Fraunhofer
2 | 22

Fraunhofer

The magazine for people shaping the future

War, energy crises, climate change
What can artificial intelligence do to help?

Protection and security

A new era, new challenges, new solutions

Reflecting the times we live in
Caroline Schweitzer, managing director of the Fraunhofer Segment for Defense and Security VVS, at the International Aeronautical Exhibition in Berlin

Quick, safe, objective coronavirus monitoring
How Fraunhofer's mobile laboratory measures viral load

»Cybersecurity will be an ongoing task«
German Federal Minister for Digital Infrastructure Volker Wissing

Fraunhofer

Save the new date:
Sept. 28 – 29, 2022

The Quantum Breakthrough

FUTURAS IN RES, Berlin

The second-generation quantum technologies have already resulted in an increasing number of practical applications and bear a high innovation potential for the years to come. Our invited international experts from research and industry will present you the latest R&D advancements and applications in the visionary areas of Quantum Imaging & Optics, Quantum Communication, Quantum Sensing and Quantum Computing. **Find out more: www.fraunhofer.de/fir2022**

Editorial

Ready for a new era

Prof. Reimund Neugebauer

Security is the order of the day: for energy, supply chains, distribution systems and prices, as well as online and in our national defenses. This desire for security may be rooted in emotion, but we must take a rational approach to fulfilling it.

In this issue of the Fraunhofer magazine, Germany's first Minister for Digital Affairs, Dr. Volker Wissing, talks about the contradictions that need to be resolved with the power of reason. Even in this era of cybercrime and cyberwarfare, he reaffirms what his party put on their election posters: "Digital first, doubts second." In his interview with Fraunhofer, Volker Wissing said: "Data forms the foundation of digital business models and innovative solutions. Forgoing data means forgoing opportunities." This new member of the federal government is full of praise for the Digital Services Act, a set of measures intended to strengthen internet users' rights across Europe, and the G7's resolution to collaborate on digital protection. As part of the German Cyber Security Council, Fraunhofer scientists are working full steam ahead on improving protection for industry and end users.

Dependency is a threat to security, as the trouble caused by Russian gas supplies during Putin's ongoing military campaign have made abundantly clear. Germany and Europe are not rich in raw materials. However, they do have a wealth of knowledge, information, education and innovation. At this time, when so much that we believed to be secure is being called into question, it is precisely these assets that we must capitalize on. Until recently, phasing out fossil-based energy carriers was just one more part of the economic discussions around the future of the affected coalfields; however, security of supply and the stability of energy prices have now suddenly become central sociopolitical issues. For a secure future, we must use a variety of supply sources.

In addition, Germany must be open to using new technologies. Diversifying our energy sources is the only way to achieve a number of goals, including reducing dependencies — particularly when it comes to mobility. Electromobility is the future. However, the more important battery cells become for road transportation, the more certain it is that hydrogen will be a crucial energy carrier in the future — especially for trucks and heavy-duty commercial vehicles.

There is no one short-term, all-encompassing solution that will solve all our energy problems. In the medium term, we will need to ramp up our use of renewable energies. The Fraunhofer-Gesellschaft is a co-signatory of a joint declaration aimed at ensuring that at least 500,000 new heat pumps are installed annually in Germany from 2024 onward. In the long term, nuclear fusion may hold great potential for a country that imports nearly three quarters of its energy carriers. Needless to say, implementing a mechanism that replicates the sun's energy source will be very technically challenging. And yet the vision of being able to generate as much energy as 11 tons of coal using just 1 gram of fuel in nuclear fusion is highly motivational.

Whether it's security, energy supply or mobility, one thing is true for our society: cutting back on investments in research means cutting back on our future.

Sincerely,

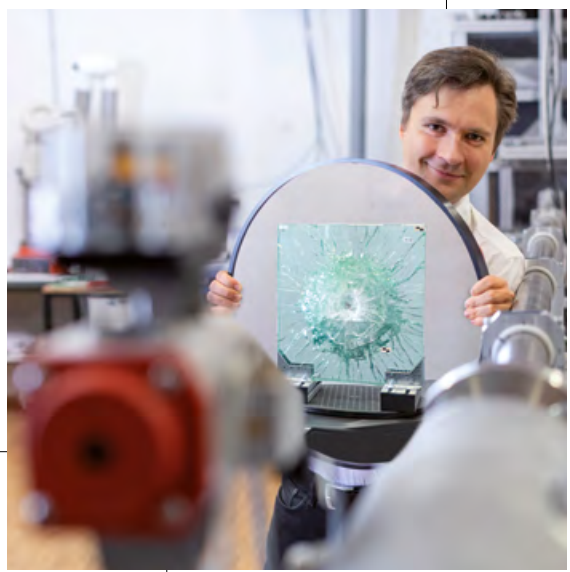
Reimund Neugebauer
President of the Fraunhofer-Gesellschaft

Learn more about the main research topics of the Fraunhofer-Gesellschaft:
Prof. Reimund Neugebauer on LinkedIn

Photo: Fraunhofer/Bernhard Huber

back to page 1

Contents



10
Title
Security that reflects the times we live in

New challenges, new solutions: Dr. Steffen Bauer (photo), Fraunhofer EMI, is developing laminated glass that can even withstand continuous gunfire.

48
"Cybersecurity will be an ongoing task."

He is Germany's first ever digital minister. And he wants to do away with all things analog. In an interview with Fraunhofer, Dr. Volker Wissing warns of the risks — but also explains why "forgoing data means forgoing opportunities."

38
Cyberwarfare
Red alert in cyberspace

In the 21st century, wars are not only fought on the battlefields. How can Germany improve its resilience?

31
Brew number two

Coffee is the Germans' favorite drink. Even the grounds contain plenty of untapped potential.

68
The search for the perfect plant

The summers keep getting hotter and drier. X-ray technology is helping in the search for heat-tolerant crops.

52
Research prizes

The Fraunhofer-Gesellschaft has been recognizing its employees' outstanding scientific achievements since 1978 — André Weidauer (left) and Christian Süß snapped up the Founder Award 2022 for their environmentally friendly method of disinfecting seeds.

The number of cybercrimes in Germany continues to increase. In 2021, the German Federal Criminal Police Office (BKA) logged a new record number of attacks, at 146,363 — more than a 12 percent increase on the previous year. The digital association Bitkom surveyed 1,000 companies in Germany. 86 percent complained of cyberattacks — and that was in 2021, before the war in Ukraine.

86%

Front and back cover photos: Gene Glover, Andreas Chudowski;
Photo content: Martin Wagenhan, Jonas Ratermann, Andreas Chudowski, Science Photo Library/Victor De Schwanberg, Fraunhofer/Piotr Banczerowski, Devin Avery/Unsplash

back to page 1

Brief report

For ecoSUP developer Christoph Pöhler of Fraunhofer WKI, going for a paddle on his environmentally friendly SUP board is twice the fun.

Sustainable paddle-boarding with ecoSUP

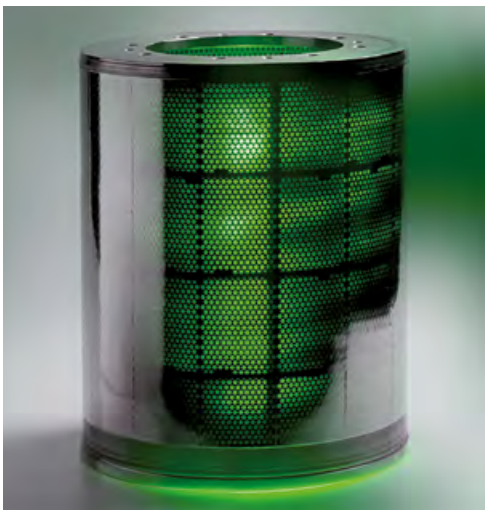
Paddling across the water on a stand-up paddleboard (SUP) means freedom and relaxation — and an awful lot of plastic. Hoping to change this, the partners in the ecoSUP project are using a technology designed by the Fraunhofer Institute for Wood Research, Wilhelm-Klauditz-Institut, WKI to develop a SUP made from renewable raw materials. As the "filling" in the boards' lightweight sandwich of layers, the researchers are using balsa wood from old wind turbine rotor blades. This means they are killing two birds with one stone: making the SUP boards more eco-friendly and re-using this material in a high-quality application. In the future, this new bio-based composite material could also be used in other water sports equipment, as well as in constructing buildings, cars, ships and trains. Until now, petroleum-based materials such as epoxy resin, polyester resin, polyurethane and expanded or extruded polystyrene have been used in combination with fiberglass and carbon fiber fabrics to produce water sports equipment such as surfboards. Glass-reinforced plastic (GRP) is also seeing increased use in other areas. The European market for GRP in 2018 amounted to around 1.1 million tons, which means it offers huge potential for saving finite resources. ■

A digital helper for manufacturing

Is it a jammed slide valve or a clogged suction cup? MADDOX helps track down the root cause of faults more quickly.

Time is money, especially when it comes to manufacturing. The self-learning assistant system MADDOX helps rectify faults in manufacturing machinery more quickly — even if there are no experienced staff on site to carry out the repairs. The digital helper was developed by Peerox GmbH, a spin-off of the Fraunhofer Institute for Process Engineering and Packaging IVV. MADDOX uses machine learning methods to analyze machine data and process data, and relies on pattern recognition to search for similar faults that occurred in the past and find out how they were resolved.

"Many manufacturing facilities can barely get their efficiency rate over 60 percent. This is mainly because they cannot rectify the cause of faults quickly," says Andre Schult, CEO of Peerox GmbH. Even if extensive documentation is provided, it can be a major challenge to find the right information when a fault crops up and the pressure is on. "That's why we use data-driven searches in MADDOX, using machine data such as pressure curves, temperatures, photoelectric sensor signals and error codes," explains Schult. A self-learning search algorithm analyzes the data and creates categories of similar data patterns. These are then linked to digital knowledge cards, where employees use text, images and video to document descriptions of faults and solutions. If a fault occurs, the algorithm analyzes the data patterns, searches for similar categories and displays the relevant knowledge card to the user via a tablet that is not dependent on any one platform. ■



In the microplastic filter, the sheets with micro-holes are attached to a coarser layer to prevent the water pressure from tearing them.

Combating microplastics with lasers

Until recently, sewage treatment plants have been unable to completely filter microplastics out of waste water. Now, for the first time, a team of researchers has managed to build a laser-drilled waste water filter for microplastics. The filter contains metal sheets with minuscule holes just 10 micrometers in diameter. The Fraunhofer Institute for Laser Technology ILT developed the technology used to efficiently drill these holes, which number 59 million in total.

The researchers used a multi-beam method involving an ultrashort pulse laser that drills with 144 beams simultaneously. The laser-drilled metal sheets were then installed in the patented KLASS Filter GmbH cyclone filter and underwent extensive testing. In the initial test, the researchers successfully filtered water that had been contaminated with a fine powder from 3D printers. The system will now be tested under real-life conditions at a sewage treatment plant. ■

Arrive on time — thanks to AI

Many hope that in the future, artificial intelligence (AI) will be able to help reduce delays in public transportation systems. This particular AI system was developed by a team at the Fraunhofer Institute for Industrial Mathematics ITWM, the Martin Luther University Halle-Wittenberg (MLU) and TU Kaiserslautern. The researchers were looking for an efficient way of designing more robust timetables for public transportation that could more effectively compensate for minor disruptions and delays.

The options for combating delays in advance are few. Although the calculations for journey durations, the pauses between successive journeys and the waiting times at stops could be more generous, this would come at the cost of economic efficiency. The new process could help optimize timetables within milliseconds in such a way that they strike a balance between robustness and the external economic conditions affecting the transportation companies. Until now, optimizing timetables in this manner has required complex computer simulations that calculate the travel routes for a large number of passengers in different scenarios. This means that creating a single simulation can quickly add up to several minutes of computing time. Optimizing a timetable requires many thousands of these kinds of simulations. ■

A short traffic jam during rush hour or a jammed door — even minor setbacks can lead to considerable delays.

Photos: Christoph Pöhler/Fraunhofer WKI, Peerox GmbH, Fraunhofer ILT, Aachen, Unsplash

back to page 1

Goodbye, patches

In the future, a pair of electronic glasses will eliminate the need to cover up the healthy eye in children with amblyopia. Until now, this was the only treatment option for functional visual impairment in one eye. However, many children won't wear the patch due to embarrassment — and so their weak eye is not trained successfully. Another disadvantage of the patches is that they restrict spatial vision.

The new glasses with multi-modal smart sensors can adaptively darken the lens over the healthy eye and help the children wear them correctly. This solution was developed by researchers at the Fraunhofer Institute for Biomedical Engineering IBMT. Thanks to this new technology, the occlusion of the eye can be controlled in such a way that it can be paused during high-intensity activities (e.g. running, jumping, cycling) to prevent accidents due to restricted spatial vision. The glasses are controlled by smart algorithms that efficiently process the multi-modal sensor data, enabling continuous treatment monitoring for the first time. ■

Unless you're playing pirates, eyes patches are rather inconvenient.

When methanol burns to form carbon dioxide and water, it gives off a blue flame with barely any soot.

More effective use of hydrogen

A team at the Fraunhofer Institute for Microengineering and Microsystems IMM has developed a small energy-efficient reformer for converting methanol into hydrogen in mobile applications. Not only is methanol easier to transport than hydrogen, but it is also easier to store. To utilize the energy contained in the methanol, water vapor is added to convert it back into hydrogen and carbon dioxide — and this can be done right where the hydrogen is needed, such as in the car itself.

The compact reformer only needs one sixth of the space of commercially available devices in a comparable power rating class. The research team has also optimized the heat management system — thus improving the reformer's energy efficiency — and the catalyst technology. "We have opted for catalyst coatings containing precious metals similar to those used in automotive catalytic converters, as these coatings cause no abrasion," says Dr. Gunther Kolb, deputy institute director and division director at Fraunhofer IMM. Although conventional catalysts cause increasing levels of by-products such as carbon monoxide during part-load operation (i.e. when the reformer is not operating at full capacity), this is not the case with the catalyst designed by Fraunhofer IMM. ■

Editorial notes

Fraunhofer. The magazine, magazine for research, technology and innovation
ISSN 1868-3428 (print edition)
ISSN 1868-3436 (online edition)

Published by:
Fraunhofer-Gesellschaft
Hansastrasse 27c, 80686 München, Germany
Editorial address as above
Phone +49 89 1205-1301
magazin@zv.fraunhofer.de
www.fraunhofer.de/magazin

Free subscription:
Phone: +49 89 1205-1301
publikationen@fraunhofer.de

Editorial team:
Roman Möhlmann (responsible for content),
Josef Oskar Seitz (editor-in-chief),
Dr. Sonja Endres

Editorial assistants:
Dr. Janine van Ackeren, Marina Babl, Mandy Bartel, Christine Broll, Meike Grewe, Sirka Henning, Dr. Monika Offenberger, Moritz Schmerbeck, Tim Schröder, Franziska Sell, Claire Stark, Beate Strobel, Mehmet Toprak, Britta Widmann

Layout and lithography:
Vierthaler & Braun
Cover image and cover story photography:
Gene Glover, Martin Wagenhan
Cyberwarfare photography:
Gene Glover, Jonas Ratermann
Printed by:
Zeitfracht GmbH, Nürnberg

Find Fraunhofer on social media:

@Fraunhofer

www.facebook.com/fraunhoferde

www.instagram.com/fraunhofergesellschaft

www.linkedin.com/company/fraunhofer-gesellschaft

www.youtube.com/fraunhofer

Carbon neutral
Print product
ClimatePartner.com/11586-2207-1002

MIX
Paper from responsible sources
FSC® C022647

Photos: marinesea/istockphoto, Science Photo Library/Charles D. Winters, Marius Knutsen/TrAM

Climate-neutral shipping on the horizon

In a world first, an electrically powered high-speed ferry that does not produce emissions will go into service in the Norwegian city of Stavanger this September.

The name speaks for itself: Medstraum means "with electricity" in Norwegian.

The Medstraum was developed as part of the EU project TrAM, which the Fraunhofer Institute for Mechatronic Systems Design IEM and the Fraunhofer Institute for Industrial Engineering IAO were involved in. By using modular engineering methods, the Fraunhofer researchers have been able to reduce the hours required for constructing the ferry by 70 percent, and saved 25 percent of the manufacturing costs — making climate-neutral shipping cheaper.

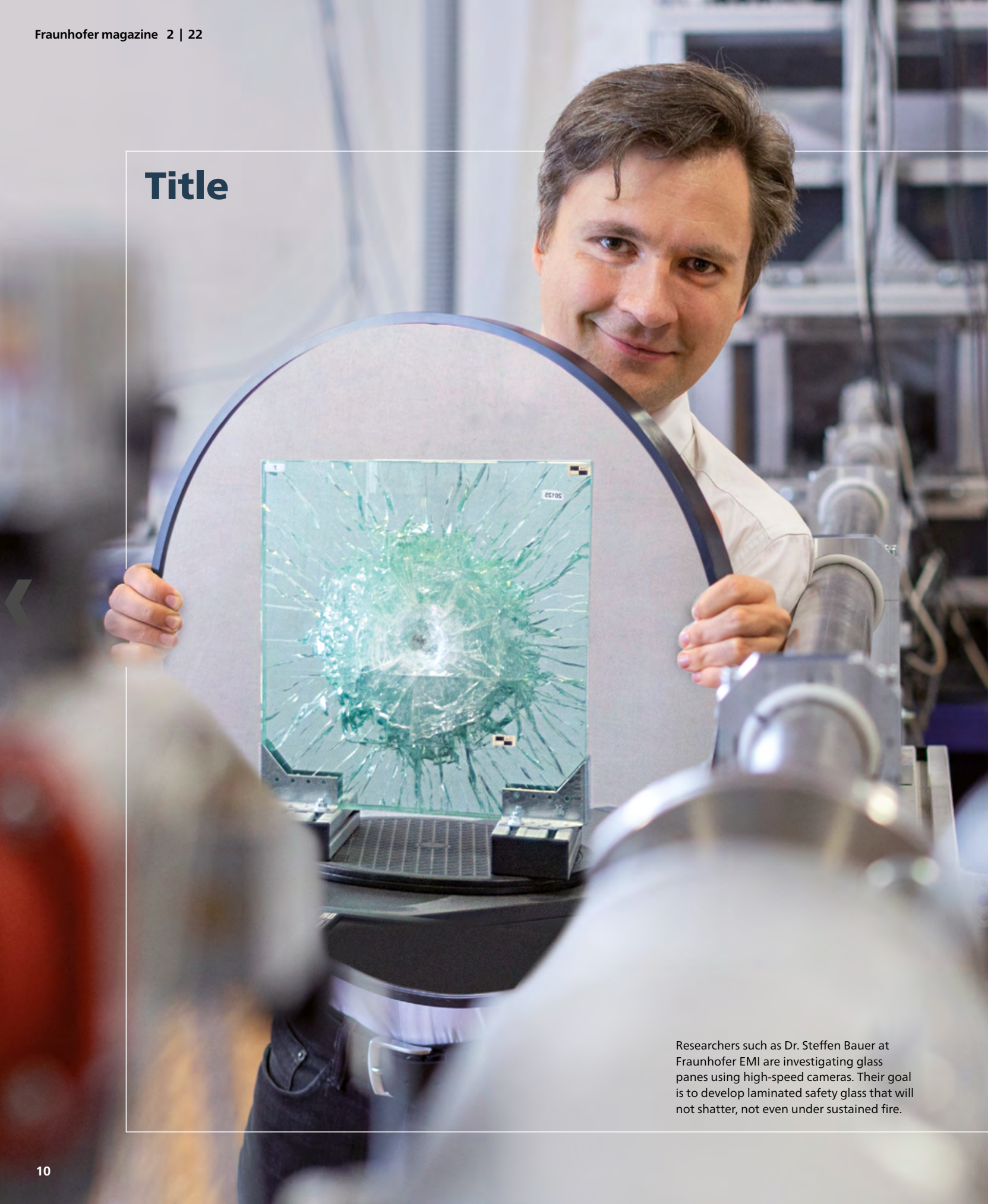
To ensure that the environmentally friendly ferries of the future can be manufactured more quickly and cheaply, the TrAM consortium use the principle of modularization, which has been widely adopted in other industries such as aviation and vehicle engineering. The researchers build system models for ferries based on a modular approach. For one thing, this makes managing the complexity and the many dependencies involved in the development process easier and more transparent. It also means the modules they develop can be transferred over to new ferry projects, quickly and cheaply.

In the TrAM project, the researchers have created a platform consisting of four parts that are combined to create the ship during the design process. There are standardized interfaces for each platform component: internal interfaces for the different internal systems, and external ones for the other platform elements. The modular product requires a customized manufacturing strategy, so as to use as many of the advantages of modularization as possible, including homogeneous processes, standardization and reusing parts for other ferries.

Until now, designing ships has been extremely complex and labor-intensive. Each ferry is designed and built individually — which is a laborious and expensive process. When it comes to alternative drive systems in particular, where any excessive energy consumption drastically reduces the ferry's range, it is crucial to design the ships with meticulous care. ■

back to page 1

Title



Researchers such as Dr. Steffen Bauer at Fraunhofer EMI are investigating glass panes using high-speed cameras. Their goal is to develop laminated safety glass that will not shatter, not even under sustained fire.

Security that reflects the times we live in

Resilience, defense capability and increased protection for civilians and against cyberattacks have become topics of public debate almost overnight. Fraunhofer is working on intelligent solutions — including measures for the best possible deployment of the 100 billion euros in special funding awarded to the German armed forces.

By Mehmet Toprak, photos by Gene Glover and Martin Wagenhan

back to page 1

Civilian technology for crisis situations

Protection against projectiles

Laboratory tests with computed tomography and high-speed cameras show the damage that projectiles can cause to transparent surfaces such as laminated glass windows. This data can be used to improve the protection of military vehicles.

Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut, EMI

Reconnaissance

The ABUL system provides a diverse range of partly AI-driven functions for evaluating the images and live stream videos from reconnaissance drones. This technology is in use in German armed forces operations in Mali, among other locations.

Fraunhofer Institute of Optronics, System Technologies and Image Exploitation IOSB

Energy supply

The aim is to develop innovative concepts to ensure that facilities, operational infrastructure (such as military camps) and vehicles of all kinds can be supplied with energy from sustainable sources in the future. This also ensures that operational readiness is not restricted. According to Prof. Karsten Pinkwart, "When it comes to energy supply for the German armed forces, we cannot continue as before. We want to help the defense forces prepare for the post-fossil fuel era."

Fraunhofer Institute for Chemical Technology ICT

Everyone is talking about the "new era," that has been triggered by Russian president Vladimir Putin's war of aggression against Ukraine. In Germany, the response has been for the German Federal Parliament (Bundestag) to approve by a large majority a change to the German Basic Law that will release 100 billion euros in special funding. The war has changed many people's perspectives of the world, and of Germany's capacity to optimally deploy its armed forces and offer its citizens the best possible protection in the case of emergency. "We're seeing a whole host of positive indicators that the government wants to act quickly to strengthen national defense," notes Prof. Jürgen Beyerer, chair of the Fraunhofer Segment for Defense and Security (abbreviated VVS) and institute director of Fraunhofer IOSB. Caroline Schweitzer, managing director of the segment, also pledges that "The research institutes of the Fraunhofer VVS can substantially contribute to our country's defense capability."

VVS is a consortium of eleven Fraunhofer institutes that combine their expertise in research fields relevant to security, military technology and defense. VVS representatives regularly provide their expertise and knowledge to the German Federal Ministry of Defence (BMVg) and its subordinate agencies and to the German armed forces.

Civil protection and defense capability often go hand in hand, as the broad spectrum of technologies that Fraunhofer-Gesellschaft researchers are focusing on developing for the benefit of industry and society also represents areas of interest for the German armed forces. Examples include digital communication technology for emergency and rescue services to use during disasters, and IT security technology for critical infrastructure. These kinds of technologies strengthen the resilience of civil systems and protect people during crises and disasters. At the same time, they help the German armed forces coordinate operations in the best way possible — in collaboration with other European countries, where necessary.

"Europe had already begun collaborating more closely on the issue of defense even before the Ukrainian crisis, and this is now paying off," says Schweitzer. "The EU drew up the Common Security and Defence Policy (CSDP), which is supported by a range of research programs. Fraunhofer helps shaping these research programs, and we are also actively participating in European consortia that develop new technologies together with partners from industry, research institutions and universities."

> "We want to help the defense forces prepare for the post-fossil fuel era."
>
> Prof. Karsten Pinkwart, Fraunhofer ICT

Schweitzer has participated in numerous expert commissions established by NATO. Since 2015, she has been managing director of VVS. She is well aware of the hot topics in the field of defense in Germany at present, as well as the contributions the Fraunhofer-Gesellschaft has made in this area. One assertion by Schweitzer is also frequently expressed by other Fraunhofer researchers: While the war in Ukraine has caused concern, she does not see it as a reason to change course. Her tone is matter-of-fact. "We don't need to open up new research fields, because we are already well positioned in all areas of technology," Prof. Beyerer also affirms.

Many examples from the VVS institutes show how Fraunhofer research has contributed to maintaining Germany's defense capability.

"Enhancing protection for our soldiers"

Defense means self-protection. Camouflaging vehicles and uniforms is a centuries-old ▶

"The research institutes of the Fraunhofer VVS can substantially contribute to our country's defense capability."

Caroline Schweitzer, managing director of the Fraunhofer Segment for Defense and Security VVS

back to page 1

Invisible to not just the eye, but potentially also to thermal imaging cameras. Dr. Max Winkelmann is investigating new types of camouflage at Fraunhofer IOSB.

practice — one that researchers at the Fraunhofer Institute of Optronics, System Technologies and Image Exploitation IOSB are currently aiming to improve upon. They are working on camouflage clothing that autonomously adapts to its environment. Integrated sensors measure the ambient brightness and predominant colors and then transmit this information to intelligently controlled LEDs integrated into the textiles. These then emit light in the appropriate color and level of brightness, allowing soldiers to essentially merge with their surroundings. The person wearing the uniform does not need to do anything — they do not have to press a button or activate any sensors. This technology is already here. In the future, if a soldier is in contact with aerial reconnaissance via an information system, the camouflage clothing will be able to adjust its color spectrum in order to avoid being detected by the optical sensors of an overhead drone. "We can use camouflage to manipulate perception," explains Max Winkelmann, research fellow at Fraunhofer IOSB. The team is not only focused on optics, however — the researchers are also conducting research into textiles that can deceive thermal imaging cameras. "We are currently experimenting with a broad range of new technologies to enhance protection for our soldiers," reveals Winkelmann.

> "We are currently experimenting with a broad spectrum of new technologies to enhance protection for our soldiers."
>
> Dr. Max Winkelmann, Fraunhofer IOSB

The Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut, EMI is also focused on optimized protection for people in deployment. Here, Elmar Straßburger and Dr. Steffen Bauer shoot at glass with metal projectiles, evaluate the damage and draw conclusions about how windows in vehicles can be better protected when under fire. Laminated safety glass is generally used for this purpose. Ultimately, its strength is determined by the thickness of the individual layers and the combination of different glass types used. "We are not simply investigating whether the projectile breaks through the pane. The pane often withstands the first shot, and the second one, too. But with the third shot, the pane shatters completely and can no longer protect people inside the vehicle." The researchers are therefore focusing on the question of how stable a pane of glass is when it has already been damaged by a projectile — and the initial damage happens right at the moment the projectile strikes, i.e. before it begins to penetrate the glass. This is because the impact creates shock waves within the glass that precede the projectile at high speed and can lead to cracks forming. Fraunhofer EMI researchers are using high-speed cameras to record these processes — from the impact to the deceleration of the projectile in just 200 microseconds. The experts are also using X-ray computed tomography and numerical simulation models "in order to make more precise predictions regarding the strength and resilience of laminated glass and laminates with different material combinations and layer thicknesses," explains Bauer.

Fraunhofer researchers are also involved in what is expected to be the largest and most ambitious European defense program of the coming decades. There are plans to integrate the Future Combat Air System (abbreviated FCAS) as an air defense system into existing platforms such as Eurofighter or Rafale from 2040 onwards, before fully replacing them at a later point. Almost all VVS institutes are participating in this ▶

Camouflage

Fraunhofer researchers are working on innovative technology for camouflaging uniforms and vehicles. A combination of sensors and LEDs integrated into fabric creates colors and patterns on uniforms that continuously adapt to the environment and purpose of the operation.

Mission planning

The digital map table is a software system that allows users to visualize and work on complex situations. Any number of users can use it to work together on the same situation — either on a large display, or from different locations with their individual devices. Using VR technology, they even can meet around a 3D map table in a virtual situation room. Ten of these systems are already in use at the Bundeswehr Command and Staff College.

Information system for networks

Coalition Shared Data (CSD) allows stakeholders to save reconnaissance data in multinational networks in a needs-based, uniform manner — in accordance with a NATO standard — as well as distribute and retrieve it, all while respecting data ownership. CSD technology is deployed in a variety of the German armed forces' foreign assignments.

Fraunhofer Institute of Optronics, System Technologies and Image Exploitation IOSB*

*The mentioned institutes are not always solely responsible for projects, but may participate in or manage a respective project.

back to page 1

Future Combat Air System (FCAS)

Germany, Spain and France have joined forces to develop the FCAS aerial defense system. Combat aircraft are combined with unmanned aircraft known as remote carriers in a networked system of systems to supply a mission with all necessary data and information in real time. Almost all VVS institutes are working on FCAS, with Fraunhofer FKIE acting as the point of contact for FCAS.

Detecting hybrid threats

Hybrid threats combine physical threats with threats related to cyberspace and information space. The threat can only be comprehensively understood by considering both physical actions, such as troop movements, radio communication and kinetic attacks, and cyberspace and information space attacks such as disinformation campaigns or hacker attacks. This knowledge is used to improve mission planning.

Military technology radar

The military technology radar (MiTeRa) provides a clear overview of relevant research activities and their maturity levels for the German armed forces, which allows them to optimize long-term planning.

Fraunhofer Institute for Communication, Information Processing and Ergonomics FKIE

mammoth project, with Fraunhofer FKIE acting as the point of contact. FCAS will be much more than just a combat aircraft. The latest generation of manned jets will be integrated into a "system of systems." Unmanned aircraft, known as "remote carriers," will accompany and protect pilots during combat missions. Central to this will be the Air Combat Cloud that will provide those involved with all relevant information in real time.

"Not a debating society, not a fig leaf."

Prof. Wolfgang Koch,
chief scientist at Fraunhofer FKIE

This new solution raises new questions. Advanced technology and digitalization are increasingly accelerating military operations and making them more data-intensive, which in turn means they are more complex. However, when AI-driven systems start making decisions by themselves, the technology is crossing a line. "The requirements for speed and complexity in future combat situations will be so high, they will not be possible without semi-automatic or automatic technical processes," explains Prof. Wolfgang Koch, chief scientist at the Fraunhofer Institute for Communication, Information Processing and Ergonomics FKIE.

This will require new evaluations and analysis of the use of artificial intelligence (AI) in weapon systems. VVS has drawn up a position paper, "Rise of Intelligent Systems in Military Weapon Systems," for this purpose. This sets out the latest technological advancements, investigates uses and risks, and presents a conceptual framework for explainable, controllable AI.

But that's not all. Researchers have established the Working Group on Technology Responsibility, which aims to define and present ethical and legal guidelines for Europe's largest defense project. In addition to Prof. Koch, participants in the working group include individuals from different social groups, such as the writer Nora Bossong, Anja Dahlmann of the German Institute for International and Security Affairs, Ulrike Franke, senior policy fellow at the European Council on Foreign Relations (ECFR), and the historian Florian Keisinger. "The working group is not intended to be a toothless debating society, and is most certainly not an intellectual fig leaf to conceal the use of AI in military operations," affirms Prof. Koch. "The plan is rather to provide systematic support and help shape the system design, operation and implementation of technologies in FCAS."

Germany, Spain and France have teamed up to develop FCAS, with additional European countries set to join their ranks over time. "FCAS is a pan-European project that could greatly boost the European Common Security and Defence Policy," explains Koch.

Precision creates security

Precise knowledge also helps improve safety for emergency service personnel. Researchers such as Dr. Stephan Palm at Fraunhofer FHR in Wachtberg are focused on reconnaissance, more specifically synthetic-aperture radar (SAR). This form of radar generates an image from many smaller images captured with a moving antenna, showing the

two-dimensional reflectivity of the scene. Scientists at Fraunhofer FHR are experimenting with circular SAR at extremely high carrier frequencies. Dr. Palm has also completed a PhD on the topic.

Research must focus on public safety and security

During this process, an aircraft or reconnaissance drone follows a circular flight path around the area to be observed while continuously directing a radar beam at the center. This generates images from multiple angles, enabling individual objects to be captured in 3D, i.e. viewed from several sides. This also allows for a much higher resolution can be achieved with conventional imaging on linear trajectories. "Circular SAR makes it possible to create SAR videos and visualize objects in motion on the ground, such as moving cars," says Dr. Palm.

> "Our aim is to create a virtual visual representation of these events and their specific effects, including using 3D VR."
>
> Daniel Hiller,
> managing director at Fraunhofer SIRIOS

Using the current experimental system, a reconnaissance aircraft flying at a height of 600 meters over the target area can identify objects smaller than 5 centimeters in size. Aircraft can also reach much higher altitudes if more output power is provided. This allows for high-resolution reconnaissance in real time, even in poor weather conditions or at night.

An additional focus of research activity at Fraunhofer is public safety and security. Daniel Hiller, managing director at Fraunhofer SIRIOS, describes enormous "challenges for society posed by dangers such as terrorism, cyberattacks and climate change." Fraunhofer SIRIOS, a collaboration between four Fraunhofer institutes, commenced operations in January 2022 in Berlin. These Fraunhofer experts are focusing on the principle of simulations that can be experienced virtually. Fraunhofer SIRIOS creates detailed simulations of the development of dangerous events such as attacks or explosions, and the probable reaction of the people affected. However, the simulation is not only limited to abstract data sets and graphics. "Our aim is to create a virtual visual representation of these events and their specific effects, including using 3D VR."

How can warnings be issued to the public?

Olaf Korte at Fraunhofer IIS is focusing on early warning systems, which are crucial in hazardous situations such as natural disasters. Many traditional warning siren systems have been dismantled in recent years, or are no longer being maintained. Although warning apps do exist for smartphones, these devices rely on a functioning cell phone network. Radio networks are much more robust. Olaf Korte and his colleagues are betting on these. The EWF (Emergency Warning Functionality) feature allows for a warning to be triggered from a central location such as an interior ministry. This is sent as a switchover or wake-up signal, and transmits an audio message with scrolling text to the display on the end device. DAB+ radios can receive the message. Higher-quality receivers also offer multilingual and more detailed text for hearing impaired people and foreign language speakers. The warnings and information text can also be used for public display boards. "An advantage of this technology is that warnings about an imminent storm, for ▶

Warning and alarm systems

High-performance information logistics and architecture for networked public warning and alarm systems.

Fraunhofer Institute for Open Communication Systems FOKUS

Defense against drones with high-energy microwaves

Detecting and tackling drones using conventional weapons is difficult, especially when the drones are small in size. Targeted disruption of drones' electronic systems for motor control, flight attitude and other control elements using high-energy microwaves offers all-round protection against individual drones, but also safeguards objects that need to be protected against swarms.

Detecting electromagnetic attacks

Weapons that disrupt, or even destroy, modern electronic systems using high-energy microwaves fall within the category of modern directed-energy weapons. Detecting this type of attack is the crucial first step. An extremely compact detector can be integrated into mobile and stationary weapon systems. It then recognizes and analyzes the type and direction of an attack using microwaves.

Fraunhofer Institute for Technological Trend Analysis INT

back to page 1

A little radio that offers greater security: Radio networks are more stable than mobile networks in times of crisis. For this reason, Olaf Korte from Fraunhofer IIS depends on EWF (Emergency Warning Functionality) instead of apps.

instance, can be regionally distributed in a highly precise way," says Korte. The distribution of DAB+ in Germany is currently only around 25 percent, but this figure is increasing.

> "An advantage of this technology is that warnings can be sent out regionally in a very precise way."
>
> Olaf Korte,
> Fraunhofer IIS

A radar for investment

Globally, research and technological development in the areas of civil protection and defense has been running at peak levels in order to better protect people not only from the impact of climate change, but also from military attacks. The military technology radar (MiTeRa) tool developed at Fraunhofer FKIE delivers a continuously updated overview of a wide range of research activities.

Dr. Hanna Geppert and Dr. Carsten Winkelholz have created this software tool together with their team and the German Federal Ministry of Defence (BMVg) to maintain a continuous overview of the maturity level, intensity and planning status of research activities related to important future technologies. "When certain communication tools become obsolete, it's important to know when new technology will be market-ready, in order to avoid gaps," explains Dr. Geppert. This is made possible by taking an ergonomic approach, and by considering who requires information to make an informed decision, what kind of information they need, and when they need it. The result is an interactive, intuitive representation based on visual analytics. The BMVg is currently using the technology radar tool in cybersecurity and IT research, and there are plans to use it in additional areas as needed.

A growing need — and government willingness put down on paper

The German armed forces and Ministry of Defense also want to know about future technological trends and what the armed forces' equipment will look like in the future. The technology that will be employed in modern weapon systems in 10 or 20 years is the subject of ongoing research projects — mostly driven by civilians — in laboratories around the world, although technology readiness levels are still low. The Fraunhofer Institute for Technological Trend Analysis INT offers an overview of this research. "We have been providing a 360° view of this complex technological landscape for over 40 years, and we advise the BMVg in terms of designing their departmental research program," explains Prof. Michael Lauster, head of Fraunhofer INT and deputy spokesperson of the Fraunhofer Segment for Defense and Security VVS. In addition, the quarterly publication from Fraunhofer INT, "Defense Technology Foresight," provides planners and decision-makers with essential information for making future-proof equipment decisions.

Germany's defense requirements are growing, the government's willingness to act is a documented fact — and research is ready and waiting. "We have already made targeted offers of services to the Ministry of Defense," says Schweitzer, VVS managing director. "We are in a position where we can rapidly react to specific requests from the German armed forces and bring new technologies into the field," Prof. Jürgen Beyerer, VVS chair, also affirms. When it comes to the current situation, the VVS chair believes that: "We will be able to demonstrate this capability to an even greater extent in the future." ■

Emergency warning

The warning system EWF (Emergency Warning Functionality) uses DAB+ digital radio to issue warnings to the public in the case of disasters, attacks or incidents of any kind. This robust system complements internet-based technology such as smartphone warning apps.

Fraunhofer Institute for Integrated Circuits IIS

SE/EKUS operations management and communication system

The SE/EKUS operations management and communication system supports special police units in operational preparation, mission management and communication. This system, which is now award-winning and has become established in Germany as standard, provides state-of-the-art web and server technologies along with mobile applications. In this way, forces on the ground can use mobile apps to stay up to date.

Fraunhofer Institute for Transportation and Infrastructure Systems IVI

Rocket detection

Bi-spectral infrared detectors can be used to detect and identify approaching rockets. This system is used by Airbus A400M aircraft, for instance.

Fraunhofer Institute for Applied Solid State Physics IAF

back to page 1

Radar reconnaissance

Using a circular flight path and a very high frequency, circular SAR radar reconnaissance is used in aircraft to provide significantly higher three-dimensional resolution for objects on the ground. Video SAR can also be used to visualize moving objects.

Mine clearance

Ground-penetrating radar using polarimetric antennas that can be installed on the front of a mine clearance vehicle. This radar even detects mines made of plastic and material mixtures.

Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR

Civil protection

Virtual simulation helps researchers to analyze natural disasters, attacks and other incidents and their effects on socio-technical systems, and to make decisions when it comes to optimizing rescue operations and restoring critical infrastructures.

Fraunhofer Center for the Security of Socio-Technical Systems SIRIOS

Fraunhofer SIRIOS — Simulating disasters in the virtual world
Scan here for the podcast:

7 hypotheses on the future of defense technology

By Prof. Michael Lauster, head of the Fraunhofer Institute for Technological Trend Analysis INT and deputy spokesperson of the Fraunhofer Segment for Defense and Security VVS.

1 Specially adapted materials are crucial to armed conflict in all domains, whether land, air or sea. Just like knights' armor hundreds of years ago, modern battle tanks are becoming heavier, and therefore less and less mobile. Robust, light materials and new protection methods are enabling the construction of smaller, lighter vehicles that offer their crews the same level of protection. They are also more mobile and require less energy for operation. Especially when considering the shortage of fossil fuels, weight is an essential factor.

2 In addition to new drive and control concepts, materials that are light but also resistant to high temperatures are crucial for the push into the area of hypersonics. Hypersonic aircraft deliver a new level of quality. They are difficult to track, can be maneuvered even at the highest speeds above Mach 5, i.e. over 6,000 kilometers per hour, and achieve ranges of several thousand kilometers. For high-value targets, they represent a threat against which there is currently little defense. To safeguard such targets, the development of new camouflage materials is growing in significance, in particular for ship and submarine protection.

3 Quantum technology (see p. 24 for "On your marks ... get set ... compute!" and p. 47 "When quantum computers attack") represents a promising area for disruptive development, and not only in the civil division. Quantum computers could play an important role in material design in the future. Their development is just one aspect of the practical application of quantum theory, which will also open up the field of subatomics for military use. Quantum communication, quantum sensors and, last but not least, weapons based on quantum effects, such as lasers with an output of over 100 kW, are all currently in development.

4 Machine learning and pattern recognition offer valuable support for evaluating sensor data or detecting adversarial behavior. For military use, the most important factors are understandable decision-making processes (explainable AI), interference resistance in the military's own AI system and the potential to deceive another AI system (adversarial AI). Digital imaging of a battlefield will be available for all levels of organization, and the required information will be transmitted according to the situation.

Following his officer's training, Michael Lauster studied aerospace technology at Universität der Bundeswehr München (military university of Munich). Prof. Lauster has been deputy spokesperson for the Fraunhofer Segment for Defense and Security VVS since 2020.

5 Space travel is set to play an increasingly significant role in security. Satellites will be used for navigation and communication, but that's not all. In the future, it will be possible to carry out reconnaissance using satellites in low Earth orbit, with customizable configurations that can be launched as required. Under the "responsive space" model, it will be possible to quickly replace disabled satellites in orbit by launching our own assets within a short time.

6 Technology has been a decisive factor in armed conflict throughout history. The side that could build more effective weaponry had a significant advantage. Swords and shields made from bronze were tougher and more durable than their precursors made of copper or wood and animal hide. The development of powerful crossbows and the first muzzle-loading firearms brought the era of heavily armored knights to an end; the invention of aircraft unlocked the aerial domain as an additional battlefield. When combined with ships from which they could launch and land, aircraft enabled global power projection. A range of nuclear weapons, alongside carrier rockets and other long-range forms of transportation led to the rise of superpowers. Still today, armies aim to use the highest-quality equipment. However, even the most up-to-date technology is useless without people who know how to use it. The difference between combat effectiveness(i.e. the type and number of weapons) and combat readiness (i.e. the determination and ability to deploy them) is crucial. Only a combination of effective technology and highly motivated, well-educated soldiers will lead to success in combat situations.

7 For all the latest technology, it is the 2,500-year-old saying from Sun Tzu's "The Art of War", the earliest historical text on strategy, that holds sway: "To fight and conquer in all your battles is not supreme excellence; supreme excellence consists in breaking the enemy's resistance without fighting." ■

"Supreme excellence consists in breaking the enemy's resistance without fighting."

Sun Tzu, "The Art of War"

Photo: Fraunhofer INT

back to page 1

No more undetected COVID cases

Mobile sewage analysis labs could help monitor the progress of the pandemic in Germany as it happens, and even identify hotspots at an early stage.

By Marina Babl

In the world's first mobile coronavirus testing lab, the space is limited. Nevertheless, it is still divided into different sections to reduce the risk of cross-contamination. The analysis takes place in the larger section.

It may have a funny name, but "Dikksi Co Vi" means business — the mobile lab is expected to significantly improve future data collection efforts regarding the development of the COVID-19 pandemic in Germany. It was originally developed by the Fraunhofer Institute for Manufacturing Engineering and Automation IPA in Stuttgart. Officially, the lab's name stands for "Diagnostics of contamination-critical samples for the reliable identification of corona viruses in wastewater," but the abbreviated form sounds quite like "Dixi-Klo," the German word for "porta-potty" — and that's no accident. For one thing, this trailer, developed by the IPA into the world's first mobile coronavirus sewage test lab, is the kind that is usually made into a portable toilet. For another, the lab is used to examine sewage samples for fragments of coronavirus that make their way into the waste system via toilets and wash basins.

"Sewage analysis allows us to provide reliable, objective data to serve for evidence-based policymaking regarding the coronavirus — particularly when combined with our mobile system," says Guido Kreck, an expert in cleanliness technology from Fraunhofer IPA. The German Federal Minister of Health, Karl Lauterbach, is another firm believer in sewage testing as an effective tool for monitoring the pandemic: he recently said as much in early July when he appeared on the German ARD TV network's Sunday talk show with Anne Will. In fact, just a handful of mobile coronavirus labs in each German state could provide a real-time assessment of infection levels across the whole country, within a few a days and at a reasonable cost.

Detecting the coronavirus at a far earlier stage

Sibylle Thude, biologist and cytotoxicity expert at Fraunhofer IPA, explains: "Sewage analysis allows us to detect the coronavirus at a far earlier stage than individual nasopharyngeal swabs." COVID victims

excrete viruses in their stool and when brushing their teeth — and on average, this begins more than a week before the onset of symptoms. This means that sewage analysis can be used to map current infection levels without the time delays that occur with individual testing, which has been the primary indicator until this point. "At the same time, the sewage samples give us a conclusive average value that covers every individual in the respective treatment plants' catchment area — we don't have to allow for undetected cases any more," emphasizes Dr. Udo Gommel, head of the Ultraclean Technology and Micromanufacturing division and the

The safety of the researchers conducting the tests is one of the many important concerns for the mobile lab.

Intelligent Automation and Cleanliness Technology department at Fraunhofer IPA. "Many people are tired of being tested, so they're no longer willing to go in for COVID screening. This solution gets around that issue without impacting data protection requirements." The test results show a relative viral load value for the water sample, which can be compared across different places or measuring points in order to ascertain how the virus is spreading. These tests are so sensitive that they can return a positive result if as few as 10 people out of 10,000 are infected.

There are already established methods for analyzing coronavirus fragments in sewage. First, the samples from the treatment plant are heated to kill any potential pathogens. Then, they are cleaned and concentrated. A magnet-based technology is used to collect all the RNA and DNA fragments in the sample. The scientists have special probes that can specifically identify, mark and reproduce the SARS-CoV-2 fragments. In the process, a light signal is produced, which can then be detected and assessed via quantitative real-time PCR measurement.

Stationary sewage analysis facilities for coronavirus monitoring are already being used to great effect in many countries around the world, such as the Netherlands, where they have been implemented on a large scale. However, the German government has proven much more hesitant so far, attempting just a few small, individual pilot projects. Meanwhile, last spring, the EU Commission requested that the member states implement more systematic initiatives for coronavirus monitoring via sewage analysis, and that they incorporate this technique into their national testing strategies for fighting the pandemic.

At the same time, Germany's established stationary sewage testing facilities are reaching their limits: most samples are not analyzed at the site where they are collected, but rather are sent to external testing labs, which leads to delays. "On top of that, you have the issue that, as yet, there is no standard protocol for analyzing sewage," points out Thude. Analysis guidelines for nasopharyngeal swabbing were created and widely distributed at an early stage, which meant that comparing data from different labs became possible very quickly. However, for sewage monitoring, each individual municipality is essentially left to decide for themselves how they will proceed.

Results within hours

"This is where our mobile testing laboratory comes into play," highlights Kreck. "It allows us to conduct the analyses directly at the sample collection site, and it only takes a few hours to get the results. Because all the analyses are performed by the same lab and we have a standardized procedure, the results can easily be compared with each other." The resulting data is also fed into an algorithm that uses artificial intelligence to predict the direction and speed at which the virus is spreading. "Then, based on the results, we get a recommended strategy for subsequent testing, so we don't have to carry out testing over an extensive area," Dr. Gommel explains.

A nationwide testing strategy

The project began back in summer 2020, with the mobile lab obtaining approval for road usage last winter. It was particularly challenging to incorporate all the elements of a standard stationary laboratory into the smallest possible space.

To keep the risks of cross-contamination as low as possible, two different compartments were created: one small section for water treatment and another larger one for the actual analysis. A hatch for passing the samples through links the two compartments. The researchers have also taken other steps to physically separate the stages of the workflow as far as possible. The equipment was specially selected so as to ensure that the smallest possible number of different instruments would be needed, while also allowing for a certain level of redundancy in case any equipment breaks down. The trailer is also equipped with a heating system, air conditioning and a fire alarm, as well as facilities for reagent cooling and safe waste disposal. Protective clothing is provided for the staff and all the necessary hygienic precautions have been taken.

"We have taken every possible aspect into account here, and created a laboratory with adequate space and equipment for conducting multiple, consecutive tests. The only thing it doesn't have is space to sleep," says Thude with a laugh.

Dikksi Co Vi has already completed its first successful test runs in the Stuttgart metropolitan region. Dr. Gommel is firmly convinced that the mobile lab could go all the way: "It would only take a very reasonable number of these units to implement an effective German-wide test strategy." ■

Photos: Fraunhofer IPA/Rainer Bez (2)

back to page 1

On your marks… get set… compute!

Quantum computers are an extremely promising technology. However, before they can really start providing comprehensive solutions to practical problems, they must overcome some obstacles first. The key question is, which technology will ultimately win the race to become the most reliable, scalable and economical qubit?

By Mandy Bartel

Take a normal computing bit and give it super powers: congratulations! You now have a qubit, the smallest unit of quantum computing — and that just happens to be our brightest hope for many scientific and technological fields that will play important roles in our future. However, the question of which method will become the established approach to solving the various different problems is still up in the air. After all, any quantum particle could theoretically be used as a qubit, from atoms and ions to electrons and photons. The particle only needs the ability to take on two different states, such as $|0\rangle$ and $|1\rangle$, the two lowest energy levels of the particle. This is known as a two-state system. However, what really makes quantum particles stand out is superposition, i.e. their ability to be in two states at the same time, and qubit entanglement, whereby the bits' states cannot be described independently of each other. It is these two effects that enable the unique functions of quantum computers and differentiate them from conventional computing systems. Quantum computers operate in a probabilistic rather than a deterministic way, so the results they deliver are always given in terms of probabilities.

The goal is to have the highest possible probability of obtaining the correct result. However, there are some significant obstacles in the way: existing systems are still prone to errors, because external factors disrupt the fragile quantum states. The coherence times during which the qubits are in a state of superposition or entanglement are still too short and the number of qubits is too few. This is why researchers in the Fraunhofer Competence Network Quantum Computing are currently trying out multiple technologies, and comparing them under various different headings: number (scaling), quality (coherence), execution speed and coupling of the qubit gates.

The speed merchant: superconducting qubits

Superconducting systems are in pole position in the quantum race at the moment, with backing from large manufacturers such as IBM and Google and the highest technology readiness level among the contenders. Superconducting qubits are artificial atoms manufactured on the basis of semiconductor technology. They enable rapid switching between quantum states and offer excellent prospects for scaling. However, their coherence times are very short and their calculations still suffer from high error rates. "The more qubits it uses simultaneously, the more error-prone a given algorithm will be. This means that researchers need to focus on significantly mitigating or correcting these errors, either by means of error mitigation protocols or connected, auxiliary qubits that identify errors," explains Dr. Christian Tutschku of the Fraunhofer Institute for Industrial Engineering IAO in Stuttgart. Another disadvantage of the superconducting qubits is that they must kept at temperatures close to absolute zero (-273.15 degrees Celsius), a very costly process. Various Fraunhofer institutes are currently collaborating in a wide range of projects aimed at developing quantum computing demonstrators based on superconducting circuits, integrating them into existing computing systems and optimizing the challenging process of manufacturing the superconducting qubits. Scientists are also ▶

Superconducting qubits must be cooled to

–273

degrees Celsius.

While a conventional computer uses bits for computing, a quantum computer uses qubits. Quantum computers are not just limited to a value of 0 or 1 — with quantum state superpositioning, they can also use any combination of the two states.

Photo: BADW/Kai Neunert

back to page 1

researching error correction techniques and new algorithms for practical applications, using the superconductor-based IBM Quantum System One in Ehningen.

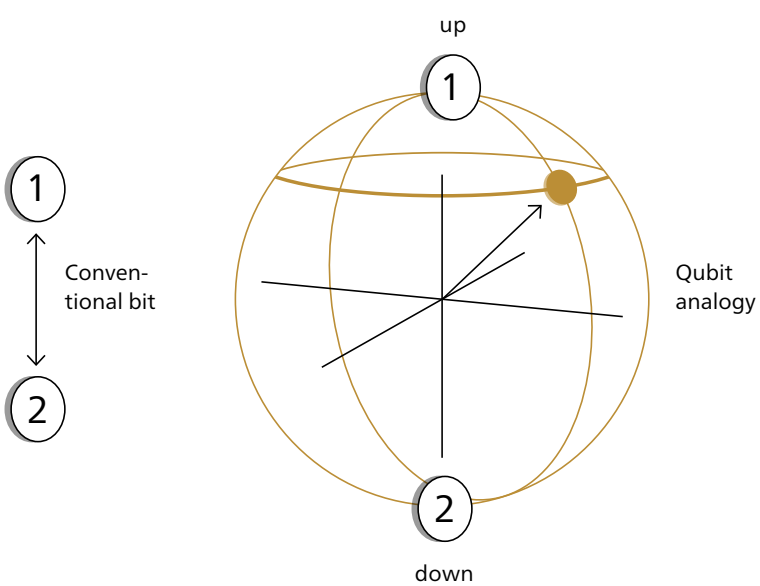
Mr. Slow-and-steady: trapped-ion qubits

Ions are a serious contender in the qubit world series. Electrical fields are used to catch them in ion traps where they can be controlled and operated via laser beams. They can also process quantum information. The ions may be slower than their superconducting rivals, but they allow for a higher quantum volume, a metric that enables comparability and takes into account not only the number of qubits but also their connectivity, error rates and stability. An important factor, given that in some applications, having just a few computing units with greater error tolerance can be more effective than many highly error-sensitive units. The primary points in favor of trapped-ion qubits are their excellent connectivity levels and long coherence times. In the IQuAn and ATIQ projects, Fraunhofer researchers are developing quantum computer demonstrators based on trapped atomic ions that can be used in fields such as quantum chemistry, solving optimization problems with parallel gates, and credit risk assessments. "Currently, our research is focused on scalability and improved performance, which we hope to achieve through new trap designs that use 3D structures. Sometimes just a few micrometers in size, these structures allow easier functionalization of ion traps and better shielding from parasitic electrical fields. The entire trap is manufactured using our selective laser-induced etching (SLE) process," explains Sebastian Simeth of the Fraunhofer Institute for Laser Technology ILT, which is one of the project participants.

Ions may be slower than their superconducting rivals, but they allow for a higher quantum volume.

The jewel in the crown: Diamond-based spin qubits

Spin qubits are also making their presence felt in the scramble for quantum supremacy. Experts manufacture them using optically addressable F-centers in a diamond substrate. F-centers are nitrogen defects in the diamond matrix, consisting of a foreign nitrogen atom within a vacancy in the matrix. The electron spin of the F-center can function as an output qubit, when coupled with the nuclear spin of the surrounding atom. In SPINNING, a joint project led by Fraunhofer, researchers have set out to create photonic connections between individual quantum registers via light particles. "At the end of the project, we aim to realize up to 20 qubits in a spin-photon-based quantum processor. The photonic coupling allows us to achieve a compact structure, while also giving us the ability to scale the processors in the long term," says Daniel Hähnel, a department head at the Fraunhofer Institute for Applied Solid State Physics IAF and coordinator of the SPINNING project. Unlike superconducting quantum computers, diamond-based qubits can maintain superpositioning for multiple milliseconds, even at room temperature. However, more research is required to improve the error tolerance and the reproducibility of the process.



Qubits can be visualized as rotating particles, where the spin axis only settles on a fixed position when they are measured. Correlations of qubit states are used for computing.

In the SPINNING project, scientists are working to develop a compact, scalable quantum processor that can be connected to a conventional computer.

The shining lights: photonic qubits

One option that can be described in glowing terms — literally — uses "squeezed" light in special, integrated light channels on silicon wafers. In these photonic integrated circuits, the light particles can be used as qubits and can be monitored and controlled with almost no losses even at room temperature. The photonic approach also offers advantages in terms of scaling, because the functions needed for the computing operations can be implemented on a single chip using established semi-conductor manufacturing processes. In the PhoQuant project, some 14 partners are developing a new, photonic computer architecture for industrial applications, such as optimizing airport schedules in real time when unexpected delays arise. The researchers are not only developing algorithms for specific problems, but also for universal quantum computing applications. In PhoQuant, the Fraunhofer Institute for Applied Optics and Precision Engineering IOF in Jena is laying the technological groundwork for quantum computing, with solutions such as optically integrated quantum light sources and low-loss optical and fiber-optic interferometers for combining light waves. The Dresden-based Fraunhofer Institute for Photonic Microsystems IPMS is bringing its expertise to bear by developing FPGA and ASIC architectures; these are integrated circuits with active interfaces, which make it possible to control and evaluate the functionalities of the photonic chip with great precision. This project represents an important step on the road to scalable, error-tolerant, photonic qubit technologies.

The tough guy: atom qubits

Atom qubits have very low susceptibility to disruption. As part of the Munich Quantum Valley initiative, Fraunhofer is working to develop a quantum processor based on neutral atoms in the MUNIQC-Atoms project. Individual strontium atoms, which function as the computing units, are caught in special optical traps using laser pincers and cooled. These atoms can be excited and moved using individual laser beams. As only individual atoms require cooling, the expensive process of keeping the entire qubit system at extremely low temperatures is not necessary here. What's more, due to their electrical neutrality, atoms are less sensitive to disruptions, which results in longer coherence times. The project partners aim to demonstrate the basic functionality of the quantum processor, its scalability and the possibility of accessing it externally. The Fraunhofer Institute for Integrated Circuits IIS is developing control electronics for directing the lasers. The researchers' goal is to create a quantum processor with up to 400 qubits by 2026.

In the coming years, a winner will emerge victorious from the quantum marathon. However, by themselves, hardly any of these technologies are likely to make it to the finish line. Ultimately, the greatest potential lies in a combination of quantum and classic high-performance computers (HPC). In this kind of system, quantum processors could massively increase the speed of the type of computing operations they are suited to, while the other processors would handle the remaining tasks. The old saying still holds true: many hands make light work. ■

Atom qubits have a very low susceptibility to disruption. As only individual atoms require cooling, the expensive process of keeping the entire qubit system at extremely low temperatures is not necessary.

Photo: AdobeStock

back to page 1

Ready for action with artificial intelligence

The new era of 2022, as proclaimed by German Chancellor Olaf Scholz, is defined by the pervasive feeling that nothing in our world is certain any more. What's more, he believes Germany and Europe need to prepare themselves in order to make their economies and societies resilient enough to withstand these times of war, energy crises and climate change. Could artificial intelligence help?

By Beate Strobel

In the future, artificial intelligence may be able to predict natural catastrophes well in advance, like the virtually unprecedented flooding on the Elbe in August 2002.

In an analysis of the potential of artificial intelligence (AI) back in 2017, the Fraunhofer Big Data and Artificial Intelligence Alliance stated that "We have come to a turning point." The alliance predicted that this technology, "in the form of talking devices and digital assistants, cooperative robots, autonomous vehicles and drones," would pervade our everyday lives with "astonishing speed," making us more comfortable and safer.

The DAKI-FWS (Data- and AI-supported early warning system for stabilizing the German economy) project, commissioned by the German Federal Ministry for Economic Affairs and Climate Action (BMWK) as part of its AI innovation competition, is an ambitious step in this direction. Launched in December 2021, the goal of the project is to develop an early warning system that can detect both infectious disease crises, such as a virus pandemic, and natural and climate-related catastrophes such as floods and heat waves. This system will place a particular focus on warning companies well in advance, so that they can make decisions in good time.

Predicting catastrophes using data analysis is not a new idea. "There are already a lot of very specialized expert solutions in this area," confirms mathematician Dr. Jackie Ma, head of the Applied Machine Learning Group at the Fraunhofer Heinrich Hertz Institute HHI, which has taken on the overall management of DAKI-FWS. However, the wide range of possible catastrophes that this project covers is what sets it apart. "What's especially exciting is that in DAKI-FWS, we've linked infectious disease data — such as incidence rates, hospital bed occupancy and transmission rates — with data sources such as temperature, rainfall and traffic data," explains Dr. Ma. The researchers have set themselves the lofty goal of building up a more comprehensive overview of the complete picture and making more precise projections.

So, are we on the verge of having a supercomputer with a flashing blue light to tell us when things are getting dicey in Germany or Europe? "That's not how it works in reality," laughs Fraunhofer HHI expert Dr. Ma. The intention in the DAKI-FWS project is to create an AI-based crisis intervention platform that can be fed with a large amount of varied data in the simplest way possible. An AI will analyze this and develop projections, which will then be shared with as many companies as possible — similar to the COVID-19 dashboard that the Robert Koch Institute uses to publish the current numbers of coronavirus cases.

> "An early warning system like DAKI will only work if politicians, industry and the general public trust it."
>
> Dr. Jackie Ma,
> head of the Applied
> Machine Learning Group
> at Fraunhofer HHI

Fraunhofer HHI can build on the expertise gained through previous successful Fraunhofer projects: The SAUBER project provides AI projections regarding the air quality in different cities and regions, using data from the Copernicus space program as its primary basis. The KLIPS project, on the other hand, focuses on AI-driven predictions of what are known as heat islands in cities. "In terms of technology, there are a lot of similarities between these two projects and our new early warning system," explains Dr. Ma. "However, the scale of DAKI-FWS is significantly larger." In addition to Fraunhofer HHI, the consortium project involves the Charité university hospital in Berlin, the Justus Liebig University in Giessen, the Robert Koch Institute, the Zuse Institute Berlin and the Hasso Plattner Institute for Digital Engineering gGmbH, as well as the companies Budelmann Elektronik, Data4Life, LOGIBALL, NET CHECK and Esri Deutschland.

While artificial intelligence has proved its worth in the sales and finance sectors, applying AI in the field of natural catastrophes is much more challenging. "Modeling the planet is unbelievably difficult," explains project manager Dr. Ma. "The models required are extremely complex, and the quantities of data we're feeding in are enormous and technically very difficult to handle." Like weather and climate phenomena, viruses do not generally tend to stay within geopolitical boundaries — which is why it only makes sense to use global data in the DAKI-FWS project in the long term. However, in terms of quality and quantity, this data can vary hugely: While China, for example, collects data on everything but is extremely reluctant to share it, far less data is collected in the Global South. Then there's the fact that strict German and European data protection laws make it difficult to use Big Data. "You can't cut corners when it comes to data protection," says Dr. Ma. "An early warning system like DAKI will only work if politicians, industry and the general public trust it."

These days, artificial intelligence is already a "master projection maker," as the Zukunftsinstitut (institute for the future) in Hamburg puts it. And its potential is becoming more obvious all the time. Particularly when it ▶

Photo: picture-alliance/Jens Büttner

back to page 1

comes to analyzing enormous quantities of data in the short possible period of time, identifying patterns and using them to make predictions, nothing can beat artificial intelligence. This technology is also being harnessed by the energy industry to an increasing extent, as this sector is facing problems due to the growing volume of decentralized renewable energy being fed into the grid: How can grid operators guarantee a reliable supply of energy to industry and society when energy sources like wind and solar power are as unreliable as, well, the weather?

For the energy sector, particularly grid operators, the task now is to strike a balance between energy production and consumption. Due to the energy transition, as energy production becomes more reliant on the weather and increasingly decentralized, operators have to intervene more and more often — such as when energy produced by wind turbines in northern Germany is needed in the south. If there is a threat of a power supply overload in a section of cable somewhere along the electricity highways, large power plants upstream of the expected electricity congestion must be shut down, while downstream power plants increase production. These kinds of interventions by the grid operators to change the power plants' original feed-in plan ("dispatch") is known as "redispatch." As they cause extra costs and lead to expensive processes like shut-downs and supply from alternative sources, they should occur as infrequently as possible.

> "The world isn't made up of simple if-then statements — it's a web of extremely complicated relationships that still contain a lot of unknowns."
>
> Dr. Jackie Ma

Since October 2021, Germany's Redispatch 2.0 regulations have ensured that a significantly greater number of small, controllable energy production plants are being included in redispatch processes. However, the BMWK is going a step further by supporting the Redispatch 3.0 research project. In order to avoid bottlenecks even in the smallest sections of the power grid, the projections in this project will also incorporate medium- to low-voltage grids, right down to the level of private micro-plants. Led by the computer science institute OFFIS, the project was launched this year and involves research institutions, grid operators, software manufacturers, the Fraunhofer Institute for Applied Information Technology FIT and the Fraunhofer Institute for Energy Economics and Energy System Technology IEE.

Redispatch 3.0 faces a challenge: "Unlike maximum- and high-voltage grids, there are only a few measurement points at lower voltages," explains Dr. Frank Marten, subproject manager at Fraunhofer IEE. The researchers plan to use artificial intelligence to fill in the blind spots in the grid map. "The AI fills in the incomplete grid overview by analyzing the measured values for each cable and connection and searching for the state that would best explain those figures," says the physicist. "To do that, you have to train neural networks with real measurement data from the distribution grid, or from power grids that have been modeled on a computer. In the next step, the neural network is given new data that is incomplete — and is tasked with filling in the gaps."

The complete overview that this produces can not only quickly create outlines of real-life situations, but also possible future ones, which helps with making predictions regarding the grid. Because when you take into account the many uncertainties associated not only with renewable energy sources, but also with energy consumers, "just predicting the next few hours would result in an astronomical number of possible combinations in the equations for the grid," Dr. Marten points out. "The result would be a range of possible future grid states. The trained AI helps us bypass the complicated grid calculations and proceed directly to the estimation step much more quickly." With weather-dependent renewable energy production currently on the rise, Redispatch 3.0 could not only guarantee a secure energy supply, but also keep costs under control.

But does this mean our world is going to become a land of complete predictability, where artificial intelligence gives us advance warning of everything from running out of milk to major earthquakes in the Pacific right up to large-scale military conflicts? Mathematician Dr. Ma doesn't believe so. "The world isn't made up of simple if-then statements — it's a web of extremely complicated relationships that still contain a lot of unknowns." In particular, geopolitical upheaval such as the Russian war of aggression against Ukraine are very difficult predict in the long term. Even with artificial intelligence, it's still hard to explain the human lust for power. ■

Scan here for the podcast:

Brew number two

You can read your fortune in coffee grounds — And now, as part of the InKa project, researchers are working on more sustainable uses for this rich substance.

By Claire Stark

Valuable waste: Coffee grounds contain up to 25 percent coffee oil.

A team from the Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT is aiming to process coffee grounds into high-quality intermediate products. The researchers have identified potential uses for this in fields such as the paper and cardboard industry and bioplastics production.

The industrial production of instant coffee generates large quantities of coffee grounds. This process uses far more effective extraction systems than standard household coffee machines. Nevertheless, every 1 kilogram of soluble coffee produces 2 kilograms of wet coffee grounds, and at present, most of this is thermally recycled, i.e. burned. The valuable substances they contain remain unused. To put various possible recycling methods to the test, the researches separated the coffee grounds into their individual components. These included coffee oil, which amounted to 20–25 percent of the grounds.

This oil consists of up to 44 percent glycerol esters of linoleic acid, a double unsaturated fatty acid. "The only other place you will find these amounts of linoleic acid are in high-quality edible oils," explains Dr. Inna Bretz, head of the Circular and Bio-based Plastics department at Fraunhofer UMSICHT. "Our goal is to isolate and modify this fatty acid in order to make it usable for other products or for chemical syntheses." To do this, the researchers carry out a process of transesterification, where the bond between the linoleic acid and glycerin is broken and the fatty acid forms a new compound with an added alcohol, allowing it to be isolated. It is then chemically modified so that it can be used as an additive in bio-based plastics.

There are also potential ways to use the de-oiled coffee grounds. Together with their project partner BellePapier GmbH, Fraunhofer is investigating how these can be applied in the manufacture of paper and cardboard — as a brown dye for cardboard, for example. They are also currently experimenting with using the oil as an additive in tissue products such as wet wipes.

There are still a number of challenges to overcome before the method is ready for the market. This includes scaling up processes from the laboratory to industrial production. "There are up to five steps involved in the process of turning coffee grounds into additives for bioplastics. And when scaling up, every step has to be adjusted accordingly," says Dr. Bretz. The logistical aspects are also challenging. Transportation and storage must be optimized to prevent the formation of mold, which can alter the substances contained in the grounds, resulting in the production of toxic materials. For this reason, InKa will only work with industrial partners who already use freeze-drying to produce instant coffee, as this means they can also ship the coffee grounds freeze-dried. To this end, the project is seeking other companies in the industry that are interested in collaborating. ■

Scan here for the podcast:

Photo: Unsplash/Devin Avery

back to page 1

A voice from the business world

Dr. Volker Treier, Chief Executive of Foreign Trade at DIHK, at the 16th export control day (Exportkontrolltag) in Berlin.

Supply chains in disarray

With container ships stuck in traffic jams and staff shortages in the logistics sector, we can no longer rely on goods arriving "just in time." The time has come to build up greater resilience.

Dr. Volker Treier, Chief Executive of Foreign Trade at the Association of German Chambers of Commerce and Industry e. V. (DIHK), shares his thoughts

Some 36 percent of companies expect a change in their transportation routes in the long term. 27 percent expect a greater diversification of their suppliers, while 22 percent plan to relocate production facilities or branches, or at least anticipate that they will do so, in order to move closer to sales markets and shorten transportation routes. These are the findings of a recent survey conducted worldwide among the member companies of the German Chambers of Commerce Abroad.

The coronavirus pandemic has thrown global supply chains into disarray — including the international German economic network. Before,

companies could rely their materials being delivered "just in time" for production. However, for months now, jams in container ship traffic, staff shortages in the logistics industry and an imbalance between supply and demand have been leading to empty warehouses, reduced production and enormous price increases. Supply chain management has become a major challenge for German industry, which is oriented towards exports and largely consists of medium-sized companies.

The return of lockdowns in China, Germany's most important trading partner, as well as upheavals in world trade caused by the war in Ukraine and sanctions against Russia, mean that, once again, there is no immediate improvement in sight for supply chains.

The effects of material shortages and price increases could be mitigated through new measures in the areas of trade, industry and environmental policy. In the short term, the suspension of duties or punitive tariffs on certain scarce products could bring some relief. The European Union (EU), for example, imposes various anti-dumping duties on steel, aluminum and fertilizer products that are either currently in short supply in Europe or have seen sharp increases in price.

Political intervention aside, companies are working at full steam to make their supply chains more resilient. And as survey figures show, they are examining their supply relationships and production sites with a critical eye.

The German Chambers of Commerce and Industry, a network of 79 chambers of industry and commerce in Germany, and the German Chambers of Commerce Abroad (AHK), which has 140 locations in over 90 countries, actively support companies to help them restructure their supply chains. A number of "German chambers of commerce abroad" (German organizations established in foreign countries with the aim of advising, supporting and representing German companies) have come together to set up the AHK Industrial Suppliers Forum. The purpose of the forum is to connect industrial suppliers from European countries with buyers and sales partners from Germany, thereby creating one of the largest supplier communities in Europe. In addition, the German Federal Ministry for Economic Affairs and Climate Action (BMWK) is supporting competence centers that focus on raw materials, which are located at several AHKs in resource-rich countries. The aim of these competence centers is to provide information about the opportunities and risks associated with the markets and to support companies in establishing business relationships, whether for procuring raw materials or marketing their own mining technologies.

Politicians must support the realignment of supply chains by providing suitable framework conditions. Diversifying import sources and working to expand and intensify trading partnerships through trade agreements, for example, can help companies to spread their supplier network across several countries and regions. After all, reliable trade agreements break down barriers to trade and create common standards based on legal security and planning security. For example, the EU could implement the trade agreements negotiated with Mercosur, South America's common market that includes Chile, Mexico and New Zealand.

In addition to trade policy measures, the EU will also provide vital momentum for ensuring the resilience of supply chains in terms of industrial and environmental policy. Expanding the circular economy in Germany and the EU can help ensure that raw materials remain sufficiently available. Increasing the rate at which materials are reused will not only ensure a lower output of emissions, but also a greater level of independence when importing primary raw materials. There is a need for greater research and development, both in terms of materials that can be recycled, i.e. as part of a circular economy, and in terms of recycled materials that can be used in place of primary raw materials. Higher rates of energy efficiency in industry will also contribute to alleviating shortages of raw materials, offering scope for further research regarding, for instance, increasing the utilization rates of energy carriers and increasing the energy efficiency of production by converting machines and making it possible to process alternative materials. Political measures to promote research projects, help the workforce acquire the necessary expertise and remove regulatory hurdles in these fields would also have a positive effect.

However, at a time when company supply chains are in such disarray, increasing the bureaucratic requirements that companies must meet, for example through the Supply Chain Due Diligence Act (Lieferkettensorgfaltspflichtengesetz, LkSG), creates further challenges. In order to get an overview of the risks in their supply chains, companies will tend to limit themselves to fewer suppliers from fewer countries, which prevents necessary diversification processes and negatively effects the resilience of their supply chains. ■

"There is a need for greater research, both in terms of materials that can be recycled, i.e. as part of a circular economy, and how recycled materials can be used in place of primary raw materials."

Dr. Volker Treier

- Chief Executive of Foreign Trade at DIHK and Member of the Executive Board since January 2019.
- Dr. Treier first started with the German Chambers of Commerce and Industry e. V. in 2003 and has since held numerous positions, from head of the department for economic cycle and growth policy, to Managing Director International Economics Affairs.
- Studied economics and completed a doctorate in Economic Sciences in Bamberg on the subject of fiscal competition in Central and Eastern Europe entitled "Realität oder Fiktion?" (Reality or fiction?).
- Was born in Creglingen in Baden-Württemberg on August 6, 1969.

Photo: DIHK/Jens Schicke

back to page 1

Alexa, we have to talk!

Amazon Alexa and Google Assistant collect user data non-stop. A research team at Fraunhofer FIT aims to support users in better protecting their privacy.

By Britta Widmann

Alexa, Google Assistant and co. are a wonder of the smart home — for some. For others, voice assistants are modern-day spies. Indefatigable and always on standby, voice assistants embedded in smart speakers and smartphones collect data on users' daily lives. In the CheckmyVA project, researchers at the Fraunhofer Institute for Applied Information Technology FIT are working with partners to develop an online platform that supports users in safeguarding the rights guaranteed to them under the General Data Protection Regulation (GDPR). Using established data science and AI methods, the platform will process users' data to create a user-centric visualization, with the aim of making consumers aware of the behavioral patterns that can be deduced from their data and the purposes for which third parties could use this information.

Not only that, but users will be given a simple tool they can use to implement their GDPR rights. The GDPR gives consumers the opportunity to obtain information on their collected data, as well as to modify and erase it. However, most people are not familiar with the process required. Furthermore, if the information is presented as a collection of raw data, it is incomprehensible to non-experts.

"The platform will have a dashboard that runs as a browser plug-in. Users will be able to easily request a copy of their data here. The link to the privacy settings is easy to find," says Dominik Pins, project coordinator and scientist at the Human-Centered Engineering and Design department at Fraunhofer FIT.

Cartoon: CLOUD SCIENCE/TechToons

The dashboard shows conversations with voice assistants on a timeline and makes the transcriptions more transparent. For example, it shows the commands that were given and how often a user unintentionally gave a command. The dashboard will also show the voice assistant's responses. "Thanks to the platform, users are able to reflect on their data traces," says Pins, the project manager. "This way," he believes, "they can improve their data literacy." The dashboard can be downloaded for Google Chrome and Mozilla Firefox free of charge through the respective browser settings, or from the project website.

The methodology of the project is based on an experimental learning environment known as a living lab. 33 households from all across Germany are taking part, including families, couples and single-person households. The researchers will monitor the participants for a period of almost three years. During that time, they will hold regular discussions with the participants regarding their use of voice assistants, as well as any concerns they have on the subject. How do they use the voice assistant (the focus primarily being on Amazon Alexa and Google Assistant)? Do they use smart home functions? Is the voice assistant always left on, or is it only activated when needed? Does their use change over the course of the project? Are the households aware of what happens to the recordings? What data protection practices do the users employ? What problems come with this? What does a voice assistant know about a household? What data does it save? The aim of the living lab is to collect information on usage practices, to work with consumers in developing requirements for the platform and to test the use of the prototype platform under real conditions. ■

Knowledge relay

hydrogen

Knallgas

safe

?

back to page 1

Alexa, we have to talk!

Amazon Alexa and Google Assistant collect user data non-stop. A research team at Fraunhofer FIT aims to support users in better protecting their privacy.

By Britta Widmann

Alexa, Google Assistant and co. are a wonder of the smart home — for some. For others, voice assistants are modern-day spies. Indefatigable and always on standby, voice assistants embedded in smart speakers and smartphones collect data on users' daily lives. In the CheckmyVA project, researchers at the Fraunhofer Institute for Applied Information Technology FIT are working with partners to develop an online platform that supports users in safeguarding the rights guaranteed to them under the General Data Protection Regulation (GDPR). Using established data science and AI methods, the platform will process users' data to create a user-centric visualization, with the aim of making consumers aware of the behavioral patterns that can be deduced from their data and the purposes for which third parties could use this information.

Not only that, but users will be given a simple tool they can use to implement their GDPR rights. The GDPR gives consumers the opportunity to obtain information on their collected data, as well as to modify and erase it. However, most people are not familiar with the process required. Furthermore, if the information is presented as a collection of raw data, it is incomprehensible to non-experts.

"The platform will have a dashboard that runs as a browser plug-in. Users will be able to easily request a copy of their data here. The link to the privacy settings is easy to find," says Dominik Pins, project coordinator and scientist at the Human-Centered Engineering and Design department at Fraunhofer FIT.

Cartoon: CLOUD SCIENCE/TechToons

The dashboard shows conversations with voice assistants on a timeline and makes the transcriptions more transparent. For example, it shows the commands that were given and how often a user unintentionally gave a command. The dashboard will also show the voice assistant's responses. "Thanks to the platform, users are able to reflect on their data traces," says Pins, the project manager. "This way," he believes, "they can improve their data literacy." The dashboard can be downloaded for Google Chrome and Mozilla Firefox free of charge through the respective browser settings, or from the project website.

The methodology of the project is based on an experimental learning environment known as a living lab. 33 households from all across Germany are taking part, including families, couples and single-person households. The researchers will monitor the participants for a period of almost three years. During that time, they will hold regular discussions with the participants regarding their use of voice assistants, as well as any concerns they have on the subject. How do they use the voice assistant (the focus primarily being on Amazon Alexa and Google Assistant)? Do they use smart home functions? Is the voice assistant always left on, or is it only activated when needed? Does their use change over the course of the project? Are the households aware of what happens to the recordings? What data protection practices do the users employ? What problems come with this? What does a voice assistant know about a household? What data does it save? The aim of the living lab is to collect information on usage practices, to work with consumers in developing requirements for the platform and to test the use of the prototype platform under real conditions. ■

Knowledge relay

When it comes to *hydrogen*, many people are concerned about the *Knallgas reaction* — Prof. Tobias Melz, *how safe are these new technologies*?

back to page 1

Knowledge relay, episode 5

When it comes to hydrogen, many people are concerned about the Knallgas reaction — Prof. Tobias Melz, how safe are these new technologies?

Series:
Knowledge relay

The times we live in are raising **lots of questions — Fraunhofer researchers are working hard to find the answers.** A specialist **answers a question,** then poses a **question of their own** for the **next expert** to answer — it's a **"knowledge relay."** In this edition, **Prof. Tobias Melz,** Director of the Fraunhofer Institute for Structural Durability and System Reliability LBF, responds to a question posed by **Prof. Anke Weidenkaff,** Director of the Fraunhofer Research Institution for Materials Recycling and Resource Strategies IWKS.

Even though many people know very little about hydrogen (H_2) technology, it is still set to be an important part of our future energy supply system. Climate protection, the war in Ukraine and the extreme impact on natural gas supplies are all making H_2 look like a very promising alternative — even with all the justified criticism surrounding it. Discussions currently center on production, costs and infrastructure, with questions regarding safety also arising frequently. As any chemistry student will tell you, the combustion of hydrogen and oxygen causes a Knallgas explosion. What are the risks associated with this? And can they be controlled?

Safety and reliability are important. Every new technology comes with new opportunities and risks that must be identified, understood and safely controlled. As engineers, we must handle this task. Just in the far-reaching world of Fraunhofer alone, three major projects are currently addressing the questions that have been raised about hydrogen technology — H_2Giga, H_2Mare and TransHyDE. The Fraunhofer Institute for Structural Durability and System Reliability LBF is also carrying out intensive research into hydrogen, particularly in relation to reliability. The LBF researchers are focusing on the properties of H_2 to begin,

Prof. Tobias Melz is director of the Fraunhofer Institute for Structural Durability and System Reliability LBF.

especially as regards its interaction with materials and the precautions that can be taken to improve safety.

H_2 molecules are very small, and they can permeate metal surfaces and react with them. At room temperature, H_2 is a gas; it becomes liquid at -253 °C and can easily react with oxygen to form water. This reaction, which releases a large amount of energy, is the whole reason that we can use H_2 as an energy carrier. If not controlled, it can actually be explosive; however, when it is controlled, for example in fuel cells, the reaction is safe because it takes place at the molecular level in the fuel cells, rather than in large volumes of gas.

H_2 — a true all-rounder

Hydrogen has been used on a large scale in industry for quite some time, whether in the extraction of raw materials, in processes or in the production of ammonia and fertilizers. The concepts of electrolysis and fuel cells have been around for over 150 years. However, in recent years, these fields have heralded many new developments, including innovative materials, structures, applications and many overall] influencing factors. In addition, repurposing existing structures such as the natural gas network needs to be considered.

Apart from economic challenges, there is one significant problem associated with H_2: especially under standard operating conditions, H_2 can react with various materials, causing brittleness and cracking, which leads to damaged seals, uncontrolled leaks or even ruptures. It is important that we understand the chemical and mechanical stresses that simultaneously affect components and systems, as well as the resulting impact on safety and reliability at both a small and large scale, and bring these factors under control in the design and operation phases. To achieve this, after the material, component and system stresses have been identified, a stress resistance analysis is usually carried out. It is increasingly common to conduct this analysis using a combination of digital simulations and real-world experiments. In addition, the components that come into contact with H_2 can also be continuously monitored during operation, in order to detect damage as quickly as possible and initiate countermeasures. If the mechanisms causing damage are known, suitable digital twins can be used to monitor the components, make reliability predictions for the overall system and estimate the effects of damage and failures in sub-systems.

However, dealing with these kinds of connected systems actually gives rise to another safety-related question: How well prepared are Germany's critical research and industry infrastructures in terms of cybersecurity? ■

Safety and reliability are important. Every new technology comes with new opportunities and risks, that must be identified, understood and **_safely controlled._**

In the next issue:

How well prepared are _Germany's critical_ research and industry _infrastructures_ in terms of cybersecurity?

Photo: Piotr Banczerowski/Fraunhofer LBF

back to page 1

Cyberwarfare

Red alert in cyberspace

As the invasion of Ukraine has shown, wars are no longer fought on battlefields alone — the virtual world has long become a conflict zone, complete with highly professional hacking attacks and targeted disinformation. How can Germany improve its defenses?

By Dr. Sonja Endres
Photography: Gene Glover, Jonas Ratermann

"The lines between internal networks and the outside world are becoming blurred. In the face of this development, security models based on bundling every component into one secure network no longer make the grade," says Martin Seiffert of Fraunhofer AISEC.

back to page 1

The online war began months before Putin gave his troops their marching orders. Hackers had been preparing for the Russian invasion since at least the December of the previous year, according to Prof. Haya Shulman, who has been researching the cyberattacks on Ukrainian infrastructure. In addition to holding a professorship at the Goethe University Frankfurt, Prof. Shulman heads up the Cybersecurity Analytics and Defences department at the Fraunhofer Institute for Secure Information Technology SIT in Darmstadt and coordinates the Analytics Based Cybersecurity research division of the National Research Center for Applied Cybersecurity ATHENE.

Among other things, she discovered that the malware that caused a system breakdown in the communication satellite KA-SAT on the day of the Russian invasion of Ukraine had infiltrated it months in advance. KA-SAT is a broadband internet provider with customers across Europe and is used by the Ukrainian army for emergency communications. "The hackers' goal was to prevent communication, and they succeeded. It took a month to rectify the damage, or at least the majority of it," relates Prof. Shulman. The Russian attack on KA-SAT took its toll in Germany and across Central Europe too, as remote maintenance and control ground to a halt for some 5,800 wind turbines. The outage impacted turbines in remote locations that access the internet via a satellite connection. While they did keep generating electricity, it was only possible to detect and rectify technical problems directly on site.

Malicious software also found its way into the Ukrainian railway system infrastructure ahead of the Russian invasion. Luckily, it was discovered before the war broke out, and the system was cleaned up. "Otherwise, the Ukrainian people's ability to escape the war would have been much more limited," states Prof. Schulman. She and her team have also identified numerous denial-of-service attacks, whereby web servers are deliberately bombarded with so many requests that the system can no longer keep up with the number of tasks and breaks down. The hackers had set their sights on targets such as telecommunications companies, the media and important government agencies. Official websites were often unavailable and large portions of the population had no access to up-to-date information about the war. Prof. Shulman and her team also noted attacks known as defacements, where hackers often imitate their target websites. Sometimes their goal was to spread disinformation, but they can also use these attacks as a means of installing malware. All it takes is one click on the fake webpage, and an execution program opens and installs malware on the computer. Wiper attacks have also been coming in droves. A wiper is a form of malware that renders systems unusable by deleting critical data. "They used at least seven different wiper programs, some specially designed for end user devices, some for servers and others for network devices. Wiper malware was involved in the KA-SAT attack, for example," explains Prof. Schulman. The objective of all these attacks was to impede communications across the board, incite panic and chaos, and generally weaken the country. This kind of warfare is nothing new on the internet: the Russian invasion of Georgia in 2008 was supported by very similar cyberattacks.

"Just because we haven't noticed anything does not mean that nothing is happening. Malware can lie dormant in systems for years, undiscovered and always ready to strike."

Prof. Haya Shulman, Fraunhofer SIT

Hacking attacks cause extensive damage

After the annexation of Crimea in 2014, Ukraine suffered severe hacking attacks more and more frequently. In 2015, government or government-affiliated groups from Russia crippled parts of the Ukrainian power grid. In 2017, ▶

Prof. Haya Shulman has already snapped up many a big catch in the shark tank of the world wide web. An Israeli with German roots, she learned her trade in the cybersecurity division of the Israeli army, which is known worldwide as a training ground for the elite warriors of the cyber world.

back to page 1

146,363
cybercrimes were recorded by the BKA in 2021.

the malware NotPetya caused enormous damage, first in Ukraine and then worldwide, ultimately amounting to at least 10 billion US dollars. Ukraine learned from these painful experiences, and over the last number of years, it has made significant improvements to its cybersecurity, with some help from the West. This is why the country was able to discover and defeat the malware in its railway system in time, before it could be activated. "Germany also urgently needs to substantially increase cybersecurity for our government authorities, companies and overall infrastructure," warns Prof. Shulman emphatically. German Federal Minister of the Interior, Nancy Faeser, believes that more than 10 billion euros will have to be invested in improving cybersecurity by 2030 — particularly as regards the governmental networks that ministries and authorities use to communicate.

Even as early as 2021, the German Federal Office for Information Security (BSI) rated Germany's IT security situation as being in a "serious to critical" condition. According to the BSI's report, the problem is not just that the number of malware variants detected has grown at meteoric speed, reaching the highest value ever measured at up to 553,000 new variants per day; the quality of the attacks has also increased considerably. Last year, the German Federal Criminal Police Office (BKA) logged a new record number of cybercrimes, at 146,363 — an increase of more than 12 percent when compared to 2020. The coronavirus pandemic accelerated the digital transformation process, which has created a whole host of new opportunities for cybercriminals. According to the BKA, the Ukrainian war and the hybrid attacks used by the combatants could potentially act as an additional catalyst for cybercrime.

Prof. Shulman and her colleagues at Fraunhofer SIT are collaborating closely with the authorities. Their worry is that, as the Russians come under increasing pressure due to sanctions and their political and economic isolation, they will respond with even more disinformation, cyberattacks and cyberespionage. These attacks are probably already well underway, Prof. Shulman argues, recalling Russia's systematic preparations for the attack on Ukraine. "Just because we haven't noticed anything does not mean that nothing is happening. Malware can lie dormant in systems for years, undiscovered and always ready to strike. Cyberespionage is always covert. A successful attack is one that no one discovers — and the hacker groups run by the GRU, Russia's armed forces and the FSB, its national security service, are extremely professional."

"If these controls are based on a zero-trust strategy, this means that traffic and every access to resources are constantly monitored and validated."

Martin Seiffert, Fraunhofer AISEC

The USA is leading the charge here. In January, binding orders were issued to the effect that all American federal authorities must implement **zero-trust security architectures** by the end of **2024**

We can't just carry on as before

If we want to be better prepared in this area, it will not be enough to continue as before. Standard measures such as eliminating vulnerabilities, regularly installing updates and blocking spam emails are still as important as ever — but they will not be enough to reliably ward off cyberattacks in the future. This is why Prof. Shulman is calling for a fundamental switch to using zero-trust security architectures across IT systems. The principle behind these architectures is that no one can be trusted — not even within the system's own network. Traditional perimeter-based models protect IT systems by means of firewalls and virtual private networks (VPNs). Once an attacker overcomes these defenses successfully, they can move around at will within the network. But not in a zero-trust system: here, every time data is accessed, a new authentication is required. The group of authorized personnel is kept as small as possible in order to reduce security risks and the directives regarding which users, services, devices and applications are permitted to interact are constantly updated.

Even before the war in Ukraine, there was a clear trend toward adopting zero-trust systems. The USA is leading the charge here. In January, binding orders were issued to the effect that all American federal authorities must implement zero-trust security architectures by the end of 2024. The recent geopolitical developments could give Germany's implementation process a significant boost. Haya Shulman and her team, as well as their colleagues at the Fraunhofer Institute for Applied and Integrated Security AISEC, help a wide range of companies and various organizations in making their IT systems more secure. Their first step here is to create a model of the whole system. "We check what data is exchanged between components, what data is stored and why. Then we identify security goals, such as ensuring confidentiality of the data or their integrity, i.e. making sure it cannot be modified," explains Martin Seiffert, a senior scientist in the Secure Systems Engineering department at Fraunhofer AISEC. Finally, they analyze how easily an attacker could breach these security goals and develop controls for countering these threats.

"Whether a post is actually disinformation or not is something for a human to decide. We only identify suspicious messages."

Prof. Martin Steinebach, Fraunhofer SIT

"If these controls are based on a zero-trust strategy, this means that traffic and every access to resources are constantly monitored and validated. However, data protection requirements must always be guaranteed," Seiffert continues. If, for example, a user were to access data first from Germany and try then again from Panama an hour later, the system would notice that something is not plausible. The access request would be denied. However, this should not impact usability, as the extra layer of monitoring, which queries a variety of criteria in order to verify trustworthiness, runs automatically in the background. "There's a lot of technology involved in zero-trust systems," Prof. Shulman points out. "You don't have to take on all of that. We analyze the whole system and advise companies as to what it would make sense to implement in their individual case." In general, she sees making the switch as a worthwhile investment, in light of the enormous damage cyberattacks can cause.

However, even zero-trust architectures cannot guarantee 100 percent security. This is why Prof. Shulman is advocating for the establishment of an active national cyberdefense strategy, involving targeted initiatives aimed at stopping ongoing cyberattacks or incapacitating attack infrastructures at an early stage. It is also important to avoid collateral damage in the process. If, for example, certain networks are blocked, this could also effect people with no involvement in the attacks. It takes an expert to assess what the consequences of these defense measures might be before they are implemented. The damage an attack could cause and the risks involved in possible defensive countermeasures must be weighed up and compared carefully. Prof. Shulman and her team conduct simulations and develop procedures for effectively combating attacks while also minimizing damage. However, she emphasizes that having an active cyberdefense system does not mean conducting "hackbacks," as so many people mistakenly believe. Despite hacker groups affiliated with Russia carrying out virtual retaliatory strikes of that nature and Ukraine calling for similar operations at the start of the war, Prof. Shulman strongly advises against them. "Inexperienced hackers can unintentionally wreak havoc online. If the whole world were to start launching cyberattacks, things could escalate uncontrollably in a very short space of time."

Target acquired: weaken democracy

But cyberattacks are not the only danger — there's a hybrid threat to reckon with. Cyber warfare also involves disinformation campaigns aimed at ▶

But cyberattacks are not the only danger — there's a hybrid threat to reckon with. Cyberwarfare also involves disinformation campaigns aimed at undermining the truth in media and politics.

back to page 1

Prof. Martin Steinebach of Fraunhofer SIT wants to combat the spread of lies online — and artificial intelligence is his weapon of choice.

undermining the truth in media and politics and weakening democratic societies. Of course, history shows that disinformation and propaganda have been around for many years, but the speed and extent of their spread across websites, social media and messaging services is a new phenomenon. For the last five years, an interdisciplinary research team comprised of computer scientists, media psychologists, journalists and lawyers and led by Fraunhofer SIT have been working on effective ways of combating this phenomenon — starting in project DORIAN, and now continuing in DYNAMO, a follow-up project. However, the highly dynamic nature of this research field presents challenges. Disinformation campaigns result from ongoing political controversies. For example, in 2015/2016, they focused on the refugee crisis and issues relating to migration, integration and national security. The coronavirus followed not long after, and now they are targeting the war in Ukraine. As these events unfolded, both the people involved in creating disinformation and the channels they use to share it have changed. Five years ago, disinformation was still spread almost exclusively via fake news websites and social media. However, as time went on, messaging services became another important avenue for fake news proponents.

Winning the war on lies requires a whole bundle of initiatives, from programs for improving media skills and political literacy and statutory regulations that create stricter requirements for social media platforms and messaging services, to initiatives for bolstering high-quality, independent media outlets and investigative journalism. Journalists will have a key role to play in this process. They must provide the population with reliable, fact-checked content, while also taking action against the spread of disinformation by producing evidence-based counter statements — but with the daily deluge of news they face, that is a Herculean task.

Prof. Martin Steinebach and his team at Fraunhofer SIT aim to use artificial intelligence to support journalists in this endeavor. The SIT computer scientists are developing automated forensic methods for analyzing text, images and videos and filtering out possible fake news. "Whether a post is actually disinformation or not is something for a human to decide. We only identify suspicious messages," says Prof. Steinebach. In order to teach the AI systems to recognize disinformation, the researchers feed enormous ▶

back to page 1

Cyberattacks on Germany:

28 %
from Russia

12 %
from China

8 %
from Iran

Source: German Economic Institute, last updated: January 2022

quantities of data into the system, which then learns independently and extrapolates rules from the examples (machine learning). But what those rules are, no one knows. In many cases, it is impossible to find out what they are, and when it is possible, then only after the fact and often only to a limited extent. One thing is certain: higher quality, more extensive AI training data produces better results.

This is why Prof. Steinebach and other scientists are calling for large platform operators like Facebook and Twitter to be obliged to cooperate with researchers and make the relevant data available. "So far, there's been very little willingness to cooperate here, and our efforts have gone unrewarded."

Nevertheless, the Fraunhofer SIT team have achieved a success rate of around 70 percent in the automated identification of disinformation in texts. "Of course, for disinformation relating to different topics, such as the coronavirus or the conflict in Ukraine, you have to train a new network in each case," emphasizes Prof. Steinebach. "It's not possible to create a generalized network."

The Fraunhofer SIT team were even more successful in the area of automatically identifying photographs that have been manipulated or used in a misleading way outside of their original context. The latter kind are by far the most common in the realm of disinformation. "This is probably because photo manipulation is a relatively effort-intensive process and it's generally not needed. Just searching for a suitable image online is much quicker," Prof. Steinebach speculates. Companies such as Google and TinEye already offer reverse image search functions for recognizing images that have already appeared in different contexts. However, this technique is quite limited and can easily be overcome by just using a section of an image, or mirroring or compressing it. Now, Prof. Steinebach and his team have managed to develop a reverse image search that cannot be confused by such simple tricks, making it much more accurate. The error rate is less than one-tenth of a percent and the system can also reliably recognize photo montages.

Deepfakes — a powerful new weapon in the information war

Unlike the refugee crisis or the coronavirus pandemic, disinformation campaigns around the war in the Ukraine are making use of deepfakes — videos manipulated using AI. One widely viewed deepfake showed the Ukrainian president, Volodymyr Zelensky, declaring the country had surrendered and calling on Ukrainian troops to lay down their arms. This was countered by another deepfake featuring the Russian president, Vladimir Putin, calling for peace. "These weren't even that well done," Prof. Steinebach comments. "With the Putin deepfake, for example, it was obvious even to the naked eye that his lips returned to the same fixed starting position whenever he stopped speaking." However, he is certain that deepfakes are getting better and better as time goes by. He also pointed out that automated detection would be technically feasible here too, as the deepfake algorithm leaves telltale traces in the video.

Calls for teamwork

"Overall, I'm excited to see all the possibilities the computer scientists can open up," says Prof. Katarina Bader. A journalist and communications expert, she teaches online journalism, journalistic presentation formats and research at the Hochschule der Medien (media college) in Stuttgart and has been part of the interdisciplinary research team from the start. She believes that the tools the team has developed are important for helping editors to review news items quickly, particularly when they are working under time pressure due to wars and crises. "Disinformation levels have risen sharply since the war in Ukraine started. The information war is raging online," Prof. Bader confirms. "Videos play an important role here, especially eyewitness videos. I am sure that editors will see more and more deepfakes crossing their desks." In addition to deploying automated detection systems, she hopes that in the future it will be possible to use a digital watermark as a standard guarantee that videos are real and have not been tampered with — and the Fraunhofer SIT team have already developed the necessary technology. "That would make journalists' work much easier," Prof. Bader asserts. Computer scientists would have to revise and update these tools for detecting fake news continuously, while journalists would have to learn to operate them autonomously and build up an understanding of the technical possibilities for manipulating photos and videos. "In a time when the truth is being attacked in so many ways and at so many levels, teamwork is becoming an ever more important factor," Prof. Bader stresses. ■

When quantum computers attack

Encryption techniques are used to secure online banking, ID documents, smart cards and masses of confidential information. The security of these techniques is based on assumptions regarding the difficulty of mathematical problems. But what if quantum computers develop the ability to solve these problems rapidly — and soon?

By Mandy Bartel

A quantum computer is something of a savant when it comes to mathematical calculations. It will take much longer than a normal computer to multiply two simple numbers together, but will breeze through the factorization of multidigit numbers. Because of quantum parallelism, quantum computers can find factors for large numbers or certain discrete logarithms much more quickly and efficiently than conventional computers. This is why the continued advancements in quantum technology present such a challenge: because almost all the cryptographic processes that users currently rely on to keep their money and identities secure could be cracked within hours using quantum processes.

The BSI is operating on the assumption for the high-security sector that quantum computers could impact cryptographic primitives by as early as 2030. Because our world is increasingly connected, this would put ever more security-critical applications at risk: blockchain, the internet of things and Industry 4.0. "Shor's quantum algorithm could break the factorization-based public key systems that we currently use, like RSA encryption and other asymmetric signature methods, in the foreseeable future," explains Prof. Daniel Loebenberger of the Fraunhofer Institute for Applied and Integrated Security AISEC. "Also, solutions like Grover's algorithm are threatening the security of symmetric methods too, although using larger keys seems to mitigate the problem.

Hybrid, agile encryption solutions

To address this vulnerability, researchers at Fraunhofer AISEC, together with industry partners and government authorities like the BSI, are working on the question how novel post-quantum cryptography (PQC) methods can be applied in practice. These new technologies will be used for encryption and decryption. However, they must also facilitate easy use for digital signatures. "Researching how new encryption methods have to be applied in practice involves a constant interplay with the very dynamic developments taking place in the field of quantum computing. This is why we have to take steps now to organize the change process as efficiently as possible and make products quantum-safe — especially when they have a long service life, as with industry equipment," Prof. Loebenberger adds.

However, unfortunately, due to the totally new algorithm properties of PQC processes, such as their different algorithmic properties such as time or space consumption, for example, it is not possible to replace existing cryptographic methods just like that. "The implementations of the novel PQC primities are at the moment still combined with classical implementations, so hybrid solutions will tend to predominate far more. Crypto-agility — that is, the ability to support multiple cryptographic methods and rapidly switch between them — will also be an important consideration in this context. This is the only way that we can react to threats that remain as yet unknown and adapt systems in a flexible way," Prof. Loebenberger affirms.

"Researching how new encryption methods have to be applied in practice involves a constant interplay with the very dynamic developments taking place in the field of quantum computing."

Prof. Daniel Loebenberger, Fraunhofer AISEC

In order to support companies and government bodies in making the transition to quantum-resistant cryptographic processes, Fraunhofer AISEC established the Competence Center for Post-Quantum Cryptography. The specialists at the center are independent of any particular manufacturer, and provide neutral advice on issues such as compatibility with existing solutions or crypto-agility, as well as conducting security analyses and building up a publicly accessible pool of knowledge on post-quantum cryptography. ■

back to page 1

Interview

“Cybersecurity will be an ongoing task”

He is Germany’s first ever digital minister. And he wants to do away with all things analog. In this interview, Dr. Volker Wissing talks about why he is taking this risk in a time of high data crime levels – and how he aims to make systems more resilient.

Interview: Josef Oskar Seitz

Cyberwarfare and cybercrime cast a dark shadow over any digital project. But Volker Wissing, German Federal Minister for Transport and Digital Infrastructure, is staying optimistic.

It's nice to see you in 3D, Dr. Wissing. And to meet Germany's first ever digital minister – the man who wants to do away with analog systems.
What I mean by that is that we have to be ambitious. If we continue to rely on analog solutions, we are robbing digital infrastructure of some of its efficiency – and accepting the high costs resulting from dual structures. It is my task as digital minister to face this challenge and take society down this path.

"Digital first. Doubts second." – was how your party phrased this idea on an election poster.
This aspiration is one that I have really taken to heart. We need to move away from analog systems and from the structures that we are familiar with.

You want to increase the amount of data that we collect, store and exploit – even now, when we are experiencing ever more cybercrime, as well as ongoing cyberwarfare in Ukraine?
Any political decision involves a process of weighing up opportunity versus risk. Data forms the foundation of digital business models and innovative solutions. Forgoing data means forgoing opportunities. I take an optimistic view and my focus will always be on highlighting opportunities for digital transformation. Although data that is not collected can't be misused, it also can't be exploited. That is not an option for the future.

You were a public prosecutor, Dr. Wissing, so let's translate this into the language of your previous field: The only person who cannot be stolen from is someone who doesn't have money – but despite this, few people think that owning nothing is a goal worth striving for.
The same applies to the digital world. We cannot forgo digital innovation simply because the possibility of data misuse exists. Politics can't stop at outlining the problems; it must come up with solutions. Our task is to eliminate misuse to the greatest extent possible through regulation. On the European level, we have made great strides in this regard thanks to this year's Digital Services Act.

"The example of Ukraine has shown us all that war is being waged online, too."
Dr. Volker Wissing

So the principle is: Anything that is prohibited offline should be prohibited online, too. But do criminals and warring parties really care about that?
Cybersecurity will be an ongoing task. The more closely we coordinate with friendly countries, the better equipped we will be against attacks. This is why I brought this issue to the table at the G7 summit of digital ministers in Düsseldorf. We must analyze cybersecurity vulnerabilities and open up a dialogue around how we can make our digital systems more resilient. We require a new error culture that views mistakes as an opportunity or a challenge to do better.

Was a consensus reached at the summit?
We received concrete proposals for cooperation. The digital minister from the Ukraine was well-informed and offered to enter into a dialogue with us on his country's experiences with cyberwarfare – once the current war has ended. Ukraine cannot currently disclose the exact measures it is taking to repel Russian attacks. The example of Ukraine has shown us all that war is being waged online, too.

You are talking about mistakes, about a new error culture.
Every cyberattack looks for vulnerabilities. If a vulnerability is found, this means someone made the mistake of not fixing it in time. This is precisely where learning and dialogue are crucial. International coordination is the only way that we can take full advantage of the learning potential. I am responsible for network security and resilience. If we want to drive society's digital transformation further, we need to create a more secure digital world. Digital transformation and reinforced cybersecurity should go hand in hand in. ▶

Standing in the entrance hall of the federal ministry, Dr. Wissing, the man of the house, talks about the history of the building, which was constructed in 1878 for the Prussian Geological Survey.

Photos: Andreas Chudowski

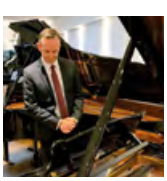
back to page 1

2016

Among his peers: Carnival and the iconic Mainzelmännchen cartoon characters from TV station ZDF are part and parcel of being a politician in Rhineland-Palatinate. In 2016, Dr. Wissing was the top candidate for the Free Democratic Party (FDP), leading the party back into the state parliament. He was State Minister for Economics, Transport, Agriculture and Viticulture until 2021. Before entering politics, Dr. Wissing worked as a public prosecutor and judge.

2019

The Minister for Viticulture already knows plenty about wine: His family has a vineyard, and he describes cultivating the grapes as a "very grounding experience."



2020

In Trier, Wissing marvels at the work of piano makers. He himself has played the organ from a young age, and trained as a church musician. One of his favorite pieces of music is Bach's Cantata BWV 26 "Ach wie flüchtig, ach wie nichtig."

How much has the digital transformation of the processes in your own ministry progressed?
We are of course working on digitalizing processes within the ministry. However, we also have to deal with a lot of analog-based tasks. Transport infrastructure is a very hands-on field, for example. However, we do intend to digitalize this sector, for instance by installing sensor technology in bridges to allow for digital maintenance control. We want to digitalize our transport systems and make mobility data available. For this reason, we've created the "Mobility Data Space" – a secure space that allows for equal access to data, thus unlocking its value creation potential. We want to take advantage of the possibilities offered by digitalization within the ministry as well as everywhere else.

One objection, Minister: According to the history books, the Copper Age came to an end in 2200 BC, but in Germany's world of data, it seems to still be around in even in 2022 – in the form of copper cables. Who can solve this long-term problem?
This task is too important for me to delegate, so I'm focusing on it personally and am confident that we will make significant progress. I'm an optimist.

Then let's take an optimistic look forward to 2030. Will half of German households have a fiber-optic internet connection by then?
That would be too few.

Will we see 15 million electric cars on the roads of Germany by that point?
We are living in a market economy, where there are no car quotas.

But this figure has been mentioned.
The coalition agreement set out this figure and it is part of a plan for achieving climate targets in the transport sector. However, the objective of this policy relates much more to compliance with climate targets in the transport sector than it does to reaching a certain number of electric vehicles. As transport minister, I want to work together with the automotive industry to create a charging infrastructure that makes electromobility an attractive option. At the same time, companies need to offer good mobility services. But in the end, it will be members of the public that make their own mobility choices, not politicians.

What about autonomous vehicles?
We in the German Federal Parliament have just passed a regulation allowing Level 4 for the whole of Germany. We are the first country in the world to have taken this step.

When will your department's digital strategy be published?
This summer. It will be a serious effort, but a necessary one.

Is being digital minister a hindrance or a help, when so many digital issues are connected to other ministries – for instance digital medical records fall under the remit of the health minister Lauterbach and digital innovation via start-ups falls to the economy minister Habeck… the list goes on.
As digital minister, my role is to set the pace for a consistent digital policy focused on one common theme. Digitalization is a cross-sector task. It will work if the German federal government develops an overall strategy and unites to approve it in cabinet, and every department commits to achieving the defined goals. There's no question of a hindrance when a government works well together.

Even in spite of rivalries?
I wouldn't call that rivalry – I would call it constructive cooperation. This does not mean all members are always in agreement, but that we are all striving to find the best solution.

That's an interesting way of putting it, but you won't find those words as synonyms in thesaurus.
In the end, we will be measured against the results we achieve, not against brief snapshots or declarations of intent.

So many tasks, so many security issues, so much data to protect – And yet, Minister Wissing, the budget of the digital and transport department has been cut by 13 percent to 36 billion euros. How badly is this affecting you at present, when so many projects need to be moved forward?
A federal budget is not a wish list. It is the result of considering and comparing various tasks from a sociopolitical perspective. As a minister, you naturally want more opportunities for your own department. But on the other hand, of course I realize that there are other policy areas in which we, as a state and society, are called

"Science and research are essential as we search for the best solutions for our country."

Dr. Volker Wissing

upon to act. The budget for my ministry is one of the largest investment budgets in Germany. By this I mean: We can't do everything, perhaps, but we can do a lot.

Out of every 5 euros your predecessor in office could have used for 2021, he only drew down 4, leaving 5.1 billion euros unused. How do you plan to improve on this performance?
We want to accelerate planning and are making systematic use of digital technology to do so. We intend to build up and strengthen data platforms in order to advance infrastructure projects. The focus is on building information modeling, i.e. an intelligent cloud model for connected collaboration.

How can research assist you?
Through genuine innovation. This is urgently required to make up for shortcomings in the areas of mobility and CO_2 neutrality in the future. And we also need science in order to avoid mistakes. Science and research are essential as we search for the best solutions for our country.

Business newspaper "Handelsblatt" used the caption "Mission impossible" when outlining the wide range of tasks assigned to you. Does this worry you?
The variety of tasks the ministry faces is a challenge. However, you don't overcome challenges by fearing them, but rather by carefully analyzing and approaching them logically.

While still enjoying what you do?
Politics represents an opportunity to change society for the better. But this comes with a huge level of responsibility, of course, and society must make a leap of faith to trust you. Every politician needs to prove themselves worthy of this trust.

Speaking of the facts of life, Germany consistently occupies a fairly low position in digital rankings.
We are our own country with our own history, our own geographical position, our own federal structure, and therefore our own challenges. International comparisons are important for analyzing our shortcomings and identifying areas for improvement, but it is also important not to lose sight of specific national issues. However, there is no doubt that we could and must do better. Tackling this challenge and working each day to ensure we do better – that's what drives me. We have the opportunity to enhance our future and make our country a better place to live in. Let's make the most of it. ■

2021

Predecessors and successors
Dr. Wissing took over the ministerial role from Andreas Scheuer on December 8. According to "Der Spiegel", the departing minister talked about himself for almost 20 minutes during the official handover. Dr. Wissing got his revenge when he went public about an item that Scheur had left behind in his office: bathing trunks from Berlin's public transport company.

2022

"Bread ambassador"
— was the accolade the state of Rhineland-Palatinate gave Dr. Wissing, who is a passionate baker himself. Even at the end of this interview, the minister talked enthusiastically about homemade bread and showed us photos of his baking creations.

Photos: Andreas Chudowski, private collection (5), Thorsten Silz

back to page 1

Dr. Markus Eppel, Dr. Frank Oehler and Dr. Heinrich Milosiu won the Joseph von Fraunhofer Prize for developing an energy-efficient chip.

Always ready for signal reception

RFicient® chips pave the way to a sustainable internet of things

With a 99 percent energy saving, Fraunhofer IIS' RFicient® chip represents a massive step forward for the internet of things and sustainability. It was a natural choice for the Joseph von Fraunhofer Prize.

By Dr. Janine van Ackeren

Imagine a trash can with a built-in fill level sensor, that can autonomously detect when it needs to be emptied and reports this to the garbage disposal service. Or how about a refrigerator that can put together a shopping list and send it to its owner's smart phone? These are just two examples of the remarkable possibilities opened up by the internet of things, or IoT — objects that are connected to the internet and send data to each other. Smart fridges and garbage cans may still be a long way off, but the internet of things is making its presence felt ever more strongly in many other areas. The number of wirelessly connected devices is growing rapidly, in industry as much as in the private sphere. However, the challenge here is that, for devices to be reachable at all times, their wireless receiver needs to be permanently switched on, which limits the battery life of small, battery-powered IoT nodes to just a few weeks.

This is why the RFicient® chip from the Fraunhofer Institute for Integrated Circuits IIS represents such a gigantic leap forward. "With our chip, we can save

Research prizes

Since 1978, the Fraunhofer-Gesellschaft has awarded prizes to its employees for outstanding scientific achievements.

99 percent of the power, meaning that a battery that would last just over a month with conventional technology could now hold out for ten years," relates Dr. Frank Oehler enthusiastically. The appeal of this product lies in the fact that, even with the extended battery life, the sensor node is still ready to receive signals at any time: it needs just 30 milliseconds to respond to a signal by performing an action. The development of this market-ready product, including applications for 16 patent families, has secured the Joseph von Fraunhofer Prize for Dr. Frank Oehler, Dr. Heinrich Milosiu and Dr. Markus Eppel — although naturally, they represent the whole team in this. In addition to the complete process chain covering everything from the initial idea to implementation, the project's particular societal relevance was the deciding factor for the jury, as the number of devices with wireless connections is skyrocketing — raising energy consumption levels with it.

RFicient® is always on watch

"The carrot for us was bringing energy use down, while still continuously receiving signals," says Dr. Milosiu with a chuckle. To achieve this, the team took a conventional sensor node — which consists of a sensor, a microcontroller, external memory, a power source, a transceiver and actuators — and added in their wake-up receiver. "With the RFicient® chip, all these components will be put into deep sleep mode, so that they use a negligible amount of power. But the chip stays on watch: it is always ready to receive signals from neighboring nodes, a gateway or a base station. And it only needs 3 microamperes of power for that," emphasizes Dr. Eppel. What's more, it does it all in real time. While other wake-up receivers are often switched off for minutes at a time — often only responding when it is already too late — the RFicient® chip guarantees an immediate response. This is vital for time-sensitive applications and situations where many services run simultaneously — such as airports, train stations and football stadiums — or where requests are sent to many individual chips.

The RFicient® technology has already blossomed from an initial idea to a commercially available standard chip. The team have also acquired suitable industry partners, bringing the American semiconductor manufacturer Globalfoundries Inc. onboard to produce the 1.3 by 1.3 millimeter chips and RoodMicrotec GmbH to produce the plastic casings and monitor the quality. Meanwhile, EBV Elektronik GmbH & Co. KG will take care of global sales and marketing. "The industry sector needs IoT receivers that are always reachable, and can react quickly and function for long periods of time without needing maintenance work. Thanks to the new Fraunhofer receivers, we can now deliver this for the first time ever," says Thomas Staudinger, president of EBV Elektronik GmbH. Dr. Oehler was also full of enthusiasm about the interest coming from the industry sector. "The over 100 requests that came from a variety of different fields were a serious motivator for us," he revealed. "Our customers are ready and waiting to equip their new products with Rficient® chips." Conservative estimates suggest that over 50 million IoT devices will benefit from the RFicient® technology in the coming years. Its developers have put their finger on the pulse of the current age in two ways: first, by greatly expanding the possible applications for the internet of things and, second, by simultaneously driving progress in sustainability. ■

Conservative estimates suggest that over

50 million

IoT devices will benefit from the RFicient® technology in the coming years.

Photo: Fraunhofer/Piotr Banczerowski

back to page 1

Unique measurement technology

3D-based position monitoring in radiation therapy

A new hope is rising in the fight against the one of the world's most dreaded diseases, as a new system for treating tumors with radiotherapy is improving patients' chances of recovering from cancer. That definitely merits a Joseph von Fraunhofer Prize.

The winning team from Fraunhofer IOF: Dr. Peter Kühmstedt, Matthias Heinze and Dr. Christoph Munkelt (from left to right).

"Developing this system was like walking a tightrope at the outer limit of technological possibilities," recalls Dr. Peter Kühmstedt, head of the Imaging and Sensing department at the Fraunhofer Institute for Applied Optics and Precision Engineering IOF. "But now, at the end of that rope, we've actually found an industry solution." He's referring to a novel system that allows doctors to monitor a patient's position continuously, both before and during radiation therapy. This significantly increases the treatment's chances of success, which in turn increases the patient's chances of recovery. In other words, this system is making a vital contribution to increasing the effectiveness of cancer treatment, while simultaneously reducing the dangerous side effects on the patient. Dr. Peter Kühmstedt, Dr. Christoph Munkelt and Matthias Heinze from Fraunhofer IOF were awarded the 2022 Joseph von Fraunhofer Prize for the overall system, which was developed in collaboration their industry partner, Varian Medical Systems, and is ready to go into production. The aspect that particularly stood out to the jury was the relief it afforded cancer patients undergoing treatment.

To treat tumors, doctors harness the destructive power of radiation, using it to target and kill tumor cells so that cancer patients can recover. The most important factor here is to treat the entire tumorous region with the radiation, while avoiding damage to the surrounding healthy tissue as much as possible — the success of this treatment is fundamentally dependent on this level of precision. To do this, medical personnel start by creating an accurate image of the tumor using computed tomography scanning methods based on X-rays. This image is then used to plan the treatment. When the actually radiotherapy session takes place a few days later, the patient must be in the exact same position as in the initial examination, and they must stay this way throughout the session.

High-frequency frame rates meet half-millimeter accuracy

This is where the award-winning technology comes into play: it can be used to monitor a patient's position continuously over the course of the treatment. "The system produces 3D images of the patient before and during radiotherapy that are accurate to below the half-millimeter level and all with a high-frequency frame rate — that is unique," emphasizes Dr. Munkelt. "This enables doctors to monitor the optimum direction of the rays with minimum additional radiation exposure from imaging X-ray systems. Optical systems also allow for precise monitoring of patient positioning during high-dose radiation treatment with fewer sessions. The treatments are very effective and also reduce physical and mental stress." During the initial examination using computed tomography, an optical sensor projects a variable infrared pattern — invisible to the human eye — onto the body, which is then recorded by two cameras. This means that the light does not put additional stress on the patients, who are generally already under great emotional pressure due to their illness — another point in the system's favor. Based on these images, the system generates a 3D model that is later used to arrange the relevant body parts — an irradiated body area of approximately 30 x 30 cm — in exactly the same position as they were for the preliminary examination.

A further advantage here relates to cases where the patient moves during treatment (for example, because they are breathing heavily or adjusting their position for comfort) and thus changes the irradiated body area. The system makes these situations safer for the patient, because if their position changes, the system immediately registers this and turns the radiation off as a precaution. Going forward, the system will be able to adapt to smaller changes, caused by breathing for example, and adjust the radiation positioning in real time. In the future, it is expected that the system will even be able to cope with more challenging types of radiation treatment involving tumors that are difficult to track down, for example in the abdominal region.

Virtually impossible? Think again!

The team had to get around quite a few obstacles to develop this system. For example, the measurement technology had to continuously take data readings at a very high frequency, so that movements caused by breathing could be recorded correctly, and then transmit that data with a guaranteed latency of less than 100 milliseconds. At first, achieving this measurement frequency across a measurement area as large as the human body seemed virtually impossible. Solving this puzzle took an interdisciplinary team consisting of experts in optics, physics and engineering from three different countries: Switzerland, Hungary and Germany. "The key aspect of this development was translating the methodology of the entire package into an industrial solution and creating a sensor network for it," explains Heinze. In the long term, the global corporation Varian Medical Systems expects that this innovative system will be widely used for patient position monitoring all over the world. ■

"The system produces 3D images of the patient before and during radiotherapy that are accurate to below the half-millimeter level and all with a high-frequency frame rate — that is unique."

Dr. Christoph Munkelt

Photo: Fraunhofer/Piotr Banczerowski

back to page 1

A new, high-precision technique

Fluorescence measurement technology for quality assurance in production

A team of researchers from Fraunhofer IPM have discovered the secret of using fluorescence spectroscopy to conduct quantitative measurements with high spatial resolution — and turned it into a tool for quality assurance in industrial production contexts. For their discovery, the IPM team have bagged the Joseph von Fraunhofer Prize.

Is that a real dollar bill? Or has someone slipped you a fake? You can find out by checking it for fluorescent particles that start to glow under UV light. This technique is commonly used in biology and medicine as well, as qualitative results like the marking and tracking of biomolecules are generally obtained using fluorescence. However, until now, fluorescence has been seen as a rough estimate rather than a reliable form of quantitative measurement. Moreover, calibrating the instruments requires not only precise reference procedures, but also an in-depth understanding of the factors that influence fluorescent radiation. "We have turned this imprecise process into an extremely robust, high-speed precision measurement technique," explains Dr. Albrecht Brandenburg of the Fraunhofer Institute for Physical Measurement Techniques IPM. It seems as though the world has just been waiting for this technology, as it is spreading at an astonishing pace both nationally and internationally. Fraunhofer IPM's sales figures for the solution are already reaching into the millions. Dr. Albrecht Brandenburg and Dr. Alexander Blättermann have received the Joseph von Fraunhofer Prize for their research. The jury's decision was motivated by the project's high levels of technical advancement and the quantifiable financial benefits for companies that have adopted the technology.

An opportunity for the production industry

This technology is not only precise, but can also be used for inline measurements. "Our system is the first to enable the checking of complex 3D components in production cycles mere seconds long — and with 100 percent accuracy, even under extremely harsh manufacturing conditions," relates Dr. Brandenburg, a Fraunhofer IPM stalwart with 30 years of research under his belt. It was his idea to use imaging fluorescence measurement technology to carry out checks on components — with a particular focus on detecting contamination from oil or dirt. This is vital information, especially when it comes to safety-critical processes, for example, joining car components together. To carry out the measurement, a short-wave laser beam scans the component's surface, causing organic contaminants to emit long-wave light. This fluorescent light is detected by the laser scanner, which converts it into quantitative measurement data and compiles it to form an image — and it works just as well for a meter-long metal sheet or a tiny electronic component. "The performance data is spectacular: We can measure 40 million points per second and detect contaminants of 1 milligram per square meter. From 10 milligrams and upward, we can take quantitative measurements," says Dr. Blättermann, who developed the inline system and put it into operation. "These figures make fluorescence measurement technology a viable option for quality assurance and process control."

The high performance levels result from a combination of multiple innovations. One of these developments is that the researchers use rapidly moving laser beams to excite the contaminants' atoms and cause them to fluoresce. The excitement effect then becomes very intense, making the measurement more sensitive, as well as very precise when it comes to the spacial scanning. This results in high-resolution images of

> "Our system is the first to enable checking of complex 3D components in production cycles mere seconds long."
>
> Dr. Albrecht Brandenburg

coatings and contaminants with a high depth of field. Another important factor is having an optical detection system that uses extremely intense light, so that not even a single photon goes undetected — otherwise, it could not pick up the weak fluorescent radiation. The researchers use a highly accurate weighing system as a reference to calibrate the instruments. As the amount of contamination increases, the fluorescent radiation levels also grow in a linear fashion. In other words, the more oil or dirt is present, the brighter the light will be. "And finally, by using our patented combination of this system and infrared reflection analysis, it's possible to record quantitative data regarding unknown mixtures of substances on metal sheets that are moving at speed," Dr. Blättermann adds.

Worldwide demand

Robert Bosch GmbH has been one of the team's customers since the early days of the project. "With this new Fraunhofer process, we can detect minuscule traces of contamination on surfaces and increase quality, and so also safety in adhesive joining in electronic control devices," says Dr. Heiko Elsinger, a process developer in the Automotive Electronics division at Bosch. "This improves operational safety, speeds up processes and helps make production more sustainable." In the car manufacturing industry, the system is also used during the forming of metal sheets into 3D components, as a reliable means of detecting whether the coating of forming oil has been applied too thickly or thinly. If the coating is the wrong thickness, this can cause cracking or deformation during forming, ultimately resulting in unusable components. The technology has been adopted by many companies since its creation, with the team bringing in around 3.5 million euros in industry contracts since 2015 — totaling 20 customers across 5 countries. "These days, I sign quotes for various types of fluorescence-based inspection equipment — for Germany and the whole world — practically on a weekly basis. And those numbers are rising quickly," says Prof. Karsten Buse, institute director at Fraunhofer IPM. The word is getting out: Fraunhofer has the expertise. ■

This innovative technology can sniff out trace contamination from oil and dirt. It was developed by Dr. Alexander Blättermann (left) and Dr. Albrecht Brandenburg.

Photo: Fraunhofer/Piotr Banczerowski

back to page 1

Germ-free seeds

Electron treatment allows safe, sustainable disinfection

Environmentally friendly, sustainable and economical: a new electron-based treatment spells the end for fungi, viruses and bacteria lurking on seeds. It's no wonder the recently founded company E-VITA GmbH snapped up the 2022 Fraunhofer Founder Award.

André Weidauer (left) and Christian Süß are working to make chemical-free seeds a reality.

Simply scattering harvested seeds on the fields is not a good idea. This is because there are fungi, viruses and bacteria clinging to the seed husks that could drastically reduce the yield. Seed producers tackle these pathogens using chemical dressing agents. However, this presents certain disadvantages. As the dressing agent sticks to the seeds, the farmer has to handle potentially dangerous substances when sowing them — this could harm the farmer, the natural environment and the soil. There are restrictions in place that are aimed at curbing these risks to the environment. For example, seed dressings are off-limits in water protection areas and the treated seeds cannot be sown in very windy conditions, as the dressing agent containing the active ingredients might be blown further field. To cap it all, any leftover seeds are classified as hazardous waste. In addition, numerous fungicidal dressing agents have already been banned. The number of available product groups has declined drastically in recent years, particularly for insecticides and fungicides. Very few of the more than 20 active ingredient groups that used to be sold on the fungicide market can still be obtained today. But it would be impossible to do without them entirely — that's why every year, special emergency authorizations for using the remaining dressing agents are issued once again.

Chemical-free, sustainable and field-tested

However, E-VITA GmbH, a joint venture by the Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology FEP and Ceravis AG, may soon put an end to this cycle. Instead of using dressing agents to eliminate pathogens like fungi from seeds, they are working on a chemical-free, sustainable, field-tested and economical alternative — accelerated electrons. Fraunhofer Venture and the High-Tech Gründerfonds were quick to notice the direct benefits the technology creates for society and presented the start-up with the Fraunhofer Founder Award.

The basic principle of this electron treatment requires little explanation: the seeds are "bombarded" with energy-rich electrons, which kill harmful organisms very effectively — but without damaging the embryo and endosperm within the seed at all. "The end result is clean seeds without any traces of harmful substances or toxins that could affect humans or the environment. They can be sown in windy conditions and in water protection areas — in fact, they can even be fed to livestock," reports André Weidauer, managing director of E-VITA GmbH. Another point in favor of the electron treatment is that it does not cost farmers the earth — in fact, the prices are much the same as for chemically dressed seeds. "This constitutes a strong motivation for farmers to buy E-VITA seeds. They get sustainable, higher quality seeds for the same price," summarizes Weidauer.

The process is nothing new. The Manfred von Ardenne Research Institute began basic trials on electron treatment of seeds back in the 1980s. Fraunhofer FEP then brought the technology from this initial testing stage to industry readiness by means of four large pilot plants covering different stages of the development. "The question was, what is the next step for a technology like this?" the company founder recalls. "Our big breakthrough stemmed from two developments: The first key step consisted of converting the large-scale, fully automated, stationary system into a mobile unit that we can rent out together with expert personnel. This unit consists of a 40 foot container towed by a truck and can process 25 tons of seeds per hour." In the second and more important development, the Fraunhofer FEP researchers managed to create a much smaller version of the electron source, thereby laying the groundwork for systems that can remain economically viable even at a lower throughput of 8 tons per hour. "Reaching this milestone laid the foundations for the E-VITA spin-off," recalls Weidauer. E-VITA aims to build a pilot version of one of these small units inside a 20 foot container by 2023. In the long run, the start-up hopes to capture a market share of up to 50 percent with its small units — first in Germany, and then across the rest of Europe.

High yields even during water shortages

The E-VITA founders also hope to make an impact in the fight against challenges such as water shortages and the reduction in fertilizers that supply plants with nitrates and phosphates. To this end, they are also adding naturally occurring microorganisms to the treated seeds. The conditions under the seed surfaces cleaned by the electron treatment are perfect for growing microorganisms that can then help the seeds to absorb water and nitrates. Essentially, these microorganisms increase yields, improve nutrient efficiency and provide long-lasting protection for the seed. This means that E-VITA seeds help to fulfill the requirements of the European Green Deal and implement the targets of the EU's Farm to Fork strategy. "Once our small systems are available on the market, there will be absolutely no more reasons to uphold the emergency authorization granted for dressing agents that pollute the environment," says Weidauer emphatically. ■

In the long term, the recently founded company aims to capture a market share of up to

50%

with its small units — first in Germany and then worldwide.

Photo: Fraunhofer/Piotr Banczerowski

back to page 1

Very nearly friction-free

Virtual material probe sheds light on the friction gap

What determines whether a power plant functions smoothly or a car is energy-efficient? In many cases, it comes down to just a few atoms. Thanks to a new virtual material probe, we can now see and control wear and tear processes at an atomic level for the first time — an achievement worthy of the 2022 Stifterverband Science Prize.

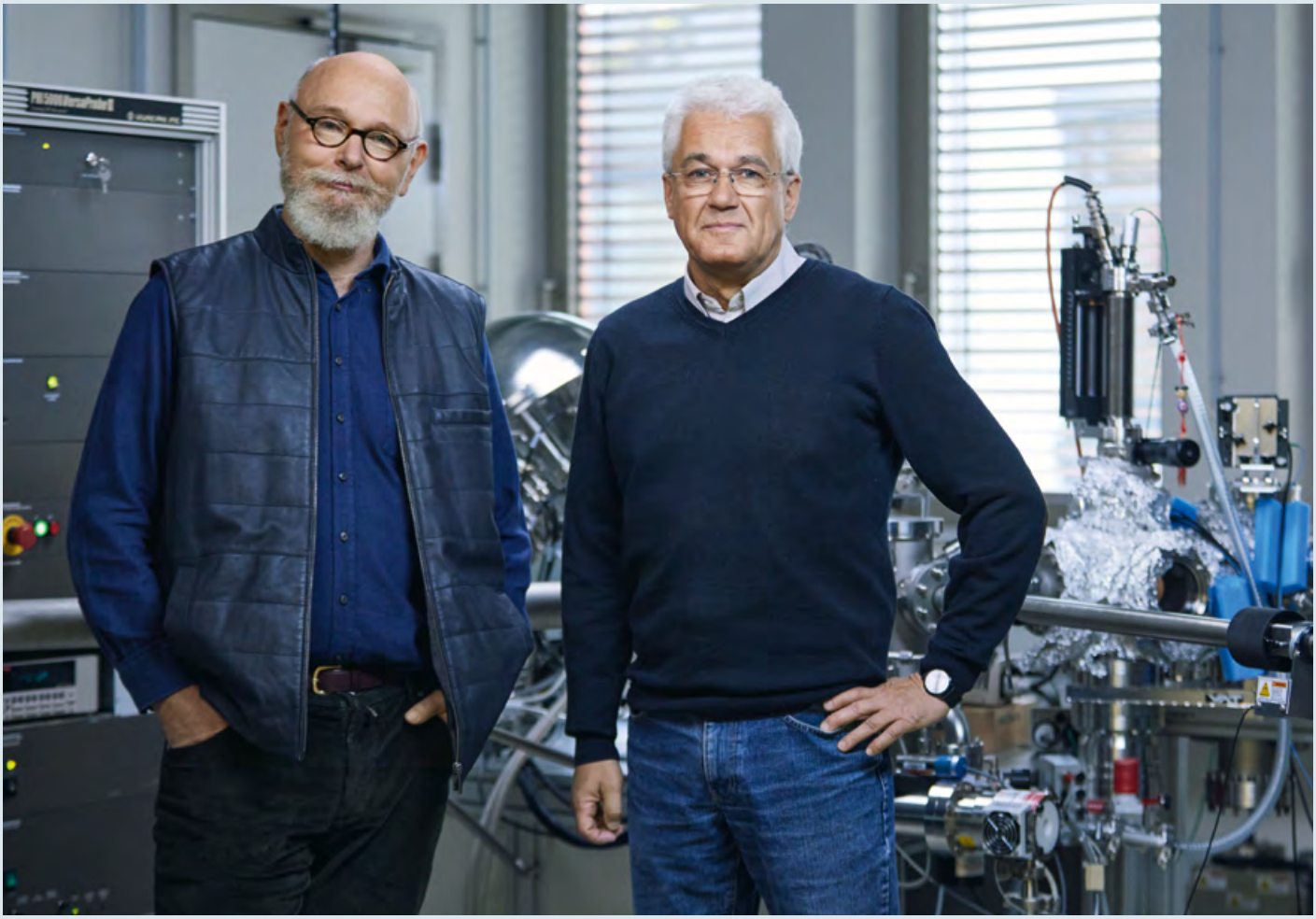
Diamonds are hard; in fact, they're hard enough to be the perfect material for places that are subject to serious wear and tear, such as mechanical seals in pumps and compressors. The crystalline material ensures a long service life for equipment by protecting components that rub against each other and allowing them to slide smoothly over one another. However, the coefficient of friction can fluctuate dramatically and, in rare cases, can even cause system breakdowns that result in millions in damages — as happened in a Canadian power plant, where the coefficient values at the mechanical seals skyrocketed inexplicably. However, until recently, no one understood what caused these high values or knew what conditions were needed to keep friction at consistently low levels.

Now, a team of researchers has solved the diamond friction mystery using a virtual material probe that combines simulations at multiple scales with real-world experiments. This probe, which can effectively "see into" the friction gap as the components come into contact, represents a world first. Prof. Michael Moseler and Prof. Matthias Scherge of the Fraunhofer Institute for Mechanics of Materials IWM have received the Stifterverband Science Prize 2022 for developing it. A third project partner, Joachim Otschik of EagleBurgmann Germany GmbH & Co. will also be receiving the award. The jury was particularly impressed by the many years of collaborative research the trio conducted in order to develop the probe and the great contribution they have made to our understanding of friction phenomena in mechanical seals.

> The virtual material probe is here to bring lasting change to the world of friction processes.

The virtual material probe brings light into darkness

The virtual material probe can be used to shed light on any instance where two objects rub against each other and lubrication consists of a liquid film just one atom thick — for example, in components that may be used in a future hydrogen economy, electric vehicle drive trains or heat pump compressors. "Experiments alone will never enable us to measure the actual contact area or understand friction effects or the impact of an ultra-thin lubricant film — when it comes to the contact between objects in wear and tear processes, we are essentially in the dark," explains Prof. Scherge. He set out to find someone that could provide expertise in simulations, the missing piece in his engineer's toolkit and so bring light into this darkness. He struck gold some ten years ago when he met Michael Moseler of Fraunhofer IWM. As he had hoped, the combination of experimentation and simulation won the day. Working on a micro-tribometer, that is, a test bench just a few squared centimeters in size, Prof. Scherge was able to identify the critical friction points. Prof. Moseler then examined them more closely using multiscale material modeling. "Using basic physics



Prof. Matthias Scherge (left) and Prof. Michael Moseler have won the "Collaborative Research" Stifterverband Science Prize.

equations, we can zoom in from the millimeter scale to the atomic scale or even the quantum mechanical electron level in extreme cases, allowing us to gain an understanding of bonding in the friction gap." Getting a visual of the atomic level is no joke — after all, even a relatively small number of the "right" or "wrong" atoms on the surface of a component can make the difference between a seal working perfectly and total failure due to friction and wear. However, developing the virtual material probe would not have been possible without industry collaboration. The company EagleBurgmann has been a partner in the project for more than 15 years. "Our perseverance paid off. This unique synergy between ourselves and Fraunhofer IWM is expanding and constantly picking up the pace," relates Otschik. "My colleagues' understanding of this field is absolutely world-class."

The virtual material probe has actually already shone a great deal of light into the darkness of the friction gap. In the case of that Canadian power plant, for example, it turned out that the mechanical seal comes to a standstill for the briefest of moments when the rotational direction is changed. During this pause, the atoms "bond" with each other in a process known as cold welding, and it takes effort to break them apart again when the rotation starts again in the other direction. "These results have allowed us to develop a robust technological solution — the only one of its kind worldwide — reduce development time by at least 99 percent and secure a contract worth millions," reports Otschik. The seals at the Canadian power plant are now running smoothly once again, but that is not enough for EagleBurgmann. They also want to use the new tool to help develop an atom-proof seal that experiences almost entirely no friction or wear and tear. In short, the virtual material probe is here to bring lasting change to the world of friction processes. ■

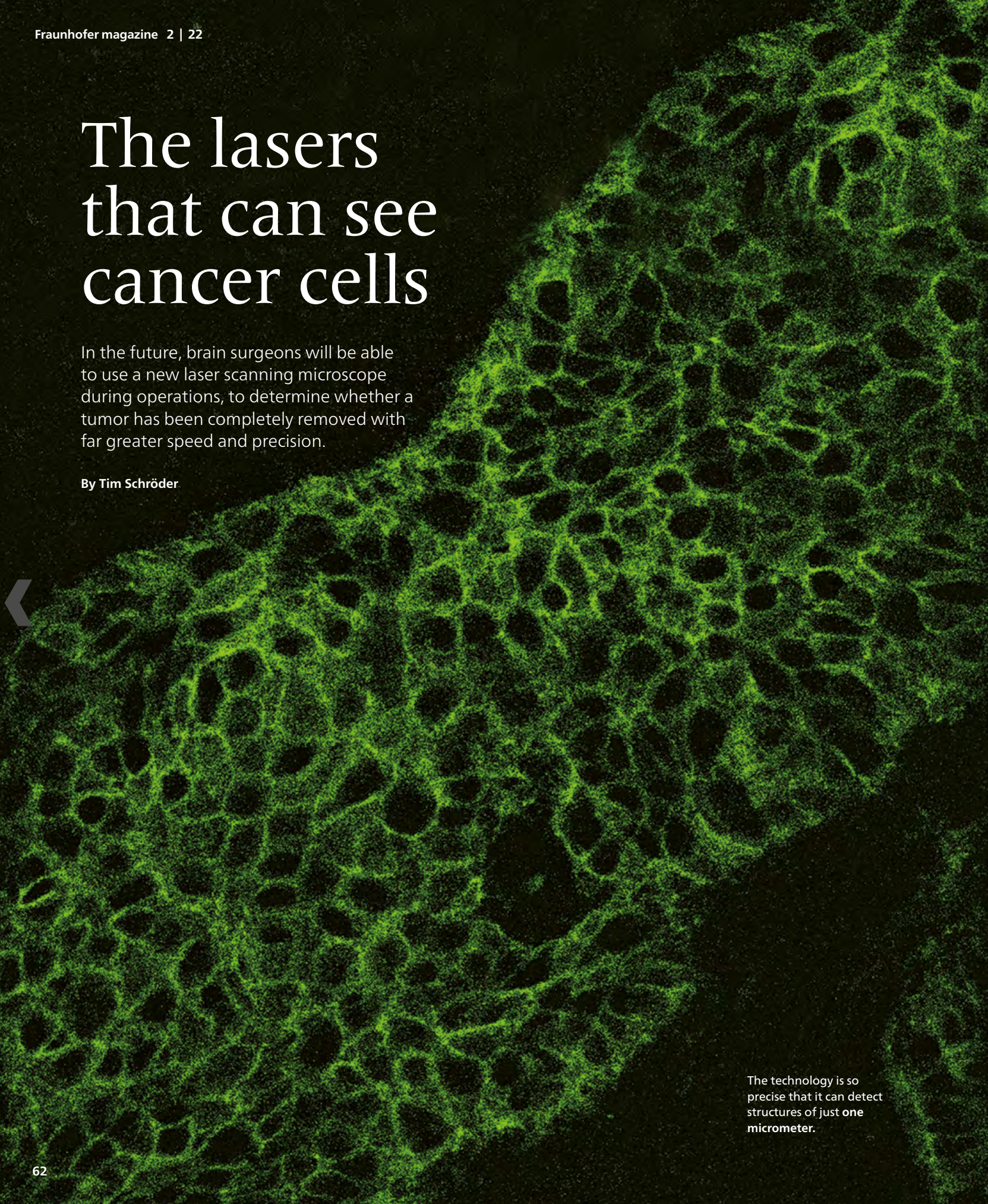
Photo: Fraunhofer/Piotr Banczerowski

back to page 1

The lasers that can see cancer cells

In the future, brain surgeons will be able to use a new laser scanning microscope during operations, to determine whether a tumor has been completely removed with far greater speed and precision.

By Tim Schröder



The technology is so precise that it can detect structures of just **one micrometer.**

To operate on a brain tumor is to work on a knife's edge, in the truest sense of the word: Surgeons must completely remove the affected tissue so that no cancer cells remain. Otherwise, the tumor could flare up again. On the other hand, they must not remove too much healthy tissue in order not to damage the brain. For this reason, surgeons often perform multiple checks during surgery to determine whether the cancer foci have been completely removed. In particular, it is crucial to check the edges of the wound, as this is where cancer cells often remain. The doctor takes a tissue sample and sends it to the hospital laboratory. Then it is simply a matter of waiting. The operation can only continue once the results arrive back at the operating room. If there are any remaining tumor cells, then more tissue must be removed. If the foci have been completely removed, then the doctors can close the wound. Depending on the size of the hospital and the staff's workload, this entire process can take up to 20 minutes — meaning valuable time is lost.

Detecting cancer cells directly in the operating room

This situation is problematic for doctors and patients alike. That is why researchers at the Fraunhofer Center Microelectronic and Optical Systems for Biomedicine MEOS in Erfurt have developed a laser system that can be used right in the operating room to check whether or not a tissue sample still contains tumor cells. Their method involves what is known as a confocal microscope, which uses a laser scanner. The system creates a microscopic image by scanning the surface of an object with the laser. The challenge here was to develop a compact device that is small enough to use on-site. "The primary concern for medical professionals is reducing the length of anesthesia, as this puts a huge strain on the patient," explains Dr. Michael Scholles, head of Fraunhofer MEOS. "Thanks to our innovation, doctors can study the tissue almost directly at the operating table. After two minutes, the results are there."

The way the laser scanning microscope works is that the laser beam stimulates the tumor cells, causing them to fluoresce and become visible under the microscope. "We had to combine a variety of technical elements in the device, which was particularly challenging," says Scholles. It was in development for a total of three and a half years. The project's participants included experts from the Fraunhofer Institute for Photonic Microsystems IPMS in Dresden and the Fraunhofer Institute for Cell Therapy and Immunology IZI in Leipzig. Researchers from Fraunhofer IZI, for example, developed a staining technique specifically for use with the laser scanner microscope, using special antibodies that dock onto cancer cells. These antibodies are combined with dyes so that they fluoresce green under the light of the laser, making the cancer cells visible.

"Thanks to our innovation, doctors can study the tissue almost directly at the operating table. After two minutes, the results are there."

Dr. Michael Scholles,
head of Fraunhofer MEOS

Scanning tissue at lightning speed

The project partners aimed to make efficient use of space when installing the various components in the microscope. After all, the device has to fit in the operating room alongside many others. The components include the laser unit and a mirror mechanism. Its core element is a movable mirror, just 1.5 millimeters in size. This oscillates several thousand times per second, guiding the laser beam over the tissue sample and scanning it at lightning speed. There is also a highly sensitive detector that picks up the weak fluorescent light, as well as an electronic analysis system that reconstructs an image of the tissue based on the numerous fluorescence signals and the movement of the mirror. The technology is so precise that it can image structures of just 1 micrometer — that's accurate enough to detect even individual fluorescent cancer cells.

In the process of developing the new laser scanning microscope LSC-Onco, the team made good use of their many years of experience with the various technologies, for example when it came to designing the mirrors. These are entirely etched from silicon discs known as wafers with great precision, in a similar process to a computer chip. Even the mirrors' mounting is made from silicon. Experts refer to this as a microelectronic-mechanical system (MEMS). "At Fraunhofer IPMS, we have been working on MEMS technology for more than 20 years. We have really benefited from this now while designing the highly sensitive optics of our laser scanning microscope," says Dr. Scholles.

In the meantime, several doctors have put the LSC-Onco system to the test. The feedback has been consistently positive, says Dr. Scholles. The fluorescence image of the tissue sample is displayed on a screen in the operating room so that the surgeons can selectively remove remaining cancer cells without damaging healthy brain tissue.

Since it is possible to change the focal plane of the microscope, the surgeons can detect cancer cells that lie a little deeper. In principle, the system can be used for other types of cancer as well. Dr. Scholles is also working with dermatologists, among others.

In the medium term, he and his colleagues want to make the device even more compact so that it can be installed in surgical robots. The robots will then use the fluorescence image to position themselves in a fully automatic manner and cut out tumors with a high degree of precision, all without any waiting time. ■

Photo: Fraunhofer IPMS

back to page 1

With classic medicines, effects often wear off quickly.

Outsmart the garbage disposal

Cells have an efficient waste disposal system. By taking advantage of this system, proxidrugs have enabled new treatments for cancer, infections and Alzheimer's disease.

By Christine Broll

Dr. Aimo Kannt specializes in sustainability — though for him, this means sustaining the effects of medicines. "Conventional drugs work by binding to disease-causing proteins, which has the effect of inhibiting their function," explains Dr. Kannt, head of the Drug Discovery and Preclinical Research departments at the Fraunhofer Institute for Translational Medicine and Pharmacology ITMP in Frankfurt am Main. "However, proxidrugs destroy the pathogenic protein, giving them a longer-lasting effect."

Dr. Kannt believes this new class of medication known as proximity-inducing drugs — or proxidrugs for short — will open up previously unimaginable possibilities in medicine. "80 percent of all possible protein target structures are inaccessible to the active pharmaceutical ingredients we currently use. Proxidrugs could help us reach a large number of these, allowing us to develop treatments for diseases that are currently incurable." The field is the subject of intensive research worldwide, and the first clinical trials are already underway. However, there is still a long way to go before these new active substances become part of standard practice.

Kannt is doing his part to pave the way, together with a consortium of universities and industry partners, as part of the PROXIDRUGS project. The project is being funded by the German Federal Ministry of Educa-

tion and Research through the Clusters-4Future competition, which received 137 submissions. PROXIDRUGS was one of seven projects to receive the highly coveted funding.

The inhibitory effect of traditional medications begins to wear off as soon as the drug is broken down in the body. This is why drugs that combat conditions such as high blood pressure must be taken on a regular basis. Proxidrugs, on the other hand, tackle the pathogenic proteins, thereby eliminating the cause of the disease. They use the cells' own protein shredders, called proteasomes, to trigger the protein degradation process. These proteasomes are part of an efficient cellular recycling strategy. A biological monitoring system continuously searches for defective or spent proteins and, upon detecting such a protein, marks it with a "flag" in the form of a molecule called ubiquitin. This ubiquitin marker acts as a recognition signal for the proteasome. Once captured, this unwanted protein is unfolded and broken down into smaller components within the barrel-shaped proteasome complex.

Shredding flagged proteins

Proxidrugs ensure that disease-related proteins are marked with a ubiquitin flag, allowing them to be recognized as waste by the cell's own waste removal system and broken down by the proteasome. It's simple in principle, but is technically difficult to implement. The ubiquitin flag is attached to the protein by means of a special enzyme, E3 ligase. Proxidrugs are designed so that they can bind to the target protein on one side and the E3 ligase on the other. The substance class gets its name from the proximity induced between the target protein and the E3 ligase (see the illustration).

"In the PROXIDRUGS project, we are addressing all aspects associated with these active substances," says Dr. Kannt. The consortium consists of 10 partners, including Goethe University Frankfurt (the coordinating institution), the Technical University of Darmstadt, the Max Planck Institute of Biophysics and the pharmaceutical companies Merck and Abbvie.

80 percent of all possible protein target structures are inaccessible to the active pharmaceutical ingredients that are currently used.

The project focuses on three medical problems: cancer, neurodegenerative diseases and infectious diseases. In all three fields, the aim is to eliminate the proteins that promote the disease process. In the case of cancer, for example, these are messenger substances that stimulate the growth of tumor cells. In the field of neurodegenerative diseases, such as Alzheimer's disease, the goal is to target proteins that are involved in the formation of deposits in the central nervous system. Fraunhofer ITMP is taking the lead for this subproject.

New strategy to fight multi-drug-resistant germs

Proxidrugs offer a completely new approach to fighting infectious diseases. There is hope that effective new drugs will be found to tackle multidrug-resistant bacteria. One such bacteria that the project is focusing on is Acinetobacter baumannii, a dangerous hospital bug that primarily causes pneumonia and wound infections.

To make the process of searching for effective proxidrugs more efficient, Fraunhofer ITMP is working with other partners to develop special test systems that can be used to identify active substances that can counter the various target proteins. At the same time, Dr. Kannt is also establishing a cross-institute platform for the development of proxidrugs as part of the Fraunhofer Cluster of Excellence Immune-Mediated Diseases CIMD. The platform is expected to cover the entire value chain, from the search for suitable active substances (drug discovery) to preclinical tests. Here, the focus is on inflammatory bowel diseases and fibrotic lung diseases. "Proxidrugs seem to be well tolerated by the human body and very effective," says Dr. Kannt. He adds: "This is motivating us to work extremely hard on developing this new drug class." ■

How proxidrugs work

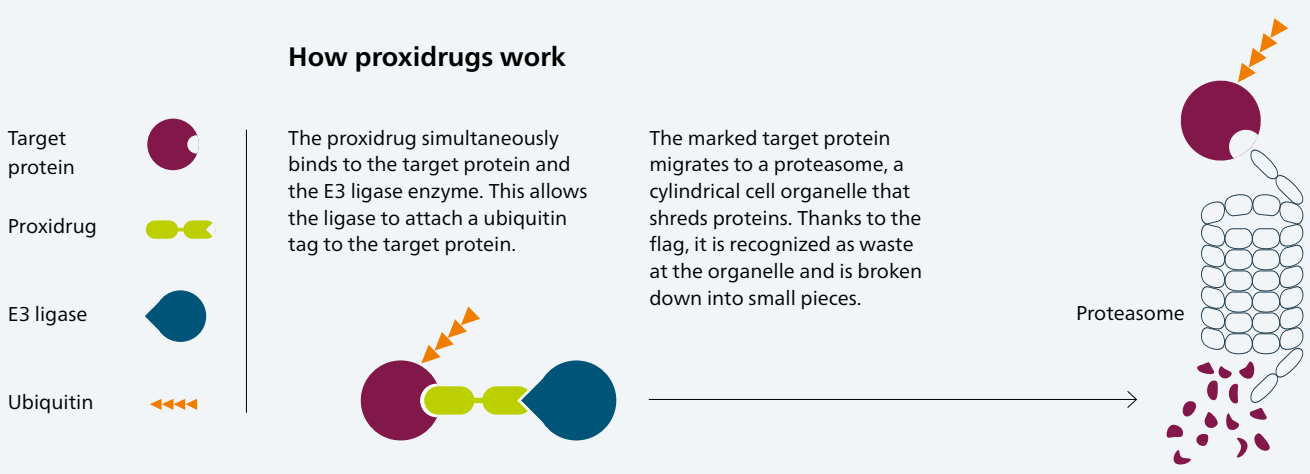


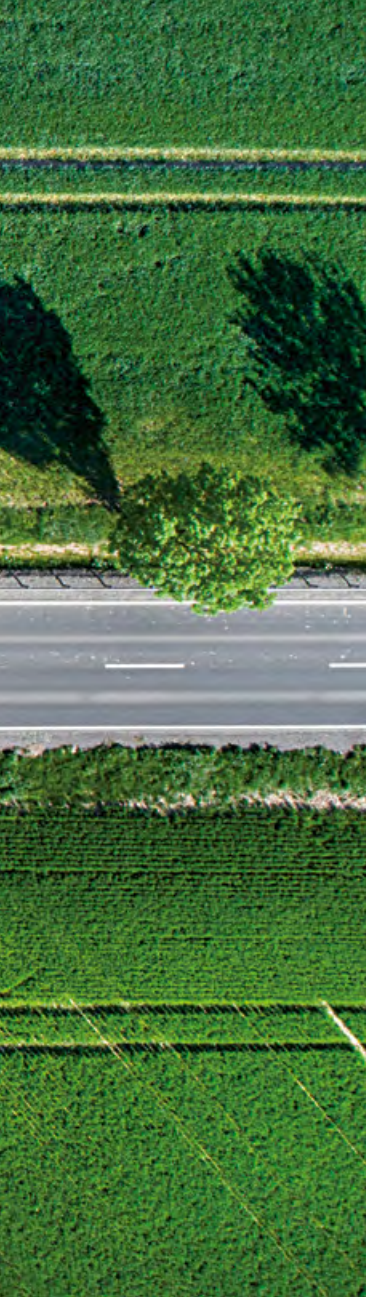
Photo: Science Photo Library/PHANIE/VOISIN; Illustration: Vierthaler & Braun

back to page 1

Kick-starting the bus and rail network

An extensive, digitally connected mobility service is our ticket to the future — in both urban and rural areas.

By Moritz Schmerbeck



In rural areas, the school bus is often the only bus that runs at all.

Photo: Ollo/istockphoto

Launching the mobility transition will take more than abstract ideas. Even with the massive rise in gas prices, the financial savings alone are not a strong enough argument for switching to bus and rail travel. In rural areas in particular, many people are still reluctant to use public transport, despite the German government's introduction of a special, discounted nationwide travel pass costing just 9 euros. Because what good is a cheap ticket if there is no bus to use it? The Fraunhofer Institute for Experimental Software Engineering IESE and the Fraunhofer Institute for Material Flow and Logistics IML recently joined forces to investigate how to make public transport a more attractive option in the long term.

In their study on the future of the mobility transition as far as 2030, the Fraunhofer researchers focused on rural and suburban areas in particular, because in these regions, public buses are often the only means of transport available apart from owning a car — but a kind of chicken-egg situation is causing problems here. Rural bus services tend to focus heavily on school transport, without considering commuters' needs in their schedules.

"This is the exact issue we're tackling," explains Patrick Mennig, a senior digital innovation designer at Fraunhofer IESE. "When planning and evaluating mobility services, the focus has to be placed on people that don't use it, in order to try and make public transport an attractive option for them."

Lots of options — anywhere, anytime

According to the Fraunhofer scientists, the only way to create demand is to start by providing an attractive service.

In big cities like Berlin, Hamburg and Munich, travelers can already take their pick from a whole smorgasbord of options — for any destination and at any time. They not only have access to train, subway, bus and tram services, but also on-demand shuttles, driving services, carsharing platforms, e-scooters and bike rental systems — and there are even multiple different providers, too. For more and more users, these public mobility services are coming to represent a more individualized, tailored solution than the one-size-fits-all approach of buying a car. "In an ideal world, mobility services would actually be so attractive that people would prefer to use public transport services instead of a car of their own," says Mennig.

> "In an ideal world, mobility services would actually be so attractive that people would prefer to use public transport services instead of a car of their own."
>
> Patrick Mennig, Fraunhofer IESE

Connected and coordinated through digital networks

The full potential of public transport will never be unlocked until mobility services are connected via a digital network and coordinated based on data-driven methods. This is the only way that people will be able to use it as a reliable, comfortable means of getting around from door to door — and not only more cheaply, but also more quickly than driving a car. In this context, even big cities have some catching up to do. Even now, if a user wants to take an on-demand shuttle from their house to reach a regular bus service, ride that bus as far as the route allows and then use an e-scooter for the last leg of their journey, they still need three apps from three different providers with three different pricing structures.

"Users want a seamless customer journey, taking them through every step from looking for connections to reaching their destination without interruption. And virtually all of this needs to happen in one smartphone app that also provides easy payment options," explains Mennig. "For this to work, mobility service providers have to stop seeing each other as competitors. They need to work together to realize the vision of creating a high-quality, climate friendly service for all users. Collaborating with others may look like a loss of market power to begin with, but these new partnerships and the more attractive services they facilitate will ultimately result in an expanded customer base." ■

back to page 1

The search for the perfect plant

Intelligent field robots and X-ray technology help cultivators to select heat-tolerant plant varieties.

By Christine Broll

Wheat is most comfortable at 25 degrees Celsius, making it particularly vulnerable to climate change.

Is this Mars or Southern Germany? A long-legged vehicle reminiscent of NASA's Mars Rover trundles through a wheat field, moving as though guided by an invisible hand. But this robot is on a very earthly mission. As it makes its way through the densely packed ears of wheat, it continuously X-rays the plants and simultaneously generates 3D images using an optical system. For the cultivator who owns the field that the robot is working in, this is important information — it allows them to essentially look inside the ears of wheat and determine whether the variety they are cultivating will produce a good yield.

The sensors on this high-tech machine were developed by the Fraunhofer Institute for Integrated Circuits IIS, where for many years, research has been carried out into technologies that can identify plant phenotypes. This refers to their external appearance, which includes a multitude of factors such as leaf size, leaf arrangement, root thickness and yield. "People have been selecting crops based on external characteristics for thousands of years," explains Dr. Stefan Gerth, head of the Fraunhofer Development Center for X-ray Technology at Fraunhofer IIS. "We're developing technologies to objectively measure these phenotype characteristics and optimize cultivation based on this data." After all, the cultivators face great challenges. Heat-tolerant, drought-resistant plants are in demand on account of climate change. These new varieties should also be able to survive with as little fertilizer and pesticide as possible.

The experts team up

The most important objective of the trans-regional Fraunhofer project on biogenic value creation and smart farming is to support cultivators. This is why the project participants are launching the Fraunhofer Center for Plant Phenotyping Technologies in Triesdorf, Bavaria, where Dr. Gerth and his colleagues intend to expand their expertise and translate it into real-life application. Triesdorf, Germany's smallest town with a university, is home to agricultural teaching institutes and the Weihenstephan-Triesdorf University of Applied Science, making it a trans-regional center for agriculture. Fraunhofer IIS works closely with the Competence Center for Digital Agriculture located there.

High-tech cultivation

In the Fraunhofer IIS greenhouse, Stefan Gerth demonstrates how cultivators will work in the future. On the narrow conveyor belt in front of the X-ray machine, pots of various crop plants are arranged in neat rows. The door of the X-ray machine opens, and a pot rolls inside. Once the door has closed, the pot undergoes a computer tomography scan, among other tests. Just five minutes later, it's time for the next pot. "Over ten years ago, we started X-raying potato plants to get information about the tubers' growth," reports Dr. Gerth. "Based on the 3D X-ray scans, we can determine the weight of the tubers without having to dig them up." This process is being used for tasks such as selecting particularly heat-tolerant varieties. To this end, the plants are placed under heat stress inside the greenhouse. The scans then show which plants deal with the stress most effectively, forming strong tubers in spite of the heat.

> "People have been selecting crops based on their external characteristics for thousands of years."
>
> Dr. Stefan Gerth, Fraunhofer IIS

Whereas only thick roots and tubers could be X-rayed with the first computer tomography scans, the new systems can also capture the delicate underground root structure of wheat. "Our new X-ray machine is the most modern, powerful system for X-raying parts of plants that lie underground," says Dr. Gerth.

Researchers at Fraunhofer IIS are also conducting 3D digital imaging of the parts of the plants that are above ground, such as leaves and ears of wheat. This data can be used to determine more than just the area of the leaf surface — the 3D images also provide information on the plant's heat tolerance. Does the plant raise its leaves to protect itself from the sun? Does it curl up its leaves due to stress?

The efficiency of Fraunhofer IIS's optical plant recognition systems was clearly demonstrated in a test field at the seed company Strube D&S GmbH. In this case, the second BlueBob prototype was used — a field robot that navigates on its own and automatically removes weeds in sugar beet fields. As it moves between the rows, it records images of all the living plants using multispectral cameras. "Through artificial intelligence, the phenotype of each individual plant is analyzed and classified as either a weed or a beet plant," explains Christian Hügel, Head of the Technical Center of Seed Research at Strube. If BlueBob 2.0 identifies a weed, it removes it from the ground with its hoeing tools. It cuts down weeds both between the rows (using static tools) and within the rows (using moving tools). As a result, almost all of the weeds around the beet plants are removed. This means the use of chemical weed killers can be drastically reduced.

One major work package at the new center in Triesdorf will involve processing the data obtained during phenotyping. "Our main goal is to use our technology to support cultivators in the SME bracket," emphasizes Dr. Gerth. "That is why we are collaborating closely with the practitioners themselves in Triesdorf, to develop business models that offer added value for the company." ■

Scan here for the podcast:

Photo: Science Photo Library/Victor de Schwanberg

back to page 1

Fraunhofer worldwide

Locations of the Fraunhofer-Gesellschaft

In the operating room, 5G networks and artificial intelligence make it possible to quickly evaluate large amounts of data.

FRANCE

The clinic of the future

Scientists from the Fraunhofer Institute for Manufacturing Engineering and Automation IPA are working together with French partners on a digitalized "clinic of the future." As part of the 5G-OR project, a dedicated 5G network will be installed in the operating theaters at three clinics in Strasbourg, Mannheim and Berlin. 5G technology makes it possible to build a network connecting a large number of mobile devices in a very small space with minimal delays, considerably relieving the burden on staff. For example, it enables automatic, digital analysis of vital signs such as heart rate, breathing rate and oxygen saturation during an operation. All of the data on the vital signs is sent wirelessly to a central computer, where it is evaluated by artificial intelligence in real time, allowing medical staff to see at a glance where they most urgently need to action. At present, vital signs are measured using non-connected devices. These can only record around 5 percent of all possible biosignals.

Fertilizers are often used inefficiently.

PORTUGAL

Fertilizers on demand

The AFRICA project enables small farmers in Africa to produce inexpensive, tailor-made fertilizers on site. Female farmers will be supported above all. To this end, the Fraunhofer Center for Assistive Information and Communication Solutions AICOS in Porto developed an IoT sensor platform to determine the condition of the ground and the environment, meaning texture, pH value, humidity, color, air temperature and incidence of light. The nutrient requirements determined through the sensors is transmitted to a miniature system that produces specially tailored fertilizers and is operated directly on the farm through solar energy. At the same time, the farmer receives information on how to fertilize the soil, and in what quantities. The plant is currently producing nitrogen-based fertilizer. However, it will be expanded to produce other nutrients.

Small farmers in Africa produce 80 percent of the continent's food. However, due to population growth, food consumption is increasing almost ten times faster than the rate of production. Since the nutrient content of the soil is oftentimes not correctly assessed, arable land becomes over-fertilized — this not only affects crop yields, but also has a negative impact on climate change.

PORTUGAL

Sustainable irrigation

In the future, an underground sensor-based system will help remotely monitor the moisture content of soil and accordingly make precise adjustments to irrigation systems. The LoRa4UProbes system is being developed by Fraunhofer Portugal AICOS, together with the company Aquagri. What sets LoRa4UProbes apart from other ground monitoring solutions is its use of underground hardware with extended range, which is compatible with probes from various manufacturers.

The modular structure varies depending on the size of the area.

Climate change is making it necessary to optimize agricultural irrigation.

One unit is sufficient for an average-sized garden, while multiple units are required for a golf course. LoRa4UProbes can currently communicate with a gateway over a distance of 1.7 kilometers, which the data packets all forward at the same time. The researchers are currently working on increasing the range.

AUSTRIA

Food: Less waste, more prediction

Every year, 88 million tonnes of food end up in garbage across the EU. Researchers working in the APPETITE project aim to reduce this waste by up to 10 percent.

To this end, artificial intelligence will be used to regulate supply and demand at participating supermarkets, ensuring that large quantities of food are no longer sent to the wrong branch. The research consortium led by Fraunhofer Austria Research GmbH is developing a prototype for a forecasting platform that can process all the necessary data in close to real time. This data includes checkout and logistics data for the individual stores, as well as information on when large crowds occur and the weather conditions. After all, expected sales are heavily dependent on these external influences. If the retail chain can recognize demand in good time, it can relocate groceries to where they are likely to be bought to avoid them being left behind elsewhere. If the logistics cannot be modified in time, food-saving organizations can be informed at an early stage and the goods can be passed on.

Artificial intelligence will help to better predict consumption.

GREECE

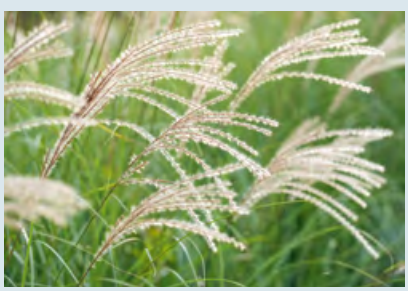
Renewable raw materials to replace crude oil

Researchers in BioMates, a European project, are looking to reduce the use of fossil fuels. To this end, they are converting plant waste into high-quality bio-based intermediate products (BioMates) that can be used for fuel production in conventional refineries.

The Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT developed a recipe that researchers have now used to produce their first 1,000 liters of bio-oil. The recipe calls for both straw and miscanthus, a fast-growing Chinese grass.

In a laboratory refinery, the Greek research center CERTH, which coordinates the project, is testing how the bio-oil can be further processed into fuel under industrial conditions. Their goal is a bio-based fuel consisting of 90 percent fossil fuels and 10 percent BioMates.

So far, only ready-to-use biofuels can be mixed with conventional fuels at the end of the production process for this kind of hybrid fuel. BioMates would make this step unnecessary. The advantage would be savings in terms of both fossil fuel energy and costs.



Bio-oil from fast-growing miscanthus grass can be processed into fuel in conventional refineries.

back to page 1

Protecting crops without poison

Insects devour a third of the world's harvests each year. How can we fight these pests without endangering the huge numbers of useful insects? Fraunhofer IME has imitated one of nature's clever tricks to protect plants in an environmentally friendly way.

By Dr. Monika Offenberger

German Federal Minister of Food and Agriculture Cem Özdemir is afraid that East Africa is facing its worst famine in 40 years. When it comes to what she calls "the largest famine since the Second World War," Minister for Economic Cooperation and Development Svenja Schulze believes "the situation is extremely serious." The best-known causes are the coronavirus pandemic, climate change and the associated severe droughts, and the war in Ukraine — but crop failures due to pests also play a role here. A team of researchers from the University of Twente has calculated that almost a third of the crops cultivated worldwide are lost to diseases and insect pests. The worst affected crop is rice, but potatoes, wheat, soy beans and corn also experience losses of between 17 and 23 percent. "We are concerned to see that certain insect pests are spreading massively," confirms Prof. Andreas Vilcinskas of the Fraunhofer Institute for Molecular Biology and Applied Ecology IME in Giessen. 2018 saw an EU-wide ban on using deadly neonicotinoids for pest control, which is an important step for protecting bees and other useful insects. However, without an effective substitute, "farmers feel they've been left in the lurch, because their weapons have been taken away," according to Prof. Vilcinskas.

When it comes to beet cultivation, you can understand their urgency: The crop yields of more than 26,000 beet farmers in Germany are being threatened by aphids and plant hoppers. Only a few millimeters in size, these insects suck on the leaves of the crop and infect them with viruses and bacteria, which can reduce the sugar content in the beet by up to 40 percent. The aphids and plant hoppers spread rapidly — in Germany, they have already affected around 40,000 hectares of arable land. "Since the ban on neonicotinoids, we've had nothing to use against them," says Prof. Vilcinskas. "Our goal is to develop new strategies for pest control, beyond using chemical pesticides that have the side effect of killing off useful insects."

Selective gene silencing

Genome research is the key to protecting crops without harming the environment and insects. First of all, researchers need to identify the genes that are typical of and required for the survival of certain types of pest — but for that type only! Once they have found these genes, the researchers look for a targeted way to silence them. As is often the case, biologists have found a way by imitating nature itself: It's called RNA interference (RNAi for short), or RNA silencing. "All higher organisms use this mechanism to protect themselves against invading viruses. We want to use it to silence species-specific genes," explains Prof. Vilcinskas. They achieve this remarkable feat using double-stranded RNA fragments with sequences that exactly complement the selected genes in the insect in question, as animal and plant cells normally only produce single-stranded RNA. As soon as they detect doubled-stranded RNA fragments in their cells, they recognize them as foreign and begin to break them down. A significant side effect here is that during this process, individual RNA strands from

Double trouble: When biting and sucking on plants, aphids also transmit viruses and bacteria.

Photo: Science Photo Library/Heath McDonald

There are around 850 known species of aphid in central Europe alone.

the same sequence are simultaneously destroyed. If you want to silence a single gene, all you need to do is copy the RNA sequences that it codes as double-stranded RNA and make sure that the RNA gets into the pests, i.e. is consumed.

There are two ways of doing this. The first is to program the genome of the cultivated plant so that it produces the double-stranded RNA that counteracts an essential gene in its predator. "The best thing about this method is that it allows you to have species-specific control over pests, so long as we can silence the selected genome in this organism alone, and not in others. This means even closely related organisms are not affected, especially bees and other animals, or people," emphasizes Prof. Vilcinskas.

Taking the example of aphids, we can see how his team plans to proceed. This insect feeds on the plant sap by breaking through to the vascular tissue within the host plant. A special protein in its saliva hardens upon contact with the sap, and acts like a drinking straw for the aphid. "If we can silence this specific protein using RNAi, they can no longer form this drinking straw, and will starve to death," explains the biologist. Other research groups have succeeded in using RNAi technology to make potato plants resistant to voracious potato beetles. It is hoped that this new technology will be used worldwide as an environmentally friendly alternative to poisonous crop spraying. However, due to significant reservations regarding the use of GM plants, it is not yet clear whether the resilient pea and potato varieties will also be cultivated in Germany in the future.

For this reason, Prof. Vilcinskas favors the second option. "We want to produce the double-stranded RNA in the lab and then spray it directly on the fields. The pests will ingest it there as they feed. Even in large quantities, this is harmless, as RNA doesn't contain any toxic compounds and completely decomposes outdoors," explains the insect researcher. However, the biomolecules must not be allowed to decompose or be digested too soon. "Many insects produce enzymes in their saliva that break down RNA. We need to find a solution for that as well. Ultimately, the RNA must be ingested by the insects and move through the intestinal epithelium intact. Only then can it take effect. This means that for each type of pest, we have to develop a suitable formulation that fulfills all these conditions and can also be sprayed using commercially available equipment," explains the Fraunhofer researcher. A compound developed by Fraunhofer IME together with the US company Greenlight Biosciences has already been proven successful in combating the potato beetle, and is now undergoing field testing in collaboration with the Julius Kühn Institute. "In the USA, the outdoor tests carried out this year have been successful, and they have already applied for authorization to bring it on the markets," says Prof. Vilcinskas. "Next we're going to test an agent to combat common pollen beetles. These beetles eat the pollen from rapeseed blossoms, which prevents the rapeseed pods from maturing."

Tried and tested — and affordable

In order for the new biopesticides to be competitive, they need to be affordable. The Fraunhofer researchers in Giessen are working toward this goal with Greenlight Biosciences. The company has developed and patented a cell-free process for synthetic RNAi production that is significantly less expensive than the conventional production methods based on genetically modified yeast cell cultures. The German Federal Ministry of Food and Agriculture is also betting on RNAi-based pesticides, and is supporting Fraunhofer IME in developing appropriate compounds for combating aphids and plant hoppers. At the same time, Prof. Vilcinskas has his sights set on dozens of other harmful bugs, including a number of beetles and caterpillars — and about a dozen viruses that affect one of our most important "farm animals": honey bees. The deadly pathogens are spread through beehives by mites or other parasites, or are transmitted from one insect to the next as they visit flowers.

Prof. Vilcinskas believes RNAi could also be helpful here. "We want to silence genes that these viruses require to live, in order to prevent them from multiplying." His team are working on finding specific gene sequences and packaging them in such a way that they remain stable for several days. If dissolved in sugar water, they could be fed to honey bees in winter, and then unleash their healing effects. Prof. Vilcinskas stresses that this would also benefit their wild relatives. "More and more often, we're seeing that viruses from honey bees are being transmitted to bumblebees and other wild bees when they visit flowers. If we could render these pathogens harmless using RNAi, that would be an important step toward saving these pollinators, as they are crucial in the natural world and in agriculture." ■

back to page 1

With a wingspan of up to seven meters, manta rays are imposing giants — however, they and other devil rays are not dangerous to humans: Unlike stingrays, they do not have a venomous stinger.

Photo & Fraunhofer

Robo-ray on the hunt

It's a race against time. The 1.6 million tons of mines and explosive devices from the Second World War are ticking time bombs in the North and Baltic Seas. As they rust, carcinogenic TNT, nitroaromatics and mercury are released into the water. Now, working in conjunction with partners, researchers at the Fraunhofer Institute for Reliability and Microintegration IZM have developed a flexible sensor skin for an underwater robot that, thanks to its innovative, digitally connected sensors, can detect metal lying on the seabed or buried in shallow sand. Its mobility and agility is based on the model of the manta ray. The robo-ray also explores narrow places that are difficult to reach, and could previously only be inspected by professional divers.

Autonomous underwater vehicles (AUV) have already existed for a number of years. Taking inspiration from living creatures, they have been optically and anatomically adapted to the marine world. So far, however, the robo-rays have not been smart enough to take over the dangerous work of divers. In the Bionic RoboSkin project, the robotic manta rays are covered with a flexible, bionic sensor skin that allows the underwater vehicles to autonomously find their way around their respective environments. The sensors are located on the surface of the wings. Researchers at Fraunhofer IZM are developing the integrated sensor modules, thanks to which the AUV can recognize and analyze things that approach and touch them, as well as their surroundings.

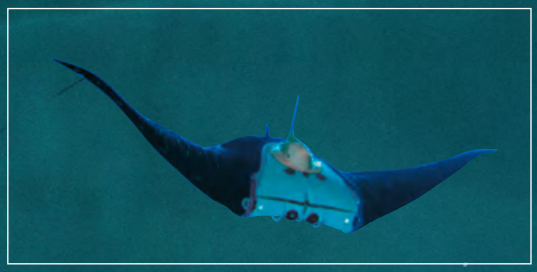


Photo: Mark Carwardine/EvoLogics GmbH

back to page 1

Making excellence more measurable

For the most part, engineers' work is focused on application. That means the current academic procedures for assessing their achievements do not do them justice.

By Franziska Sell

There is no call for long publications lists in Industry 4.0.

When it comes to competing for the best positions and funding in the scientific world, the publication list is the measure of all things: How long is your list? Have you had articles published in renowned specialist journals? How often have you been cited by others?

"However, this is only of limited significance in applied engineering sciences, especially when it comes to Industry 4.0, which aims to digitalize industrial production." So says Dr. Michael Schmidt, chief scientist at the Fraunhofer Institute for Material Flow and Logistics IML. In this case, the central question — namely, what practical projects the candidate has actually implemented — receives far too little attention. There is no better example of the inadequacy of the present system than the Industry 4.0 handbook ("Handbuch Industrie 4.0"): "The handbook has been downloaded millions of times. But the number of downloads is not treated as a relevant criterion in determining what is known as the h-index, an indicator that demonstrates how often a person has been quoted. Despite this, the manual is considered a standard work and greatly influences industry practice: Over one million people have read it and learned from it."

> "It was exciting to see the sheer variety of relevant, measurable variables that came out of our many discussions."
>
> Dr. Michael Schmidt, Fraunhofer IML

In response to this, Fraunhofer IML, together with the Speech and Language Technology Lab of the German Research Center for Artificial Intelligence DFKI in Berlin and the company Ubermetrics Technologies GmbH, started the EVALITECH research project, with funding from the German Federal Ministry of Education and Research (BMBF). Dr. Schmidt says, "Our goal was to make it easier to measure scientific excellence in the area of industry 4.0. In doing so, we hoped to help identify the most suitable candidates during application and appointment procedures, for example in universities and other research institutions."

The project team developed their own indicator system. First of all, they analyzed the usual evaluation parameters and determined which additional qualification features had to be systematically taken into account. "It was exciting to see the sheer variety of relevant, measurable variables that came out of our many discussions," reports Schmidt. After all, there are other factors that influence scientific success, for instance management experience, the amount of state and industry funding an individual has received, their presence at trade fairs and their lecturing experience. "These are all relevant and meaningful parameters — and they are not easy to determine." The specialists from Ubermetrics provided support based on their media analysis expertise here, while the DFKI team also pitched in by using in-house speech recognition solutions to extract information from documents that had been collected previously, such as résumés.

The researchers at Fraunhofer IML analyzed the data, divided it on the basis of whether it would be collected automatically or manually, and then used their findings to build a demonstrator. They worked out the different ways that the data could be distributed and compared, and developed algorithms that enable users to compare individuals on the basis of flexible criteria and carry out any search they want.

Artificial intelligence (AI) was used to collect, filter and process the data, but not to evaluate it. For that last step, the experts created flexible, adjustable profiles to use when evaluating candidates, for example "entrepreneur," "scientist" and "influencer." "These individual profiles can be combined with the automatically collected data in order to work out who is suitable for a specific position and just how well suited they are. For example, does the individual have a particularly extensive network? Are they noticeably active on social media? Or are they in touch with a lot of start-ups?" explains Dr. Schmidt. "In the future, with our flexible, multi-layered indicators, it will be easy to analyze a database of 1,000 candidates and interactively filter them using various sliders." ■

Photo: Adobe Stock

back to page 1

Fraunhofer ALUMNI

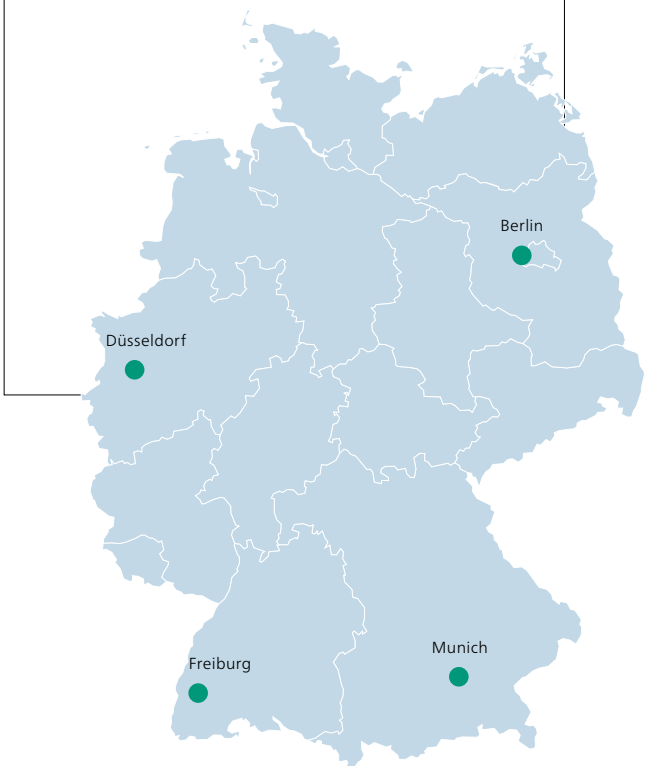
6th Fraunhofer Alumni Summit 2022

»Live wire – innovative energy technologies«
November 18, 2022, Freiburg

In collaboration with the Fraunhofer institutes EMI, IAF, IPM and ISE

www.fraunhofer-alumni-summit.de

Fraunhofer on the road



Berlin
September 20–23, 2022
InnoTrans
International trade fair for transport technology

Berlin
September 28–29, 2022
Futuras in Res — The Quantum Breakthrough
A series of conferences by the Fraunhofer-Gesellschaft

Düsseldorf
October 19–26, 2022
K
The world's most important plastics and rubber industry fair

Düsseldorf
November 14–17, 2022
Medica/Compamed
The leading international trade fairs for the medical sector

Munich
November 15–18, 2022
electronica
The leading international fair and conference for electronics

Freiburg
November 18, 2022
6th Fraunhofer Alumni Summit

Last updated: July. Changes may occur due to the pandemic. Please keep an eye out for information from the event organizers.

back to page 1

"A zero-trust strategy means that traffic and every access to resources are constantly monitored and validated."

Martin Seiffert of Fraunhofer AISEC on the battle against cybercrime

Fraunhofer