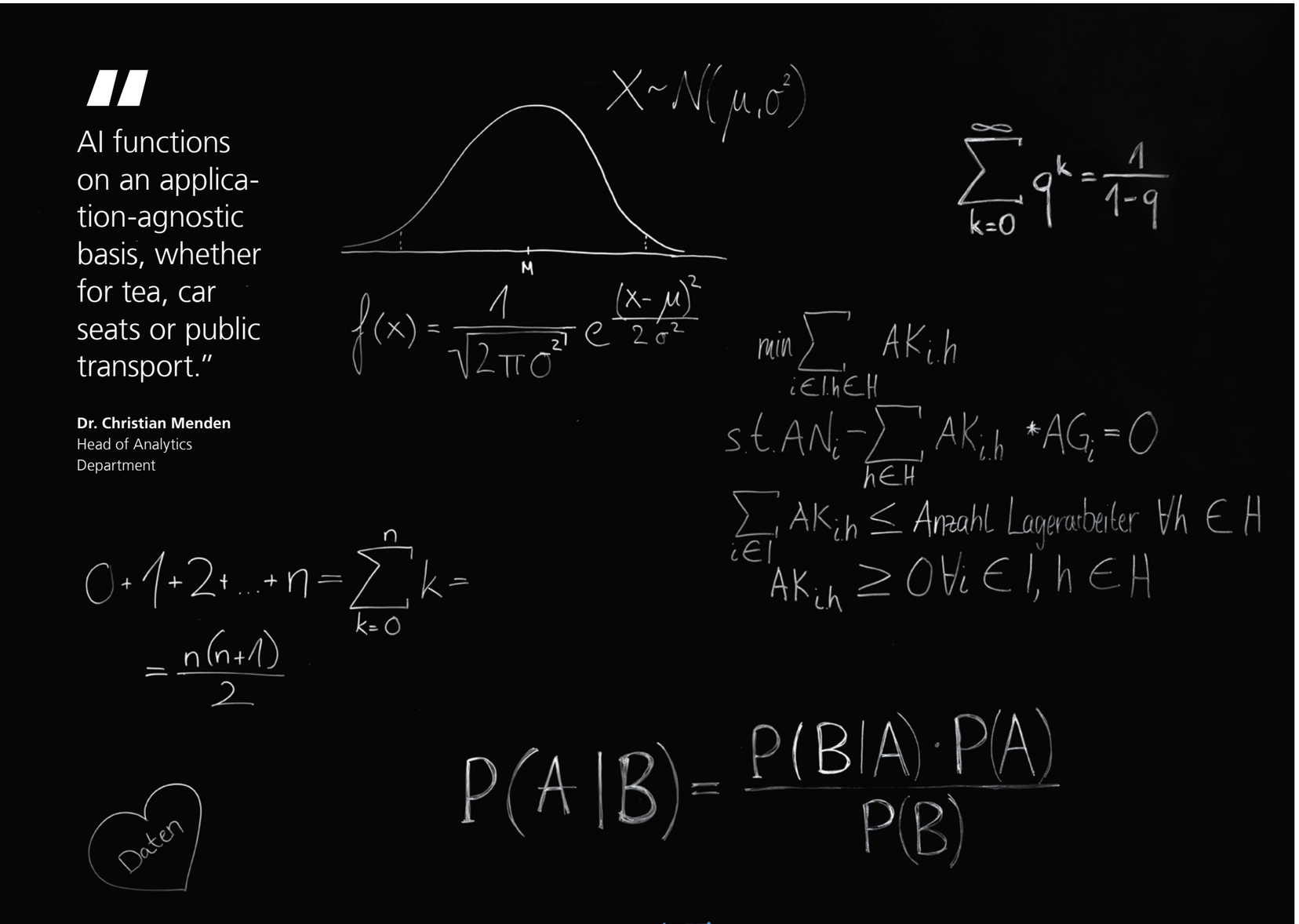
The impact of applied research goes far beyond its direct benefits to clients: Fraunhofer institutes enhance businesses' performance, improve social acceptance of advanced technology and educate and train the urgently needed next generation of research scientists and engineers.

Highly motivated employees up on cutting-edge research constitute the most important success factor for us as a research organization. Fraunhofer consequently provides opportunities for independent, creative and goal-driven work and thus for professional and personal development, qualifying individuals for challenging positions at our institutes, at higher education institutions, in industry and in society. Practical training and early contacts with clients open outstanding opportunities for students to find jobs and experience growth in business and industry.

The prestigious nonprofit Fraunhofer-Gesellschaft's namesake is Munich scholar Joseph von Fraunhofer (1787–1826). He enjoyed equal success as a researcher, inventor and entrepreneur.

www.fraunhofer.de/en

Know I #WeKnowDigitalTransformation



"AI functions on an application-agnostic basis, whether for tea, car seats or public transport."

Dr. Christian Menden
Head of Analytics Department

AI revolutionizes the supply chain

We are employing AI methods to make data in supply chains usable in order to increase added value. In the Analytics department of our Center for Applied Research on Supply Chain Services, we are developing application-oriented algorithms that propose decision scenarios on a (partially) automated basis and combine predictions with solid optimization.

At a glance

1 | We use AI algorithms to optimize supply chains in an application-oriented manner and use data in a new way.

2 | With suitable analytics methods, we are able not only to analyze processes, but also to predict and optimize them.

3 | The best AI models are automatically selected in real time using AutoML.

Whether we are talking about tea, car seats or subway lines, AI can deliver added value in all applications in the supply chain. "It functions on an application-agnostic basis," says Dr. Christian Menden, Head of Analytics Department, "which is to say, methods that were developed for one application can be transferred relatively easily to new ones, as the algorithms focus only on the structures inside the data. Consequently, AI techniques developed in the fields of genetics or bioinformatics can be adapted for industrial applications with just a few tweaks. We work with algorithms that we develop until they suit the respective use case and can also make decisions automatically. In this way, we can increase added value throughout the supply chain with AI."

Nuremberg public transport: Real-time-capable algorithms act as driver assistance system controlling subways

One example is the driver and track control system in the Nuremberg subway. On some days, two subway lines not only travel automatically, but can also be optimized to save energy. So when a subway train sweeps into the station and stops at the platform with a gentle hiss, most commuters have no idea that it perhaps braked three seconds earlier than usual. But these few seconds can reduce the operator's energy costs by an impressive amount. The driver assistance system develops an optimal timetable, searches for energy-efficient speed profiles, uses coasting phases and avoids too many simultaneous departures, which generate high and expensive load peaks. It was developed at the ADA Lovelace Center for Analytics, Data and Applications. This is where Fraunhofer IIS, under the project management of the Center for Applied Research on Supply Chain Services, collaborates with FAU Erlangen-Nürnberg, LMU Munich, Fraunhofer IKS and Fraunhofer IISB on research into subjects such as the mathematical foundations of artificial intelligence in order to develop powerful new techniques and bring them to practical maturity in industrial collaborations.

Schnellecke: Complex and dynamic warehousing

Another organization that needs optimal timetabling is the Schnellecke Group, although in its case inside a warehouse. The service provider based in Leipzig picks and delivers items directly to automotive production lines according to tight schedules. Every day, dozens or even hundreds of trucks deliver goods in boxes, which have to be stored in warehouses. "Schnellecke has regularly encountered major challenges in the warehousing of goods. Even brief delays disrupted the process flow. Where's the best place to store the boxes? Maybe it's not such a good idea to put urgent items in the farthest-flung corner? And window handles and glass panels should ideally be stored together," says Menden. Our algorithm not only makes optimal use of the space, but also takes into account health and safety and short driving and walking distances. As a solution, we developed a mixed-integer optimization model, which breaks problems down successively into ever smaller subproblems using exact optimization algorithms and then solves them with simpler methods.

Magna Seating: Car seats – lack of data for troubleshooting

We find another AI success story with the automotive supplier Magna Seating, which manufactures car seats. Every now and again, a seat has a little fault that needs to be rectified. The checks are time-consuming, and the faulty parts jeopardize deadline commitments. By selecting and applying suitable statistical techniques, we enabled our customer to identify regularities in fault incidents and take appropriate countermeasures. Although these faults are rare, this very scarcity makes analyzing them a challenge. Employing conventional statistical methods for the analysis, Menden's team identify precisely the events that correlate with the fault, paving the way for higher product quality with less rework. And AI is even able to determine the optimum sequence in which the seats should be loaded into the delivery truck.

Algorithms can be used in the warehouse for tasks such as optimized dynamic warehousing or AI-based inventory planning.

Tea manufacturing: Blends of raw materials with variable qualities

Avoiding production errors is not the issue at the Martin Bauer Group; rather, it is how to manufacture products of consistent quality using raw materials with varying properties. The group produces herbal and fruit tea blends for supermarkets and drugstores. As the ingredients of the botanical raw materials vary, warehouse and production planning are very time-intensive operations at the Martin Bauer Group. We solved this pooling problem for tea blends with optimization software that takes into account stock levels, storage periods, laboratory analytics, intermediate and end products, and the various quality requirements of customers. With the solution jointly developed by researchers from our working group and FAU Erlangen-Nürnberg, the dispatchers are able to quickly run through various scenarios, which otherwise would have too many combinations to be solved by humans alone. This kind of problem is not limited to tea manufacturing either, but also arises in many other areas of the food industry and in industrial manufacturing.

OBER: Optimal inventory planning quantifies uncertainties of forecasts

"Out of stock" has been an oft-heard refrain in recent times. Wood, bathroom fittings, canned vegetables and toilet paper are not in stock when customers come in to buy them. At the same time, goods that are not in demand are taking up valuable space. Before now, businesses have usually relied on very simple forecasts based on average sales to date, even though these predictions are riddled with uncertainties. In the OBER research project, we combine forecasts specially designed for the wholesale sector with mathematical optimization, taking into account restrictions such as the best price, available storage space and financial resources. Moreover, the AI we developed quantifies the uncertainty of the prediction. It calculates the optimum strategic course of action even for goods that will not be ordered for a few months.

AutoML – automatic selection of the best model at any given moment

Finding the most suitable mathematical procedure for any given application is time-consuming. For a solution, we looked to AutoML (automated machine learning). We use an umbrella model that automatically analyzes the various algorithms and independently selects the most suitable model. With Online AutoML, moreover, it is possible to continuously review whether the model currently being used is still the best one. Because when production suddenly changes the recipe for gingerbread or if a different car model is to be manufactured, then another machine learning algorithm might be better suited to the new task. AutoML is therefore versatile and can be used in many domains, as its abstraction at the mathematical level works for many applications.

www.scs.fraunhofer.de/en-supplychainanalytics

Contact

Dr. Christian Menden
Center for Applied Research on Supply Chain Services

Phone +49 911 58061-9540
christian.menden@iis.fraunhofer.de

Left:
Subways in Nuremberg travel in an energy-saving manner thanks to mathematical optimization.

Right:
AI can help e.g. a car seat manufacturer obtain higher product quality with less rework.

Experimentation as opportunity: The research project supports the development of business model innovations for future-proof retail.

Business model innovation in retail sector

Inspiration and experimentation rooms for future-proof retail

Competition from the online trade, changing inner cities and new customer purchasing behavior: brick-and-mortar retailers have been hit hard by digitalization. And the COVID-19 pandemic has heaped even more pressure on the sector.

How should small and medium-sized brick-and-mortar retailers respond to these pressures? Where will they find the ideas that will put their business model on a new, sustainable footing? As each retail concept, with its specific products and customer groups, has to be evaluated individually, standard solutions are of only limited utility. Retailers must actively experiment with their business model and value proposition. To do this, they need inspiration and practical support.

This is where "Experimenting in Retail" comes in. In this project, funded by the Günther Rid Foundation for Bavarian Retail, we built up a database by systematically screening competitions, trade journals and newsletters and supplementing this with interviews. The database describes innovative, forward-looking concepts in retail and evaluates them in relation to business model changes and market readiness. This has created a source of inspiration about current trends, among them 24/7 opening hours, self-checkout and the shopping experience. Concepts that combined several trends into harmonious overall concepts were deemed to be particularly innovative and promising. However, this combination must be realized in practice by retailers themselves, so that the concepts suit the company's existing value proposition to its customers.

For this reason, we also got together with downtown retailers, politicians and research organizations to develop an innovation infrastructure concept, which encompasses elements such as providing spaces for experimenting with new ideas, helping and guiding businesses with quick and pragmatic implementation, choosing suitable technologies and trend scouting. Michaela Pichlbauer, Chair of the Rid Foundation, is very satisfied with the initiative: "We're excited about a solution-oriented cooperation between the retail sector and Fraunhofer. Through this kind of joint experimentation, digitalization will become a genuinely useful tool to solve real problems in retail."

www.scs.fraunhofer.de/digital-transformation

Data Efficient Automated Learning

Machine learning (ML) for more efficiency in industrial quality assurance

ML is becoming increasingly important in industrial contexts, and especially in quality assurance. This often entails a lot of cost and effort, particularly when strict fault tolerance specifications, which can be in the range of less than 0.1 percent, have to be observed. In such cases, every wrong prediction of the analysis system takes many extra man-hours to remedy.

Suitable ML methods could significantly reduce this added work. In industrial and production environments, however, ML-based process optimizations and decision-making supports are difficult to implement at present. The reason for this is that most well-established processes, which already have low error rates, tend to produce one-sided data material and too little of it.

To address this problem, the "Data Efficient Automated Learning – DEAL" research group at the Center for Applied Research on Supply Chain Services is carrying out research into the possible applications of machine learning in the industrial and manufacturing sector. The group is further developing deep learning methods that facilitate the training of high-quality models even with unbalanced data sets.

A feasibility study on quality assurance for a customer from the automotive sector confirmed that this approach works. The spot weld inspection system on-site, which used conventional image processing methods for its analyses, identified far more errors than actually existed. The DEAL group employed standard deep learning approaches to improve the decision-making. In developing the algorithm, it was vitally important to have the right evaluation strategy. This made it possible to achieve the required scores on key performance indicators as regards quality and computation time.

www.scs.fraunhofer.de/data-analytics

"Pick-by-Tag" research project supports picking processes

More flexibility and lower costs in visual picking support

Pick-to-light is a widely used system in order picking. By means of visual displays indicating storage compartment and quantity, orders can be picked faster and with a lower error rate. The weaknesses of this method, however, are its high costs and its low flexibility, as these systems are usually installed with fixed wiring. In the "Pick-by-Tag" research project, the Center for Applied Research on Supply Chain Services and the Positioning & Networks division have teamed up with the Chair of Materials Handling, Material Flow, Logistics at the Technical University of Munich to jointly develop a completely autonomous system with wirelessly transmitting readers and compartment displays based on passive RFID tags. In this system, the compartment displays do not need a power supply of their own. As such, the containers can be flexibly reorganized at any time – at low cost and with optimum system range. As the project revealed, it was possible to charge the passive RFID tags over short distances; the reliable range is approx. 3.5 meters. This makes the RFID tags very suitable for picking in assembly applications.

As regards software, the project team optimized a software component for the initialization, configuration and monitoring of picking processes. In addition to the web front end, for example, we developed an additional Android app as well as several interfaces to RFID and ERP systems. The software also enables tag-ware relationships to be created via QR scan and for superordinate shelving nodes to be controlled at the same time, which permits better localization in large warehouses. With these innovations, the software component functions as a versatile interface between commercial warehouse and picking management systems.

www.scs.fraunhofer.de/en-iot-applications

Machine learning in industrial quality assurance: The use of suitable ML methods yields higher efficiency.

AI for energy-saving mobile communications

2nd prize in innovation competition organized by German research ministry: "Electronics for Energy-Saving Information and Communications Technology"

In the joint "EdgeLimit" project, our experts are working together with Fraunhofer IAF and the University of Freiburg to evaluate and optimize power electronics in connection with modern edge cloud systems. In connected IoT systems, data is processed and analyzed not only in a central cloud structure, but increasingly at the edge of the network – that is, as close as possible to the application. This minimizes the time-consuming transfer of data between cloud and edge.

With a complete antenna system consisting of several sending and receiving units (MIMOs), the Fraunhofer scientists implement technologies for what are known as remote radio heads (RRHs), which enable energy-efficient sensor data transmission in the 5G millimeter wave band. As part of our work on GreenICT at Fraunhofer IIS, we are investigating the energy consumption of such massive MIMO antennas at our 5G Bavaria Industry 4.0 test bed in Nuremberg. Our team of experts also develops and tests AI solutions for edge computing that are designed to reduce energy consumption to a minimum right from the design process of connectivity solutions.

Meanwhile, intelligent and adaptive management in the mobile communications system ensures that energy is used only as required. In all our development work and considerations, we strongly prioritize energy efficiency without sacrificing the performance of the systems in the application.

Together with industrial partners, we are now launching a three-year research project to explore our findings in even greater depth and adapt them to new solutions.

www.iis.fraunhofer.de/edgelimit_en
www.iis.fraunhofer.de/en/magazin/2021/green_ict_interview

Optimizing response of rescue services with 5G

"5G: City – Country – Saving Lives" project develops radio technologies to coordinate rescue missions more effectively

We are exploring how 5G mobile communications technology might further improve the response of rescue services. In the project, we are working with partners to develop and test positioning and networking technologies for three application fields: emergency call, first aid and rescue forces. These technologies are designed to give rescue personnel fast, secure and effective support on-site and to inform those affected by the emergency. For example, our experts use hybrid methods such as satellite-based positioning together with 5G in order to navigate automated supply drones carrying first-aid materials precisely to the deployment site.

For their safety, rescue forces wear or carry sensors that record physiological parameters in a so-called wireless body area network. Sensors integrated into their clothing or devices carried with them use 5G signals or ultra wide band (UWB) to permanently monitor the distances of rescue forces to each other and determine changes in movement by means of inertial sensors. Combined with telemetric data about the position of the rescue forces both indoors and outdoors, they can be issued precise instructions that will guide them very quickly out of a situation in which their life or health is at risk. Combining all the data provides a quick and exact overview of the situation.

www.iis.fraunhofer.de/rescue
www.iis.fraunhofer.de/medical-sensors-and-analytics

Inductive positioning and material detection

IndLoc® positions objects in defined volumes, displays fill levels and identifies materials

IndLoc® is suitable wherever objects have to be positioned or identified in defined volumes with high precision and in real time. The technology works using passive coils. In the case of conductive objects, the coil or additional markers are not required. This inductive near-field positioning technique is capable of determining the type, size and shape of the material and the object in manufacturing and logistics environments.

In inductive near-field positioning, a weak magnetic field is generated around a defined area of variable size. The object or material to be detected must either have conductive elements itself or else contain a coil, which then generate(s) a secondary magnetic field. Sensor antennas record the changes in these magnetic fields. The data is then forwarded to an analytical system to be interpreted.

This enables IndLoc® technology both to position objects without visual contact and to precisely distinguish various metallic objects such as screws. In picking applications, for example, short-term changes in the fill level can be displayed and electronic components can be distinguished from one another in closed packaging.

Integration of a machine learning model additionally generates individual magnetic "fingerprints" of the objects, which help optimize the precision and detection capability even further.

www.iis.fraunhofer.de/indloc-en
www.iis.fraunhofer.de/material-detection

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Machine learning for hand tools

Using TinyML to optimize work processes and ensure quality

Even in Industry 4.0, there are manual processes in the production chain. To incorporate these processes, experts from the domains of positioning, networking and machine learning (ML) have developed an embedded intelligent sensor module for hand tools, which can be integrated into existing production IT infrastructure. This use of ML to optimize and implement AI-based processing chains on embedded systems is known as tiny machine learning (TinyML).

The compact sensor module uses acceleration, rotation rate and magnetic field sensors and can be attached to hand tools. Data captured by the sensor forms the basis for an AI pipeline, which detects and identifies all work steps of the hand tool. As such, the system detects relevant actions such as the tightening or loosening of a screw, for example, or identifies the location or condition of the respective tool at the time of the action. An app provides notifications about the progress of the work or any deviation from the target process. The training process and the evaluation of new models run on a fully automated basis (AutoML) and require no expert knowledge. Activities to market and launch the technology are being undertaken with our partner, the High-Performance Center Electronic Systems (LZE).

www.iis.fraunhofer.de/en/ff/lv/dataanalytics/tinyml

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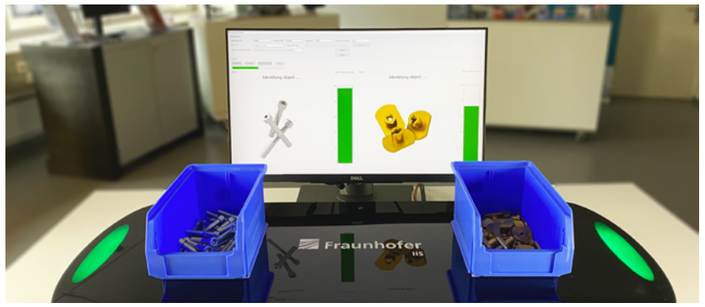
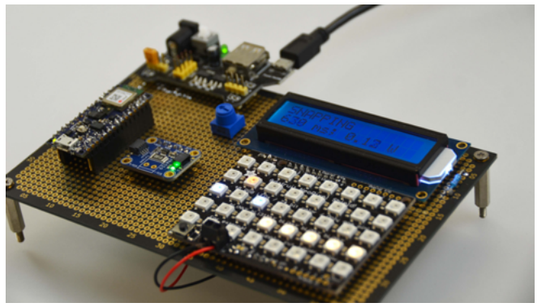


Using inductive near-field positioning, IndLoc® recognizes fill level and materials.



The mobile campus network brings 5G everywhere.

Golden opportunity to try out 5G

Businesses with their own campus network benefit from a customized 5G network with guaranteed bandwidth, low latency and high reliability. Our mobile campus network provides companies with a simple and cost-effective way to find out in advance whether setting up and operating their own 5G campus network is worthwhile.

As the door of the ambulance closes, an invisible data gateway to the hospital is already opening. An initial emergency diagnosis of the patient's health condition can be transmitted immediately via video conference to the hospital on the journey there. This means the relevant team in the ER department receives an initial medical assessment before the patient arrives and gains valuable minutes in which to prepare specific acute emergency measures.

To test the data transmission from an ambulance, we installed a temporary mobile campus network in Berlin as part of the Health5G project. This application scenario could subsequently be implemented in real-life operation with a network slice in the public 5G network; that is to say, a piece of the wireless network in which the data does not collide with that of other users. Just like the flashing blue lights in road traffic, so the transmitted data from the ambulance would also be given priority in the data traffic.

Currently, however, the only way to try out this prioritized data exchange between rescue services and hospitals is by using a mobile campus network.

At a glance

4 | A 5G campus network offers guaranteed bandwidth availability, rapid connections and high reliability.

5 | As a mobile solution with compact network equipment, our campus network can be set up quickly for 5G tests.

6 | With the mobile campus network, organizations can test in advance whether a permanently installed campus network is suitable for the planned application.

Customized 5G campus networks with guaranteed available bandwidth

A campus network is a local 5G network that companies and other organizations can operate for their own use, independent of the public cellular infrastructure. In Germany, the Federal Network Agency makes the licensed frequency range of 3.7–3.8 gigahertz available for this purpose. This means that up to 100 megahertz of bandwidth are guaranteed available locally – for example, at the company site – for 5G applications at all times.

The performance of a private 5G campus network can be tailored precisely to specific requirements of the planned applications. Usually this involves things like more data throughput, lower latency and utmost reliability in transmission. Anyone who wants to try out a campus network before investing in their own 5G infrastructure has a golden opportunity with the mobile campus network. Basically, this is a transportable testing environment for 5G that can set up a little 5G network for testing purposes practically anywhere.

> Our mobile campus network is basically a transportable testing environment for 5G.”

Bernhard Niemann
Head of Broadband and Broadcast Department

Testing 5G applications directly at the site of the action

The mobile campus network consists of an antenna, a radio head and a local computer that fulfills the role of the 5G base station and the 5G core network. As such, the equipment is compact and can be set up quickly and easily on a few square meters. A 5G cell is erected with a range of up to a few hundred meters and can be used both in buildings and outdoors.

Meanwhile, there are fixed testing installations for 5G that can be used for comprehensive performance tests. In venues such as the factory floor, company premises, construction sites, event locations and farm settings in particular, it is often important to test 5G specifically in the place where it will later be used. This renders the benefits of 5G directly visible in the concrete application case. A good example is the For5G project, in which we are involved, where 5G is used in cherry farming to transmit images of the cherry trees taken by a drone. Using the transmitted image data, digital twins of the trees are created, which help monitor their health and develop yield forecasts. In this project, our mobile campus network provides the requisite – but not yet available on-site – 5G coverage, which makes it possible to transmit the image data from the drone to the network in the first place.

Full network load ahead

The mobile campus network opens up detailed insights into the performance capabilities of wireless transmission. With a 5G load generator, additional data traffic is generated in the network. It increases virtually, so to speak, the number of devices transmitting in parallel in the campus network. As a result, it is possible to investigate the effect of the network load on the performance of planned applications. This makes it clear from the beginning whether an application will work without problems even when the network is working at full capacity, and whether installing a permanent campus network is worth it.

For further detailed analyses, we can carry out supplementary investigations at our 5G Bavaria Industry 4.0 test bed. The test bed allows us to conduct a more comprehensive range of tests with more configuration options in a full-performance campus network with on-site industrial equipment.

Test phase is just the beginning

After intensive testing, it is a matter of utilizing the results and taking them into account when, for example, a company wants to build its own campus network. After all, 5G creates new opportunities in all sectors for further developing products, systems and processes in highly innovative ways. And our commitment to the task extends far beyond the testing of new 5G technologies: backed by our know-how from the development of wireless communication systems and current 5G standardization, we create concepts that illuminate the most suitable technological implementation possibilities for every use case. When it comes to concrete implementation, we offer companies ongoing assistance with 5G projects, advising them on the choice of suitable technologies and equipment and supporting them through technical coordination. Our goal is to help our customers get 5G up and running so that they can create improved products, services and processes that secure their competitiveness.

www.iis.fraunhofer.de/campus-network

Health5G
Health5G is a project being carried out under the aegis of the European research initiative CELTIC-NEXT.

For5G
For5G is a funded implementation project from the 5G innovation competition organized by the German Federal Ministry for Digital and Transport.

Contact

Claudia Wutz
Communication Systems Division

Phone +49 9131 776-4071
claudia.wutz@iis.fraunhofer.de

mioty® goes satellite

Massive connectivity of IoT transmitters via satellite is no problem with mioty®

An IoT system with mioty® enables the transmission of up to **3.5 m** telegrams per day via satellite.

mioty® communication technology enables the simultaneous transmission of data packets from a large number of sensor nodes. This can be done over long distances and is particularly energy efficient. For the Internet of Things (IoT) in a terrestrial network, this has meant a range of up to 15 kilometers before now.

In transmission tests carried out in 2021, we showed that data transmission with mioty® also works via satellite without adapting the wireless protocol. This paves the way for an entirely new class of applications in which sensors can transmit data from the ground directly to a satellite. Some sectors in particular – logistics, transportation, mobility, shipping and agriculture – will benefit greatly from direct IoT solutions via satellite, which can provide connectivity even in the most remote corners of the world.

In the test setup, the transmitters with integrated mioty® sensor nodes sent data packets directly to the EchoStar XXI communications satellite. The transmitters used the mioty®-specific Telegram Splitting Ultra Narrow Band (TS-UNB) wireless protocol without any special adaptations for satellite communication.

With this mioty®-specific transmission method, data packets – so-called "telegrams" – are split into smaller subpackets and sent at different times and frequencies. The method is particularly robust against interference and allows a huge number of sensor nodes to be served.

To fully test the total capacity of the transmission system, the number of data packets sent was virtually increased by a massive amount during the test. Overall, the tests showed that in an IoT system with mioty® and an occupied bandwidth of just 200 kilohertz, up to 3.5 million telegrams per day can be successfully transmitted via satellite. In practical terms, this is the equivalent, for example, of a fleet of almost 25,000 vehicles with each one transmitting its positioning data every 10 minutes.

Despite the enormous distance to the satellite of about 38,000 kilometers, the user terminals could be operated at transmission power similar to that of terrestrial networks. This allows individual satellite IoT transmitters to be energy efficient in practice and to transmit data autonomously for years.

www.iis.fraunhofer.de/satellite-iot

Energy-efficient user terminal with integrated mioty® sensor node.

Know I #WeKnowCommunication

5G tested via GEO satellite

Satellite-based 5G services have potential to improve global connectivity

If 5G mobile communications can also be used via satellite, this means the coalescence of terrestrial and satellite-based communication. While terrestrial cellular networks expand their coverage areas with satellite support, the satellite industry gains the opportunity to expand its range of services far beyond the provision of satellite TV and Internet.

The challenge is that radio signals that are transmitted via satellites have to cover large distances. In the case of a satellite in geostationary orbit (GEO satellite), the distance is around 38,000 kilometers each way from Germany. This leads to delays in transmission, making an enhanced radio interface necessary for the use of 5G New Radio (NR) via satellite. The foundations for this are currently being laid down in the 5G standardization. New features have been developed to facilitate the use of 5G in non-terrestrial networks.

Together with the SPACE Research Center of the Universität der Bundeswehr München, we tested some of the planned enhancements for 5G via GEO satellite in 2021. It was particularly important here to have a precisely tailored method for runtime compensation, as both the terminal and the base station were located on the ground during the transmission tests. Despite the long transmission path, the synchronization between terminal and base station worked perfectly. Measurements showed that it took the signal between 530 and 570 milliseconds to make the round trip from the base station to the terminal and back again.

The components that were used in the tests as the base station and 5G terminal are fully software-defined solutions. They are based on OpenAirInterface (OAI), an open-source implementation of 5G NR, which can be used on a great variety of hardware platforms. Our contributions to OAI consisted of selected features of the 5G NR waveform and adaptations for satellite communication.

In an additional field test at the end of 2021, we demonstrated 5G satellite transmissions in the United States together with the companies Kymeta and Intelsat.

www.iis.fraunhofer.de/5g-sat

The satellite ground station used for the tests at the SPACE Research Center of the Universität der Bundeswehr München.

Switching and measuring with unique precision

Know I #WeKnowSmartSensing

Switches may well no longer go “click” in future. One of our teams has successfully managed to develop cost-effective high-tech 3D magnetic field sensor chips that will allow switching, turning and tilting motions to be perceived magnetically without any contact at all. This will make wear a thing of the past. The new sensor chips are uniquely precise, because they contain several sensing elements that eliminate interference from outside.

At a glance

1 | The 4-pixel-cell chip enables six-dimensional motion measurement for first time.

2 | The combination of the four pixel cells makes position measurement robust against interference.

3 | The chip opens up new fields of application both in the mass market and in the high-tech sector.

Know I #WeKnowSmartSensing

The rotary dial on the microwave, the joystick for video gaming or the button on the satnav – switches in various forms are part of our everyday lives. But for all their variety, they generally have one thing in common: they are mechanical. In the case of the rotary dial on the microwave, for example, the number of watts is set via an electronic sliding contact. There are disadvantages to such mechanical controllers and switches. As a result of the motion, the material wears over time and the switches fail. Furthermore, commercially available switches usually work only in one direction or dimension – they can be either turned or moved back and forth or tilted to the side. For modern applications, however, there is a demand for inexpensive wear-free switches that can be moved in all spatial directions as well as rotated. An example is the button in cars that operates the on-board computer, which designers wanted people to be able to turn, push and tilt in any direction so that they could select many functions in a natural, intuitive way.

Magnetic field sensor senses movements

For such applications and many more, our scientists in the Smart Sensing and Electronics research division have developed magnetic field sensors over the past few years that employ magnetic fields to measure the motion of switches or other objects without contact. The basic idea is to fit a switch or other component with a magnet so that its position and motion can subsequently be measured. The latest development is a measurement chip on which no fewer than four 3D sensors called "pixel cells" are integrated. "Our 4-pixel-cell chip measures with unprecedented precision in all dimensions," explains Hans-Peter Hohe, group manager at Fraunhofer IIS, who developed the new chip together with his colleague Dr. Markus Stahl-Offergeld and a team of experts.

4-pixel-cell chip with unprecedented accuracy in all dimensions

Simple magnetic field sensors have been on the market for over 50 years. However, they can perceive movements in only two dimensions – for example, when a magnet moves past from left to right, or when it comes closer to or moves further away from the sensor. Complex movements as in the satnav button of the future are beyond its capabilities. "Thanks to the four pixel cells, we're now able for the first time to measure the movements of a magnet in all six dimensions," Hohe emphasizes – first, in the x, y and z directions, which is to say forward and back, left and right, up and down; and second, rotation around these three axes. "That means we can fully capture the movement of a magnet, which opens up many new application areas," Stahl-Offergeld adds. The technology is based on something called the Hall effect.

Precision times four

Such measurements do in fact become possible only through the combination of the four pixel cells, because this enables disturbance variables to be excluded. It is these variables that generally complicate the task of measuring a magnetic field precisely. One source of interference is the Earth's magnetic field, for example, which constantly changes slightly over the course of driving a vehicle from one place to another. And temperature also has an effect on measurements. If the temperature falls, a magnet's field expands. A single sensor could incorrectly interpret this as a movement of the magnet – as a magnet that is apparently approaching the sensor. Such errors can be excluded by combining several pixel cells in a suitable manner.

With the combination of four pixel cells on one chip, the researchers have opened the door to the mass market, such as the automotive industry. For anyone looking to solder four individual sensors on to a printed circuit board, it would take a lot of time and effort to align them so precisely with each other that no measurement errors occur. This would make manufacturing time-consuming and expensive. With the new 4-pixel-cell chips, which will soon be made available for purchase by the High-Performance Center Electronic Systems, such elaborate assembly becomes obsolete.

Precision cameras measure high-quality magnets

However, the team is not only targeting the mass market, but also has sophisticated high-tech applications – such as magnetic field cameras – in its sights. Such cameras are capable of measuring the field of magnets with millimeter precision. This is important because magnets need to have very uniform magnetic fields for challenging applications such as in electric vehicles. The new 4-pixel-cell chips have the advantage that the distance between the individual pixel cells is only around a millimeter – approximately half the distance that is usual for magnetic field cameras today.

To manufacture the field of view of a large magnetic field camera, dozens of pixel-cell chips are soldered alongside each other on a printed circuit board. The smaller the distance between the chips or between the pixel cells, the higher the resolution of the camera – and the more precisely a magnet can be measured. "In industry, there have long been calls for higher resolution. With the 4-pixel-cell chip, which we have developed with an industrial partner, we're setting new standards," Stahl-Offergeld says.

Through the design of the new chips, the team has also made application easier. The individual 4-pixel-cell chips can be linked with each other according to the daisy chain principle. This means that not every chip has to be connected to the controller via its own cable; rather, the information in the chips can be read out successively through a single data line – that is, via a BUS system. This greatly simplifies the assembly of cameras. At present, the controller that reads out the sensor data is fitted as a separate component on the printed circuit board. In the next generation of chips, the controller unit is to be integrated into the chip. When that happens, the sensor will not just deliver magnetic field values, such as are useful for camera applications, but will directly supply the position of the magnet, which will further simplify the production of "non-click" switches and similar products.

www.iis.fraunhofer.de/magneticfieldsensor

Contact

Hans-Peter Hohe
Smart Sensing and Electronics Division

Phone +49 9131 776-4472
hans-peter.hohe@iis.fraunhofer.de

Energy-saving sensor interface

Process and product monitoring with smart sensor technology as part of the KI-Predict project

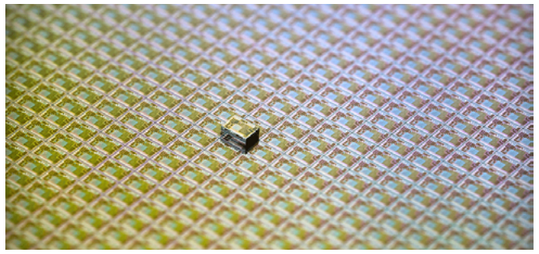


Illustration of a chip.

The optimization of production processes and operational procedures in Industry 4.0 requires cost-effective electronic systems for data acquisition and signal processing. In particular, integrating sensors with high data rates for condition monitoring using AI algorithms has been considered costly. Wireless solutions were often not economically viable on account of their high energy consumption. As part of the KI-Predict project, a holistic approach is being developed, which enables intelligent process monitoring with direct signal processing and feature extraction through the combination of new AI methods with specially optimized, integrated hardware.

As a contribution to the project, we are developing an energy-saving sensor interface as an application-specific integrated circuit (ASIC) with built-in microcontroller (MCU) and AI processing units. Taking this development approach greatly reduces the data volumes to be transmitted and significantly increases the efficiency of feature extraction. This makes it possible to implement extremely energy-saving wireless sensor solutions as required. In addition, companies can continue to use their existing systems infrastructure. The standard sensors currently used are replaced with sensors containing AI technology, leading to higher efficiency in the data processing chain and cost savings.

www.iis.fraunhofer.de/kipredict

DHPcare – sensor-based patient monitoring

Getting away from snapshots at medical examinations thanks to wearable sensors with medical-grade data quality

A lot of us have been there: you feel unwell the whole time, but as soon as you enter the doctor's office, the symptoms vanish. Up to now, doctors could record the patient's state of health only at the time of the examination. At Fraunhofer IIS, we want to get away from such snapshots. "Using wearable sensors with medical-grade data quality, we want to continuously measure the symptoms of chronic illnesses – and so improve the treatment," explains Assistant Professor and sport scientist Dr. Heiko Gaßner, group leader at Fraunhofer IIS and at Universitätsklinikum Erlangen. In the case of Parkinson's disease, for example, sensors on the patient's shoes can recognize the typical shuffling gait and generate clinical added value by means of objective parameters. Similar approaches are conceivable for heart rate measurement in cardiology or measuring stress levels in psychosomatic medicine. In the Fraunhofer Attract program DHPcare, Gaßner's team has already fitted some patients with sensors and carried out initial investigations. The results showed that environment and situation very much have an influence on the patients' motor symptoms. In the EU study Mobilise-D, the team is working with the Universitätsklinikum Erlangen to investigate how to digitally capture patients' mobility in everyday life. The aim is to define an objective outcome parameter that allows pharmaceutical companies to test the effectiveness of their drugs.

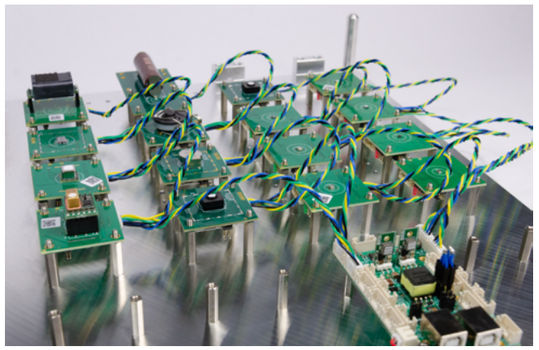
www.iis.fraunhofer.de/dhpcare

Low-cost sensor technology for gases and odors

When gas sensors meet AI: A great combination for many applications

Fire detector in the kitchen? Until now – despite the general utility – this has not been a good idea, as the number of false alarms is too high. With our intelligent low-cost sensor technology for gases and odors, however, this shortcoming could be remedied in the future: the fire alarm could not only distinguish whether a steak is frying or burning, but could also monitor the air quality in the room. First, we investigated various commercially available gas sensors for different target gases in the Campus of the Senses, a joint project with Fraunhofer IVV. How reliably do they work? For what conditions are they suitable? In the next step, these sensors can then be combined and, using specific AI methods, optimized for the selective detection of target gases in a specific application. "In this way, we can both increase the performance of the individual sensors – by making the best possible selection and also by means of artificial intelligence – and improve the interplay of various sensors, for example by having the AI take into account typical cross-sensitivities," says group manager Sebastian Hettenkofer, listing the benefits. Building on this work, other topics can be investigated in addition to fire detection, such as air quality in homes or in food production, sensitive traffic control in inner cities and the detection of food that has gone bad in refrigerators.

www.iis.fraunhofer.de/digital-sensory-perception



Sensor clickboards are used for the combined evaluation of selected gas sensors.

Neuromorphic hardware: We bring AI to the edge

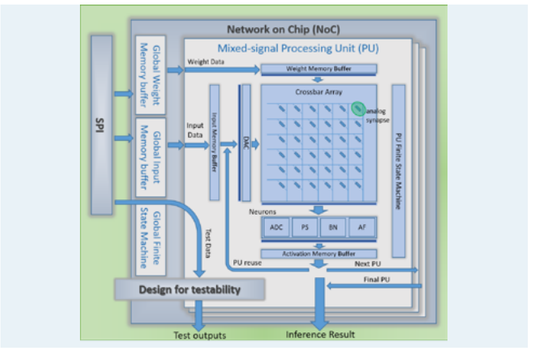
Highly efficient and application-specific neuromorphic hardware for edge AI solutions

AI applications on edge devices can no longer be implemented by means of improving CPUs (central processing units) and GPUs (graphics processing units) – we have reached the end of Moore's law. New ideas and architectures are required. To meet this need, new neuromorphic hardware has been developed to enable the highly efficient processing of sensor data on edge devices.

In general terms, neuromorphic hardware refers to a hardware design with efficiently running "deep neural networks" inspired by the human brain. Embedding AI directly on edge devices and processing the data locally offers advantages over conventional computing architectures, among them lower latency, higher energy efficiency and better data protection. By using neuromorphic hardware, many calculations can be carried out in parallel, such that the hardware can work more efficiently and deliver faster results.

We are developing highly efficient and customized integrated circuits for AI accelerator IPs, which permit challenging and difficult applications. Our co-design framework lets customers benefit from optimized development times. In this way, we offer a solution to bring AI energy efficiently to edge devices with secure and rapid data processing. There are possible use cases in domains such as audio technology, Industry 4.0, wearables and autonomous driving.

www.iis.fraunhofer.de/neuromorphic



Scalable multi-core chip architecture.

Know I #WeKnowXRay

New gold standard for industrial CT

At a glance

1 | Fraunhofer is co-operator of the globally unrivaled BM18 computed tomography beamline at the European Synchrotron Radiation Facility (ESRF) in Grenoble.

2 | This beamline is available for industrial measurements and is capable of imaging objects up to 70 centimeters wide with a resolution of 25 micrometers.

3 | The Development Center X-ray Technology offers students doing a master's degree or a doctorate the opportunity to complete their dissertations at the synchrotron in Grenoble.

At the electron synchrotron facility in Grenoble, a globally unparalleled measuring station is being created for the non-destructive testing of large components. The computed tomography system offers a resolution of 25 micrometers, which puts it well ahead of the previous standard resolution of 100 micrometers. Through its Development Center X-ray Technology division (EZRT), Fraunhofer IIS is playing a leading role in the development of the measuring station.

European Synchrotron Radiation Facility (ESRF)

Founded in 1994 in Grenoble at the edge of the French Alps, the ESRF is funded by 17 countries. The electron storage ring operated by the ESRF is the third largest of its kind in the world. It generates X-rays that are ten trillion times brighter than the X-rays used in medicine. Researchers from around the world use the beams for experiments around the clock.

Industrial requirements for component testing are constantly increasing. And this demand is coming from a wide variety of sectors: from automotive manufacturing to the aviation industry to manufacturers of wind turbines. These businesses want to use computed tomography (CT) for things like checking the welds on a car door or evaluating the structure of a fiber-reinforced plastic. The CT systems used in laboratories are coming up against their physical limits in trying to meet the demand for ever better resolution. These limits can only be overcome by X-ray systems that are operated at an electron synchrotron installation, such as the European Synchrotron Radiation Facility (ESRF) in Grenoble.

The ESRF possesses an electron storage ring with a circumference of 844 meters. In this storage ring, electrons are constantly circulating at close to the speed of light. The enormous energy of these electrons is used to generate X-rays. There are several installations at the storage ring that act as X-ray sources. From there, the radiation is guided tangentially away from the ring in straight tubes known as beamlines and used for a wide variety of scientific experiments.

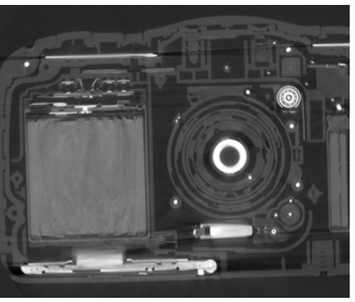
"In the course of renovating the electron storage ring, the ESRF built new beamlines. One of them is the BM18 beamline, which we are expanding into a unique system for industrial CT," explains Prof. Simon Zabler, head of the EZRT locations in Deggendorf and Passau and manager of the BM18 project. Zabler is a recognized expert in synchrotron imaging. He wrote his undergraduate degree and master's theses in Grenoble over twenty years ago. "Together with the Universities of Passau and Würzburg, Fraunhofer is responsible for developing the detector technology, the IT hardware and the data processing," the physicist reports. The project is being funded by the German Federal Ministry of Education and Research to the tune of 6.3 million euros.

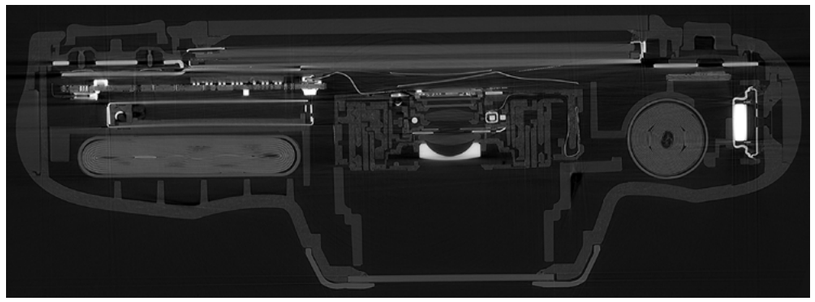
Extremely sharp images with unique phase contrast

In the BM18 beamline, the X-ray beam generated in the electron storage ring is guided 200 meters through a vacuum tube before it arrives at the large experimental hall. Here it encounters the object, which rotates on a podium and is scanned successively. After passing through the object, the X-ray strikes the detector, which is up to 40 meters away. "Through the large distance of the object to the X-ray source and to the detector, we obtain extremely sharp images with a unique phase contrast," Zabler says.

In order to capture these images, the researchers have developed an X-ray detector that sets new standards. Whereas the highest-resolution X-ray camera before now supplied around 8,000 pixels per line, the new detector achieves over 16,000 pixels per line. This makes it possible to scan a 40-centimeter-wide object with a resolution of 25 micrometers per pixel. The X-ray camera is based on XEye technology, which was developed at the Development Center X-ray Technology EZRT.

X-ray image of a camera, two views.





Two gigabytes of data per second

The data volumes supplied by the X-ray cameras are huge. "In full operation, we generate two gigabytes of tomography data per second," Zabler explains. To manage this deluge of data, the EZRT is working closely together with the chairs of Prof. Tomas Sauer in Passau and of Prof. Randolf Hanke in Würzburg. The main task here is to reconstruct the volumetric image of the object from the data of the individual scans.

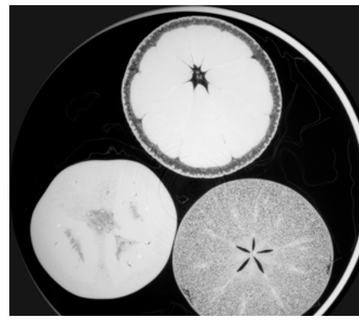
"If we were to just save the raw data on the ESRF servers, the entire storage capacity of this major research institution would be full after only a month," Zabler points out. Therefore, the project team is working on the loss-free compression of the image data. The basis for this is the JPEG 2000 standard, which Fraunhofer IIS was involved in developing. Compression makes it possible to open a data set that originally comprised 100 terabytes on a laptop.

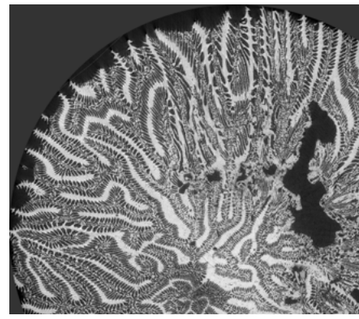
Although the project was affected by the pandemic after its launch in the spring of 2020, the team managed to carry out the first sample measurements at the end of 2021. The team will use the year 2022 to optimize the system and scan sample objects that will illustrate the system's potential as showcase pieces. In December 2022, measurements are to begin for industrial customers.

Measuring components up to 70 centimeters wide

"The customers we look after with the laboratory CT are showing great interest in the BM18 beamline," says a delighted Zabler. "We can expand the field of view to 70 centimeters by doing a half-field scan, whereby we scan first one half and then the other half of the object." For customers that want to X-ray a whole range of components, BM18 offers a huge advantage. "Analyses for which we need a week with the laboratory CT, we can complete in a few hours in Grenoble – and in much better quality, too," Zabler promises. "Naturally, the EZRT handles the entire measuring process from start of finish."

One-eighth of the beamtime of the BM18 beamline will be reserved for industrial customers. The remaining time will be available for scientific investigations. Already, many more researchers have applied for a slice of beamtime than can be accommodated. An independent jury will select the fortunate scientists. One project is already approved: the Human Organ Project. In this project, diseased and injured human organs will be scanned with tremendous precision and made available to the general public as an anatomical 3D atlas.





Top:
X-ray image of a bowl of fruit.

Bottom:
X-ray image of a coral.

Contact

Thomas Kestler
Fraunhofer Development Center
X-ray Technology EZRT

Phone +49 911 58061-7611
thomas.kestler@iis.fraunhofer.de

Weed control with AI instead of chemistry

Autonomous systems help replace pesticides

> Fundamentally, we can employ deep learning methods to train the algorithm we're using to work for any crop. This will make the technology useful in all weed scenarios with which farmers are faced."
>
> **Oliver Scholz**
> Deputy Head, Contactless Test and Measuring Systems

The agricultural industry is faced with a big challenge when growing crops, as regulations are increasingly restricting the use of pesticides. Spraying such chemicals has often been unavoidable as a way to prevent weeds growing up next to the crop, competing with it for nutrients and leading to lower yields.

A crop plant that suffers major yield losses without active weed control is the sugar beet. The crop is the most widely cultivated sugar plant in German latitudes. Almost 30 million metric tons of sugar beet is harvested in Germany every year. Its importance as a raw material is often not appreciated: in addition to sugar production, various by-products of the sugar beet are used to make feed products, and it is also an excellent starting product for the manufacture of biogas and bioethanol.

Researchers at the Development Center X-ray Technology EZRT at Fraunhofer IIS are therefore working with project partners from the industrial sector on an environmentally friendly and sustainable alternative to herbicides. As part of the BlueBob project, initiated by the seed producer Strube D&S GmbH, the project partners are developing an autonomously navigating field robot that will use state-of-the-art sensor technology, intelligent algorithms and active weeding tools to remove weeds from within crop rows. In combination with the use of conventional weeding tools between crop rows, this will make it possible to attain comprehensive mechanical weed control – which can reduce the use of herbicides in sugar beet cultivation and even eliminate it in the long term.

The biggest challenge for the researchers was to teach BlueBob to precisely differentiate between sugar beets and weeds. To solve this conundrum, the Fraunhofer researchers are employing a combination of special cameras for optically capturing the plant parts in conjunction with an AI algorithm developed especially for this application. Using machine learning techniques, the robot thus decides within fractions of a second where within the row the weeding tool should do its work. The tool is then deployed with centimeter precision as it removes the weed and spares the crop.

The project is a collaboration between Fraunhofer IIS, Strube D&S GmbH and the French robot manufacturer Naïo Technologies, which developed the robot platform with its mechanical components.

"Fundamentally, we can employ deep learning methods to train the algorithm we're using to work for any crop. This will make the technology useful in all weed scenarios with which farmers are faced," explains deputy head of the Contactless Test and Measuring Systems department, Oliver Scholz.

Burnout: Designing power electronics that last longer

X-ray imaging helps with early detection of design weaknesses in semiconductors

Technical components are getting smaller and smaller, yet their performance is constantly increasing. Semiconductor components in particular – and especially those designed for automotive applications – are at risk of being exposed to strong current pulses. So as to ensure maximum failure safety and longevity even for such highly sophisticated components, manufacturers put prototypes through extensive testing prior to market launch.

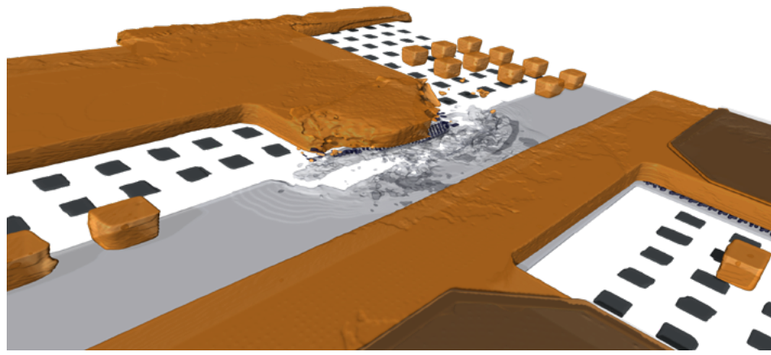
Power temperature cycling tests are used, for example, to find out whether the components will continue to function reliably even under exceptional conditions. In these tests, the components are subjected to periodic voltage spikes, which result in temperature rises of several hundred degrees Celsius in very strongly delimited local areas.

Because of the complexity of the components, which are frequently made up of several layers, it is often difficult after a failure to draw conclusions about the exact course of events or the affected individual components. Furthermore, several failures usually occur in the moment of duress, the exact sequence of which is difficult to reconstruct and interpret.

Researchers at the Fraunhofer Development Center for X-ray Technology EZRT at Fraunhofer IIS have been able to demonstrate, via a technology demonstration, that the use of high-resolution computed tomography in the error tracking of electronic components in pilot production can deliver additional insights in failure analysis. For the first time, three common failure phenomena were represented in 3D across all layers of the component. Even creeping defects, such as those caused by electromigration, can be pinpointed in this way.

This allows manufacturers to better identify and track design weaknesses and the expected damage sequence in advance. Detected weaknesses can be corrected before the component is ready for the production stage.

Technically, the demonstration is based on the ntCT system developed by Fraunhofer IIS, which is capable of visualizing tiny structures. The system is also able to use the full spectrum of the X-ray source in order to exploit higher photon energies even with maximum resolution. This is necessary for scanning chips with high metallization. With a resolution down to 150 nanometers, even the finest defects inside of circuits can be rendered visible.



3D nano-CT analysis of a microchip after failing a power temperature cycling test. The measurement clearly shows the damage caused by local overheating at the various levels of the metallization, from the conductive layers (orange: copper; gray: aluminum) to the cylindrical through-connections each just 350 nanometers in diameter (dark blue: tungsten).

Know I #WeKnowAudio

Better audio experiences around the world

The continued uptake of our 4th generation audio codecs by prominent licensees in 2021 has advanced their further establishment. Indeed, companies all over the world have embraced the Fraunhofer IIS codecs, which improve listening experiences in a huge variety of areas: from 3D soundbars to Bluetooth accessories to smart speakers.

At a glance

1 | Fraunhofer IIS audio codecs contribute to the efficient transmission of audio signals worldwide.

2 | The LC3 / LC3plus and EVS communication codecs ensure maximum call quality and clarity as well as minimum latency for Bluetooth and cellphone connections.

3 | With the MPEG-H and xHE-AAC broadcasting and streaming codecs, distributing and consuming media content becomes efficient and convenient.

International successes for MPEG-H Audio

VIA Licensing, one of the leading administrators of patent pools, announced the establishment of a patent pool for MPEG-H 3D Audio in July of this year. In addition to Fraunhofer, the well-known innovators Dolby, ETRI, Orange, Royal Philips, Sony Group Corp., VoiceAge and WILUS were all founding members. In the following December, Samsung joined the pool. Thanks to the licensing program, providers can now license essential patents for the MPEG-H 3D Audio standard at fair and appropriate conditions. The patent pool makes it much less complicated to integrate MPEG-H Audio into consumer electronics, paving the way for its widespread use.

In the domain of content creation, insights derived from their real-life use went into the production tools published last year. On top of the release of an optimized version of the MPEG-H Authoring Suite (MAS 4.0), the ADM Info Tool was thoroughly revised and republished as the MPEG-H Info Tool (MHIT). In addition, a collaboration with Fraunhofer IDMT produced the Fraunhofer Immersive Panner, which enables users to create 3D audio productions for live applications with conventional production tools. Meanwhile, a collaboration with the company New Audio Technologies from Hamburg resulted in the Spatial Audio Designer (SAD), which permits the complete production of MPEG-H Audio for broadcast, music and live environments.

MPEG-H Audio has also made great progress internationally as a broadcast audio standard. In March, an MPEG-H Audio training center opened in São Paulo, Brazil, where Latin American professionals can familiarize themselves with the technology. In Brazil, the digital TV infrastructure is currently undergoing a comprehensive upgrade. As the first broadcaster in Latin America, Grupo Rede Amazônica is providing a 24/7 MPEG-H Audio service on one of its terrestrial channels using the ISDB-Tb TV 2.5 standard. As the next step toward TV 3.0, the country's entire TV infrastructure is to be converted from analog to digital by December 2023.

In December, the Brazilian SBTVD Forum completed the technical evaluation phase for the future Brazilian television standard. In this phase, several proposed technologies were compared. In the area of audio coding, the MPEG-H Audio system fulfilled all criteria of this selection process and was therefore chosen as the sole mandatory audio format for the future terrestrial UHD system in Brazil.

www.iis.fraunhofer.de/mpeg-h
www.mpegh.com

xHE-AAC is preferred codec of international streaming services

Since this year, xHE-AAC can count the industry giants LG Electronics, Netflix and Facebook among its licensees. This means the codec has established itself as one of the technologies of choice for mobile streaming. xHE-AAC enhances the experience of all kinds of content – movies, music, audio books and podcasts – more than any other technology. Since January, a web-based test service is available, with which developers and manufacturers can test their implementations of the xHE-AAC audio codec for conformity with the MPEG standards. Since then, use of the trademark xHE-AAC® is also being licensed for products that pass the test. This lets manufacturers and consumers recognize which products have been tested for interoperability with the expanded functions of the xHE-AAC codec.

xhe-aac.com

Unprecedented clarity and lowest latency: LC3 / LC3plus

LC3 (Low Complexity Communication Codec) improves the performance of devices with Bluetooth audio support. This year, the codec passed the official qualification process of the Bluetooth Special Interest Group (SIG) and is now listed as a qualified and tested component. Manufacturers of products that are based on this profile are spared the trouble of additional codec tests. Thanks to the sister codec LC3plus, which is equipped with numerous additional functions, the high-end manufacturer Bang & Olufsen can now provide its customers with the highest audio quality in its new wireless streaming devices.

www.iis.fraunhofer.de/lc3

EVS: Better call quality in mobile networks

The Enhanced Voice Services (EVS) communication codec improves the robustness and quality of cellphone conversations. Recently, the Groupe Speciale Mobile Association (GSMA) made EVS implementation mandatory in 5G-capable devices in its "IMS Profile for Voice, Video and Messaging over 5GS" (NG.114), so that the technology will now be used consistently in all 5G voice services. Another big step in the continuing spread of the codec is its implementation is its implementation in the VoLTE networks of Airtel India and Vodafone Idea, two of the largest cellphone providers in India. Together, the two network operators have almost 625 million customers[1].

www.iis.fraunhofer.de/evs

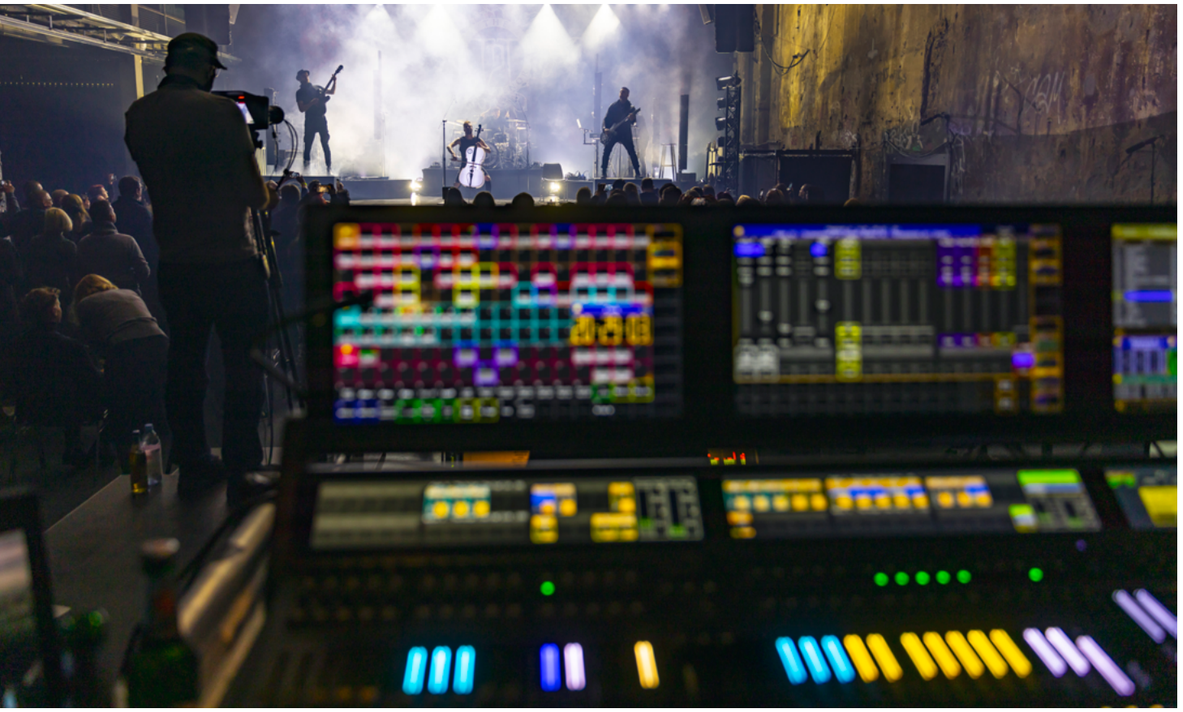
1 As of September 2021, source: www.trai.gov.in/sites/default/files/PR_No.50of2021_0.pdf.

Contact

Mandy Garcia
Head of Marketing Communications
Audio and Media Technologies

Phone +49 9131 776-6178
amm-info@iis.fraunhofer.de

Virtualization of live events



Fraunhofer IIS, Fraunhofer FOKUS and Fraunhofer HHI bring Virtual LiVe into being

Hosted in the 3IT technology center, the Virtual LiVe project is being funded by the Fraunhofer-Gesellschaft as part of the SME Acute (*KMU-akut*) program, Research for SMEs. The project aims to digitally supplement or even replace traditional event formats by using immersive new media formats (e.g. 3D audio, 360-degree video, light fields, volumetric video), when physical attendance is not possible.

The complexity of new technologies and the high implementation costs associated with them when building one's own online platforms make it difficult to keep a portfolio available at the state of the art. Virtual LiVe is therefore seeking to develop a platform that offers adaptable and scalable high-end solutions for the event streaming requirements of a wide variety of sectors in the form of a modular system. Out of this system, small and medium-sized enterprises (SMEs) can put together a program tailored to their specific event needs. The objective of the ongoing research and evaluation projects is to provide significant added value to existing offerings with regard to quality and accessibility (in relation to topics such as paywalls, hardware connections, prerequisites and high Internet speed). This is also designed to cover all relevant legal aspects, especially with respect to data sovereignty and EU data protection rules.

www.audioblog.iis.fraunhofer.com/virtual-live

youtu.be/ZvDvHyo24no

QoEVAVE: Welcome to the virtual laboratory

Realistic virtual environments help to optimize experiments in many scientific fields

Over the past few years, substantial progress has been made in the understanding of auditory cognitive processes and capabilities. Simple virtual environments were used in the experiments that yielded this progress. What these simple environments offer in good control, they tend to lack in realism. Many limitations of earlier laboratory environments can be overcome by interactive virtual environments (IVEs). But how can we evaluate the quality of IVEs, and which benchmark values are relevant for this purpose?

This question is now being investigated by the "Quality of Experience Evaluation of Interactive Virtual Environments with Audiovisual Scenes" (QoEVAVE) project, which is funded by the German Research Foundation (DFG). The project is based on insights from Quality of Experience (QoE) research and includes elements from the VR domain to develop the first comprehensive QoE framework for IVEs. It seeks to obtain an integrated view of the perception of IVE quality as a cognitive process and of the cognitive load for certain tasks as an indicator of the quality of an IVE.

Prof. Emanuël Habets, Head of Department at Fraunhofer IIS and Professor at the International Audio Laboratories (AudioLabs) Erlangen, and Prof. Alexander Raake from TU Ilmenau are heading up the research in the QoEVAVE project. Working together in a multi-stage process, their teams are devising and testing a method for evaluating the quality of IVEs.

www.audioblog.iis.fraunhofer.com/qoevave

SPEAKER project: Building a B2B AI platform

The customized voice assistant solution for German industry meets European data security standards

Voice assistants based on artificial intelligence (AI) that comply with European data security standards are an important future prospect for many companies. Under the leadership of Fraunhofer IIS and Fraunhofer IAIS, the SPEAKER project has been developing a German voice assistant platform since April 2020. Funded by the German Federal Ministry for Economic Affairs and Climate Action as part of an AI Innovation Competition, the goal of the project is to provide infrastructure, technology components and standards for voice-controlled dialog systems for business-to-business (B2B) applications.

Natural interaction with technology via language is becoming increasingly important in many sectors. In the field of medical care, for example, voice dialog systems can make it easier for doctors to consult patient data without using their hands, operate medical devices without touching them and document diagnoses by means of voice input. In industrial settings, voice assistants offer big advantages for the digital inspection and quality assurance of machines, vehicles and infrastructure. And service and administration processes can be structured more efficiently with dialog-based assistants. In all applications, however, it is vital to bring technology and data sovereignty into perfect harmony.

In the B2B environment in particular, companies will be able to adapt the voice assistant technologies available on the platform to the specific technical terms, workflows and requirements of the respective industry. This will enable the project partners of major industrial companies, SMEs, start-ups and research institutions to employ AI methods in their immediate environment. The data sovereignty of personal and company-relevant information remains solely with the German companies and complies with European data security standards.

In close consultation with the subsequent user groups, the project partners are developing initial pilot applications, which are being tested directly in practice. The prototypes are meant to be tranferred into production immedately after the three-year project phase.

www.speaker.fraunhofer.de/en

Trusted electronic hardware – from Achilles heel to rock-solid foundation

New methods and development processes will secure the design of trusted electronics in the future

The goal is to define measurable standards and criteria for components, the implementation of which can be tested and tracked after manufacturing.

For electronic components to be trusted in every sense, they must be protected against manipulations and know-how theft. On the other hand, it must be possible to verify and consult the original specifications after manufacture. So that these standards can also be implemented for the complex, international value chains of electronics manufacturing, we need new and improved design methods. This is where the VE-VIDES (Design Methods and HW/SW Co-Verification for the Unambiguous Identifiability of Electronic Components) research project comes in. As part of the project, researchers from our Engineering of Adaptive Systems EAS division are working with others on a holistic concept for the design of trusted electronics.

For properly thorough implementation, it is important to systematically identify potential security gaps during the design phase and protect electronic systems against attacks and IP theft with reliable mechanisms. It is particularly important to take into account the entire international production chains, which are still frequently opaque to European developers today.

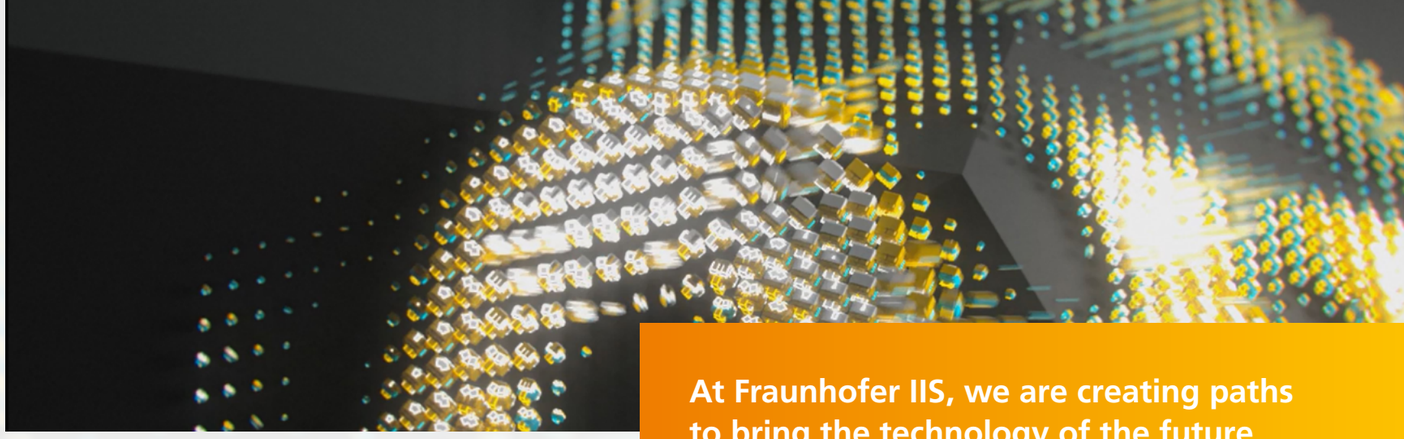
The Fraunhofer IIS / EAS scientists are devising a new methodology for managing the complex requirements for trusted electronics. Their goal is to define measurable standards and criteria for components, the implementation of which can be tested and tracked after manufacturing. To this end, another focus of their work will be on processes for verifying typical integrated circuit IP. As a concrete implementation example, the project team will develop a trusted automotive design flow.

As a result of the collective efforts of all twelve of the project's scientific and industrial partners, recommendations for action will be drawn up for the electronics industry, which will subsequently be standardized, all going to plan, paving the way for much greater transparency and traceability. The German Federal Ministry of Education and Research (BMBF) has granted 10 million euros of funding to the project as part of its flagship Trusted Electronics initiative.

www.eas.iis.fraunhofer.de/trusted-electronics-en

#WeKnowHow

Quantum world: From research to application



At Fraunhofer IIS, we are creating paths to bring the technology of the future quantum computing from theory to practical application.

Quantum world sounds theoretical, you might think. And you would be right! But Fraunhofer IIS is bringing the theory into practice nonetheless. By means of quantum computers, for example, which are much faster and more efficient than the high-performance data centers of today. We are developing not only the requisite hardware for controlling the qubits, but also corresponding algorithms – thus bringing quantum computing a big step closer to practical application.

We develop the requisite hardware for controlling the individual qubits, and we develop the algorithms.

The quantum world cannot be grasped with our everyday experiences – indeed, it actually runs counter to our physical intuition. It was not for nothing that the physicist Niels Bohr observed: "Anyone who is not shocked by the quantum theory has not understood it." But quantum mechanics can very much be used for practical purposes all the same. Quantum computers are a good example: they are considered one of the key technologies of the 21st century, and researchers worldwide are working on their development. In contrast to classical computers, the quantum computer does not operate with the two binary numbers of zero and one, but calculates a superposition of solutions. Exploiting superposition, entanglement and interference, quantum computers approach things differently than classical computers.

Quantum computers contain a lot of potential for efficiently solving things like complex optimization problems, such as faced by Deutsche Bahn when drawing up timetables. However, there is also a risk with the new quantum computers, as they will quickly and easily crack the kinds of encryptions commonly used today. This is where the field of quantum communication comes in, which is devoted to facilitating secure information transmission in the long term. It works like this: If information is transmitted via quantum states, it is possible to determine whether somebody is eavesdropping. If somebody drops into the communication uninvited, as it were, they destroy the original quantum state and alter the system – which is promptly detected. Quantum sensing in turn uses the sensitivity of quantum systems for measurements that are more precise by many orders of magnitude than classical sensors, such as used in measuring temperatures or magnetic fields.

Hardware, algorithms and machine learning

At Fraunhofer IIS, we use our expertise twofold: we develop the requisite hardware for controlling the individual qubits, and we develop the algorithms. And we are already thinking of future applications today. "For controlling qubits, we use high-frequency technology," explains Dr. Thorsten Edelhäußer, head of research planning at Fraunhofer IIS. The requirements are no joke: not only does the high-frequency technology have to be very low-noise, it also must be designed for extreme temperatures – after all, quantum computers often work at very low temperatures just barely above absolute zero. In addition, researchers at Fraunhofer IIS are working on suitable control electronics that generate high-precision signals free from phase shift for very many channels.

Using machine learning methods, the signal shape can be optimized and tasks can be better solved with quantum computers.

But how can the potential of quantum computing be leveraged in industrial environments? This is precisely what our researchers are investigating at the Bavarian Competence Center for Quantum Security and Data Science (BayQS), which was officially opened in April 2021 and has been granted 17 million euros in funding by the State of Bavaria. Other partners in the initiative are Fraunhofer AISEC, Fraunhofer IKS, the Technical University of Munich, Ludwig-Maximilians-Universität Munich and the Leibniz Supercomputing Centre of the Bavarian Academy of Sciences and Humanities. "We're investigating and developing quantum algorithms for relevant problems, such as time series forecasting, improving mobile communication data transmission and positioning and evaluating complex sensor systems," Edelhäußer explains. To this end, the Fraunhofer-Gesellschaft and its partners have exclusive access to an IBM Q System One quantum computer with 27 qubits – the first system of its kind in Europe, situated at the German site in Ehningen. We are using this quantum computer in the QLindA project by the German Federal Ministry of Education and Research (BMBF): together with Siemens AG, we are working on the development and testing of quantum algorithms for reinforcement learning to solve problems – such as control optimization in process industry, the use of distributed automation systems in the smart factory, and optimization in production planning.

In the Munich Quantum Valley (MQV) project, we are working with partners – again supported by the State of Bavaria, with funding of 300 million euros in total – to develop special components for more powerful quantum computers, which are based on three different technologies: superconductivity, neutral atoms and ion traps. "The interdisciplinary team of various research institutions is pooling Bavarian expertise and covers the entire development, from the algorithmics and the electronics to the actual quantum systems," Edelhäußer says. In short: at Fraunhofer IIS, we are creating paths to bring the technology of the future quantum computing from theory to practical application.

www.iis.fraunhofer.de/quantumtechnologies

Contact

Dr. Thorsten Edelhäußer
Head of Research Planning

Phone +49 9131 776-1070
thorsten.edelhaeusser@iis.fraunhofer.de

On the road to digital sovereignty in Europe with Fraunhofer IIS

The development of technologies, services and standards that prioritize European values is very important to us. By doing this, we make Europe more independent from other global players and strengthen European competitiveness. In addition, we ensure the resilience of critical infrastructure and give ourselves the power to act autonomously. Below, the three Institute Directors give their views on questions of digital sovereignty.

Prof. Alexander Martin
Director of Fraunhofer IIS

Prof. Bernhard Grill
Director of Fraunhofer IIS

Where do Europe's strengths lie when it comes to digitalization?

Alexander Martin: Europe is focused on the innovative, responsible use of data for the general good – this is manifest, for instance, in the European data strategy. At Fraunhofer IIS, we develop digital technologies that are founded upon European values and regulations such as data security, transparency, sustainability and EU legal standards. Such regulations require a lot of time and careful planning at the beginning, but in the long run they increase people's trust and confidence in digitalization.

Are digitalization and sustainability a dream team?

Of course, digitalization leads to an increase in CO_2 emissions in the first instance. But digitalization can also help advance sustainability. We design the entire life cycle of our technologies so as to conserve resources and to protect the environment. For example, we develop energy-efficient electronics and computer hardware (green ICT) and carry out research into data-efficient and energy-efficient algorithms for signal processing and AI. We view data as a valuable raw material and ensure that its generation, transmission and storage can be accomplished in an energy-efficient manner (eResourcing).

Consequently, our solutions help put partners and customers in a position to provide information about their current performance indicators – for sustainability reporting, for example – at all times and become more sustainable in an economic, ecological and social sense.

Data sovereignty is also a factor in our development work in the domain of speech technologies. What exactly is Fraunhofer IIS doing here?

Bernhard Grill: We've been working on speech technologies for over 20 years now. Starting from the development of the AAC communication codec and the EVS standard, the mandatory speech codec for 5G voice services, we're currently expanding our activities in the direction of voice signal processing and voice assistance systems. One of the main prongs of our strategy is the SPEAKER project, which is funded by the German Federal Ministry for Economic Affairs and Climate Action as part of its AI Innovation Competition. Under the leadership of Fraunhofer IIS and Fraunhofer IAIS, the consortium partners are developing a German voice assistant platform that guarantees the data sovereignty of users.

What is the goal of this German voice assistant platform?

The goal is to provide infrastructure, technology components and standards for voice-controlled dialog systems for business-to-business (B2B) applications that comply with European data security standards. Whether in the health sector, financial services or industry, such voice assistants hold out a lot of promise for many companies in the future.

Unfortunately, if a company today invests in a standard voice assistant to ease the workload, it often gets a black box where it is completely unclear where the voice recordings are stored, how and where the data is processed and who else might have access to any sensitive information.

Building on SPEAKER, the OpenGPT-X research project is creating a large and thus high-performance AI voice model for Europe. The OpenGPT-X partners are developing intelligent voice applications that will be made available to companies across Europe via the decentralized GAIA-X cloud solution. Funded by the German Federal Ministry for Economic Affairs and Climate Action, the project is headed up by Fraunhofer IAIS and Fraunhofer IIS as the lead partners. Additional voice processing components are being developed at the Center for Digital Signal Processing using Artificial Intelligence (DSAI), which is funded by the Bavarian Ministry of Economic Affairs, Regional Development and Energy (see p. 70).

Prof. Albert Heuberger
Executive
Director of Fraunhofer IIS

And last but not least, it is important to make progress in the area of technological sovereignty in general, and specifically in the domain of microelectronics. What contributions are Fraunhofer IIS and the Fraunhofer-Gesellschaft making here?

Albert Heuberger: In microelectronics, the chief strengths of Germany and Europe are in the areas of chip design, photonics, packaging and power electronics. Fraunhofer IIS and the Research Fab Microelectronics Germany (FMD) make important contributions here in research and design as well as by supporting partners with small-volume production and the development of electronic systems. At the EU and national level, we want to help get back more sovereignty in the long term with new programs for research and infrastructure for microelectronics.

In concrete terms, how can we make it easier for industry to access microelectronics technologies?

We provide our clients with support in the development of integrated circuits all the way through to complete electronic systems, and we supply them with chip prototypes and small batches through our virtual foundry. Our high-performance infrastructure can be used for testing and trialing. And at our High-Performance Center Electronic Systems, we make technologies directly available to our customers.

What strengths can Fraunhofer contribute here?

The dependability of microelectronics is becoming increasingly important, since we as a society are relying on electronic systems to an ever greater extent. With different microelectronic components being manufactured in highly specialized facilities internationally, it is harder for industry to access trusted electronics. However, this access will play an important role for innovative product developments and their marketing in the future. We're pooling the strengths of Fraunhofer in this field in the Bavarian center for trusted electronics, "Trusted Electronic Bayern" (TrEB).

What role do talented young people and training play in this context?

Sovereignty also means the skills to master major parts of a complex technology and making these capabilities available to our clients. To do this, we need the brightest minds. For the development of semiconductor chips, for example, we are training specialists in applied chip design. They're working at Fraunhofer IIS under very good conditions on basic technologies for digitalization such as artificial intelligence and wireless communication.

Creating a sustainable future

Scientific guidance for the transition to sustainability

Successfully managing the transition to sustainability is one of the important challenges, if not the single most important, of our decade – in Germany, Europe and worldwide. Fraunhofer IIS is leveraging its specific skills in the domain of digitalization for the benefit of environmental protection, economic performance and social responsibility. For we are convinced: **Digitalization is a powerful tool for greater sustainability.**

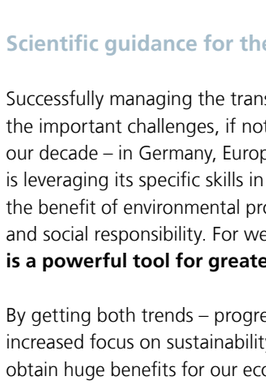
By getting both trends – progressive digitalization and an increased focus on sustainability goals – to dovetail, we can obtain huge benefits for our economy and our working environments. We are laying some of the groundwork for these revolutions by developing resource-conserving electronic (Green ICT) hardware that works in a particularly energy-efficient fashion. We are pursuing low- to zero-power solutions in this area. In addition, we are using our expertise at every stage of the data life cycle – from the sensor technology for data acquisition to data analysis and utilization – in order to make processes leaner and minimize resource consumption in application fields such as manufacturing, agriculture, logistics and local public transport. And on top of this, we are carrying out research into data recycling topics under the general heading of “eResourcing.”

Our natural language communication systems will help reduce business trips. In projects such as Virtual LiVe, we are working on concepts that allow people to enjoy events from home in a highly realistic experience. And our expertise is also directed toward improving social sustainability within companies, such as the working and user environments of employees.

As an organization and employer, we are very conscious of our corporate responsibility. The operations of the entire Fraunhofer-Gesellschaft will be carbon-neutral by 2030. On top of this, we have identified various fields of action in research and administration. In these areas, we are working together with all our employees so that our decisions take into account and conscientiously combine economic, environmental and social concerns.

www.iis.fraunhofer.de/research-sustainability

Prof. Albert Heuberger
Prof. Bernhard Grill
Prof. Alexander Martin



Sylvie Couronné
Senior Engineer

Green ICT – sustainable information and communications technology

Resource efficiency and sustainability are playing an increasingly important role in mobile communications and the Internet of Things (IoT). With the Green ICT hub at Fraunhofer IIS, we want to pool together the expertise of twelve Fraunhofer Institutes with a view to implementing energy-efficient IoT systems using new technologies such as intelligent sensor platforms, edge computing and AI. With the systematic environmental assessment of ICT ecosystems as a service for businesses, we intend to reduce their carbon footprint via so-called hardware ecodesign and promote and advance sustainable digitalization. The energy consumption of components while in operation and on standby is to be designed so as to save battery power by means such as energy harvesting, wake-up modules and the adjusted distribution of data processing throughout the ICT chain. As an active water sports enthusiast, marine pollution and the melting of the polar ice caps are the issues that are driving me to do what I can for climate protection in my professional capacity.

Alexander Ennen
Head of Department

Recycling with X-ray technology

It never ceases to impress me how versatile X-rays are and how many different disciplines can benefit from them. For instance, X-ray technology helps us in the recycling process to distinguish hazardous substances from other materials. We are very well able to detect alloys containing lead, for example, or wood that has been treated and therefore contaminated, by virtue of differences in their material density. These substances must be reliably separated out before the recycling process in order to prevent them from contaminating the remaining materials to be processed, as this would render them useless for the purposes of environmentally friendly recycling. As a Fraunhofer researcher, it is a win-win when my work not only leads to new insights that benefit science and our industrial partners, but also represents a step toward greater sustainability for us as a society.

Susanne Sczogiel
Research Associate

Employee-centric culture for organizational development

Digitalization expands people's scope for action and improves their quality of life. To this end, solutions must be developed that are focused on people’s needs and that train, motivate and engage them. This is what we mean by social sustainability. Using data-based methods, including techniques from behavioral and social research and mathematical optimization, we analyze and optimize not just processes but also working and user environments from the perspective of people – within companies, but also in public spaces. For example, we use co-creation approaches in public innovation labs in order to involve all relevant social groups in the development of innovative new solutions. We investigate what employees need if they are to work with new technologies in a healthy and motivated manner. Mathematics and analytics can be used to organize workflows in a way that accommodates people’s needs – such as software software that plans shifts not only to save time, but also to avoid monotony. All these things make people more content. And that is what motivates me personally.

Julia Rupprecht-Hein
Deputy Group Manager

Corporate responsibility

Under the heading “Sustainability at Fraunhofer IIS,” we deal with our responsibility and our objectives as an organization and employer: that is to say, our corporate responsibility. We put together a team and evaluated our institute based on the “LeNa – Sustainability management in non-university research organisations” guidelines. We scored well: in many areas for action, we are either well or very well positioned. But we want to do even better. That is why we are developing participatory formats in consultation with institute management to which all employees can contribute and bring their ideas to the subject at hand – climate-friendly mobility, for instance. Sustainability is very important to me personally. It heartens me to see the determination with which Fraunhofer is approaching this topic. It is our responsibility to bequeath a world to our children and grandchildren in which they can live well, in peace, and in good health.

Top:
Acceleration sensors attached to a collar provide information about the animals' movement patterns and individual behavior.

Middle:
Sensors on buses and at bus stops operated by the city of Bamberg's public utility company continuously measure the level of pollutants in the air.

Bottom:
Sensor-based soil analysis furnishes data on soil humidity and temperature.

IoT for smart cities and smart agriculture

Pioneering collaboration in the FutureIOT center of excellence

The FutureIOT research project, which was funded by the Bavarian Research Foundation for three years, has come to a close. The goal of the project, which had been run since 2018 by a group of scientific institutions and companies comprising over 40 partners, was to search for innovative solutions for the use of the Internet of Things (IoT) in cities and in the countryside. It involved the intelligent networking of technologies from the fields of communications, sensor technology, positioning, information security and IoT platforms.

mioty® conveys data

One contribution to the success of the project was made by our IoT transmission network mioty®. With the wireless transmission technology, data was continuously amalgamated from highly responsive sensors over long distances and comprehensively evaluated. This makes it possible to monitor, control and manage processes and conditions.

With various types of sensors involved, the use of connected technologies was broadly based. Intelligent solutions were developed for cities and also for agriculture. Acceleration sensors ascertained the behavior of cattle out in the pasture and, when the data was linked with numerous environmental parameters, allowed conclusions to be drawn about the animals' health. Based on the data sets acquired, machine learning models were developed for the behaviors of lying, grazing and ruminating.

Sensors in the ground measured the moisture and nitrogen content of the soil with a view to optimizing fertilization and plant growth. Among other innovations, a new soil sensor was developed for this use case in collaboration with a start-up partner in the group; it is now available on the market.

Air-quality sensors fitted to urban buses continuously recorded the levels of pollutants in the air. In the long term, this data will help improve environmental management in cities. An easily accessible and precise monitoring of the indoor climate was implemented by several partners in the group on their premises.

The occupation of inner-city parking spaces was also measured by means of special sensors. This would make it possible to provide information on free spaces to drivers looking for somewhere to park.

A strong network for the future

The successful center of excellence wants to collaborate on the further development of the platform in the future as an alumni network. Further research questions are already lined up, and industrial partners and group partners are in the starting blocks. One thing is certain: connected solutions that bring direct benefits to people and the environment are the future!

www.iis.fraunhofer.de/en/pr/2021/20210702_future_iot.html

youtu.be/wzFbHTxeHd4

AI becomes even smarter through purposeful integration of specific prior knowledge

New Operator-Based Learning research group emerges from Fraunhofer Attract program

A new Operator-Based Learning group has been established at the Fraunhofer Development Center X-ray Technology EZRT at Fraunhofer IIS. The research group emerged from the Fraunhofer Attract program, which offers external applicants the opportunity to put forward their own ideas to a Fraunhofer Institute as research topics.

AI in image reconstruction

Thanks to machine learning, we can manage many tasks a good deal more efficiently and purposefully than before. The self-learning systems draw on a huge database of existing knowledge for their task and "condition" themselves to come up with ever better results.

This artificial intelligence (AI) is very suitable for use in image reconstruction in the field of X-ray imaging. Particularly when using higher energies or as the consequence of special constraints when X-raying, unwanted image artifacts appear in the reconstruction results. This is a side effect that reduces the quality of the data, but that cannot be avoided with conventional methods. A self-learning algorithm that recognizes the effects of such an unwanted structure and can correct for them while taking into account the prevailing physical and mathematical realities would be a leap forward in quality for nondestructive testing.

Research topic: Known operator learning

One of the core tasks of the new team led by group manager Prof. Andreas Maier will be to confront the challenge of the so-called black box. This refers to the methodologically determined property of a deep-learning-based AI approach, whereby it is not possible for humans to know what decision paths the AI took and how it arrived at its results. Accordingly, it is difficult for people to identify and correct the sources of errors. "If you train AI based on numerous CT scans of the human body, for example, it will begin to interpret certain bodily structures into other entities where they do not exist. This must not be allowed to happen," explains Professor Andreas Maier, who holds the Chair of Pattern Recognition at Friedrich-Alexander-Universität Erlangen-Nürnberg.

To solve this problem, the researchers are using specific "prior knowledge" in AI so that it can evaluate the plausibility of its work by itself. This can include things like the knowledge of the basic laws of physics, advance knowledge about objects such as CAD data or material data, and traditional signal processing. A known conjunction of information like this is referred to as a known operator. Its use in AI effectively forces the technology to find only such solutions as correspond with the physical and mathematical prior knowledge.

Opening up new areas of application

The new research group's medium-term goal is to combine these approaches from AI research with other projects at Fraunhofer IIS so as to create synergies for more reliable image interpretation in nondestructive testing and also for applications in the domain of inline testing. "We want to make our research findings available to other project groups across the institute in a spirit of collaboration so that we can jointly open up new areas of application. We also plan to offer licensing models for the technology to our external partners in the future," Maier summarizes.

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>
> **Prof. Andreas Maier**
> Group Manager for Operator-Based Learning

New center for artificial intelligence in digital signal processing (DSAI)

Erlangen to become the flagship of Bavarian AI research

Artificial intelligence (AI) offers a whole range of new approaches for signal processing solutions. A new center was founded in 2020 to systematically develop the technology, and, as a flagship project, it has received 13 million euros in funding over five years from the Bavarian Ministry of Economic Affairs, Regional Development and Energy as a flagship project. Under the leadership of Dr. Frederik Nagel, various AI-assisted basic technologies are being developed in four work areas. They are available for consulting and licensing and, in the long term, for customized solutions. Audio signal processing, natural language user interfaces (NLUI), computer vision and data transmission benefit from the use of AI and machine learning and are further expanding our competitive edge in signal processing on an international level.

> With the methods of artificial intelligence, we will be in a position in the future to alter voice signals so that they can be understood without noise interference and with virtually no loss of audio quality."
>
> **Dr. Frederik Nagel**
> Head of AudioLabs-IIS Department

Audio quality and speech recognition

The participants in a video conference are annoyed. Somebody nearby is constantly typing on their keyboard and bothering everyone with their tip-tapping. "With the methods of artificial intelligence, we will be in a position in the future to alter voice signals so that they can be understood without noise interference and with virtually no loss of audio quality," says Dr. Nagel, outlining technological progress that will of benefit not only for future participants in online conferences but also in other fields of application. In television, AI-based techniques can clearly distinguish background noises and dialog from each other, so that viewers can individually adjust their respective volumes. In addition, the experts are carrying out research in the field of audio signal processing and voice assistants for secure communication with organizations such as banks and insurance companies, where the data has to remain in Germany.

Image processing and communication

Whereas online customers today must make do with a conventional, two-dimensional picture of e-commerce items, the use of new AI methodology will help provide a 360-degree image containing detailed information about the qualities of the merchandise. "In image processing, we're expecting new solutions for the efficient generation of virtual scenes from individual pictures," the head of department announces. "And if you are no longer annoyed by poor network coverage and low robustness of transmission in the future, this will be partly owing to the combination of AI and signal processing in communication systems." Wireless transmission systems have long been a core area of Fraunhofer research. Their use in shared radio systems for communication and radar sensing can contribute to optimized resource allocation and therefore save valuable energy.

www.iis.fraunhofer.de/en/dsai

High-Performance Center Electronic Systems (LZE)

The High-Performance Center Electronic Systems (LZE) is a joint initiative of the Fraunhofer-Gesellschaft, its institutes Fraunhofer IIS and Fraunhofer IISB, and Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU)

In collaboration with selected partners from industry, the high-performance center functions as a strategic cooperation platform. Its primary focus is on the product-oriented transfer and exploitation of technology and on excellent application-oriented research into state-of-the-art electronic systems.

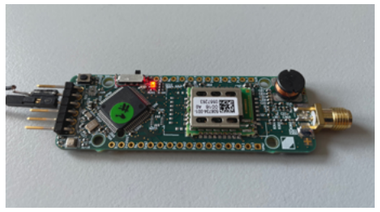
To this end, "KMU-Springboard LZE" was launched at the start of 2021 with the goal of building up an SME transfer platform for future technologies in the domain of electronic systems in order to fulfill the special requirements of cooperation with SMEs. Fraunhofer IIS was involved in two subprojects.

In the first subproject "XRAY4KMU", we devoted ourselves to the development of novel, digital and optimized processes for X-ray services in our Development Center X-ray Technology (EZRT) division. In this way, we make it easier for SMEs to get to grips with this subject and simplify the use of these services specifically for this customer group.

Furthermore, many innovations relating to the Industrial Internet of Things (IIoT) require new communication solutions. Here, again, the threshold for SMEs is very high. In the "IIOT4KMU" subproject, we created shared interfaces with industrial partners so that projects can be implemented with greater speed and efficiency. Components that were not available from industrial partners were developed and made available through the marketing avenues at the high-performance center's disposal. These measures make it considerably easier for SMEs to make the move into modern IIoT solutions.

Even though the "KMU-Springboard LZE" project ran its course on December 31, 2021, new projects are already ready to go. The next project phase at the high-performance center will begin in 2022 and run until 2024.

www.lze.bayern/en



Top:
In the "IIOT4KMU" project, standardized interfaces and universal components were created along the IIoT process chain. These interfaces and components can be networked with each other in modular fashion.

Bottom:
X-ray technology was used to study a cello made by the legendary luthier Antonio Stradivari to facilitate the evaluation of restoration work on the body of the rare instrument.

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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, Andrea Auner, Christine Broll, Sylvie Couronné, Dr. Katja Engel, Alexander Ennen, Mandy Garcia, Simon Hagen, Syndia Ioannidou, Thomas Kestler, Matthias Krempl, Sandra Kundel, Yvette Kunze, Jan Plogsties, Angela Raguse-Fößel, Daniela Rembor, Julia Rupprecht-Hein, Susanne Sczogiel, Tim Schröder, Diana Staack-Tettling, Dr. Bettina Williger, Claudia Wutz

Layout and production
Claudia Matthias

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

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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 1100 employees conduct contract research for industry, the service sector and public authorities. Founded in 1985, the institute has 14 locations in 10 different cities: Erlangen (headquarters), Nuremberg, Fürth, Dresden, Ilmenau, Bamberg, Waischenfeld, Würzburg, Deggendorf and Passau. 75 percent of the budget of 191 million euros a year is financed by contract research projects. Approximately 25 percent is subsidized by federal and state funds as well as internal projects of the Fraunhofer-Gesellschaft.

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www.iis.fraunhofer.de/en

You can see the organizational structures of the individual locations in the organizational chart on pages 18 and 19.

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 managers, reports on technical innovations and successes, plus films, podcasts and animations on all the latest topics from our institute.

www.iis.fraunhofer.de/en/magazin

Cover image
The new building of the Engineering of Adaptive Systems EAS division of Fraunhofer IIS in Dresden was completed in 2021. With a floor space of 4300 square meters on a site close to the Technische Universität Dresden, the building is equipped with laboratory spaces that offer a wide range of testing and experimentation possibilities. A lot of passion and energy went into creating a sustainable building.

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.