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How research helps fight manipulation

Bring on the water!

Improving management of this vital resource

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"We take the situation seriously!"
Interview with Nancy Faeser, the German Federal Minister of the Interior

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Editorial

Minimizing risk, maximizing opportunities

By Prof. Holger Hanselka

Prof. Holger Hanselka

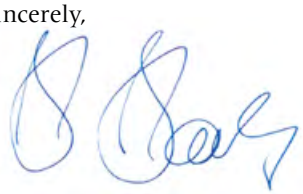
New reports come pouring in every day. Artificial intelligence (AI) creates whole new opportunities for manipulating the masses, which is especially alarming at a time when there are crucial elections coming up in countries like Germany and the U.S. German federal interior minister Nancy Faeser also warns about the challenges involved. "The perpetrators are getting more and more professional," she says in an interview with the Fraunhofer magazine (see page 46). That's the political aspect. And what about the economic side? AI costs jobs. AI creates jobs. AI is revolutionizing our working world. Anything and everything seems to be possible. And like anytime when so much seems to be in flux, when disruptive and radical change is afoot, both hopes and fears are on the rise.

Even amid all the concerns about risks, which are certainly justified, I personally believe the opportunities clearly outweigh them. Even just by itself, AI-supported robotics will enhance Germany's competitiveness as a hub of industry. AI will unlock whole new potential in the fight against cancer. AI will boost the efficiency of our energy system — and thus also support the energy transition. DZ Bank just recently published the results of a representative survey of the management of 1,000 medium-sized companies. According to their findings, managing directors expect the use of generative AI to help with obtaining information (30 percent) and with creativity (24 percent). And with one of their biggest problems, too: Nearly 60 percent of respondents say generative AI will help them cope with bureaucratic burdens.

Fraunhofer takes a position on this, too. In our latest position paper on generative AI, we stress how crucial it will be to implement the EU Artificial Intelligence Act quickly, with little bureaucracy, and with foresight. It will also be critically important to support innovation partnerships between industry, medium-sized businesses, and applied research. This is the only way we will move generative AI into industrial application at the necessary speed and as widely as needed. According to a recent study by the German Economic Institute (IW) in Cologne, generative AI applications will generate an additional 330 billion euros in value creation for the German economy. As we can see, overcoming our fears will be worthwhile. We will benefit if we master the risks. We will gain the opportunity to strengthen Germany's technological sovereignty as a hub of industry in the long term, together with our European allies.

The Fraunhofer-Gesellschaft will be a helpful partner along the way, especially for medium-sized businesses. Fraunhofer got involved with the development of generative AI very early on and has invested more than 50 million euros of equity in building expertise in this field. Through its institutes, the Fraunhofer-Gesellschaft is involved in developing large sovereign applied AI models such as OpenGPT-X and EuroLingua. To give just one of many examples, the Fraunhofer Institute for Applied Information Technology FIT is involved in multiple projects with industry focusing on introducing AI in real-world practice at businesses. These kinds of connections in application and forms of collaboration like this help companies to minimize risks and maximize opportunities. Fraunhofer is glad to help them along the way with its research experience. Let's all continue to work together on innovative solutions across industry and the medium-sized business and research sectors. For prosperity. For society. For our future.

Sincerely,



Prof. Holger Hanselka
President of the
Fraunhofer-Gesellschaft

Photo: Fraunhofer / Stefan Obermeier

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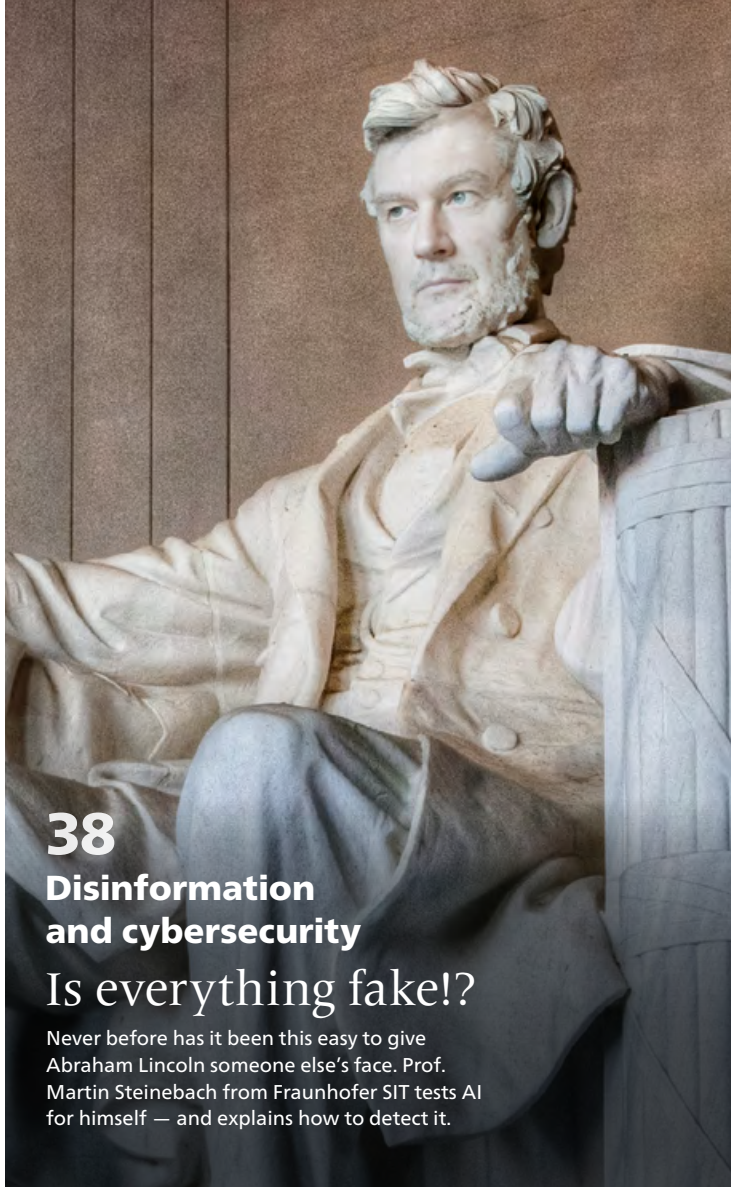

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Goodbye, bleeding gums!

New prophylactic paste effectively prevents gum disease

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How can more sunlight be brought into the office?

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High five!

Geckos have superpowers — as researchers are learning from the scaly lizards.

Just 8 percent of Germany's rivers and streams are healthy, as the German Environment Agency (UBA) found in 2021. The European Water Framework Directive requires all bodies of water to be in good environmental condition by 2027. We are far from meeting that goal, as the UBA's most recent Environmental Monitor shows.

8 %

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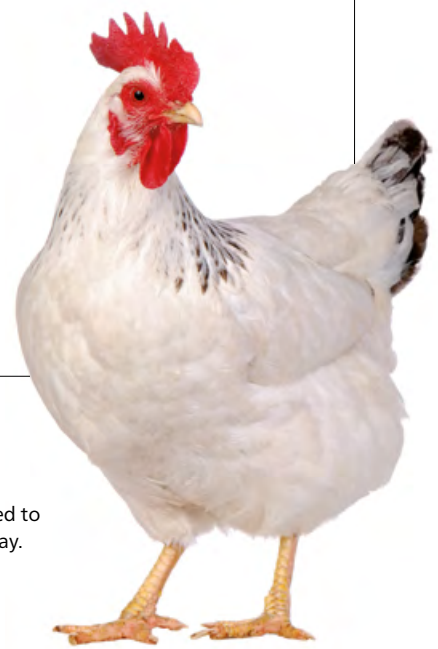
Brief report



The researchers at Fraunhofer IGB are relying on chicken feathers instead of the petroleum typically used to produce adhesives today.

Adhesives made from chicken feathers

Researchers at the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB have developed sustainable adhesives made from keratin, a highly versatile protein compound found in sources such as chicken feathers. With its particular biopolymer structure and outstanding linking properties, keratin is a perfect fit for production of binders of all kinds.

Feathers are a large-scale byproduct of poultry meat production. Until now, they have been destroyed or mixed into animal feed. In the KERAbond project, the team of researchers has joined forces with Henkel to develop a method that makes these feathers usable in adhesive production. They are first sterilized, then washed and ground up mechanically. After that, an enzymatic process is used to split the long-chain keratins. The output product is a platform chemical that serves as a base material for further development of specially formulated adhesives. Parameters such as the curing time, elasticity, thermal characteristics, and strength of the desired specialty adhesive can then be determined individually. ■

A simple way to test and enhance resilience

How resilient am I? A new web platform lets people test and build their mental resilience so they are better equipped for drastic events and challenging life circumstances going forward. The resiLIR web application was developed by researchers at the Fraunhofer Institute for Industrial Mathematics ITWM in cooperation with the Leibniz Institute for Resilience Research (LIR). It is freely available at www.resilir.eu.

Dr. Alexander Scherrer, deputy head of the Optimization in the Life Sciences department, comments: "Our AI methods ensure that resilience data and training progress to date are analyzed and the web platform then puts together individually suitable training content." Expert input from the psychologists at LIR and the current status of resilience research, prepared in digital form, serve as the basis. resiLIR is designed as an educational game that provides even complex methodological solutions and sophisticated psychological content in an accessible format. ■

People with high mental resilience are better able to cope with stress and setbacks.

The German Federal Statistical Office predicts that the number of people requiring nursing care will increase by about 37 percent between now and 2055.

Photos: soleg, Little City Lifestyle Photography, Manassanant Pamai / all photos from iStockphoto (3), Fraunhofer IOF

Artificial intelligence supports long-term care

The Fraunhofer Institute for Industrial Mathematics ITWM is developing and testing a knowledge-based, data-driven assistance system for professional process design in long-term care in collaboration with partners as part of the ViKI pro project. The AI-based system allows specialists to identify individual care needs and plan appropriate measures using digitalized specialist knowledge. The documentation of the care measures implemented in the web application also helps to accumulate practical knowledge that can be used for future planning.

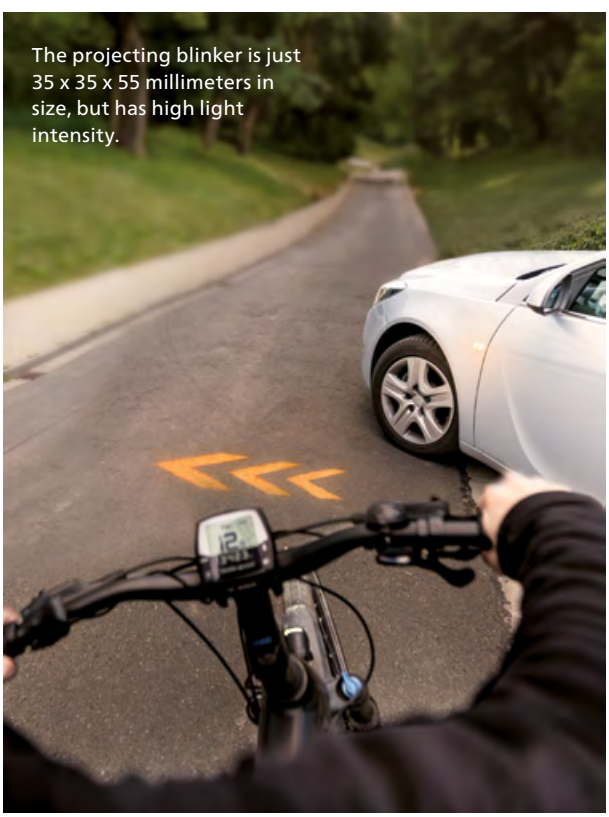
The quality of the data sets used is key here. Each care case is therefore entered with a comprehensive and detailed medical history including a risk matrix, considering numerous factors such as whether the patient is bedridden, able to take care of themselves, overweight, depressed, and so on. The system then uses artificial intelligence to suggest suitable care measures, which care planners then choose from based on their experience. The goal of ViKI is to help improve the quality of inpatient care and conserve resources, which are in short supply. ■

More safety on the road

Researchers at the Fraunhofer Institute for Applied Optics and Precision Engineering IOF have devised a blinker that displays the desired direction of travel not just on the vehicle itself, but on the road surface as well. To do this, it projects a dynamic sequence of arrow symbols at a light intensity of over 7,000 Lux onto the road surface, ensuring good visibility even in daylight.

The two-sided microlens array (MLA) consists of an array of arrow-shaped "lenslets" on the light input side and smaller square ones on the output side. By illuminating the MLA at different angles, light paths are steered between certain combinations of input and output lenslets. This design approach makes it possible to generate arrow symbols in different positions with a single projector system, which simplifies installation and reduces costs and space requirements.

The two-sided microlens arrays are produced using grayscale lithography and then replicated as polymer-on-glass tandem arrays. The combination of polymer and glass permits precision control of optical properties because the polymer material can be applied to the glass surface and shaped on a targeted basis. ■



The projecting blinker is just 35 x 35 x 55 millimeters in size, but has high light intensity.

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A new recycling glossary aims to improve comparability across packaging systems.

Untangling the vocabulary of recycling and reuse

Where exactly is the dividing line between reuse and recycling? What is meant by "reuse rates"? A new glossary provides answers to questions like these, which have become more pressing as a result of the EU's Packaging & Packaging Waste Regulation (PPWR). The glossary was created by the Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT and the Fraunhofer Institute for Material Flow and Logistics IML on behalf of Stiftung Initiative Mehrweg, a foundation focusing on recycling and reuse. It is intended to bring clarity to the terms used for reuse and circular use of packaging, which can often be fuzzy, and to facilitate communication between the research sector, government, businesses, and consumers.

For example, there is a lot of uncertainty surrounding the terms reuse and recycling. These are sometimes viewed as competing processes, but sometimes "recycling" is the catchall term, and at other times it is "reuse." Co-author Jürgen Bertling from Fraunhofer UMSICHT clarifies the difference: "We view reuse as a nondestructive circular process. So, the object and its shape are maintained, while recycling is a destructive process that focuses mainly on preserving the substance or material itself." ■

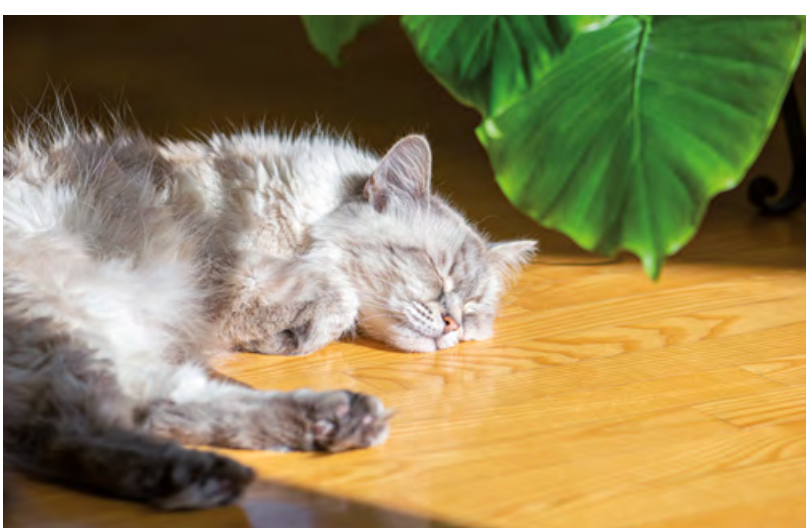
Natural sun protection for wood

Researchers from the Fraunhofer Institute for Process Engineering and Packaging IVV and Naturhaus Naturfarben GmbH have developed a bio-based transparent coating that protects hardwood floors and furniture from UV radiation.

"We've been using proteins as natural binders in coating systems at Fraunhofer IVV for quite some time now," explains Dr. Melanie Platzer, a research scientist within the Process Development for Plant Raw Materials department. "What was new to us was combining them with secondary plant substances intended to provide UV protection for a water-based finish." The team of researchers succeeded in linking proteins and plant-based substances closely together, creating a permanent bond.

Over the project's approximately two-year term, the scientists tried out many combinations and also worked with mixtures of various secondary plant-based substances, all with great success. The team used peels left over from making apple juice and pomace from wine production, for example. All of the options they identified are non-toxic, and direct contact or inhalation is not harmful to either human or animal health — unlike previously available coatings containing potentially concerning UV blockers such as benzophenones and benzotriazoles. ■

Safe for health and the environment: the new plant-based wood finish from Fraunhofer IVV.



Editorial notes

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

Editorial team:
Monika Landgraf (responsible for content), Josef Oskar Seitz (editor-in-chief), Dr. Sonja Endres, Beate Strobel

Editorial assistants:
Dr. Janine van Ackeren, Mandy Bartel, Sirka Henning, Andrea Kaufmann, Manuel Montefalcone, Lisa Scherbaum, Kathrin Schwarze-Reiter, Franziska Sell, Stefanie Smuda, Mehmet Toprak, Anja Wächter, Yvonne Weiß, Ulla Wolfshöfer

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Nitrosamines can form in meat at temperatures of 130 degrees Celsius and above.

Not always harmful to health

Barbecue season is in full swing — bringing with it warnings about nitrosamines in charred meat and meat products. A recent study by Fraunhofer ITEM shows that not all of these items are dangerous.

Amines are present not only in foods, but also in many medications, as they are highly effective in pharmacological terms. When they encounter nitrites from food in the acidic environment of the stomach, nitrosamines can form. These compounds are believed to be carcinogenic and mutagenic.

A team from the Fraunhofer Institute for Toxicology and Experimental Medicine ITEM and other partners worked on behalf of the European Medicines Agency (EMA) to study which active substances pose an elevated risk. Dr. Sylvia Escher, head of the In-silico Toxicology department, comments: "Luckily, relevant amounts of nitrosamines developed under realistic physiological conditions in the case of only four of the twelve substances studied." Further studies of cell cultures also allowed the team of researchers to show that not all nitrosamines have mutagenic effects — far from it, in fact. "Larger nitrosamines that have a more complex structure are less active, which makes them less of a concern," explains Dr. Christina Ziemann, head of the Genetic Toxicology working group.

The results corroborate a new evaluation system used by the EMA, which divides nitrosamines into five categories based on certain structural features, from highly potent to least concern. Highly sensitive in-vitro testing systems adapted to nitrosamines should also help to identify critical nitrosamines that require further study early on, thereby accelerating the approval of medications on the whole. ■

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Title

Let's talk water

Sometimes there's too much, sometimes too little: Water, the most important factor in our survival, doesn't make it easy for us. How can we ensure an adequate water supply even amid climate challenges?

By Beate Strobel, photography: Enver Hirsch

Staying afloat: Dr. Lukas Kriem looks for ways to use wastewater more effectively in his work at Fraunhofer IGB. For *Fraunhofer* magazine, he decided to take a dip in a swimming pool instead.

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Pessimists view the glass as half empty: According to a study by the GFZ German Research Centre for Geosciences, Germany lost 750 million metric tons of water a year from 2002 to 2022 through factors such as declining soil moisture, decreasing groundwater, melting glaciers, and generally sinking water tables. The country's total stores of water shrank by 15.2 cubic kilometers over this period. That's almost half of the total water consumed by industry, agriculture, and private households across the whole of Germany in a year.

Optimists look to the stores of water still present in Germany. Groundwater levels rose nationwide in 2023, a relatively wet year, and 2024 has turned out to be fairly damp as well so far. Per capita drinking water use has declined significantly, from 147 liters a day in 1990 to 121 in 2023. "There is a growing public awareness of water management," says Dr. Marius Mohr, head of the Water Technologies, Resource Recovery and Scale-up innovation field at the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB in Stuttgart. And with good reason, he says, in light of the increase in extreme weather events such as torrential rains and droughts. Although spring 2024 felt very different, he notes, "We will experience periods of drought in Germany in the foreseeable future much like those Spain already has today."

Given these forecasts, keeping the glass at least half full will require big changes in how people use water. The German federal government's 2023 National Water Strategy calls for sustainable use of water resources along with improved protection for natural water stores to guard against contamination with chemicals and microplastics. This will require significant efforts across all sectors: industry, agriculture, public water supply. There are currently eleven Fraunhofer institutes participating in the Fraunhofer Water Systems Alliance (SysWasser), all contributing their expertise to make water infrastructure systems more sustainable and more resilient. The ultimate aim is to move water and wastewater management in the direction of a circular economy and to support the agriculture sector in adjusting to new climate conditions.

Private households and municipalities: greater digitalization

The research sector, government, and industry all hope the digital transformation will provide powerful leverage in the world of water management. For example, the InDigWa project was launched in the fall of 2023 within the Morgenstadt (City of the Future) Innovation Network, a network of Fraunhofer institutes, municipalities, and businesses. As part of the project, the Fraunhofer Institute for Industrial Engineering IAO, the Fraunhofer Institute for Systems and Innovation Research ISI and Fraunhofer IGB plan to collect data on the entire drinking water cycle, from well to use and disposal.

63%

of all water used by private households in Germany is used in the bathroom, for bathing, showering, and flushing toilets.

(Source: German Association of Energy and Water Industries (BDEW), last updated 2021)

Smart interconnectivity: "Industry and medium-sized businesses and the various stakeholders in the municipal water supply and wastewater disposal space have already developed a lot of individual innovations," explains project manager Susanne Liane Buck from Fraunhofer IAO. "Our approach is to link these isolated solutions together into a single system and incorporate consumers as well in order to enhance the efficiency of the drinking water supply on the basis of collected data."

The project calls for existing approaches such as low-flow showers and separate cycles for drinking water and "gray" water, meaning wastewater with moderate levels of contaminants, to be installed and tested in selected homes in a residential development in Bremen. For outdoor areas, there are plans for smart rainwater management to improve the efficiency of managing water supply and disposal systems, including during periods of drought and heavy rain. An innovative watering system for green space in the immediate area is intended to reduce the use of drinking water. Buck explains: "Our goal is to create a template for holistic water management that works in both new construction and existing neighborhoods."

Twelve project partners, from the local water supplier and a housing developer to building technology and sensor companies and the wastewater disposal provider, are all on board in the interdisciplinary InDigWa project. Collecting data from private households is a challenge in light of privacy regulations, Buck says. After all, water use is a reflection of very private areas of people's lives. But that window on what happens in the bathroom or kitchen is especially important in terms of further developing water-saving fixtures, for example. As a sociologist, Buck also knows that implementing innovations is never just about the technology itself. It also involves how willing people are to participate. And people in Germany, at least, are used to having top-quality water flow from the tap anytime they turn it on. That is why Mohr, for his part, takes a dim view of installing a second ▶

"Our approach is to link isolated solutions together into a single system to enhance the efficiency of the drinking water supply."

Susanne Liane Buck, Fraunhofer IAO

Building bridges: Buck, a sociologist, plans to optimize water management in a local area in Bremen by connecting all stakeholders together.

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"We analyze what incentives can spur sustainable water use."

Dr. Marc Jentsch, Fraunhofer FIT

Improving the flow of data: IT expert Dr. Marc Jentsch is setting up a living lab.

supply line inside buildings to provide "second-class water" for things like watering plants: "Once you increase the number of supply networks, the risk of improper connections rises, and that's something we can't have when it comes to drinking water. Even the slightest doubt about quality will be enough to turn people against using the drinking water that comes from the tap and send them running to buy water in plastic or glass bottles instead, which is even less sustainable."

Projects like InDigWa can also help maintain water quality, however. "Increasingly long periods of heat also bring hygiene problems with them, such as a rising risk of Legionella bacteria in the water," Buck explains. Continuous data collection is likely to make it possible for municipalities to monitor these factors more efficiently going forward.

For consumers, reports on their own consumption through an app or in other forms could also come as a wake-up call of sorts. After all, who among us knows how much water they use to shower in the morning or water the plants? Putting a figure to everyday usage like this and communicating it back to the consumer, whether that means a private individual or a company, is also the goal of the CrowdWater project funded by the German Federal Ministry for Economic Affairs and Climate Action (BMWK): Under the overall coordination of the Fraunhofer Institute for Applied Information Technology FIT, selected households and businesses are being equipped with smart meters and connected together to create a "living lab" that surveys water use in different sectors under real-world conditions.

"Our goal is to develop a decentralized data platform that can be used to measure water consumption in connection with specific events and then report it back to the consumer," explains Dr. Marc Jentsch, an IT expert at Fraunhofer FIT. "After that, we plan to analyze the degree to which knowing their usage data changes people's consumption habits and what incentives can spur sustainable water use." Right now, Jentsch and his team are still looking for private households and manufacturing companies in the districts of Troisdorf, Kirchen (Sieg) and Hennef that are interested in participating in the living lab (for more info, visit crowdwater.info).

A sports school is already on board. To date, the school only has a single central meter for water consumption, so there are no details about how much water is being used for the swimming pool, showers, or watering the green space. Jentsch explains: "The school is hoping to use smart sensors to monitor water use by different areas in real time in the future." As for the utility companies, they see huge potential for optimization in detecting leaks. "CrowdWater will help us significantly increase the density of the sensor network so leaks can be detected and stopped much faster," Jentsch says. According to a study by the International Water Association, 346 million cubic meters of water is lost on the way to the consumer worldwide each day. The estimate for Germany is about 400 million cubic meters of water loss per year.

Worldwide water consumption **sextupled from 1930 to 2000** — as the global population tripled.

(Source: German Federal Agency for Civic Education (BPB))

Agriculture: plants need water to grow

And those levels of loss are becoming less and less acceptable. After all, water is not only a vital resource in its own right, but also the foundation of food production. Sixty-nine percent of global water stores from groundwater and freshwater sources such as lakes and rivers are currently used for agriculture. But with the global population on the rise, the agriculture sector is expected to require as much as 50 percent more water by 2050 — even as water is increasingly in short supply due to climate change. Hydroponics, an approach that has been proposed to help with this dilemma, seems contradictory at first glance. Wouldn't no longer growing plants in a soil substrate, but entirely in containers of water instead, actually increase water use?

No, says Marc Beckett, who works on development and implementation of sustainable water management and water use systems at Fraunhofer IGB. First, the water that supplies the plant with needed nutrients can be recycled, so it is enriched and reused over and over, while the water used for conventional agriculture seeps down into the soil or evaporates. That means the water doesn't reach the plant, leading to higher water usage. "With hydroponics, we can cut water use by as much as 90 percent in these situations," Beckett explains. Second, this form of cultivation also requires significantly less space, and because it does not depend on a specific location, it can be implemented even in urban environments, including through vertical farming.

Even more important when it comes to water conservation is the fact that hydroponics does not necessarily require the use of potable water. Wastewater can also be used, although this does, of course, require prior purification to remove germs and other harmful substances, whether using UV light or membrane or activated charcoal filtration. The HypoWave project and its successor HypoWave+, in both of which Fraunhofer IGB is involved, are working to develop solutions for hydroponic ▶

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plant production, using municipal wastewater as a source of water. "Instead of removing nutrients like nitrogen, phosphorus, potassium, and calcium from the wastewater in an energy-intensive process, we leave that task to the plants," Beckett explains. This approach is already being piloted in the Gifhorn district.

Tailored nutrition for plants: To that end, microbiologist Dr. Lukas Kriem is also planning to use waste to produce nutrient solutions for use in hydroponics: "Potassium, for example, is relatively easy to isolate from waste such as banana or potato peels. Reclaiming phosphate and nitrate from waste and wastewater is trickier. We're working to develop suitable microbiological processes for that."

This research approach was born of necessity: In a project at a refugee camp in the Sahara, scientists Beckett and Kriem were looking for a way to work with local stakeholders to further develop a hydroponic system so vegetables and herbs could also grow using hydroculture. In the NexusHub successor project, Fraunhofer IGB experimented with reusing animal and bone meal in hydroponic cultivation of vegetables and developed processes to create a hydroponic nutrient solution out of organic waste and use it to grow cilantro and kale. The energy needed to do this is to come from a solar array that is under development by the Fraunhofer Institute for Chemical Technology ICT. This will make this style of cultivation a sustainable possibility for even remote areas. The approach has already been implemented on a pilot scale in Kenya. "We aim to develop robust solutions that add value to even substances viewed as worthless in the past," says Kriem.

Outside Africa, efficient and low-cost wastewater treatment is also growing more important. And not only because wastewater from households and industry contains pollutants such as microplastics and PFAS, or "forever chemicals," which then get into the environment. In the ROOF WATER-FARM joint research project, the Fraunhofer Institute for ▶

"Instead of removing nutrients like nitrogen, phosphorus, potassium, and calcium from the wastewater in an energy-intensive process, we leave that task to the plants."

Marc Beckett, Fraunhofer IGB

Waterlogged: Marc Beckett works to advance hydroculture through his research at Fraunhofer IGB.

It takes

119 liters

of water to produce 1 kg of potatoes in **Germany.** The same amount of **potatoes from Egypt** require **418 liters**.

(Source: German Environment Agency (UBA))

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"We aim to develop robust solutions that add value to even substances viewed as worthless in the past."

Dr. Lukas Kriem, Fraunhofer IGB

Dr. Lukas Kriem taps into new sources of nutrients.

Environmental, Safety and Energy Technology UMSICHT developed a method that can be used to treat "black" water — wastewater from toilets — on a decentralized basis and use it for vegetable production. In the SUSKULT project, the researchers are working on integrating water treatment facilities into agriculture. After all, from nutrients and water to heat and CO_2, all of the resources needed for agriculture are present at a wastewater treatment plant. In the RoKKa project, Fraunhofer IGB is also working to convert treatment plants into wastewater biorefineries, including the use of residue and waste products: The researchers are using six pilot plants at the Erbach treatment plant in Baden-Württemberg to demonstrate

Aquaculture instead of the ocean: the seas in miniature

This year's End of Fish Day came on February 29 — that's the day when, viewed purely in arithmetic terms, Germany had used up its own fish reserves in the North and Baltic Seas in 2024, marking the start of reliance on imports. The date has been moving up; in 2020, it was on April 4. In response to this trend, Bund für Umwelt und Naturschutz Deutschland (German Federation for the Environment and Nature Conservation, BUND) has called on people to eat less fish and more plant-based alternatives. But is that the only solution?

Fish is healthy. But to give fish stocks in the oceans a chance to recover, a significantly larger portion of the fish consumed should come from aquaculture in the future. "The challenge is designing these processes to have as little environmental impact as possible while also ensuring animal welfare," explains Dr. Henrike Seibel, head of the Aquaculture and Aquatic Resources department at the Fraunhofer Research Institution for Individualized and Cell-Based Medical Engineering IMTE in Büsum. "If we want to move End of Fish Day back to where it was, later in the year, we need to make aquaculture more efficient, and thus economically attractive, by making more intensive use of the available water without harming the environment," says her colleague, biologist Michael Schlachter. "And that requires circular technology."

Closed-loop water circulation systems have the advantage of controlling influences like light, climate, and water supply and moderating them according to the fish species. That lets us breed marine animals right here in Germany that are actually native to other parts of the world, where they are produced on a large scale, often with extreme environmental impact. Schlachter cites shrimp as an example: "Closed saltwater systems, where only about two percent of the water needs to be replaced regularly, can now be used to cultivate shrimp even in Bavaria, for example."

Researchers at Fraunhofer IMTE have various systems available to them, from small aquariums up to huge basins, for exploring industrial questions relating to filter technologies and fish nutrition, reproduction, and health. Their research focuses on closing cycles and cascading uses of different material flows with an eye to bioeconomy, including through the concept of integrated multi-trophic aquaculture (IMTA). In this approach, the fish are kept along the food chain with other suitable marine organisms so that the portion of the nutrients from the fish food that is left over by the fish also ends up being used. "Mussels or worms, for example, can take in the particular substances that fish exude, while seaweed converts the dissolved nutrients," Schlachter

the production of useful substances from sewage sludge. "The nitrogen that is present in high concentrations in the sewage water is especially interesting," Mohr explains. Typically, nitrogen is produced from the air for use in fertilizers, an energy-intensive process. Separating the nitrogen early on could also reduce the harmful nitrous oxide emissions that typically arise when these substances are broken down.

Industry: recycling water, reclaiming raw materials

The research institutes that make up the Fraunhofer Water Systems Alliance (SysWasser) are also looking for innovative ways to process industrial and municipal wastewater streams so the water can be recycled in the manufacturing or agriculture sectors. This approach offers huge potential in terms of sustainable water management, as Germany's manufacturing sector uses 4.5 billion cubic meters of water annually. At the same time that water conservation efforts are under way, there is also a growing awareness in industry that process water often contains chemicals or residual substances that could be reused in industrial applications. Wastewater from metalworking businesses can even be used as a source of costly raw materials such as silver and copper, which can be extracted and then recycled. This aspect makes reclamation an exciting prospect for both environmental and economic reasons.

What is in the water? To find out, the Fraunhofer Institute for Photonic Microsystems IPMS has developed an integration technology that can be used in the future to measure water parameters such as pH levels and nitrate, phosphate, and potassium concentrations continuously in parallel and in real time, all with just one sensor chip. Multiple ion-sensitive field-effect transistors (ISFETs) are built into the chip to determine the concentration of numerous ions in the water. Dr. Olaf R. Hild, head of the Chemical Sensors business unit at Fraunhofer IPMS, believes in the new technology: "This ▶

Fans of fresh fish: Dr. Henrike Seibel and Michael Schlachter from the Fraunhofer research unit IMTE focus on the circular economy.

explains. This not only lowers emissions, making it easier to clean the water, but also enhances product diversity.

"Aquaculture often gets a bad rap with consumers, but that's unfair," Seibel says. After all, the days when fish farming used huge amounts of antibiotics to prevent disease in fish stocks are over. "Consumers across the entire EU can assume that antibiotics are rarely if ever used in aquaculture these days." This is because advances in aquaculture long ago yielded better options, such as preventive vaccination or, in circular systems, full control over water quality and the use of UV light and other methods of killing germs. Aquacultures, Seibel says, "are typically much better controlled than the water in the ocean."

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kind of measurement system unlocks new possibilities for applications in environmental analytics, agriculture and water management, and in the booming market for indoor farming applications."

Researchers from the Fraunhofer Institute for Ceramic Technologies and Systems IKTS have set up a technology platform on the grounds of the Bitterfeld-Wolfen wastewater treatment plant to develop and test different treatment and purification methods to meet the needs of industrial customers. This sewage treatment plant is one of the largest in central Germany, and it processes wastewater from nearly 300 businesses located in a nearby chemical park. By combining advanced ceramic membranes with electrochemical, sonochemical, photocatalytic and biological processes, even process water with extremely heterogeneous compositions can be filtered and treated as required. The result is water and valuable materials, both ready for reuse.

This circular approach can make even sustainable products more sustainable. Take solar panels, for example: Scientists from the Fraunhofer Institute for Building Physics IBP and the Fraunhofer Institute for Solar Energy Systems ISE worked together with TU Berlin and Rena Technologies GmbH to create a model of water flows in a 5-gigawatt solar cell factory. Then, on that basis, they reviewed the introduction of various strategies for circular use of water. The researchers found that the amount of water used to produce the solar cells could be reduced by as much as 79 percent and wastewater by up to 84 percent, all with production technologies already available today. And that makes it easier to build new solar cell factories, even in locations with less water available.

"We have two approaches to recommend: reuse of low-contaminated wastewater (LCR) and what is called minimal liquid discharge (MLD), in which certain residual substances are reused for other purposes," explains Peter Brailovsky from Fraunhofer ISE. This makes it possible to use residual etching solutions and other substances in cement production.

Repurposing used materials: In the near future, reprocessing of water needed for recycling lithium-ion batteries will be similarly important. The wastewater contains dissolved metal ions such as lithium, nickel, cobalt, copper, and aluminum — all critical materials for battery production that Germany typically has to import at high prices. At the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM, Spanish chemical engineer Dr. Cleis Santos is working in the MeGaBatt project to develop electrochemical technologies with which process water from the battery recycling process can be treated in eco-friendly, low-cost ways so the critical raw materials are also kept within the cycle. "We already know this works at the lab scale," she explains. "But our goal is, by the time the project ends in 2028, to have built a pilot plant that demonstrates that this method also makes economic sense on a large scale." Forecasts predict that the volume of batteries requiring recycling in Europe will increase from the current level of 50 kilotons to 2,100 kilotons in 2040. In the medium term, smart battery recycling could reduce dependence on battery material imports, at least to some degree. The MeGaBatt project is part of the BattFutur initiative, with which the German Federal Ministry of Education and Research (BMBF) is supporting next-generation battery researchers under the Forschungsfabrik Batterie (Battery Research Factory) umbrella project.

Scientists expect summer precipitation in Germany to **decrease by as much as**

7%

by the end of this century.

(Source: German Environment Agency (UBA))

Electrochemical deionization of water, in which electrodes are used to remove ions from the water, is also interesting to other wastewater producers, such as hospitals, Santos says — and for desalination of seawater. More water from seawater? That's an intriguing prospect. In fact, there are already 22,000 desalination plants around the world, producing both potable and process water from the oceans. But existing technologies — thermal desalination and pressing seawater through a membrane that can retain salt — require a lot of energy, which makes them expensive. Electrochemical desalination requires less energy, Santos notes.

Mohr, from Fraunhofer IGB, sees an urgent need for development of new concepts on this point. Although it is unlikely that people in Germany will have to resort to drinking desalinated seawater anytime soon, he still points out: "Water is no longer a national issue. It should be viewed as a global challenge instead." He has been working on the big issues relating to water for over 20 years now. Is there any risk that his research will become boring or routine? No, Mohr says: "To this day, it still feels like pioneering work." ■

Fraunhofer Water Systems Alliance (SysWasser)
Find out more about water research at Fraunhofer:
www.syswasser.de/en.html

Illustrations: Rakdee/istockphoto (4)

"Our goal is, by the time the project ends, to have built a pilot plant that demonstrates that this method also makes economic sense on a large scale."

Dr. Cleis Santos, Fraunhofer IFAM

Bright ideas: At Fraunhofer IFAM, Dr. Cleis Santos researches ways to use electrochemical processes to recover critical materials from wastewater.

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3×3 questions: water

Prof. Thomas Rauschenbach,
Director of the Advanced Systems Technology branch AST of the Fraunhofer Institute for Optronics, System Technologies and Image Exploitation IOSB

"Water reuse is a key element."

1 What water resource should play a larger role in tackling the threat of global water shortage?
The Fraunhofer Water Systems Alliance (SysWasser) is working to develop ways to make the water supply more resilient. Water reuse is one key element of this. Intersectoral water reuse in particular — by which I mean recycling water regionally across the municipal, industrial, and agricultural sectors — offers considerable potential.

2 How can the digital transformation help to optimize water management?
Sensors and smart meters make a key contribution here, supplying online data on water quality and consumption. Building on that, simulation models that enable optimum use and allocation of water resources can be developed. In agriculture, sensor data and models of plant growth can be used to optimize irrigation. The NiMo 4.0 project, in which Fraunhofer IOSB was involved, used artificial intelligence to successfully predict the nitrate content of groundwater.

3 Can you give us a tip for daily life on how private individuals can significantly reduce their water use?
Low-flow shower heads are a good place to start. While a normal shower head has a flow of about 15 liters of water per minute, the better low-flow models are down to just six liters a minute. ■

Dr. Burkhardt Fassauer,
head of the Circular Technologies and Water department at the Fraunhofer Institute for Ceramic Technologies and Systems IKTS

"Much of our wastewater can be processed and reused."

1 What water resource should play a larger role in coping with the threat of global water shortage?
The key aspect that should be mentioned here is water that has already been used by people, either for personal use or as part of the business cycle, which means that it is viewed as wastewater according to the current understanding. Instead of drawing mainly on resources like groundwater and natural water sources, much of our wastewater can be processed these days and then be reused safely for a whole host of different purposes. The technology already exists, and we're hard at work to refine it so it gains more widespread traction.

2 How can the digital transformation help to optimize water management?
Aside from protecting the aquatic environment, providing water in sufficient quantity and quality is the most important task involved in water management. And that's extra hard to do in shortage situations, like long periods of drought. Those situations are precisely when digitalization can be extra helpful through improved sensors for monitoring and smart volume management that set limits, assure quality, and create new connections between municipalities, industry, and agriculture in terms of water technology.

3 Can you give us a tip for daily life on how private individuals can significantly reduce their water use?
It should be said that a lot of people are already really conservative in their use of water. Awareness has been growing tremendously in recent years, some of which were abnormally dry. Bathing and showering are the biggest areas where most people can reduce their water use, accounting for more than a third of the water used in a private household. Not running the bathtub full, or generally taking shorter showers, are the quickest ways to help reduce water use — and save energy, too. ■

Photos: Fraunhofer IKTS, Fraunhofer IGB, Fraunhofer IOSB-AST, Enver Hirsch

Dr.-Ing. Ursula Schliessmann,
Deputy Director of the Fraunhofer Institute for Interfacial Engineering and Bioengineering IGB and Head of Central Office of the Fraunhofer Water Systems Alliance (SysWasser)

"Switch to more drought-resistant plants."

1 What water resource should play a larger role in tackling the threat of global water shortage?
There are — and this is something we're working on at Fraunhofer IGB, too — decentralized solutions such as capturing water from ambient moisture. But on the whole, I do think it's necessary to ramp up our recycling of water. Within the SysWasser alliance, we're working on conceptual and technological tools to process water on a targeted basis and build monitoring and control systems. This is putting the structures in place so processed municipal wastewater can be used safely for applications like agricultural irrigation going forward.

2 How can the digital transformation help to optimize water management?
Sensors, models, digital twins, and AI offer incredible application potential in terms of resource management, from monitoring water quantities and quality to optimizing technical systems and facilities for water processing. At Fraunhofer IGB, we are establishing efficient data infrastructures that link process, system, and sensor data together in communication terms so we can control the entire system as well. This lets us identify solutions for competing objectives for a hydroponic greenhouse without any soil. That means things like removing nutrients as part of the wastewater purification cycle while at the same time ensuring that the plants receive an adequate supply of nutrients.

3 Can you give us a tip for daily life on how private individuals can significantly reduce their water use?
The biggest impact can be achieved in the places where households use the most water: the bathroom and the kitchen. People can use low-flush toilets and turn off the water whenever they aren't actively using it, such as when brushing their teeth, rinsing vegetables, or washing dishes. Never run a less than full load of laundry. And if you collect rainwater and it still ends up not being enough to water your plants in the summer, think about switching to more drought-resistant plants in the long term. ■

Water guardians: Fraunhofer researchers (photo: Michael Schlachter, Fraunhofer IMTE) are working on ways to use water more effectively as a resource.

"Bathing and showering are the biggest areas where people can reduce their water use."
Dr. Burkhardt Faßauer, Fraunhofer IKTS

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All aboard: Some 90 percent of all international commercial goods are transported by ship.

The energy of the future?

Could ammonia bring a turning point in the climate crisis? Seven Fraunhofer institutes are studying the gas as a climate-neutral energy source.

By Kathrin Schwarze-Reiter

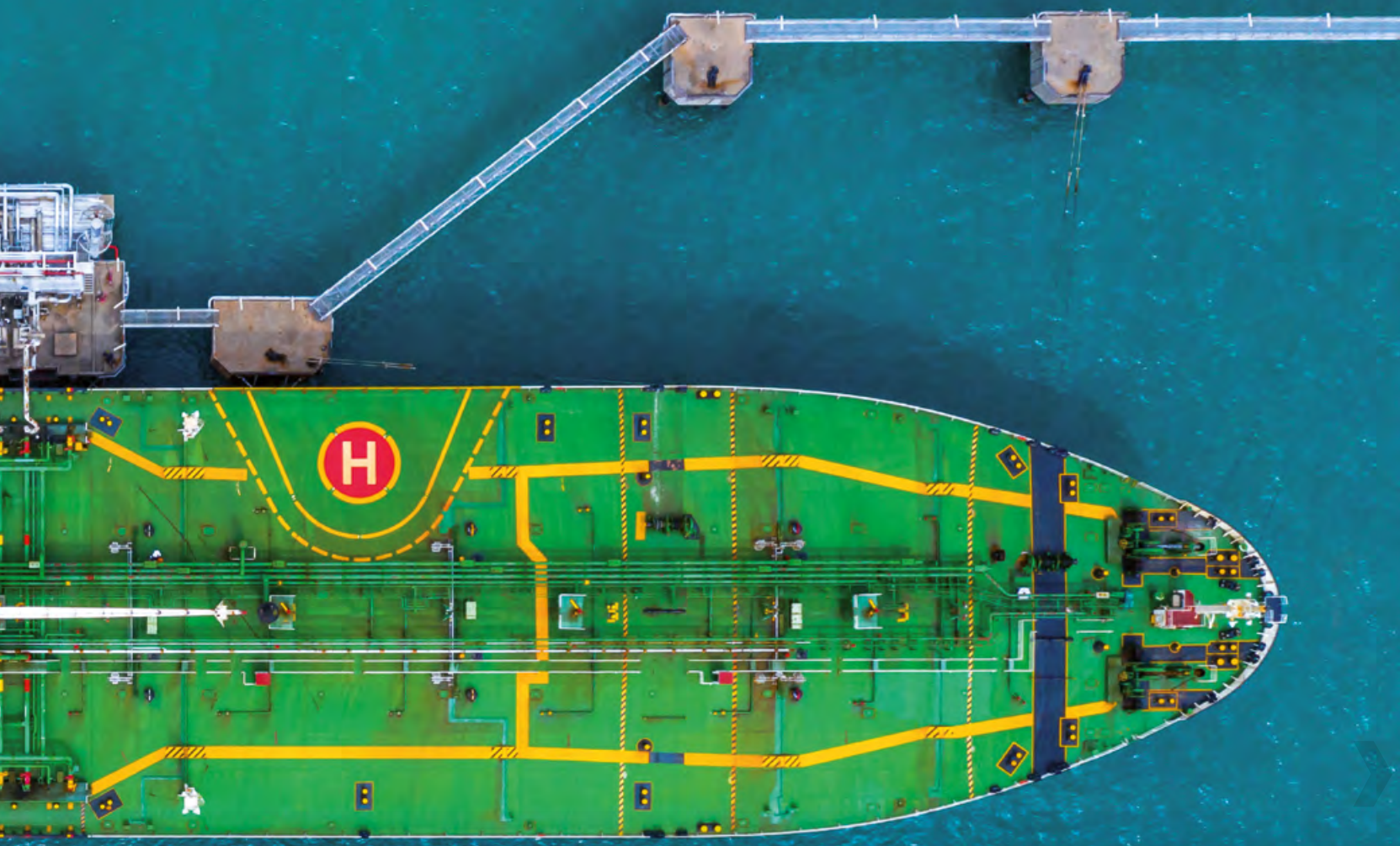

Photo: Ivan Spasic / istockphoto

It is colorless and dissolves easily in water. But it is also toxic, a respiratory irritant with an incredibly biting smell. It reeks of urine, to be specific. That is because inside the body, ammonia — a compound of nitrogen and hydrogen — plays an important role as a byproduct in the formation and breakdown of amino acids, and once its job is done, it is excreted as urea.

What does the pungent gas have to do with the climate crisis? What role might it play in a sustainable supply of energy? Seven Fraunhofer institutes, led by the Fraunhofer Institute for Environmental, Safety, and Energy Technology UMSICHT, are studying that very question. As part of the AMMONVEKTOR project, one of Fraunhofer's flagship projects for 2024, they are scrutinizing the potential value chain for ammonia. Other projects are also under way in this field. AMMONPAKTOR, at the Fraunhofer Institute for Microengineering and Microsystems IMM, is developing reactors, and PICASO, at the Fraunhofer Institute for Solar Energy Systems ISE, is analyzing production sites.

For a long time, ammonia took a backseat to hydrogen. "But ammonia is also a really exciting substance," says Dr. Gunther Kolb, head of the Energy section and the deputy institute director at Fraunhofer IMM. "Right now, the gas is mainly used to produce fertilizers or as a coolant or refrigerant. But there is a lot more it could possibly be used for." Unlike other fuels, ammonia does not generate any carbon emissions when it is burned, only water and nitrogen, which means it has potential as an emission-free option for ▶

Ammonia: bright prospects

Free ammonia is a rarity in nature — only rotting plants and active volcanoes emit it as a gas. The biggest emitters are cattle, pigs, and horses. However, scientists discovered how to synthesize the gas with the chemical formula NH_3 over 120 years ago. A method known as the Haber–Bosch process is used to liquefy air and break it down into oxygen, nitrogen, CO_2 and water. As the next step, hydrogen derived from processes such as electrolysis of water and nitrogen can be used to produce ammonia using an iron-based catalyst at temperatures between 400 and 450°C and pressures of 120 to 220 bar. Worldwide ammonia production currently stands at about 180 million metric tons per year.

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energy-intensive industries like shipping or the steel sector. Says Kolb: "Using ammonia fuel cells or combustion engines could make ships greener."

Under Kolb's leadership, researchers from Fraunhofer IMM have developed ammonia-based systems to supply energy on a mobile, decentralized basis. "Suitable catalysts are used to split ammonia into nitrogen and hydrogen in small cracking reactors." The mixture is flammable and can be used as an energy source in the form of "cracked gas." The cracking reactors can be used to generate hydrogen for fuel cell vehicles right at the filling station. The reactors are many times smaller than conventional ones — they can be transported compactly on ships and combined with each other any number of times. "The AMMONPAKTOR reactor is also highly efficient — the second-generation cracking reactor produces 70 kilograms of purified hydrogen a day," Kolb says.

Hydrogen can be many things: energy source, electricity storage medium, raw material for industry, emission-free fuel. The chemical element with the symbol H_2 is set to play an important role going forward: Various studies forecast that about two-thirds of energy in Germany will be imported in the form of hydrogen 20 to 30 years from now. But hydrogen has one big drawback: It is difficult to store and transport, since it requires either high pressure in its gaseous state or very low temperatures as a liquid. This makes it a good idea to convert hydrogen into derivatives like ammonia. "Ammonia is one of the most promising candidates when it comes to solving the issue of transporting hydrogen," says Dr. Achim Schaadt, head of the Sustainable Synthesis Products department at Fraunhofer ISE. Hydrogen could be produced in remote areas that have a lot of sunshine and wind and then transported as ammonia. The infrastructure, experience, and expertise working with ammonia that would be needed for this are already in place, as ammonia is already produced and transported on a large scale.

Working on behalf of the H2Global Foundation, Fraunhofer ISE joined forces with Ulm University and the Fukushima Renewable Energy Institute in the PICASO (Process Intensification & Advanced Catalysis for Ammonia Sustainable Optimized Process) project to study 12 countries that are especially good candidates for sustainable production of these Power-to-X products by 2030. "Brazil, Colombia, and Australia are particularly suitable for imports of green ammonia," says Robert Szolak, also one of the heads of the Sustainable Synthesis Products department at Fraunhofer ISE. The researchers are working on a novel Power-to-Ammonia (PtA) process for sustainable, resource-conserving production of ammonia. "We're developing an integrated reactor technology and tailor-made operating strategies that allow for lower operating pressures and temperatures," Schaadt explains. "At the same time, we can significantly increase the efficiency of the entire PtA process in terms of both material and energy. This considerably reduces the initial outlay for new facilities, which could mean that down the road, green ammonia can be produced cost-effectively in remote areas with high renewable energy potential, or even offshore." This means the gas could be a huge opportunity for other countries as well, especially those in the Global South: a disruptive technology that replaces a conventional fossil process and lowers CO_2 emissions by as much as 95 percent.

> "Ammonia is one of the most promising candidates when it comes to solving the issue of transporting hydrogen."
>
> Dr. Achim Schaadt, Fraunhofer ISE

On arrival at its destination, ammonia can be split back into nitrogen and hydrogen. The scientists at Fraunhofer ISE are researching this as well with an eye to covering the entire value chain from ammonia production to reformation and then technical and economic analyses. "Achieving greater energy efficiency in the process of reforming ammonia is key to its use as a hydrogen storage and transportation medium," Szolak explains. However, before ammonia and hydrogen can be used as an energy source across the board, there are some significant hurdles that need to be cleared in terms of its transport and storage. "Production, transportation, and storage all need to be made more efficient, costs need to be brought down, and safety has to be improved," says Prof. Michael Bortz, head of the Optimization — Technical Processes department and deputy head of the Optimization section at the Fraunhofer Institute for Industrial Mathematics ITWM. While very few accidents are known to have occurred to date, ammonia is still a highly toxic and potentially deadly gas. German environmental organization NABU and the Oeko-Institute have also issued warnings about ammonia as a green fuel, saying that the gas should only be used if the nitrous oxide generated during production, transportation, and combustion is eliminated, for example with special purification systems. Nitrogen oxide emissions, which are harmful to health, will also need to be brought under control. "It's crucial to account for every eventuality so ammonia can be handled, stored, and transported safely," Bortz says, agreeing that there are concerns. With this in mind, all Fraunhofer systems in the ammonia segment are also developed with purification and filtration elements, and the reactors undergo extensive safety testing. Ammonia cannot become a cornerstone of the sustainable energy supply until all of these aspects are ironed out. ■

A breath of fresh air

An industrial poultry house smells bad, but that's not all. It's also a hotbed of pathogens. To treat infections, the birds have to take antibiotics — and that poses a risk to animal and human health alike. Fraunhofer researchers are developing a different approach that involves no drugs at all.

By Yvonne Weiss

Silence can be deadly. Each year, some 9,600 people in Germany die of what has been called a "silent pandemic": bacterial infections that have become resistant to antibiotics. According to one 2022 study, antibiotic-resistant pathogens are implicated in another 45,700 deaths. And that figure is rising.

The search for the root causes of this pandemic leads researchers straight to chicken coops, especially industrial ones. With thousands of birds literally cooped up together, the air is teeming with germs. Microorganisms in excrement become airborne, for example. More than 600 metric tons of antibiotics were used to fight infections in 2021, making these settings a breeding ground for the emergence and spread of resistant strains.

A new, antibiotic-free approach is being studied by Thomas Westerhoff, a scientist at the Advanced Systems Technology branch AST of the Fraunhofer Institute for Optronics, System Technologies and Image Exploitation IOSB. In tandem with partners from the research sector and industry, Westerhoff is literally aiming to bring a breath of fresh air to poultry houses in Germany with UV light: "We're developing a unit that cleans the air intake and exhaust at poultry houses. It's based on UV LED technology."

UV light is known to damage bacterial and viral DNA, deactivating it. What is new is the LED technology Westerhoff plans to use in his machine. Not only does it have lower environmental impact than conventional mercury vapor lamps, it also cleans the air more efficiently.

The scientist's idea combines two mechanisms of action: LED lamps inside the air purifier are tasked with disinfecting the air directly while also beaming UV light at a surface holding a photocatalyst. When the light hits that surface, the catalyst initiates a chemical reaction that produces molecules known as hydroxyl radicals.

The radicals neutralize unpleasant odors caused by volatile organic compounds (VOCs). They also disinfect the air additionally, killing both bacteria and viruses. This lowers the likelihood of infections, which means less antibiotic use, lower antibiotic levels in meat, and less resistance among pathogens.

Esterhoff and his team are currently studying a poultry facility in the state of Thuringia, seeking to answer various questions. What VOCs are there in the air? What about microorganisms? How much dust and other particulates are there? Once the results are on hand, the team plans to develop a demonstrator and then present it by the time the project ends, in mid-2026.

Attached to the top windows in the house, the demonstrator will serve two functions at once. It will clean the exhaust before it leaves the house, removing odors, and also filter the air intake before it enters the inside. That is a crucial advantage, especially now, with bird flu on the rise: "If just one sick bird from outside flies in the window, the virus can get inside and infect the whole flock," Westerhoff says. "Our technology has the potential to curb pandemics." ■

Photo: Sonsedskaya / Adobe Stock

A new Fraunhofer technology keeps chickens healthy.

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A voice from the business world

Oliver Zipse, 60, trusts in Germany's innovative strength as a hub of high technology.

Growth as part of change

There is little commitment to growth in Germany's policy sector. We need a mental paradigm shift for our country and for Europe as a whole: more carrot and less stick, more entry strategies than exit ones.

Oliver Zipse, Chairman of the Board of Management of BMW AG, makes his case

"Prosperity without growth." "Rightsizing." "Green growth only." Anyone who has been following public debate in Germany in recent years about the right economic strategies might easily conclude that economic growth has outlived its usefulness as a necessary and desirable objective. That it is incompatible with efforts, both important and morally correct, toward greater climate action and resource conservation. That responsibility and growth are incompatible and even mutually exclusive.

But is that actually the case? Has economic growth shaped our understanding of a modern economy for too long? Was it, and is it, the wrong benchmark for an economy's performance and important decisions by investors, companies, and policymakers?

The answer is no. A growing economy remains an expression of economic success, increasing prosperity, social progress, and a society's future viability, all of which is positive. For an economic area like Europe in general and an export-oriented economic powerhouse like Germany in particular, qualitative and quantitative growth remains a must.

What's more, sustainable economic growth has arguably never before been so crucial in enabling the step-by-step transition across our industries and entire economies toward a way of doing business that is compatible with our climate goals while conserving resources.

For one thing, a growing company offers career opportunities and development prospects, making it more attractive to existing employees and new talent. And that is an increasingly important factor in light of the shortage of skilled workers and workers in general.

Growth is also fundamental to capital-intensive investment of all kinds, whether in new business models or exploration of new markets. Or even, most especially, in research and development for future technologies that will make more-sustainable business possible in the first place. And I'd like to point out that sustainable growth doesn't come in just one color. It spans many different shades. Wind turbines, heat pumps, electric cars — all the products we think of as green are developed by technicians and engineers and then made in factories, by blue-collar workers.

"Growth is fundamental to capital-intensive investment — most especially in research and development of future technologies."

Oliver Zipse

- became the CEO of BMW AG, which has more than 150,000 employees worldwide, in August 2019. His contract was just recently renewed for two years, until August 2026.
- "bucks the trend," as the *Frankfurter Allgemeine Zeitung* recently wrote about him. Zipse is a staunch advocate of openness to technology. He opened his speech to the general meeting in May by saying, "Here at BMW, we are different." BMW is continuing to build gasoline engines and forging ahead with research on hydrogen drives.
- joined BMW AG as a trainee in 1991 and has stayed with the group his entire career, in roles including Senior Vice President Technical Planning and, in 2012, Senior Vice President Corporate Planning and Product Strategy.
- studied computer science and mathematics at the University of Utah and went on to earn a *Diplom* degree in general mechanical engineering at the Technical University of Darmstadt. He has been an honorary professor at the Technical University of Munich since 2022.
- was born in Heidelberg, Germany, on February 7, 1964. Zipse is married and has two grown sons.

That's why sustainable growth, in all its many colors and aspects, needs to remain a key element of our economic and industrial policy. This belief, and the unmistakable public commitment to growth that goes with it, is sorely lacking in the political debate in this country.

We're not talking about quarterly GDP figures here. It's about the fundamental question of what role growth should play in Germany and the wider ramifications of this kind of decision. No investor will decide to put money into projects in a place that doesn't have any stated growth ambitions. Instead, investments are made in more-promising economic areas, and in the worst case, there is a threat of spiraling deindustrialization.

A commitment to sustainable growth must be accompanied, including at the European level, by a mental paradigm shift. Instead of hastily slapping bans on things and mapping out exit strategies, we should put the same energy into entry strategies that set the stage for growth. Simply prohibiting and ending something doesn't automatically mean something new and better will take its place.

In addition, growth no longer necessarily means increasing environmental impact, whether that is measured in carbon emissions or resource consumption. Where, if not in Germany as a high-tech hub, do we have the skill and talent to, for example, develop and apply innovative production methods that lead to greater efficiency in manufacturing processes?

Instead of constantly coming up with new bans, there should be positive incentives for a responsible path to growth with elements of a circular economy and carbon reduction. A path that reflects Germany's strengths in research, science, and industry and promotes them as factors critical to success. Charting the right course for this is a fundamental task for our policymakers, and an urgent one. ■

Photo: Rainer Häckl

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Taking a “bite” out of bacteria — preventing resistance

Gum disease, or periodontitis, is a widespread condition, affecting nearly half of all adults in Germany. A new approach to prevention and treatment aims to help these 35 million people — and prevent antibiotic resistance.

By Mandy Bartel

Losing their grip: gum disease is the most common cause of tooth loss in adults.

It starts with bleeding gums. Left untreated, gum disease can progress to tooth loss and is even suspected of contributing to other serious diseases. Persistent bacterial infections of the gums are implicated in diabetes, rheumatism, Alzheimer's disease, and chronic bowel disease. This means serious cases of periodontitis are typically treated with antibiotics. But there are two issues with that. First, these kinds of medications kill more than just harmful bacteria. They also kill the good bacteria present in the mouth flora. Second, since gum disease is so common, use of antibiotics is widespread, and that is contributing to antibiotic resistance. The Global Research on Antimicrobial Resistance (GRAM) Report points out the consequences of antibiotic overuse: In 2019, 1.27 million people worldwide died of infections caused by multidrug-resistant germs. Fraunhofer spin-off PerioTrap Pharmaceuticals GmbH is working with partners to minimize these kinds of risks.

Inhibiting the effects of bacteria instead of killing them

In the Paropaste project, the researchers are working together to develop a completely new approach to not only treating gum disease, but preventing it altogether: Instead of killing pathogenic bacteria in the mouth, the idea is to use a specific active ingredient to merely "defang" them. It does this by inhibiting an enzyme found almost exclusively in these bacteria. Without the enzymatic effect, the pathogens can no longer cause any harm, but they also do not die off. Dr. Mirko Buchholz, CSO and co-founder of PerioTrap Pharmaceuticals GmbH, explains the principle: "Traditional antibiotics impair the fundamental growth of all germs, good and bad. Our goal is to use something called a patho-blocker to inhibit only the pathogenic effect of harmful bacteria. This preserves the natural microbiome in the oral cavity, and it doesn't create any niches for other pathogens to colonize."

The innovative treatment method was first devised in several places, including the Department of Drug Design and Target Validation of the Fraunhofer Institute for Cell Therapy and Immunology IZI. PerioTrap Pharmaceuticals GmbH was spun off in the city of Halle in 2019. As part of the project, which is receiving funding from the German Federal Ministry of Education and Research (BMBF), the partners are now working to further optimize the substance using more complex microbiological systems. To that end, they are developing new bioanalytical methods, testing local bioavailability, and studying drug delivery and toxicity. "We already have a wealth of data from in-vitro experiments," Buchholz says. "It confirms that this chemical compound is highly tolerable, and that there are no health concerns up to very high concentrations." The project team is being supported in developing the right formulation and in the associated scale-up processes by Skinomics GmbH, a service provider also based in Halle.

One of the big challenges is the method of delivery: How can the active substance be applied directly inside the mouth in such a way that it stays where it is needed for long enough without simply being swallowed right away? To answer that question, PerioTrap turned to another Fraunhofer institute in the immediate vicinity for its expertise in materials science. Researchers at the Fraunhofer Institute for Microstructure of Materials and Systems IMWS, also in Halle, study not only how different formulations can be distributed effectively, how well they stick, and how readily they release active substances, but also how they interact with dental tissue and foods. The goal of all this is to prevent undesired side effects such as discoloration. Based on the active substance and the formulation, the team is currently developing a dental gel intended to prevent gum inflammation.

To treat advanced cases of periodontitis, the partners worked with Prof. Karsten Mäder from the Pharmaceutical Technology Group at Martin Luther University Halle-Wittenberg to develop another approach in an earlier project. With that method, short threads are used to deliver an approved antibiotic active ingredient directly to the inflamed pockets around the teeth. The threads are broken down, and the antibiotic is released locally over a long period. This strategy enables targeted, limited use of antibiotics. Since the effect is limited to the pockets themselves and no antibiotics reach the gastrointestinal tract, the likelihood of resistance is also very low.

Prophylaxis and treatment

Buchholz explains how complementary the two approaches are: "The new enzyme-inhibiting active ingredient has more of a prophylactic effect, for example in that it specifically targets pathogenic bacteria in a gel that clings to the surface, thereby preventing the formation of the toxic biofilm that causes gum disease." And what if the disease is already advanced and causing symptoms? "Then the antibiotic threads help locally, extending the therapeutic success of dental treatment without burdening the entire organism with antibiotics."

The team is currently working toward approval for both methods. Because the antibiotic threads contain a known active ingredient, they could be available in as little as two to three years. Approval processes for medicinal products involving entirely new drugs typically take seven years or longer, by contrast. This is why in addition to the ongoing project, PerioTrap is also planning to launch a toothpaste with a significantly lower concentration to maintain oral health on the market faster as a cosmetic product. That means the microbiome-preserving properties of the new approach could benefit many people not too long from now — and, in the future, prevent complex periodontitis treatments. After all, an ounce of prevention is worth a pound of cure, as the saying goes. ■

Photo: Thordis Rüggeberg / plainpicture

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Shields up!

The images we see in the news are of tanks, military drones, and explosive detonations. But military operations long ago moved beyond the battlefield. Modern war is also waged online. How NATO is gearing up for serious situations.

By Dr. Sonja Endres

A strong team: Martin Lambertz and Jan-Niclas Hilgert from Fraunhofer FKIE. In 2018, the two of them won the prize for the best scientific paper at the Digital Forensic Research Workshop USA, one of the world's leading conferences for digital forensics.

Attacks in cyberspace don't make a sound. Oftentimes, they go unnoticed entirely — which can make them even more fateful. Data and information are secretly siphoned off to enemy servers, security vulnerabilities are exploited, and malware infiltrates IT systems, ready to strike at a moment's notice.

Threat levels are higher than ever before, as the German Federal Office for Information Security (BSI) cautioned in its report on the state of IT security for 2023. German federal interior minister Nancy Faeser offers a warning as well: "This year, with the European elections and other elections coming up, we have to be especially on our guard against hacking, manipulation, and disinformation." (See interview, p. 46.)

NATO tests its defensive capabilities for cyberwar scenarios in Locked Shields, the world's largest cyber defense exercise. This time around, 3,500 IT specialists from 32 member states participated in the annual exercise — more than ever before. A team from the Fraunhofer Institute for Communication, Information Processing and Ergonomics FKIE has been participating for the past three years.

No time to sleep

The four scientists from Fraunhofer teamed up with some 150 experts from the Bundeswehr, German federal police, various federal agencies, industry, and business to fend off waves of attacks launched by the "red" team — hackers working on behalf of NATO who specialize in penetrating adversary systems — which was based in Tallinn, the Estonian capital. The blue team, in Germany, set up operations in a building at the decommissioned Kalkar nuclear power plant, near the Rhine, which has been converted into a conference center and amusement park. "We didn't get the chance to try the rides, though. There was no time," jokes Jan-Niclas Hilgert, a cyber forensics expert at Fraunhofer FKIE. During the most critical phase of the attack, the IT pros didn't even have time to sleep. They worked through the night, side by side with colleagues from partner country Singapore, which was assigned to support the German team this year.

The NATO Cooperative Cyber Defense Center of Excellence (CCDCOE) puts huge effort into Locked Shields. The scenario: The fictitious nation of Crimsonia attacks another fictitious country, Berylia. The Berylian armed forces spring into action to defend themselves, with help from NATO. There are 18 blue teams in all, spread all over the world. Their mission is to protect Berylia's critical IT infrastructure, which includes the energy supply, telecommunications, hospitals, the banking sector, and military IT networks. The means and methods used are state-of-the-art, taking inspiration from real-world attacks. "There are even people who imitate users who have clicked the wrong link in a phishing e-mail — all just like in real life," Hilgert's colleague Martin Lambertz explains with a smile. The cyberattacks are flanked by disinformation campaigns and fake news, which are fought separately, in the "media track" of the exercise. ▶

Detecting and defending against cyberattacks in real time is the subject of the Locked Shields exercise, which has been running annually since 2010.

Locked Shields:

3,500

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Photos: Volker Lannert, Stefan Uj / Bundeswehr

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IT pros from industry also supported the German team.

"It was a big help that we were all sitting together in a large room for the first time. That really got us talking to each other."

Jan-Niclas Hilgert, Fraunhofer FKIE

The blue teams compete against each other, tasked with defending against the same attacks. Points are awarded to the team that is most effective at defending the networks and IT systems. There are also extra points for those who are the first to detect malware and let the other teams know, for example. "This fosters dialogue between teams, because in a live situation, we're supposed to support each other, after all," Hilgert says. Communications were handled via the Malware Information Sharing Platform (MISP), which is also used in real life by numerous organizations and government agencies worldwide.

Hacker attacks on air traffic control and power plants

The full exercise took two weeks. The "live fire," when teams had to defend against attacks in real time, was concentrated into two days. Before that, participants spent the familiarization period getting to know the various systems and applications involved. "But we weren't the only ones to get access. The red team did, too — and they spent that time placing a few exploits and putting back doors in place," Hilgert explains. Lambertz adds, "If we didn't manage to identify and remove those fast enough, they were used for merciless attacks right in the initial phase."

Once the "game network" was opened, the attacks rained down unremittingly on the blue team. To maintain a big-picture view, the cyber specialists set up a user dashboard to visualize data and systems in graphic format. "You could look at it and see right away that everything was okay if there was a green light. But once the light turned red, there was an urgent need for action," Lambertz says.

Sub-teams were assigned to work on specific critical areas, such as the energy supply, communication network, or government network. "I was responsible for the armed forces," Hilgert says. Attacks in this sector were aimed at air traffic control, among other things. "All the planes suddenly disappeared from the radar screen — a horror scenario for any pilot. But our colleague from the Bundeswehr got things back under control."

In the energy supply sector, simulated power plants were targeted as well. Lambertz: "Two years ago, the red team even posted an overview showing the individual power plants on a wall at their base in Tallinn. When they succeeded in gaining access to a power plant's control system, they actually had it explode there, and there was a shower of sparks that they streamed live. Everyone could see which blue team hadn't performed so well." The German team was able to defend its power plant. The IT pros at the Kalkar nuclear power plant would have been safe there even in a real attack, though — it was never connected to the power grid, both for political reasons and due to security concerns.

Both the targets and the nature of the attacks varied. Among other tools, the hackers on the red team "defaced" numerous websites, a form of attack in which bad actors modify the content of high-traffic sites, such as those of government agencies or public broadcasters. Hilgert explains: "This lets them post disinformation on supposedly trustworthy websites, sowing confusion in the populace." This is also an easy way to spread malware. One click on the defaced site, and an executable program opens on the unwitting user's computer.

The task of identifying, analyzing, and fighting malware fell to a special team in the exercise's "forensic track," Hilgert and Lambertz's area of specialization at Fraunhofer FKIE. As part of these activities, they supported the public prosecutor's office and police in analyzing servers and hard drives, such as those of large ransomware groups that gain access to the data of companies or institutions, encrypt the data, and then blackmail their victims. "It's a bit more exciting to defend your systems during the live phase. We don't get the chance to do that otherwise. Nothing against forensics, of course. It's great. But we're here to learn new things," Hilgert says.

Rankings kept secret

The collaboration with the forensics team and all the other specialty teams — such as the firewall team, which succeeded in protecting the network infrastructure — worked very well, Hilgert says. "It was a big help that we were all sitting together in a large room for the first time. That really got us talking to each other." Participants were able to see and hear when others cheered a win — and when desperation set in.

Lambertz and Hilgert agree that participating in Locked Shields is well worthwhile. They garnered a lot more points for their defensive work than in previous exercises. The German–Singaporean team also made a solid showing in the overall rankings. Just how solid has to remain a secret, though — the rankings and exact points scores are top secret. After all, NATO isn't about to give adversaries any clues to where there are still gaps in its shield. ■

Knowledge relay

new directions: AI change ?

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Knowledge relay

Upheaval and ***new directions:*** ***Prof. Hanselka,*** how will ***AI change our world?***

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Knowledge relay, episode 12

Upheaval and new directions: Prof. Hanselka, how will AI change our world?

Series:
Knowledge relay

The times we live in have raised **many questions — questions Fraunhofer researchers are working hard to answer.** 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. Holger Hanselka,** President of the Fraunhofer-Gesellschaft, answers a question from **Prof. Michael Lauster,** head of the Fraunhofer Institute for Technological Trend Analysis INT.

Upheaval and new directions is an apt description for the changes brought by recent technological advances in AI research and application, which are still taking shape. We don't have to look into our crystal ball to see what's going on: AI technologies already offer a broad spectrum of potential applications, from robotics to optimizing logistics networks and advances in medicine.

Many institutes of the Fraunhofer-Gesellschaft have been working for quite some time on various groundbreaking AI applications, including generative AI. Through these activities, we are making a key contribution to a European AI landscape and a trustworthy, powerful range of AI platforms and infrastructure. I am personally making efforts in this direction as well, for example as part of the Zukunftsrat (Future Council) advising the German chancellor and as a member of the newly founded Research7+ engagement group in the G7 context. One of our prime objectives is to establish a strong, independent European AI landscape that reflects European values and interests and strengthens Europe's competitiveness in the digital era.

Right now, the growing and increasingly innovative use of AI technologies and systems marks the dawn of a new era, one in which AI will also act as a catalyst and a cross-cutting technology for change and transformation:

1. **AI makes us faster**
   Machine learning and AI can be used to analyze large volumes of data fast and identify complex patterns accurately. This means systems like these can also learn and improve on a continuous basis. New insights and connections can be unlocked faster, which in turn increases the pace of innovation and dramatically accelerates advances in science and technology.

2. **AI boosts economic output**
   AI technologies can be used to automate routine tasks, but that is not all. With sufficient processing power, they can also handle complex tasks and processes, 24/7. That makes it possible to ramp up production volumes even as the error rate goes down. AI systems and robots would thus make a substantial contribution to boosting overall economic output — all without needing to take breaks or be paid a wage. Especially now, amid the shortage of skilled workers, that holds out great potential for reserving human labor for higher-order tasks and management of AI systems.

3. **AI creates new business models and industries**
   Not only are AI technologies evolving at a rapid pace, opening up new opportunities for automation, analysis, and decision making, but demand for AI-supported products and services is also rising steadily. Entrepreneurial thinking and actions and effective knowledge transfer between stakeholders in the research sector and private enterprise can, will, and must give rise to whole new (disruptive) business models and industries. But there is still quite a bit of work to be done on that score, for example for the use of training data, especially company-specific training data, in secure data spaces, solutions that address the large amounts of resources currently being used up to train and host models, and fine-tuning for reliable applications.

Holger Hanselka has been the president of the Fraunhofer-Gesellschaft since August 15, 2023.

The growing capabilities of our AI systems have also already produced acute issues, as we are seeing right now in the form of fakes, abuse, poor data quality, and high resource usage (energy, water, microelectronics, specialists, and so on). Swift action is needed here so we can lay the technological and social groundwork for a future in which AI is used reliably and responsibly, in a way that can be trusted and aligns with our values. What is not very helpful is vague fears and nebulous debate about hypothetical worst-case scenarios in a distant future.

We shouldn't let these challenges discourage us, let alone retreat from them. On the contrary, Germany — and Europe as a whole — must take swift and decisive action to transfer innovative AI technologies, even beyond purely generative AI and large language models, into broad industrial application both quickly and securely. If we allow ourselves to be left behind now, we run the risk of even greater dependence and a widening innovation gap as a result of the rising dominance of AI platforms from the United States and China.

Upheaval and new directions: AI has already changed our world and is having an impact at every level of national economies and the business sector. The spread of AI systems cannot be halted at this point without causing a huge setback in terms of prosperity, competitiveness, and ability to innovate. What we need to do now is forge boldly ahead and take the future into our own hands. It's up to us, and it's our responsibility, to decide how our AI systems will be designed and what purposes we use them for.

In the next issue:

***What* can research *do for our safety in these troubled times*?**

Photo: Fraunhofer / Stefan Obermeier

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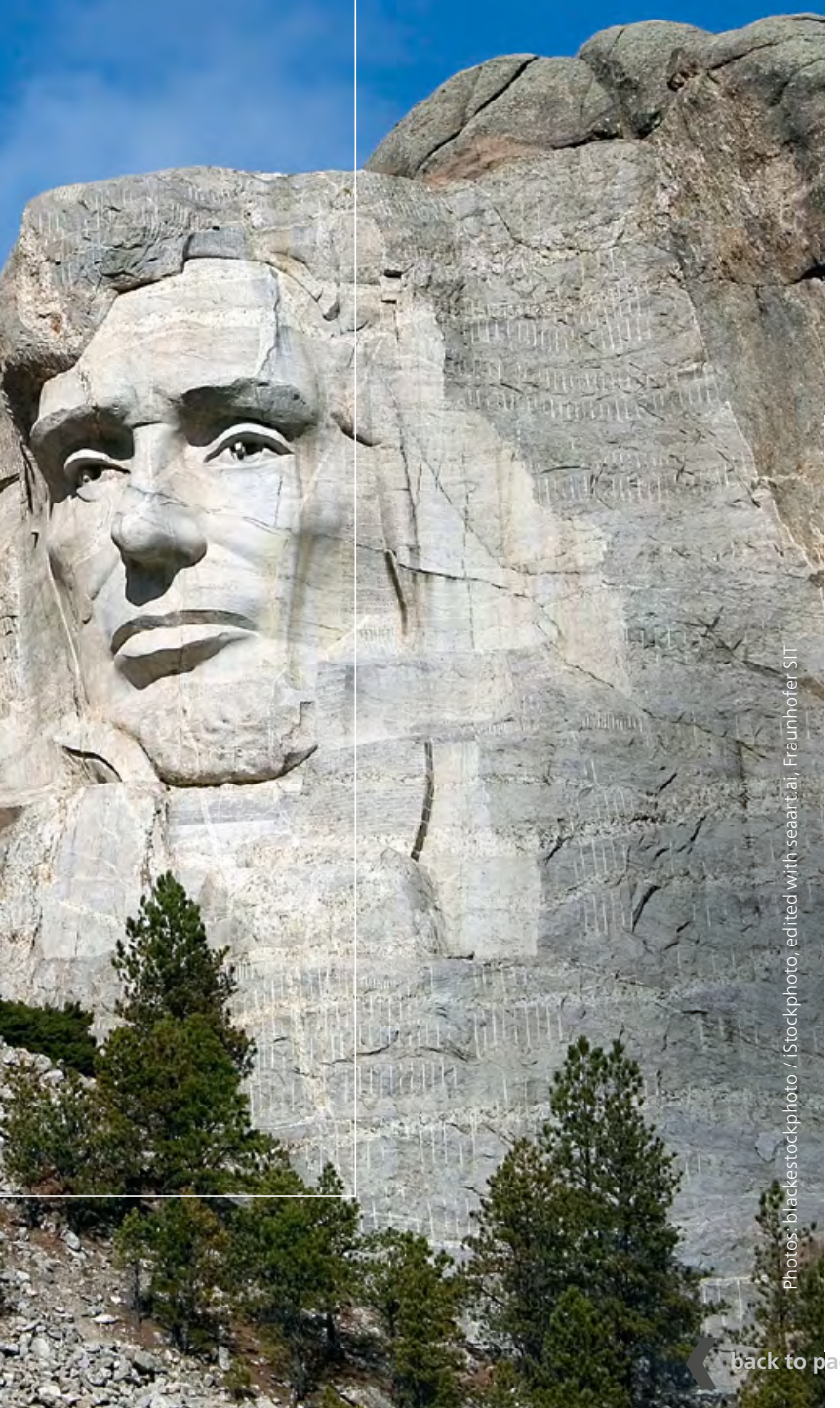
Disinformation

Is everything fake!?

During this year of back-to-back elections, reality is catching up with the warnings experts have been making for years: deepfakes and disinformation have been supercharged by artificial intelligence. With fakes now so convincing, more and more people are asking themselves: Can I believe my eyes and ears?

By Mandy Bartel

Prof. Martin Steinebach doesn't actually need to build a monument to himself like the one here, at Mount Rushmore, since his expertise in media forensics is sought after in government and industry. But he does it anyway — thanks to deepfake technologies.



Photos: blackestockphoto / iStockphoto, edited with seaart.ai, Fraunhofer SIT

"Hardly anyone would have thought the methods of making deepfakes would evolve at such a breakneck pace."

Prof. Martin Steinebach, Fraunhofer SIT

Olaf Scholz, the German chancellor, gives a speech in which he announces that the AfD political party has been banned. Donald Trump is shown being arrested. Ukrainian president Volodymyr Zelenskyy capitulates on his country's behalf. Plenty of people would be happy to see these news items. But these videos and images aren't of real events; they're deepfakes. Just like the one of Tom Cruise accusing the International Olympic Committee (IOC) of corruption, shortly before the Paris Olympics, and the various steamy videos purporting to show superstar Taylor Swift that are all over the internet.

Image manipulation and disinformation have always existed, especially in the run-up to elections. But creating deceptively realistic fake content has never before been as easy as it is today: With the right prompts and a little adjustment, photos of situations that never occurred can be created en masse. Just a single photo and a short audio clip can be used to put words in people's mouths that they never said. A few seconds of authentic voice recording is enough to generate fake clips of an allegedly conspiratorial phone call. The days when people could trust their own senses are long gone.

"Hardly anyone would have thought the methods of making deepfakes would evolve at such a breakneck pace," says Prof. Martin Steinebach. "Two years ago, you still needed good actors to make deepfake videos seem even remotely realistic, but today, some deepfakes almost look better than the original." Steinebach, a multimedia forensics expert, has been working on technical recognition methods at the Fraunhofer Institute for Secure Information Technology SIT in Darmstadt for years now. He studies how different methods of creating the fakes work, what traces they leave, and how those can be detected automatically.

What is new is not only the quality, but also the quantity, of disinformation campaigns: Spamouflage, a campaign operated by a Chinese network, spans ▶

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The number of crimes committed from other countries against victims in Germany rose

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hundreds of thousands of accounts on more than 50 websites, including all the major social networks. These accounts generate millions upon millions of posts. Upon until 2022, the spammers focused on spreading pro-Chinese narratives, but now they have turned their attention to the U.S. elections and are spreading targeted disinformation. The really treacherous thing about it is that where the Spamouflage posts used to be readily identifiable as fakes due to glaring spelling and grammar errors, which limited their impact, AI has been a game changer.

Targeting the private sector

An example from Hong Kong shows just how perfectly fake worlds can work. An employee of an international corporate group there sat through a whole videoconference with multiple employees of his company — but it was all fake. His alleged colleagues prompted him to transfer almost 24 million euros to the people behind the scheme. They had evidently hacked into the company's internal video records beforehand and used AI to generate voices to go with the videos. The target of the fraud did not notice that he was the only real person in the conference until afterward, when he talked to his real boss on the phone.

Scenarios like this one could become more commonplace in Germany in the future as well. The German Federal Criminal Police Office published a report on the national cybercrime situation in 2023 this past May. The report shows that the number of crimes committed from other countries against victims in Germany rose 28 percent from the previous year. The attacks caused 206 billion euros' worth of damage.

Disinformation is the world's biggest issue today

"The most significant challenge of our time is not climate change, the loss of biodiversity or pandemics. The biggest issue is our collective inability to distinguish between fact and fiction," concludes the Club of Rome — the well-known organization that, over 50 years ago, denounced the environmental impact of economic growth. The consequences of digital manipulation are loss of trust and a polarized, uncertain society where people can no longer agree on fundamental facts. Where trust erodes, people tend to believe information that confirms their own viewpoints. And that further shrinks the factual basis available for democratic discourse. With all these factors in play, it is little wonder that 81 percent of people in Germany think disinformation is a danger to democracy and social cohesion, as this year's study titled "Verunsicherte Öffentlichkeit" (Unsettled Public) from the Bertelsmann Stiftung shows.

Sixty-seven percent of respondents believe disinformation campaigns originate with groups of protesters and activists, while 60 percent blame bloggers and influencers and nearly half say foreign governments are at fault. The study also permits a comparison with the United States, where uncertainty about and perceptions of disinformation are even more pronounced than in Germany. While 39 percent of Americans surveyed worry about being deceived by disinformation themselves, so they are increasingly verifying content with a more critical eye, Germans firmly believe in their own judgment, with only 16 percent saying the risk that they might be influenced by disinformation themselves is high or very high and 78 percent saying it is low. This self-confidence could prove to be misplaced now, with the new possibilities created by AI.

Where AI can help to identify deepfakes

There are a wide range of methods used for manipulation. In face swapping, two faces from different photographs are simply swapped. In facial reenactment, a person records a fake text and remotely controls a target person in a real video with their movements and gestures — in real time. "What is new is the ability to use voice cloning and lip synchronization to create convincing videos of any kind of content," says Steinebach, the forensics expert from Fraunhofer SIT. "Existing videos are simply given an AI-generated fake soundtrack, and the lip movements are synchronized to match."

To recognize images or videos that have been manipulated in this way, Steinebach and his team rely on a combination of deep learning and traditional signal processing, which can help to identify the blurry or slightly washed-out structures in an image that are typical of deepfakes. "We measure the frequencies of certain sections of the image and compare them to other parts, such as the background. If there are any discrepancies, it could be a sign of a fake." Since deepfakes only replace one area of a real video, that area also has different statistical properties, which can be identified using a more advanced pixel analysis. If only the soundtrack is changed, not the video itself, recordings that are already known are often easy ▶

Keeping a level head even amid the rising tide of disinformation: Fraunhofer scientist Steinebach — here, as the Buddha in Thailand — uses practiced judgment and analytical tools to identify deepfakes.

Photo: Ibrahim Halil Yapici / iStockphoto, edited with seaart.ai

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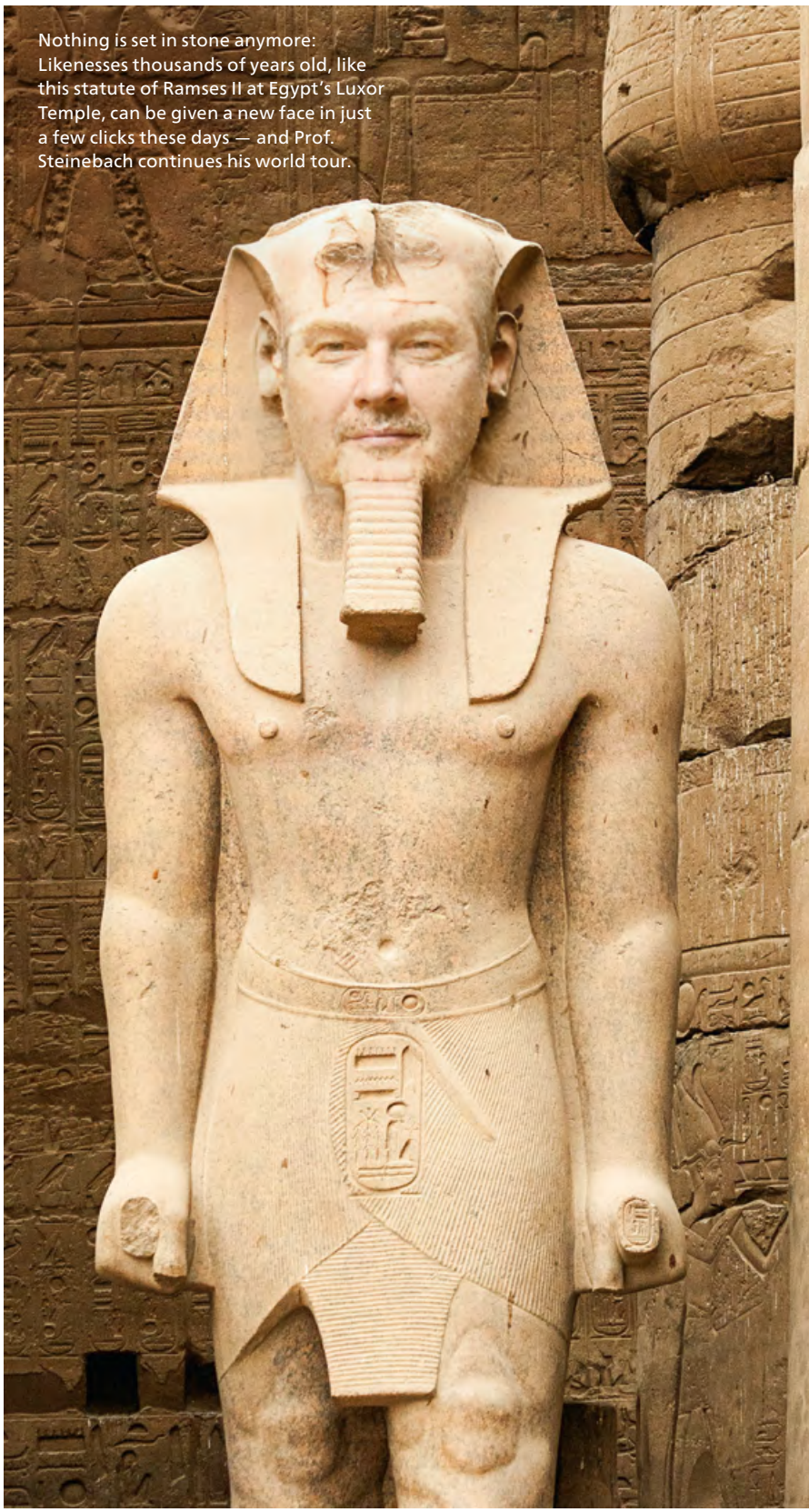
to find using a reverse image search. One telltale sign is if the gestures are the same, but the movements of the lips differ.

Automatic detectors: caution warranted

There are already a number of AI-based detection tools on the market that promise simple, cheap technical solutions. But how realistic is this idea of reality at the push of a button? Steinebach warns against relying on online detectors in videoconferences or browsers. "The error rates are still too high for that, and it would cause more uncertainty than benefit if there were constant warnings." Instead, he argues that these kinds of solutions should be used only in conjunction with the eyes of multiple trained experts. Forensic reports that incorporate additional factors, such as sources, falsification scenarios, plausibility checks, and potential circumvention strategies, offer significantly greater certainty. But owing to the cost, these kinds of analyses are typically commissioned only in areas that are especially critical from a security standpoint or of special legal relevance.

A recent example shows how much caution there should be given that the standard detectors currently available could even be abused, with error rates generally still in the double digits: After the Hamas attack on Israel on October 7, 2023, the Israeli government published multiple photos of the burned corpses of babies as proof of the gruesome acts committed by the terrorists. One of the photos was erroneously

The security experts at Fraunhofer AISEC also use AI for counter-attacks: They train and develop solutions to automatically unmask audio deepfakes.



Nothing is set in stone anymore: Likenesses thousands of years old, like this statute of Ramses II at Egypt's Luxor Temple, can be given a new face in just a few clicks these days — and Prof. Steinebach continues his world tour.

flagged as fake. The terrorists then used AI to generate a new picture in which they swapped the children for dead dogs and said that was the real photo. This was intended to discredit all the other photos that were not flagged as fake by association, suggesting that the Israelis were deceiving the public.

The British royal family also had its own experience with this kind of "false positive" this past spring. All it took to touch off a firestorm of scandal was for an online detector to find irregularities in a family photo of the royals. A whole host of experts chimed in that there was nothing suspicious about it, just standard photo editing like the kind many amateur photographers do, but their voices were almost drowned out in the breathless reporting.

With detection of fakes still that error-prone, a different method can help to at least recognize the originals: "The only strategy people can be relatively sure of today is a positive signature: Newer digital cameras leave a cryptographic signature in their pictures that is difficult to falsify. There are also cell phone apps that do this," Steinebach says. "Big tech companies are also working on new security strategies in which, like with blockchain, all of the steps in processing an image are signed and stored, for example." The royals and others should be pleased to hear that.

Deepfake audio: Don't believe your ears

"Voice cloning" techniques are increasingly popular with criminals. Attackers used voice cloning to influence the Slovakian parliamentary elections in 2023. Two days before the election, social media was abuzz with an audio clip purporting to be of a prominent journalist and the head of the Progressive Slovakia party, talking about how to rig the elections. The fake discussion never happened, but the clip reached thousands of users. Democratic voters in the U.S. got a surprise at the start of this year, too: a personal call from Joe Biden asking them not to vote in the primaries. The U.S. president's voice was AI-generated, and the calls were made automatically.

"Just 20 seconds of audio material is enough these days to filter out typical voice characteristics and use them to generate whole new sentences," says security expert Nicolas Müller from the Fraunhofer Institute for Applied and Integrated Security AISEC in Garching, describing a machine learning technique known as few-shot learning. A short clip of a public speech is sufficient to manipulate discussions or presentations. A year ago, many programs still could not manage to consistently falsify a minimum of 16,000 data points per second, but with AI, that's not an issue now. Plus, it works in near real time. Still, Müller says there are clues to be found in these cases, too, if you really listen closely: "An AI-generated voice is monotonous in some cases, with unnatural intonation, subtle delays, and little emotion."

The security experts at Fraunhofer AISEC also use AI for counterattacks: They train and develop solutions to automatically unmask audio deepfakes. To do this, they first generate artificial audio and video data and then use the information to develop algorithms that recognize the fakes from the tiniest discrepancies, barely noticeable to humans. The Fraunhofer AISEC researchers provide their developments to the general public online at deepfake-total.com. Links or files can be uploaded there to test whether the content is fake. "These kinds of tools generally have an easier time recognizing recordings from known generators than content from entirely new sources," Müller says.

The increasing quality of audio fakes is also increasing the direct risk of fraud. Müller advises anyone who receives a suspicious call from a relative or friend asking them to transfer funds quickly or disclose confidential information to hang up and call back, if at all possible using a different channel. He and his team are also researching methods to make systems for facial recognition or voice authentication, such as voice ID systems, more robust and resilient to manipulation and attacks. Aside from the risks, the researcher also believes it is important to point out the possibilities unlocked by speech generators. "For example, they can help people with speech impediments to be understood better, or even at all, by voice assistants or other people." Right now, for example, Google is researching AI that can translate atypical, hard-to-understand speech into fluent speech.

Speed versus careful attention: the social media dilemma

Where fake content is concerned, it is also worth looking at how it spreads. Social media platforms are obligated to flag suspicious content, but they have a hard time keeping up. After all, it's a lengthy process. First, they need to recognize whether the content is problematic. This is either done by internal research teams, or the company relies on user reports, which is anything but reliable and effective. That's because nothing is black and white: "Telling whether content is entertainment or actual news, whether it should be taken seriously or is exaggerated satire, is hard for both people and machines," Steinebach says. "And ▶

"Just 20 seconds of audio material is enough these days to filter out typical voice characteristics and use them to generate whole new sentences."

Nicolas Müller, Fraunhofer AISEC

Photos: violinconcertono3 / iStockphoto, edited with seaart.ai, Oliver Rüther

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something else people often overlook is that a lot of disinformation isn't just flat-out lies. It's truth, spread maliciously or taken out of context." The next step is to decide whether a post is relevant in the first place, meaning that it is frequently shared or intended to have a destabilizing effect. Only then can the content be marked accordingly, deleted, or blocked. "But by then, days have gone by, and the fake news has been spread all over the world," the forensic expert says. So speed is of the essence. And therein lies the rub: Responding swiftly can hamper the careful attention needed to conduct a thorough review.

Even when fake content has been removed from the big platforms, it often circulates for a long time afterward on messenger services like Telegram. The researchers at Fraunhofer SIT are scrutinizing these channels as part of the Dynamo project. To understand the dynamics of disinformation campaigns there, they are studying how the content spreads via messengers and how they interact with other channels as well. They are interested in which properties make these services prone to disinformation campaigns, whether there are patterns to the spread of fake news, and what counter-strategies can be identified as a result. The goal is to develop technical aids and approaches to combat fake news and provide them to the public, which will likely take place this fall.

"AI is no better at judgment calls than a human."

Prof. Martin Steinebach, Fraunhofer SIT

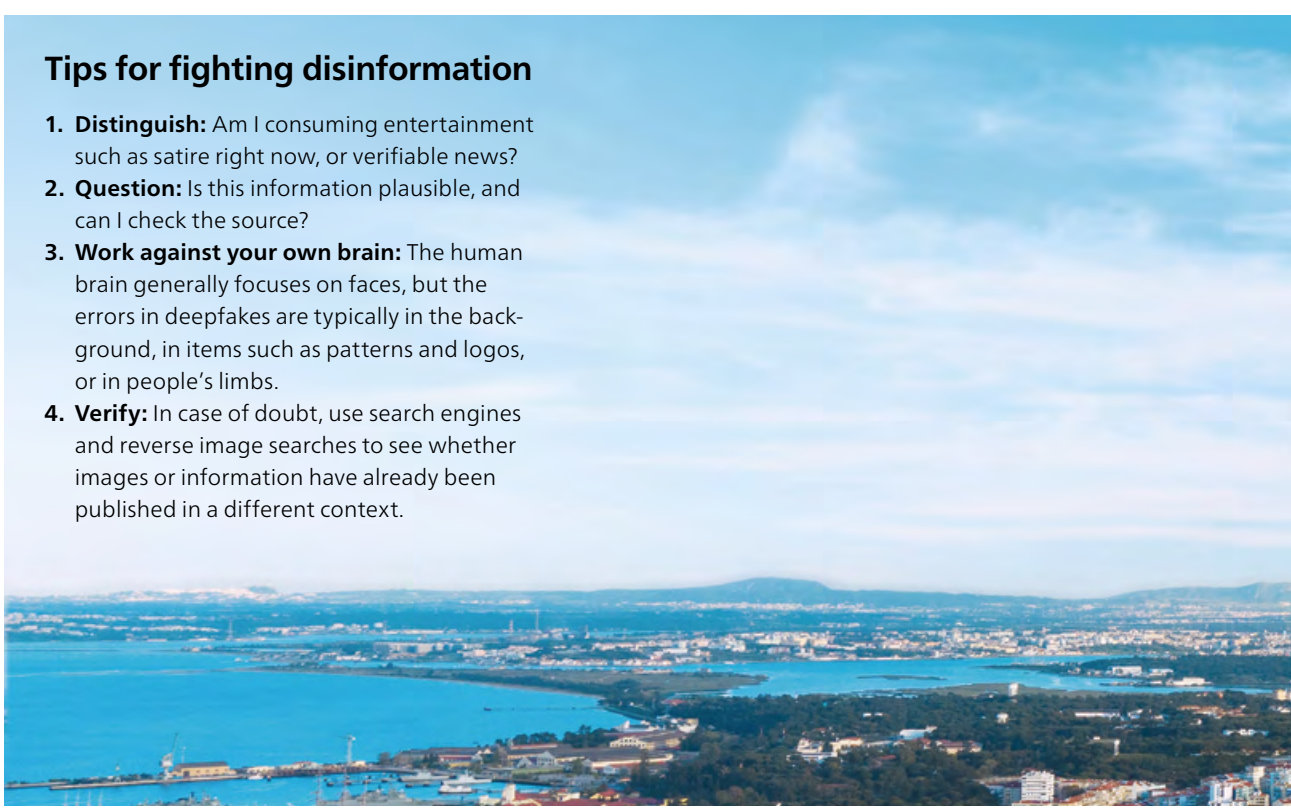
Research tools for media

It is also growing increasingly difficult for media creators and fact checkers to sift through the flood of daily information and tell fakes from facts. Steinebach's colleagues are working to help with that as part of their research within the National Research Center for Applied Cybersecurity ATHENE. Their "check worthiness tool" is intended to make the process of grasping and evaluating texts faster. They are using natural language processing (NLP) to train an AI to automatically recognize and flag relevant passages within news items for further checking. This is intended to let editors see at a glance exactly where they should do some more digging.

As the second step, the tool will later also be able to find multiple credible online sources to support or debunk the flagged statements. To do that, it needs to automatically recognize similarities with the source text. That is no easy matter: The algorithms used must first recognize which texts even refer to the content in question, before automatically checking whether

Tips for fighting disinformation

1. **Distinguish:** Am I consuming entertainment such as satire right now, or verifiable news?
2. **Question:** Is this information plausible, and can I check the source?
3. **Work against your own brain:** The human brain generally focuses on faces, but the errors in deepfakes are typically in the background, in items such as patterns and logos, or in people's limbs.
4. **Verify:** In case of doubt, use search engines and reverse image searches to see whether images or information have already been published in a different context.



the texts confirm or refute the original statement. This means they must also be able to reliably recognize synonyms and alternative phrasings. One issue is that there is often a lack of public data records that can be used to train the AI. That means finding suitable data will still be a lot of work for the developers.

AI tools are not a substitute for critical thinking

Whether they are applied to images, audio, or text, technical detection methods can ultimately only provide clues to where a closer look is needed. Ultimately, it is still up to individuals to decide for themselves what is plausible and what is true or false. "We do have some concerns about the widespread belief in some corners of government and across society that technology alone will be enough to counteract disinformation campaigns or AI will be able to decide for us what is true or untrue," Steinebach cautions. "That's too easy an answer. AI is no better at judgment calls than a human."

That means AI tools will also be unable to provide simple answers in situations where most people already have a hard time making sound decisions. Unfortunately, that is exactly the kind of subject targeted by disinformation campaigns: Manipulators have been most active during the coronavirus pandemic, the war in Ukraine, and the current conflict in the Middle East. "The most dangerous fakes are always the ones containing a kernel of truth. But those are also the hardest to detect — by humans and AI alike," Steinebach says. Still, he has a tip for public figures and politicians in particular, who are often the victims of campaigns like these. He recommends that they build research infrastructure. "It could be databases or sections of a website where all the official image and video material is stored. Forensic technicians could then compare possible fakes against that material, making them easier to detect."

It is understandable that people are looking for easy answers at a time of complex information situations and uncertainty, but AI will not substitute for critical thinking and making our own decisions. Instead, we all face a difficult balancing act between guarding against disinformation on the one hand and protecting freedom of expression on the other. And the only way we will strike that balance successfully is through broad discourse across society, finely honed media literacy skills, and a vigilant and critical public. ■

Click here to listen to the Deepfakes podcast.

In his guise as a statue of Christ over Lisbon, Steinebach preaches education instead of blind faith in technology: AI will not decide for us what is true or untrue.

Photo: Daria Kulkova / iStockphoto, edited with seaart.ai

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Interview

Nancy Faeser, the German Federal Minister of the Interior, is concerned about cyber-attacks: "The perpetrators are getting more and more professional."

"We take the situation seriously!"

Germany is the target of Russian attempts to spread uncertainty, as the Federal Minister of the Interior confirms. Right now, her ministry is forming a unit to detect disinformation earlier. Nancy Faeser has a stark message: "We will never be intimidated."

Interview: Josef Oskar Seitz

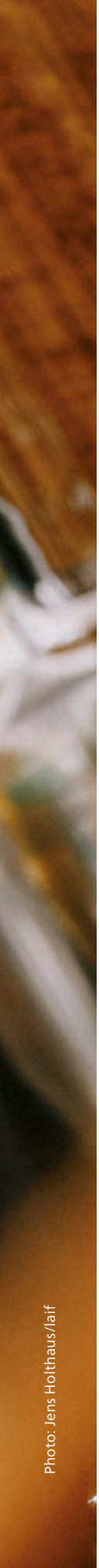

Photo: Jens Holthaus/laif

Ms. Faeser, it's an election year in Germany. Are we adequately prepared for cyberattacks?
Cyberattacks can never be entirely prevented, but our agencies are ready and sparing no effort to protect our elections against these kinds of attacks. The Federal Returning Officer, who oversees elections at the federal level, and all the other electoral bodies at the state and district levels are taking action to keep our elections secure. The German Federal Office for Information Security (BSI) is supporting them in these efforts and providing advice and information. But the very best protection is still our paper ballots.

When the national report on the cybercrime situation was unveiled, you pointed out that there has been an increase in politically motivated hacking activity since the start of Russia's war of aggression against Ukraine. That's the quantity aspect. What signs are you seeing of a difference in quality?
Let's take DDoS attacks as an example. The goal of these attacks is to deliberately overwhelm Internet services by flooding them with traffic. These kinds of attacks are gaining in intensity, and it takes less and less time for them to reach a critical stage. Plus, the perpetrators are getting more and more professional. Our security agencies see this as another point where things have been exacerbated since the start of Russia's war of aggression against Ukraine. Pro-Russian "hacktivists" deliberately target government agency websites, for example. In most cases, they don't do much damage. But we assume there is a clear strategy behind all this: to sow confusion in our communities and damage trust in democratic institutions and in the state's ability to protect the populace.

Putin's hackers attacked the German federal parliament (Bundestag) back in 2015. Almost ten years have gone by. What have security agencies done in that time to improve protection?
One very important point is that we've strengthened the security agencies themselves, in terms of both adding staff and expanding their expertise. We've made great progress in detecting and analyzing cyberattacks, for example. Another crucial point is that our agencies are working together even more closely, including internationally. And we're putting more effort into raising awareness in the general public and among potential victims than before, which is something the German Federal Office for the Protection of the Constitution and the BSI, our cybersecurity authority, are spearheading. But that's not enough on its own. I'm working to ensure that we take other important steps. The BSI needs to be empowered to act faster and with greater ease. And not just when government agencies come under attack, either, but also when the targets are places like universities or medium-sized businesses. It's all been much too complicated in the past. To fix that, we plan to further improve collaboration between the German federal and state governments and expand the BSI into a central agency, like the Federal Criminal Police Office, the BKA.

> "We definitely want to promote the use of AI and cultivation of AI in Germany."
>
> Nancy Faeser

Chancellor Olaf Scholz has repeatedly affirmed that Germany cannot become a party to an armed conflict. But didn't Germany become a target for the Russian war effort long ago?
In my role as federal interior minister, I am watching with concern, just like the chancellor, the impact that Russian aggression against Ukraine is having on the security situation in our country as well. Cyberspace plays an important role in this, of course. Yes, Germany has been targeted by Russian meddling attempts to exert influence and spread uncertainty. But the critical point there is that we take the situation seriously and are hardening our defenses against these threats. And let me reiterate loud and clear: We will never be intimidated by the Russian regime. We will continue to make every effort to protect our democracy — and we will continue to provide massive support to Ukraine.

There has been debate in Germany about military helmets, about tanks and rockets. But should we also get used to picturing war a different way?
We can see what war means from the terrible Russian attacks on the civilian population of Ukraine. So we should be careful with terms like that. But it's clear that we do need to grapple with changing realities. For example, we need to strengthen not just military defense, but civil defense as well, for example through a strong Federal Agency for Technical Relief that springs into action in a crisis or disaster. And, of course, we need effective preparations to defend against hybrid threats like cyberattacks, disinformation, and espionage. We've massively strengthened our security agencies in these areas. ▶

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Taking the fight to the right

SPD domestic affairs specialist Nancy Faeser calls on the Hessian state parliament to ban the right-wing NPD party in 2009. The ban fails. The 2019 murder of local politician Walter Lübcke by a neo-Nazi extremist had a "profound impact" on her.

Congratulations, Mom

Faeser was elected to chair the SPD in Hesse in 2019 with 88 percent of the votes cast. Her son Tim, just 4 at the time, was among the well-wishers. Faeser, who turn 54 on July 13, grew up in an SPD family. Her father served as mayor of Schwalbach am Taunus for 13 years.

Enthusiasm on and off the job

Politics is one of Faeser's passions. Horses are the other. She started horseback riding at the age of eight. "I was the classic horse girl," she recalls. She is always happy to give a police horse a pat or two when she meets them.

Annalena Baerbock, the Foreign Minister, and her colleagues from France and Poland have vowed to fight together as allies against Russian disinformation and cyberattacks. Where do you see progress being made?
In recent years, we have made great and very concrete progress in the EU in the fight against disinformation and other forms of illegitimate meddling. We are working together more and more closely and helping each other, for example by utilizing toolboxes and teams of experts. That's an important step in the right direction. We're also much more involved in raising public awareness of hybrid threats these days. We're communicating even more openly and transparently about the threat situation and the actions we're taking to guard against it. At the federal level, we're at work right now building a unit within my ministry that will detect disinformation even earlier. We need to uncover the lies before they flood the internet in these huge waves.

Do we also need a turnaround of sorts for the internal security of our democracy and economy?
We've been in that process for quite some time now. External and internal security are inseparably linked.

Can retreating to our own national interests be a solution?
No. The challenges are too big for that. And I caution against listening to those who say that would solve any of the problems we are seeing in internal security.

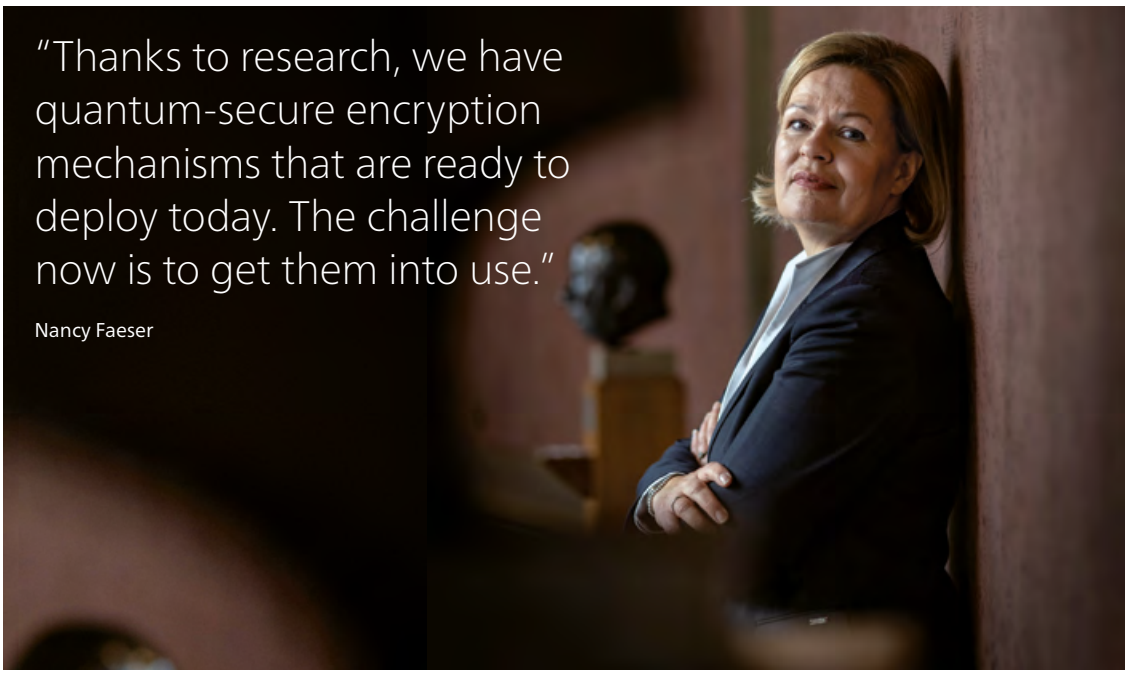
You plan to create a legal framework for the use of AI. What is it going to contain? And how will it differ from the EU Artificial Intelligence Act?
We have an extensive legal framework for the use of AI. The AI Act has now been adopted at the European level. We also have our data protection laws and other regulations. So it's not like there's a legal vacuum. Our goal is to tap into the opportunities AI offers while also minimizing the risks posed by things like deepfakes, which can manipulate democratic debate. We definitely want to promote the use of AI and cultivation of AI in Germany.

AI-generated fake news spreads on social networks in particular. How could the operators of these services take action to help curb that?
We've taken a big step forward in the EU with the Digital Services Act. That's one of the ways we're countering the spread of criminal hate postings and disinformation. The operators of very large platforms have a special responsibility, and that's as it should be. Now, they need to deliver. For example, through active steps to identify and shut down fake accounts and fight automated systems that deliberately amplify these kinds of content. It's also important for platform operators to ensure that AI-generated content is labeled.

There have been media reports that employees of your ministry are prohibited from using AI programs. Why is that, and doesn't it send the wrong signal?
AI has great potential, and administration is no exception. There's no doubt about that. So we don't ban it outright. But of course, especially in the realm of security, we do have special requirements when it comes to protecting classified information and data. My focus is on using AI responsibly. Take services that scoop up data and send it off to wherever, with no controls or transparency. We obviously don't use those.

Where do you see opportunities for the use of AI within your sphere of responsibility?
Well, first, our agencies have been using "classic" AI applications for several years, in constituent communication with our federal chatbots and to help with data analysis. But it also seems like new possibilities are springing up almost daily. In the Federal Ministry of the Interior, the BMI, we are currently developing an advising center for artificial intelligence. It will function as a central point of contact and coordination for AI projects within the federal administration. We are supporting joint developments, for example through the "marketplace of AI possibilities" that we're setting up right now. What is definitely looming for public administration, as in other areas of life, is the use of large language models to do tasks like analyze and edit texts. Our goal is to achieve the greatest possible transparency with all of that. I think it's important for our constituents to know where AI is being used and that they can trust the government in this regard as well.

How can research help to create security?
We've talked a lot about AI. That's one area where research makes a very important contri-



bution, not just in enhancing the security of AI applications, but also in developing AI applications that are themselves aimed at enhancing cybersecurity. Let me give another example: We're on the cusp of a big change in some of the fundamental elements of cybersecurity, by which I mean the methods used for encryption and authentication. Quantum computers could crack those in the not-too-distant future. That's why we need to act fast now to start rolling out new methods that are resistant to these kinds of attacks. Researchers started working to develop these kinds of quantum-secure methods decades ago, back when quantum computers were just a theoretical concept. Thanks to their findings, we have quantum-secure encryption and authentication mechanisms that are ready to deploy today. The challenge now is to get them into use.

As the Federal Minister of the Interior, you deal with a lot of "isms": Right-wing and left-wing extremism, antisemitism, Islamism, racism, sexism. Where do you think the biggest danger lies?

The biggest extremist threat to our democracy is right-wing extremism. At the same time, we're extremely vigilant about the threat of Islamist terrorism, left-wing extremism, and the hybrid external threats we've already talked about. We need to be on our guard in all directions. We've seen a sharp increase in antisemitic crime since the terrible terrorist attack by Hamas on Israel on October 7, 2023. There is also an increase in incidents of violence against politically engaged people from all parties. Just recently, the terrible knife attack in Mannheim by a presumed Islamist that cost a young policeman his life really shook the country. Our security agencies are working to contain all of these threats.

You're a first in two important ways: the first Federal Minister of the Interior to come from the SPD party since Otto Schily, almost 20 years ago, and the first woman ever to serve in this position. What do you see as the main areas of focus in your work?

Everyone has their own way of holding an office like this. And every period has its challenges. To me, security is also a question of social justice. Our government and legal system needs to protect everyone, regardless of where their families might once have come from, how much money they have, what they believe in, and who they love. In my role, I try to see the perspectives of those who are threatened by extremism or criminal activity along with others. My close contact with families of the victims of the horrendous racist murders in Hanau was really formative for me, as was my work on the campaign of terror perpetrated by the National Socialist Underground, the NSU. Those experiences had such an impact, in fact, that they still inform my actions today. ■

The first woman in office

Faeser takes the oath of office as Interior Minister before Bundestag President Bärbel Bas on December 7, 2021. She is the first woman ever to hold this office, and the first Interior Minister from the SPD party in nearly 20 years.

The man by her side

The Federal Minister of the Interior with husband Eyke Grüning, local SPD politician and attorney. Faeser also studied law. One of her key practice areas at a major firm was real estate law.

Politics even at the stadium

FIFA has banned captain's armbands on the pitch, so the minister wears one in the stands at Germany's first game at the Qatar World Cup. They end up losing the game to Japan, but Faeser and German Football Association (DFB) president Bernd Neuendorf have fun anyway.

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Faster diagnosis of rare diseases

Some four million people in Germany suffer from "rare diseases." In many cases, it takes a long time to find the root cause of their symptoms. How artificial intelligence can help shorten the journey and reduce suffering.

By Dr. Sonja Endres

The EU has been supporting the development of medications to treat rare diseases and conditions since 2000, when a new regulation on "orphan medicinal products" was passed.

The patient complains of fatigue, lack of appetite, abdominal pain. It could be a gastrointestinal bug or some form of gastritis — or it could also be Wilson's disease. This genetic, life-threatening metabolic disorder is one of the approximately 6,000 "rare diseases" listed worldwide to date. What all of them have in common is that the symptoms are generally nonspecific. As a result, it takes six years on average for patients to receive the correct diagnosis — which Dr. Andreas Jedlitschka and Patricia Kelbert from the Fraunhofer Institute for Experimental Software Engineering IESE think is too long. In cooperation with the university medical centers in Frankfurt am Main and Dresden, they are working on an AI-based portal called SATURN, which aims to provide future support to doctors during the diagnostic process.

In the EU, a disease or condition is considered "rare" if it affects fewer than one in 2,000 people. This means there is not much data on these issues. Jedlitschka explains: "With this in mind, we combine different AI methods to arrive at the best result, meaning the most likely diagnosis." A technique known as "case-based reasoning" compares the current case against clinical data from other cases and makes inferences based on similarities. The "rule-based approach" extracts principles from medical guidelines and interviews with experts and then uses those to make a diagnosis. The research team's objective is ultimately to harness various machine learning methods to identify characteristic features of diseases and disease patterns from clinical case data.

Tools for diagnosing rare diseases and conditions are already available on the market. But often, they are inaccurate because they are typically based on a small pool of data and a single AI method. "There is seldom transparency around how certain the diagnosis is, or even how it is made," says Jedlitschka, who heads the Data Science department at Fraunhofer IESE. And that, he says, causes patients unnecessary anxiety. Many do not know that the answers they receive are only probability values. "In some cases, the likelihood might be as low as 30 percent or less," Jedlitschka cautions. The AI has often been trained exclusively with data on rare diseases, so it ultimately diagnoses one of those conditions in every single case — even if there is a 95 percent chance that the patient actually has the flu. Most users of diagnosis apps are not aware of this. With this situation in mind, SATURN is to be provided exclusively to physicians in order to help them investigate suspected cases. This is because doctors should be able to interpret the results correctly. There are also plans to connect the tool to the SE Atlas, an online information platform operated by Goethe University Frankfurt that lists medical centers for rare diseases and conditions, specialists, and numerous tips.

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2,000

people. This means there is not much data on these issues.

An initial test version of SATURN already exists. It is based on medical literature as well as patient data for about 20 different diseases, which the cooperation partners provide in a structured, anonymized form. "Right now, we're interviewing medical specialists to incorporate their specific knowledge and experiences into our AI models as well," explains Kelbert, who is a bioinformatics expert. The goal, she says, is to give primary care providers — typically the first point of contact for patients — a concrete tool to help them make decisions. What questions should they ask to corroborate or rule out a suspected diagnosis? What aspects require special attention? "If we screen more effectively beforehand, we can also significantly relieve the burden on specialist practices, which are typically where patients turn for further guidance," Kelbert says.

To make the AI's decisions as transparent and understandable as possible, the portal displays the percentage certainty behind the diagnosis and the data and sources used to arrive at the final outcome. "So, for example, the system might report that this information is an 80 percent match for Wilson's disease. The symptoms are listed in the treatment guidelines for the most part, we have a number of comparable cases, and the expert interviews also substantiate this suspicion. But symptoms X and Y are still lacking."

More training data will be needed in order to further improve the AI models. Especially in the area of rare diseases and conditions, where data is sparse, it would be important to gather and analyze data worldwide to improve the quality of care. The European Commission took the first step in this direction five years ago. The European Platform on Rare Disease Registration was established to enable the exchange of data on diagnosis, treatment methods, and care for patients with rare diseases, which has thus far been spread around hundreds of different registers — all of which are subject to the EU's stringent data protection rules. "Unfortunately, it's really complicated for research projects to get their hands on this data," Kelbert says. The groups of patients with whom the scientists are in touch would like to share their data so they can spare others the lengthy suffering they have experienced. "I hope we can find a way to simplify medical research using health data here in Germany," Jedlitschka says, adding: "The potential is huge." ■

Photo: Lubitz + Dorner / plainpicture

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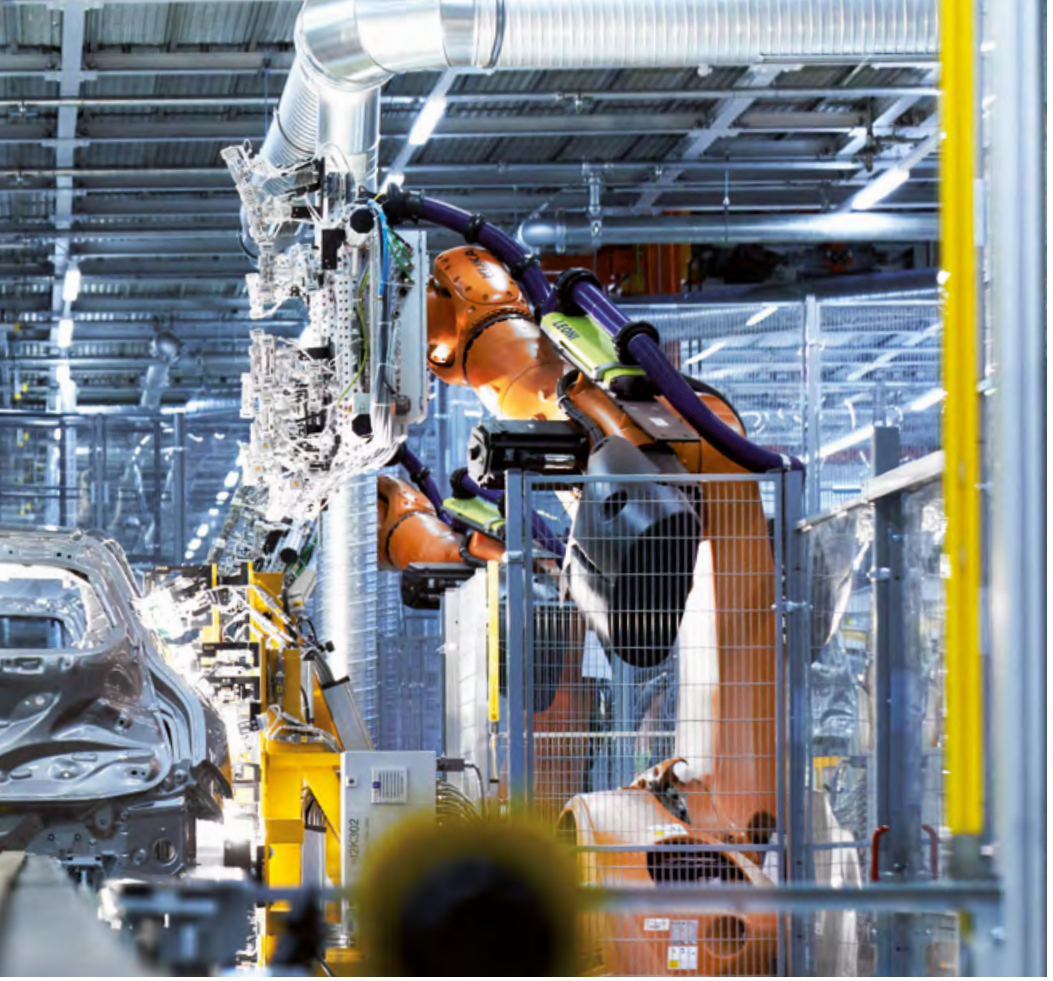
Cars made without new materials (almost)

The future still belongs to electric: Now that rebates and other incentives to buy electric cars have been phased out, the transition has slowed. But research is bringing new momentum to electric mobility.

By Manuel Montefalcone

Cars are to be built almost without new raw materials in the future. That corresponds to more than 1.5 metric tons of material conserved per vehicle. Researchers from the Fraunhofer Institute for Machine Tools and Forming Technology IWU are working on this recyclable electric vehicle in the EU's ZEvRA project. By 2035, EU regulations call for new cars to be made almost entirely from parts that have been recycled, overhauled, repurposed, repaired, or reused. Under the leadership of Fraunhofer IWU, a project consortium comprising 28 European partners, including five automotive manufacturers, is developing approaches to lower resource usage in automotive manufacturing. The model consists of the key material classes that make up more than 84 percent of the materials used in a typical electric car. After that, the partners will create a demonstration vehicle that incorporates the physical and virtual results. ZEvRA is intended to spark developments in industry and the research sector that will shrink the carbon footprint per car by at least 25 percent in the future.

The future still belongs to electric, say the researchers involved in the Fraunhofer Transport Alliance. "Electric mobility is our only hope of reaching Germany's climate targets," says engineer Felix Horch, member of the Fraunhofer Transport Alliance and head of the Sustainable Energy Systems department at the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM. Plans call for reducing greenhouse gas emissions by at least 65 percent between now and 2030 and 88 percent by 2040, with Germany reaching net zero by 2045. Those are the



It's what's inside that counts: Electric cars are to become even more sustainable, thanks to resource-conserving production methods.

Fraunhofer Transport Alliance

For more info on the future of the automotive sector, visit www.verkehr.fraunhofer.de/en.html

targets set out in the German Federal Climate Change Act (Klimaschutzgesetz, KSG), which the Bundesrat approved on a final basis in May. "Based on what we currently know, it would make no sense to stubbornly cling to the combustion process as a drive option. Electric motors are much more efficient, plus they are climate neutral." Prof. Thilo Bein, another member of the Fraunhofer Transport Alliance and the head of knowledge management at the Fraunhofer Institute for Structural Durability and System Reliability LBF, concurs: "Cars will definitely be powered by electric batteries in the future. But for smaller, medium, and large commercial vehicles, we'll see a diversification in powertrains. Hydrogen, e-fuels, and fuel cells could also be used in this segment, at least for long-haul transportation."

The charging infrastructure has some catching up to do. According to figures from the German Federal Network Agency, there were 120,500 EV charging points in Germany in November 2023. That number is rising, but right next door in the Netherlands, charging points are springing up everywhere. There are 144,450 charging stations, which works out to 111.8 charging points for every 100 kilometers of road — more than twice as many as in Germany. The country needs to keep up on two fronts: charging infrastructure and EV production. "The competitiveness of technological solutions really counts — success will only come to those who can manufacture them cost-efficiently in global competition," Horch notes.

Scientists at the Fraunhofer Research Fab Battery Cells FFB in Münster have been working on this for three years now. The facility, which encompasses some 6,800 square meters of research space, aims to advance the production processes for battery cells made in Germany. The protected environment provided by the FFB PreFab gives partners from a wide range of industries the opportunity to work with Fraunhofer researchers to run through their development and commercialization processes for existing and future cell formats at an accelerated pace. "Through our work, we can help lower the manufacturing costs of battery cells," explains Dr. Thomas Paulsen, head of the Strategic Business Development department at Fraunhofer FFB. "The cell is one of the most important parts of a battery pack. So if, for example, we can reduce the waste generated during ramp-up of a production facility, that drives costs down as well," he points out. "This means our work is helping to make batteries for EVs cheaper and achieve technological sovereignty in Europe as well, since so far, about 80 percent of the battery cells in European cars come from Asia." There are plans to build another 20,000 square meters of production and research space soon to enable industrial production research in the gigawatt range, marking an important step toward an electrified future in the automotive sector. ■

Photo: Guenter Schmied/BMW

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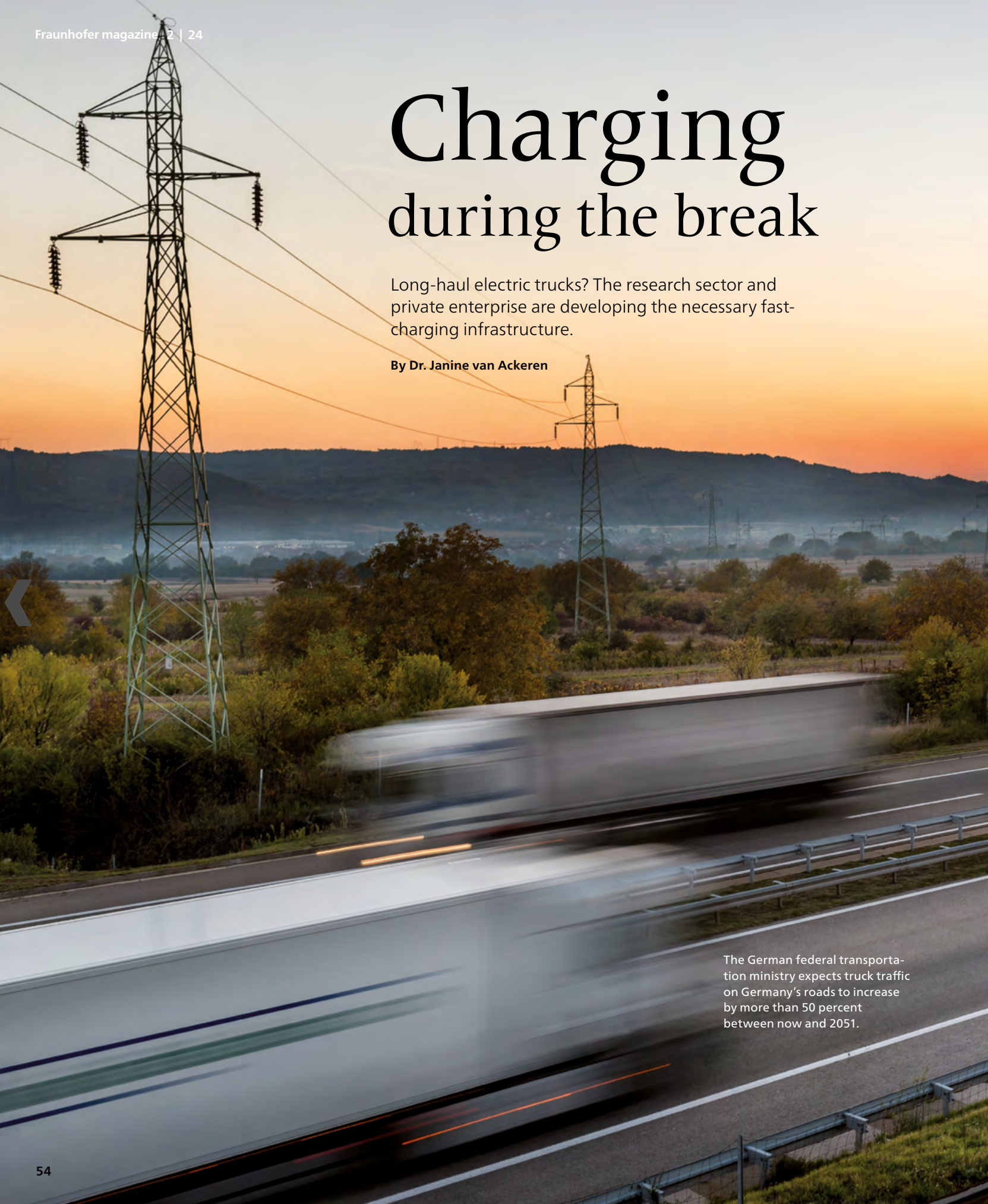
Charging during the break

Long-haul electric trucks? The research sector and private enterprise are developing the necessary fast-charging infrastructure.

By Dr. Janine van Ackeren



The German federal transportation ministry expects truck traffic on Germany's roads to increase by more than 50 percent between now and 2051.

Electric bikes and cars definitely work for everyday use. But long-haul electric trucks? Semis pulling two or more trailers (longer combination vehicles, or LCVs) with heavy goods from a port in the Netherlands clear across Germany to Eastern or Southeastern Europe? "We have the technology to build an electric truck with a range of 1,000 kilometers with no problem. Both batteries and charging performance have improved significantly," says Dr. Patrick Plötz, head of the Energy Sector business unit at the Fraunhofer Institute for Systems and Innovation Research ISI. "But that big a range isn't even necessary in most cases. It would only drive costs up for no reason."

Fast-charging infrastructure for EU Member States

Most of the trucks zipping back and forth down Europe's highways are crewed by just one driver — and by law, that driver has to take at least a 45-minute break after 4.5 hours on the road. The driver uses that time to recharge, and going forward, so could the truck's batteries. "A real-world range of 500 kilometers would be more than enough in that scenario. The sticking point is the fast-charging infrastructure," Plötz explains. "Long-haul electric trucking is still in its infancy," he admits. But the EU is hoping to spur development in this area: To lower greenhouse gas emissions from traffic and transportation, and especially from heavy trucks, all EU Member States are required to build alternative fuel infrastructure in the next few years. And that especially includes building public fast-charging infrastructure for trucks along major highways. EU regulations have also set minimum requirements. Plans call for about 2,800 charging stations to be built Europe-wide along the nearly 110,000 kilometers of trans-European transportation networks by 2030. The new stations are to have at least 7.5 gigawatts of charging power in total.

Researchers are studying the challenges involved as part of the HoLa project, which is exploring high-performance charging for long-haul trucking. Four truck manufacturers — Daimler, Volvo, MAN and Scania — are taking part, along with charging station manufacturers and the Fraunhofer Institute for Industrial Engineering IAO. Fraunhofer ISI is in charge of overall project management for HoLa, which was launched in 2021 and is scheduled to run until the end of September 2025. The project is receiving a total of 12 million euros in funding from the German Federal Ministry for Digital and Transport (BMDV), since after all, it serves to test this new system. Plötz, the project manager in charge, puts it this way: "We want to incorporate electric trucks into logistics processes early on, test new fast charging capabilities, and build experience from real-world operation — and, of course, use our data to pave the way for this technology to be rolled out across the board."

> "By 2030, we'll need at least 1,000 megawatt charging points at 142 locations in Germany if we don't want drivers to have to wait more than five minutes for a free charger even during rush hour."
>
> Dr. Patrick Plötz, Fraunhofer ISI

Test charging stations along Germany's A2

The first step will be showing that the megawatt charging approach works. This feasibility demonstration is taking place on the A2 autobahn between Berlin and the Ruhr region. The project team is setting up charging stations at five locations, each one initially featuring two chargers that use the current standard, the Combined Charging System (CCS), so they are rated for about 400 kilowatts. At the same time, the project partners are also developing the Megawatt Charging System (MCS), which will be used to upgrade four of the five charging stations and make them the first public megawatt truck chargers in Germany. Long-term plans for regular and fast-charging stations to operate alongside each other, since after all, current electric truck models are not yet equipped for rapid charging. The producers are providing the logistics companies involved in the project with at least two CCS vehicles and one megawatt charging-capable vehicle each to serve as prototypes for real-world testing.

How much megawatt charging is needed?

The Fraunhofer institutes are focusing on researching the field: How many of these chargers will be needed, and when? And what might a charging network be like — not just for Germany, but also for Europe? "We plan to use various calculations and simulations to contribute to a blueprint for the widespread development of public truck charging infrastructure," Plötz says. While researchers from Fraunhofer IAO scrutinized a single truck stop in detail, the team from Fraunhofer IAO zoomed out to analyze demand across the whole of Germany.

Their findings surprised even the project manager himself. "Only about a third of trucks are involved in long-haul traffic at all, and of that amount, many of them don't even travel such long distances that they would need megawatt charging infrastructure," Plötz says. In fact, only about ten percent of Germany's trucks will need megawatt charging in the long term. Still, he says, it is definitely a needed option. "It's like with private cars. I generally charge my car at home. But for the few times I need to travel long distances on the highway when I'm going on vacation, the fast-charging infrastructure is fundamental." Plötz lays out his calculations: "By 2030, we'll need at least 1,000 megawatt charging points at 142 locations in Germany if we don't want drivers to have to wait more than five minutes for a free charger even during rush hour." ■

Photo: Avigator Photographer/Istockphoto

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Smart spy

Materials don't talk. Or so one might think. Researchers working on the SmartRust project are investigating how they can communicate anyway, making our lives safer.

By Yvonne Weiß

Condition? Satisfactory. That's the rating for almost half of all German highway overpasses in 2023. A quarter of them ended up merely rated "Sufficient," and just under five percent were not even that.

There are many causes — moisture, fluctuating temperatures, mechanical stress. To find out what environmental influences affect an object and may cause it to deteriorate, researchers from Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU) and the Fraunhofer Institute for Silicate Research ISC are pursuing a new approach in the SmartRust project.

The idea: Magnetic particles are incorporated into materials during the manufacturing process. Since these particles consist largely of iron oxides — rust, in other words — they are cheap to produce. They are also the namesake of the SmartRust project, which is receiving funding from the EU under a prestigious ERC Consolidator Grant. The particles are to provide information on what has happened to materials in the past, thereby bringing even hidden defects to light.

"How much moisture has an object been exposed to? What about heat? Has it undergone mechanical stress? The idea is for the particles to answer questions like these for us, like tiny spies," explains Karl Mandel, a professor of inorganic chemistry at FAU and deputy institute director and scientific director at Fraunhofer ISC.

The approach: The magnetic particles enable communication with the outside world. "When the particles interact with each other, it can be measured as a signal. You could almost say they're whispering to each other — like little kids with a secret," says Mandel, the project's initiator.

To be able to measure environmental influences, the researchers also plan to incorporate non-magnetic particles into materials; together with the magnetic particles, they form what is called a "supraparticle."

The non-magnetic particles react to specific environmental influences, such as salt, which dissolves in the presence of moisture. The supraparticle also changes when exposed to these external influences — so its "whispers" change in tone. A portable sensor can be used to register the difference in signal. Then, with the right kind of decoding, researchers can find out what has happened to the object.

The potential applications are many and diverse. Even through the sealed packaging of a vaccine, it would be possible to tell whether the cold chain had been interrupted, damaging the contents. In the automotive industry, people could find out whether plastic components had been heated to the specified temperature to form a sufficiently firm adhesive bond. Dangerous cracks in the blades of a windmill could also be detected and repaired early on. "The particles could let us see all the way into the invisible depths of an object — quickly, cheaply, and without destroying it," Mandel explains.

Once the technology is in use, he says it could be used for three main fields in the future. First is predictive maintenance, which brings greater product safety. Second would be greater efficiency in recycling, as it would enable reliable determinations of whether plastic still possesses the desired properties. And the last is more control in Industry 4.0, as objects could give robots feedback on aspects such as whether screws or bolts are actually placed correctly. Mandel is optimistic: "I'm fascinated by the idea of giving materials a voice down the road." ■

"I'm fascinated by the idea of giving materials a voice down the road."

Prof. Karl Mandel, Fraunhofer ISC

Ironclad assurance: Magnetic particles could help make bridges and overpasses safer.

Photos: Bernhard Kuh/dpa, Akintevs/istockphoto

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Fraunhofer worldwide

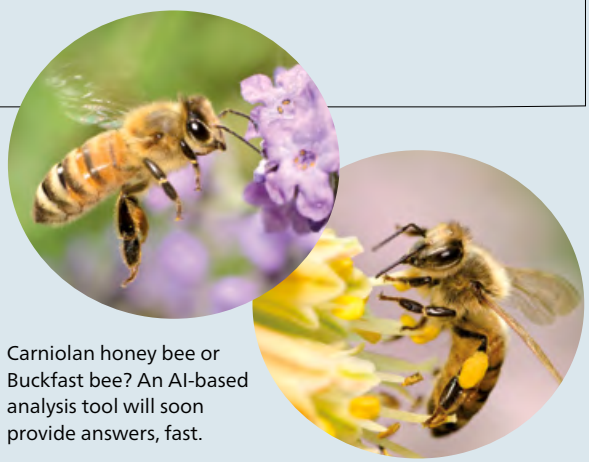
Locations of the Fraunhofer-Gesellschaft

EUROPE

Sustainable maritime shipping

Maritime cargo transportation requires huge volumes of fuel, primarily of fossil origin. Researchers working on Europe's GAMMA joint research project aim to show that a different way is possible by equipping a bulk carrier with an innovative energy system that uses hydrogen to generate electricity. In the future, the goal is to replace diesel generators with fuel cells that supply electricity for on-board systems. Ammonia and green methanol serve as alternative sources of energy aside from hydrogen, and solar panels provide the energy needed for conversion to hydrogen. The Fraunhofer Institute for Microengineering and Microsystems IMM is developing the systems that convert ammonia and methanol into hydrogen, such as compact plate heat exchangers with special catalyst coatings that have been specifically designed for maritime requirements and the high overall energy demand of one megawatt. The technologies will be evaluated during live operation to assess efficiency, costs, weight, volume, tank systems, and safety precautions.

Plans call for this freighter to be able to transport some 60,000 metric tons of cargo with zero emissions.



Carniolan honey bee or Buckfast bee? An AI-based analysis tool will soon provide answers, fast.

AUSTRIA

Using AI to identify bees

There are nearly 700 species of bees buzzing around Austria. Researchers at the Fraunhofer Austria Innovation Center for Digitalization and Artificial Intelligence KI4LIFE are working on AI-based image recognition that allows for rapid classification. Measurements of certain wing characteristics, such as vein structure, are used to identify the different species. So far, the team has manually marked wing photos with dots that can be used to calculate an index to enable association with a specific bee species. Existing university analysis tools have also been tested for accuracy and functionality as the first step toward automation. A larger follow-up project is planned in cooperation with the Landesverband für Bienenzucht in Kärnten, the Carinthian state beekeeping association.

FINLAND

Ultra-accurate mapping of underwater structures

Two innovative LiDAR systems can now be used to survey offshore wind farms.

In the CoLiBri project, scientists from the Fraunhofer Institute for Physical Measurement Techniques IPM are working with the Finnish Geospatial Research Institute (FGI) on a unique monitoring method that combines precision laser-based measurements from underwater and aerial photographs. Two compact sensor modules are used to gather data: a mobile, pressure-resistant underwater scanner and an ultra-lightweight drone scanner. This makes it possible to capture information on the structure of the sea floor right down to the millimeter, along with the water surface and depth and the shoreline, including the adjacent terrain. After being analyzed, the data is then combined into a point cloud forming a uniform system of geospatial coordinates. This creates a cohesive visualization of both system components.

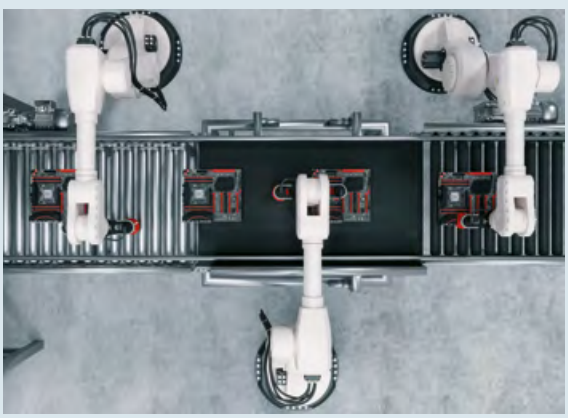
The Asian tiger mosquito alone can transmit 20 different viruses that present a risk to human health.

EUROPE

Preventing epidemics

How high is the risk of new zoonoses, meaning infectious diseases transmitted to humans by animals? Researchers from the Fraunhofer Institute for Cell Therapy and Immunology IZI are working with an interdisciplinary team of researchers to pursue that question in the EU's ZOE project. Their goal is to identify risks early on and prevent epidemics. To achieve that, the scientists from Europe and Latin America are studying various factors, including biodiversity in forested areas with varying levels of human impact. They are using satellite images and field research to map landscape features and survey the animal and plant species found there. They are also collecting information on the distribution of potentially dangerous microorganisms by testing common vectors for zoonotic pathogens, like rodents, ticks, and mosquitoes, for bacteria and viruses. Fraunhofer IZI is developing analytical methods that can be used to test these samples for the relevant antibodies, comprehensively and with high throughput.

Future goals: keeping production up and running even in a pandemic.



FRANCE

AI makes robots more efficient

Intelligent and versatile industrial robots that ensure interruption-free production, high levels of automation, and low energy consumption are the goal for GreenBotAI, a Franco-German project led by the Fraunhofer Institute for Machine Tools and Forming Technology IWU. The researchers are working on AI-based programming that allows the robots to autonomously sense environmental conditions, adjust to production requirements, handle complex tasks spontaneously, and identify errors. On the technical side, GreenBotAI is focusing on reducing response and latency times, optimized path planning, and execution of tasks on the fly, meaning while the robot is still moving. The aim is to harness AI solutions that rely on reduced data and faster gripping motions to significantly reduce energy consumption. A 25 percent reduction has already been achieved, with 50 percent as a target.

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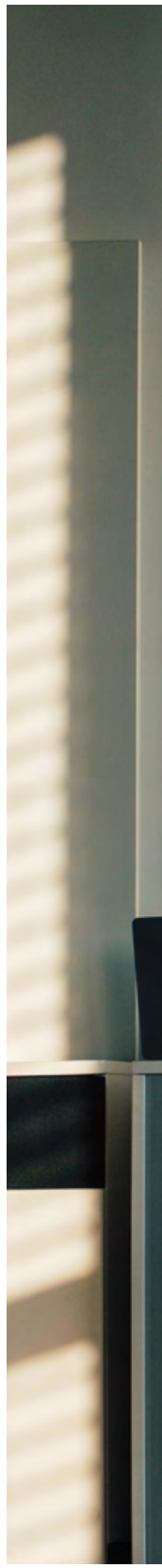
Let there be light!



Bringing more sunlight into the office through skillful redirection into the space.

How can as much natural light as possible be used inside offices without glare and excessive heating from the sun? Micro-optical components in windows could be a solution.

By Beate Strobel

Office workers have an issue in the summer: The sun comes out, and automatically, down go shades all over the building, so it hardly feels like summer at all. That can even leave people inside working under artificial light, even in broad daylight. But without this kind of exterior darkening, sunlight quickly heats the inside to uncomfortable levels while also causing bothersome glare on screens.

Researchers at the Fraunhofer Institute for Building Physics IBP set out to find a happy medium between bright and dark. In two projects funded by the German federal economics ministry, TaLED and TaHo, they teamed up with partners from research and industry to develop micro-optical components for vertical glass facades. The idea was not to block out the sun, but rather to first refract it toward the ceiling so the indirect light could then also illuminate the rest of the space without glare — and without causing excessive heating. The savings are twofold: The energy typically needed for artificial office lighting is cut by as much as 80 percent, and there is also no need to spend on air conditioning, thus conserving electricity.

The positive impact goes beyond energy costs: Studies show that employees who can work in natural light tend to have higher motivation, be able to concentrate for longer, and make fewer mistakes as well. "Working in artificial light for eight hours is suboptimal, both physiologically and psychologically," explains Dr. Jan de Boer, Group Manager Lighting Technology and Passive Solar Systems at Fraunhofer IBP. "People always prefer natural light."

The targeted redirection of sunlight is made possible by special triple-pane insulating windows featuring a sawtooth-like microstructure on both sides of the middle pane. The structure is created through hot stamping and a nanoimprint process. Other aspects should also be especially welcome in the construction industry, which is heavily focused on cost. "The production methods allow for fast, low-cost manufacturing of high unit volumes," de Boer notes. "The nanoimprint production is even a roll-to-roll method, which makes it possible to apply the necessary micro-optic structures endlessly on films."

The researchers have already demonstrated how the technology is also impressive outside the lab in two buildings. The micro-optical components were built into the facades of three offices of an administrative building in Dortmund and three classrooms at a school in Krefeld. All of the rooms were more than four meters deep. The researchers' expectations were borne out, as natural light was much more available even in areas far from the facade.

While the optimized windows are being launched on the market by one of the project partners shortly, the Fraunhofer researchers are already at work on potential skylight versions. They do let maximum amounts of natural light into the rooms below, but they also heat them up quickly. Taking inspiration from the architecture of shed roofs that block high-intensity direct light from southern exposures while letting diffuse, "cooler" northern light into the building, miniature dormer structures have been developed. The structures have been stamped and embossed for initial samples made of materials including foil. In the future, the foil could either be an integral element of the glazing or, like a fabric shade, be pulled across the window surface as needed.

This part of the project, de Boer says, is still at the lab stage, but the team is already thinking about the possibilities for scaling up. After all, it seems obvious that demand for this kind of indirect use of natural light will only tend to increase going forward. For one thing, people need to use energy more and more sparingly, whether for lighting or cooling. And for another: Who doesn't want to work from a place in the sun? ■

"Working in artificial light for eight hours is suboptimal, both physiologically and psychologically."

Dr. Jan de Boer, Fraunhofer IBP

More natural light
Video of the technology demonstration at a school in Krefeld

www.youtube.com/watch?v=2D6Zr9Pwv6s

Photo: Joseffson/ Westend61/mauritius images

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Photo & Fraunhofer

What makes geckos sticky

Researchers view geckos as true superheroes: The scaly lizards can climb even slick surfaces, thanks to the hierarchically branching surface structure of their feet. The interplay of tiny hairs on a gecko's foot creates a wonderful contrast: extremely good adhesion on nearly any surface, but also easy release.

Researchers from the Fraunhofer Institute for Microstructure of Materials and Systems IMWS in Halle are building on this example. They have developed a method that significantly improves the adhesive properties of polymers. Hot stamping gives the polymer surfaces a hierarchical structure similar to that found on gecko feet. The stamping tool used for this is made of aluminum, which is structured using lasers and anodic oxidation.

The change in the plastic surface at the micro and nano levels is invisible to the naked eye: A single strand of human hair is about 100 micrometers in diameter, and a nanometer is 1,000 times smaller than a micrometer. But these tiny stampings on the polymer surface increase adhesion on wet surfaces by as much as 85.4 percent.

Dr. Andrea Friedmann, a biotechnologist at Fraunhofer IMWS, believes there are a whole host of possible applications for this patented method. Her first thought was biomedical applications, but there have now also been inquiries from the packaging, automotive, and aviation industries — and even from the realm of work apparel, with goals such as increasing the adhesion of roofers' shoes. Another bonus, Friedmann says, is that the improved material properties are not based on added elements such as additives or coatings: "This means the materials can stay pure, which considerably simplifies recycling later on."

Inspiration for science: Geckos can cling to even panes of glass, thanks to millions of ultra-fine hairs on their feet. The adhesive force is many times greater than the reptiles' weight.

Photo: Petlin Dmtry, Danchai Nortown/beide istockphoto

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Fraunhofer start-ups:
Applying research in industry

Successful with laser technology

It started out 25 years ago as a one-person company at the offices of Fraunhofer IWS. Today, ALOtec Dresden supports companies all over the world with laser hardening and laser material deposition or cladding. It continues to rely on Fraunhofer research.

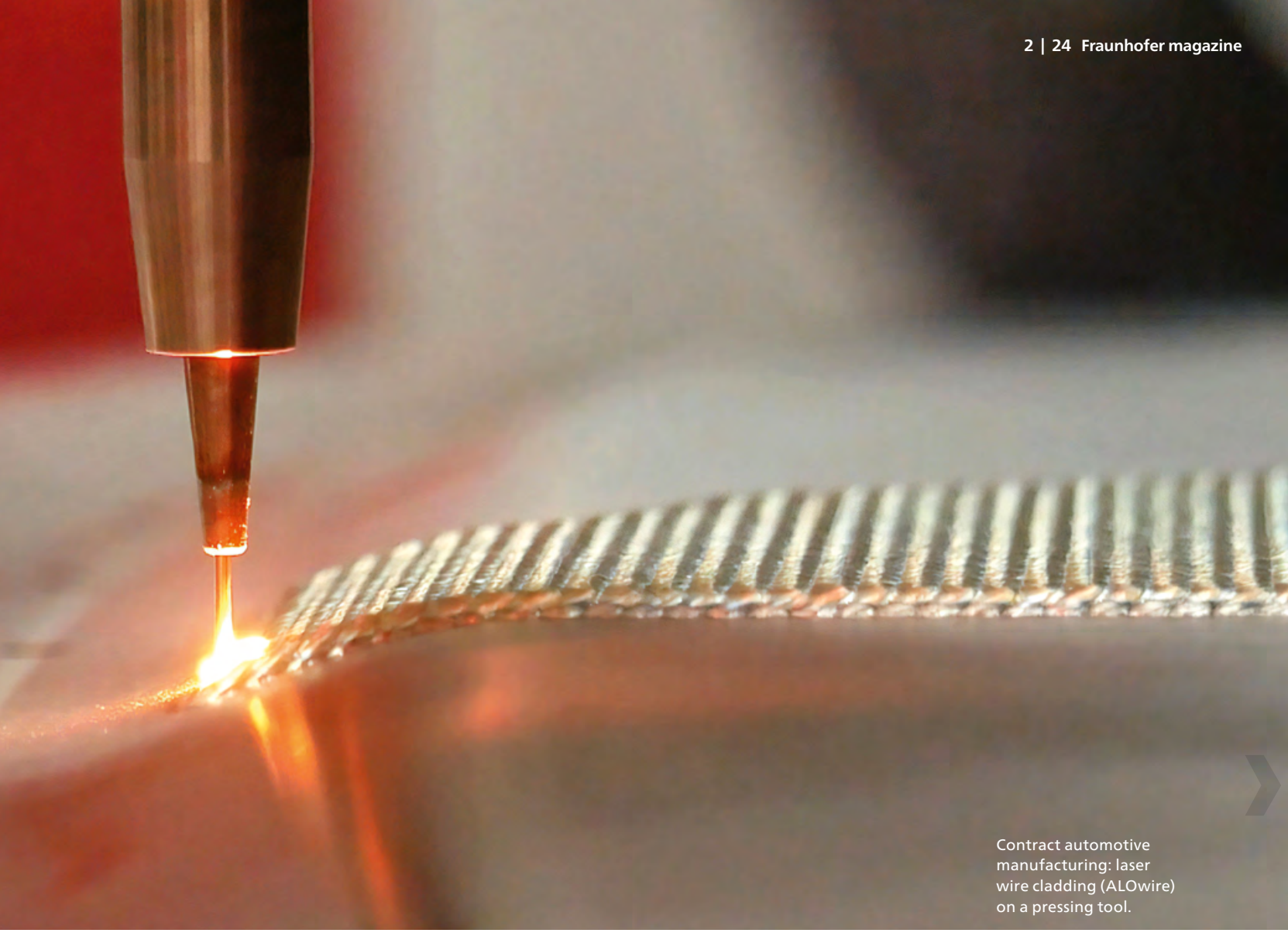
By Beate Strobel

Applying research findings is the objective of the Fraunhofer-Gesellschaft and its research institutes and has set them apart from others for 75 years now. The history of ALOtec Dresden GmbH shows just how long the ties forged in the process between the research sector and industry can last. The company originated in the late 1990s, when Prof. Ralf Eckhard Beyer, at that time the head of the Fraunhofer Institute for Material and Beam Technology IWS in Dresden, had an idea. The goal of the spin-off was to create a way to offer laser material processing solutions developed at the institute to companies based in the local area and beyond, all at affordable prices. To raise the necessary share capital, Fraunhofer IWS allowed individuals, not just companies, to acquire financial stakes in the tech start-up — a form of crowdfunding before the idea caught on as a trend in financing innovative business ideas. To this day, many employees of Fraunhofer IWS hold shares in ALOtec Dresden GmbH.

The start-up took the first steps toward profitability under the leadership of Managing Director Dr. Eckehard Hensel, when it was still located on the grounds of Fraunhofer IWS. The company moved its headquarters to the town of Kesselsdorf, west of Dresden, in 2011, and has grown from a single employee to 17 in the meantime. The business model has also expanded over the years. In addition to contract manufacturing in laser hardening and laser cladding with powder or wire, its service portfolio now also includes development and production of customer-specific laser system equipment and mobile use of systems for laser hardening, cladding, and CMT welding. ALOflex, for example, is arguably one of the world's smallest and most versatile laser processing systems. It fits on a standard-sized pallet and moves on treads, so it can easily be maneuvered by remote control right to where it is needed.

Reuse, repair — don't throw away

Twenty-five years after the company was first registered as a business, laser material processing is still in demand: "Laser hardening and cladding technology enable targeted and efficient use



Contract automotive manufacturing: laser wire cladding (ALOwire) on a pressing tool.

Photo: ALOtec Dresden GmbH

of energy, minimizing environmental impact," explains Dr. Clemens Kuhn, who has been the managing director at ALOtec Dresden since 2021. "These methods allow us to extend the service life of components that are exposed to heavy wear and strain and offer sustainable solutions by repairing and reusing old or defective parts."

Fraunhofer IWS has worked with ALOtec to further develop and refine existing laser processing methods. Laser hardening with thermal field control based on the LASSY dynamic beam shaping system is one example: The goal here was to guide a laser beam with a long focal length and fixed round or rectangular focus over a scanning mirror system to be able to harden components with even the most complex geometries, such as freeform surfaces, case corners, or tapered cutting edges. The Efaqs pyrometer developed at Fraunhofer IWS or a special thermal imaging camera (Emaqs) can be used to determine the exact temperature distribution at the surface, all without touching it. Equipped with both systems, the actual thermal field controller can then adjust the laser output accordingly, compensating for temperature discrepancies caused by the geometry.

"We gather information and ideas from real-world practice and approach Fraunhofer with topics and requirements from industry and manufacturing."

Dr. Clemens Kuhn,
ALOtec Dresden GmbH

"Our partnership with Fraunhofer IWS is not only shaped by joint projects, but in general by lively dialogue," Kuhn says. "We gather information and ideas from real-world practice and approach Fraunhofer with topics and requirements from industry and manufacturing." ■

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Ready for the 21st century

Thinking beyond PISA: A testing method developed by Fraunhofer FIT is making it possible to measure core competencies for the working world of tomorrow for the first time.

By Beate Strobel

Learning by laptop: Media literacy is one of the skills that are becoming ever more important.

Can't school be a little bit more like TikTok? That might sound like a teenager's plaintive remark, but it is also a good encapsulation of what nonprofit start-up DigitalSchoolStory (DSS) has set out to do. In DSS projects, schoolkids turn selected pieces of learning content into video clips in social media format, working as a team and with support from their idols on platforms like Instagram and YouTube.

Goethe on TikTok instead of on paper? To Boomers, that probably sounds infantilizing. But the DSS learning method is anything but a silly game. It is intended to strengthen the soft skills that have previously been neglected in educational assessments such as the PISA study, but will be essential to professional success as working environments become increasingly digital and automated. To make these skills measurable, thereby accelerating their implementation in school curricula, researchers from the Fraunhofer Institute for Applied Information Technology FIT have now developed a new testing method.

After all, factual knowledge alone is no longer enough in the world of the 21st century, which is shaped by what are known as the "VUCA" factors: volatility, uncertainty, complexity, and ambiguity. "This world no longer rewards us solely for what we know — Google already knows everything anyway. It rewards us for what we can do with what we know," education researcher and OECD director Andreas Schleicher explains in the OECD Learning Compass 2030.

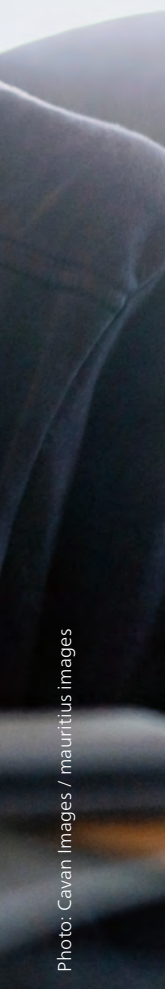

Photo: Cavan Images / mauritius images

Rethinking the ideal education with the "4 Cs"

The Partnership for 21st Century Learning (P21), an American nonprofit, has identified four core competencies for coping with and shaping the world's growing complexity: creativity and innovation, critical thinking and problem solving, collaboration, and communication. So, instead of viewing education primarily as imparting knowledge that can be retrieved on demand, the DSS approach calls for students not only to develop the knowledge themselves, but then prepare it afterward in such a way that others understand the issue as well. Anyone who has ever tried to turn complex matters into a coherent story and explain them understandably in a 90-second clip knows that it's not just a silly game.

The PISA study regularly measures the performance of students worldwide in the base skills of reading, mathematics, and science. But what about core competencies for the 21st century? "Until now, there has been no measuring tool for capturing information on the 4 Cs in the German-speaking countries," explains Gülsah Keskin, a psychologist and the project manager at Fraunhofer FIT. But that information is needed, since as Keskin notes, "A teaching concept has to be empirically proven effective first before the chances improve that it will achieve greater visibility in terms of education policy."

The measuring tool Keskin developed in cooperation with DSS encompasses the 4 Cs along with media literacy as an additional skill (dubbed the "4C plus" model). But unlike PISA, it does not test students' knowledge. There are 25 questions, with five to eight items per competency, asking students to rate themselves on a scale from one to five. The students' teacher also completes one survey per student, so the self-assessments are supplemented by an external viewpoint.

The project group from Fraunhofer FIT used the tool at several schools before and after the DSS project. They found that educators are seeing positive change in the competencies of creativity and innovation, critical thinking and problem solving, and media literacy in particular, even if students themselves do not perceive these changes quite as sharply. Regular instruction alone made no significant difference to the 4 Cs.

Learning according to the "TikTok principle" works, DigitalSchoolStory concludes: Co-creative development of video formats strengthens both media skills and critical thinking. Keskin, the project manager, also interprets the study's results as encouragement to continue measuring the "4C plus" factors and developing innovative digital education concepts. She hopes surveys of core competencies will soon add a subjective component of skills assessment to the objective test of knowledge conducted as part of the PISA study to provide effective impetus for educating the young generation.

Learning for life, with the "TikTok principle"

Writing in the year 62 AD, the Roman philosopher Seneca was already critical of learning not for life, but for school: What was being taught in schools, he wrote pointedly, did not help students "to live correctly, but at most to speak like educated people." His criticism is still cogent today. In her day-to-day life, Keskin notes time and again "that each of the five core competencies is important to professional success." Ideally, some elements of these core competencies will show up early on, in initial interviews with applicants: "Anyone can learn quickly how certain systems work. But problem-oriented thinking, willingness to engage in lifelong learning, and constructive collaboration with others across different cultures can't be taught in a two-hour training course." Incorporating the "4C plus" aspects into the education students receive in school, and potentially into vocational training as well, is something she views as important — so that the next generation learns not just for school, but actually for life. ■

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"An intestine on 16 legs"

Can caterpillars help study Crohn's disease? Fraunhofer IME shows how and offers solutions not only for chronic gastrointestinal diseases and conditions, but also for greater biodiversity.

By Stefanie Smuda

It is only about ten centimeters long, thick as a person's thumb, and currently happily munching its way through a tobacco leaf: The tobacco hornworm (Manduca sexta) is actually native to the Americas, but now also makes its home at the labs of the Fraunhofer Institute for Molecular Biology and Applied Ecology IME in Giessen. It's "an intestine on 16 legs," jokes Anton Windfelder, junior group manager at Fraunhofer IME. To him, that's a good thing: "The intestines of mammals and insects are comparable, especially when you look at the immune system. About 75 percent of the genes that can cause disease in humans are also present in caterpillars."

And that makes the tobacco hornworm useful as a model organism for research on human diseases. Fraunhofer IME uses them to study chronic inflammatory gastrointestinal diseases such as Crohn's disease, for example, and to develop and test potential treatments. In addition to the similarities in the immune system and gastrointestinal structure, the tobacco hornworm is also favorable in size. At up to eight centimeters in length, not only is it about the same size as a mouse, but the gastrointestinal volume is comparable — plus, it is large enough for imaging to be used.

Working with partners from Düsseldorf and New York, Windfelder and his team have developed an innovative imaging platform. The researchers in Giessen can use computed tomography (CT), magnetic resonance imaging (MRI), and positron emission tomography (PET) scans to zero in on and diagnose inflammation in the insect's intestinal tract. The benefit is that many insects can be scanned to analyze their entire gastrointestinal tract in just a short time. For example, clinical CT can be used to scan 100 caterpillars in just a few seconds. If a certain region of the tract needs to be targeted, small animal MRI and CT scanners with higher resolution are used, since they provide the researchers with more information and a better view. Windfelder says combining the two methods yields the most meaningful results. The caterpillars come through anesthesia and imaging with no issues and continue their lives unharmed. The researchers at Fraunhofer IME have also used scanning electron microscopy and nano-CT to create detailed 3D atlases of the surface of the larvae's intestines. This gives students a way to explore the complex structure of the insect gastrointestinal tract via VR headset.

Studying muscular and metabolic disorders

There are many possible uses for caterpillar models in other areas of biomedical research: "Insects lend themselves to research on all kinds of questions about the gastrointestinal tract and immune system. But there are limits, since insects don't have an adaptive immune response based on B and T cells, so antibody research isn't possible," Windfelder notes. However, taking differences in anatomy into consideration, caterpillars can be used to study diseases of the musculature and metabolism. In the lab, for example, the scientists are using them to test new medications and find the correct dosage.

In collaboration with chemists from the University of Twente, in the Netherlands, and Heinrich Heine University Düsseldorf, Windfelder and his team have used Manduca larvae to test a new MRI contrast agent in vivo. The cooperation partners developed a biodegradable phosphorus contrast agent as a greener alternative. "In the in-vivo tests, the new active ingredient was clearly distinguishable from the larval background and remained detectable in the hemolymph — the larvae's blood — for 24 hours," Windfelder explains.

Another application sounds like a major use for tobacco hornworms: The scientists at Fraunhofer IME are studying insect death in relation to pesticides. Thus far, there are only a few testing methods available, and they concentrate mainly on contact exposure. But insects typically consume pesticides orally, so the toxins affect the gastrointestinal system. "Our functional imaging methods let us analyze what happens in the insect's gastrointestinal tract, which we can use as a basis for developing objective measurement parameters for government agencies and industry," Windfelder says. Going forward, this will pave the way for tests showing the form in which pesticides are harmful to insects. ■

"About 75 percent of the genes that can cause disease in humans are also present in caterpillars."

Anton Windfelder,
Fraunhofer IME

Photo: Liz W Grogan / iStockphoto

A pest in agriculture, a handy helper for researchers: the tobacco hornworm.

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Healing fractures with glass

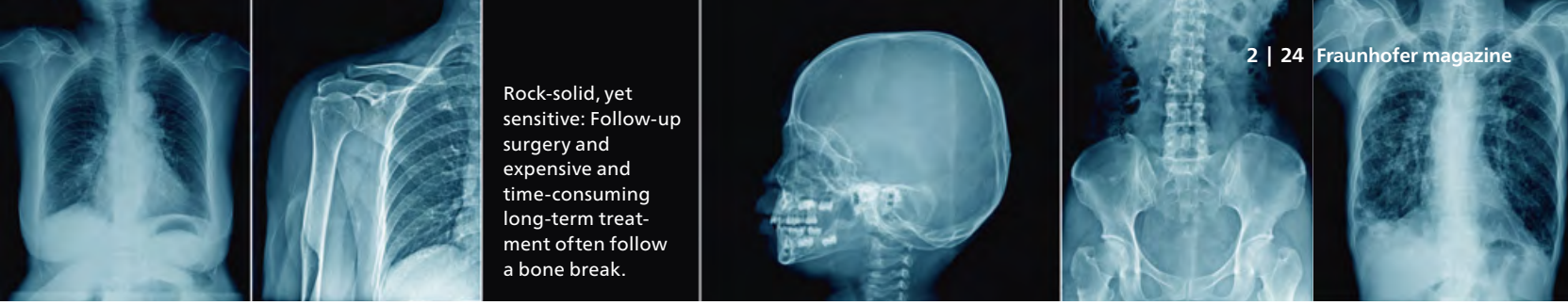
Some 800,000 broken bones are treated in Germany each year. The Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM is developing a way to help fractures heal faster and more reliably — with biodegradable polymer and bioactive glass.

By Anja Wächter

Healing bone defects faster and more reliably: Researchers at the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM in Bremen are working to do just that. Working together with the Department of Trauma and Reconstructive Surgery at Heidelberg University Hospital and Leipzig-based medical technology firm BellaSeno, they have developed a composite material for a supporting structure that can be used to improve treatment of broken bones. The technology is being realized as part of the SCABAEGO (Scaffold Bioactive Glass-Enhanced Osteogenesis) joint research project funded by the German Federal Ministry of Education and Research (BMBF).

Each year, about 800,000 broken bones are treated in Germany. In as many as ten percent of cases, the bone does not heal optimally, resulting in segmental defects (pseudoarthrosis or non-union). Patients cannot put weight on the bone, which creates substantial restrictions in activities of daily living and leads to lasting pain. It is not unusual for problems with bone healing to be caused by a low-grade infection. When this occurs, patients typically face prolonged hospital stays, with follow-up procedures and long-term treatment. Hospitals are wary of these complications, too, as they result in time-consuming and expensive therapy.

Worldwide, defects like these are treated by taking a sample of healthy bone marrow and



Rock-solid, yet sensitive: Follow-up surgery and expensive and time-consuming long-term treatment often follow a bone break.

transferring it to the defect. And yet, conventional treatment methods reach their limits when the bone defect is large (5 cm or more) or infected. This is because it is difficult to hold the soft bone substance in place at the site of the defect to ensure proper healing, and because it may also be necessary to treat a local infection at the same time. This is where SCABAEGO comes in. "Our composite material combines polycaprolactone, a biodegradable polymer, with bioactive glass," explains Dr. Kai Borcherding, head of the medical technology and life sciences business unit at Fraunhofer IFAM. Project partner BellaSeno uses this material to 3D print a custom-made supporting structure called a scaffold for the bone fracture site. The data used to shape the individual scaffold comes from computed tomography (CT) mapping of the broken bone.

Up to ten percent of bone fractures do not heal properly, resulting in segmental defects.

Dr. Tobias Grossner, senior physician and head of experimental trauma surgery at Heidelberg University Hospital, explains the new method's benefits: "Surgery is performed to take bone substance from the iliac crest or the medullary space inside the long bones of the body and then transferred to where it is needed at the site of the fracture. The scaffold, which has a mesh-like structure, holds the bone transplant material in place so new bone can form."

Unlike in previous methods, this minimizes the risk that the transplanted bone marrow will move out of place. It also helps make certain vascularization occurs undisturbed, so the break can heal cleanly. The bioactive glass inhibits the growth of any bacteria that may be present.

Lowering the risk of infection

The combination of polycaprolactone (PCL) and bioactive glass has further benefits. For one thing, the material transforms into a substance very similar to bone inside the body, and the bioactive glass also helps fight the risk of infection. Borcherding: "Our initial tests showed that the biological activity of the composite is right in the target range for inhibiting bacterial growth. A 4-log, or 99.99 percent, reduction in MRSA (methicillin-resistant Staphylococcus aureus) was demonstrated on the composite. This antibiotic-resistant bacterium is responsible for infections that are difficult to treat. This means the result is impressive in terms of both protecting the surface of the implant and reducing the risk of infection. "

The SCABAEGO research team is currently working with Heidelberg University Hospital to further refine the method. At the same time, the team is also optimizing the makeup of the composite material, particularly the percentage of glass. "Our goal is to leverage the biologically positive characteristics of glass as much as possible while maintaining the core strength of the scaffold," says Borcherding. ■

Photo: angkhan/istockphoto

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RoboKeeper — the world's fastest goalie

Manuel Neuer or Marc-André ter Stegen? When it comes to the top goalkeeper on the German national team, it's hard to choose. Now, the world-class goalies have a new rival to compete with: the RoboKeeper.

By Manuel Montefalcone

Image, right:
World-class without a motor: goalie Manuel Neuer

The other giant guarding the goal: The high-tech keeper keeps balls out, too.

Even legendary players like Messi and Neymar didn't stand a chance against it: The RoboKeeper, from the Fraunhofer Institute for Material Flow and Logistics IML, uses 3D image processing, control technology, and algorithms to stop almost every ball. The robot, which looks like a life-sized goal keeper figure, was developed during the 2006 World Cup in Germany. Since then, it has been used at various events worldwide and has undergone ongoing optimization. The latest version came out right in time for the 2024 UEFA European Championship.

These days, with artificial intelligence (AI) all the rage, the robot goalkeeper might not seem that impressive at first glance. Two cameras analyze the ball's trajectory as it approaches the goal, and a motor sets the goalie in motion. All with no AI at all. But on closer inspection, it is clear just how cleverly designed the mechanisms behind the RoboKeeper are. "AI wouldn't be smart enough for our goalie," explains engineer Thomas Albrecht, head of driverless transportation systems at Fraunhofer IML. "It would probably slow it down and make it more expensive."

Faster than a Formula 1 race car

The goalkeeper figure is attached to an assembly comprising an efficient and dynamic motor-drive combination with high power density. The drive, the motor controls, and the two gigabit color cameras are connected to a computer running 3D image processing software. All of the components — motor, cameras, and software — work at the highest level. After all, the RoboKeeper has to be able to stand up to the likes of Messi and Neymar. Just 50 milliseconds after the ball is kicked, the system knows where it will hit the goal. At a shot speed of 100 kilometers per hour, the ball has already traveled 1.5 meters by then. Immediately after it is launched, the cameras capture it at a rate of 90 frames per second (FPS). The image processing software then calculates a parabola describing the ball's trajectory, and the system shows the keeper where the ball will hit. A drive with engine power of 21 kilowatts (about 28.55 HP) accelerates and brakes the figure at 20 times the acceleration due to gravity, or 17 times faster than a Formula 1 race car. The tips of the figure's fingers reach a maximum speed of 53 kilometers per second in the process.

In use worldwide and (almost) unbeatable

All this makes it no wonder the RoboKeeper is a hot export these days. There are 44 of them in use worldwide now, marketed by sports marketing partner 4attention. The software in particular has undergone continuous improvement in recent years. But hardware components such as the camera, motor, and computer have also been replaced by advanced, higher-performance devices. The most recent upgrade is especially exciting, since even the RoboKeeper is not infallible: "Balls can reach the goal if the shot is really hard or hits the top corners because the RoboKeeper can't reach them with its dimensions," Albrecht says. Shots from a distance of ten meters, aimed at up to 100 kilometers per second straight at the left or right corner, are the hardest for the keeper to catch. The researchers at Fraunhofer IML just recently developed a ball retrieval robot that automatically brings the ball back to the player in these cases.

Although the RoboKeeper is a real challenge even for practiced players, Albrecht does not think using it to train the German national team would be very fruitful: "When our players practice shooting targeted goals, it just makes sense for the goalie to train with them." Going head to head against top scorers builds the experience that world-class goalies like Neuer need — which will always give them an edge over the RoboKeeper. ■

Video
Messi and Neymar put the RoboKeeper to the test in Barcelona.

www.youtube.com/watch?v=gp23q8VAi5E

Photos: Timm Ulrich/4attention, Kai Pfaffenbach/Reuters/dpa

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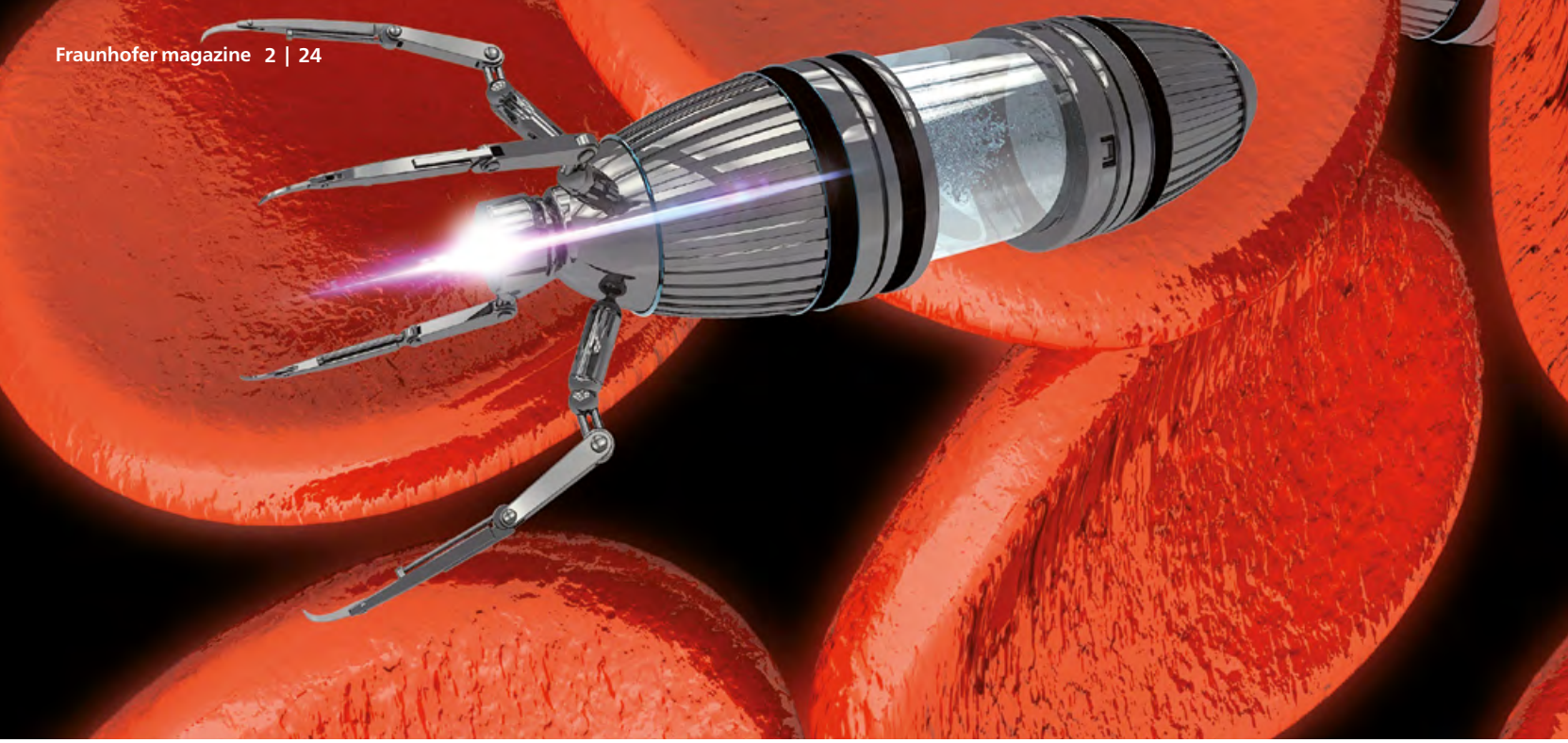

Full speed

Scientists have devised tiny submarines to transport medications right to where they are needed inside the human body or repair life-threatening aneurysms. Magnets are used to steer them.

By Dr. Sonja Endres

A miniature submarine that travels through the bloodstream, taking active ingredients directly to the site of a tumor? If that reminds you of the 1966 sci-fi classic Fantastic Voyage starring Raquel Welch, you're not far off. In the movie, a team of researchers are shrunk down, submarine and all, to remove a deadly blood clot from a patient's brain. Unlike in the fictional version, though, the miniature submarine from the Fraunhofer Research Institution for Individualized and Cell-Based Medical Engineering IMTE doesn't require a miniaturized crew to navigate. "We steer our submarine, which is coated with iron oxide, with a rotating magnetic field of about 10 to 20 Hertz, piloting it right to where it needs to go," explains Dr. Anna Christin Bakenecker, Magnetic Methods group manager. In this way, chemotherapy drugs can be transported directly to the site of a tumor itself, significantly easing the burden on patients because the drugs' destructive power is not spread throughout the body. Common side effects like dry, flaky skin, inflammation of the mucous membranes, and hair loss can be significantly reduced. "The magnetic fields are harmless to people, so they can penetrate deep inside the body with no risk," Bakenecker points out.

Therapeutic hyperthermia is another potential application for the tiny submarine, meaning overheating the tumor to create a localized artificial fever that kills off cancer cells. Hyperthermia is already in use as a cancer treatment, especially because it also makes the tumor more sensitive to drugs. So far, medical professionals have used focused ultrasound for this. Bakenecker and her team instead use a significantly higher-frequency magnetic field of 400 to 700 kilohertz, which causes the magnetic iron oxide nanoparticles to vibrate back and forth like thousands of tiny compass needles, producing heat. The magnetic field can be configured with great precision, targeting exactly where the tissue is to be heated. "This is a huge advantage over ultrasound, which is more generalized," Bakenecker says. The researchers can read the signals that the magnetic nanoparticles generate in real time. That means they always know exactly where the submarine is located, and they can also determine the surrounding temperature, for example — which Bakenecker notes is another key benefit: "With the ultrasound

"We're working on a whole fleet of mini, micro, and nano robots. This new technology opens up a huge range of possibilities."

Dr. Anna Christin Bakenecker, Fraunhofer IMTE

Variable in shape, size, and material depending on where they are used in the body: smart transporters from Fraunhofer IMTE.

method, you never know just how hot the tumor actually gets."

The team of researchers from Fraunhofer IMTE has spent three years working closely with the Lübeck campus of University Hospital Schleswig-Holstein on the submarines, which were initially about three millimeters in size — making them too large for many medical applications. In the meantime, sophisticated 3D printing technology has allowed the team at Fraunhofer IMTE to shrink them down to 400 micrometers. Unlike the older model, which looked more like corkscrew pasta, the new one is more like a screw. Bakenecker explains: "When you make something much smaller, you need a different shape for the propulsion system for physical reasons. The older sub had a forward propulsion system like a ship, while the new one "spirals" forward.

While the miniaturization process has been a success, Bakenecker and her team are still tinkering with the perfect production material. The scientists are testing various hydrogels, which are gels made from polymers that can bind water. "There's a wide range of hydrogels that have really exciting properties, are easily tolerated, and can be used in a whole spectrum of applications," Bakenecker explains. They could also be printed with the drugs built right in, for example. "Right now, I'm working with a hydrogel that dissolves as soon as the pH value changes, which happens near a tumor. So, the mini sub would break down at its destination, releasing the therapeutic agent." The iron oxide coating can also be broken down by the body, so it is tolerated well.

To get active ingredients to hard-to-reach areas of the body, such as joints, Bakenecker plans to make the transporters even smaller: "We can do without the submarine as a vehicle and simply use the iron oxide nanoparticles, which the drugs bind to. You do need a huge quantity of particles to get to an effective dose, of course. And then you can picture them zooming through the body like a swarm of bees, controlled by our magnetic field." The nano-transporters could be used to ensure that anti-inflammatory drugs spread through injured joints more effectively. "Synovial fluid, the fluid inside the joints, has high viscosity, so medications don't spread as easily there," Bakenecker explains.

The larger miniature submarines are a better choice for other applications, such as if a larger volume of an active ingredient needs to be transported or repairs are required for a life-threatening aneurysm — an abnormal bulge that forms in a defective arterial wall. Blood can collect there, and there is a risk of bursting. "In that case, we wouldn't use our submarine to transport a drug. Instead, we would steer it to the bulge and close it. The blood would then clot around the foreign body, holding it in place," Bakenecker says. The idea is to create a permanent solution, stopping the blood from flowing continuously into the bulge and pressing against the weakened spot. This form of the boat would need not to dissolve, but instead remain stable. "There are many different potential scenarios where our tiny subs could be used. The size and production materials could be adjusted depending on the intended purpose," Bakenecker explains. "So, we're working on a whole fleet of mini, micro, and nano robots. This new technology opens up a huge range of possibilities." ■

Photo: Victor Habbick Visions/Science Photo Library

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Bio-based plastics

Innovative plastic film material made from PLA bioplastic

Flexible single-use packaging items such as shopping bags and garbage bags are among the main sources of plastic waste. A new class of bioplastics based on a biopolyester known as polylactide (PLA) could help in the future.

By Ulla Wolfshöfer

Disposable packaging items often wind up as litter, destroying the natural world, including the oceans. Sustainable solutions are needed. Recycling and defossilization play a crucial role in this context. After use, plastics are ideally broken down into their basic components and used to produce new plastics with the same properties. However, part of the material is lost in the cycle of production, use and reuse. "To further advance the circular economy, these losses must be offset by non-fossil raw materials. But this isn't easy to accomplish, since most fossil plastics don't have bio-based analogues with the same material properties," explains Dr. Antje Lieske, head of the Polymer Synthesis department at Fraunhofer IAP in Potsdam.

Together with her colleagues André Gomoll and Dr. Benjamín Rodríguez, Lieske set out to develop a bio-based plastic that can compete with low-density polyethylene (LDPE), the material most commonly used in flexible film applications today. LDPE is petroleum-based, not biodegradable, and can only be recycled mechanically, with significant functional degradation. Ideally, the researchers wanted the newly developed plastic to cost as little as possible, be compatible with existing LDPE processing equipment, and be biodegradable.

Bio-based and biodegradable

They ended up choosing a biopolyester known as polylactide (PLA) as the base polymer. It can be chemically recycled into new products with relatively low energy input. However, PLA is a very stiff and relatively brittle material, making it unsuitable for production of flexible single-use packaging such as stretch film or shopping bags. The solution: "We added plasticizers known as polyethers directly to the polymer chain to make the material permanently more flexible. Polyethers are nontoxic, commercially available and can also be produced from bio-based raw materials. Until now, plasticizers have been mixed into PLA as additives. However, the plasticizer molecules migrate out of the material over time, making the PLA stiff and rigid again. To prevent this migration, we embedded the polyether directly in the polymer. To achieve this, we synthesized PLA-based block copolymers in which the polyether chain segment

Dr. Antje Lieske (left), André Gomoll (center) and Dr. Benjamín Rodríguez from Fraunhofer IAP are making a valuable contribution to greater sustainability in plastic packaging materials.

Joseph von Fraunhofer Prize 2024

Research prizes

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

The innovative PLA material is at least 80 percent bio-based.

is covalently linked to PLA chain segments at both ends," explains Rodríguez.

The result is a novel, flexible PLA material that does not require migrating plasticizers and, unlike LDPE, is at least 80 percent bio-based. "In the long term, we might be able to increase this proportion to almost 100 percent," Gomoll explains. "In addition, our material can be produced cost-efficiently from commercially available raw materials in a simple synthesis process. This process does not require large-volume synthesis plants but can be implemented locally by medium-sized companies as a continuously operated process. Finally, the new PLA material can also be processed into plastic films using conventional processing plants in a similar way to LDPE — and it can be chemically recycled with considerably less energy input than LDPE," Gomoll continues.

Gomoll, Rodríguez, and Lieske have been awarded the Joseph von Fraunhofer Prize for 2024 for developing this flexible and recyclable PLA material.

Successful commercial implementation

The sustainable material developed by Fraunhofer IAP is the first of its kind — a full substitute for LDPE in flexible film applications in terms of material parameters. This prompted a company called Polymer-Group to commercialize the new material. In 2023, SoBiCo GmbH, a subsidiary of Polymer-Group, commissioned a production plant for the new PLA block copolymers. It produces 2,000 tons of the new bioplastics per year under the name Plactid®. In the long term, it is set to produce 10,000 tons of the new flexible PLA material each year.

The material will represent an important contribution to making plastic packaging materials more sustainable. In addition to flexible packaging films, the new material might also tap into completely new use cases in fields such as the automotive sector, the textile industry and additive manufacturing. ■

All photos: Fraunhofer / Piotr Banczerowski

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Solar energy

High-efficiency colored solar panels for buildings

Solar panels often look aesthetically out of place when installed on building exteriors. The solution is a solar facade element that can be incorporated into a building's exterior practically invisibly and without any significant loss of efficiency.

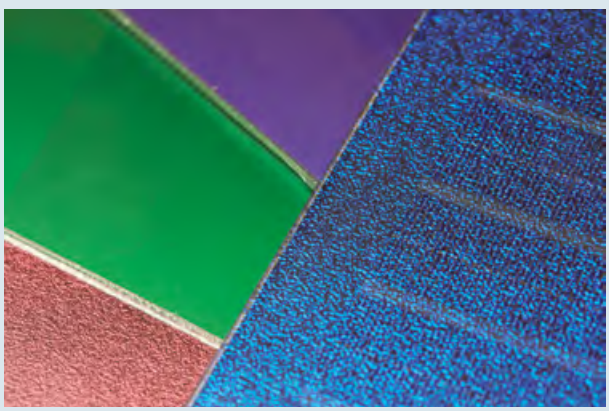
By Ulla Wolfshöfer

Photovoltaic systems are not a popular design feature among architects and building owners. A team of researchers from the Fraunhofer Institute for Solar Energy Systems ISE, based in Freiburg, set out to change that by developing aesthetically pleasing, high-efficiency colored solar panels whose actual purpose is disguised, but that still deliver very high efficiency. With the development of MorphoColor® coating technology, Dr. Oliver Höhn, Dr. Thomas Kroyer and Andreas Wessels have made an important contribution to the expansion in Germany of integrated photovoltaic systems, which involve not only high energy yield but also aesthetics and acceptance as important factors. Their efforts have earned the three researchers the Joseph von Fraunhofer Prize for 2024.

There was a challenging balance to strike with solar panels for building-integrated photovoltaic use: First, they need to behave optically like a traditional colored element, and second, they should still be able to generate as much power as possible. From the perspective of the Fraunhofer ISE experts, that is a contradiction in terms, since after all, color means reflecting light, which in turn brings a loss in terms of electricity generation. So how did they manage to reconcile these conflicting goals and create colored solar panels that feature the desired angularly stable, saturated color, but without any significant loss of efficiency?

Drawing inspiration from nature

"The inspiration came from blue morpho butterflies, which have 3D photonic structures on their wings that allow for an intensive, angularly stable colored impression thanks to a fundamentally low-loss interference effect," explains Kroyer. "A morpho butterfly's wings give an impression of color not through colored pigments, but rather thanks to a visual effect. They have an extremely fine surface texture that reflects a narrow range of specific wavelengths, which is to say a certain color," Kroyer continues. Following this biological model, the experts from Fraunhofer ISE succeeded in using a vacuum process to apply a similar surface structure to the back of the glass covering their solar panels. Depending on the fine structure, this method can be used to produce glass coverings in various colors.



The innovative solar panels can be manufactured in various colors.

The coating system for colored solar panels has now surpassed the biological model in terms of its properties. Its high transparency and color saturation make the MorphoColor® technology far superior to all other comparable technologies available on the market. "Independent measurements confirm that the colored solar panels with MorphoColor® coatings can achieve about 95 percent of the power of a comparable uncoated panel," Wessels explains.

Patented technology with a bright future

The MorphoColor® technology developed at Fraunhofer ISE was patented in 2017 as a plug-in solution that can be used with all standard commercially available solar technologies as well as those foreseeable in the future, plus it can be manufactured industrially at low cost. Cell and panel technologies with a uniform appearance are an especially good fit. These include rear contact solar cells and the matrix shingle technology also developed at Fraunhofer ISE. Normally the tile-sized photovoltaic cells are soldered together. To keep them from showing through the colored protective glass like checkerboard squares, the researchers at Fraunhofer ISE developed an assembly method that evokes a masonry effect. "In matrix shingle technology, the conductive adhesive bonding of the solar cells eliminates the need for reflective metallic connectors between the cells, creating a homogeneous appearance. That means the solar cell technology remains completely invisible behind the colored layer. And that in turn enables aesthetically pleasing and complete visual integration into facades or roofs," Höhn explains.

The MorphoColor® trademark is already registered in the EU, Switzerland, China, the United States, Japan, and South Korea. A license was granted in 2023 to Switzerland-based Megasol Energie AG, a leading European producer of solar panels and in-roof and facade installation systems that is currently establishing the MorphoColor® technology on the market. Integration of solar panels into vehicles is another promising field of development. Fraunhofer ISE presented glass car roofs and hoods with integrated MorphoColor® solar panels at the IAA automotive fair, generating great interest from German carmakers. ■

"A morpho butterfly's wings give an impression of color not through colored pigments, but rather thanks to a visual effect."

Dr. Thomas Kroyer, Fraunhofer ISE

Dr. Thomas Kroyer (left), Dr. Oliver Höhn (center) and Andreas Wessels are working to increase acceptance of solar panels.

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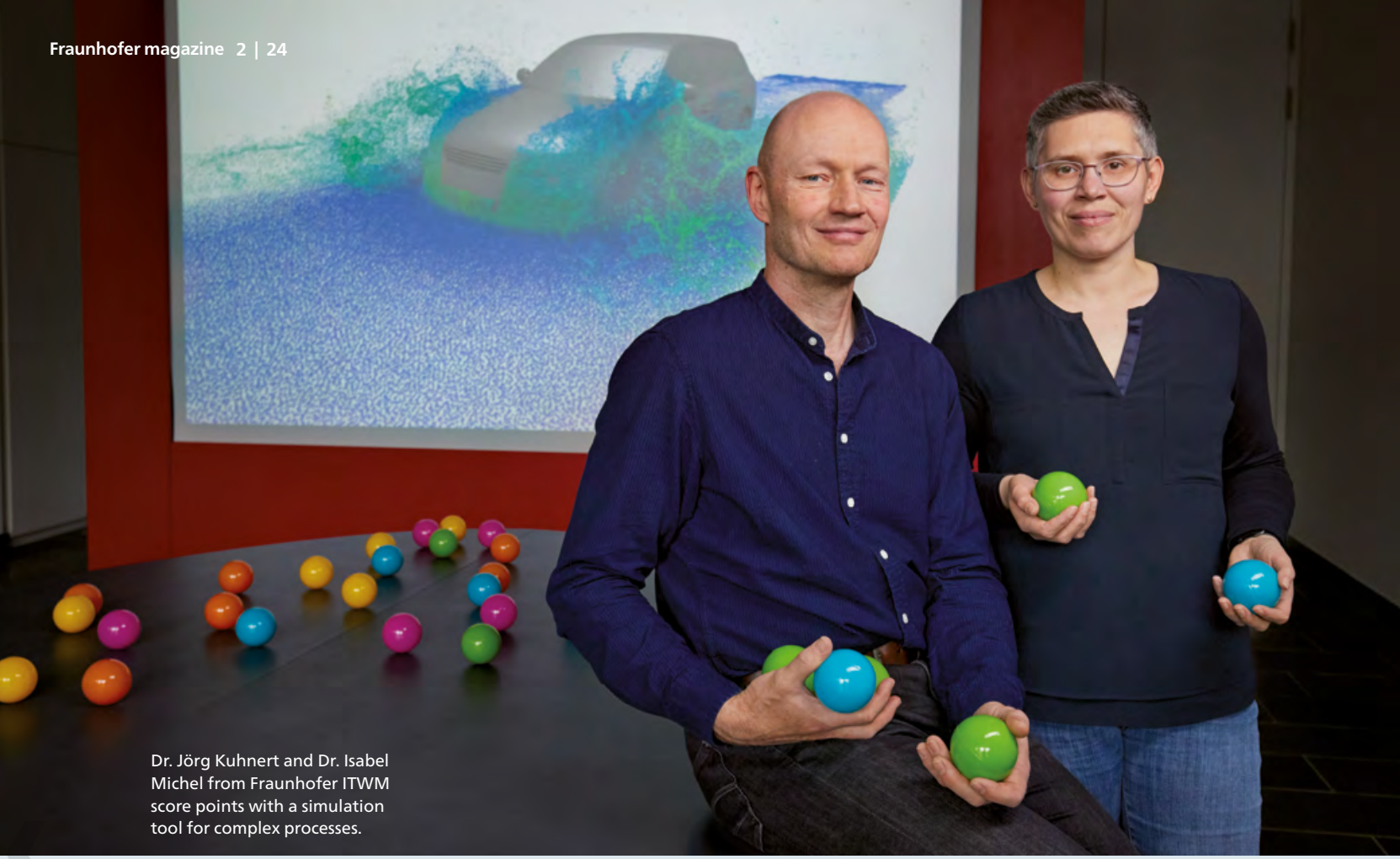


Dr. Jörg Kuhnert and Dr. Isabel Michel from Fraunhofer ITWM score points with a simulation tool for complex processes.

Simulation methods

Time-saving ways to model complex processes

From the automotive sector to production, simulations and digital twins are crucial to many companies. Researchers at the Fraunhofer Institute for Industrial Mathematics ITWM have developed a tool called MESHFREE that can simulate even complex processes such as hydroplaning with huge time savings. Their efforts have earned them the 2024 Joseph von Fraunhofer Prize.

By Lisa Scherbaum

Rigid specifications are seldom a good fit for agile processes, and what is true of organizations is doubly so for simulation methods. When visualizing complex processes in virtual space, it is not possible to predict the movements of all the components and set them up in a suitable computational mesh like those customarily used for simulations. The MESHFREE tool works based on points, without any computational mesh at all. This allows it to directly visualize how liquids, air-filled containers such as airbags, and other free surfaces behave in dynamic situations at any point in time.

MESHFREE: a substitute for real-world tests

"Our very first task within the project team, over 20 years ago, was to simulate how an airbag would deploy in a vehicle collision," says Dr. Jörg Kuhnert, who does research with his colleague Dr. Isabel Michel at Fraunhofer ITWM. "Back then, there was no way to quickly verify the safety of new developments in this field aside from costly real-world crash tests." That is because the more objects move and interact with each other in a given situation — in the case of a rear-end collision, for example, that means the car itself, the people inside, and the airbag as it deploys — the more difficult it becomes to visualize them reliably and at reasonable levels of time and effort using traditional simulation methods.

Based on Kuhnert's dissertation, the team — joined in 2012 by Michel, who specializes in Pelton turbines — developed the innovative mesh-free approach to meet this challenge at Fraunhofer ITWM. The new approach makes it possible to visualize highly complex and dynamic situations, in some cases for the very first time. All of the team's research findings since then have gone into the MESHFREE software tool, which is unique: No other simulation tool at the international level makes it possible to use the generalized finite difference method (GFDM) for industrial purposes.

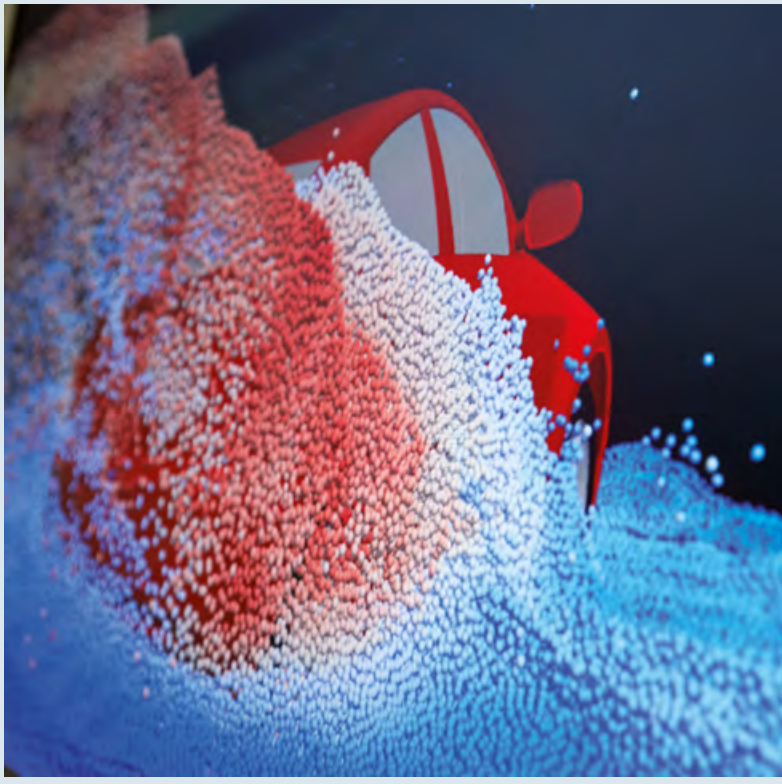
Flexible method for dynamic processes

Traditionally, simulations use the finite element method, in which engineers design a mesh that fits the relevant geometry and use it as a basis for calculating the changes in each individual element. The initial process of setting up the mesh structure is already highly time-consuming, and frequent adjustments are required during the simulation as well. The MESHFREE software, by contrast, combines the generalized finite difference method, which it uses to solve the conservation equations of mass, momentum and energy, with efficient algorithms for solving linear systems of equations. These were developed in cooperation with the Fraunhofer Institute for Algorithms and Scientific Computing SCAI and offer a huge advantage sincethe cloud of numerical points that is used can adapt flexibly to moving geometries. This eliminates the need for laborious subsequent corrections in the computational mesh. Kuhnert and Michel are the recipients of the Joseph von Fraunhofer Prize for 2024 for their development, which can replace real-world testing.

The award-winning method can be used for a wide spectrum of applications. One current area of focus is the automotive sector. In addition to airbag simulation, the researchers have assisted their numerous industry partners in a variety of ways so far, including by modeling driving through water or how vehicles will behave on sand or gravel. In process engineering, MESHFREE has helped companies optimize process parameters when working with molten glass and using plastic parts and to boost the efficiency of water turbines by simulating aspects such as the influence of air on the flow and the abrasion of blades due to sand particles. Fundamentally, this method can be used anywhere that a substitute is needed for measurements or experiments, or where these methods do not work well or not at all. Michel sums up: "We're not fixated on the traditional use cases for computational fluid dynamics. MESHFREE can do much more. We deliberately kept the tool more general." ■

> "Back then, there was no way to quickly verify the safety of new developments in this field aside from costly real-world crash tests."
>
> Dr. Jörg Kuhnert, Fraunhofer ITWM

Adjusting flexibly to movement: the cloud of numerical points used in MESHFREE.



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Intensive care medicine — pathogen identification

Next-generation sequencing optimizes diagnostics

Time is critical when it comes to invasive infections like sepsis, also known as blood poisoning. Fraunhofer researchers and their partners have established a principle for detecting pathogens that can play a crucial role in saving lives.

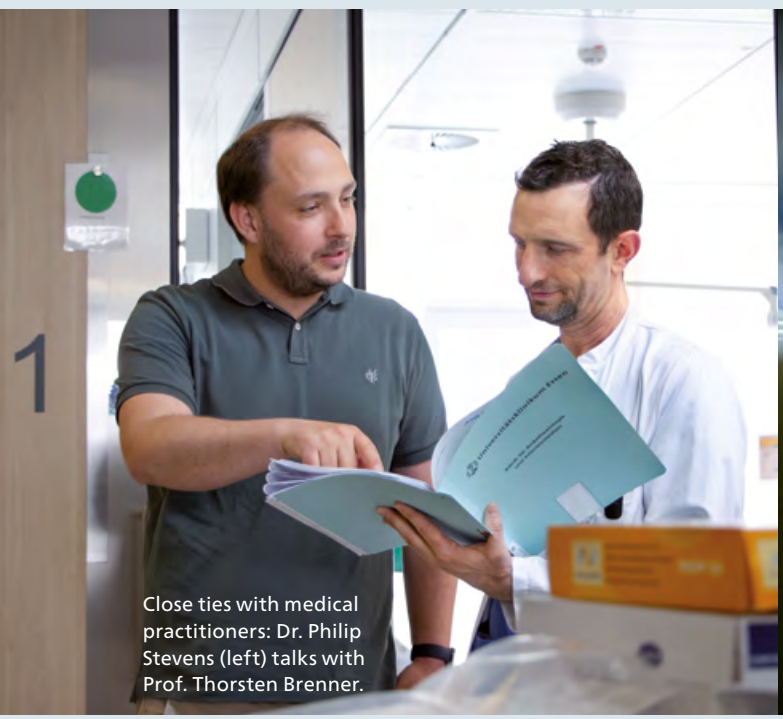
By Franziska Sell

According to a recent study, sepsis claims a human life in Germany every six minutes. Researchers from the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB teamed up with leading clinical networks and biotech company Noscendo GmbH to establish a diagnostic method of identifying pathogens in patients in intensive care, enabling fast and targeted treatment for invasive infections. For this achievement, Dr. Kai Sohn, Head of the In-vitro Diagnostics department at Fraunhofer IGB, and his partners, Prof. Thorsten Brenner from University Hospital Essen, and Dr. Silke Grumaz and Dr. Philip Stevens, both from Noscendo GmbH, have been awarded the Stifterverband Science Prize for 2024.

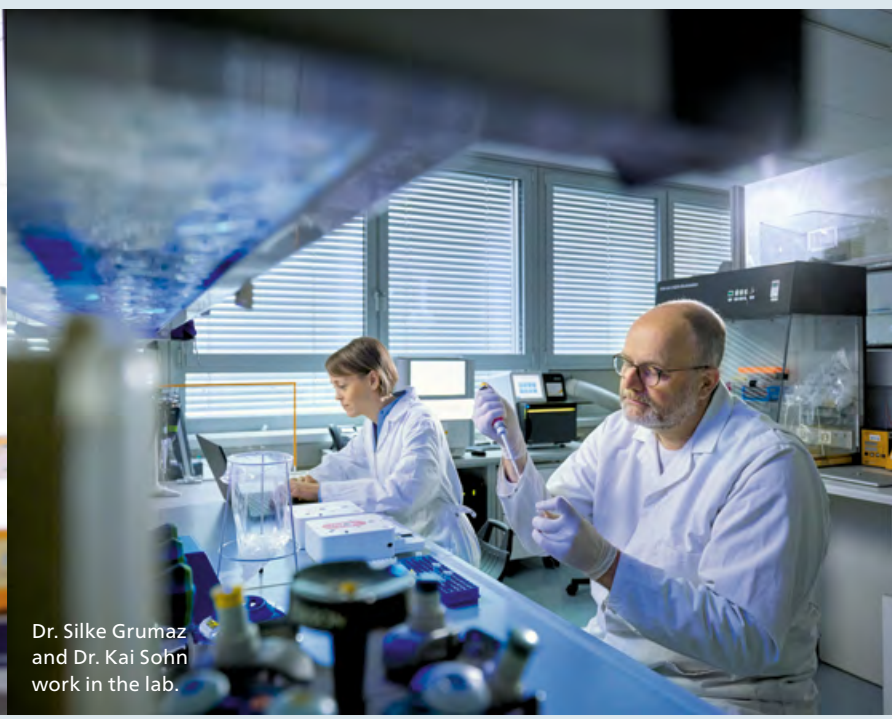
DNA left at the scene

So far, the standard method of identifying the organisms that cause sepsis has been to culture them (in the form of a blood culture, for example). If a pathogen grows in the incubated culture flask, it can then be identified using mass spectrometry. But there are drawbacks: Testing yields a positive result in fewer than 30 percent of cases — and even if it is possible to detect the pathogen in the blood, culturing it often takes more time than patients have. In intensive care, this means doctors are often forced to rely on past experience alone to treat their patients.

The novel method developed by the Fraunhofer experts takes inspiration from law enforcement: Since the patho-



Close ties with medical practitioners: Dr. Philip Stevens (left) talks with Prof. Thorsten Brenner.



Dr. Silke Grumaz and Dr. Kai Sohn work in the lab.

Stifterverband Science Prize 2024

For more than 20 years, Stifterverband and the Fraunhofer-Gesellschaft have been recognizing joint applied research projects of particular excellence that Fraunhofer institutes are working on in collaboration with industry and/or other research organizations.

gens can seldom be "caught in the act," the scientists instead study the clues they leave behind at the scene — fragments of their genetic information in the blood. The researchers use a fully automated process to isolate the DNA fragments and then sequence them with high throughput. If they find fragments of a non-human origin, the specialists compare them against a specially developed database containing the genomes of bacteria, viruses, fungi, and other pathogens.

Proven in clinical practice

Numerous clinical studies show that this method is highly reliable and accurate and provides healthcare professionals with valid results. The pathogen that is causing the disease can be identified in up to 70 percent of patients studied. "Our diagnostic method has helped over 6,000 patients in the past four years alone," says Dr. Philip Stevens, a bioinformatics scientist and CEO and co-founder of Noscendo GmbH. "Patients are able to leave the hospital much faster and have fewer long-term effects. That also eases the burden on hospitals and health insurers."

Outstanding collaboration

This success is the product of more than ten years of interdisciplinary cooperation. The method itself is a three-step process involving optimum sample preparation, high-throughput next-generation sequencing (NGS), and bioinformatic analysis via diagnostic algorithms. Initially developed at Fraunhofer IGB, this method is one building block of the new approach.

Clinical validation required close collaboration with leading medical centers. The experts there provided suitable samples and patient data, but that was not all. Under the leadership of Prof. Thorsten Brenner from University Hospital Essen, the new approach was compared against the previous diagnostic standard, and its diagnostic benefit was evaluated by bodies made up of independent experts.

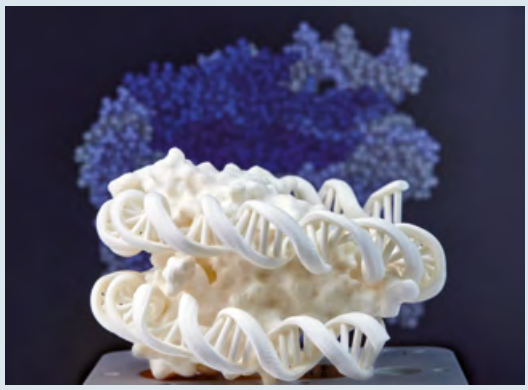
For their part, Stevens and his colleague Dr. Silke Grumaz, now Chief Scientific Officer at Noscendo GmbH, had worked on the method's foundations during their time at Fraunhofer IGB, Stevens in bioinformatics and Grumaz in molecular biology. By founding Noscendo GmbH, they created a channel for hospitals to submit samples for rapid analysis at any time. Grumaz comments: "We generally get results within 24 hours after the blood sample arrives at our lab. If a hospital doesn't use the method itself, the logistics can take another 12 hours. In most cases, that's still faster than any blood culture."

Dr. Kai Sohn, Head of the In-vitro Diagnostics department at Fraunhofer IGB, stresses how happy everyone on the team is at their shared success: "Our method could only have been established and successfully brought right to the patient's bedside through partnership between Fraunhofer, leading clinical networks, and Noscendo GmbH."

A milestone with more to come

The partners do not see the award as marking the conclusion of their work. "Right now, we're moving into pediatric intensive care. Fast, reliable diagnosis is critically important in this field, since the amount of blood that can be taken from the littlest patients is very small," Brenner explains. The prize winners also plan to apply their method to other diseases, such as localized infections that are difficult to diagnose. They are also working to apply the method to other bodily fluids and tissue samples, expanding it beyond blood samples alone. ■

DNA fragments in the blood help to identify pathogens.



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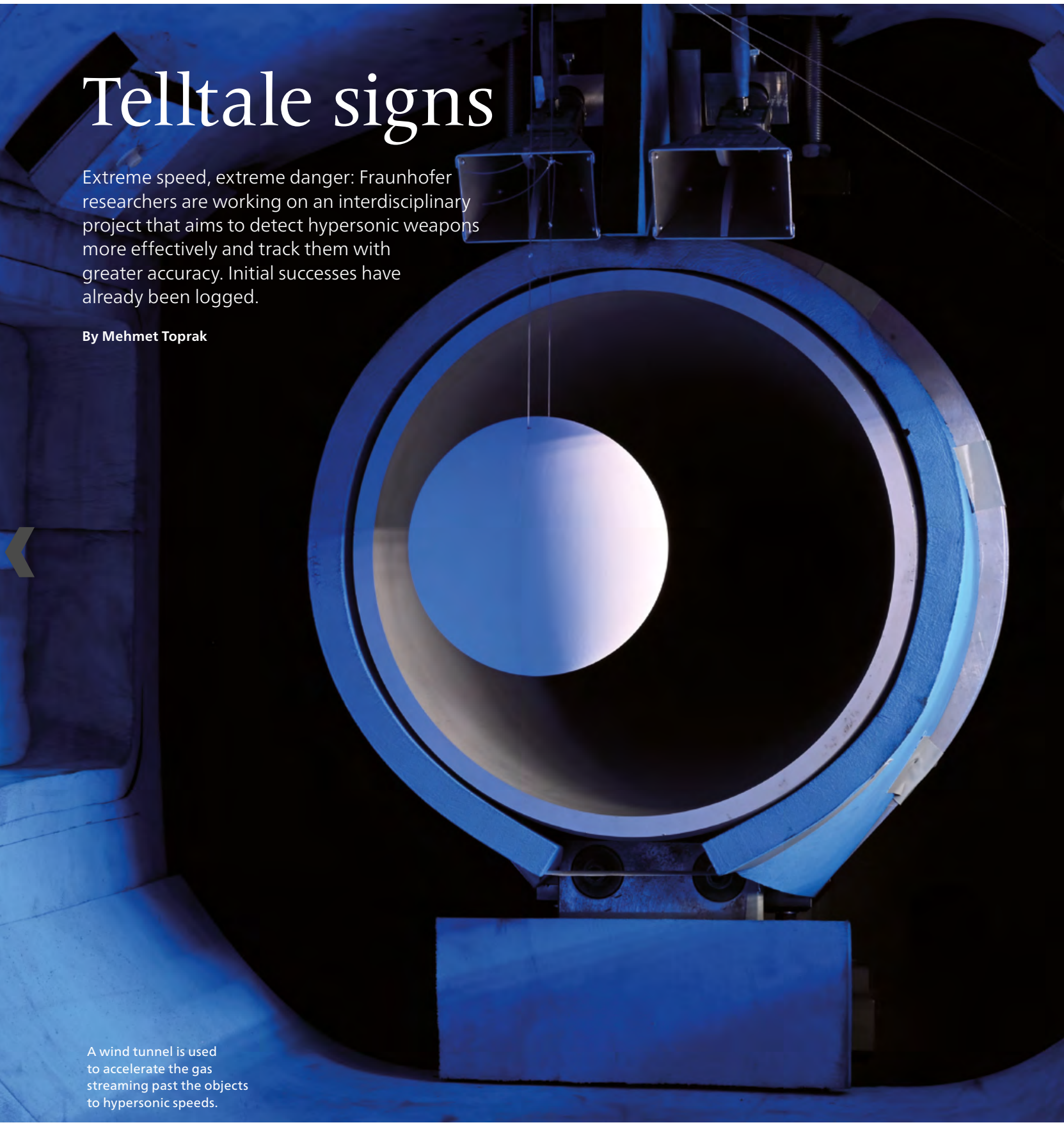
Telltale signs

Extreme speed, extreme danger: Fraunhofer researchers are working on an interdisciplinary project that aims to detect hypersonic weapons more effectively and track them with greater accuracy. Initial successes have already been logged.

By Mehmet Toprak



A wind tunnel is used to accelerate the gas streaming past the objects to hypersonic speeds.

Looking at the term HypS²tar 3b, a person could certainly be forgiven for thinking it is an ultra-secure password. In fact, it stands for a tough-to-crack task instead: detecting and tracking hypersonic objects. The war in Ukraine has really brought home to many people just how dangerous hypersonic weapons are — and how hard it is to defend against their destructive capabilities.

Unlike objects that move at the speed of sound (343 meters per second) or slower, these objects travel at about Mach 5, at speeds greater than 1,700 meters per second. This presents a huge challenge for conventional radar systems. "At speeds like these, radar echoes can be too weak, blurred, or too far apart when they show up on the screen. That makes it harder to track these objects," says René Petervari from the Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR.

Wind tunnel experiments can help to better understand the complex physics involved and devise solutions. In the interdisciplinary Hypersonic Signature Studies for Radar (HypS²tar) research initiative, Petervari is working with experts from the French-German Research Institute of Saint-Louis (ISL) in Saint-Louis, France, and the German Aerospace Center (DLR) Institute of Aerodynamics and Flow Technology in Göttingen and Braunschweig, Germany, to further understand the radar echoes created by hypersonic objects. The Fraunhofer researchers' job is to refine the radar systems and optimize the algorithms. The radar signatures created in the wind tunnel help with this, along with detailed, true-to-life aerodynamics and radar simulations.

"We started back in 2021 with a sphere in the wind tunnel, and then refined the results."

René Petervari, Fraunhofer FHR

But how do you build a wind tunnel in which the air streams past the objects at more than five times the speed of sound? Petervari explains the principle: the researchers use a type of wind tunnel known as a shock tube. A gas like hydrogen or helium is compressed to a pressure of several hundred bar. The pressure causes a metal diaphragm to rupture along special perforations. The high-energy gas this releases is then accelerated to hypersonic speed via a de Laval nozzle, a development also used in rocket technology.

"We started back in 2021 with a sphere in the wind tunnel, and then we moved on to a cone and continued refining the results in stages," the Fraunhofer expert recalls. "Right now, we're working with the HypS²tar 3b, a glider-shaped flying object 1.5 meters in size. Its glider-like shape and metallized surface make it a realistic test object," Petervari says.

The radar system the team of researchers uses is known as software-defined radar. Fraunhofer FHR has a wealth of expertise and experience with this technology. The systems have very few analog components, relying on software modules instead.

The software algorithms are adjusted and refined in an iterative process as the wind tunnel experiments progress. They allow for a better focus on the radar echoes while preventing reductions in range and malfunctions during automatic tracking. Owing to limits in processing capacity, conventional radar systems had previously relied on approximations, but they reach their limits as object speed increases. The Fraunhofer researchers have developed a better understanding of the physics involved through their experiments and are now focusing on powerful electronics, state-of-the-art radar systems, and advanced software. This eliminates the need for these kinds of approximations and enables greater accuracy in calculating an object's speed and trajectory.

For their project, the researchers at Fraunhofer FHR can also rely on the resources of the Fraunhofer Segment for Defense and Security VVS, in which twelve Fraunhofer institutes develop technologies that contribute to the security of people, society and the state. Fraunhofer VVS Managing Director Caroline Schweitzer comments: "Our experts have been conducting interdisciplinary research on detecting and repelling hypersonic threats for years. This will be strategically important in the future to protect high-value targets within our critical infrastructure." ■

The flying object used for testing is 1.5 meters long.

Photos: Fraunhofer FHR /ISL, Fraunhofer FHR/DLR

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2024

Science Year Freedom

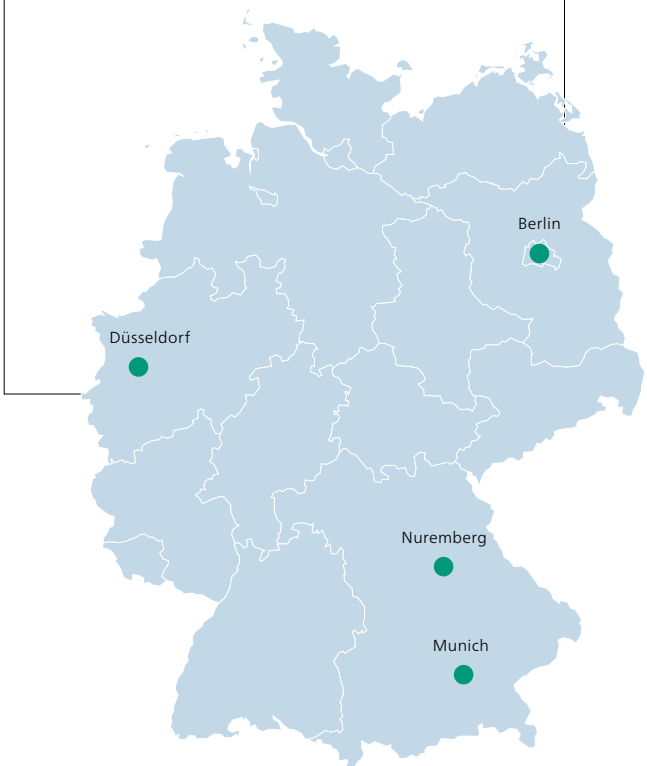
What does freedom mean in a high-tech society? How do AI and similar advanced technologies affect our freedom? How trustworthy are these technologies and the decisions they make? Fraunhofer is exploring these questions in Science Year 2024.

Fraunhofer calendar of events

Until October 3 MS Wissenschaft tour
July 1 Nürnberg Digital Festival
August 21 Meet the Scientist on the MS Wissenschaft floating science center in Bonn
September 25–29 Bitkom – AI & DATA Summit Berlin
November 1–10 Berlin Science Week

Scan for more upcoming events:

Fraunhofer on the road



Berlin
September 24–27, 2024
Innotrans
International trade show for transport technology

Berlin
October 15–17, 2024
Smart Country Convention (SCCON)
Understand and shape future solutions for digital administration, connected cities, and mobile spaces

Nuremberg
October 22–24, 2024
It-sa
Trade show and congress for IT security

Düsseldorf
November 11–14, 2024
MEDICA
The leading international trade show for medical technology

Düsseldorf
November 11–14, 2024
COMPAMED
The leading international trade show for medical technology suppliers

Munich
November 12–15, 2024
Electronica
The leading international trade show and conference for electronics

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Water, water everywhere
The idea was to take some pleasant summer pictures. The reality? Drab weather in Stuttgart, dreary in Cologne — and near gale-force winds in Büsum. For this North Sea photo, Dr. Henrike Seibel and Michael Schlachter from Fraunhofer IMTE soldiered on, even when the tide came in and they were left to wade 100 meters back to shore with their boots full of water. Photographer Enver Hirsch (right) was impressed with the Fraunhofer researchers: "They were all so amazingly relaxed!"

Fraunhofer