FRAUNHOFER
75 YEARS OF INNOVATION

Review of Fraunhofer research

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Fraunhofer world records

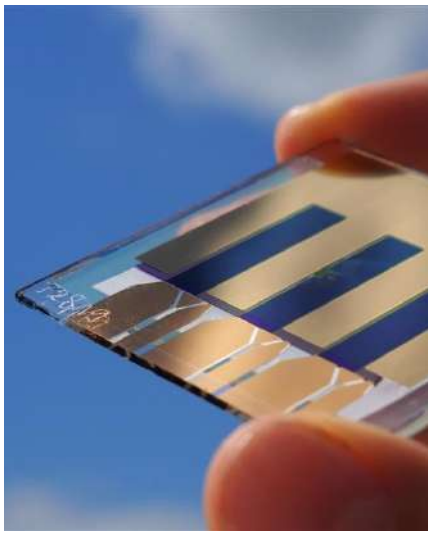
Setting standards for heat pump systems worldwide

Power electronics for innovative heat pumps

Fraunhofer researchers have been working on the ElKaWe flagship project since 2019 with the goal of developing high-efficiency electrocaloric heat pumps as an alternative to the currently widespread technology involving compressors and refrigerants. An ultra-efficient circuit topology for voltage converters based on gallium nitride (GaN) transistors with 99.74 percent electrical efficiency was finalized at the Fraunhofer Institute for Applied Solid State Physics IAF in July 2023. The GaN-based multilevel DC/DC converter is setting standards worldwide. Increased electrical efficiency leads directly to a higher coefficient of performance for the entire heat pump system, making it a milestone on the road to more-efficient heat pumps. Realizing a high coefficient of performance in electrocaloric heat pumps requires very high efficiency in materials, electronics, and heat transfer alike. Further research is still needed, but in the future, electrocaloric heat pumps could become a more efficient, fully emission-free solution for heating and cooling.

Organic solar cell with 15.8 percent efficiency

At the Fraunhofer Institute for Solar Energy Systems ISE and the Materials Research Center FMF of the University of Freiburg, the record last set by the team in September 2020 for a 1-square-meter organic solar cell was beaten in July 2023. The new solar cell established a new world record in this category again with an efficiency of 15.8 percent. The improvement of the record solar cell was primarily achieved by using an anti-reflective coating through which more light is absorbed into the photo-active layer of the cell, thus generating a higher current. The thin coating system required for the coating — deposited using a sputtering process — was also developed at Fraunhofer ISE. Organic solar cells could open up new fields of application for solar energy, as these cells are ecofriendly and inexpensive to produce as well as being flexible, plus they can be made transparent.



Anti-reflective coating for higher efficiency

Cryogenic drive inverter for electric drives in aviation

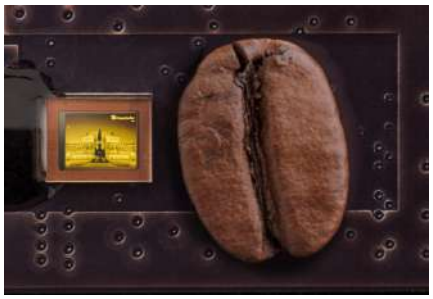
Drive inverter for electric flight

Compact, lightweight electric drives are essential to the electric aviation of the future. Superconductive systems, in which electrical current flows with almost no resistance and barely any losses, would be a good solution. This enables maximum performance in terms of efficiency, weight, and installation space. Many electrical conductors do not become superconductive until they reach cryogenic temperatures. And that means all of the drive components, including the complex inverter, must be designed for these kinds of conditions. The Fraunhofer Institute for Integrated Systems and Device Technology IISB in Erlangen has demonstrated a cryogenic-capable 500 kW drive inverter for the first time. It is cooled with liquid nitrogen at 77 Kelvin (K), corresponding to –196 degrees Celsius. The cryogenic inverter is the result of a cooperation with Airbus UpNext. As part of its ASCEND program, Airbus is now building a prototype of a fully cryogenic electric aircraft powertrain. The Fraunhofer IISB drive inverter has made this possible in the 500 kW power class for the first time.

Photos: Fraunhofer IAF, Fraunhofer ISE, Fraunhofer IISB

Unprecedented pixel density in OLED microdisplays

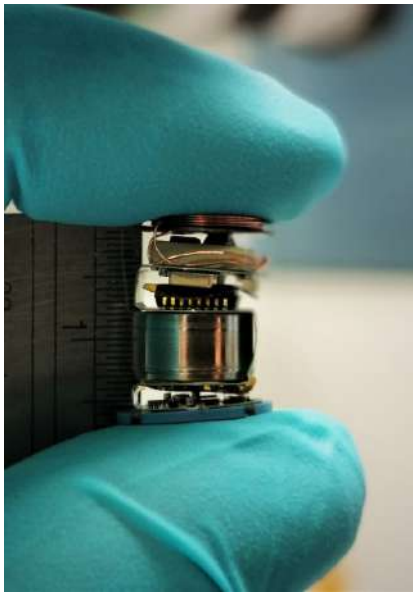
OLED microdisplays were previously limited in pixel quantity and size, with the maximum pixel density previously about 8,000 dpi (dots per inch). Higher pixel densities are not possible using traditional production methods, which involve conventional CMOS technologies on 200-millimeter wafers. The Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology FEP presented OLED microdisplays with an unprecedented pixel density of 10,000 dpi for the first time at SID Display Week in Los Angeles in May 2023. The first OLED microdisplay with 10,000 dpi has tiny, 2.5-micrometer pixels with a display diagonal of 0.18 inches. The CMOS backplane was designed and produced with small-node technology in a 28-nanometer CMOS backplane process on 300-millimeter wafers. The new backplane technologies also allow control concepts that can reduce the current consumption of mobile applications. The research, conducted as part of the Backplane interdisciplinary project, was funded by the Saxony State Ministry for Economic Affairs, Labor and Transport. The Microdisplays and Sensors business unit at Fraunhofer FEP was integrated into the Fraunhofer Institute for Photonic Microsystems IPMS with retroactive effect from January 1, 2024.



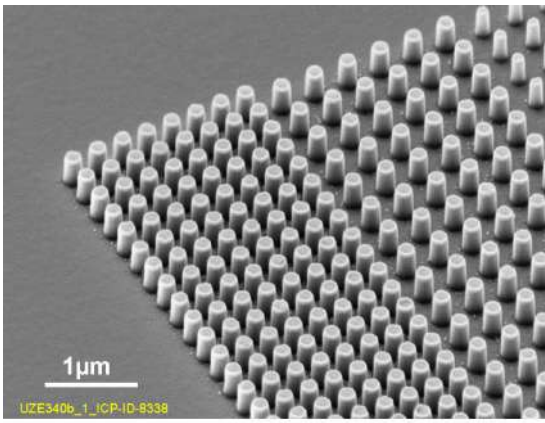
OLED microdisplay with the world's smallest pixels

The world's smallest impedance spectroscopy system

At 11 x 16 square millimeters, the Fraunhofer Institute for Reliability and Microintegration IZM developed the world's smallest system for impedance spectroscopy with its partners Micro Systems Technologies (MST) and Sensry GmbH. The sensor consists of a biocompatible, water-tight polymer. Six sensors were placed next to two electrodes to create a frequency spectrum from a medium. The developer group overcame the challenge of extreme miniaturization several times: for example, with the coil diameter for wireless charging (10 millimeters) or with the IoT system. This is located in a six-layer interposer; the electrodes for the impedance spectroscopy were placed in a 0.5-millimeter-thin ceramic plate from MST. Sensry GmbH devised the clever design structure. The flexible, biocompatible circuit board with over 70 components made of liquid crystal polymer was produced by MST in four layers. Electrochemical impedance spectroscopy fundamentally unlocks diagnostic options for a wide range of different applications, such as material studies and endoscopy.



Extremely miniaturized spectroscopy capsule for a wide range of diagnostic options



Electron microscope image of the meta-grid

30-centimeter metasurface

"Metasurfaces" could be an alternative to lenses and mirrors. Previously, the function of a lens or mirror was defined by macroscopic geometry, which is why they are thick and curved. Metasurfaces, by contrast, concentrate their entire optical function in a nanostructured surface. This means that in theory, metasurfaces can be produced to be much thinner than lenses. However, thus far it has only been possible to produce surfaces of a few square millimeters for applications in science and research — which is not yet enough for many industrial applications. In the spring of 2023, researchers at the Fraunhofer Institute for Applied Optics and Precision Engineering IOF succeeded in producing the world's first metasurface with a diameter of nearly 30 centimeters. To achieve this, they used a special writing strategy when illuminating the nanostructures with electron beam lithography. In this method, called character projection, complex patterns are divided into smaller units. An electron beam is then used to create each of these small patterns in turn on a surface in parallel with high precision and efficiency and at a comparatively high speed. The scientists published their method in the *Journal of Micro/Nanopatterning, Materials, and Metrology.*

Photos: Fraunhofer FEP, Fraunhofer IZM, Fraunhofer IOF

Projects and results

Five social goals for a future worth living

DIGITAL TRANSFORMATION 1

FULLY CIRCULAR ECONOMY 2

COMPLETE ENERGY TRANSITION 3

AFFORDABLE HEALTHCARE 4

SECURITY AND A RESILIENT SOCIETY 5

Digital Transformation

Real-world production machine (left) in the metaverse

Energy-efficient heterogeneous high-performance computing

The industrial metaverse at your fingertips

The metaverse is made up of interactive, immersive 3D environments. Extended reality (XR) technologies such as smart glasses, VR headsets and gesture input enable seamless interaction between the real and digital worlds. The industrial metaverse focuses on professional applications in industry and society, spanning fields such as transportation, plant engineering, urban development, and medicine. It can be viewed as the next stage of the digital transformation, following Industry 4.0. Key technological building blocks of any metaverse include digital twins, simulations, XR technologies, artificial intelligence (AI), blockchains, and data spaces. Because the industrial metaverse offers such a wealth of technological potential, the Fraunhofer ICT Group has dedicated an entire strategic roadmap to this topic within its research portfolio. The 20 institutes that make up the group act as technology suppliers and advisors on the planning and execution of use cases involving industrial metaverse technologies.

The 5G Troisdorf IndustrieStadtpark (Troisdorf 5G industrial park) project, which received funding from the German federal government, realized metaverse applications for remote maintenance and training in mechanical engineering and production applications. A technology demonstrator was presented at the Hannover Messe in 2023 and at the German federal government's 2023 open house event. The technological basis comprises 5G Internet, remote rendering of CAD data, and mobile mixed reality and virtual reality headsets. A digital twin was developed for the production machine operated by project partner ZWi Technologies, which is used on the production line at Kuraray Europe, another partner in the project. The machine's digital design data are custom-displayed in the user's field of vision by the headsets, which also present additional information. Communication among geographically dispersed users is supported by avatars, pointing gestures, direct manipulation, and audio and video communication. This enables distributed learning scenarios for the operation and maintenance of the machine, for example, including active dialogue in virtual space. The project coordinator is the Fraunhofer Institute for Applied Information Technology FIT.

Saving electricity with top digital performance

The digital transformation is opening up promising possibilities, but the underlying systems need to be made more energy-efficient. That is the goal of the NAAICE joint research project. The project is developing network-attached accelerators for energy-efficient heterogeneous high-performance computing (HPC).

This type of computing is used in fields such as climate modeling, astrophysics, and biology. It requires powerful processors, which in turn need a lot of energy. The NAAICE consortium is working to harness capacity in HPC data centers more efficiently. Conventional data centers generally use computers that are built on a base of homogeneous standard components and used for many different processes. For HPC applications, they typically utilize only specific parts of a standard computer, so a lot of capacity is lost. By contrast, the NAAICE partners are developing a heterogeneous system architecture in which computers are flexibly equipped for specific applications. To achieve this, the team is working with special integrated circuits known as field programmable gate arrays (FPGAs), which allow for new functions to be added continuously. The project's core technology is the novel concept of the network-attached accelerator (NAA), which is based on FPGAs. It was developed at the Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institut, HHI, Berlin. Unlike in previous concepts, in which FPGAs are integrated into data centers, NAAs are decoupled from the server processors. They are connected via the network instead, making them dynamically usable. Ultimately, they offer both more flexibility and lower energy consumption due to improved capacity utilization. The partners' current development targets include software for integrating NAAs into HPC data centers.

NAAICE was launched in 2022 with funding from the GREEN HPC line provided by the German Federal Ministry of Education and Research (BMBF). Along with Fraunhofer HHI, the University of Potsdam, the Zuse Institute Berlin, the Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences, and PERFACCT GmbH are involved in the project. The results will be made available as open source software at the end of the project.

Photos: Fraunhofer FIT, shutterstock/aimediaPL

Digital Transformation

Flexible production architecture helps with supply chain disruptions

Infrastructure for development of innovative computers

Production architecture for the factory of the future

The manufacturing industry faces a number of challenges, including market volatility, supply crises, and rising energy prices. To address these factors, researchers have developed a modular and flexible production architecture in the Fraunhofer flagship project SWAP, which was launched in 2020. The project is disrupting the static structures and schematic processes of conventional production facilities and bringing fresh dynamism to the processing of work steps. It incorporates both the end product that is being manufactured and the machine technology required to manufacture it, including robots and autonomous transportation systems. To achieve this, the researchers are developing a standardized, semantically simplified language to describe machines, processes, and products. This language, the Production Flow Description Language (PFDL), is used to define the end product or component before manufacturing begins so that the desired special features can be added afterward. Once the orders are written up, they are processed autonomously by machines or robots.

This creates a smart and adaptable production environment. The new approach allows each order to be executed efficiently and adapted individually to the requirements. Conventional manufacturing, with its standardized workstations, cannot achieve the same case-by-case flexibility. Manufacturers can now adapt processes on the factory floor flexibly to suit their targets. The project consortium has already produced optics made out of polished metal — not glass — for a laser telescope based on the principle of the SWAP-IT production architecture developed in the project. The innovative production method offers options for lower-cost production than conventional methods for space telescopes in New Space and more.

SWAP should be viewed as a continuation of Industry 4.0 megatrends, featuring technologies such as sensors, connectivity, and digital twins. The researchers are also working on a practical process model for implementation purposes to make it easier for businesses to switch to the innovative production architecture.

Test lines for next-generation computers

Processing-intensive technologies such as artificial intelligence (AI) and edge computing are pushing traditional digital computers to their power limits. Quantum computing (QC) and neuromorphic computing (NC) open up fundamental opportunities for next-generation computing technologies. Without these, many competition- and security-critical missions would be impossible going forward.

The Research Fab Microelectronics Germany (FMD) is supporting the emerging next-generation computing ecosystem with its infrastructure and scientific know-how. The goal is to enable cutting-edge hardware development, particularly within the framework of the Quantum and Neuromorphic Computing Module — Module qnc funding line. The objective of the FMD-QNC project is to enable partners from the research, development, and innovation sectors and businesses to quickly implement their findings from lab settings in prototype and small series form. This is made possible by the extended process options that are part of the FMD-QNC project. In the fall of 2023, the QNC Space deep tech accelerator, which is part of FMD-QNC, opened up an easy way for research groups, founders, start-ups, and SMEs to access FMD-QNC partners' infrastructure for the first time.

The FMD-QNC funding project of the German Federal Ministry of Education and Research (BMBF) is supplemented at the European level by the PREVAIL funding project. Several research organizations — CEA-Leti (France), Fraunhofer (Germany), imec (Belgium), and VTT (Finland) — are working to create an interconnected 300-millimeter technology platform that will unlock possibilities for chip prototypes for AI or neuromorphic computing. Project activities within PREVAIL and FMD-QNC are interconnected. They represent important preparations for the technological foundation of the European Chips Act.

Photos: Fraunhofer IFF, Fraunhofer IPMS

Fully circular economy

Development of bioplastics made of polybutylene succinate

Finger orthoses made from fully compostable plastic

More types of PBS bioplastic

Recyclable and biodegradable plastics made from locally available plant residue instead of petroleum: That is the goal for the 18 partners working on the RUBIO project, which is funded by the German Federal Ministry of Education and Research (BMBF). The Fraunhofer Institutes for Applied Polymer Research IAP and for Microstructure of Materials and Systems IMWS are participating in the project. Fraunhofer IAP is developing new types of a bioplastic called polybutylene succinate (PBS) that will be more versatile than before. Fraunhofer IAP worked with POLIFILM EXTRUSION GmbH, in the state of Saxony-Anhalt, to develop a PBS film suitable for shipping pouches. The German company produces plastic films for the construction, agriculture, and automotive sectors as well as other industries. Cooperation between the applied research sector and businesses has made it possible to produce these films using standard extrusion systems, unlocking options for further development geared toward the needs of industry. The polymer experts at Fraunhofer IAP are providing support in terms of the methods used to synthesize new types of bioplastic, but that is not all. They are also transferring the results from the laboratory and pilot plant to the industrial pilot scale at the Fraunhofer Pilot Plant Center for Polymer Synthesis and Processing PAZ. At the Processing Pilot Plant for Biopolymers Schwarzheide, newly developed PBS types and mixtures are being studied with an eye to various criteria, such as thermoplastic processing, biodegradability, recyclability, and printability.

Few plastics processors have been bold enough to switch to bioplastics so far. Issues with supply chain reliability, higher costs, too little choice of different types of bioplastics, and questionable suitability for certain applications pose serious obstacles. Recycling, too, is only worthwhile for plastics that are present in large quantities in waste streams. With all this in mind, the RUBIO project consortium is continuing to develop PBS bioplastic. In the future, the goal is to source the raw materials for the plastic from local residue and waste — from biogas plants, agricultural operations, or paper production. If they are successful, shorter transportation distances could then even lower the prices.

The biological side of Industry 4.0

How can automotive manufacturing be made sustainable? A consortium led by the Fraunhofer Institute for Production Systems and Design Technology IPK has developed pilot processes for sustainable value creation as part of the BioFusion 4.0 funding project (German Federal Ministry of Education and Research, BMBF). Partners included Mercedes-Benz AG, Werner-von-Siemens Centre for Industry and Science e.V., and Technische Universität Berlin. The 13 entities involved developed solutions to support workers through biointelligent assistance systems and solutions for the use of biogenic materials, for example.

As one use case, an orthosis for component assembly in automotive production was developed: Intelligent algorithms are used to produce individual 3D bioplastic orthoses for workers' hands. The bioplastic is made from grease or fat, making it 100 percent compostable. The consortium also devised a multi-agent system that can be used to automatically control the distribution of production orders. Workers can use a dashboard to track how far along orders that have been received are in the process, visualize any workstations that are down, and get support with automatic adjustment of production steps. This kind of self-organized process control allows production companies to operate with greater flexibility and resilience.

A product's individual lifetime carbon footprint is also calculated. The aim is to incorporate these data into the Catena-X nonprofit organization via the Fraunhofer network. This collaborative, open data ecosystem represents the largest automotive industry project in relation to future production concepts: trusted data exchange among all stakeholders in the automotive industry — from the initial supply stage right through to the original equipment manufacturer (OEM). This exchange is based on the software services of International Data Spaces (IDS) and Gaia-X.

Photos: POLIFILM, Fraunhofer IPK / Larissa Klassen

Fully circular economy

The project team, visiting a claim site

Lithium carbonate like that produced in South America

Reducing "forever chemicals"

One of the most serious forms of environmental degradation caused by humans is the contamination of soil and water with per- and polyfluoroalkyl substances, or PFAS. They are found in everything from dental floss and outdoor apparel to fire extinguishers and crop protectants, along with many other products. PFAS, some of which are harmful to human and animal health, are also known as "forever chemicals," as they are extremely stable. Removing them is a laborious process. Activated charcoal filtering, for example, binds PFAS but does not eliminate them, meaning that the residue must be disposed of or stored as special waste.

Researchers from the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB have succeeded in developing a plasma method of energy-efficiently removing PFAS from contaminated water. The plasma is generated by applying high voltage between the electrodes of a combined glass and stainless steel cylinder. The contaminated water then flows along the outside of the (stainless steel) electrode. The energy-rich plasma atmosphere breaks apart the PFAS molecule chains, shortening them. The process is repeated several times in a closed loop. The molecule chains grow shorter each time they pass through until they have been broken down entirely. The AtWaPlas (Atmospheric Water Plasma Treatment) joint research project was carried out in cooperation with Aachen-based industry partner HYDR.O. The company, which specializes in cleaning up contaminated sites, supplied the water samples. The plasma method can also be used with the same setup to clean up other forms of water pollution, such as medication residue, other industrial chemicals, or plant protectants. As the next stage in development, these kinds of plasma systems could also be set up as a standalone purification stage at wastewater treatment plants or deployed as mobile units to contaminated open space.

AtWaPlas received funding from the German Federal Ministry of Education and Research (BMBF) as part of the Wasser: N initiative.

Domestic lithium from geothermal systems?

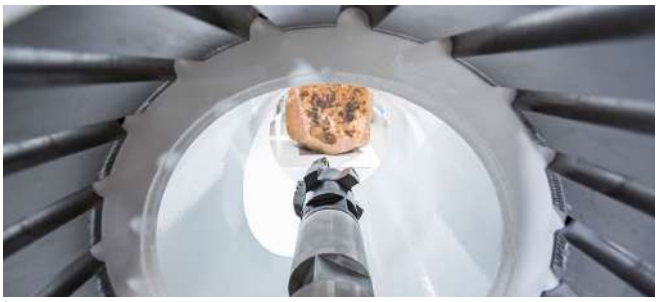
Lithium is the key raw material driving the energy transition, especially for the batteries needed for electric mobility. Germany remains dependent on imports — primarily from Australia and South America, produced under environmentally damaging conditions. But lithium is also found in Germany — on the Upper Rhine Plain, in the Ore Mountains, and in the North German Basin.

The trigger for the most recent research work was a study by Karlsruhe Institute of Technology (KIT) that was named an outstanding paper of 2022. The KIT researchers demonstrated that thermal water at a depth of several kilometers has a high concentration of lithium ions. Since then, several initiatives have been under way to study how the valuable metal can be combined with hydrothermal geothermal systems. Among those involved are EnBW AG, Vulcan Energie Ressourcen GmbH, the Fraunhofer Institutes for Chemical Technology ICT and for Physical Measurement Techniques IPM.

First, the lithium ions must accumulate through adsorption and then be released using desorption solutions. The lithium chloride produced in this way can be converted to lithium hydroxide through electrolysis and then traded in this form as lithium. A first lithium ion screen was produced under the auspices of KIT. It is based on a lithium manganese oxide with a special crystalline structure known as a spinel and was made using hydrothermal synthesis. The consortium is working to refine the screen and improve the method's cost-effectiveness. An optical sensor that enables spectral material analyses in ongoing processes helps with this. This development from Fraunhofer IPM is intended as a replacement for the costly, time-consuming, and laborious lab measurements that were previously needed for precisely controlling the time to change the through-flow direction in the lithium ion adsorption and desorption process. The sensor is to undergo testing during real-world operation at a geothermal site in the near future.

Photos: HYDRO.O., IMAGO

Complete Energy Transition



Drilling to explore geothermal energy

Modeling the expansion of the electrical grid

Drilling to harness geothermal energy

Water from decommissioned mines can contribute substantially to municipal heating and cooling needs. "Cold local heating networks" can be used to distribute heat to surrounding buildings. Heat pumps there are a very efficient option for heating the water to domestic hot water levels, as they supply heat pumps in surrounding buildings at even low working temperatures. Many of the decommissioned coal mines in Germany's Ruhr region contain large reservoirs of water. The D2Grids project, located on the grounds of a former Opel plant in Bochum, offers a blueprint for grid-connected low-temperature heating and cooling solutions in northwestern Europe. The former Dannenbaum coal mine is to be used to provide a climate-friendly supply of warm and cold water for the urban district being developed on the former Opel grounds (approximately 70 hectares). Pumping tests conducted in the spring of 2023 confirmed that the geothermal potential is sufficient. That marked the start of construction of an energy center. Going forward, warm water at temperatures of 27–28 degrees Celsius is to be pumped from a depth of 807 meters, then heated to approximately 48 degrees Celsius using heat pumps, and finally fed into the network. For cooling supply purposes, "cold" water at a temperature of about 17 degrees Celsius will be pumped from a depth of some 340 meters. This will be enough to cover about 75 percent of local needs.

The Fraunhofer Research Institution for Energy Infrastructures and Geothermal Systems IEG was responsible for the underground activities, such as drilling through a substrate packed with old mine parts, and the logistics for the extensive pumping tests. It also advised local utility company Stadtwerke Bochum on the overall energy concept, including geothermal systems, heat networks, underground reservoirs, and large-scale heat pumps. Using the water from the mine as an energy source is expected to reduce carbon emissions by about 3,200 metric tons a year compared to a conventional supply involving natural gas and electric compression chillers.

D2Grids is supported by the programs Interreg for northwestern Europe and Wärmenetze 4.0 (Heating Networks 4.0).

Electrical grid development — down to the block

Transmission system operators 50Hertz, Amprion, TenneT, and TransnetBW presented the first draft of the electrical grid development plan for 2037/2045 to the German Federal Network Agency in the spring of 2023. For the first time, the plan describes an electrical grid with which climate neutrality can be achieved by 2045. To do this, the Fraunhofer Institute for Energy Economics and Energy System Technology IEE modeled the regionalization of renewable energy using specific maps for the expansion of wind and solar energy facilities.

The plan expects present-day electricity consumption levels to double to more than 1,000 terawatt-hours. Serving that level of demand will require installed output from renewables to approximately quintuple to as much as about 700 gigawatts in 2045. Incorporating this high level of output into the electrical grid while also ensuring safe and reliable operation requires accelerated action to expand the grid. The regionalization study by Fraunhofer IEE models right down to the postal code level how the construction of additional wind turbines and solar farms will be distributed around Germany in the future. With separate areas for onshore wind energy and for solar arrays in open areas and on rooftops, various data sources were used to localize existing and planned facilities and set their output in relation to the power specifications for each federal state designated in the grid development plan. Known potential and areas identified in potential analyses were weighted according to various parameters, such as availability, suitability, soil quality, and potential for conflict and then assumptions were made regarding development with new installations until the relevant output specifications were reached.

The results are summarized in map form for the existing status as of 2022 and then for the two scenarios underlying the grid development plan, which are set for 2037 and 2045. This means the study by Fraunhofer IEE gives transmission system operators a detailed basis for developing the network with an eye to the future and bringing renewable energy to wider areas of the country.

Complete Energy Transition

Using carbon-free gas from ammonia for combustion

Power on the hood, not under it

Ammonia offers hope for the energy transition

Green hydrogen is a promising climate-neutral energy source. The cost of transporting and storing it remains an open question. At the same time, ammonia, known as a base material for fertilizers, could enjoy a whole new career as a storage medium for hydrogen. It can be liquefied at a moderate temperature of –33 degrees Celsius, plus it can bind more hydrogen at lower volume than can be achieved when compressing hydrogen at 700 bar. Liquefied ammonia is easier to transport than hydrogen. With all this in mind, the Fraunhofer Institute for Microengineering and Microsystems IMM is developing systems based on ammonia that can supply the infrastructure, transportation, and industrial sectors with clean energy on a mobile basis.

But there are still very few technologies aimed at using ammonia to generate energy. The researchers have found a solution to that issue, too: the AMMONPAKTOR reactor, which splits ammonia into nitrogen and hydrogen. This produces a cracked gas that can be burned as a source of fuel. A method of producing bricks with zero carbon emissions has already been demonstrated with an industry partner, using ammonia from green hydrogen. This energy source can also be used for mobile fuel cell applications such as vehicles or maritime vessels. A cracking reactor developed at Fraunhofer IMM features a subsequent purification stage, splitting pure hydrogen from ammonia that can be fed directly into PEM fuel cells in vehicles.

The AMMONPAKTOR reactor achieves efficiency of 90 percent in the process of converting ammonia back to hydrogen, compared to 70 percent for conventional technologies. The size has also been reduced by 90 percent compared to conventional reactors. The second-generation cracking reactor, which is currently in the manufacturing process and has a throughput of 25 kg/hour of ammonia, produces 70 kilos of purified hydrogen per day. The reactor is included in Fraunhofer's AMMONVEKTOR flagship project, which aims to develop an overall strategy for ammonia from production to transportation and use.

Solar cells on the hood and roof

The hood of a car, covered with a matching-color film made of integrated solar cells: This exhibit from the Fraunhofer Institute for Solar Energy Systems ISE drew throngs of visitors at IAA Mobility 2023. "Power on the hood," publisher VDI Verlag wrote on their portal ingenieur.de, and "Researchers produce solar power with an engine hood," ran the headline in the online edition of *Auto Bild*.

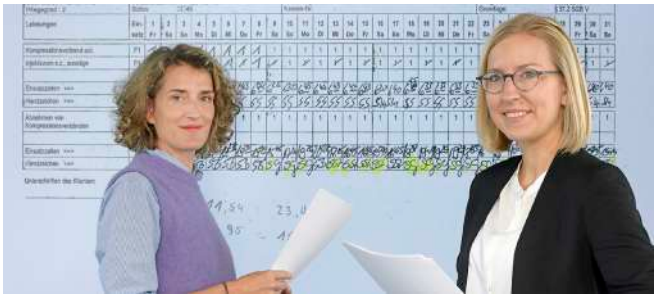
The challenges involved in building the solar cells into the hood of the vehicle were the area, the curved shape, and the substrate, which was made of sheet metal rather than the traditional solar panel backing of film or glass. The research teams from Fraunhofer ISE tested various solar cell types with different material combinations to use as much of the space available on the hood as possible and check their solutions' adhesive properties. After that, prototypes featuring different cell and wiring technologies underwent extensive lab testing to ensure their electrical output and the reliability and service life of the solar cell hood demonstrators. Laminating the surface with film creates a textured surface structure, which can be adjusted to match the vehicle's color using the MorphoColor® technology developed at Fraunhofer ISE. The hood exhibited at IAA MOBILITY has a rated output of 115 watts. It features 120 PERC shingle-style solar cells. The color is MorphoColor® Gray.

The technology can also be applied to metal car roofs, and it would also be lighter than solar panel car roofs made of glass. Taking the roof and hood together, the solar range of an electric vehicle in a city that gets a lot of sunshine, like Freiburg, could be as high as 4,000 kilometers a year. Back in 2017, a study performed by Fraunhofer ISE in collaboration with shipping companies found that a truck roof in Europe would have 5,000 to 7,000 kilowatt-hours of annual power generation potential. The technology behind the solar cells integrated on a film backing is suitable for both electric vehicles and those with internal combustion engines.

Illustration: Fraunhofer ITWM, photos: Fraunhofer IMM, Fraunhofer ISE

Affordable healthcare

Doctor's letters drafted with natural language processing (NLP)



Using AI to combat billing fraud in healthcare

AI to help with doctor's letters

Around 150 million doctor's letters are written every year in Germany, a time-consuming process. And yet, a large portion of the medical information involved is already present in text form. In the future, the laborious process of analyzing and further processing this information will be handled by natural language processing (NLP), a combination of algorithms and artificial intelligence (AI). To accomplish this, the method involves extracting information from texts and providing it in structured form. Processes like quality assurance, preparation of statistics, support for clinical decisions, and billing can all be streamlined in this way. RightCoding (RICO), a software program developed by the Fraunhofer Institute for Intelligent Analysis and Information Systems IAIS, is already in use. It greatly simplifies the coding and billing process at many hospitals. Doctor's letters will soon be generated automatically as well. A team from Fraunhofer IAIS plans to test a prototype for discharge papers at Universitätsmedizin Essen as early as 2024. The project is part of the SmartHospital.NRW flagship project, which itself is part of the KI.NRW expertise platform. Text, speech, and signal processing technologies are being studied in particular.

Scientists at Fraunhofer IAIS wrote a white paper titled "Natural Language Processing in der Medizin" (Natural Language Processing in the Medical Sector) that summarizes the overall possibilities that NLP opens up for the field of medicine. The paper highlights recent developments and current uses for AI in document-based processes in the medical field. Health data is currently one of the fastest growing data sets. At the same time, the healthcare sector faces numerous challenges, such as staff shortages, cost pressure, and information overload. The goal now is to work with healthcare institutions to tap into the full potential of AI-based automation, with particular attention to patient wellbeing and easing the workloads of healthcare professionals.

AI uncovers fraudulent healthcare billing

Billing fraud in the healthcare sector adds up to several billion euros in losses every year. The digital transformation of processes gives rise to new possibilities for systematically identifying fraud — whether in nursing care, hospital settings, or public administration. In the PflegeForensik project, researchers from the Fraunhofer Institute for Industrial Mathematics ITWM in Kaiserslautern joined forces with the office of the public prosecutor general in Dresden and the white-collar crime unit of the Leipzig police department to tackle billing fraud in the healthcare sector. The partners created a software solution that uses artificial intelligence (AI) to help with investigations. First, image processing was used to develop algorithms to automatically scan the mountains of paper and analyze them intelligently. The algorithms can do things like find signatures and associate them with the correct individuals. Comparing the rounds and schedules for nursing staff against billing data can flag potential instances of fraud.

To find these and other anomalies and analyze them digitally, the researchers worked with users to translate typical investigations into mathematical models. Training the AI algorithms involved first anonymizing several hundred documents and then manually marking them with particular properties. Working from this data as a basis, AI algorithms can then learn problem-related patterns. The solution was specifically developed to allow it to be adjusted to new data and improved or corrected over time. A workshop held to mark the project's conclusion, in 2023, gave representatives of law enforcement agencies, the judiciary, and health insurance funds an opportunity to try out a software demonstrator. The work received support from Germany's Federal Ministry of Education and Research (BMBF) under the Research for Civil Security program. The partners plan to continue the project and ideally create live software that offers maximum intuitiveness and ease of use while at the same time supplying results that can be used in court proceedings.

Photos: iStock.com/sarinyapinngam, Fraunhofer ITWM

Affordable healthcare

A digital ecosystem links many components together

Patient models help the healthcare system

Healthcare in rural areas

Medical care in rural areas needs an overhaul. A study by the Robert Bosch Stiftung found that some 11,000 general practitioner positions in Germany will be vacant by 2035, and nearly 40 percent of districts are at risk of a shortage of GPs. To counteract this trend, the Fraunhofer Center for Digital Diagnostics ZDD is working with several Fraunhofer institutes in the Neighborhood Diagnostics project with the goal of developing a digital ecosystem to help with diagnosis close to where patients live and to support medical treatment in rural areas. The idea is that this will relieve some of the pressure on doctors and specialized personnel and provide rapid, early diagnoses and high-quality care to patients, without them having to travel long distances.

All medical data are to be brought together in a single digital platform. Components will include home monitoring devices that measure markers of patient health such as blood pressure or blood sugar levels, along with wearables — small computer systems such as smartwatches worn directly on the body. These devices will use a Neighborhood Diagnostics app to transfer their measurement data to the platform. A warning is to be issued if any measurements seem unusual. Going forward, applications like these will allow the ecosystem to interpret data, arrive at diagnoses, and make recommendations for medications, physical therapy, and other medical services.

Fully automated health stations are a key part of the digital ecosystem, handling further tasks that would normally fall to medical practices and labs. Registered patients will receive various test kits so they can perform a nasal or throat swab or take a sample of capillary blood, for example. They will then return the kit with the specimen. The tests in the diagnostic devices will be performed autonomously within the station by sophisticated robots and, if necessary, held in cold storage. Depending on their individual health situation and diagnosis, patients could receive the results on-site, via the app or from their doctor. The model region of Brandenburg is the starting point for the trial phase, focusing on providing care for those with chronic conditions. The system is then set to be gradually expanded to rural areas all across Germany.

Ensuring that treatments have optimum effects

Point-and-click prevention, diagnostics and treatment: A system to support decision making, developed as part of the Fraunhofer MED²ICIN flagship project, is opening up new possibilities for the healthcare sector.

So far, patient data has often been kept in various different systems at different times and in different places. In MED²ICIN, the consortium for the Fraunhofer flagship project of the same name has developed a system that combines the data and helps medical professionals make decisions. In cooperation with Frankfurt University Hospital, the Fraunhofer institutes involved also incorporated the experiences of practicing physicians. An online survey of some 50 gastroenterologists from hospitals and medical centers confirms that the patient model meets the target objectives. A system like this can be expected to save 23 percent on costs and 35 percent on treatment times. Effective ways to curb healthcare spending are urgently needed in light of demographic trends and the huge shortage of skilled workers. In this digital patient model, users can access AI-based analyses and specialized medical publications and check the guidelines for treatment as well as the costs of each treatment option. A cohort module sets individual patient information in relation to data on similar diseases and conditions. This helps treating physicians identify the treatments with the best outcomes in specific cases. All of the information is presented in an easily understandable dashboard. Right now, the researchers are advancing the project at the European level with Finnish partners. Using 10,000 sets of patient data, they will continue to develop the model so that it can be incorporated into commercial systems and used in day-to-day medical care.

Illustration: Fraunhofer IESE, photo: Fraunhofer IGD

Security and a resilient society

Key cash supply points identified for emergency situations

Infrared imager in the ERNST small satellite

Supply of cash in a crisis

The global polycrisis of recent years has made it clear that people should be prepared for sudden emergencies such as widespread power outages or the failure of the IT and communication network — including the case of electronic payment systems, which typically stop working when these kinds of situations arise. In early 2023, an alliance of researchers and key stakeholders in the cash cycle published a security concept containing recommendations for how the cash cycle can be made more resilient. A project titled Resilience of Cash Supply — Security Concepts for Emergencies and Crises (BASIC) was coordinated by the Brandenburg Institute for Society and Security (BIGS). Researchers with the Supply Chain Services working group of the Fraunhofer Institute for Integrated Circuits IIS have developed an optimization algorithm to identify key cash supply points in Germany.

Working on specific scenarios, they used mathematical optimization to pinpoint the optimum supply of cash to supply points that should be able to maintain operations in a crisis. These specific ATMs or bank branches should be equipped with emergency power generators to keep them operational in a crisis, for example. Another area of focus for the project was harmonizing the specific emergency and crisis plans for all stakeholders in the cash cycle and further safeguarding working processes, especially those of cash and valuables service providers.

The project partners were Brandenburgische Institut für Gesellschaft und Sicherheit gGmbH (BIGS), Bundesvereinigung Deutscher Geld- und Wertdienste e.V. (BDGW), Cash Logistik Security AG, and the Supply Chain Services working group of Fraunhofer IIS. The consortium project received a three-year grant from the German federal government's Research for Civil Security program along with support from the German Federal Ministry of Education and Research (BMBF).

Small satellite detects hypersonic flying objects

The first small satellite mission for the German armed forces is due to launch into low Earth orbit in June 2024. Its mission is to detect the launch of ballistic missiles or hypersonic flying objects into low Earth orbit early on.

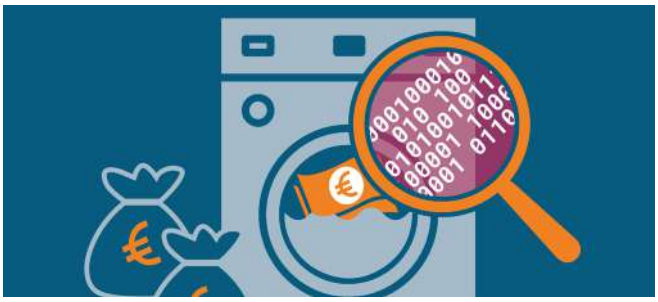
To achieve this, several Fraunhofer institutes led by the Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut, EMI developed a nanosatellite called ERNST. A cryogenically cooled infrared camera is the centerpiece of the satellite, which is about the size of a crate of beer. For effective early warning to enable interception measures, the surface of the planet is monitored in different short- to medium-wavelength infrared ranges. The detection concept, which was developed by the Fraunhofer Institute for Optronics, System Technologies and Image Exploitation IOSB, combines various spectral ranges to detect and track a rocket's infrared signature, which changes during the different phases of flight.

For ERNST and its mission, Fraunhofer EMI combined and modified available products from New Space and the defense segment with elements developed in-house. One special feature is the bionic-seeming optical table where the camera components are placed, which was made using generative manufacturing. Among other things, a radiator with a three-dimensional structure was incorporated. It discharges heat over a much smaller surface area than conventional flat radiators. To carry out its mission, the small satellite is equipped with a visual camera for georeferencing and a radiation monitor developed by the Fraunhofer Institute for Technological Trend Analysis INT. The monitor uses detector elements with various types of shielding to measure the total dose of radiant energy hitting the satellite, along with the influence of protons and neutrons.

If all goes well with ERNST's 2024 launch, the small satellite will then carry out its three-year mission and return to Earth afterward by unfurling a braking sail. The goal here is to demonstrate sustainable use of the space environment.

Security and a resilient society

Help with exploiting drone images



Zeroing in on suspected money laundering

Automated image exploitation for drones

Uncrewed aerial vehicles such as drones play an increasingly important role in the security sector, on search and rescue missions, and in defense. The Fraunhofer Institute for Optronics, System Technologies and Image Exploitation IOSB has been devising a modular video analysis system known as ABUL since 2005 for the LUNA drone, which the German armed forces have been using successfully for years. The system has undergone continuous further development during that time, in line with evolving requirements and research findings.

The video data collected by the drones is transmitted to ground stations via various data connections and then exploited by the personnel on duty there. ABUL was developed to support staff with tasks such as monitoring and exploitation to be carried out over several hours. The system features optimized real-time functions such as image stabilization for online reconnaissance. Over time, functions based on artificial intelligence (AI) have been incorporated for purposes such as detection, classification, and tracking of vehicles, people, and additional classes of objects. Offline reconnaissance mission features have been added, and image mosaics enable improved transmission of results. The basic idea behind ABUL is a dual screen system with an adjustable graphical user interface (GUI) for various sensor systems. The first screen shows a window containing the video streams from all sensors. It also provides control elements for efficient navigation and image processing by personnel. The second screen shows a map window with exploitation functions. In addition to multi-stream exploitation, cooperative exploitation of multiple workstations is also possible.

The ABUL system is used not only in the German armed forces' LUNA drone, but also by the Swiss air force, which has incorporated it into their new ADS 15 reconnaissance drone. The system is currently being optimized for a new field of application, protecting infrastructures with mast-based camera systems.

Enlisting AI to better identify money laundering

In the fight against money laundering, various analytical methods are used to verify financial transactions. The process typically flags a large number of potentially suspicious cases, each of which has to be reviewed individually by a specially trained analyst and reported to the relevant authority, the Financial Intelligence Unit (FIU). The FIU received about 300,000 reports a year in 2021 and 2022. A project called MaLeFiz aims to change that by harnessing AI and machine learning methods to make detecting money laundering more efficient. Having fewer false alarms will ease the burden on analysts at financial institutions in particular. The FIU and law enforcement agencies will benefit indirectly, as there will be fewer reports to process.

However, if the results delivered by these kinds of AI-based tools are to be usable in court, there are certain requirements that must be met. In particular, the decisions made by AI must be understandable (no "black box" decisions), and the reasons a transaction has been flagged as suspicious must be disclosed transparently. In keeping with this situation, the project team is exploring legal and ethical issues. For example, they are drafting a set of minimum requirements for AI-based tools used in sensitive areas that could touch on people's fundamental rights. Among other goals, these requirements are intended to ensure that it is possible to verify during an audit that AI-based tools are being used in compliance with applicable laws and that they are trustworthy. To align the AI as closely as possible to real-world application and take user needs into account wherever possible, the project partners are conducting interviews, workshops, and tests with users. The results are being incorporated into a demonstrator that is to be tested at banks first and foremost. The project is scheduled to conclude in the fall of 2025. The minimum requirements and additional project results will be published at that point. The project partners involved are Deloitte GmbH, the Fraunhofer Institute for Secure Information Technology SIT, Martin Luther University Halle-Wittenberg, Leipzig University, and the Center for Technology and Society at TU Berlin. The MaLeFiz project is funded by the German Federal Ministry of Education and Research (BMBF).

Photo: Fraunhofer IOSB, illustration: Fraunhofer SIT

Awards

Fraunhofer research prizes

Fraunhofer Prize for Human- and Environment-Centered Technology
This prize is presented by the Fraunhofer-Gesellschaft, the Fraunhofer-Zukunftsstiftung (Fraunhofer Future Foundation), and the former executive board members, institute directors, and associated supporters of the Fraunhofer-Gesellschaft. It is awarded every two years for achievements in research and development that improve people's quality of life or help make our world more sustainable. In 2023, the Fraunhofer-Zukunftsstiftung (Fraunhofer Future Foundation) contributed for the first time to the prize money, which amounts to €50,000. The Fraunhofer-Zukunftsstiftung (Fraunhofer Future Foundation) supports research projects of the Fraunhofer-Gesellschaft that facilitate and accelerate the transformation to a sustainable economy and way of life. Its activities are guided by the United Nations' Sustainable Development Goals (SDGs).

Joseph von Fraunhofer Prize
Since 1978, the Fraunhofer-Gesellschaft has awarded the Joseph von Fraunhofer Prize to its employees for outstanding scientific achievements that solve practical problems. Criteria for awarding the prize include how new and innovative the scientific-methodical approach is, the advancement of knowledge, and the implementation of the scientific results in applications. Three Joseph von Fraunhofer Prizes were awarded in 2023, each one with €50,000 in prize money.

Hugo Geiger Prize
The Bavarian Ministry of Economic Affairs, Regional Development and Energy awards the Hugo Geiger Prize for outstanding doctoral theses written in collaboration with Fraunhofer institutes. The award is named after the Bavarian secretary of state Hugo Geiger, who sponsored the inaugural assembly of the Fraunhofer-Gesellschaft on March 26, 1949.

Fraunhofer Prize for Human- and Environment-Centered Technology 2023

Satellite technology: Sustainable use of water in agriculture

A new satellite technology has made it possible to irrigate plants on a targeted, as-needed basis. It detects radiant heat from orbit and measures land surface temperatures. This allows researchers to deduce how much water a plant needs. Researchers from the Fraunhofer Institutes for High-Speed Dynamics, Ernst-Mach-Institut, EMI and for Applied Optics and Precision Engineering IOF, together with the companies constellr GmbH and SPACEOPTIX GmbH (both spin-offs of these institutes), have taken inspiration from the founding principle of constellr GmbH to develop the infrared camera LisR — short for Longwave infrared sensing demonstratoR. LisR was successfully tested on the International Space Station (ISS) in 2022. Based on these discoveries, constellr now plans to launch its own satellites into orbit. Leveraging the satellite network would make it possible to save 180 billion metric tons of water and 94 million metric tons of CO_2 annually starting from 2026 and increase global harvests by up to four percent.

Cassi Welling, Dr. Henrik von Lukowicz, Dr. Matthias Beier and Clemens Horch (from left)

Joseph von Fraunhofer Prize 2023

Microspeakers: Energy efficiency for earbuds

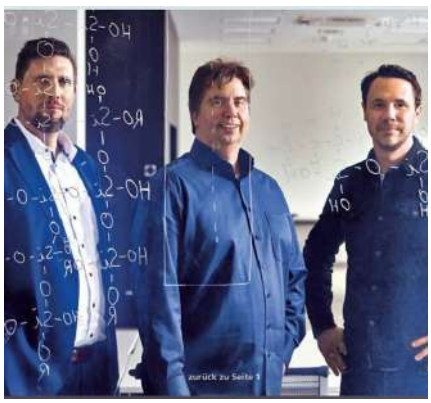
In the future, smart earbuds with direct Internet interfaces could substitute for many smartphone features. The foundation for this was laid by a team of researchers from the Fraunhofer Institute for Photonic Microsystems IPMS. The speakers developed there are made entirely of silicon, cost little to manufacture using microelectronic technology, and achieve the specified volume of 120 decibels without the high power consumption of an amplifier circuit. This is made possible by a completely new speaker design, among other things. Now, for the first time, the sound-displacing elements are positioned vertically inside a silicon chip. In order to commercialize the speakers, Arioso Systems GmbH was set up in 2019 as a spin-off from Fraunhofer IPMS and the research conducted at Brandenburg University of Technology Cottbus-Senftenberg. The spin-off was acquired by Bosch Sensortec GmbH in the summer of 2022 with the aim of developing cutting-edge products for the global mass market.

Dr. Sergiu Langa, Dr. Bert Kaiser and Dr. Holger Conrad (from left)

Joseph von Fraunhofer Prize 2023, EARTO Innovation Award

Building insulation: Sustainable, affordable building insulation with aerogels

Building insulation can make a substantial contribution to cutting carbon emissions. However, conventional insulation materials such as expanded polystyrene are based on petrochemical sources. Nils Mölders and Andreas Sengespeick from the Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT and Christoph Dworatzyk from PROCERAM GmbH & Co. KG have succeeded in producing a sustainable, low-cost aerogel-based mineral insulation material that is suitable for mass production. Within just six years, the team developed a new aerogel manufacturing process that does not require any chemicals hazardous to the environment — from laboratory to pre-industrial scale. Manufacturing costs for the aerogels fell by 70 percent, and manufacturing time from more than 10 hours to just 4 hours. The project also received the Innovation Award from the European Association of Research and Technology Organisations (EARTO) in the "Impact Expected" category in October 2023.



Christoph Dworatzyk, Andreas Sengespeick and Nils Mölders (from left)

Joseph von Fraunhofer Prize 2023

Audio technology: Customized listening experiences in 3D

A team from the Fraunhofer Institute for Integrated Circuits IIS is developing a complete system that covers the entire chain from sound production to transmission through to playback. MPEG-H Audio includes production tools, file and transmission formats, and innovative playback methods as well as software solutions for integrators. One example of the many developments around MPEG-H Audio is the immersive object-based music format 360 Reality Audio from the electronics company Sony. It can already be found on many streaming services. An album produced with this technology even won the Grammy for Best Immersive Audio Album in 2023. The MPEG-H Audio system brings the three-dimensional world of sound to more and more playback devices. This Fraunhofer IIS technology uses a process that clearly sets it apart from other 3D sound systems: Instead of simply using conventional soundtracks, the production process works with audio objects.

Adrian Murtaza, Harald Fuchs and Dr. Achim Kuntz (from left)

Photos: Fraunhofer / Piotr Banczerowski

Hugo Geiger Prize 2023
First place

New material for semiconductor memory

In his dissertation with the Fraunhofer Institute for Photonic Microsystems IPMS, Dr. Maximilian Lederer developed methods of producing hafnium oxide. This makes it possible to realize faster, energy-saving and secure RAM or USB storage and neural networks for artificial intelligence. The ferroelectric capabilities of hafnium oxide, a material used in semiconductor technology, were not fully understood previously, so it could not be used reliably in non-volatile ferroelectric memory (FeRAM). Lederer used new methods to study the material's crystalline microstructure and find out how physical processes taking place at the molecular level and deposition and process conditions affect the ferroelectric switching behavior of HfO_2. Using this as a basis, he developed new production processes that optimize the material's growth or composition, such as the electric field-induced crystallization that he showed for the first time. Globalfoundries, a chip manufacturer based in Dresden, is currently testing ferroelectric storage components in a research and development line.

Dr. Maximilian Lederer

Hugo Geiger Prize 2023
Second place

Efficient 3D audio with superior sound quality

Through his dissertation with the Fraunhofer Institute for Integrated Circuits IIS, Dr. Sascha Dick has contributed to the high-quality, efficient transmission and processing of 3D audio signals. He conducted extensive listening tests and discovered that the accuracy of localizing spatially distributed sound sources can also be determined through data analysis. The psycho-acoustic model he developed on this basis describes how the spatial distribution of the volume emitted by different sound sources is perceived. This can be used as a foundation for aggregating the sources that are indistinguishable and reducing their number by a factor of ten — all while maintaining excellent sound quality. This makes it possible to develop efficient 3D coding algorithms that enable not only high-quality cinematic conversion for home theater use, but, thanks to significantly reduced data rates, real-time applications in virtual reality and gaming as well. Intelligent aggregation of sound sources can also help improve the intelligibility of speech, and thus improve acoustic accessibility.

Dr. Sascha Dick

Hugo Geiger Prize 2023
Third place

A novel approach to early detection of cancer

In her doctorate with the Fraunhofer Institute for Cell Therapy and Immunology IZI, Dr. Susann Allelein laid the groundwork for simpler liquid biopsies for faster cancer diagnosis by means of extracellular vesicles. Thanks to these particles, long viewed as mere cellular waste, liquid biopsies involving blood or urine samples could take the place of tissue biopsies in the future, eliminating the disadvantages of that method. Cells exchange information on their properties and components with each other via the extracellular vesicles in bodily fluids. In her groundbreaking dissertation, Allelein studied how these particles can be used for early detection of prostate cancer. She developed new methods to efficiently characterize the vesicles, which are about the size of viruses, and isolate the relevant ones among them from the many cellular information packets moving around the body. Although the protein specific to prostate cancer that she originally studied turned out to be unsuitable as a marker, Allelein laid important foundations for further research involving extracellular vesicles, whose potential extends beyond cancer diagnosis to precision treatment monitoring and development of vaccines.

Dr. Susann Allelein

Photos: Fraunhofer IPMS / Sebastian Lassak, Fraunhofer IIS / Paul Pulkert, Fraunhofer IZI / Michaela Grunert

Research competitions — national and international

German Logistics Award

Together with Dachser, the Fraunhofer Institute for Material Flow and Logistics IML received the German Logistics Award from German logistics nonprofit Bundesvereinigung Logistik (BVL) for the development of the Advanced Indoor Localization and Operations (@ILO) digital twin. Special AI-based algorithms built into the @ILO software interpret the data, collected in cycles lasting just seconds by hundreds of optical scanning units on the ceiling of the fulfillment center. The objective is to identify and localize each and every package directly and automatically. In the future, measurement capabilities will be added as well. A digital twin forms a full image of the warehouse and its processes that is always up to date. Employees receive this information, which is presented intuitively on mobile devices and displays.

Individual process flows between when goods are received and when they go out are accelerated by 15 to 35 percent. This eliminates the need to scan barcodes manually or take daily manual inventory of packages. Vehicles with local routes can start delivering faster in the morning, for example, so drivers gain valuable time amid rush-hour traffic. The technology was developed jointly at the Dachser Enterprise Lab and has already been implemented at two branch locations: Unterschleissheim, near Munich, and Öhringen, which is close to Heilbronn. The new technology is scheduled to roll out in stages, with the first stage starting in 2024 and additional European branch locations following after that.

The 2023 winners celebrate on behalf of the Dachser and Fraunhofer R&D teams

Technology Award

The secureAR project won the Technology Award at the conference marking the conclusion of the "Zukunft der Wertschöpfung" (Future of Value Creation) program funded by the German Federal Ministry of Education and Research (BMBF). The Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology FEP is involved in the development. The consortium created a cross-industry cloud-based service platform with open industrial interfaces. These include an assistance system with smart glasses whose OLED microdisplay was developed at Fraunhofer FEP. The results are based on the latest research findings combining computer vision, machine learning, and data security. The service platform collects information along the entire value chain, from planning and production processes to system and plant maintenance, and enables location- and situation-based provision and visualization of data via the innovative AR assistance system. Industrial production sites operated by Airbus and Siemens were used as sample scenarios. The AR system was integrated into personal protective equipment for this purpose.

AR assistance system equipped with electricity-conserving 720p OLED microdisplays

Photos: Bundesvereinigung Logistik (BVL) e.V., Fraunhofer FEP

Prof. Karl Mandel (Fraunhofer ISC) and Dr. Oliver Höhn (Fraunhofer ISE) (from left)

European Research Council Consolidator Grant

The European Research Council (ERC) awards five-year Consolidator Grants valued at up to €2 million to promising postdoctoral researchers. Two Fraunhofer scientists will be able to intensify work on their projects starting in 2024. Prof. Karl Mandel from the Friedrich-Alexander-Universität Erlangen-Nürnberg and the Fraunhofer Institute for Silicate Research ISC is pursuing a project called SmartRust with the goal of transforming objects into material that can sense and communicate environmental influences. Mandel's aims include ensuring product safety and material reliability, enabling predictive maintenance, and making the complex recycling status of materials transparent. Dr. Oliver Höhn from the University of Freiburg and the Fraunhofer Institute for Solar Energy Systems ISE plans to advance his research on resource-friendly, ultra-thin, and high-efficiency solar cells as part of the PHASE project. Among other things, the funding will be used for a plasma etching system for semiconductor materials in main chemical groups III and V of the periodic table. PHASE aims to extend the concept of ultra-thin single solar cells to tandem solar cells, thus significantly reducing the cost and amount of materials used for the resource-intensive semiconductor part. Across Europe, 2,130 researchers had applied for the current ERC grant round. Just over 300 Consolidator Grants were awarded.

Prof. Kathrin Adlkofer is the founder of Cellbox.

Cellbox wins EIC Accelerator Award

Cellbox was spun off from what is today the Fraunhofer Research Institution for Individualized and Cell-Based Medical Engineering IMTE in 2016 with the idea of shipping live biological material for the first time. The solution developed there for transporting live cells or organoid systems at external temperatures and not frozen, as before, is increasingly important these days for applications such as treating severely ill patients with cell therapies (CAR-T therapies or with ATMPs) or for alternatives to toxicological animal testing in drug development. Previously, the cells or tissue had to be frozen with liquid nitrogen before being transported, for example from a hospital to a lab or between biotechnology and drug companies. This can harm sensitive cells. Cellbox is the first ever transportation system available to preserve these materials without freezing them. The Cellbox team currently has 15 members. They sell the company's transportable cell incubator worldwide, serving customers from Germany, elsewhere in Europe, the United States, and Asia, with a particular focus on China. In 2023, the European Innovation Council granted the Fraunhofer spin-off its Accelerator Award, one of the lines of funding under the EU's Horizon Europe program. The award comes with €2.5 million in base funding with the option of matching an additional €10 million in equity capital over the next few years. The spin-off plans to work with a number of other Fraunhofer institutes to further develop the Cellbox shipper for other applications, including the advanced therapy medicinal product (ATMP) market.

Photos: Cellbox Solutions / Lars Wehrmann, Fraunhofer ISC / Katrin Selsam, University of Freiburg

EIT Digital Challenge 2023

One example of transferring digitalization technologies to a broader market is Threedy, a spin-off of the Fraunhofer Institute for Computer Graphics Research IGD. Threedy had already won the Fraunhofer Founder Award in 2022. Then, in 2023, it was selected as one of Europe's ten most exciting scale-up start-ups in the Digital Challenge 2023 competition organized by the European Institute of Innovation and Technology (EIT). These are start-ups with especially fast growth. Threedy's instant3Dhub product is a platform for visual computing in industrial processes. The group of researchers got the idea for their spin-off in 2015, when a German automotive group placed an order with them. Threedy's client base is concentrated in the automotive and mechanical engineering sectors. With instant3Dhub, it provides 3D data to all of the areas involved at every step of the process, without complications and in real time. This simplifies processes, saves significant time, and takes quality and error management to the next level.

In addition to the central support offered for employees interested in starting their own business, Fraunhofer IGD also provides additional funding for spin-offs. Its objective is to intensify transfers from research to practice and from applications back to the research sector.

Christian Stein, Dr. Johannes Behr, Maik Thöner and Sascha Räsch founded Threedy (from right)

Otto von Guericke Prize

Franz Balluff and Thomas Hess from the Fraunhofer Institute for Manufacturing Engineering and Automation IPA were awarded the Otto von Guericke Prize for 2023 in recognition of their prospective solutions for coating technology. Both engineers, the two researchers studied ultra-precise and selective coating processes for an innovative method known as digital painting. Their method uses individual drops to create entire coats of paint and sharp lines, areas, or logos with hardly any overspray. The team studied coating properties to create drops and worked out specifications for paints and nozzles to be used in multi-color paint jobs, along with selective corrosion protection and complete elimination of overspray. A toolbox for paint producers and painting businesses presents their findings. Digital painting could add up to tremendous resource conservation and cost savings in practice, as less masking and clean-up work will be needed. The research prize, which comes with €10,000 in prize money, has been awarded by the German Federation of Industrial Research Associations (Arbeitsgemeinschaft industrieller Forschungsvereinigungen "Otto von Guericke" e.V.) since 1997. It is given out in recognition of particular innovations in precompetitive industrial collective research with public funding from the Federal Ministry for Economic Affairs and Climate Action (BMWK).

Thomas Hess and Franz Balluff from Fraunhofer IPA (third and fourth from left) received the award for sustainable painting processes

Photos: AiF e.V., Threedy

Sustainable Award in Automotive

Corporate consulting firm Arthur D. Little presented the third Sustainability Award in Automotive in 2023 in cooperation with Springer's professional publications focusing on automotive and engine technology. EDAG Engineering GmbH was recognized for its modular vehicle concept in the "Technology: Full Vehicle" category. The idea traces back to collaboration with the Fraunhofer Institute for Machine Tools and Forming Technology IWU. The goal of the joint project was to develop a vehicle platform for electric cars that is durable and offers protection in the event of a collision. The modular vehicle concept design makes it possible to replace individual components and reuse others multiple times. The judges pointed out that this extends the vehicle's life.

Science Prize for Operations Research

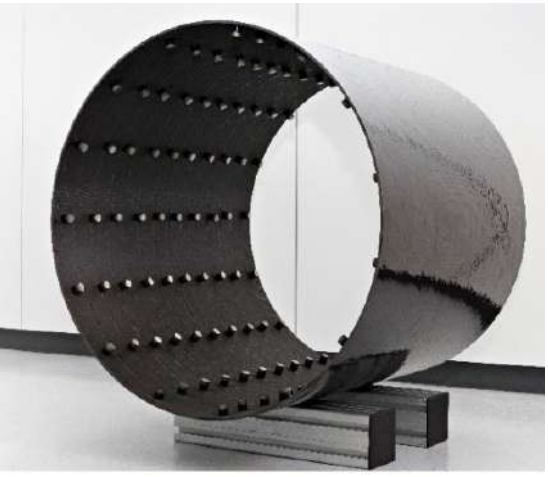
The German Operations Research Society (GOR) awards a science prize every two years. The prize for 2023 went to Prof. Anita Schöbel, head of the Fraunhofer Institute for Industrial Mathematics ITWM and a professor at the University of Kaiserslautern-Landau (RPTU). The field of operations research supplies mathematical models for decision making. Schöbel stressed that she wanted to raise the profile of these methods across society at large, government, and industry and pointed out that distribution of energy and planning of mobility are challenges that operations research can help with.

Prof. Anita Schöbel

Prof. Peter Liggesmeyer

German Prize for Software Quality

The German Prize for Software Quality for 2023 (DPSQ23) was awarded to Prof. Peter Liggesmeyer in June. Liggesmeyer, the head of the Fraunhofer Institute for Experimental Software Engineering IESE and holder of the chair of Software Engineering in the Department of Computer Science at the University of Kaiserslautern-Landau (RPTU), works on the topics of safety, security, reliability, and availability, particularly in the autonomous systems segment. The German Prize for Software Quality has now been awarded three times by the Working Group Software Quality and Training (ASQF), a specialist group of the German Informatics Society (GI-TAV), and the German Testing Board (GTB).



Vibro-acoustic metamaterials bring significant improvement in vibration behavior and are versatile in use

Best idea ever entered in INNOspace Masters competition

In 2023, the vibro-acoustic metamaterial (VAMM) technology from the Fraunhofer Institute for Structural Durability and System Reliability LBF was selected as the best idea from a research organization ever to have been submitted since the INNOspace Masters competition was first inaugurated, in 2015. The Fraunhofer LBF team has placed in the top three several times over the years. For example, Fraunhofer researchers began working with project partners MT Aerospace and OHB-System AG in 2017/18 to build three space demonstrators. Their work took the stresses involved in launching carrier rockets into account and showed how suitable the materials are for use in space. The findings of the Silent Running research project showed that VAMMs can be used in space and that the technology opens up new options for lightweight construction and vibration reduction. VAMMs contribute to lightweight construction solutions in the costly field of space systems, but that is not all. They also help to ensure that optical assemblies are not adversely affected by micro-vibration, so they can function without disruptions. Metamaterials display behaviors not found in nature. Along with optical and electromagnetic metamaterials, these kinds of materials can also be used to reduce noise and vibration.

Photos: Fraunhofer LBF / Ursula Raapke, Fraunhofer ITWM, Fraunhofer IESE / Matthias Heyde

Rising Digital Award for Logistikbude spin-off

Conciso, an IT company based in Dortmund, held its second round of awards for start-ups that unlock new benefits through digital transformation. Logistikbude, a spin-off of the Fraunhofer Institute for Material Flow and Logistics IML, won out over a number of prominent start-ups. The company organizes the management of pallets, containers, and various other reusable assets for companies. A Web-based solution and interfaces bring transparency to stock levels and flows, while coordination processes are automated. This kind of digital transformation of reusable management unlocks huge potential for resource conservation: according to Logistikbude, as much as 80 percent on staff, up to 40 percent on follow-up purchases, and up to 20,000 metric tons of carbon emissions. The start-up received €30,000 in prize money, along with several months of business development mentoring.

The founding team: Jan Möller, Dr. Philipp Hüning, Patrik Elfert and Michael Koscharnyj (from left)

German federal transport minister Volker Wissing presented the German Mobility Award to Dr. Claus Doll (Fraunhofer ISI), Nina Rösner (takomat GmbH), and Michael König (KIT) (from left)

German Mobility Award

The MobileCityGame research project, featuring the MobileCity app simulator, received the German Mobility Award in the "Digital Transformation & Data Driven Mobility" category. The app makes complex interrelationships in traffic and transportation systems understandable in an engaging way and serves as a visual aid for mobility models in contexts such as teaching or participatory processes. The team also developed a professional simulation tool for research and municipal mobility planning to develop sustainable and affordable mobility systems. The app is based on various simulation and analysis models, expertise, and data from the city of Karlsruhe. It is the only app in the world in which a complete traffic and transportation model runs locally on digital devices. Through their successor project, CarGoNE-City, the consortium plans to extend the simulation to urban logistics and translate it to three European cities. The app has been used in a seminar at Karlsruhe Institute of Technology (KIT) since the winter semester of 2023/24. The 30-person project team comprised researchers from the Fraunhofer Institutes for Systems and Innovation Research ISI and for Optronics, System Technologies and Image Exploitation IOSB, KIT, and takomat GmbH. The German Mobility Award is presented annually by the German Federal Ministry for Digital and Transport (BMDV).

Photos: Logistikbude GmbH, M. Golejewski

People in research

“The transformation of the energy system over the next two decades will be based mainly on technologies that are fairly well known today.”

Photos: Fraunhofer / Mike Abmaier, iStock.com/onurdongel

Prof. Mario Ragwitz

Joint Director of the Fraunhofer Research Institution for Energy Infrastructures and Geothermal Systems IEG | Professor of Integrated Energy Infrastructures at Brandenburg University of Technology Cottbus-Senftenberg | Part-Time Professor at the Robert Schuman Centre for Advanced Studies, European University Institute | Honorary Professor at the University of Freiburg

Transformative technologies

High praise indeed: "Hiring Mario Ragwitz was the best thing | ever did for Fraunhofer," says Prof. Harald Bradtke, Ragwitz's first boss at the Fraunhofer Institute for Systems and Innovation Research ISI. Ragwitz moved from the Max Planck Institute for the Physics of Complex Systems to Fraunhofer ISI in 2002, bringing with him the very latest discoveries in mathematical chaos theory for the modeling of climate-neutral energy systems. Today, Ragwitz is one of Germany's leading energy system experts. What drives him?

"We need to mitigate the impacts of climate change if we are to survive. That means transforming the energy system is a necessity." One of the key factors in his decision to apply for a position at Fraunhofer was that his research would be able to have an impact in the real world — applied research, in other words. In 2023, some 21 years on, Ragwitz and Prof. Rolf Bracke serve as joint directors of the Fraunhofer Research Institution for Energy Infrastructures and Geothermal Systems IEG. He has been the spokesperson of the Fraunhofer Hydrogen Network since 2020 and the coordinator of the Fraunhofer Cluster of Excellence Integrated Energy Systems CINES since 2019. In addition to the German federal government, he also advises the European Commission and the EU Parliament, the German Bundestag, the World Bank, the governments of other countries — and companies as well, of course.

Ragwitz says one of the key steps in the scientific success and trust in the reliability and robustness of his models was a 2004 study performed for the European Commission. "FORRES 2020: Analysis of the Renewable Energy Sources' Evolution up to 2020" already presented an analysis showing that the EU would not manage to reach its goals for the proportion of the energy supply derived from renewable sources by 2020 unless it ramped up its efforts. Ragwitz's subsequent activities included helping to identify the EU's renewable energy targets for 2020 and 2030. He was also involved in evaluating and further developing the Renewable Energy Sources Act in Germany.

Which technologies does Germany depend on in bringing about a fast, safe transformation of its energy system? Expansion of a flexible energy network across the electricity, gas, heating, and mobility sectors? Development of the hydrogen sector, including electrolyzers and retooling gas lines? Storage technologies like pit thermal energy storage and the scale-up of heat pumps to megawatt-hour capacity? Or expansion of geothermal systems, deep or near the surface, depending on suitability? There are questions and more questions, and they sound like there are too many unknowns. Ragwitz counters: "The transformation of the energy system over the next two decades will be based mainly on technologies that are fairly well known today and have proven that they work on a fundamental level." Those who would like to see for themselves can check out the Fraunhofer IEG locations, which are located in Germany's lignite-producing (or former lignite-producing) areas. Ragwitz believes that 90 percent of Germany's electricity can come from renewable sources if demand doubles between now and 2035 — and at reasonable cost, to boot. "I'm confident that we will be able to stabilize a price level that permits competitiveness, even taking into account carbon emission taxes, within a decade."

Prof. Liliana da Silva Ferreira

Computer Scientist | Member of the Executive Board of Associação Fraunhofer Portugal Research | Director of the Fraunhofer Center for Assistive Information and Communication Solutions AICOS, Porto | Invited Full Professor at the Faculty of Engineering, University of Porto

Returning to excellent research conditions

Prof. Liliana da Silva Ferreira led what is now the largest independent foreign Fraunhofer affiliate in Europe, the Associação Fraunhofer Portugal Research (or Fraunhofer Portugal for short), from 2017 until the end of November 2023. The first Center for Assistive Information and Communication Solutions AICOS was created in her hometown, Porto, under the umbrella of the newly formed nonprofit Fraunhofer Portugal in 2008, and Ferreira joined in the role of senior scientist not long after, in 2011. Her doctorate, which dealt with automated information extraction for medical reports, was an excellent fit for the topics covered by the new research institution. The subject was very current then, as it is now. Natural language processing (NLP) is a subfield of artificial intelligence (AI). While NLP relates to the analysis of natural language by computers, human-like content can now be produced by generative AI, such as ChatGPT.

Ferreira accepted an offer from an industrial group in 2016 and moved to the Netherlands with her family, including her children, who were small at the time. An insight came to her while working on the other side of the development and transfer equation: "It wasn't until | worked in development on the industry side that | realized that we at Fraunhofer AICOS were already operating at the highest international level in terms of science, right up there with top industry players." That realization has stayed with her to this day, giving her fresh drive. In 2017, Ferreira returned with her family — to Porto, and to Fraunhofer. The reason was that the Portuguese research ministry was planning to build another Fraunhofer center. Its themes were to be water and resource management. Both are pressing issues that demand solutions in Portugal, as they are across the whole of southern Europe. The populace and economy alike are already greatly suffering from the effects of climate change; one ministry employee Ferreira negotiated with about the Portuguese part of the base funding went without running water at home for several weeks in December 2017 — which should actually be the season when Portugal's many reservoirs are refilling. Ferreira brought a number of partners on board to develop the second Fraunhofer Portugal Center, especially the National Foundation of Science and Technology, the University of Évora, and the University of Trás-os-Montes and Alto Douro. Another objective was to raise funds for equipment and infrastructure for the Center for Advanced Water, Energy and Resource Management.

Her move to become the President of the Executive Board of Associação Fraunhofer Portugal Research marked a definitive shift for Ferreira as she transitioned from science to research management. She was able to present impressive figures during the successful evaluation of Fraunhofer AICOS in October 2023: External project revenue rose from €1.91 million in 2018 to a projected €3.84 million for 2023. Fraunhofer AICOS has been involved in 19 EU projects since it was first founded. It maintains partnerships with over 400 organizations in 37 countries and has been granted 18 patents based on the 38 applications filed to date. The head of Fraunhofer Portugal was awarded the Fraunhofer Thaler at the internal International Day event in 2023 in recognition of her years of work in various positions.

Ferreira stepped down as executive board president at the end of 2023. She has remained a board member and will be focusing more on Fraunhofer AICOS in her role as its director going forward. She was succeeded as the President of the Executive Board of Associação Fraunhofer Portugal Research by Pedro Almeida. Ferreira is happy to be moving back to a familiar range of duties, as it will give her an opportunity to work with her team as a computer scientist, creating digital applications that benefit humanity in line with the motto "Proposing Futures. Impacting Lives."

"It wasn't until | worked in development on the industry side that | realized that we at Fraunhofer AICOS were already operating at the highest international level in terms of science, right up there with top industry players. That realization has stayed with me to this day, giving me fresh drive."

Photos: Fraunhofer / João Macedo, iStock.com/mediterraneanan

“Transdisciplinary research will not only make it possible to achieve a sustainability transformation across society, but also to bring more young people into the study of engineering with social science aspects in the future.”

Photos: Fraunhofer LBF / Ursula Raapke, iStock.com/FotografiaBasica

Dr. Dominik Spancken

Metalworker | Mechanical Engineer | Plastics Engineer

First Doctor of Sustainability

Germany's very first doctorate in sustainability has been awarded. The proud recipient of the new title is Dominik Spancken, team leader for resource-efficient composites at the Fraunhofer Institute for Structural Durability and System Reliability LBF. Darmstadt University of Applied Sciences is the first and only institution in Germany to date to offer a doctorate in sustainability sciences. Spancken, an engineer, defended his dissertation in July 2023, and it was published in November. He studied how conventional plastics used in major appliances such as dishwashers or washing machines can be replaced with recycled plastics. As a demonstrator, he chose the interior base of these kinds of appliances — components that consumers don't see because they are tucked away behind the paneling, but are subject to heavy wear. The potential in this area is impressive: If the entire interior base, which weighs about two kilograms, were made from recycled plastic instead of new plastic, annual consumption of crude oil for a production level of about three million dishwashers would drop by some 2,500 metric tons and carbon emissions by 7,800 metric tons. Aside from these possibilities, Spancken also analyzed the obstacles that stand in the way of industry switching to more sustainable plastics. They include the cost of recycled plastic, which is still slightly higher, along with the fact that conventional plastics still have better and more reliable availability. But Spancken firmly believes a rethink is possible: "Transdisciplinary research will not only make it possible to achieve a sustainability transformation across society, but also to bring more young people into the study of engineering with social science aspects in the future."

Spancken learned early on to forge his own path. Before earning his doctorate in sustainability sciences, he started out as an apprentice mechanic. He then took the exams to move back into academia and ended up studying mechanical engineering. Spancken is a marathoner, so he knows what endurance training is like. He was supported by his professional network. Prof. Andreas Büter, a department head at Fraunhofer LBF who teaches at Darmstadt University of Applied Sciences and RWTH Aachen University, brought Spancken to work at Fraunhofer LBF, first as a student and then, starting in 2011, as a scientist. He also supervised his doctoral studies. Multiple potential applications were considered with customer BSH, a major appliance producer, in 2020. The breakthrough came quickly: "We came up with the idea of recycled plastics in major appliances on a Friday. The plan and concept were in place by Monday, and we hit the ground running on Tuesday!" Robert Bosch GmbH and BSH provided €150,000 in funding for material studies as part of the dissertation. Spancken is currently working on behalf of Robert Bosch GmbH on material databases to make product development more efficient and reliable.

What is the runner's objective? In the long term, plastics expert Spancken would like to see a closer connection between engineering and social and cultural studies, including in formal instructional settings. He thinks industry and consumers need to develop an awareness of the resources used, including questions of what is really needed, costs, and flawlessness. Spancken is not alone in his efforts: A draft regulation put forward by the European Commission calls for cars to be made of 25 percent recycled materials starting in 2030.

Katrin Klug

Data Scientist | Business Analytics | International Business | Marketing and Commercial Distribution

The move to generative AI

From business and economics in aviation to a hotspot of generative artificial intelligence: Katrin Klug worked as a data scientist at Germanwings, then the International Air Transport Association in Montreal, and then Eurowings before making a change in 2020. She had already worked with applications and solutions relating to various aspects of data analysis when writing her master's thesis at Hochschule Düsseldorf University of Applied Sciences. At that time, she developed an AI forecast model for Eurowings Technik GmbH to predict flight delays and cancellations, which provided effective support for fleet management purposes. Her work paid off, and Klug received a special award in 2020. Verein der Förderer des Fachbereichs Wirtschaftswissenschaften der Hochschule Düsseldorf e.V., a nonprofit association of supporters of the business school at her university, praised her model's outstanding practical relevance.

Klug applied to work as a data scientist at Fraunhofer IAIS later that year. Her first assignment was to advance knowledge and technology transfer for artificial intelligence (AI). To that end, she set up a blog on machine learning (ML) and AI named the "ML-Blog." Researchers from the Fraunhofer Institutes for Intelligent Analysis and Information Systems IAIS and for Material Flow and Logistics IML, the University of Bonn, and TU Dortmund University all write posts there under the umbrella of the Lamarr Institute. Writing for the general public and companies alike, they explain the innovative potential of AI in robotics and illustrate what generative AI (GenAI) is all about and how it can be used. Their work is so accessible that media outlets such as heise have reported on it.

These days, Klug assists companies in making the move to AI — from testing research findings through to successful implementation. She developed the "GenAI Campus" collaboration format at Fraunhofer IAIS to support these activities. These several-day workshops bring employees of private enterprises together with scientists for close cooperation. Together, they take a deep dive into the fundamentals and potential applications of generative AI. The goal is to develop concrete use cases with the companies and test various foundation models or AI language models directly. The workshop concludes with a proof of concept, ideally followed by joint technological development. A GenAI Campus event is also a forum for questions surrounding the trustworthiness of AI — the famed "black box" question — and its limitations, such as hallucinations.

"We show how effective artificial intelligence can be in making people's day-to-day work easier. With our support, companies can dive into the new technologies very quickly, try them out, and gauge their benefits and suitability for their use cases. Those could be anything from form assistance features for administration and analytical tools for the financial industry to smart purchasing and quote management," says Klug, who, as an AI expert, now works as a project manager and instructor within the Fraunhofer Big Data AI Alliance training program.

She is also participating in the work to generate doctor's letters automatically via generative AI as part of the KI.NRW flagship project SmartHospital.NRW (see p. 52). Around 150 million doctor's letters are written every year in Germany. This takes precious time which could be used elsewhere. "Studies show," Klug says, "that healthcare professionals in clinical settings spend three hours a day on administrative tasks. That's three hours that could be used for patient care instead if generative AI takes care of those tasks."

“We show how effective artificial intelligence can be in making people’s day-to-day work easier and how much potential it can unlock. | really enjoy discovering this together with companies.”

Photos: Fraunhofer IAIS, iStock.com/monsitj

"Safely crushing melted radioactive material at Chernobyl to collect it for interim storage is a challenge that no one has solved so far."

Photos: Fraunhofer IWS, iStock.com/Saharrr

Oleksandr Proskurin

Engineer | In early 2023, Oleksandr Proskurin moved from Kyiv to Dresden, where the robotics expert spent six months at the Fraunhofer Institute for Material and Beam Technology IWS. His stay was funded as a pilot project by the new Rebuilding Ukraine program from the Fraunhofer-Zukunftsstiftung (Fraunhofer Future Foundation).

Pooling expertise for dismantling nuclear power plants (NPPs)

Like many members of his family, Oleksandr Proskurin is originally from Kherson, which has been heavily damaged in the war with Russia. While a student at the Kyiv Polytechnic Institute, he specialized in dynamics and machine strength. During this period, he completed several internships, including periods at the design office of the Ukrainian aircraft manufacturer Antonov and at the Chinese company Xianchu. Since completing his master's degree in 2015, Proskurin has been conducting research on robotic applications in nuclear situations at the Institute for Safety Problems of Nuclear Power Plants (ISPNPP). The institute forms part of the National Academy of Sciences of Ukraine.

It was Dr. Andreas Wetzig who convinced Proskurin to join his host team in Dresden. In his role as head of the technology field for Cutting and Joining at Fraunhofer IWS, he has been establishing contacts to companies and organizations in the NPP decommissioning sector since 2016. Wetzig and his team see great potential for the use of laser technology in this field since laser cutting generates very little dust when disassembling contaminated materials, unlike other technologies. All of the material, not just contaminated construction and nuclear material, needs to be collected before it can be sent to decay in interim storage facilities. At any rate, as Wetzig and Proskurin are aware along with others, the global community has less than 100 years to find a solution. That is when the second sarcophagus, which was moved into place atop the ruined nuclear facility in Chernobyl along a set of purpose-built tracks in 2016, will no longer be able to contain the radiation from the fuel core, which has melted down into lava. Robot and laser researchers share a common goal: remotely control laser robots to crush the baked radioactive material and prepare it for interim storage. They also tested the cutting of basalt as a substitute substance for the fused radioactive material in the Fraunhofer IWS laser laboratories. "Safely crushing melted radioactive material at Chernobyl to collect it for interim storage is a challenge that no one has solved so far," says the robotics expert, who hopes that their collaboration will continue.

In July 2023, Oleksandr Proskurin returned to Kyiv, where he is living and working today. He tries to find distraction from the war and the frequent air raids through DIY activities and sports — from (table) tennis to bike tours. In August 2023, he attended a radiation safety seminar in Slavutych, a satellite city of Chernobyl. It is considered a global research site for safety and decommissioning issues related to nuclear energy.

Rebuilding Ukraine

The new funding program from the Fraunhofer-Zukunftsstiftung (Fraunhofer Future Foundation) promotes collaborative efforts for applying Fraunhofer technology in Ukraine. The program's current objective is early planning for the repair of war damage in Ukraine and preparing for reconstruction using technologies that are sustainable. Oleksandr Proskurin was the first visiting scholar whose stay was co-funded as a pilot project through Rebuilding Ukraine.

Dr. Eva Ehrentreich-Förster

Chemist | Deputy Head of the Bioanalytics and Bioprocesses Institute Branch at the Potsdam-Golm Site of the Fraunhofer Institute for Cell Therapy and Immunology IZI | Head of the Department of Molecular and Cellular Bioanalytics

Diagnostics as a special case in analytics

Eva Ehrentreich-Förster officially graduated in chemistry at TU Bergakademie Freiberg, in what was then East Germany, on November 9, 1989, the very day the country opened its borders. She didn't end up joining the throngs crossing to the west the day the Berlin Wall came down, since she was happy just to get home amid the transit chaos following her graduation ceremony. But her decades of work as a researcher after that would often see her straddling the line between different worlds: transcending disciplines as a project manager for lab-on-a-chip systems, navigating between the institute and executive board perspectives as an elected representative of the scientific and technical council at Fraunhofer, and in the role of acting institute director until just recently. Prof. Antje Bäumner stepped in as institute director in August 2023, heading the Brandenburg part of the Fraunhofer Institute for Cell Therapy and Immunology IZI. Ehrentreich-Förster has been happy to go back to her position as deputy institute director and department head. "The more challenging my tasks became as | moved through my career from young researcher to acting director, the more | went running," she says. A former heptathlete, Ehrentreich-Förster still runs long distances.

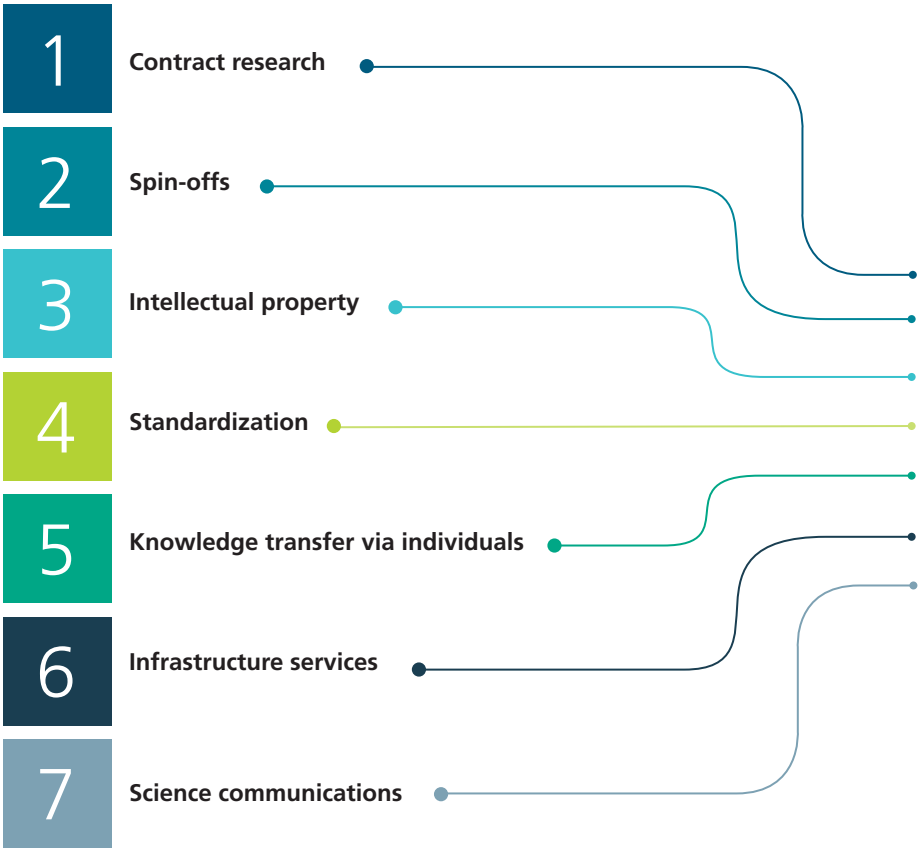
Ehrentreich-Förster's research field is microarrays, bioanalytical platforms for diagnostic purposes — whether for foods, the environment, or people. "Knowledge of sensors, evidence of the formation of a bond, has been with me since | got my degree," she says. After earning her secondary school diploma, she worked first in the lab at the Graupa Product Toxicology Research Center. She was recommended for the chemical degree study program by her boss. She went on to postgraduate studies in toxicology at the University of Leipzig and then received a German Academic Exchange Service (DAAD) fellowship to go to the University of Córdoba during her doctoral studies. Her first role as a research scientist was at the Max Delbrück Center for Molecular Medicine. She then moved on to the University of Potsdam before joining Fraunhofer with her junior research group as part of a German Federal Ministry of Education and Research (BMBF) competition, initially working at a branch lab. "I was so proud to get the job," she recalls. She also remembers how tough the first few years were: "There's a mindset that goes into doing research like a scientific company, and you have to learn that first. It's not something you cover in grad school." There was also a certain amount of cultural adjustment involved, as Ehrentreich-Förster had to become acquainted with both general public-sector guidelines and the freedom to design her own research topics.

Ehrentreich-Förster moved on to managing internal Fraunhofer interdisciplinary funding projects relating to the in-vitro diagnostics platform, and she was instrumental in the 2014 presentation of the very first "Taschentuchlabor" (Lab in a Hankie) for infection diagnosis, which was the result of a project funded by the BMBF. Research findings like these have continued to flow to the Fraunhofer Center for Digital Diagnostics in Potsdam, which was founded in 2021. Within the center, the Fraunhofer Institutes for Cell Therapy and Immunology IZI and for Experimental Software Engineering IESE work together under the leadership of the Bioanalytics and Bioprocesses branch of Fraunhofer IZI to advance medical and diagnostic care in rural areas like Brandenburg. The goal is to provide patients with good medical care now and into the future, despite the lack of general practitioners in private practice and the cost pressure affecting the healthcare system. For that to happen, however, there are some regulatory obstacles in the field of medicine that need to be overcome: equipment approvals as well as data protection and privacy solutions. Ehrentreich-Förster has been working on platforms that can automate analysis and — if the approval process goes smoothly — diagnosis as well. She is familiar with costs and affordability as factors. And she wonders whether greater funding should be put into certain questions. "Everyone knows about antibiotic resistance, and everyone also knows that very little research is being funded in this area worldwide. Health should be for everyone!"

"Health should be for everyone!"

Photos: Fraunhofer IZI-BB / Martina Steude

Selected transfer activities



Impact on industry and society

Fraunhofer customers commercialize more innovations and increase their sales and returns. Fraunhofer activities have been shown to create jobs in Germany, generate investment impact in the industry sphere and increase government revenue.

Impact of Fraunhofer research

Putting research into practice: results that find their place in industry and society

The efforts that Germany's non-university research institutions put into strengthening the country's industry and society are transmitted along seven transfer paths. As the Fraunhofer-Gesellschaft's mission is centered on applied research, the deciding factors it uses in measuring its own success are whether research results are being put into practice, and what impact they are making financially, environmentally and socially.

1. Contract research

Key figures for 2023
€679 million from industry contracts (within Germany and international, excluding license-fee revenue)

Investigational medicinal products for cancer treatment using live cells
In Europe, all innovative medications are first tested in clinical trials involving selected patients before they are approved for widespread use. These investigational medicinal products must be produced according to stringent pharmaceutical quality standards (good manufacturing practice, or GMP). That is a complex undertaking for innovative cell and gene therapies like chimeric antigen receptor (CAR) T-cell therapy, an advanced form of cancer treatment, since these therapies are based on living cells taken from patients. The cells cannot be standardized, and their condition depends on the specific patient's disease and past treatments. Processes and technologies must be developed to balance the requirements and the starting basis for GMP standards. The GMP Cell and Gene Therapy department at the Fraunhofer Institute for Cell Therapy and Immunology IZI specializes in tasks like this. The institute's GMP facilities have been manufacturing what are known as CAR T-cell therapeutics for more than ten years. These are investigated in clinical studies and followed through to approval. In 2023, Fraunhofer IZI received a contract from an international pharmaceutical company for technology transfer and validation of the manufacturing process for a new CAR T-cell therapy. All process steps, including quality control, must be aligned to Europe's high quality standards in order to obtain manufacturing authorization pursuant to section 13 of the German Medicinal Products Act (Arzneimittelgesetz, AMG). Afterward, all of the investigational medicinal products for the study — which involves numerous medical centers around Europe — are produced in Fraunhofer IZI's cleanroom facilities.

2. Spin-offs

Key figures for 2023
23 spin-offs
1 shareholding

Tapping the power of sunflowers
How can food proteins be produced from sunflower seeds as a form of sustainable nutrition? Over a 20-year period, specialists at the Fraunhofer Institute for Process Engineering and Packaging IVV developed a method of producing a high-quality protein ingredient from shelled sunflower seeds. First, a mechanical process removes the oil, which increases the seeds' protein content as compared to seeds that do not undergo this process, without harming the protein itself through factors such as exposure to high temperatures. Then the remaining oil is extracted using solvents, a process that also leaves the seeds intact. The team of researchers found a way to use ethanol instead of hexane, a petroleum derivative commonly used for these purposes. Ethanol is a green product that can be derived from renewable raw materials. After the product and method were patented, Sunbloom Proteins GmbH was spun off from Fraunhofer IVV in 2017. Zentis was brought in as an investor in 2019, and leading dairy firm Molkerei Ehrmann joined not long afterward. In cooperation with these partners, the company opened its own plant in Drégelypalánk, Hungary, in 2022. The new plant can produce the protein concentrate, which has great nutritional and functional benefits, for foods at an industrial scale. In 2023, Sunbloom Proteins GmbH was sold to the Avril Group, which is based in France. The Fraunhofer spin-off has now added its sustainability technology to the expertise portfolio of one of the leading industrial and financial players in the plant oil and protein segment.

3. Intellectual property

Key figures for 2023
€158 million in license-fee revenue
506 invention disclosures
7,068 active patent families
406 patent applications

DRYtraec®: a game changer in battery cell production
Previous methods of producing battery cells are energy-intensive and costly. When battery electrodes are produced, thin metal foils are coated with a wet paste of active material, conductive carbon black, binders, and solvents, some of them toxic. The subsequent drying of the electrode layer requires a lot of energy and space.

By contrast, the DRYtraec® dry coating technology developed by the Fraunhofer Institute for Material and Beam Technology IWS uses no toxic solvents at all. A special roller unit is used to mechanically anchor particles of the active material and conductive carbon black by causing the binder to form fibrils, a process known as fibrillation. This means the process of creating the electrode layer is entirely dry. Energy-intensive drying is eliminated, and both sides of the electrode can be coated at the same time. The process was first developed for electrodes in lithium-ion batteries and has now been adjusted for lithium-sulfur and solid-state batteries as well. The first prototype system of its kind in the world has been developed with German plant engineering firms. Fraunhofer IWS has operated a full-spectrum technology platform for dry coating with a high level of technological maturity since 2020. Fraunhofer IWS and the Fraunhofer Research Institution for Battery Cell Production FFB are currently planning a scaled pilot plant on the basis of the DRYtraec® method for installation in Münster. High-quality, low-cost production of battery storage is crucial to the electrification of the German automotive industry. However, Europe is still in the process of building production capacity for battery cells and remains highly dependent on technology groups based in Asia. The patented DRYtraec® technology developed by Fraunhofer IWS (EP 3625018, IWS – 2017F59214, patents granted in Europe, Japan, and Korea) can make a crucial contribution to greater cost efficiency and ecofriendliness in cell production in the future. A license agreement with a leading German automotive company was signed in 2023.

4. Standardization

Key figures for 2023
1,366 standardization activities

Clearing the way for the 5G wireless standard
Now in its fifth generation (5G), wireless technology has gone from voice telephony to the mobile internet and beyond, becoming a universal communication standard for linking sensors, devices, and machines. The technical specifications for this global standard are developed and adopted by the 3rd Generation Partnership Project (3GPP) and implemented as specifications by the standardization bodies in the relevant areas. During the time between when new functions are defined in the wireless standard and when they become available on the market, it is nearly impossible to test future applications for lack of suitable test environments and detailed knowledge based on ongoing standardization. This means closing these kinds of gaps between research, standardization, and application is crucial to rapid market entry. The Fraunhofer Institutes for Telecommunications, Heinrich-Hertz-Institut, HHI and for Integrated Circuits IIS have been involved in defining and further developing this important wireless technology since 2015, when 3GPP began working on the 5G specifications. They made over 900 contributions to the 5G standard between 2015 and 2023. Parallel participation in relevant industry bodies such as NGMN, 5GAA, and 5G-ACIA supports Germany's industry in incorporating key requirements and functions into the standard, which in turn is a requirement for implementation in the mobile network and devices. The focus is on the radio access network (RAN). In their work, the institutes have come to concentrate on professional applications in the area of the internet of things (IoT), satellite integration into mobile networks, production automation, and connected vehicles (V2X).

5. Knowledge transfer via individuals

5.1 Continuing professional development for external specialists and managers

Key figures for 2023
Over €10 million in revenue from Fraunhofer Academy professional development courses
Approx. 6,600 participants in 600 courses

Customized training for companies
Since 2018, the Fraunhofer Institute for Material Flow and Logistics IML has been helping Interroll Holding GmbH to meet its employees where they are in terms of knowledge transfer relating to logistical issues. Interroll Holding GmbH is a provider of conveyor technology and an international listed company with some 2,500 employees. Its customers are equipment manufacturers, engineering firms, or system integrators. The company has adopted a sales approach known as consultative selling. To do this effectively, sales and marketing employees need to know how innovations in logistics and intralogistics affect process organization on the end customer's side so they can use those innovations to explore new projects. A course titled Process Management imparts current knowledge of the intralogistics market, future trends, and industry-specific know-how. The specialists from Fraunhofer IML contribute their knowledge of the intralogistics market in particular, including the latest planning tools. The course is now in its eighth cycle, which involves blended learning in the form of short webinars and supervised group work. Theoretical base content is combined with practical simulations and on-site visits to end customers. Pre-learning activities and context-specific follow-ups have also been incorporated into the overall concept to ensure that participants retain the understanding of the system that is taught in the course.

5.2 Employees and careers

Key figures for 2023
Some 2,200 people left Fraunhofer to continue their careers — in industry or the research sector or by starting their own company.

Training for positions of responsibility
One key aspect of Fraunhofer's mission is the training phase that scientific staff in particular complete during their period of employment with Fraunhofer. Fraunhofer had a 9.9 percent turnover rate in its scientific section. As part of the exit interviews, departing employees were asked where they were planning to go next in their careers. Approximately 70 percent of these departing employees said they were moving on to roles in industry.

Jobs and careers at Fraunhofer

6. Infrastructure services

Key figures for 2023
No figures are available in this area (yet). These can currently be seen in other transfer paths.

Intelligent sensors for the energy transition
The Intelligent Signal Analysis and Assistance Systems InSignA high-performance center was founded in Ilmenau in 2021 as one of Fraunhofer's most recent high-performance centers. Five Fraunhofer institutes are involved, along with TU Ilmenau and IMMS Institut für Mikroelektronik- und Mechatronik-Systeme gGmbH, which is based in the German state of Thuringia. One of InSignA's core competencies is the development of low power wide area networks (LPWANs). Compared to technologies like 5G, the mioty® LPWAN standard that the Fraunhofer Institute for Integrated Circuits IIS was instrumental in developing enables the development of much lower-cost networks with a battery life of over a decade. In addition, practically no infrastructure is needed, so mioty® can be used even in areas with inadequate mobile coverage. Together, the high-performance center's partners built a test bed for LPWAN in Ilmenau, with support for various transmission systems. A study conducted with local utility company Stadtwerke Ilmenau, for example, focused on supporting the energy transition: Can a solar array, charging station, or heat pump still be connected to the power grid when a new building is being built or an old one renovated, or would that be enough to overload the grid? In partnership with Stadtwerke Ilmenau, the InSignA high-performance center was able to show that mioty® allows for development of very low-cost, easily installed retrofit sensors. In this kind of retrofit, new sensors are built into existing buildings to get them ready for the requirements of the digital transformation and Industry 4.0. The LPWAN test bed gives Stadtwerke Ilmenau a way to detect potential grid overloading early on during the process of approving new sources or consumers of electricity. This has generated significant added value in Ilmenau for many of those involved in the energy transition: private individuals, municipalities, and manufacturers of these kinds of equipment.

7. Science communications

Key figures for 2023
According to a media engagement analysis, Fraunhofer appeared in 10,991 articles; of these, 62 percent were initiated by Fraunhofer itself. They were viewed 6.050 billion times.

Into the universe with Fraunhofer AVIATION & SPACE
"Our Universe" was the theme of Science Year 2023 in Germany. Fraunhofer researchers supported the initiative sponsored by the German Federal Ministry of Education and Research (BMBF) with numerous public formats and exhibits. The activities were coordinated by the Fraunhofer Aviation and Space Alliance and the central Public Formats and Initiatives department. On average, half of all missions conducted by the European Space Agency (ESA) in the past 20 years had Fraunhofer developments on board. During the science year and beyond, a number of spectacular developments have been and continue to be involved in space missions. Back in 2020, Fraunhofer delivered the GESTRA radar system to the German Aerospace Center (DLR) to improve monitoring of low Earth orbit for risks posed by space junk. The metal mirrors for the Mid-Infrared Instrument (MIRI) used in the James Webb Space Telescope, which transmits images of unprecedented quality, come from Fraunhofer. So does the imaging spectrometer used in the EnMAP mission. The LisR infrared camera module proved its value on board the International Space Station (ISS) in 2023, and the ERNST small satellite is scheduled to launch in 2024. For Fraunhofer, the highlight of Science Year 2023 was an exhibit titled "Down to Earth Space Technology," held at the Fraunhofer Forum Berlin in early May. In various formats, scientists talked with young people and adults about subjects such as how advanced space technologies can help to deepen our understanding of climate change and its impacts, identify environmental degradation and pollution, protect critical infrastructure, and make agricultural water use more sustainable.

Click here for the quick-start guide for customers.
Here you will find more information on collaboration methods, including for SMEs, opportunities for reciprocal technology transfer and continuing professional development courses.

Initiatives

Generative artificial intelligence

Research on, as well as the development and availability of, generative AI models and resulting applications such as chatbots already represent key competitive factors today. The use of these models is expected to have a major influence on the digital transformation and make an even greater contribution to gross value added in the future. Fraunhofer institutes have been driving these trends in various fields for years now. For example, the OpenGPT-X initiative has created large European language models. As of 2023, the Fraunhofer intranet offers all employees access to FhGenie, an adapted internal model based on ChatGPT 3.5. The "Learning Systems and Cognitive Robotics" AI innovative center in Stuttgart helps companies unlock the economic opportunities offered by AI, especially machine learning, in applied research projects. In the summer of 2023, Fraunhofer published a concept paper titled "Analysis and Recommendations on the Subject of Language Models and Generative AI" (*Analyse und Handlungsempfehlungen zum Thema Sprachmodelle und Generative KI*). It recommends a three-step approach: access, adapt, and advance. The goal is to build in-depth expertise and a custom-fitted range of solutions for the use of generative AI across industry and the research sector. Access to large volumes of high-quality training data is a key prerequisite for this. The challenge after that is to link models with reliable fact checks, accurate and reliable sourcing, and data control, especially for industrial applications. The paper also includes suggestions for training AI specialists. Joint strategies with German and European partners could offer advantages, especially when it comes to the costly process of training foundation models. Fraunhofer is also involved with the draft EU Artificial Intelligence Act (AIA), which aims to create a shared regulatory and legal framework for AI.

Raw material transition and bioeconomy roadmap

In light of its strategic raw material dependence, the EU is increasingly focusing on bringing about a rapid transition in raw materials. Fraunhofer's research and innovation activities are making a critical contribution to this. Fraunhofer is a co-founder of the Advanced Materials Initiative 2030 (AMI2030), which serves as an integrative forum for research and innovation in this field. Subject to the approval of the Member States, the initiative is expected to yield a partnership within the Horizon Europe framework program in early 2024 to place this topic on the European research and innovation agenda on a long-term basis. Fraunhofer's new ORCHESTER flagship project is blazing a trail in this regard with the objective of providing reliable and safe materials for the energy transition along the entire value chain. At the same time, Fraunhofer's circular bioeconomy roadmap is helping to enable innovative methods and products, new business models, and value creation networks for sustainable and resource-efficient economic activity. The roadmap was presented in September 2023 by the Fraunhofer EU Office in Brussels and the Fraunhofer Strategic Research Field Bioeconomy at a high-profile event involving the European Commission.

Energy partnerships

The Fraunhofer Representative Office Korea organized the fourth Germany-Korea Hydrogen Conference in late fall 2023. The Fraunhofer representative office was supported in these activities by the German Federal Ministry for Economic Affairs and Climate Action (BMWK) and the German Federal Ministry of Education and Research (BMBF). The energy partnership between Korea and Germany has existed since 2019. With over 230 participants, the purely analog conference set a new record for attendance, drawing a large proportion of industry participants and high-ranking government officials from both countries. Multiple Fraunhofer institutes contributed to the program. With four future Fraunhofer innovation platforms and two ICON collaborations, Korea is an especially desirable target country for international strategic research collaborations.

Also in late fall, the Fraunhofer Cluster of Excellence Integrated Energy Systems CINES and consulting firm GHD Advisory published the National Hydrogen Strategy of the United Arab Emirates (UAE). Fraunhofer CINES and GHD Advisory had

been commissioned to draft the strategy as part of Germany's energy partnership with the UAE. The UAE is striving to become one of the world's biggest producers of hydrogen by 2031. Demand for hydrogen is expected to be significant, both domestically and for export. With an eye to a defossilized future, the team of authors from Fraunhofer CINES and GHD Advisory conclude that the UAE's low-carbon hydrogen production capacity could reach 7.5 million metric tons per year by 2040 and nearly 15 million by 2050. The goal of the strategy is to develop long-term measures based on the analysis for a sustainable energy policy and to attract additional investment to this area.

Fusion research — a clean energy source of the future?

Research groups all over the world are working to explore new emission-free sources of energy. One promising possibility lies in the fusion of hydrogen atoms to form helium in magnetically enclosed fusion plasmas. The Wendelstein 7-X stellarator-type fusion device at the Max Planck Institute for Plasma Physics, for example, is one of the world's leading large-scale devices in this field. Laser-driven inertial fusion energy (IFE) is another potential fusion source. A significant breakthrough in this area was made at the Lawrence Livermore National Laboratory in the United States in late 2022. Researchers demonstrated the physical feasibility of igniting a fusion plasma for the first time. This is a key requirement for realizing a fusion power plant. Much as with magnetic confinement fusion, there are already concepts for power plants based on IFE. Further technological advances over at least a decade will likely be needed before this can become a reality.

The German Federal Ministry of Education and Research (BMBF) founded an expert committee in 2023. It is being led by Prof. Constantin Häfner, executive director of the Fraunhofer Institute for Laser Technology ILT and Fraunhofer commissary for fusion energy. In a memorandum, the committee outlined issues and ways to realize an IFE power plant in technical terms. The memorandum is now being followed up internally by the German Federal Ministry of Education and Research (BMBF) with an eye to the key technologies needed to implement a power plant concept. A Fraunhofer task force brings together the available expertise in fusion research, including high-performance lasers, production of high-quality optics, technologies for targets and fuels, and technologies for development of reactor walls. One of the Fraunhofer-Gesellschaft's main goals is to empower industry to develop relevant key technologies in global competition.

Launching Fraunhofer flagship projects

AMMONVEKTOR — Green ammonia as a cross-sector vector for the energy transition

The Fraunhofer consortium is focusing on ammonia as an elementary building block of the hydrogen economy. Ammonia features better properties of storage and transport efficiency compared to hydrogen, thanks to its volumetric energy density. This makes it attractive as a carbon-free, economically viable hydrogen carrier to serve the immense industrial demand for electricity and process heat. This is especially true of medium-sized, energy-intensive companies that are threatening to relocate abroad due to high energy prices and will not be directly connected to a hydrogen pipeline in the future. Ammonia can be used in engine applications and in fuel cell cogeneration of heat and power, where it serves for decentralized power generation.

The project's development objectives will look at the entire value chain for ammonia as an energy vector. This includes developing reactors and catalysts for flexible, energy-efficient ammonia production, as well as technology for ammonia cracking on a small scale, in order to make pure hydrogen available on a decentralized basis. Storage and logistics systems for decentralized use of ammonia are also being created, and technical and financial analysis is being leveraged to develop new business models. These advances in technology will address the most significant hurdles to using ammonia as an energy vector (see p. 51).

ORCHESTER — ecosystem for a resilient and sustainable supply of materials

This research team is tackling the challenges of the circular economy and ensuring the security of the supply of materials. The focus is on resilience, sustainability, and reliable functioning of materials. The objective is to broaden the selection of materials through more-detailed knowledge of the interactions between chemistry, processes, microstructure, and properties. The researchers also aim to increase the percentage of materials being recycled by achieving better control of impurities in secondary metals and lowering the proportion of rare earths that are used in raw materials production, as these elements are critical from an origin standpoint. At the same time, they plan to move away from material specifications defined by the material composition and process route and toward function-based specifications instead. This will permit faster substitution of critical materials, enhancing the resilience of the supply.

The researchers plan to show this using components such as bipolar plates for electrolyzers and fuel cells, where costs are determined to a significant degree by the proportion of nickel. Nickel is a critical element; it faces significant supply risks and is also highly important in economic terms. In a crisis scenario, the proportion of nickel would need to be reduced without jeopardizing the plates' key functional properties. In the case of compressor wheels for hydrogen pipelines, fuel cells, and heat pumps, plans call for maximizing the secondary material proportion of the aluminum alloy to minimize the energy footprint. The researchers will also be looking at ways to recycle and reuse permanent magnets for applications in electric motors and wind turbines. Goals include using simulation models and machine learning to predict how material composition influences the effects of materials. ORCHESTER is leveraging the experience gleaned from existing initiatives such as Gaia-X and Materials Data Space® to build its own digital ecosystem.

Completed Fraunhofer flagship projects

EVOLOPRO — Evolutionary self-adaptation of complex production processes and products

Over 50 researchers from seven Fraunhofer institutes analyzed various evolutionary biology elements of flexibility and self-adaptation and applied their findings to production of complex components. These elements served as the basis for a new generation of "biological manufacturing systems" (BMSs). Like biological organisms, BMSs independently adjust to new requirements and environmental conditions — and, thanks to Industry 4.0 technologies and principles, they do it in just a short time. To that end, the researchers developed biologically inspired algorithms and digital twins that interact with a digital environment.

The concepts were validated in three pilot chains: Aviation, Optics, and Automotive. For milling blade-integrated disks, an innovative simulation environment was created on the basis of biologized algorithms, significantly reducing the time, effort, and expense that go into process planning and the insertion process. For production of complex glass optics, the team digitalized the entire manufacturing chain and developed a self-learning method for automated assembly of optical components. In the Automotive pilot chain, a model-based controlled body manufacturing system was established while tapping into the full potential offered by Industry 4.0.

A cloud-based data lake architecture was created to hold the huge volume of process data. It also provides standardized data interfaces and specific description models for unambiguous identification of the data uploaded. Building on the results, further research projects will continue to pursue the digital twin and digital environment concepts. The measures from the pilot chains are to be further developed specifically in the direction of market readiness for concrete use in industry.

Go to video

QMag — Quantum Magnetometry

Quantum magnetometers are highly sensitive sensors that can measure even the tiniest magnetic fields, so they offer tremendous potential for optimization of industrial processes. The consortium for the Qmag flagship project studied and developed quantum magnetometers. The researchers relied on two principles: nitrogen vacancy (NV) centers in diamonds, and optically pumped magnetometers. The two measurement methods are a perfect fit when it comes to achieving superior spatial resolution and extreme sensitivity.

The project team succeeded in developing customized measurement systems for various industrial applications. Especially in terms of material characterization, both types of sensors were used to achieve goals such as detecting microscopic damage in ferromagnetic materials. In the automotive and aerospace industries, these systems can help to make materials more resilient, safer, and more reliable. Quantum magnetometers can also be used in chip production to visualize the nanoscale magnetic fields of electronic circuits. The researchers also developed new measurement methods such as magnetometric flow measurement, which measures the speed at which fluids move through a pipe, and the long-range magnetometer for fast imaging measurements of large areas. These methods are suitable for applications in quality and process control and in biomedicine.

Go to video

For more information about completed Fraunhofer flagship projects, please see p. 2 (Production architecture for the factory of the future — SWAP) and p. 13 (Ensuring that treatments have optimum effects — MED²ICIN).