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Our dreams of longevity are coming true

The era of the founder

New impetus for the economy

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An interview with chancellor candidate Armin Laschet

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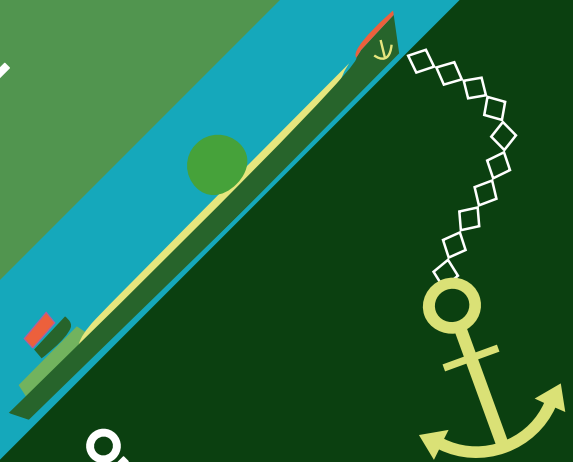

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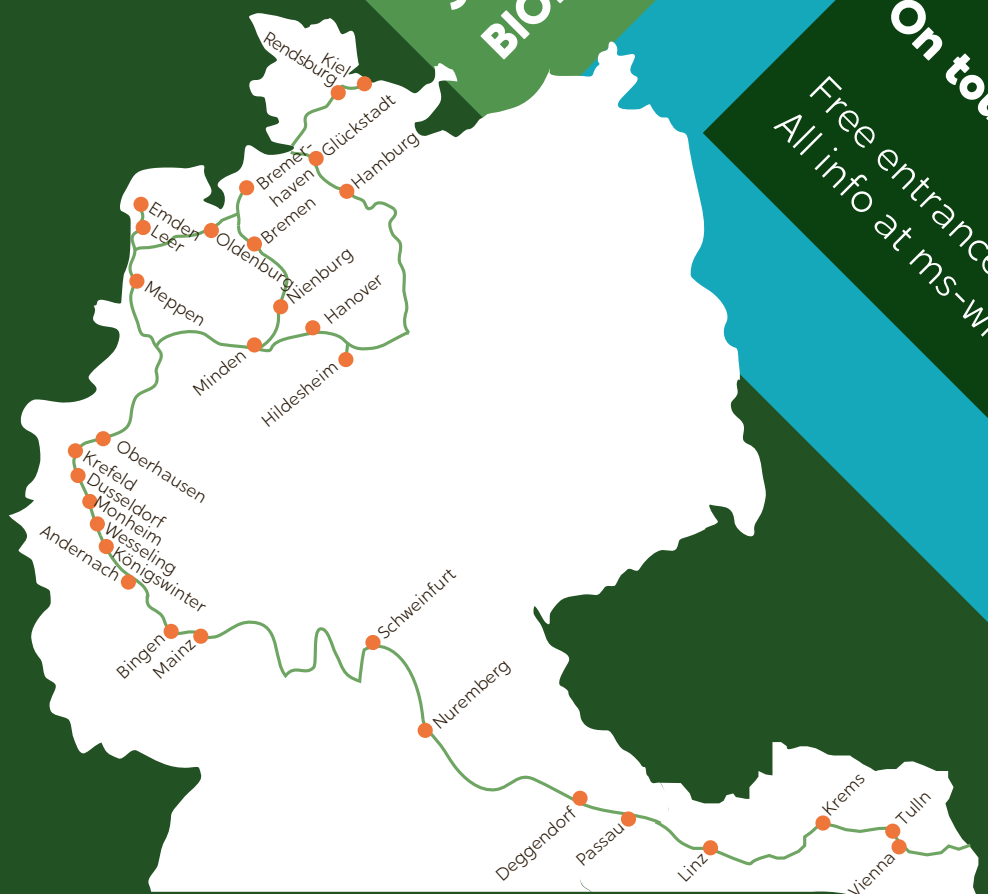

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Science Year 2020|21

BIOECONOMY

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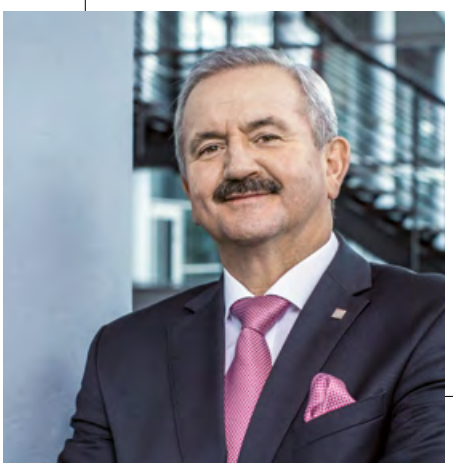
Editorial

Transformation requires security



Prof. Reimund Neugebauer

The coronavirus pandemic has accelerated the process of digital transformation in many companies. Furthermore, digital technologies such as artificial intelligence, next generation computing and quantum computing have become core enablers for future innovation and value creation — both directly, in the form of new products, services and platforms, and indirectly through new possibilities for research and development.

Digitalization and investment in the right technologies are decisive for Germany's competitiveness. However, this also creates a need to enhance the security of data networks — in particular as regards centralized infrastructures for electricity grids, transport routes, hospitals and administration. "Security and resilient society" is one of the main objectives of the Fraunhofer-Gesellschaft. In collaboration with the Technical University of Darmstadt and Darmstadt University of Applied Science, Fraunhofer runs the National Research Center for Applied Cybersecurity ATHENE. The 550 scientists at this center develop concepts, methods and technologies for improving and safeguarding cybersecurity and data privacy across all areas of life and critical infrastructures, in the long term and using new technologies.

To facilitate the practical training of IT professionals and security experts in companies, industry and public administration, Fraunhofer offers a cybersecurity training lab at 16 locations in eight German states, in cooperation with selected universities of applied sciences, thus promoting the development of local IT security ecosystems.

By collaborating with outstanding partners all over the world, Fraunhofer is enhancing the transfer of knowledge and stimulating new developments that benefit both Germany and its international partners. One example in the context of cybersecurity is the Fraunhofer Project Center for Cybersecurity at the Hebrew University of Jerusalem. Within the framework of this bilateral research and development platform for companies, experts from the Fraunhofer Institute for Secure Information Technology SIT and from the Hebrew University are developing new strategies for protecting data, IT systems and critical infrastructures from unauthorized access.

Fraunhofer is facilitating the rapid transfer of excellent, cutting-edge research, pioneering technologies and agile processes to practical applications, thereby making a decisive contribution to the expansion of technological sovereignty. Only on a solid foundation that is independent of competitors can we develop innovative — even disruptive — solutions that are essential for our economic future and the well-being of society. Let's shape the future together.

Sincerely,

Reimund Neugebauer
President of the Fraunhofer-Gesellschaft

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

Photo: Fraunhofer/Bernhard Huber

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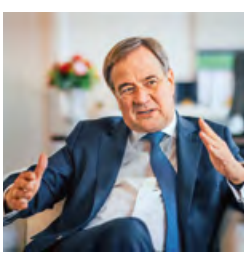

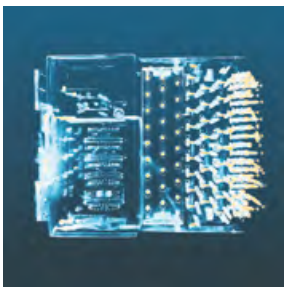

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The mystery of the seven Baltic Sea Enigma machines. How a special scan helps to solve the riddle.

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Outstanding scientific achievements — from the Internet of things to safe vaccines.

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Virus-free flying

How Airbus and Fraunhofer aim to disinfect airplane cabins together.

The pandemic led to an increase in working from home, online shopping and digital learning — and also to more cybercrime. The National Situation Reports on Cybercrime 2020, published annually by the German Federal Criminal Police Office, recorded a rise in registered convictions of about 8 percent to 108,474.

8%

Cover photographs: Jan von Holleben (5), Julia Sellmann/laif, istockphoto; Contents: Jan von Holleben, Dominik Asbach, AdobeStock, Ramon Kagie/unsplash, Fraunhofer ISIT, Fraunhofer IMTE

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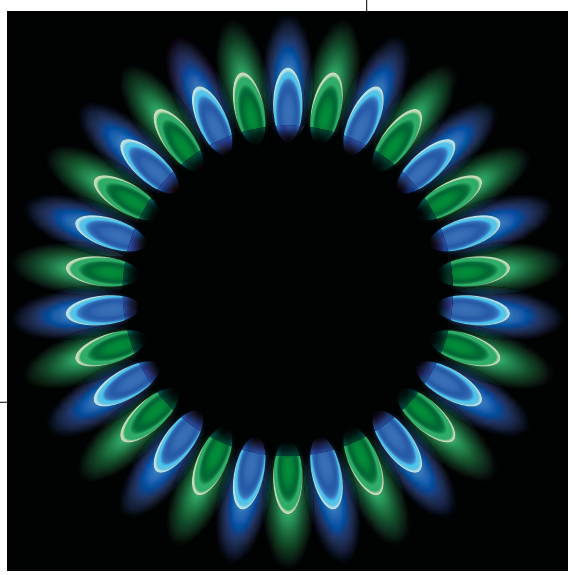
Brief report



There is no wide-ranging distribution network for green hydrogen in Germany — natural gas pipelines could be the solution.

Bringing green hydrogen directly to consumers

An innovative membrane technology makes it possible for hydrogen and natural gas to be carried through the national natural gas grid together and then separated from one another at their final destination. This solution was developed by researchers at the Fraunhofer Institute for Ceramic Technologies and Systems IKTS. The tubular membrane is made of carbon, which is applied as an ultra-thin layer to a porous, ceramic substrate in a complex, multistage process. The pores in the carbon are less than a nanometer in diameter, which makes them well-suited to gas separation. Physical and chemical processes can be employed to adjust the membrane's separation behavior. In this way, climate-friendly green hydrogen produced using renewable energy could be transported directly to consumers via Germany's 511,000 kilometer gas network in the future (see also the interview on p. 33). ■

Pediatric intensive care: Every minute counts

The Fraunhofer Institute for Toxicology and Experimental Medicine ITEM is working with partners to develop a digital alarm system that collates and analyses important vital signs and lab results directly at the patient's bedside. The ELISE machine learning system is intended to relieve the load on doctors and nurses in pediatric intensive care. In this field, diseases are sometimes difficult to detect and also progress differently, depending on age and gender. Regardless, doctors need to reliably detect whether their seriously ill patients' conditions are deteriorating in a life-threatening manner — under significant time pressure, because every minute counts when it comes to treatment. ELISE will continuously interpret figures so that critical situations can be quickly detected. Initially, it is intended that ELISE will primarily assist with diagnosing acute organ failure and associated circulatory collapse — a problem that often occurs following surgery. ■

The researchers are examining data from 5000 young patients to find recurring patterns, so that ELISE can be trained in a targeted way.

Reduce crop loss the smart way

Year after year, pests and parasitic weeds that compete with cultivated plants for nutrients, water and light cause crop losses of up to 30 percent. The Fraunhofer Institute for Optronics, System Technologies and Image Exploitation IOSB in Ilmenau is working together with partners to investigate the possibility of using digital technologies for crop protection.

FarmerSpace, a platform for practical experiments, offers stakeholders from research, practice and industry the opportunity to test sensor and data transmission systems, radio sensor networks, optical and machine-supported sensors, drone technology, robotics and machine-learning methods in the fight against parasitic plants. The initial focus is on early detection and combating of weeds and leaf diseases in sugar beet and spring wheat, which were sown specifically for research purposes in a testing field near Göttingen. ■

Digital technologies help detect viruses, fungi, aphids and other pests early on, and initiate targeted countermeasures.

Due to climate change, many pathogens are spreading and impacting production regions that are not prepared for them.

Real-time control

The MARQUIS software solution has the potential to enable component inspection on the go and in real time, using a combination of machine learning and augmented reality. When components are delivered, they must undergo an incoming goods inspection to ensure they have the correct dimensions and fit perfectly. Until now, component quality inspections by employees in the manufacturing industry have primarily been visual. In MARQUIS, researchers at the Fraunhofer Institute for Computer Graphics Research IGD have developed a much more precise alternative. It allows comparisons to be made between CAD data and the physical product. "As well as inspecting individual components, the system can also inspect assemblies made of multiple parts," explains Holger Graf, research fellow at Fraunhofer IGD. The most extraordinary feature of the new system is that it's mobile — workers simply pull out their smartphone or tablet and point it at the component concerned. ■

One look at a tablet is enough to uncover defects.

Photos: istockphoto, Adobe Stock (2), Fraunhofer IGD

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The RIGRID planning tool takes 3D data from the affected areas, including buildings, and transfers them to a virtual setting.

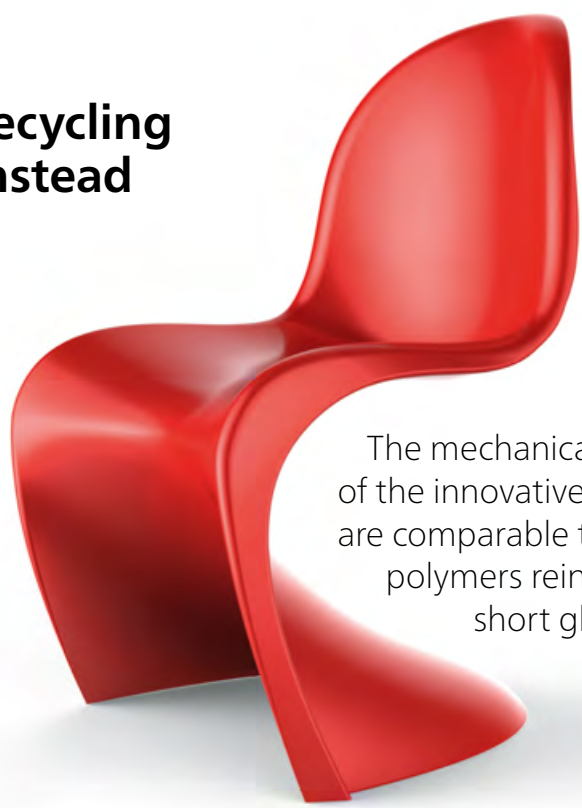
Secure energy supply for rural regions

Rural areas of Europe in particular suffer from outdated electricity networks. As electricity consumption increases, supply bottlenecks are becoming more frequent. In the RIGRID project — short for Rural Intelligent Grid — the Fraunhofer Institute for Factory Operation and Automation IFF is working with partners to provide a secure, cost-effective and at the same time ecological power supply in rural areas.

The researchers build on the expansion of renewable energies and the development of decentralized, intelligent supply networks, so-called smart grids. These enable the integration of small energy producers into the supply network and offer greater independence from centralized energy supply structures. For this purpose, they developed an interactive planning tool in the project. In the future, communities will be able to use this tool to individually and transparently plan their energy supply system and the infrastructure required for it, and to weigh up their design according to ecological, economic and acceptance criteria. The innovative tool was successfully tested in the Polish city of Puńsk, where it not only increased energy efficiency but also reduced CO_2 emissions. ■

Putting household recycling waste to good use instead of burning it

Working together with an industry partner, researchers at the Fraunhofer Institute for Structural Durability and System Reliability LBF have developed a new sustainable plastic made from used PET bottles. The mechanical properties of the innovative material are comparable to new polymers reinforced with short glass fibers. Unlike these, however, it has a significantly smaller CO_2 footprint, as the project partner Öko-Institut determined through a life-cycle analysis conducted for guidance purposes. Due to its mechanical properties, the recycled plastic is particularly suitable for producing larger components in technical applications, for example in cars, furniture or the construction sector. ■



The mechanical properties of the innovative material are comparable to new polymers reinforced with short glass fibers.

Editorial notes

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

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

Editorial assistants:
Dr. Janine van Ackeren, Mandy Bartel, Christine Broll, Meike Grewe, Sirka Henning, Dr. Monika Offenberger, Moritz Schmerbeck, Sibylle Schmitt, Tim Schröder, Eric Schütz, Mehmet Toprak.

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Drilling into climate history

Drilling in Lake Constance to depths of more than 200 meters is something no one has ever managed before. The core sample allows scientists to draw conclusions about the climate over the past 15,000 years.

Deposits on the bottom of lakes and oceans provide important insights into the Earth's climate history. Using the innovative Hipercorig drilling system, experts achieved a first, by pulling a 24 meter-long core sample from the deepest part of Lake Constance. The technology was developed by researchers at the Fraunhofer Research Institution for Energy Infrastructures and Geothermal Systems IEG, together with partners from Germany, Austria and Switzerland.

The deeper sediments of lakes in mountainous regions, which are particularly interesting for climate research, have remained inaccessible to conventional drilling equipment up until now. Hipercorig is constructed on a modular basis, making it easy to transport, assemble and disassemble — important criteria when you want to investigate remote lakes in mountainous regions across the world. "At the heart of this system is a hydraulic hammer drill on a long pressure tube, which independently generates the driving force in the core hole using around 70 hammer blows per second, and without the dampening effects of a long, heavy drill pipe," explains drilling expert Volker Wittig from Fraunhofer IEG. Rather than a traditional drilling fluid, lake water is used to drive the 200-bar hammer unit, which prevents environmental damage in sensitive ecosystems.

Lakes that are formed by glacial action often have dense, hard, coarse sediments. The drilling technology available to science until now could hardly get beyond a depth of 10 meters into the sediment when extracting core samples. The core samples obtained with Hipercorig, which are more than twice as long, are like a detailed climate atlas for geologists, allowing them to draw conclusions about precipitation rates and glacial melting, and thus temperatures. This knowledge of the past makes it possible for scientists to create models for future climate development. ■

The hammer drill is operated from a compact floating platform.

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Connecting to the digital world by ear: The Arioso Systems startup team with Jan Blochwitz-Nimoth, Holger Conrad (below, from left), Hermann Schenk and Lutz Ehrig (above, from left).

Title

Fortune favors the bold

Germany needs startup founders. But what do founders need? Ideas, and energy. Passion, and the power to persuade. Optimism — and optimal support too. Time and again, Fraunhofer has provided the support founders need.

By Dr. Janine van Ackeren
Photography: Jan von Holleben

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There's good news for Germany again: The economy is gaining momentum. In the final quarter of 2020, gross domestic product in Germany rose by 0.3 percent compared to the previous quarter, despite lockdown. Forecasts for 2021 are also encouraging, with the German federal government anticipating economic growth of 3.0 percent. While these figures should provide a boost for major companies, they are especially heartening for startup founders. After all, they are the ones who are most particularly behind the idea they are promoting, are passionate about their cause and follow their company though thick and thin to conquer the market. Startup founders often invest their own assets in order to make their dream of owning their own company a reality and to help their technology gain a foothold in the market. According to Statista, 78.4 percent of startups are financed at least partially by the founders' own savings. In turn, the economy benefits from the courage and determination of these young entrepreneurs. As noted by Armin Laschet, CDU/CSU candidate for chancellor of Germany, in an interview with Fraunhofer (see p. 26): "You can't reproduce Silicon Valley in Germany. But particularly in the field of research, I can sense a certain readiness to take on challenges." He also adds: "We need a thousand more like them."

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teams using Fraunhofer technology **took the plunge** and set up their own company in 2020.

"Incredibly valuable"

Many business founders come from academia, with 30.8 percent of startup founders in 2020 having a master's degree and 18.5 percent having a bachelor's degree, according to the German Startup Monitor (DSM). Young company founders do not just come from universities — the Fraunhofer-Gesellschaft itself is also a "forge" for entrepreneurship. Despite the pandemic, 26 teams using Fraunhofer technology took the plunge and set up their own company in 2020. Their market chances are good: When compared with the results of the KfW Entrepreneurship Monitor, Fraunhofer spin-offs often generate significant turnover well above the average, and can gain the interest of investors faster too. For example, at the end of May, Austrian public real estate company Bundesimmobiliengesellschaft m.b.H. (BIG) got on board with Munich startup Ampeers Energy. With 7.3 million square meters of leasable space, BIG is one of largest real estate owners in Austria.

While there are other factors involved in the speed with which these startups reach the market, the support offered by the research institutions that prepare spin-offs for a successful market entry plays an important role. CTO of Fraunhofer spin-off ConstellR Marius Bierdel is enthusiastic about this form of support: "I find it incredibly valuable." Fraunhofer Venture has had its own department in the Fraunhofer-Gesellschaft since 2001. It is now marking its twentieth year as a one-stop shop for successful startups.

The startup aid offered by Fraunhofer has paid dividends. Some 97 percent of these spin-offs are still operating on the market three years after starting out. One of them is Volterion GmbH, which spun off from the Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT back in 2015. The company continues to enjoy great success. On the technological level, for instance, the team has succeeded in making the production of stacks for redox flow energy storage significantly cheaper. As a result, the redox flow cells are now ready for the mass market for the first time, meaning they could become an indispensable element of the energy transition. On another level, the company has increased their visibility. The founders of Volterion have just been awarded the Joseph von Fraunhofer Prize (see p. 68). Founding a successful startup is rewarding! ■

“Going to work every morning is a pleasure”

Sometimes, the market does not offer what is needed. Dr. Karsten Schmidt looked to Fraunhofer for a solution. His spin-off Ampeers Energy GmbH has what it takes to make the energy market more straightforward and profitable.

He aims to optimize energy supply in buildings: Dr. Karsten Schmidt, founder of Ampeers Energy.

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People who are conscious about climate change rarely eat meat. They avoid flying. They are more likely to jump on a bicycle than drive. All these are ways of reducing their CO_2 emissions. However, the real estate sector, i.e. everything housing-related, accounts for around 30 percent of CO_2 emissions. While property owners and affiliated companies may intend to switch to renewable energy sources, when it comes to concrete questions about types of renewable energy, optimal operation and consumption-based billing for tenants, they have not exactly been looking on the sunny side; in fact, they are quite literally out in the cold.

Carbon-neutral housing: Aspirations and reality

Dr. Schmidt was able to quickly identify the gap between our aspirations and the reality. He was in the right place, after all. At the Fraunhofer-Gesellschaft, he was involved in corporate business development in the area of energy. In the Open District Hub, a joint initiative between Fraunhofer and more than 40 industry partners engaged with the topic of renewable energy in city districts, Schmidt was continuously confronted with a wide range of questions. One in particular came up again and again: "Didn't Fraunhofer have smart software solutions for simplifying renewable energy deployment and making it profitable?" In short, the need for planning tools and software solutions that would enable optimized operational management and energy flow billing was enormous, but almost nothing was being offered for this on the market. So, Schmidt set out on a technology search within Fraunhofer and found what he was looking for with Prof. Peter Bretschneider at the Fraunhofer Institute for Optronics, System Technologies and Image Exploitation IOSB. Prof. Bretschneider and his team had developed a kind of underlying technology — in fact, it came from deployment planning at power plants. Schmidt decided to use this as a basis for developing decentralized energy systems to the point of market readiness. "I embarked on a kind of scouting expedition at Fraunhofer to find the right kind of technology, struck it lucky and brought it to the market as the spin-off Ampeers Energy GmbH," he says with a smile. "It was exactly the right decision. Going to work every morning and developing the concept further together with my colleagues is still an absolute pleasure."

An invaluable sparring partner: Fraunhofer Venture

Finding co-founders did not take long. Dr. Schmidt, Gerrit Ellerwald and Tobias Müller had already worked together in the Open District Hub, and Schmidt and Ellerwald had even studied together. Industry partners were also familiar with the founders. "We had already sent proof of work to many members of professional associations, so the first investors from this circle were ready to help finance our idea straight away," reveals the young entrepreneur and father of two young boys.

> "We have an amazing chance to make a major contribution to the energy transition!"
>
> Dr. Karsten Schmidt

The Fraunhofer-Gesellschaft also was convinced that the concept was viable. "The advisors at Fraunhofer Venture were always invaluable guides, and accompanied us step by step through all stages of the process, both during the pre-seed phase as well as the startup phase itself. They are still on board even today," adds Dr. Schmidt enthusiastically. He particularly emphasizes the two-pronged approach offered to every startup team. A commercial planner offers support for aspects such as business plans and company networks, while a legal advisor helps with startup documentation and license agreements with the Fraunhofer-Gesellschaft and other stakeholders. In addition to this initial pillar for success — in other words, the good preparation — Schmidt views the way that his young team works as the second pillar. "There are two important things that a startup should bear in mind. The first thing is marketing, marketing, marketing — you need to approach customers and let the market know that you exist. Secondly, it's all about team, team, team — whether you win or lose, it can only be done together." Because we possess these two strengths, we've been able to solve all challenges so far."

The product being offered is of course fundamental for the success of a startup. Schmidt has hit the mark there. "We offer a software solution that covers everything from planning forms of renewable energy and optimizing operation to billing and implementing lucrative business models within the real estate sector. This makes us unique on the market," he notes with pride.

We're all passionate about what we do!

The market appears to be ready for the technology too, with the small company that started out two years ago with three founders already having grown to 35 employees. "We even emerged from the lockdown unscathed. By switching real on-site conversations to digital meetings with clients, we were even able to reach more clients than before and dramatically increase our reach. Despite — or perhaps thanks to — the coronavirus, the market quickly noticed us," enthuses Schmidt. "Every one of us has indeed been working much more than would be the case if we had other jobs. But our work brings us all huge satisfaction and we have an amazing chance to make a major contribution to the energy transition. After all, we're all passionate about what we do." ■

All ears: Holger Conrad, Head of MEMS Production and Development, Arioso Systems GmbH.

"We do everything differently!"

Can an earphone work as a gateway to the digital world? With an innovative microspeaker offered by the team behind the startup Arioso Systems GmbH, this may soon be possible.

Smartphones can do a lot of tasks these days. But wouldn't it be useful if you woke up tomorrow morning and all you needed to pay for a coffee, get the weather forecast or find a destination was a small, wireless, in-ear device? Or imagine being able to receive a direct translation of what the owner of your vacation rental in Italy is saying, even though you can't understand a single word of his friendly chitchat? According to Holger Conrad and Jan Blochwitz-Nimoth, these kinds of language-controlled true wireless systems could soon offer a new gateway to the digital world.

The two entrepreneurs already have the necessary technology in the bag, and are now aiming to conquer this market area with their company Arioso Systems GmbH. They aim to provide 100 percent silicon microspeakers that can be cheaply mass-produced using standard CMOS processes in a clean room environment. The microspeakers also generate sound in a highly energy-efficient way. "The new technology is completely different from everything that's come before," explains Conrad. "We've thrown the idea of the membrane, which is the main element of a loudspeaker, out the window, as it were. To replace it, we have built a large number of thin bending strips, similar to the strings of a harp, into a MEMS silicon chip. This creates a large internal acoustic surface, while the external surface is kept at an absolute minimum." The results speak for themselves: The active chip surface of the speaker is only around 10 square millimeters in size and can generate 120 decibels at the highest audio quality. Up to 50,000 micro speakers can be produced using just 25 silicon wafers, which makes production highly economical. "In addition to its distinctive technical characteristics, our technology can also be used for price leadership in the future," adds Conrad confidently.

The active chip surface of the speaker is only around **10 mm²** in size — and can generate **120 decibels.**

From a flop to a win

The product beginnings were far from successful. In fact, the first attempt ▶

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was a flop. At the Fraunhofer Institute for Photonic Microsystems IPMS, Conrad was tinkering around with mirrors with an adjustable radius of curvature. "I wanted to use piezoelectric bender actuators to move the mirrors, but it was a failure in terms of the technology," he recalls. So, he fished a previously rejected concept for a micro-actuator out of his toolbox, and started everything from scratch. He replaced the piezos with an electrostatic bending actuator. From this came a patent, tremendous support from institute director Harald Schenk, a dedicated project group and a number of publicly funded research projects. The idea grew and grew. However, a concrete application for the new micro actuator was lacking. Conrad hoped to use it for a problem to which a solution had not yet been found. Microspeakers for hearables and true wireless earbuds turned out to be the answer. "From then on, doors started opening everywhere," Conrad remembers fondly.

One of these doors led to commercialization. Hermann Schenk, who had experience with spin-offs and sat on the Board of Trustees for Fraunhofer IPMS, became aware of the idea. After getting Jan Blochwitz-Nimoth on board, together with Conrad and his Fraunhofer colleague Lutz Ehrig, they officially launched Arioso Systems GmbH in 2019 with support from Fraunhofer Venture; operational activities got underway in 2020. "We have a fantastic team of founders — Herman and I bring experience in spin-offs to the table, and Holger and Lutz bring the necessary drive," explains Blochwitz-Nimoth excitedly.

Scaling up to 100 million units

Arioso Systems has already received 2.6 million euros in funding from five investors. The company's sales argument is powerful, since the technology they use is scalable, and suited to clean-room use. "We need to scale up to 100 million units per year, because it is expected that in the future, hearables will be sold to the same extent as smartphones, i.e. up to two billion a year. It's a very promising market — hearables have tremendous pull," says Blochwitz-Nimoth. The number of employees is also set to increase. Arioso is anticipated to grow to 13 employees by the end of 2021 and to between 50 and 60 in the coming years. However, Managing Director of Arioso Systems Jans Blochwitz-Nimoth has not forgotten the role played by Fraunhofer. "Without our work at Fraunhofer IPMS, we would not exist, and Fraunhofer is still an important partner for us." After all, not only did the idea come about at Fraunhofer IPMS, but the Arioso team are still able to make use of the clean rooms there while they gradually transfer production to external locations.

"We have seen a lot of enthusiasm from customers — and enthusiasm is everything," reports Blochwitz-Nimoth. In addition to innovative technology, he sees the recipe for success in approaching customers early. "Early customer contact is helping us speed up our transformation from a Fraunhofer research company to an independent, successful company." ■

"Without our work at Fraunhofer IPMS, we would not exist, and Fraunhofer is still an important partner for us."

Jan Blochwitz-Nimoth, Managing Director of Arioso Systems.

"We started up right in the middle of the pandemic"

Founders need courage and perseverance, especially during this pandemic. These were precisely the qualities demanded of Claas Blume and his company, clous GmbH.

Claas Blume had a dream. "I always dreamed of having a high-tech startup!" he says. But he did not just leave it at that. While still studying mechanical engineering, he founded his first company, which had prisoners producing stickers for MacBooks. However, the idea did not have long-term viability. He applied to the Fraunhofer Institute for Production Systems and Design Technology IPK in Berlin to complete his master's thesis. "After all, there's no better place to look for technology for a startup than Fraunhofer," he says during our video interview, and grins at his laptop camera. In the course of various Fraunhofer IPK research projects in the area of toolmaking, Blume observed that mechanical and plant engineering has been placed under huge time and cost pressure as a result of globalization. "We have been involved in shaping Industrie 4.0 and have achieved great success with it. But when you look at the process steps prior to the production stage, you can see that in the past 30 years, little or perhaps nothing has changed. You have a highly-qualified, highly-paid engineer who's sitting there wasting their valuable time on tasks that actually aren't really that complex," states the young founder. "For me that just didn't add up."

Making the startup dream a reality

Blume and his Fraunhofer IPK colleague Thomas Vorsatz, who was also won over by his idea, focused on how to translate these kinds of tasks into algorithms and automate them. Since full automation is too expensive and did not work as a business idea, the two mechanical engineers developed algorithms that split entire engineering processes into a number of simplified steps. These tasks can be completed independently of each other, meaning they can be run parallel. This significantly reduces the biggest cost factor for a production company, i.e. the time taken to bring an idea to a successful prototype test.

> "There's no better place to look for technology for a startup than Fraunhofer."
>
> Claas Blume,
> founder of clous GmbH

The idea proved to be viable. Engineers can now isolate less complex tasks using the algorithms and assign these to clous GmbH, the startup founded by Blume and Vorsatz. The company outsources these tasks for processing by a master's student in Germany or an engineer in India overnight, for example. In the future, the clous founders aim to use algorithms to evaluate these tasks as well. There are two advantages of the service offered by clous GmbH: First, the engineer has more time for their own tasks, and second, it is more cost-effective for the company's bottom line. "We often compare it to how a head surgeon works. They let the anesthetist work with the patient first, and then they focus on the main task, for instance, heart surgery. Engineers can and should continue focusing on core tasks too. We can take care of all their basic tasks for them — at the press of a button and at a set price," outlines Blume.

Available for advice and support at all times

Blume was supported during the startup process by the Fraunhofer-Gesellschaft. By taking part in FDays® — short for Fraunhofer Days, where business models are developed and evaluated systematically — he encountered professional startup culture for the first time. This spurred him on even further. "A large part of what got us actually up and running was provided by the Fraunhofer technology transfer program AHEAD, which was just being established at the time. Our two contacts at Fraunhofer Venture were available for advice and support at all times, whether that was regarding legal questions or ▶

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access to venture capital," recalls the clous GmbH CEO.

There were some obstacles to the dream at the beginning, however. "We started up right in the middle of the pandemic," says 34-year old Blume. More specifically, the company was launched in December 2019, but by March 2020, it was in a tight spot, with industry sponsors who had made a verbal commitment pulling out. Then co-investors opted out too. "That of course was a particularly deep plunge on this roller-coaster ride. We could not extend contracts for our first research assistants," says Blume, somewhat self-consciously. "But we were determined to do it!" Fraunhofer Venture remained steadfast at the startup's side, and things began to look up. In May 2020, the young founding team succeeded in bringing Axel Springer Porsche GmbH & Co. KG in as an investor, and in September 2020, they were approved for early stage financing by Investitionsbank Berlin, a business development bank. The company was able to attract more angel investors, get venture capital funding and expand their reach. And what's more, they are set to grow from an initial two founders and two research assistants to 12 employees by the end of 2021. "Our goal for the next half year is to develop robust processes — from sales pitch through to satisfied customers," says Blume. "That's what makes this kind of startup so appealing." ■

"Robust processes — from sales pitch through to satisfied customers"

Neatly boxed up: Startup founder Claas Blume brings global engineering experts together — while ensuring only the client has access to the overview of the deliverables.

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“We just had to bring it to the market!”

A global need in the medical field — and an innovative solution: That’s what has made Cellbox Solutions GmbH so successful.

The joy of innovation: Startup founder Prof. Kathin Adlkofer

No longer needing to freeze cells — that's the future", says molecular biologist Prof. Kathrin Adlkofer. She is not talking about steaks in the fridge freezer here, although those do also contain biological cells. Instead, her focus is on cell systems as used by researchers in the area of biotechnology. There are a whole range of applications for these cell systems. For instance, organoid systems, i.e. cell structures that resemble a human organ extremely closely, can be used to significantly reduce the number of animals using for medical testing. Or, to give another example, if doctors could take blood cells from cancer patients, have them genetically modified and then inject them back into the patients, over time they could create a powerful weapon against tumors. However, transporting such biological material, be it from biotechnology company to pharmaceutical company or from hospital to laboratory, has been a problem up until now. In a lab, cells are cultivated and stored under constant temperatures, CO_2 levels and humidity in incubators, but for transport, they always had to be frozen in liquid nitrogen, a process known as cryopreservation. This places the tissue under stress and the cells undergo physiological change. Transporting structures that are too sensitive for this procedure has simply been impossible.

An incubator "to go"

With her startup Cellbox Solutions GmbH, Prof. Adlkofer has come up with the answer. "Now, with our Cellbox, it's possible to transport living biological material — in excellent quality and internationally too," enthuses the entrepreneur, who is also a lecturer at the Universität zu Lübeck. "In the area of regenerative medicine, it's a huge advantage for researchers and patients alike." The idea of the team behind the spin-off was to make the incubator portable. For transport by car, train or truck, the incubator maintains the required CO_2 levels using CO_2cartridges, while on a plane, it uses dry ice as a CO_2 source.

> "Now, with our Cellbox, it's possible to transport living biological material — in excellent quality and internationally too."
>
> Prof. Kathrin Adlkofer,
> founder of Cellbox Solutions GmbH

The key concept was developed at the Fraunhofer Research Institution for Marine Biotechnology and Cell Technology EMB. "Having already set up various companies in the health sector, I allowed Prof. Charli Kruse, director of Fraunhofer EMB, to talk me into heading up the cell technology department," recalls Prof. Adlkofer. There, she was given responsibility for developing a early-stage construct of the Cellbox. "The more we worked on it, the clearer it became to me that we just had to bring it to the market." In her spare time, Prof. Adlkofer is a sailor, and here too, she has proven to pack a punch. She has participated in the Olympic Games twice, and has also won the 470 World Championships twice. Together with Prof. Kruse, she decided to pursue the spin-off route.

While Prof. Adlkofer had startup experience, there are many things that she would do differently if she could do it again. "Bringing a technology or product to the market is different to marketing an app or licensing antibodies. Developing a robust pipeline right through to batch production was a massive challenge. That's why it's essential to get the right people on board," says Prof. Adlkofer. She searched for a company partner with experience in international distribution, and found what she was looking for in Wolfgang Kintzel. What was it about working in a startup that attracted Kintzel, now CEO of the company? He starts by mentioning the young, international team, adding, "We have the extremely appealing combination of product sales, consumables and the area of complex biological structures."

"Fraunhofer was with us from day one"

While pursuing the idea of a product suitable for batch production, the team received a lot of support from Fraunhofer EMB and Fraunhofer Venture. "Fraunhofer was with us from day one, and is now an active partner that provides us with know-how, international experience and financial support." The 15-strong team of employees now sells the portable cell incubators worldwide, and has customers from Germany, Europe, the USA and Asia, where China is a particular focus. "I'm really proud that we have been able to gain an international foothold in such a short space of time," says Kintzel. A few weeks ago, Cellbox Solutions GmbH even set up a subsidiary on the east coast of the USA, meaning they can now provide safe transport for biological materials on the other side of the Atlantic too. ■

Photos: Lars Wehrmann/Cellbox Solutions, istockphoto

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Help direct from space

A satellite the size of a shoe box: ConstellR is aiming to enable any farmer to get accurate weather data for their land — and help agriculture withstand climate change better.

Satellite missions with an important social impact: This was the theme of a competitive tender issued by the European Space Agency in 2017. The tender drew the attention of Marius Bierdel and his colleague Max Gulde from the Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut, EMI. They decided to apply for the tender, just for fun. More than 200 teams sent in proposals, but despite the stiff competition, Bierdel and Gulde earned a place "on the winner's podium," coming in third. "Right then, it became clear to us for the first time that our solution could actually offer significant added value for society," explains engineer Bierdel. The team intends to apply its technology to help improve efficiency in agriculture, and thus to offer a solution to both the impact of climate change and the threat of food shortages.

Added value for society? No doubt!

This is made possible by a monitoring system that is built into small satellites in order to calculate temperature data with high precision. This sounds straightforward at first, but it packs quite a punch: The data is processed by smart farming companies and detailed information about an area of land can then be conveyed to farmers. Example: "We recommend that you water your fields today and harvest tomorrow." One effect of climate change is that it is getting more difficult for farmers to base farming tasks on their own previous experience; rather, they need to be prepared for drought and extreme weather events.

In fact, modern satellites already collect this kind of data. However, some satellites are nearly as large as a bus and a single satellite mission can cost up to 800 million euros. Because of this, there are too few available for the task — a satellite might only traverse a farmer's field once every few weeks. "Breaking down regular data into a per-field basis is essential for agriculture," states Bierdel. This is where the new technology comes in. The two researchers can minimize the scale of the monitoring instruments to such an extent that they can be carried by smaller satellites the size of a shoe box. "Costs are reduced by a factor of 400 — the data can be calculated daily with a spatial accuracy of under 100 meters," says Bierdel.

Costs are reduced by a factor of **400**.

After their success with the ESA tender, the two researchers focused on the question of how to put their idea into practice. Right on time, Fraunhofer Venture was there to help. They received extensive advice through the business acceleration program Fraunhofer runs for young startup founders, including the Fraunhofer Days initiative (FDays for short). "FDays kick-started things off for us — the atmosphere there completely captivated and excited us, as did the idea of founding a startup and being able to make our own decisions," explains Bierdel. FDays also brought some changes in terms of team members: Christian Mittermaier, whom they got to know there, brought business administration experience to supplement the founder team's predominantly scientific backgrounds.

ConstellR technology on board the ISS

Thanks to the EXIST startup grant offered by the German Federal Ministry for Economic Affairs and Energy and the Fraunhofer AHEAD program, the founder team was able to secure around two million euros in public funding and further advance Fraunhofer EMI technology. In April 2020, the startup ConstellR was ready for launch. The first major event on the horizon for the team of 19 employees will take place on February 1, 2022, when ConstellR technology will be sent into space — and then operated there for four months together with NASA on the International Space Station (ISS). "In this way we can demonstrate that our systems works in space under real conditions without needing to send up a satellite of our own at this stage," says Bierdel. The company aims to have their own satellites in 2023 — four in total. "With these, we will be able to monitor as much as ten percent of agricultural land surface worldwide," he adds with pride.

The enthusiasm of the three founders and their clear roadmap has been highly persuasive to investors, too. Rather than thinking about how much money the small company could gather from investors, on the advice of a mentor at Fraunhofer, the team turned the tables and planned in terms of what exactly they wanted to achieve, and by when. Despite hearing during the first round of financing that "a startup can't really raise more than 500,000 euros," the team now has a total of one million euros in investor funding in the bank. Bierdel is excited. "Through ConstellR I can play my part in meeting the challenges of food shortages, the growing global population and climate change. This motivates me tremendously." ■

"Breaking down regular data into a per-field basis is essential for agriculture."

Turning farming upside down: Marius Bierdel aims to revolutionize agriculture to face up to climate change — from space.

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3×3 Questions

"The lockdown made us far stronger"

Wolfgang Kintzel,
Cellbox Solutions GmbH

1 Did you lose sleep at any stage?
The first lockdown coincided with the marketing phase for our technology — so of course we were wondering how this would affect our investors' willingness to invest. Would they have faith that an innovative technology could be brought to market at such a time? But it was clear that the investors still believed in our product, and we were able to use this period of time to develop new product lines — this time actually made us far stronger.

2 What advice has helped you?
The ultimate piece of advice I received was that innovation wins the day on the market. When scientific excellence is combined with market know-how, then it will work on the international level too.

3 What are you proud of?
We have been able to serve markets in Europe, Asia and America in a relatively short space of time using German technology — for a German company, that's noteworthy. I'm also proud that we are the first company to make it possible to transport biological material in excellent quality internationally. ■

"Look after your team!"

Karsten Schmidt,
Ampeers Energy GmbH

1 Did you lose sleep at any stage?
I have an entrepreneurial mindset, so the same challenges that might keep others awake, I see as opportunities. I'm a firm believer in the old saying: Every cloud has a silver lining. So I haven't had any phases where I slept badly, at least not because of work. You could say, with a twinkle in your eye, that it's more our two little boys that occasionally keep me awake, since they usually claim my time between five and six in the morning.

2 What advice has helped you?
For me, it's this piece of advice: "Firstly, look after your team. If everyone if focusing in the same direction, they will be engaged and motivated. And secondly, to pay attention to the market and let it know you exist." This is advice we always make sure to adhere to. Unfortunately, I can't remember who gave it to us along the way. I think it was an investor in the first round of funding that thought our idea was great, but too underdeveloped, and so they didn't invest.

3 What are you proud of?
I'm especially proud of the team we have built. This team that managed to bring us onto the market in less than two years. I am of course also proud that people know us on the market, and that they request our products and services and enjoy working with us. ■

Photos: Cellbox Solutions, Jan von Holleben (2)

Marius Bierdel,
ConstellR GmbH

"It's something we're all proud of"

1 Did you lose sleep at any stage?
We started with four founders, but then one resigned. Most of my sleepless nights were related to the fact that things hadn't worked out as we had imagined with a team member. Finding a solution for that was really quite challenging.

2 What advice has helped you?
Our coaches at Fraunhofer Venture gave us an important piece of advice along the way. They said that during the planning phase of the startup, the focus should not be on how much money we can secure from investors. That instead, we should ask ourselves: Where do I want to be a year from now? What do I want to achieve? And only then should we think about how we could make that happen and land the necessary resources.

3 What are you proud of?
On a personal level, I'm proud that ConstellR already employs 19 people after just one year. I'm also proud of our company culture, which is characterized by feedback, openness and transparency. Being a part of such a team and working on a solution that offers added value is something that all our team members are proud of. ■

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Interview

“We need a decade of modernization!”

This statement is one of chancellor candidate Armin Laschet’s stock phrases. In an interview, he reveals how he would make this a reality as chancellor.

Interview:
Josef Oskar Seitz

Armin Laschet, 60, has prevailed as the candidate for the role of chancellor — at least, inside the CDU/CSU union.

Photo: Dominik Asbach

The die has been cast, Mr. Laschet, and you are the CDU/CSU candidate for chancellor. Congratulations!
Armin Laschet: I'm now looking forward to a passionate election campaign!

As someone with an interest in history, were you not startled, when your co-candidate in the CSU, Markus Söder, accepted the decision with this statement, of all things: the die has been cast?
That's actually plural in the original Latin: alea iacta sunt.

It is a quote from Julius Caesar. However, he said just before crossing the proverbial Rubicon with his army — and starting the civil war.
It was very clear that deciding between two party leaders and two minister presidents would not be easy. But it's also clear to us both that the CDU/CSU partnership is only successful when we are united and have a common responsibility. With this in mind, we are both campaigning for the strength of the partnership.

That's reassuring for us. What is it that sets you apart as a candidate for chancellor?
That's for other people to say. It is an advantage to have already won one election. When someone has shown that he can govern a large state like North Rhine-Westphalia, that is also definitely a good qualification. What is decisive however, is having a fundamental direction to one's policy. I have a clear idea of where our country should go from here: We need a decade of modernization!

The coronavirus crisis mercilessly exposed some weaknesses on that front.
The issue of German health authorities still having to work with fax machines and paper at the beginning of the crisis was remedied in a very short space of time. But all governmental institutions are still facing the task of actually working digitally. Science is doing it, industry is doing it. The government must not finish last here. The pandemic has also taught us that we must be more independent from other nations when it comes to providing medical protective equipment. The cheapest surgical masks weren't available for respiratory protection because

"Putting climate neutrality into practice — this is something that will only work if research is given every possible opportunity!"

their production had completely relocated to China. This showed us that we in Europe must meet certain minimum levels of supply in the future ourselves.

Did you notice any strengths that became apparent during the crisis?
Genuine willingness to help! We saw young people being there for the elderly, and people getting involved in volunteering. The strength of our society showed itself there. I am convinced, that when we take stock, we will find that we came through the crisis well in comparison to others in Europe and elsewhere in the world. There was a lot of solidarity.

But that wasn't always apparent in politics.
Well, at the start it was. The disagreement on the question of reopening only came later. My central position on that was always that basic rights had to apply even in a pandemic. It may well be more pragmatic sometimes to close everything and prohibit a lot of things. But an attack on basic rights is something that has to be subjected to close scrutiny on a daily basis! Caution alone cannot be a justification for the government to put regulations in place to achieve its objectives in every area of life. It should only do that when there is an acute danger to health and life.

Do you see an acute danger to health and life in global warming?
Climate policy will be a key challenge for the next 30 years. I don't believe that we will overcome this social problem by enforcing particular ways of life, for example, through systematic reduction of private home ownership. I believe in the power of persuasion; it's the only way that people will go along with things in the long run. What is certain is that climate protection measures will demand a lot from all of us. We need a structural transformation. But we ▶

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"I believe we have too many regulations in too many areas and that we aren't courageous enough. We had it too good."

1980

Armin Laschet with his future wife, Susanne, on a trip to Prague with the "Junge Union," a joint CDU/CSU youth organization.

1994

He entered parliament as a representative for Aachen. Four years later, he lost the majority vote for his constituency.

90er

Armin Laschet, a proud father, is shown here with his daughter Eva and his sons Johannes and Julius.

must shape that in such a way as to maintain prosperity right across society — and thus also social cohesion. My goal is for us to become a climate neutral industrial nation: in the steel industry, the chemical industry and the automotive industry. Germany was once the pharmacy of the world. All important medicines were developed and produced here. We can start there, because the need will also be significant during future pandemics. The ambition of manufacturing green steel is a century-long task. But it is still an ambition of mine. It is also my wish that in 2045, cars — or whatever we will be calling them then —will still be driven and produced in Germany.

You're speaking as someone who also represents the interests of North Rhine-Westphalia there. What lessons from your time as minister president would you bring to the role of chancellor?
My federal state has been undergoing structural transformation for 60 years. In 1965, we still had 500,000 miners and no students in the Ruhr district. Today, we have 280,000 students there and no miners. The structural transformation from an industrial society to a knowledge society brought a lot of conflicts with it. The government was called on to mitigate the effects through social welfare. That said: It worked.

You experienced this upheaval in your own family.
My father was a miner in the Aachen area. The mines there were closed as early as in the seventies. That's when he realized that he had no prospects for the future. So he took advantage of an opportunity that made it easier for people with work experience to change careers and go into teaching. He worked at night and studied during the day — and made it possible for himself and his four sons to reach a higher level of education. However, the transformation that is coming now will be still more serious. We need advances in research for many aspects of climate change. We need research on storage technology to advance. We need research on hydrogen technology to advance. Making decisions on climate neutrality are the simple part. Putting climate neutrality into practice — that will only work if research is given every possible opportunity. We must make this transformation possible through research.

What can research expect from you as chancellor?
Firstly, a high appreciation of value. It is not enough to just maintain the funding allocated in the federal budget. It is vital that we provide money for creating the necessary overall conditions. Modernization can only be achieved through research — not with rules and regulations, not with prescriptions and prohibitions.

And how can knowledge transfer to industry and practical application be accelerated?
The government can and must create the framing conditions for that. The government must make researchers' lives as easy as possible by preventing excessive bureaucracy and assisting them in terms of the financial conditions. But transfer still requires scientists who are not only willing to publicize their knowledge, but also have the drive to find partners and put their ideas into practice.

Are you calling for a new founder culture?
You see, today in Germany, we are living off the capital of family businesses that were founded some 100 or 150 years ago. Incidentally, this is often the case in the Sauerland and Münster regions, the smallest places in North Rhine-Westphalia, where these days we have more industrial job positions than the Ruhr district. Medium-sized businesses that developed their own products and so conquered the global market, are the backbone of the German economy.

What has been lost since this period of intense founding activity you just mentioned?
I believe we have too many regulations in too many areas and that we aren't courageous enough. We had it too good. We had settled down too comfortably.

Had Germany become too complacent?
Yes, certainly. Too many systems absorbed the risks that were there. I do believe however,

This interview took place in the Minister-President's office. The green, red and white flag of his state, North Rhine-Westphalia is pictured in the background.

"Modernization can only be achieved through research — not with rules and regulations, not with prescriptions and prohibitions."

that for some years we have been at a point where the situation has been changing. You can't reproduce Silicon Valley in Germany. But particularly in the field of research, I can sense a certain readiness to take on challenges. BioNtech is a good example here. We need a thousand more like them.

That sounds like a vision. What about the reality?
That often lags behind. You see, I share the Green party's view that we should not be operating intra-German flights. We need alternatives for that. On trains in Germany, you may travel at 300 kilometers per hour sometimes, but at others, you'll find yourself on railway lines that were built right after the First World War. We need faster planning and approval processes to modernize that. However, it is a matter of course that every citizen's initiative against new railway lines will be led by the Green party. The same is true for wind energy. It's not enough just to make demands.

As we are on the topic of the Green party, when was the last time you were in Sassella?
Not so long ago. A very nice restaurant in Bonn. Members of parliament from the CDU and the Greens have been meeting there since 1994, although we were younger then. It was called the "Pizza Connection."

Anyone who was familiar with the menu knew they didn't serve pizza.
We dined well there and had many pleasant evenings. Back then, the young Greens' attitude to life was closer to ours than that of many of the older people in our own benches. Many wonderful connections were formed in those meetings. And they helped to break down those nasty stereotypes that existed back then. We may have expressed differences openly, but we appreciated each other. We have much more in common today than back then.

You were brought up as a Christian, and even worked as the chief editor of a church newspaper. How important are Christian values to you in real-life politics?
"C" is the first letter of our party name.

But you don't mean "C" as in chaos or crash?
Expressing Christian values is a serious challenge. As a politician, you must have a moral compass. Mine is always European, and will always remain Christian.

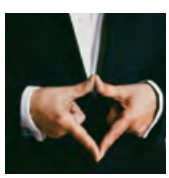
Are you an eye-for-an-eye kind of Christian? Or do you turn the other cheek when in doubt?
You have to fight for your positions in politics. And there have been many battles that I have won. ■

1998

He ends his career in the media as a publishing director. Prior to that, Laschet was chief editor for the church newspaper KirchenZeitung Aachen, a volunteer for the Charivari radio station in Munich and a freelance journalist with the Bavarian TV channel Bayerisches Fernsehen.

2018

Red-green dual leadership: Armin Laschet with Cem Özdemir at Karneval. The CDU leader is taking the wheel.



2021

Armin Laschet has already mastered the Merkel Diamond hand gesture — a must for any chancellor. More will be revealed at the parliamentary elections on September 26.

Photos: Dominik Asbach, private (3), German Press Agency (dpa) (2), NRW/CDU, Julia Stellmann/laif

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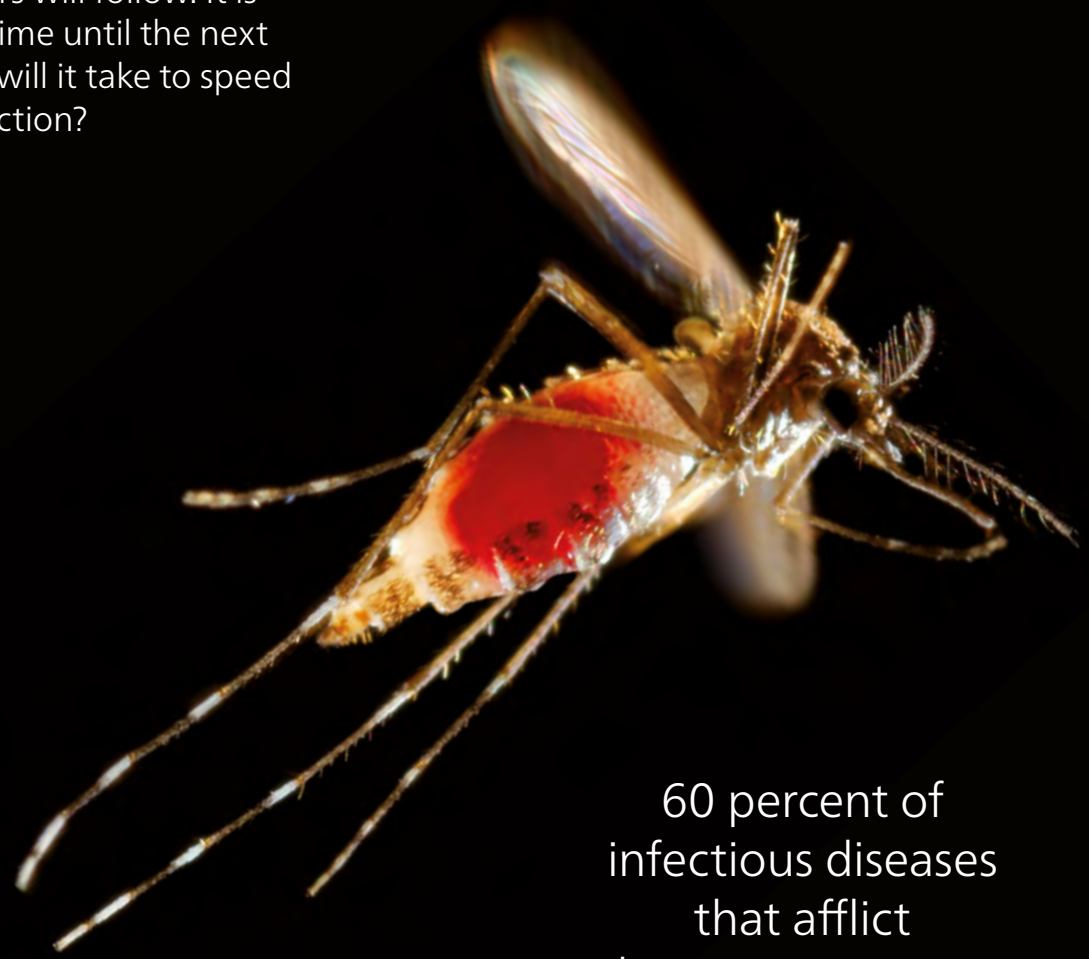
The race against viruses

The West Nile virus has arrived. Zika, dengue and others will follow. It is only a matter of time until the next pandemic. What will it take to speed up vaccine production?

By Dr. Sonja Endres



60 percent of infectious diseases that afflict humans originate in animals.

The thermophilic yellow fever mosquito is known to be the primary carrier of yellow fever, dengue and Zika.

As a consequence of climate change, tropical mosquitoes are becoming increasingly endemic to Germany, where they spread dangerous pathogens. Even local species of gnats have now become carriers. Although the number of registered cases is still low, experts expect to see a rapid rise over the next few years. The West Nile virus has already spread in the area around Leipzig, Halle and southern Brandenburg. There is no vaccine — and the same is true of Zika, dengue and malaria, although isolated cases are already appearing in southern Europe.

Zoonoses, meaning pathogens that spread from animals to humans, are becoming increasingly dangerous. The Global Virome Project, an international research initiative, estimates that 1.6 million distinct viruses are currently circulating in mammals and birds. Of these, around 700,000 are said to have the potential to infect humans. Not all of them can be spread from person to person, and not all lead to illness or even death. However, experts agree that the coronavirus will not remain a solitary case.

"If we want to effectively fight pandemics in the future, then the production of vaccines must become significantly faster," says Prof. Holger Ziehr, director of the Pharmaceutical Biotechnology division at the Fraunhofer Institute for Toxicology and Experimental Medicine ITEM. Working across various institutes and disciplines, he coordinates the Fraunhofer Vaccine Technologies research consortium, which was formed in response to the coronavirus pandemic. In the consortium, vaccine experts, bioprocess engineers, production engineers and packaging specialists work on making vaccines available more quickly — the importance of which became apparent during the months of the pandemic. To this end, they aim to bring vaccine candidates swiftly into clinical trials, develop and provide technology platforms, and optimize production and packaging and prepare them for mass-scale application.

The development and production of vaccines has been neglected for years all over the world. Manufacturing technology for conventional, inactivated vaccines has hardly changed since the 1940s, because any effort to do so would not have been profitable enough. "Awareness of the importance of this technology has grown significantly as a result of the coronavirus pandemic," observes Dr. Sebastian Ulbert, who heads up research into infectious disease pathology at the Fraunhofer Institute for Cell Therapy and Immunology IZI in Leipzig. This virologist and zoonosis expert helped to set up the Fraunhofer Vaccine Technologies consortium, together with Prof. Ziehr.

> "SARS-CoV-2 was the ideal scenario. It doesn't get any faster."
>
> Dr. Sebastian Ulbert, Head of research on infectious disease pathology at Fraunhofer IZI

"We got lucky with COVID-19," explains Dr. Ulbert. According to him, a confluence of many favorable conditions made it possible to develop vaccines quickly. Findings and preliminary work on the related coronaviruses SARS-CoV-1 and MERS were already available. The antigen responsible for triggering a protective immune reaction in the body had already been identified. Infection models for vaccine testing were also available. "SARS-CoV-2 was the ideal scenario. "It doesn't get any faster than that," he says with conviction.

Normally, it takes a number of years for a promising vaccine candidate to emerge — time that scientists simply don't have when an epidemic or pandemic is raging. For this reason, it is crucial to identify vaccine candidates for potential pathogens before they are needed in large quantities.

Dr. Ulbert and his team have already succeeded in this for the Welt Nile virus. Patients often exhibit high fever, vomiting, diarrhea, exhaustion and joint pain. In certain rare cases, inflammation of the brain or meninges can also occur — as is the case with TBE, which belongs to the same virus family. In contrast to TBE, the West Nile virus is not transmitted by ticks, but by the common house mosquito. In Leipzig last summer, 11 patients with severe cases had to be treated in the hospital.

"It is important to have a vaccine ready before the virus spreads further in Germany — which it most certainly will, especially since it is much more difficult to protect yourself from mosquito bites than from tick bites," warns Dr. Ulbert. Now, he is searching for industry partners who can help him conduct clinical trials for his vaccine candidate.

Prof. Ziehr and his team at Fraunhofer ITEM can also count a success to their names already: By shortening the conventional procedure, they succeeded in bringing an antibody agent against COVID-19 from the pre-clinical phase to the clinical phase within six months, rather than the usual two years. This so-called "passive vaccine" is intended to help the immune systems of seriously ill patients to fight off SARS-CoV-2 using externally produced antibodies. "Virus proteins for conventional vaccines could also be produced more quickly this way, and without any problems," says Prof. Ziehr. So how did they do it? Prof. Ziehr and his team did not reproduce the clone. This is the cell that most effectively produces antibodies, but is difficult to identify. Rather, they reproduced an entire cell pool, which accomplishes the same task — although the individual cells are perhaps less productive. "In a previous project, we had established that the cells which were derived from the clone were no longer entirely identical after many divisions. Obviously, mistakes occurred in the process," explains Prof. ▶

Photos: Alamy/F1 online

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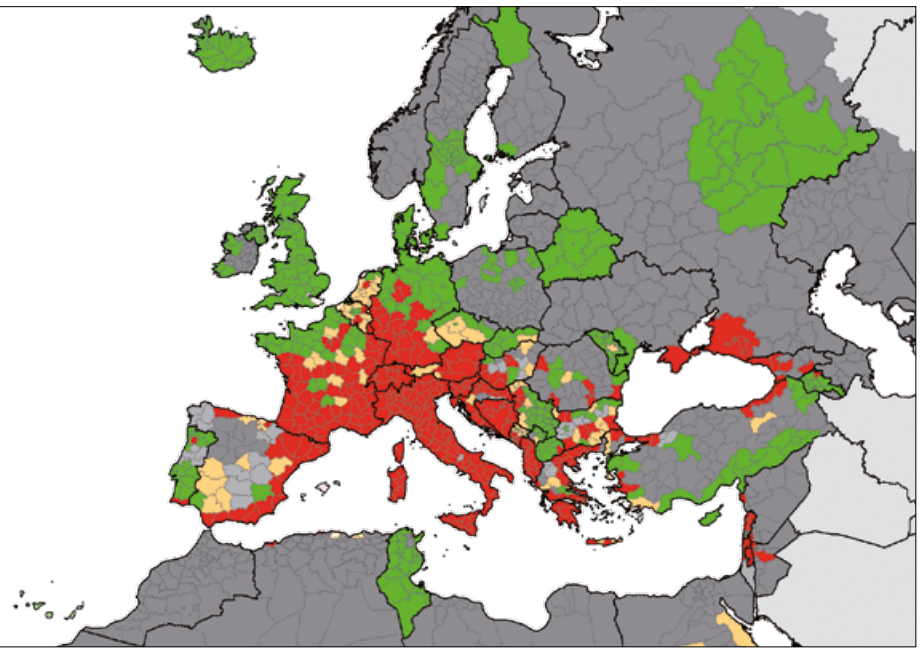
Mosquitoes gain ground

Tropical mosquitoes of the Aedes genus, which can transmit dangerous diseases, are spreading in Europe.



As of: March 2021

Source: European Centre for Disease Prevention and Control and European Food Safety Authority

Ziehr. This raised the question: Is finding the clone even worth the effort? Especially during a pandemic, when quick solutions are imperative? They dared to experiment, putting the initial suspension of around 5,000,000 cells under evolutionary pressure, which allowed them to find those that could produce the antibody. "The result proved us right. The cells produce large quantities of pharmaceutical-grade antibodies, which are already being used to treat patients."

In addition to vector vaccines, for which the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB is developing virus-like particles, innovative mRNA vaccines are a particular cause for hope in the fight against infectious diseases. However, production technology and processes are not yet as sophisticated as they need to be.

One of the biggest challenges is encapsulating the mRNA in lipids. Only with the help of this protective covering is it possible for mRNA to move through the body without being broken down, penetrate a cell and set antigen production in motion inside it. To achieve this, the capsules must have a particular thickness and composition — large variances could impact the efficacy of the vaccine. It is complicated and time-consuming to produce these tiny nanoparticles. This is why researchers at the Fraunhofer Institute for Microengineering and Microsystems IMM, the Institute for Production Systems and Design Technology IPK and the Fraunhofer IZI institute branch for Bioanalytics and Bioprocesses BB are working on enabling efficient mass production.

One encouraging prospect is micromixers, in which the lipid and mRNA solutions are pumped through a sophisticated channel structure in order to join them together as desired. The technology, which is in development at Fraunhofer IMM, has the advantage of reliably producing uniform, precisely defined nanoparticles, and with almost no waste. Furthermore, the micromixers can be scaled easily, which means they work just as well in small laboratories as in large production halls. Because the mRNA vaccines cannot be analyzed using conventional methods, the researchers have also had to create a new quality assurance system for them. At Fraunhofer IZI-BB, researchers are using isolated cell components known as cell-free systems to test whether the mRNA actually leads to the production of the target protein — an efficient, uncomplicated and consequently quick process.

However, the most effective vaccine is useless if it cannot be bottled — another significant weakness that the coronavirus pandemic brought to light. "In Europe alone, we need hundreds of millions of glass vials for injection bottles, but they simply don't exist. The production capacities are limited," explains Prof. Ziehr. Consequently, researchers at the Fraunhofer Institute for Surface Engineering and Thin Films IST and at Fraunhofer IPK are developing alternatives made of plastic, which can be produced more quickly and much more cost-effectively through injection molding. Moreover, the polymer ampules are shatterproof, lighter and therefore more suitable for transport. But there is a problem: The plastic must not react with the vaccine and render it unusable. A protective coating could be the solution.

"We are pursuing a number of approaches so that in the future, we can better keep pace with new viruses. The fact that we have built connections with each other in the research consortium is a big advantage here. It means that, for example, all the stakeholders can be brought in even in the pre-clinical phase, and requirements for mass producing the vaccine are taken into account. Processes take place simultaneously, not one after the other," explains Prof. Ziehr. "That saves time, reduces costs and leads to the best result." ■

Green hydrogen: “We are working on increasing efficiency”

Green hydrogen, produced with renewable energy: is it the “rock star of future clean energies,” the “miracle cure”, the “magic bullet”? Dr Markus Wolperdinger, chemist and director of the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB in Stuttgart, explains its true capabilities and its potential for the chemical industry.

Interview: Dr. Sonja Endres

Hydrogen is an important raw material for many base chemicals. Why is climate-friendly hydrogen obtained from water not yet widely used in industry?
Significant amounts of renewable energy are required to produce it. That’s not something we have yet. The processes we have used up to now did not allow us to efficiently produce hydrogen at a scale that matches the conventional production of hydrogen from natural gas. This has so far been the most economical means of producing hydrogen, but it causes high CO_2 emissions.

That is what you now aim to change at the Hydrogen Lab in Leuna, a platform for testing how green hydrogen can be generated and utilized. You set it up in cooperation with the Fraunhofer Institute for Microstructure of Materials and Systems IMWS. How can it help to bring about the transformation quickly?
The unique feature of our lab, which receives funding from the state of Saxony-Anhalt among other sources, is its integration with a chemical park. That way, we have a direct connection the practical applications, are involved in the material cycles and processes, and benefit from a direct exchange with the companies on site. We are testing various electrolyzer systems that apply electricity to water to separate the hydrogen and oxygen. To increase efficiency, we are working on optimizing the physical and chemical processes in the electrolyzer, for example with suitable control mechanisms. A particular challenge is structuring the electrolyzers so that they can cope well with fluctuating energy levels. Sometimes there is a lot of wind and sun, but at others, there is only a little or even none at all.

What are your solutions?
Ideally, we would create storage systems to use as a buffer; we could then feed the hydrogen into these systems in the event of overproduction and discharge hydrogen from them in the event of underproduction. Salt caverns, that is, salt dome cavities which are available in abundance in central Germany, would be particularly suitable for this purpose. Fraunhofer IMWS and a number of businesses are testing out this possibility right now.

How do you transport the hydrogen?
In the Leuna chemical park, our partner Linde has a hydrogen pipeline network that we use to transport the hydrogen to the companies there. Of course, this doesn’t exist everywhere. However, hydrogen could also be transported via standard natural gas lines, even at the same time as natural gas. The two gases could then be separated again using special membranes once it arrives at the destination. The Fraunhofer Institute for Ceramic Technologies and Systems IKTS is working on this method.

How can green hydrogen become cheaper in the future?
Cost reduction is always a question of scale. That is to say, how can I produce a larger quantity with the same system technology? The other option is to use lots of small, inexpensive systems which can be turned on or off as needed. However, this ▶

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Interview

Dr. Markus Wolperdinger

"The unique feature of our lab is its integration with a chemical park."

would require a reduction in production costs for electrolyzers, as well as a reduction in operating costs — which mostly means electricity costs. Essentially, we need an awful lot of inexpensive green electricity.

Where would that come from?
Among other things, through the expansion of renewable energies. At the moment, there are plans for an enormous wind park in the North Sea.

The German government is hoping to import green hydrogen, from Africa for example.
There is enough solar energy there, so it would make sense from a technology perspective. Seawater could be used for electrolysis — however, only if it is desalinated beforehand. That would create a new cost to consider. The issue of transport also remains unresolved. Pipelines could be a possibility. If you wanted to bring hydrogen to Europe by ship, you would have to liquefy it beforehand to reduce the volume. To do this, the hydrogen must be cooled to -253 degrees Celsius. That's an energy-intensive and expensive process. So there are numerous unanswered questions. But I'm certain that we will find the answers.

According to the latest decision by the German Federal Constitutional Court regarding the German Climate Protection Act, the government is aiming to reduce CO_2 emissions by 65 percent by 2030 — 10 percent more than previously planned. Can we reach this goal with the help of green hydrogen?
Green hydrogen will certainly make a contribution. It helps with CO_2 sequestration. For example, hydrogen and CO_2 can produce methanol, which can then be processed further to create a synthetic, petroleum-free fuel for combustion engines. We are working on this in Leuna together with the TotalEnergies refinery, one of the largest, most modern refineries in Europe, as well as with the renewable energy company, Sunfire. However, if we are to reach these CO_2 goals, then further measures are needed, such as our developments in the bioeconomy field. At the end of the day, the most important thing to avoid is CO_2. That is the critical point. ■

Photo: Fraunhofer IGB

Digitalization is a blessing.

We live online

75.3 % of people in Bavaria used the Internet every day in 2020.

We work online

70 % of people in Hamburg and Berlin worked from home at least occasionally thanks to the Internet.

We watch online

71.7 % of people in North Rhine-Westphalia streamed a movie or series on the Internet in 2020.

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Photo: Fraunhofer IGB

The coronavirus has shown: **Digitalization is a blessing. And a curse.**

We live online

75.3 % of people in Bavaria used the Internet every day in 2020.

117.4 million

new malware variants were found in Germany in 2020.

100 billion euros

in damage to the German economy alone resulted from Internet attacks in 2019.

We work online

70 % of people in Hamburg and Berlin worked from home at least occasionally thanks to the Internet.

We watch online

71.7 % of people in North Rhine-Westphalia streamed a movie or series on the Internet in 2020.

108,474 cases

of cybercrime were recorded in the statistics compiled by the German Federal Criminal Police Office for 2020.

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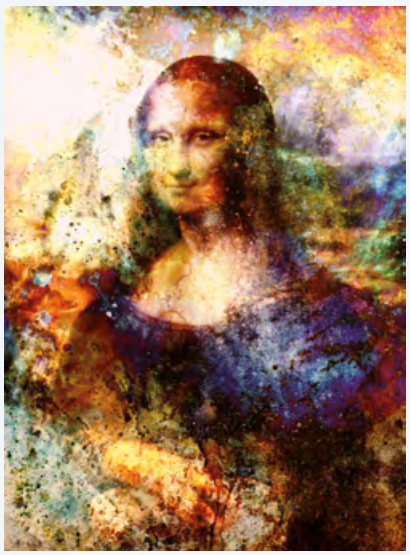
Facts vs. fakes

More than meets the eye

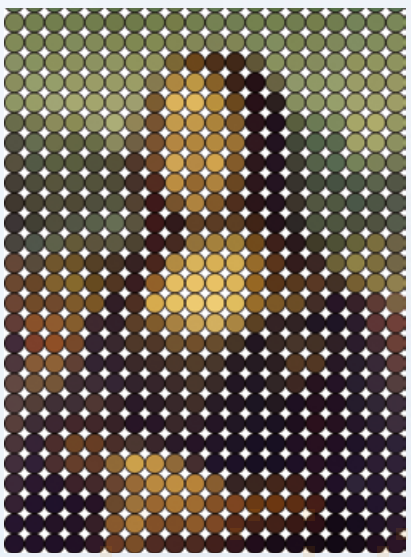
They can bring old photos to life and open new doors for art. And they are the tools behind online smear campaigns and electoral manipulation. Deepfakes are changing our past — and our future.

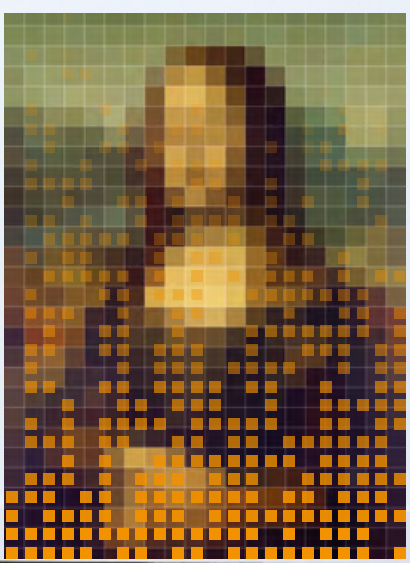
By Mandy Bartel
Photography: Oliver Rüther

Prof. Martin Steinebach, IT forensic scientist at the Fraunhofer Institute for Secure Information Technology SIT








Fotos: Adobestock (10)

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With video conferences ever more frequently replacing real-life meetings, our contact with our conversational partners is predominately digital. But can we always trust appearances in the digital world? "Face-swap algorithms are already effective in moving images, even in real time," relates Prof. Martin Steinebach, Head of Media Security and IT Forensics at the Fraunhofer Institute for Secure Information Technology SIT in Darmstadt. "But to look realistic, they also require good actors who can imitate the facial expressions and gestures of the original as closely as possible."

The forensic scientist has been working on video authenticity for more than 20 years. Deepfakes — a portmanteau of "deep learning" and "fake" — are a relatively new phenomenon in this field. Their origins can be traced back to 2014, when their technological foundations were laid with the development of Generative Adversarial Networks (GAN) — neural networks that can learn independently. GANs consist of two artificial intelligence (AI) networks, where one produces a fake image and the other attempts to detect it. When a fake is detected, the first network then optimizes its results independently, meaning that the fakes constantly improve. While this process could only produce heavy-handed, pixelated face swaps six years ago, the technology progressed at terrific speed as graphic cards improved and AI became more powerful. By 2017, ever more realistic fakes were finding their way onto the Internet.

Pornographic content continues to make up the majority of online deepfakes, representing a portion of 95 percent. According to Prof. Steinebach, politically motivated fakes tend to be the exception. However, he does warn that this technology could be a powerful tool for provoking political instability. It could be used to ruin politicians' reputations, falsify evidence and simulate or cover up crimes. The technology also allows white-collar criminals to create targeted fakes to extract sensitive data from their victims. And the crux of the matter is that even today, the AI algorithms are freely available to anyone and everyone as open-source software. However, achieving genuinely good results requires a certain level of effort. It takes professional technology and time to train the AI to the point where it can recognize faces from different perspectives and with different expressions, and to give the superimposed recordings a similar structure. For one minute of faked video material with 30 frames per second, 1800 images would have to be manipulated so that they all blend together seamlessly. "With the graphic cards that we have currently, you would need about a day to produce a 30-second video in 4K resolution," says Prof. Steinebach.

However, deepfakes are not always necessarily dangerous. The same technology and the right app can also be used to bring old family photos to life. In "nostalgia fakes," the software allows ancestors we never physically saw to crack a smile or move their heads and eyes realistically. The AI algorithms are also a great boon for the film and advertising industries, because they make it possible to depict more realistic scenes without major costs. So for example, actors' lip movements can be much better adapted to different languages when dubbing films, or doubles can be more easily adjusted to resemble the original actor. In May 2021, the electricity startup Tibber became a talking point thanks to its deepfake TV commercial, the first of its kind in Germany. This piece of over-the-top satire featured Angela Merkel promoting the energy transition. And if nothing else, entertainment apps represent a major market for these kind of AI algorithms.

Today, the technology is freely available as **open-source** software.

Audio deepfakes: When familiar voices get hijacked

AI can also be used to manipulate audio recordings, and more quickly than for videos. This is a significant security risk for vocal ID systems, which banks and telecom providers use even today for voice-based user authentication. "As normal speech recognition systems cannot yet detect these audio fakes, in the future, it could be easy to hack any kind of access system that uses voice ID for security," warns Nicolas Müller. In his team at the Fraunhofer Institute for Applied and Integrated Security AISEC, the researchers have to decide whether they want to be one of the good guys or the bad guys. "Team Red" are the attackers: they create ever more elaborate fake audio files using neural networks. "Team Blue" tries ▶

One minute of faked video material requires **1800** manipulated images.

"In the future, it may be easy to hack any kind of access system that is secured using voice ID," worries Nicolas Müller of the Fraunhofer Institute for Applied and Integrated Security AISEC.

Photos: AdobeStock (2)

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A brief history of forgery

315/317 AD

The Donation of Constantine is one of the most important forgeries in history. The document, in which the Emperor Constantine supposedly transferred authority over the western Roman empire to the Pope and his successors in the fourth century, was used by the Church for centuries to reinforce its claims to power. In the 15th century, the document was identified as a forgery dating from the year 800.

1855

"The Valley of the Shadow of Death," a photo taken by Roger Fenton in 1855 during the Crimean War, represents the birth of war photography. To achieve a greater dramatic effect, Fenton arranged cannon balls on the drab gravel path. The balls were not present in an earlier version of the image.

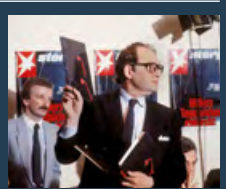
1912

Even research is by no means immune to forgery. In 1912, a British amateur archaeologist claimed to have found bones showing the long-sought evolutionary link between apes and humans. Science so badly wanted to believe that the finding of the Piltdown Man had uncovered an ancestor to the Neanderthals that it took 40 years for it to be exposed as a primitive forgery consisting of ape and human bones.

1920

During his rule, Joseph Stalin had numerous photographs from the beginnings of the Soviet Union retouched. Probably the most famous of these manipulations is the iconic photo of Leon Trotsky and Lev Kamenev at a speech given by Lenin in 1920; the two revolutionaries subsequently fell out of favor and were erased from the image.

1983



With the Hitler Diaries, the "Stern" unveiled a sensational find, which, as the Hamburg magazine claimed, would have made it necessary to rewrite broad swathes of German history. These forgeries by Konrad Kujau, which were later unmasked by means of chemical analysis, continue to represent the greatest fiasco in German media history.

1997

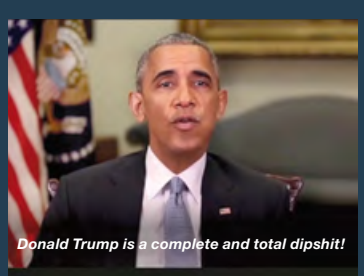
After a terrorist attack in Luxor in Egypt, the Swiss magazine "Blick" published a striking edited photo: Red coloring was used to give a simple puddle outside the temple of Hatshepsut the appearance of an enormous pool of blood.

2003/2004

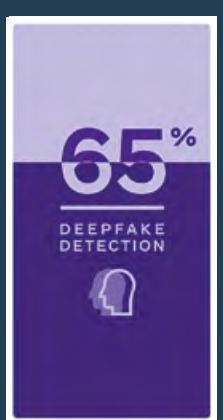
Since the founding of Myspace and Facebook, it has been possible for any content to reach an enormous audience all over the world — the line between fact and opinion is perpetually blurring. In 2018, the eight most successful fake news stories had received more interactions on Facebook than almost all the articles from the largest news sites in Germany. Today, 2.8 million people worldwide use Facebook — more than a quarter of the world's population.

2017

In fall 2017, an anonymous Reddit user going by the moniker "Deepfakes" posted a collection of pornographic videos that had been manipulated to show the faces of female celebrities. With this, the term "deepfake," drawn from "deep learning" and "fake," entered common usage. Thanks to larger data volumes and more efficient algorithms, new AI architectures are accelerating the development of deepfakes. A deepfake video in which Barack Obama called Donald Trump "a complete and total dipshit" had an explosive political effect.



2019



In Facebook's "Deepfake Detection Challenge," around 2000 participants attempted to automatically detect 10,000 deepfake videos using AI algorithms. The winning team achieved a success rate of 65 percent. The goal of the challenge was to help research in this field to advance further.

to distinguish these fakes from authentic recordings, using the same technology.

The way it works is that Team Red trains neural networks using lots of datasets, such as speeches by politicians. The networks learn the typical voice patterns so that they can then apply them to new words that were not part of the training. Meanwhile, Team Blue feeds pairs of real and fake recordings to the detection algorithm. This allows it to occasionally learn very small differences, such as a static noise or an incorrectly pronounced word. The researchers do not set any fixed rules for these neural networks, something that sets them apart from previous detection methods. Instead, they learn the differences themselves.

In this context, the process works on known datasets over 90 percent of the time. However, outside the training datasets, the success rate may be lower. Müller compares this to known art forgers, whose handwriting can be identified more quickly because it is familiar. When an unknown forger comes on the scene, the lessons the AI has learned cannot be transferred on a one-to-one basis, and it has to learn new detection methods. The problem is there are still too few valid datasets for researchers to make any reliable assertions. Consequently, Team Red has to produce the most varied fakes possible in order to expand the training data for the algorithms.

Researchers at the Fraunhofer Institute for Industrial Mathematics ITWM in Kaiserslautern are using methods from mathematics to address the training data shortage. "Analyses have shown that GANs make inherent errors when generating images. While these errors are barely visible to the human eye, they can be modeled very easily in Fourier space," explains Dr. Janis Keuper of Fraunhofer ITWM, now also Professor of Analytics and Data Science at Offenburg University of Applied Sciences. Using this as a basis, they developed a method that requires very little training data to allow these errors to be detected reliably. Crucially, as this error is rooted in the system, the algorithms cannot learn to circumvent it.

How can deepfakes be detected?

Prof. Steinebach and his team at Fraunhofer SIT employ forensic methods such as noise analysis to detect deepfake videos. Other processes, also AI-driven in some cases, can detect tiny differences in facial color or expression, unnatural pulse rates and minuscule differences in the superimposed images, such as blurriness or distortion. "We can now reach detection rates of around 70 percent for deepfake videos that haven't gone through post-processing. However, if the videos have been edited after the fact using matching algorithms, Gaussian smoothing or noise filters, this goes beyond the limits of what automated detection can do. The research is only starting out here," emphasizes the forensic scientist.

Science and industry are working closely together to find solutions. For example, Facebook announced a huge "Deepfake Detection Challenge" at the end of 2019, with the explicit goal of helping research to advance. The social network provided 10,000 deepfake videos, and around 2000 participants used a variety of solutions to try and automatically detect the fakes. The winning team achieved a success rate of 65.1 percent.

When technology reaches its limits, common sense and personal responsibility must step in. "To avoid becoming victims of this kind of deception, we must question content in a critical way, examine it closely and above all, pay attention to sensible security architecture," advises Prof. Steinebach (see the tips on the right). When video conferences are secured by means of suitable protocols and certificates, or videos with data on their origins, or signatures, things become much harder for deepfakes.

What can governments do?

Governments have long been alarmed by these new possibilities. The probability of manipulation increases with every election. This was the reason the EU recently commissioned a study on deepfakes, a project that Murat Karaboga from the Fraunhofer Institute for Systems and Innovation Research ISI is collaborating on. To consider the problem in the most holistic way possible, he and his team drew up a list of 30 recommendations for action for the EU, each approaching the issue from a different perspective. For example, the actual production of deepfakes could be monitored more effectively if the necessary technology were classified as "high risk" in the EU's proposed directive on AI and special constraints were applied when regulating the technology. If the dissemination of faked videos is to be brought under control, then in the future, the major platforms must be held to account more within the framework of the EU Digital Services Act. However, that assumes that fakes can be detected with greater certainty. In cases where authenticity is in doubt, it could be effective and useful to automatically interpose questions as to whether the content should really be shared. ▶

5 tips for better security:

Look out for technical errors in the images: For example, unusual facial movements, or distortions or blurring during transitions.

But be careful! On smartphones and laptops, it is harder to spot technical inaccuracies than on larger, calibrated monitors.

Pay attention to facial expressions: Are they natural and typical for the person in the video? Are there noticeable differences from comparable videos?

Make sure to check the source: Where does the video come from? When video conferencing, ensure that you are talking the right person by using digital signatures or verifying their identity with independent parties.

Question content critically: How believable are the statements it makes, even outside of your own filter bubble? If in doubt, research it on fact-checker websites.

Photos: public domain/Wikipedia.org, Library of Congress/USA, Alamy/F1 online (2), dpa (2), excerpt from "Blick," November 1997, YouTube, Facebook

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"The line between security and freedom, between reasonable regulation and perceived infantilization, is a fine one indeed."

Murat Karaboga

Improvements are also required in terms of protective measures for those affected by deepfakes. These days, people often cannot even prove that they have been victims of a fake, for example, when their accounts have been hacked. This means that the legal system needs new avenues for gathering evidence. Experts in security circles are discussing countermeasures like immutable logs, a kind of blockchain for an individual's life. However, according to Karaboga, these should be assessed very critically in light of the data protection concerns they cause. The question of how to deal with perpetrators must also be readdressed in the legal context. How can perpetrators actually be convicted, when they obliterate all of their digital tracks? How must laws be adjusted to facilitate suitable penalties for such criminals?

However, it is the public that must play the decisive role. These days, it is up to each one of us to be the gatekeeper for the content we consume — a task that used to fall to traditional journalists in former times. As Karaboga points out, this is why it is important to "make media education a fixed part of the school curriculum early on and set up independent fact checkers for individual media consumption, to increase people's media skills." Because the responsibility of looking closely at content and questioning its authenticity does not just fall to the government alone, but rather to each individual. This is why finding the right path is so particularly difficult in terms of setting the political framework. "The line between security and freedom, between reasonable regulation and perceived infantilization, is a fine one indeed," reflects Murat Karaboga. ■

The chip you can trust

Need protection from industrial espionage and cyberattacks? Two projects at the Fraunhofer Institute for Photonic Microsystems IPMS are working on one basic approach: forgery-proof components and light-speed encryption.

By Mehmet Toprak

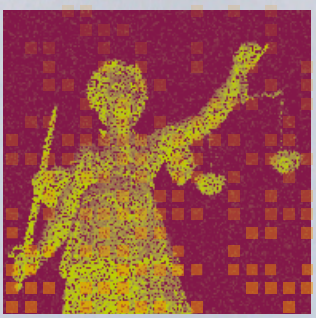
The danger is real and the incidents are piling up. Companies have to protect themselves against industrial espionage, hacking and cyberattacks from both a software and hardware perspective. The "Velektronik" research project is breaking new ground, with researchers aiming to make the whole hardware manufacturing process, from design through production up to analysis, manipulation- and forgery-proof. The goal is to create a networking platform for manufacturers of "trusted electronics," so that a company could hand off the manufacturing of sophisticated electronic components to one or more industry partners without a hitch. In this way, the manipulation of components, e.g. to build in digital back doors, could be avoided, or could be circumvented through suitable integration methods. This networking platform will incorporate every stage of the value chain.

The Fraunhofer Institute for Photonic Microsystems IPMS in Dresden is collaborating on the "Velektronik" project with the institutes of the Research Fab Microelectronics Germany FMD and other partners. The Dresden team is concentrating on the manufacturing process, or split manufacturing, to be more precise. In addition to its own chip manufacturing facility located in a clean room, the institute has many years of experience in the area of manufacturing secure MEMS components and integrating them securely with CMOS control elements, whether by monolithic (2D) or heterogeneous (3D) means. ▶

"The basic idea involves spreading the manufacturing of an electronic component across different manufacturing plants."

Thomas Zarbock

Murat Karaboga of the Fraunhofer Institute for Systems and Innovation Research ISI calls not only for more effective tools for the justice system, but for also a greater sense of responsibility and improved media skills on the user side.



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Components: The building blocks of security

Headed up by Thomas Zarbock, Division Director MEMS Engineering, Manufacturing & Test, the teams are evaluating the further possibilities of split manufacturing in this context. "The basic idea involves spreading the manufacturing of an electronic component across different manufacturing plants. These each produce one process module out of the entire product, but they cannot manipulate it as they do not know what the other modules of the component will be," explains Linus Elsäßer, Manager of Process Modules and Integration. The company that commissions the manufacturing retains its technological sovereignty and has no need to worry about individual modules being changed or corrupted.

The execution is as complex as the idea is logical. The Fraunhofer IPMS team is working on manufacturing concepts for CMOS components with multiple rewiring levels. The plan for splitting the manufacturing must be well-coordinated, as well as transparent and manipulation-proof along the entire value chain. Ideally, it should be drawn up independently of technology and manufacturing plants.

Forgery-proof components

The researchers also have ideas as to how the components themselves could be protected against manipulation and forgery. For example, a unique identifier such as a QR code could be integrated into the chip. Then, when read out, it would prove the authenticity of the product and allow it to be identified on a one-to-one basis. Another possibility would be to add hidden distinguishing marks to the products that can only be read out by someone with the right know-how. It could also be possible to use the optical material properties that only the manufacturer knows of in such a way as to enable identification by means of optical analysis.

"The idea is to focus on the sovereignty of the manufacturing process, in order to ensure that only trusted components and circuits are used. We can support companies, including SMEs, in the development of a trusted manufacturing process, offer them the expertise we have already acquired and assist them in developing new approaches. This will allow them to effectively protect their value chain from unwanted external attacks," says team head Zarbock.

A team of experts from various groups at Fraunhofer IPMS are focusing on a different angle. The "Silhouette" project (Silicon Photonics for Trusted Electronic Systems) aims to increase security for data transfer and storage within individual hardware components and beyond. To achieve this, the researchers are combining classic silicon chips with photonic components. Marcus Pietzsch, Manager of the IP Core and ASIC Design group at Fraunhofer IPMS and head of the "Silhouette" project, explains: "Light-based data transfer makes it possible to encrypt the data within the components in a highly secure way." This involves integrating special laser-optimized photodiodes and active and passive light modulators with photonic processors. The random number generators and key code generators used here are partially based on optical technology.

> The execution is as complex as the idea is logical

The unique properties of light unlock entirely new possibilities for computing operations; it enables them to be conducted at far greater speeds than traditional electronics could achieve. "For example, a photonic random number generator can produce an incomparably greater quantity of numbers than the conventional approach could possibly generate in the same period of time. The photonic generator also makes it possible to achieve a high randomness quality, that is, a uniform probability distribution for all numbers, meaning a type of white noise. As of today, hackers can't break into that," reveals Pietzsch.

Tap-proof and energy-efficient

"The chips could be very useful in the telecommunications domain, for example. If smartphones were equipped with these chips, they would be tap-proof," says Pietzsch. The "Silhouette" components are also suitable for any kind of application that requires extremely fast coding. That includes quantum computers.

At present, the system is still mounted on the lab bench. The goal of the project is to integrate all the components into one chip. Then cost-effective mass production of fast, energy-efficient, tap-proof components will be within reach. The plan is to create a universal technology platform that corporate customers can use to develop their own high-security hardware solutions. As with the "Velektronik" project, SMEs in particular stand to benefit from this technology. ■

"The chips could be very useful in the telecommunications domain, for example. If smartphones were equipped with these chips, they would be tap-proof."

Marcus Pietzsch, Fraunhofer IPMS

Photos: Fraunhofer IPMS (2), AdobeStock

German Digitalization Index 2021

70.2
Points — **2021**

68.3
Points — **2019**

62.3
Points — **2017**

- Infrastructure
- Digitalization in daily life
- Industry and research
- Digital engagement
- Digital administration

Extent of digitalization in Germany:
Progress in two-year steps

The **German Digitalization Index** comprises the following indices: **Infrastructure (25 %)**, **Digitalization in Daily Life (20 %), Industry and Research (20 %), Services for Citizens (10 %)** and **Digital Municipalities (25 %).**

All of the data gathered, and details on the methodology and the data collection period are available here: **www.oeffentliche-it.de/digitalindex**

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Germany is becoming more digital

The disparity between the German federal states, especially between the west and east, **has decreased.**

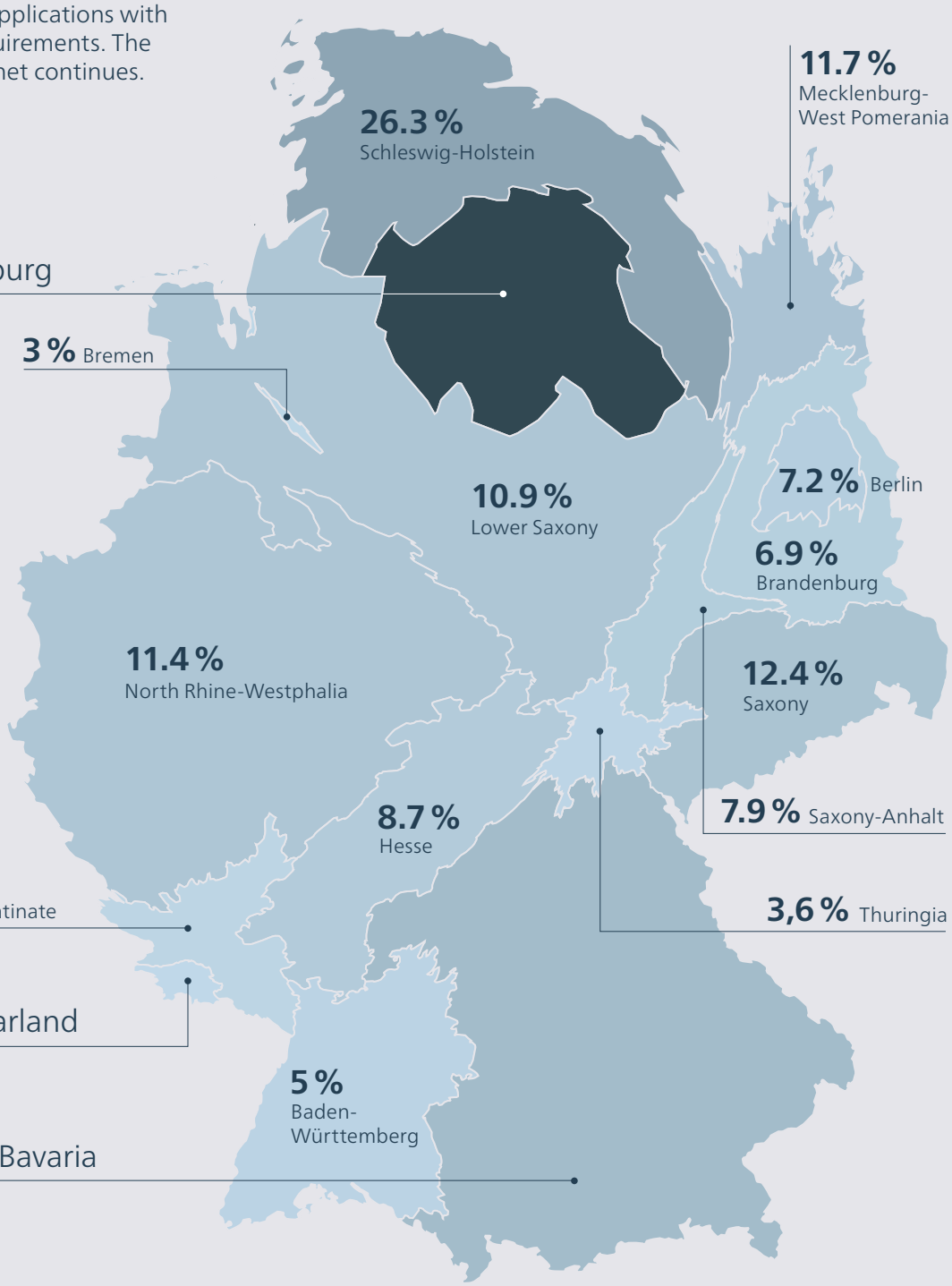
Skepticism toward the Internet and digital services has largely disappeared. **70 percent** of all citizens aged 16 and over **are tech-savvy.**

Municipal web portals hold great potential.

Demand for **digital management services** increased significantly during the pandemic.

INFRASTRUCTURE

The coronavirus pandemic has increased the use of applications with high connectivity requirements. The demand for fast Internet continues.



Fiber optic

Share of households that could be supplied with Internet through **fiber-to-the-building** at the **end of 2019**.

This information can also be portrayed by deforming the map of Germany. The map area is then no longer determined by the area of the states, but rather by the respective indicator, such as a fiber optic connection.

Internet via cell phone only

6 percent of citizens in Bremen, 5.6 percent of citizens in Saxony-Anhalt and **1.6 percent of citizens in Schleswig-Holstein** access the Internet at home using only their cell phones.

Work from home? No way

Share of employees that indicated that they could not work from home due to their Internet connection: **15.3 % Berlin, 7.1 % Baden-Württemberg, 14.6 % Hesse.**

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INDUSTRY AND RESEARCH

How effective is the IT sector? These figures are indicators of a modern society.

18 %
of new IT students
in **Germany**

+ 9 %
Average earnings
in the **IT services sector** have **risen** by **9 %** in total in **2018/2019**. The increase in **Bavaria** is particularly noticeable at **25 %**.

The share of **IT employees** is highest in **Hamburg:**

2.4 %

(Based on number of inhabitants)

DIGITAL ENGAGEMENT

Who is taking action — and what form does this activity take? These figures show regional differences.

5 % Brandenburg

3.2 % Bremen

0.1 % Schleswig-Holstein

Development of open-source software
Share of inhabitants that indicated that they **developed open-source software in the past 12 months**.

16.8 % Berlin

8.4 % Bavaria

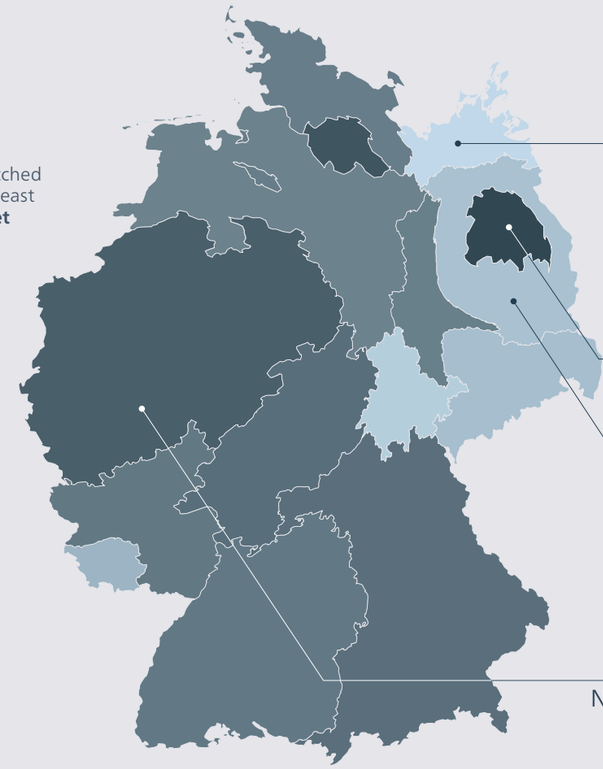
4.6 % Thuringia

Involvement in online petitions
28.9 % of the **population**;
31.8 % of **Internet users.**

Almost **4**

Who is actively engaged online and how intensively?
16.8 % of those surveyed in **Berlin** have their **own website** or **maintain a blog.** In **Bavaria**, this figure is **8.4 %**, while **Thuringia** comes in last place at **4.6%**.

Video streaming
This is how many people watched **movies, series** or **videos** at least occasionally via their **Internet connection at home.**



58.1 % Mecklenburg-West Pomerania

74.2 % Berlin

60.6 % Brandenburg

71.7 % North Rhine-Westphalia

36.0 % Berlin

21.5 % Lower Saxony

14.8 % Saxony

Online learning services
This is how many people use **online learning services**.

Telehealth
This is how many people use **telehealth services**.

↑ **7.9 %** Hamburg

⌀ **5.1 %** National average

↓ **1.8 %** Saxony-Anhalt

DIGITALIZATION IN DAILY LIFE

Digitalization changes everyday life and opens up creative possibilities. This includes, for example, obtaining information, fostering interpersonal relationships, taking action for the benefit of society and purchasing goods.

The **city states** are the epicenters of **online gaming.**

55.7 %
Bremen

53.1 % Hamburg

52.6 % Berlin

Lower Saxony
83 %

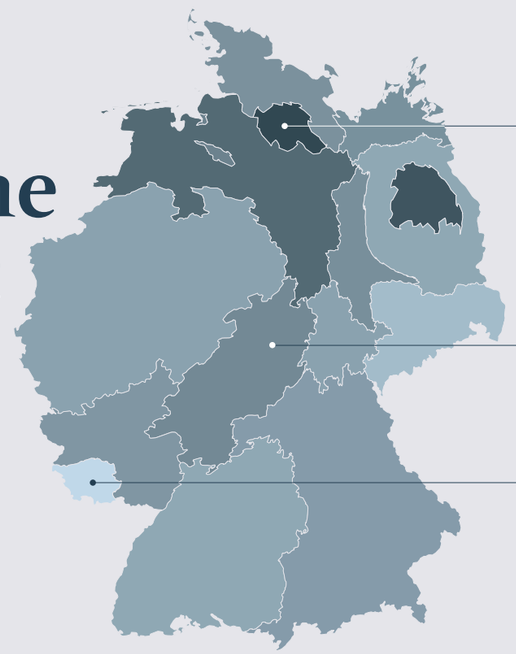
Thuringia
71 %

Regarding online shopping,
there is still a slight **disparity between west and east**. In **Lower Saxony**, **83.0 %** buy online, while this figure is only **71.0 %** in **Thuringia.**

9.1 % of inhabitants in Germany **do not use the Internet at all.**
This figure rises to **20.3 %** in **Mecklenburg-West Pomerania.**

Does everyone work at home now?

Share of employees that indicated they at least occasionally **work from home** using the **Internet**.



71 %
Hamburg

55.9 %
Hesse

38.3 %
Saarland

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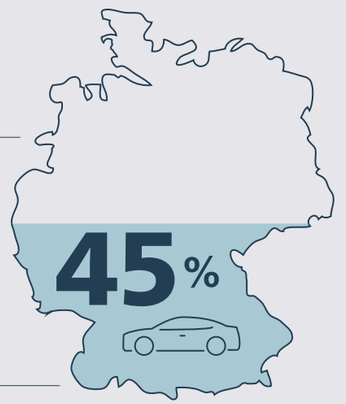
DIGITAL ADMINISTRATION

The pandemic made it clear that digital services from authorities are not just an add-on; in fact, they can rapidly become a prerequisite for a functioning administration.

100 %
Berlin
Hamburg
Bremen

Which administration services are already available in digital form?
The biggest improvement was in **motor vehicle registration. Almost half** of all **municipalities surveyed** can now facilitate motor vehicle registration **online**, while in **2019**, this was only possible in just over **one in ten municipalities**.



Do people trust digital administration?

73 %
of those surveyed indicated that they **trusted public administration** when dealing with their **personal data**.

32.5 %
National average

Online public participation
Share of **municipalities** surveyed that provided options for **digital public participation** via their **municipal web portals**.

6.7 %
Rhineland-Palatinate
Saarland

The boom in digital administration
In Hamburg,
50.2 %
of citizens have submitted forms online or have made digital applications within a one-year period.
Saxony brings up the rear: 33.9%.

Infographics: 2issue

Interview

“Slow — but solid!”

As co-author of the German Digitalization Index, Dr. Mike Weber keeps a close eye on developments. He knows where Germany is well-positioned — and which tasks policymakers must quickly tackle.

Interview: Mehmet Toprak

Dr. Mike Weber, Fraunhofer FOKUS

Mr. Weber, which result in the German Digitalization Index surprised you?
The quick spread of gigabit connections, which has once again significantly picked up speed according to the index. Almost 60 percent of households were able to surf at gigabit speeds — either through fiber optic or cable. That is a wonderful surprise.

So Germany isn’t too slow at all when it comes to digitalization?
I don’t want to take such a negative view. It is true that certain areas tend to develop somewhat slower than others. Take, for example, the number of IT startups. Or the use of fab labs and makerspaces, as well. Also, when it comes to the use of social media, we are cautious by European standards — which doesn’t necessarily have to be a disadvantage. That is always a societal issue, too. The way in which in people use digital services, and whether or not they do so, isn’t going to change overnight. Overall, however, I would say that Germany is becoming more digital.

Please give us one or two more examples of positive developments.
In many federal states, we are seeing a strong increase in the number of employees in the ICT sector (information and communication technology). The labor market is always a good indicator. In line with this, the number of trainees in the ICT sector and those studying IT is increasing. In Saarland, almost 7 percent of new students are choosing to study IT. That is a positive development.

What do policymakers need to do to resolve the shortcomings?
There’s a lot of urgent catching up to do when it comes to the provision of online services on municipal web portals. Many administration services can only be used online in a few individual municipalities. The index has shown that people place a great deal of trust in digital administration. A window of opportunity has opened up here. Policymakers should definitely take advantage of it.

Can the goal really be to digitalize everything at an ever-faster rate?
Digitalization is just a means of making people’s lives easier and more inclusive. Nowadays, extensive digitalization is a prerequisite for a society that is also willing and able to innovate. For us Fraunhofer researchers, the decisive factor in all scientific projects is that people and their needs are at the center when we are setting targets.

Sounds a little trite …
It’s not trite if you ensure that people receive a real benefit when it comes to scientific projects. The use of artificial intelligence or the digitalization of medical diagnostics, such as the early detection of diseases using imaging techniques, would be examples.

In addition, the Fraunhofer-Gesellschaft is also working on projects such as Gaia X, a European data infrastructure. This is intended to increase the availability of data, create transparency and preserve data sovereignty. That helps us all. ■

Droids take the field

Science fiction or soon to be reality? With Feldschwarm®, Fraunhofer IVI and IWU are working on a completely new type of machinery for agriculture. Autonomous field robots powered by renewable energy and using swarm behavior are set to shape the resource-efficient arable farming of the future.

By Moritz Schmerbeck

The global population is growing — and demand for food is growing along with it. To make agriculture more efficient, agricultural machinery manufacturers used to live by the motto: "bigger, faster, further." Modern combine harvesters weigh up to 27 tonnes, while sugar beet harvesters can weigh as much as 60 tonnes. A detrimental side effect of this is that heavy machinery compresses the subsoil. This lowers soil fertility in the long term and encourages flooding — the principle is reaching its limits.

Swarm intelligence instead of heavyweights

Feldschwarm® is working on a solution. The amalgamation of four research institutes and seven companies, including the Fraunhofer Institute for Transportation and Infrastructure Systems IVI and the Fraunhofer Institute for Machine Tools and Forming Technology IWU, is developing enabling technologies for the arable farming of tomorrow. The idea is that a swarm of field robots that operate autonomously or semiautonomously either guide themselves completely independently on the farmland, or follow a guide vehicle steered by humans.

Feldschwarm® units are smaller, narrower and lighter. The new tillage technology is therefore not only more flexible than the usual heavyweights, it preserves the soil while obtaining the same yield and increases the quality of the harvest due to tailored soil cultivation. To develop the technology necessary for this, the researchers are relying on close collaboration in the spheres of agricultural engineering, materials science, electrical engineering, mechanical and automotive engineering, as well as energy, systems and automation engineering.

Development is primarily focused on environmental sensor technology. On the one hand, this is to ensure that obstacles can be reliably detected and the positions of field robots can be determined to the exact centimeter. This is the only way that dynamic swarm maps can be created for navigation and that the individual units can follow their routes precisely during their swarm maneuvers. On the other hand, sensor technology is being developed that continuously analyzes the soil conditions and controls the intensity of the soil cultivation on an individual basis and in real time. This results in uniformly high-quality soil.

Functional lightweight construction and electric drive technology — two of the Feldschwarm® concept's key technologies — also contribute to reducing the weight of the machinery. In addition, soil cultivation tools that simultaneously generate propulsion forces are also being newly developed. The synergy eases the strain on the primary electric drive and consequently leads to optimal energy use with little energy loss. The additional propulsion eliminates excess weight and saves drive wheel power. The Feldschwarm® project is just one of many initiatives of the Fraunhofer-Gesellschaft in the area of smart farming.

COGNAC — An innovative thirst-quencher

In the Fraunhofer "Cognitive Agriculture" lighthouse project (COGNAC), eight Fraunhofer institutes are conducting research under the leadership of the Fraunhofer Institute for Experimental Software Engineering IESE.

Their objective is to achieve smart farming par excellence, enabling farmers to attain high productivity in a digitalized world without compromising on sustainability, resource efficiency or product quality. Using innovative automation solutions, new types of sensor technology and AI-supported decision-making aids, Fraunhofer is building a data-based agricultural ecosystem — an agricultural data space which is to become a milestone in digitalized agriculture. ■

Impressive — and impressively heavy: Modern combine harvesters weigh up to 27 tonnes.

Photo: CLAAS

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The hunt for tumor cells

A few tumor cells are hidden among billions of healthy cells in the blood of cancer patients. Detecting and isolating these tumor cells requires clever technology.

By Christine Broll

Circulating tumor cells contain important information and allow doctors to find the right treatment for individual patients.

They flow through the body like microscopic time bombs. Cancer cells that have become detached from a tumor can cause death — they flow through the bloodstream and reach other organs, where they form metastases. Only one in ten cancer deaths is due to the primary tumor. In 90 percent of cases, it is metastases that cause the loss of life.

Cancer research has already known about the destructive potential of circulating tumor cells (abbreviated CTCs) for a long time. Until now, however, it has been extremely difficult to get hold of them. In cancer patients, you find only a few dozen CTCs in a milliliter of blood — alongside ten billion red and white blood cells. A new system developed by the Fraunhofer Institute for Microengineering and Microsystems IMM can track these proverbial "needles in a haystack." "Our CTCelect system is the first that can simultaneously enrich and isolate circulating tumor cells in a fully automated process," explains project manager Dr. Sabine Alebrand of Fraunhofer IMM.

The system is thus opening up new prospects for research and treatment, as the circulating tumor cells still conceal numerous secrets. Many questions can be investigated using these cells: Which CTCs have the potential to form metastases? How can you prevent this? How do they differ compared to the primary tumor?

A blood sample is sufficient

In order to isolate the circulating tumor cells of a cancer patient, the CTCelect system only needs a blood sample — usually just 7.5 milliliters. In the first step, the CTCs are enriched. To do this, tiny magnetic beads are added to the blood sample. These beads are coated with an antibody that specifically binds to cancer cells. Using a magnet, the beads, along with the cancer cells adhering to them, can be fished out of the blood sample.

Developing the module in which the CTCs are isolated was a major challenge. The cells are first automatically marked with a fluorescent dye, and are then fed into a microfluidic chip. While the cells are flowing through the tiny meandering channels, their fluorescence is optically detected. As soon as a cell is detected, there is a pressure increase on the chip and a microdroplet that contains a single cell is dispensed from the tip. "The challenge was to control the microfluidics so precisely that there is really only one cell in each drop," explains Alebrand. "Each individual cell counts when examining CTCs."

Only **one** **in ten** cancer patients dies due to the primary tumor.

Project partner Prof. Jürgen C. Becker confirms the success of the endeavor. The head of the Institute for Translational Skin Cancer Research at University Hospital Essen examined real blood samples. "The molecular analyses of the individual cells clearly show that they were really tumor cells," explained Prof. Becker in an earlier interview, and pointed out the significance of this. "These analyses enable new insights into the heterogeneity of tumors and thus explain the success or failure of treatments, which is very difficult to predict."

Unlike many other projects, it was not only the technical development that was funded in this case, but also the clinical validation and the needs analysis among potential users. This integrative approach was made possible thanks to the VIP+ program of the German Federal Ministry of Education and Research BMBF. The program aims to shorten the path from research to market.

Keeping all types of users in mind

"The sphere of possible application areas is huge," explains Dr. Heike Aichinger of the Fraunhofer Institute for Systems and Innovation Research ISI. In order to find out the areas in which CTCelect could be used and the needs of the various user groups with respect to the system, Aichinger conducted interviews with research and diagnostics experts who, for example, work in research laboratories in university hospitals, service laboratories for routine supply or in research at multinational pharmaceutical companies. "Particularly in a scientific context, there is a desire for flexibility — as many parameters as possible should be freely selectable. The CTCelect system offers this," emphasizes Aichinger. "For example, it is possible that different types of CTCs could be isolated by swapping the antibodies used for the enrichment. On the other hand, there is a focus on standardization in routine diagnostics." It was also clear from the survey that future users want the approaches to be deployed in parallel so as to increase the throughput. There is still a great deal of development work to be done before the system can be used in routine diagnostics.

Firstly, however, an investor is being sought to bring the system onto the market. There is no shortage of research questions to be clarified in cancer medicine. Together with Prof. Becker, the Fraunhofer researchers have already initiated a proposal for further investigations on circulating tumor cells. ■

CTCelect on video:
The hurdle race of microfluidic system development
https://s.fhg.de/mikrofluid

Photo: Adobe Stock

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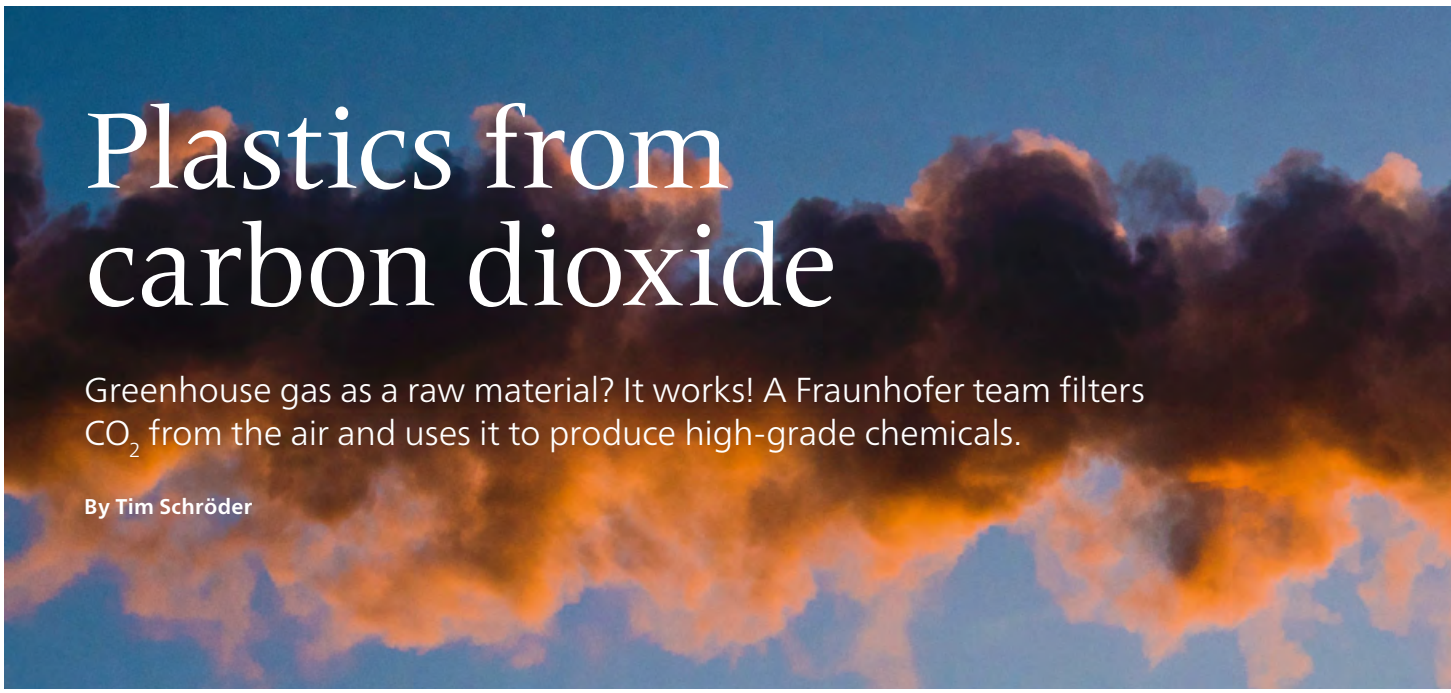


Plastics from carbon dioxide

Greenhouse gas as a raw material? It works! A Fraunhofer team filters CO_2 from the air and uses it to produce high-grade chemicals.

By Tim Schröder

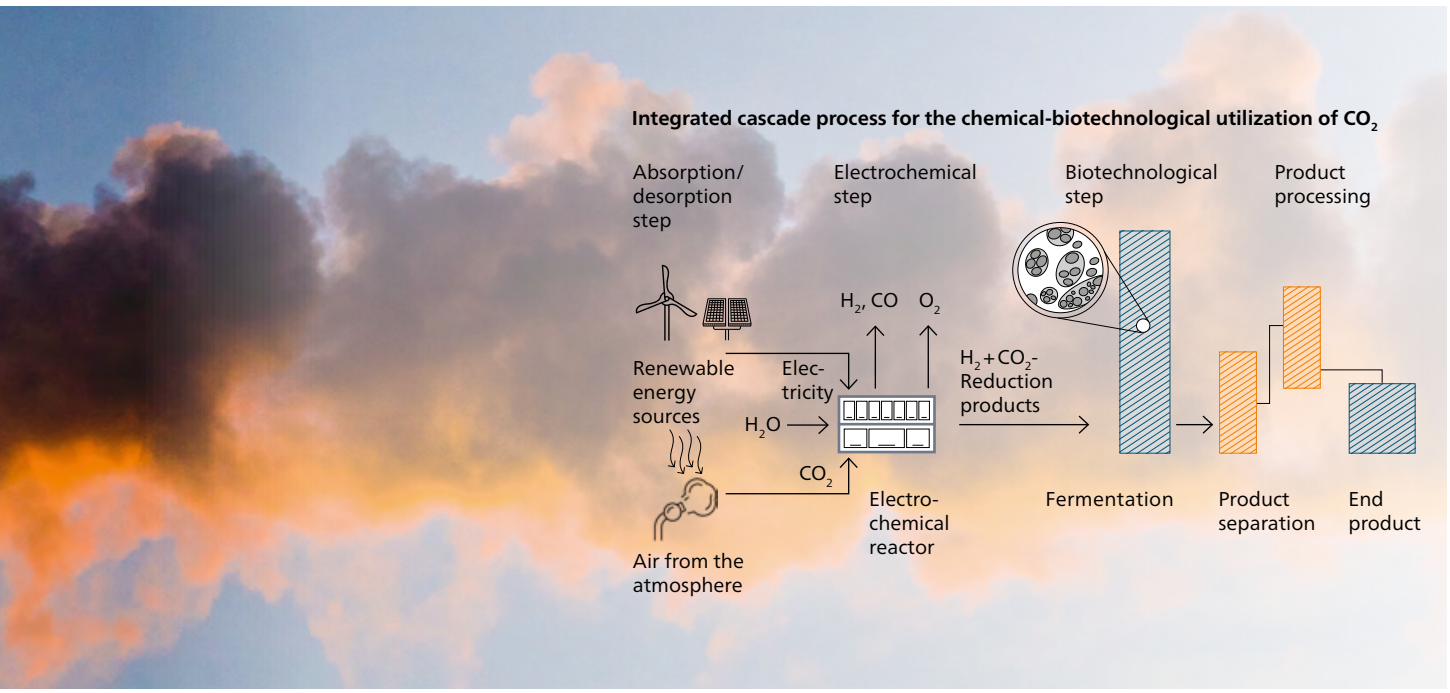
The clock is ticking. If humanity wants to prevent global warming of more than 1.5 degrees on average, then current efforts to save energy are not enough. Carbon dioxide emissions are rising worldwide — apart from in 2020, the year of the coronavirus pandemic. A whole host of further measures are needed to reach the climate targets. An idea from the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB is particularly promising: "We extract the carbon dioxide from the air and use it as a raw material for the chemical industry. For this, however, you need large CO_2 separators and special chemical processes," says Dr. Lénárd-István Csepei, head of the catalysts research field. "This is only economical if you produce particularly high-grade chemicals from the carbon dioxide."

This is exactly what Csepei has succeeded in doing. Together with his colleagues at Fraunhofer IGB and cooperation partners from industry, he has developed a complex procedure as part of the EU-funded Celbicon project. This procedure has the potential to supply a whole host of top-class products made from carbon dioxide in the future. The important thing here is Csepei and his team are linking a technical system with a biotechnological process, at the end of which bacteria produce the valuable chemicals — in much the same way as microorganisms produce insulin today. "There was no such system up to now," says Csepei. "We had to build it completely from scratch." In this process, the various Celbicon partners supplied important elements. The Swiss company Climeworks contributed its system for CO_2 separation. The interior contains a special adsorbent material that specifically binds CO_2. When the adsorbent material is saturated, it is heated to release the CO_2, and this is then stored temporarily.

"Painstaking work"

The Climeworks CO_2 separator was installed directly in the BioCat branch of Fraunhofer IGB in Straubing, which allowed the team to go through the entire chain on-site from carbon dioxide extraction through to the finished product. In the demo system, the carbon dioxide is chemically converted in an electrolytic cell with the aid of catalysts. "Firstly, here at the institute, we had to select the correct catalysts from several hundred," says Lénárd-István Csepei — which was painstaking work. However, it led to the desired outcome. The researchers even found several catalysts that could be used to produce various small compounds containing carbon in the electrolytic cell in a targeted way — including formic acid, methanol and ethanol. These then served as food for the bacteria.

"In Celbicon, we used the bacterium Methylorubrum extorquens in particular", explains Dr. Jonathan Fabarius of Fraunhofer IGB, who led the biotechnological work in Celbicon. "This organism can use simple carbon compounds such as formic acid and methanol as an energy source and produce complex compounds in its metabolic process. Other bacteria usually need very high-energy sugar molecules as food." The team led by Jonathan Fabarius succeeded in genetically modifying the bacterium so that it converts formic acid and methanol into a bright



red dye, known as a terpenoid dye. Terpenes are a chemical substance class that have a variety of uses — not just in dyes but also as flavors and odorants, for example. "We therefore managed to convert carbon dioxide into a high-grade product in a process chain for the first time."

What sounds easy was challenging work. The experts had to link the electrochemical part with the biotechnological part and ensure that there was always enough formic acid available to supply the bacteria culture. Numerous pumps, pistons, regulators and sensors had to be connected up for this. Another goal was automation. After all, these kinds of systems should operate autonomously without interruption.

And what's more, if people want to combat climate change in the future by using CO_2 separators at least to some extent, then very large quantities of carbon dioxide must be extracted from the air. Burning gas, coal and oil releases 38 billion tonnes of CO_2 into the atmosphere every year. Celbicon's target was therefore to increase the system's throughput.

Burning gas, coal and oil releases

38

billion tonnes of CO_2

into the atmosphere annually.

"The technology works"

In the first laboratory tests, the yield was approximately 150 milliliters of formic acid per round. One of the partners, the company Gaskatel, then built a larger electrolytic cell that now produces 10 liters. If you combine several cells, the yield can be increased significantly. That is, of course, still far off the future goal of reaching the thousand-tonne mark. "However, with our system we have proven that the technology works," says Fabarius.

As the next step, the researchers want to tune the bacteria to high-performance. Other microbes such as the intestinal bacterium Escherichia coli, which is used to manufacture medicinal products (among other things), were optimized during research work that lasted for decades. Methylorubrum extorquens is underresearched in comparison, and the Fraunhofer IGB team sees that there is still a need here.

In any case, the potential of biotechnological carbon-dioxide processing is huge, as bacteria can produce a whole host of chemical compounds — including lactic acid and polyhydroxybutyrate, which are suitable for the manufacture of plastics. "Such products are the start of a true circular economy," explains Lénárd-István Csepei. "Carbon dioxide from the atmosphere is converted into products. The more long-lasting these products are, the longer the carbon dioxide remains out of the atmosphere — and they can be recycled." Even if the plastics are burned at some point, the amount of carbon dioxide that is released into the atmosphere is the same as the amount that was previously removed from it. ■

Photo: Jaakko Kemppainen/Unsplash

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About 60 liters of water are needed to dye one kilo of yarn.

Fraunhofer worldwide

Locations of the Fraunhofer-Gesellschaft

Click here for more info:
https://www.fraunhofer.de/en/institutes/international.html

TURKEY

Intelligent recycling of wastewater

Textile manufacturing accounts for 20 percent of the world's industrial water pollution. In the EU project Waste2Fresh, coordinated by Turkey's Konya Teknik University, researchers are working on a closed cycle to collect, recycle and reuse wastewater.

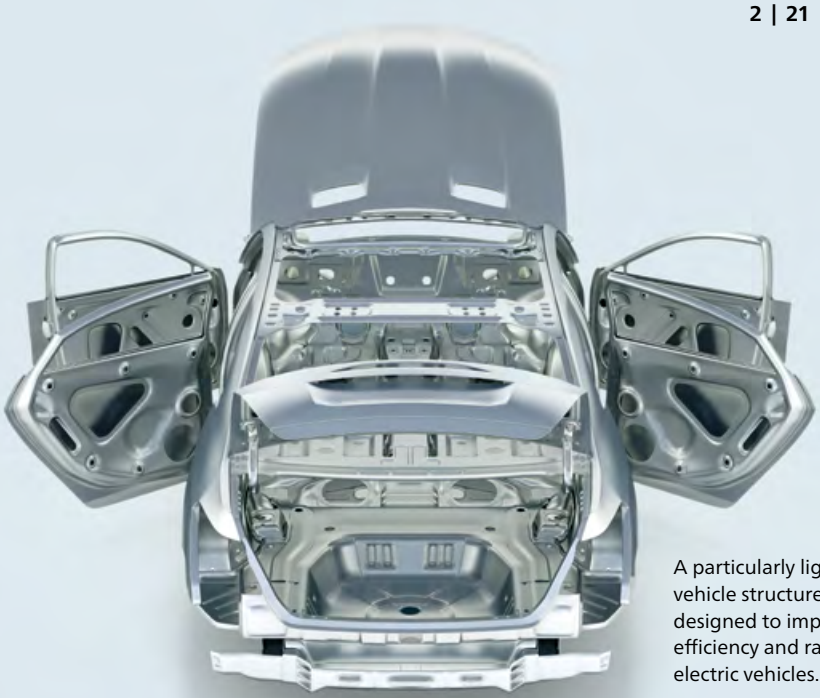
This involves developing catalytic degradation processes with highly selective separation and extraction techniques based on nanotechnology. The Fraunhofer Institute for Biomedical Engineering IBMT tests the nanomaterials in a series of in vitro toxicity studies with human cells. The results will be used to develop safety regulations for the new recycling technology.

The cobots help to reduce health hazards for workers.

ITALY

Industrial robots: Flexible, robust and safe

Fraunhofer Italia, and its partners in the CONCERT project, are developing a new generation of configurable industrial robots with autonomous capabilities and collaborative intelligence. These cobots are capable of independently mapping their environment and executing tasks sent by remote control. Their main feature is their modular construction. The components can be chosen according to form and function and individually assembled depending on the task and environment. Initially, the aim is to use them for physically heavy or potentially hazardous work on construction sites. Applications in manufacturing, logistics and agriculture are also planned.



A particularly lightweight vehicle structure is designed to improve the efficiency and range of electric vehicles.

SPAIN

Less weight, longer range

E-mobility and lightweight construction are key factors in the development of modern vehicles. In the ALMA project, the Fraunhofer Institute for Industrial Mathematics ITWM is working together with eight European organizations to make cars more energy-efficient and sustainable — for example, by reducing their weight. The Spanish Automotive Technology Centre of Galicia is in charge of project management and material characterization. Fraunhofer ITWM creates customized simulation tools that help to predict the strength and damage behavior of individual vehicle parts and to optimize lightweight structures. The goal is to reduce the weight of the vehicle structure by 45 percent.

SWITZERLAND

Digital world receiver

The Fraunhofer Institute for Integrated Circuits IIS, in cooperation with the Swiss company Starwaves, has developed a new Android app that offers interference-free, global digital radio reception on the go. It works even if local mobile networks are not available. The "Starwaves DRM SoftRadio" app includes Fraunhofer IIS developments such as the xHE-AAC audio codec for optimal sound quality at ultra-low data rates and the Journaline service, which provides current news, sports results, weather forecasts, travel tips, traffic info and emergency alerts even when there is no internet reception.

All that is needed to use the app is a common radio receiver dongle with a USB port.

SPAIN

Microelectrodes against nerve damage

With intramuscular thin-film electrodes, the Fraunhofer Institute for Biomedical Engineering IBMT is helping to alleviate pathological tremor and provide alternative therapies. Previously, complex surgical procedures were necessary to implant nerve electrodes. In the EU project EXTEND, coordinated by the Spanish National Research Council, nine partners are developing minimally invasive technologies for real-time communication between nerves and external devices to correct impaired movement, for example through electrical stimulation. Behind it all are so-called bidirectional hyper-connected neural systems (BHNS) that use a network of implanted wireless microelectrodes for synchronized recording, analysis and stimulation of neuromuscular activity.

Photos: istockphoto (2), IIT, Starwaves

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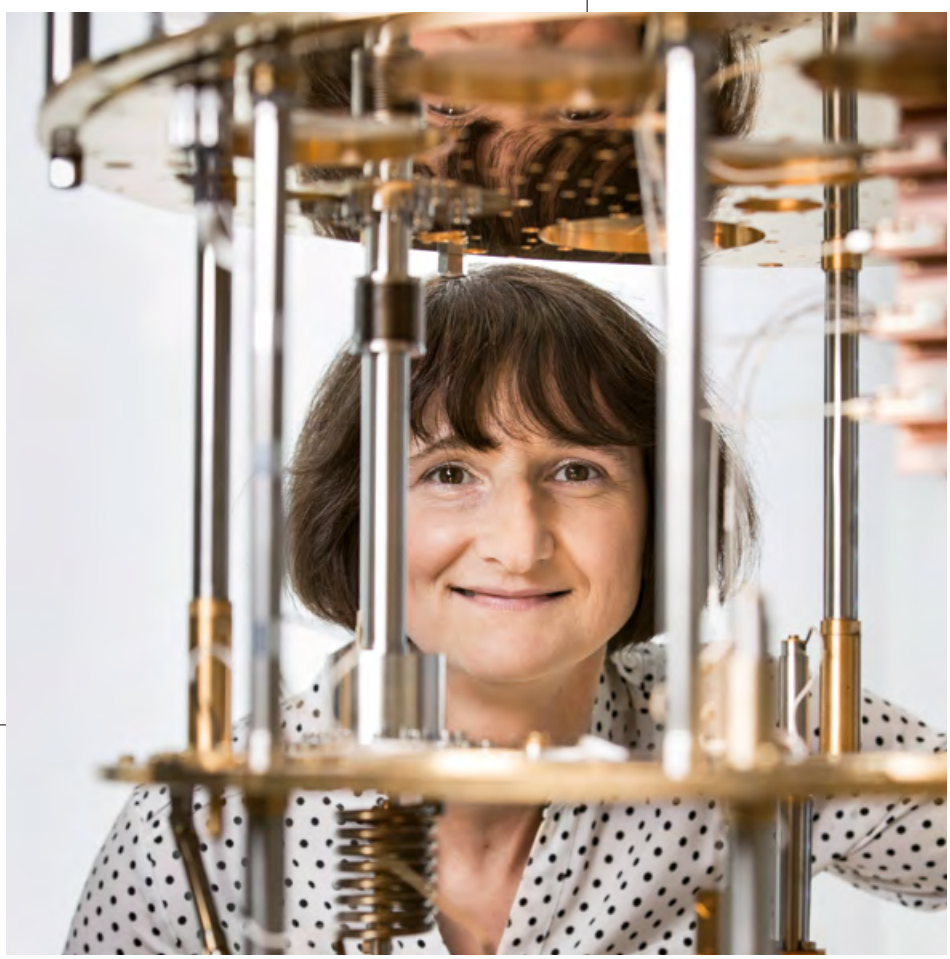
A voice from the business world



Physicist Dr. Heike Riel witnessed the first quantum processor become publicly available in the cloud — "something very special".

"We want to crack unsolvable problems!"

Technological history is being made as we speak: Fraunhofer-Gesellschaft and IBM have brought today's most powerful quantum computer for industry and research to Europe. It is a success story of our joint contribution to the future of research and industry.

A viewpoint of Dr. Heike Riel, IBM Fellow, Head of IBM Quantum Research EMEA & Africa

How did it all start? Right at the beginning of 2015, it was just a small IBM team of physicists at the T. J. Watson Research Center in Yorktown Heights, north of New York City, who unveiled the first 5-qubit processor after years of research in the lab. This small chip has since sparked a technological revolution that has the potential to shape the future of computing for decades to come. In May 2016, IBM made this very first quantum processor available to everyone in the cloud.

This was the moment I realized: Something very special is happening here — the start of quantum computing in the cloud.

A lot has happened since then. We were still faced with the real challenge: to build a quantum computer capable of solving tasks that can revolutionize industries but that classical supercomputers and mainframes aren't able to handle. Applications explored so far include, for example, quantum mechanical simulation of molecules, real-time calculation of risks in investment portfolios or accelerated analysis of elementary particle collisions using AI tools.

From our perspective, this requires bringing together three powerful ways of thinking. First, the scientific mindset, which always seeks to understand the fundamental laws and causes underlying everything. Then the "roadmaps" approach, which sets out a precise roadmap for the development of technology and products over the next few years. And finally, the idea of an agile corporate and team culture, which originates from the world of software and aims to generate continuous improvements and added value within a project.

The scientific mindset is the source of new, groundbreaking ideas — such as the quantum computer. This can only happen if the people involved have a fundamental understanding of the principles and come up with the basic idea. While all this always involves high risk, it hopefully also brings great benefit and gain. And it's not hard to guess: You need a lot of patience. In fact, with the quantum computer, it ended up taking almost 40 years to turn the idea into reality. However, a scientific mindset combined with great collaboration between universities, research institutions and industry can generate truly promising innovations and economic benefits.

"The fact that Fraunhofer, with its direct link to industry, is helping to shape this phase makes me feel very optimistic."

Dr. Heike Riel

- A special day for Dr. Heike Riel: The first IBM Quantum System One was presented to the public in Europe on June 15. The quantum computer is operated in a joint project between IBM and the Fraunhofer-Gesellschaft.
- Heike Riel, born in Nuremberg, trained as a carpenter before studying physics at the universities of Erlangen-Nuremberg and Bayreuth. Her research focused on semiconductor physics.
- In 2003, Heike Riel was named one of the top 100 young scientists by the Massachusetts Institute of Technology's "Technology Review". In 2012, she received an award from the Swiss Association of Women Engineers, and in 2005 she received the Applied Physics Award from the Swiss Physical Society. In 2013, she became an IBM Fellow.

In addition, a clearly defined "roadmap" for the technology is an essential step to building and coordinating an ecosystem of independent partners and their investments. We have made great progress in this direction with our development roadmap for IBM quantum computer hardware and software. It outlines how we will further develop quantum processors and, at the same time, build an open software ecosystem.

Over the next three years, for example, we will increase the number of quantum bits (qubits) on a processor to more than 1000 qubits and simultaneously optimize other parameters that affect performance. Our goal is to use the quantum computer to solve more and more complex problems and to achieve the so-called quantum advantage as soon as possible — in other words, to show that a quantum computer can crack problems that its classical counterparts can't solve.

The variety of potential applications where quantum computers could accelerate or even enable problem solving for the first time is vast. And we will only be able to exploit the full potential of the new technology through close cooperation with companies and research institutions.

With the Fraunhofer-Gesellschaft as the world's leading organization for application-oriented research, a key partner is now getting on board as a vital link between science and industry. The first quantum computers are moving out of the laboratory and into the hands of users from a wide range of industries. The fact that Fraunhofer, with its direct link to industry, is helping to shape this phase makes me feel very optimistic. ■

Photo: Nik Hunger/Swiss Engineering STV

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Air pollution — the downside of global shipping.

Stiff headwinds

Shipping's impact on the environment needs to be drastically reduced. In theory, regulations are clear-cut, but monitoring actual compliance has been a challenge. Now it will be possible to reliably identify the sources of pollution — climate offenders will face stiff headwinds.

By Dr. Monika Offenberger

Global shipping is a major contributor to climate change and pollution. It is estimated that 3 percent of global carbon dioxide emissions, 13 percent of nitrogen and 15 percent of sulfur emissions are caused by maritime traffic. International regulations have been introduced to drastically reduce emissions of these greenhouse gases and air pollutants: Since January 1, 2018, shipping companies have been obliged to report the CO_2 emissions of their ships to the EU when traveling to, from and within European waters. And since January 1, 2020, ships on the high seas have only been allowed to burn heavy fuel oil with a maximum sulfur content of 0.5 percent instead of the previous 3.5 percent. That's the theory. In practice, any regulation is only as good as its monitoring — and that's far from easy. The crucial question is: How can emissions be reliably recorded and clearly assigned to specific ships?

Two research teams are looking for answers at the Fraunhofer Center for Maritime Logistics and Services CML in Hamburg. In the EmissionSEA project, they use records from weather services and navigation data from ships to draw conclusions about their CO_2 emissions. And in the SCIPPER project, the CML is one of 17 partners from eight European countries developing new measurement methods for identifying and quantifying air pollutants. Both projects have a common goal: they want to contribute to global monitoring and assessment of ship emissions. The tools developed in these projects will be available to both shipowners and control authorities in the future. So, what's the difference? EmissionSEA project manager Constance Ugé sums it up in a nutshell: "We estimate emissions, the colleagues from SCIPPER measure them."

The more fuel a ship burns, the more exhaust gases it releases. As we all know from driving a car, consumption depends not only on the size and load of the vehicle and the weather conditions, but also on the chosen route and the driving style. "Only the ship's crew knows these variables. No shipping company would willingly disclose these types of trade secrets, but they are significant in terms of their impact on the environment," says Constance Ugé. Together with the Wismar University of Applied Sciences, the JAKOTA Design Group and the German Aerospace Center, the scientist is developing computational software that generates meaningful estimates even without this internal information. Instead, she matches information from weather services with position data from the Automatic Identification System (AIS): "This radio system was originally set up to prevent ship collisions. But the AIS data also provides information about which ships have sailed where, whether they were large or medium-sized, and how fast they've been moving. From the draft data given, we can conclude whether a particular ship carried a light or heavy load and how much fuel it consumed. And this ultimately tells us how much CO_2 it emitted."

3%

of global carbon dioxide emissions and

13%

of nitrogen emissions are caused by shipping.

The EmissionSEA team wants to process this information and make it available online so that interested shipowners can also benefit from the data. "We have developed a demonstrator that can be used to track the historical routes and CO_2 consumption of individual ships," explains Ugé's colleague Hans-Christoph Burmeister. This should help future users to evaluate alternative shipping routes or different travel speeds based on the CO_2 emissions involved. Above all, it should allow users to compare their own decisions on routes and the resulting consumption values with those of other fleets. "We want to use the system to create awareness and provide guidance on how to optimize fuel consumption and reduce CO_2 emissions, for example through efficient weather routing," says Burmeister, referring to route optimization based on meteorological data.

SCIPPER is less about providing a service to ship operators. "We're working on how to track down and pinpoint emission offenders," says project manager ▶

Photo: Shutterstock

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Jonathan Weisheit, describing the problem: "If a large cloud of pollutants forms over the ocean on a busy waterway, anyone could have caused it. It's safe to assume that shipping companies will deny any responsibility." The research consortium, which received a good five million euros in funding from the EU, has proven that it is indeed possible to pinpoint individual polluters: "Our partners have managed to compare nitrogen clouds detected by satellites with AIS data and assign them to specific ships," says Weisheit. As this is a very complex procedure, other techniques are also being tested for their performance in verifying and enforcing emission regulations as part of the overall project. Five measurement campaigns in European ports and shipping lanes are using sniffers to detect exhaust gases, drones and instruments, such as laser spectrometers and ultra-fine dust meters.

The data captured with these instruments is collected and reviewed at the CML. According to Jonathan Weisheit, this is the first time a Europe-wide exchange of information on different measurement techniques and detection methods will happen on such a large scale: "All project partners can upload their measurement data to our server, where it is visualized. This will provide us with an overview of the emission levels along selected shipping routes. It will also allow us to find out which methods produce robust results under which conditions." His own team is focusing on a solution that is as straightforward and as cost-effective as possible: "We've developed a sensor box that can measure NO, NO_2, SO_2 and CO_2 gases in addition to soot particles, air temperature and humidity. It can be operated directly on board and is easy to use."

This fall, the sensor box should be able to demonstrate what it can do, says Weisheit: "The Swedish shipping company Stena Line has agreed to let us ride on a ferry between Gothenburg and Kiel. We will use the opportunity to measure the same cloud of pollutants with different devices at several positions on board. This will allow us to see how effective the sensor box is compared to more elaborate measurement methods." Jonathan Weisheit hopes that a skillful combination of sensor boxes, sniffers, drones and satellites could make an important contribution to climate protection: "This would create the basis for imposing sanctions on the guilty parties and for rewarding eco-conscious shipping lines who really want to reduce their emissions and invest in the relevant technology." ■

"We're working on how to track down and pinpoint emission offenders."

Jonathan Weisheit, SCIPPER Project Manager

Beautiful yet sometimes harmful: AIS data illustrates the world's shipping routes.

Photo: JAKOTA Cruise Systems GmbH | FleetMon

Matters of the heart

Cardiac catheters: high-quality polymer for demanding tasks.

Even medical devices for the heart can be recycled today. This makes ecological sense and is medically safe — and not only pays off economically, but also for planet Earth.

By Moritz Schmerbeck

Cardiac catheterization is a standard life-saving procedure in Germany: Nearly 750,000 times a year, the procedure gets under patients' skin and penetrates their heart. Electrophysiology catheters or EP catheters, as medical professionals call them, are made of high-quality plastics, and it therefore makes sense to use them more than once. On average, remanufactured catheters save 2.1 hearts, while also helping planet Earth.

Researchers from the Fraunhofer Cluster Circular Plastics Economy CCPE prove that reprocessing medical devices can pay off in more ways than one. The Fraunhofer scientists are investigating the life cycle of EP catheters, comparing the production of new catheters with medical remanufacturing. Their findings show that medical remanufacturing reduces the carbon footprint by more than 50 percent and resource consumption by nearly a third.

Patient safety comes first. The seemingly short lifespan of a cardiac catheter is not due to a lack of high-quality material. Instead, it is driven by the high standards of certified remanufacturing processes. The medical devices must undergo validated cleaning and sterilization procedures as well as extensive functionality and hygiene tests. Before they can be used again, they have to clear numerous hurdles without any errors — even an illegible serial number can mean an early end for the product.

On average, a catheter saves **2.1 hearts.**

Medical remanufacturing is often the only chance for medical devices to remain in circulation. They are mostly made of high-performance polymers with excellent properties. In the case of cardiac catheters, the plastic must be particularly smooth, stable and flexible to pass through the veins to the heart without causing injury. However, recycling these types of special plastics is not feasible on an industrial scale and therefore uneconomical. If the cardiac catheters are simply thrown away, they end up in a waste incinerator to generate at least a spark of energy. Or they are taken to a landfill, where they outlive the cardiac catheter patients many times over thanks to their durability. Medical remanufacturing, on the other hand, ensures that the required quality is maintained and continues to meet the high medical standards even when used a second time.

The ecological and economic synergy is a model for many other fields of application. Anna Schulte, who is in charge of the studies at the Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT, sums it up: "Our study has shown that medical remanufacturing of single-use medical devices leads to significant savings in both carbon footprint and resource consumption, compared to the new production of cardiac catheters. It's a great example of how the transformation to a circular economy can succeed, even in the highly sensitive medical sector."

Numerous hospitals already rely on medical remanufacturing and appreciate its cost-effectiveness. It can provide sustainable relief for the healthcare system, without compromising on safety and functionality. ■

Photo: Vanguard AG

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From small radio sensor to large ecosystem

A team of researchers from Fraunhofer IIS has developed the market-ready mioty® radio transmission system for the Internet of Things and is receiving the Joseph von Fraunhofer Prize for it.

By Dr. Janine van Ackeren

Every researcher's dream is to make a difference and change things for the better. A team of researchers at the Fraunhofer IIS was able to make this dream come true. Communication is key both on the Internet of Things and over long distances.

"Our goal was to create an entire ecosystem and advance radio technologies to the point where they can compete against other systems on the market and even far surpass them," enthuses Michael Schlicht, division director at the Fraunhofer IIS. They have succeeded brilliantly in doing so: The research team not only worked out the basic mioty® technology, filed 30 patent families and initiated a startup, but also standardized the technology internationally, founded an industry alliance, set up a patent pool and concluded the first licensing agreements worth millions. Michael Schlicht, Josef Bernhard and Gerd Kilian will be awarded the Joseph von Fraunhofer Prize on behalf of the team. Explaining its award decision, the jury highlighted factors including the "consistent introduction of new technology for connecting sensor networks with a large number of simple, battery-operated sensor nodes".

Prizewinners: Prof. Michael Schlicht, Josef Bernhard and Dr. Gerd Kilian (from top).

Technology of the times

The networking of objects in the Internet of Things, or IoT, is a hot topic. If market analyses are to be believed, between 20 and 40 billion connected IoT devices will be needed by the year 2025. Essential elements here are simple, energy-efficient and battery-operated sensor nodes, consisting of a sensor and a radio system, that communicate with a base station over several kilometers. The amount of data involved is usually small to very small, and only needs to be transferred occasionally or sporadically. Examples include water meters that are read wirelessly. But until now, there has been a lack of suitable, reliable communication methods that would allow many thousands of data packets to be transmitted at the same time — previous technologies were very susceptible to interference. On top of this, data transmission would have to be energy-efficient, the system would have to remain stable for many years, and it would have to be easy to expand with new sensors.

mioty® offers a completely new approach to this challenge: It transmits the data from between several thousand and a hundred thousand sensor nodes per square kilometer — in other words, up to 1.5 million data packets a day — to a single collection point without any loss, even in areas without cellular coverage and all at a bandwidth of just 200 kilohertz. The end devices are so energy-efficient that the batteries last up to 20 years. Mobile operation of the sensor nodes in vehicles is also possible, even when driving down the highway at more than 120 kilometers per hour. "mioty® is invaluable wherever many small objects need to be networked in an energy-saving and secure manner over many years," concludes Kilian. Which begs the question: How did the research team manage to do it? "The trick is that we don't send the sensor data in one piece, but chop it up into many small pieces," reveals Kilian, who contributed his expertise in implementing the actual technology.

Joseph von Fraunhofer Prize

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

Measurements are taken everywhere — but how can the data be transmitted reliably and with low energy consumption over long distances?

Splitting the signal not only has a positive effect on the energy consumed by the sensor node, but also makes the transmission more robust: Even if some data snippets get damaged on their way to the collection point, the message can still be completely restored.

mioty® can be used for many different things: Environmental data collection in agriculture, checking pipelines for corrosion and leaks as well as controlling air-conditioning systems or remote maintenance and monitoring of plants such as refineries. "The applications are as varied as the data snippets that need to be transferred," confirms Schlicht, who brought his experience in licensing and marketing to the team.

The objective: Standardization, marketing and licensing

Another special feature: The research team not only developed the technology, but also submitted it to an ETSI specification — the European Telecommunications Standards Institute ETSI creates global standards for information and communications technology. Josef Bernhard led the work in the standardization group and emphasizes one of the unique selling points of the mioty technology: "mioty® offers the first standardized, low-power wide-area communication solution based on our telegram splitting technology." However, a radio communication system alone is difficult to market; after all, customers need solutions, not just technologies. Since 2018, BehrTech from Canada has been one of the companies taking on the task of developing and marketing mioty®-based solutions. For interested companies looking for chip design suppliers or distributors of the mioty® software, the international "mioty alliance" is the perfect point of contact. It currently has 25 members, including well-known companies such as Texas Instruments, Diehl, Ragsol and Stackforce. For licensing purposes, the mioty® patent pool was founded by the Sisvel company. "With a fair amount of agility and persistence, we have turned an initial idea into a licensable product on the market: a standardized radio protocol that will hold its own in the real world," Bernhard is certain. ■

Photos: Fraunhofer / Piotr Banczerowski

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Lukas Kopieth and Prof. Christian Doetsch (right) present a revolution in storage technology: Their redox flow battery is 80 percent lighter — and material costs are 40 percent lower.

Key technology for energy transition

Redox flow batteries are perfect for storing large quantities of regenerative energy, but they still have one disadvantage: the high cost of materials. Researchers at Fraunhofer UMSICHT had the courage to completely rethink the structure of the battery.

Sometimes the best ideas are born in the break room. A development of the Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT in Oberhausen also took shape there.

Prof. Christian Doetsch and Dr. Thorsten Seipp used a coffee break to discuss an important question: What is a simpler and, above all, more cost-effective way to design redox flow batteries, which are used to store regenerative energy until it is consumed?

In the middle of the exchange, Lukas Kopietz joined the small group. Instead of conducting research in the field of energy, like his two colleagues, he is involved in the development of plastics. It was actually this background that gave the trio their groundbreaking idea: "Couldn't we change the way electrically conductive plastic is manufactured so that it remains flexible and can be welded?" Lukas Kopietz mused aloud.

His colleagues were immediately won over. "If that's possible," enthused Thorsten

Seipp, "then you could completely rethink the entire stack structure ..."

Though that's no mean feat. After all, redox flow cells are one of the key technologies for energy transition: They offer cycle stability, meaning their capacity barely decreases after thousands of cycles, are non-flammable, and their output and capacity can be designed to meet demand. What's more, they also don't use any critical materials, and their electrolytes can be fully recovered. So far, however, they have simply been too expensive for the mass market.

Inexpensive, lightweight and compact

Starting from the break room idea, a finished product has now been created, which is marketed by the spin-off VOLTERION: The newly developed stack at the core of every redox flow battery offers a number of benefits: material costs are down by 40 percent, production costs have also been significantly reduced, it weighs 80 percent less than a conventional stack and is only about half the size. Christian Doetsch and Lukas Kopietz from Fraunhofer UMSICHT and Dr.-Ing.Thorsten Seipp from VOLTERION GmbH have been awarded the Joseph von Fraunhofer Prize for this development. Explaining the reasons for its decision, the jury mentioned "the spin-off and its successful exit from Fraunhofer, which serves as a prototype for marketing new manufacturing technologies".

Commercially available stacks usually consist of 40 cells, which in turn are made up of a plastic bipolar plate, an anode, a membrane and a cathode. In total, this adds up to 160 stacked components, which are held together with a large number of screws and solid metal plates and sealed with many seals. The plastic bipolar plates are injection molded. However, during this procedure they lose their malleability and become brittle — the material ends up resembling that of a pencil lead. Lukas Kopietz's idea of making the plastics both flexible and weldable could make it possible to forgo the numerous seals that become brittle over time. Without further ado, he set to work and gave it a go. "It quickly became clear that this could be really something — even if we didn't quite realize the extent of the development effort involved," recalls Doetsch. "But Lukas believed in his new plastic material, and I believed in Lukas' ability to pull it off."

"Previously, customers were used to stacks that had to be moved into place with a crane. So it's a big selling point if you can just pull the stacks out of the trunk with two people."

Dr. Thorsten Seipp

The high temperatures and pressures needed in injection molding are problematic. To get around this issue, the research team uses similar starting materials, i.e. graphites and carbon blacks, but prepares and processes them differently. More specifically: Plastic in the form of pellets is cooled to temperatures as low as minus 80 degrees, then ground into powder and mixed with 80 percent graphite by weight. The research team passes the resulting powder through a system of several different heated rollers — this is known as a calendering process. The powder is briefly melted between the rollers at moderate temperatures and low pressures and then rolled into sheets. "Crucially, this gives the new material thermoplastic properties, so it's flexible and can be welded even though only 20 percent of it is plastic," explains Lukas Kopietz. The stack uses no seals whatsoever, and even screws are unnecessary — the cells are simply welded together. A further advantage here is that this method not only allows bipolar plates to be produced much faster and thus more cost-effectively, but there are also no longer any size limits. Bipolar plates up to several square meters in size can be manufactured without problems.

Implemented right through to the battery at VOLTERION GmbH

The second step — crucial because it also reduces costs — was to develop a continuous production process: the roll-to-roll process, in which the bipolar plates can be manufactured as an "endless" roll. Very thin plates can be produced in this way. In the injection molding process, the plate has to be several millimeters thick due to the production method, but in the roll-to-roll process it can be between just 0.1 and 0.4 millimeters. As a result, the stacks need much less material, which reduces the price and makes them lighter and more compact. "This opens up totally new possibilities in design, which we have implemented right through to the complete battery at Volterion GmbH," says Seipp. "Previously, customers were used to stacks that had to be moved into place with a crane. So it's a big selling point if you can just pull the stacks out of the trunk with two people."

VOLTERION has already built more than a thousand stacks and launched them on the market. As for the Fraunhofer researchers, they have sold the technology completely to VOLTERION. "This will allow us to focus on the topic of fuel cells or electrolysis in the future — in other words, to realign ourselves and take a different direction," says Doetsch. And perhaps also contribute something revolutionary in this industry. ■

Photos: Fraunhofer / Piotr Banczerowski

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Unrivaled

Electronic microchips are set to become ever smaller, faster and more powerful. Fraunhofer ISIT and IMS Nanofabrication GmbH have landed a coup: a mask writer with no alternative when it comes to the latest generation. This won them the Fraunhofer Prize.

Smaller, faster, more powerful: This sums up the continuous development of smartphones and other electronic devices. At the heart of these devices are microchips, which — as can be expected — must also become even smaller and better in the course of this development. For decades, this has worked well, but many manufacturing technologies are now reaching their limits.

An innovative technology offers the world's only current solution: the electron multi-beam mask writer, developed by Vienna-based IMS Nanofabrication GmbH. The key component in this device comes from the Fraunhofer ISIT. Previously, it was only possible to achieve process sizes of just under 10 nanometers on the chips — an atom is 0.1 nanometers — but the new manufacturing method makes process sizes of 7 nanometers and less a possibility. In short: There can be up to 91 million transistors per square millimeter! This is unrivaled worldwide, and there is no way around the electron multibeam mask writer for further miniaturization of chips. The fact that "this technology enabled IMS Nanofabrication GmbH to achieve its market-leading position" was also praised by the jury for the 2021 Joseph von Fraunhofer Prize, who gave the award to Michael Kampmann and Martin Witt from Fraun-

hofer ISIT and Dr. Jacqueline Atanelov from IMS GmbH.

Chip production: A crash course

In order to understand the award-winning development, it is first necessary to have a look at conventional chip production. In this process, a wafer made of the semiconductor material silicon is evenly covered with photoresist. A small image is projected onto this "silicon wafer," which can be up to 30 centimeters in size, via a mask in an exposure device with fourfold reduction, by shifting the silicon wafer several times so that the entire wafer surface is exposed with fine structures — similar to a slide on a screen. In the exposed areas, the resist hardens; in unexposed areas, it remains soft. The soft resist is removed in a developing bath, where the silicon lies bare and can be processed in a precise manner: It can be coated, etched with structures, or its electrical properties can be changed. The photoresist is then removed from the previously exposed areas that were still covered, and the entire wafer is covered again with new layers and photoresist. For complicated chips, these steps are repeated with up to 70 different masks until the complex switching elements — referred to as transistors — have been created on the wafer. The silicon wafer is then cut into individual parts, the chips, using a diamond saw.

To produce the masks required for the targeted exposure of the photoresist, square quartz glass wafers are vapor-deposited with metal — the procedure is similar to that used in chip production. However, fine-structure masks use a resist that is sensitive to impinging electron beams. Recently, extended ultraviolet (EUV) exposure devices have been developed in which the wavelength of the "light" is only 13.5 nanometers. The EUV masks required for this must be written with complex nanostructures under 40 nanometers in size with very high density — since the projected image is reduced fourfold, structures of less than ten nanometers result on the silicon wafer. However, this means the current single-beam electron mask writers are reaching their limits. If you wanted to produce even smaller and denser structures, it would take more than a day to do so, which is not economical and does not meet the high quality requirements of nanostructures.

The solution to this microchip problem was developed by Michael Kampmann, Dr. Jacqueline Atanelov and Martin Witt (from top).

Complex structures within a few hours

So, what is the key feature of this new method? "Instead of writing the structures on the electron-sensitive photoresist with a single beam, we use 512 x 512 beams, so 262,000 beams," summarizes Kampmann. "This allows us to create complex structures in high quality and resolution in just a few hours," adds Atanelov. But this also means that it must be possible to program each of these 262,000 beams individually and exactly. This is where the micro-electromechanical system (MEMS) switching element from Fraunhofer ISIT comes in, which essentially forms the core of the new multi-beam mask writer. In simple terms, this microsystem switching element is like a membrane with 262,000 openings that allow the electron beams through. But unlike jets of water from a shower head, these beams do not run in parallel. Instead, they can be individually controlled and redirected by special control electrodes. The deflected beams can subsequently be blocked out.

It took the team a while to understand how the more than 200 necessary individual steps in MEMS manufacturing technology interact — and how they can be structured and enhanced. "At numerous points, we had to rethink and combine existing MEMS technologies," Witt explains. "For example, electrostatic optimization was difficult because if the MEMS switching element becomes electrostatically charged, the negatively charged electrons don't pass through." The research team solved this by adding metal layers to the membrane so that the excess charges can flow off.

There isn't currently any technology that rivals the innovative electron multibeam mask writer. And it is indispensable if you want to write the smallest possible structures on microchips. The market demand is correspondingly high. IMS currently generates annual sales of $400 million with its devices. The market forecast for 2022 corresponds to a sales volume of almost one billion US dollars. The impact can be seen at Fraunhofer ISIT as well: Industry revenue is now well in excess of one million euros a year. This prize-winning technology not only enables further miniaturization, but is also bringing about outstanding commercial success. ■

Photos: Fraunhofer / Piotr Banczerowski

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Safe vaccines — and free of chemicals!

Making vaccine production more environmentally friendly, faster and more efficient? A team of researchers from three Fraunhofer Institutes have successfully thought outside the box. In recognition of their achievement, they have been awarded the Fraunhofer Prize for "Human- and Environment-Centered Technology".

A small pinch — and then back to the usual daily routine? Only time will tell to what extent this global hope will be fulfilled. But this much is clear: Vaccines are currently a great source of hope for many people, as it is believed they will help to protect society against COVID-19 and pave the way back to a normal life. The current focus is clearly on coronavirus — but vaccines are also fundamental in combating other pathogens.

The methods available to produce vaccines have been known for decades. However, a team of researchers from three Fraunhofer institutes has shown how sometimes it is worth going outside of your comfort zone and thinking outside the box when it comes to established processes. The result is a process for producing inactivated dead vaccines that not only allows vaccines to be manufactured faster, but also in a more environmentally friendly, efficient and cost-effective way than before. Dr. Sebastian Ulbert and Dr. Jasmin Fertey from the Fraunhofer Institute for Cell Therapy and Immunology IZI, Frank-Holm Rögner from the Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology FEP, and Martin Thoma from the Fraunhofer Institute for Manufacturing Engineering and Automation IPA have been awarded the 2021 Fraunhofer Prize for "Human- and Environment-Centered Technology" on behalf of their teams. The jury emphasized "the simple and efficient method for largely retaining the structures that are important to the efficacy of the vaccine and the complete avoidance of chemical additives that would otherwise be necessary."

Award winners Dr. Jasmin Fertey, Frank-Holm Rögner and Martin Thoma (from top) rejoice with their teams.

How electron beams can replace chemicals: Killing a virus in milliseconds

Until now, the production of inactivated vaccines has been based on chemicals. The pathogens are first cultivated on a large scale and then stored in toxic chemicals, primarily formaldehyde, until the viruses' genetic information is completely destroyed and they can no longer propagate. This process is known as inactivation. If these "dead" viruses are injected into the body during vaccination, the immune system recognizes the now harmless invaders and forms the corresponding antibodies. However, inactivating viruses through chemical treatment is problematic on many levels. Firstly, the chemicals destroy not only the genetic information inside the virus, but also part of the external structures that the immune system needs to form the antibodies. Secondly, industrial-scale vaccine production generates large quantities of toxic chemicals, presenting a challenge for occupational safety and a burden for the environment. And depending on the virus, it may take weeks or even months for the virus to actually be "killed."

"Instead of inactivating the virus with toxic chemicals, we fire electrons at it."

Dr. Sebastian Ulbert, Fraunhofer IZI

The team's innovative approach gets rid of all these drawbacks. "Instead of inactivating the virus with toxic chemicals, we fire electrons at it," explains Ulbert. "The outer shell of the viruses remains almost completely intact, we have no chemicals to dispose of, and the whole process takes only a few seconds." As for disinfecting medical materials, ionizing radiation has been used for decades — but that involves radioactive gamma radiation or high-energy electrons in the megaelectron volt range. Couldn't the much less dangerous and easier to handle low-energy electron beams in the kilo-electron volt range be used to inactivate viruses? There was one hurdle to overcome: The electron beams can only penetrate liquids to a depth of a few hundred micrometers, progressively becoming weaker. If viruses circulating in the liquid are to be reliably killed by the beams, the liquid film must be no thicker than about 100 micrometers — and it must be transported evenly, too. "This required complex equipment technology, which is why we brought Fraunhofer IPA on board," says Rögner.

"The whole process only takes a few seconds," says Dr. Sebastian Ulbert, explaining one of the major advantages of the new technique.

Photos: Fraunhofer / Piotr Banczerowski

The road to an industrial application

It was a winning formula: At Fraunhofer IPA, Martin Thoma developed two ways to overcome the problem. "The pouch module is suitable for conducting preliminary tests that provide useful information — here, about 30 milliliters of liquid are transported in a sealed bag and irradiated," explains the physicist. On the other hand, the tumbler module is beneficial for larger quantities. The viral liquid is contained in a completely closed, encapsulated container. A rotating roller is half immersed in this liquid and is wetted with a thin film of liquid as it rotates. This is irradiated and stripped off before the roller takes up liquid again. Fertey studied TBE, influenza and herpes viruses, bacteria such as tuberculosis, as well as numerous other pathogens previously subjected to this procedure. "We were able to successfully and reliably inactivate all classes of pathogen," says the delighted biologist.

The potential offered by the development was also recognized by the Bill & Melinda Gates Foundation, which invested $1.84 million in the industrial-scale development of a prototype. This was completed in 2018 and put into operation at Fraunhofer IZI before undergoing further development. The next year, the team of researchers obtained a licensing partner and secured licensing revenue of nearly a million euros on the basis of contractual agreements. The production modules — which are the size of a refrigerator — could be integrated into pharmaceutical production in around five to seven years in order to produce vaccines in a quick, efficient and environmentally friendly process. ■

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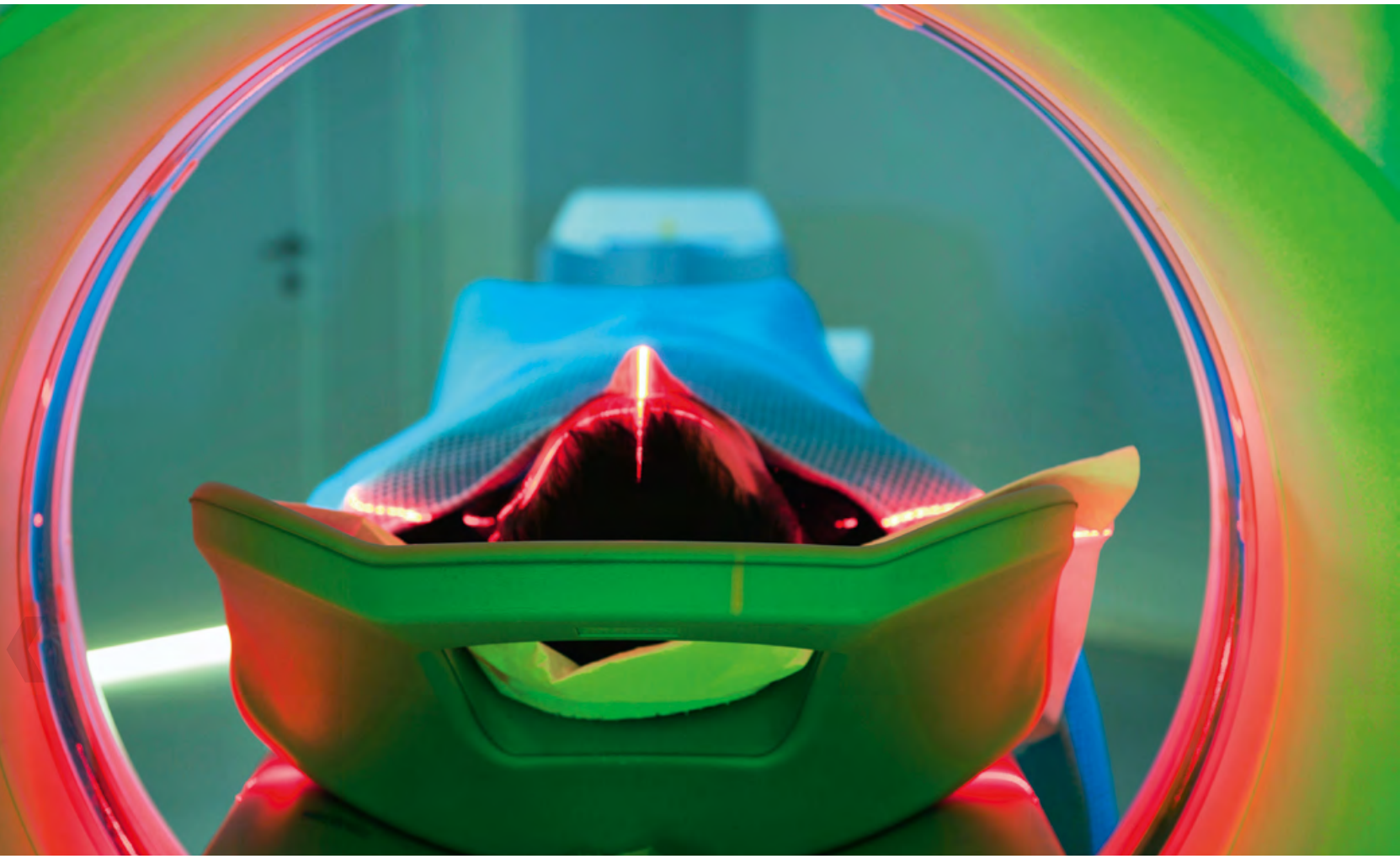


Metamaterials make MRI scans better and easier

They are the ultimate technology in medical diagnostics: MRI scanners provide detailed images of the inside of the human body. Fraunhofer researchers have now developed a technology that boosts measuring efficiency to the next level. At the same time, it makes the process less troublesome for patients.

By Mehmet Toprak

These days, magnetic resonance imaging (MRI) is one of the best non-invasive diagnostic imaging methods available to detect for detecting pathological changes in the body. The Fraunhofer Institute for Digital Medicine MEVIS in Bremen and the Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR in Wachtberg are working hard to improve the technology: boosting measuring efficiency while reducing the stress for patients, and all of this without replacing the existing devices.

MRI uses a strong magnetic field, usually generated by a cylindrical electromagnet, which penetrates the patient's body. The nuclei of the hydrogen atoms in the human body are aligned by this magnetic field and behave similar to small spinning tops. High-frequency pulses from special coils then force the atomic nuclei to move in precession. After each pulse, the atomic nuclei oscillate back to their resting position, releasing the previously absorbed energy in the form of radio waves. These radio waves are detected by coils, processed by a computer and assembled layer by layer to form a detailed image of the inside of the human body.

MRI excels in the field of tumor diagnostics, but it can also be used to examine organs in the abdominal cavity, the heart, bones, cartilage and muscle tissue, and even the brain. Figures provided by the statistics service Statista show that 143.4 MRI examinations were performed per 1000 inhabitants in Germany in 2017 alone.

Metamaterials bundle signals

To enhance MRI performance and enable new applications, researchers at the participating institutes are employing so-called metamaterials. "Their properties are modified to make them react automatically to certain external influences, without the need for any active control," explains Dr. Thomas Bertuch, team leader at the Fraunhofer FHR. Metamaterials are used in a wide range of fields, such as thermics, seismics, acoustics, optics or antenna technology, one of FHR's specialties.

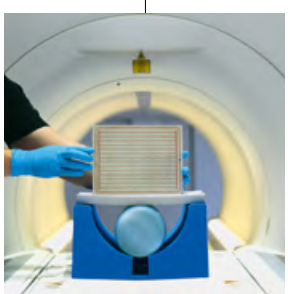
The metamaterials used in the Fraunhofer project consist of plates with printed, periodically arranged conductor tracks, which improve the reception signals of the MRI coils without requiring their own power supply.

In the MRI, these plates are placed on the specific region of the human body to be examined. It would also be possible to apply the conductor tracks to a foil and wrap it around a knee joint, for example. When the hydrogen nuclei in the body send back the radio waves, the metamaterials are excited, bundle these signals and pass them on to the receiving coils in the MRI scanner. This strengthens the measurement signals and has the same effect as increasing the measurement sensitivity of the scanner. The examining physician benefits from an image where the respective region of the body appears as if under a magnifying glass or a spotlight — and in greater detail than in a conventional MRI image. "When we use the metamaterial device together with the coils installed in the MRI, we can increase the signal-to-noise ratio by a factor of up to five," explains Bertuch. The metamaterials have also been engineered with optimal patient safety in mind to enable easy translation into clinical practice. Non-linear detuning elements ensure that only the measurement signal is boosted, while irradiation into the tissue remains at the same level.

When the increase in signal is not actually required for diagnosis, the duration of the MRI scan can be shortened instead. Dennis Philipp, research fellow at the Imaging Physics & Devices department at Fraunhofer MEVIS, says: "In principle, physicians have a choice, depending on the application: They can either opt for higher image resolution in a standard amount of time or settle for standard resolution, but a faster procedure."

The technology was extensively tested at Fraunhofer MEVIS in Bremen. "We've basically used everything from onions to grapefruit or kiwi as a test object," Philipp smiles. "The metamaterials work with existing MRI equipment, so the new technology could quickly become standard in hospitals, doctors' offices and medical centers in the future." Neither the software nor the internal electronics of the MRI scanners need to be replaced. Validation studies are now the next step on the way to clinical practice. ■

The new technology developed by Fraunhofer works with existing MRI equipment and could quickly become standard.



143.4

MRI examinations per 1000 inhabitants in Germany in 2017

Photos: istockphoto, Fraunhofer MEVIS

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The dream of eternal life

A plant that keeps growing, flies with a Methuselah gene — this research could also help humans to combat cancer.

By Christine Broll

Tobacco is an annual plant. It germinates in the spring, grows to a maximum height of 1.50 meters, forms flowers and seeds and dies in the fall. The giant tobacco in the greenhouse at the Fraunhofer Institute for Molecular Biology and Applied Ecology IME in Aachen is nothing like it. It has reached a height of more than four meters, with a sturdy trunk bearing unusually large leaves. In fact, its life expectancy has now more than tripled. And what's more, it doesn't stop growing.

"Longaevitas", or longevity, is the name of the working group investigating the unusual growth of the giant tobacco plant. Dr Philip Känel is in charge of the Attract working group. The biotechnologist is working on a family of genes that regulate development in bacteria, plants and animals. In the giant tobacco, Känel and his colleagues used gene transfer to increase the production of a flower-inhibiting protein. Instead of flowering, the tobacco plants simply kept on growing.

Flies injected with the Methuselah gene live up to **40 %** longer than untreated flies.

However, increasing tobacco production is not Philip Känel's real goal. "We are using this model plant to investigate the role of PEBP proteins in plant signaling systems," he explains. "Our aim is to find factors that can be used in practical applications." His plan is to transfer the knowledge gained on tobacco plants to important crops.

Philip Känel has not only experimented with flower-inhibiting genes, but also with flower-activating genes, leading him to try something totally new: He introduced a flower-activating gene from tobacco plants into Drosophila flies by inserting the gene into a vector that incorporates it into the DNA. He then injected this gene carrier into fly eggs. And sure enough: The gene was actually active in the flies, producing a unique effect: It acted like a Methuselah gene. Instead of dying after the usual 40 to 50 days, the flies only died after 60 to 65 days. And they didn't just live 30 to 40 percent longer than normal Drosophila flies, they were also more energetic in old age than untreated flies.

The tobacco plant on the left has far exceeded its life expectancy — and continues to grow.

Untreated tobacco plants grow to a maximum height of 1.50 meters. The giant tobacco plant keeps growing — to over

4

meters.

"We've noticed that the protein produced by the tobacco gene influences various processes in the flies," reports Philip Känel. It migrates into the cell nucleus and acts on gene regulation, but it also interacts with various proteins.

Several of these interaction partners are already known to science. One of them ensures that protein homeostasis in the body remains intact, in other words, that there is a healthy balance between the synthesis, repair and degradation of proteins, even in old age. Other interaction partners of the tobacco protein play a role in the TOR signaling pathway, which uses many variables to regulate the metabolism. "Numerous studies have already investigated the TOR signaling pathway. These have shown that influencing the signaling pathway can extend the lifespan of a wide variety of organisms," explains Känel.

He also works with the PEBP genes in humans. "Two members of this family play an important role in the development of cancer," says the scientist. This is because PEBP genes are at the interface of signaling pathways that decide whether a cancer cell dies or continues to grow. By inserting plant PEBP genes into cultured human cancer cells, Känel hopes to uncover the signaling pathways and identify potential targets for new cancer drugs. PEBP genes could then also be used to prolong life in humans.

Starvation mode without suffering?

Want to turn back your biological clock? Maybe you should go hungry more often. This applies just as much to water fleas as it does to fish, mice and rats and is due to a protein called TOR. It is inhibited during starvation phases, causing cells to switch to starvation mode. They stop growing, recycle defective proteins and trigger repair mechanisms, all of which seems to be good for the organism. And while the cells stop dividing, no cancer can develop.

Ever since they found out about this phenomenon, gerontologists have been preoccupied with one question: How can we switch on starvation mode without suffering? In experiments with mice, the immunosuppressant rapamycin showed the desired effect. The lifespan of the animals increased by an average of 14 percent, proving that drugs can extend life expectancy. Due to its strong side effects, however, rapamycin is not suitable for long-term use in humans.

The most promising candidate for an anti-aging drug is the diabetes drug metformin, which has already been in use for decades. Like rapamycin, it inhibits the TOR signaling pathway. In a year-long clinical trial involving nine subjects, Californian researchers tested a therapy that combined metformin with two other active ingredients. The results astounded experts: The treatment reversed the biological age of the test subjects, measured by changes in their DNA, by about two and a half years. In the U.S., the American Association of Aging Research is currently preparing a large-scale metformin study (TAME). More than 3000 people will be tested to see whether metformin can delay the development and progression of age-related diseases. ■

Photo: Fraunhofer IME

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Flying safely once again

Airbus and Fraunhofer are on the hunt for new ways of disinfecting airplane cabins — and it's leading them into some unfamiliar territory.

By Christine Broll

Imagine it: you just hop on a plane, leave your own four walls behind and head for the sun. But when Dr. Natalia Sandetskaya and Arianna March step into the airplane cabin, it's not bags of summer reading and sunscreen they're carrying. Instead, the two scientists from the Fraunhofer Institute for Cell Therapy and Immunology IZI are carrying a suitcase packed full of laboratory equipment — and they will not be jetting off any time soon. The cabin that they are standing in is actually a full-scale airplane model, located in a vast hangar on the Airbus site in Hamburg.

Natalia Sandetskaya and Arianna March hope to use their lab equipment to return air travel to the safe, normal experience it was before the pandemic. They are testing out disinfection methods to determine which one eliminates the SARS-CoV-2 virus most effectively in airplane cabins — information Airbus then intends to pass on to other airlines. ▶

Photo: Ramon Kagie/Unsplash

The fascination of flying: If you're looking for a rare experience with truly spectacular views, the St. Martin Airport in the Caribbean has it all, taking off next to a white beach.

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Dr. Natalia Sandetskaya (l.) and Arianna March have prepared plastic samples with a virus solution, which they now distribute in the airplane model.

The groundwork for this field experiment began several months earlier in a Fraunhofer IZI safety lab in Leipzig. "Airbus also wanted the project to investigate whether heating the cabin is a reliable method of exterminating the SARS-CoV-2 virus," explains Dr. Jasmin Fertey, who is leading both this project and the Vaccine Technologies Unit at Fraunhofer IZI. They are focusing on those areas of the cabin that the passengers come into contact with, like the fold-out tables. When an infected passenger sneezes or speaks, the expectation is that virus-laden droplets will accumulate here in high concentrations.

How long can viruses survive on airplane tables?

Examining an airplane table in a safety lab would be quite a tricky process, so Airbus provided Fraunhofer IZI with stamp-sized samples of the plastic used in the tables. For the purposes of the test, the project team grew the SARS-CoV-2 virus in cell cultures in-house. All experiments took place in a special laboratory that complies with biosafety level three precautions. The scientists adopted various safety measures,

Field tests: Fumigation with vaporized hydrogen peroxide, spraying of disinfectant, irradiation with UV-C light and heating up the cabin.

including wearing special protective gear, with fan-powered respirators worn like a flexible diving helmet.

"We sterilized the plastic samples and then dropped a solution containing the virus onto them," reports Dr. Fertey. She then placed the samples in an incubator and exposed them to various temperatures and degrees of humidity. After incubation, the samples were rinsed and viral activity was then measured in the fluid used for rinsing.

The specifications for these experiments were set forth by Airbus. For example, between landing and the next take-off, there is a maximum of two hours in which the cabin can be heated. It is during this period that the virus has to be exterminated. However, due to the adhesives used in the cabin, the temperature cannot exceed 55 degrees. "The virus is unbelievably stable," noted Dr. Fertey and her colleagues. After two hours at 30 degrees, no significant drop in viral activity was detected. As described in the conclusions drawn from the lab experiments: "Exterminating the virus requires either very high temperatures or very high humidity. The ideal would be a combination of both."

"By introducing humid hot air, we were able to eliminate **99 %** of the viruses."

Dr. Jasmin Fertey, Fraunhofer IZI

Swine flu virus as a double for SARS-CoV-2

For safety reasons, no real SARS-CoV-2 viruses could be used in the experiments in the airplane model, so the Fraunhofer IZI team searched for a virus that is harmless but behaves in a similar way. The institute had already gained experience with a number of viruses, and a suitable candidate was soon found: the porcine reproductive and respiratory syndrome virus, or PRRSV for short. While this pathogen causes respiratory disease and premature birth in pigs, it cannot infect humans. Just like the coronavirus, PRRSV is also an RNA virus. Because it behaved in much the same way as SARS-CoV-2 in the laboratory incubation tests, the project team decided to use it as a surrogate for the cabin disinfection experiments. After this preliminary work, the tests in the airplane model could start. Airbus engineers tested various disinfection methods, such as fumigation with vaporized hydrogen peroxide, spraying of disinfectant, irradiation with UV-C light and heating up the cabin.

Again, Natalia Sandetskaya and Arianna March used the plastic samples that they had already worked with in the lab. They dropped a solution containing the virus on the samples and distributed the virus-laden samples all over the cabin, including on the fold-out tables, the armrests and the washroom handles. Airbus then carried out one of the disinfection processes. After each procedure, the scientists determined the remaining virus activity to check its effectiveness.

"Hydrogen peroxide achieved the best disinfection," reports Natalia Sandetskaya. This was no real surprise, as this method is a recognized procedure for decontamination. However, hydrogen peroxide is very aggressive, which makes its application unsuitable for daily routine in airline operations. And while UV irradiation is simple to use, it did not provide convincing results. Vertical surfaces, such as the washroom handles, were not covered properly by irradiation and still carried active viruses.

With heat and humidity, on the other hand, all surfaces could be disinfected evenly. "By introducing humid hot air, we were able to eliminate 99 percent of the viruses," Jasmin Fertey is pleased to say. What's more: Using the airplane's powerful heaters, the high temperatures required for this method can be achieved without much effort. ■

Watch the video of the disinfection tests in the airplane model:
https://youtu.be/TdSBd9xP7ws

"The virus is unbelievably stable. Exterminating the virus requires either very high temperatures or very high humidity. The ideal would be a combination of both."

Dr. Jasmin Fertey

Photo: Airbus

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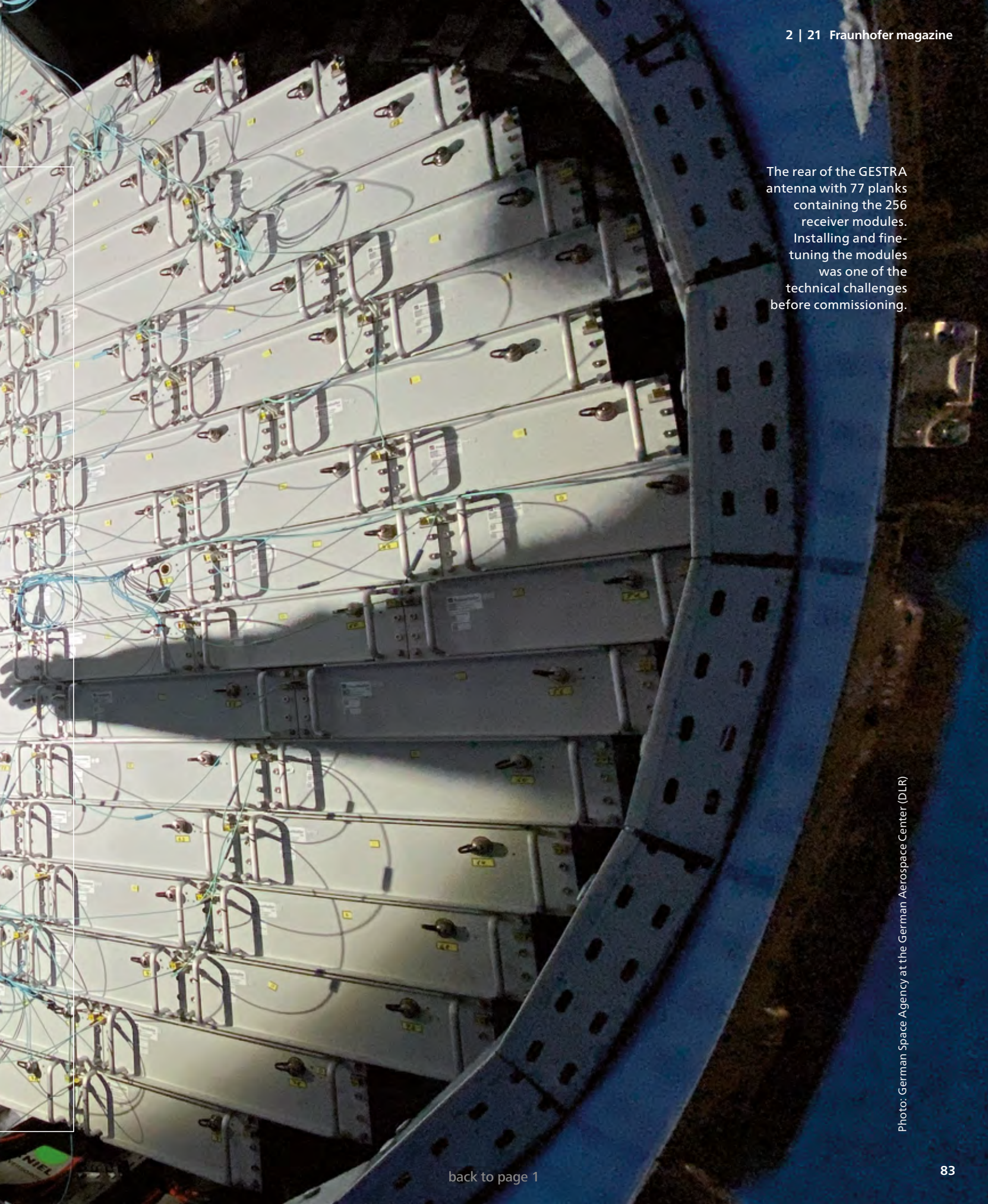
Photo & Fraunhofer

Fraunhofer and safety in orbit

Right now,there is a great deal of speculation surrounding UFO sightings. US intelligence agencies are expected to publish previously secret documents about unidentified flying objects. But at the Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR, nobody is aware of any extraterrestrials. In contrast, quite a lot is known about what we earthlings have left behind in space. More than 900,000 man-made objects, measuring more than ten centimeters, fly through space.

To avoid unnecessary evasive maneuvers, satellite orbits have to be optimized. Fraunhofer FHR, located in Wachtberg in North Rhine-Westphalia, provides the data required for this purpose with its unique TIRA (Tracking and Imaging Radar) system, the only space observation radar system of its kind in Europe. TIRA combines a tracking radar and an imaging radar with a 34-meter parabolic antenna to track satellites and space debris with remarkable precision. Fraunhofer FHR has also developed the semi-mobile surveillance radar GESTRA (German Experimental Space Surveillance and Tracking Radar). Unlike the pinpoint TIRA system, it monitors a large section of space in low-Earth orbit around the clock. So, if any extraterrestrials should approach Earth ...



The rear of the GESTRA antenna with 77 planks containing the 256 receiver modules. Installing and fine-tuning the modules was one of the technical challenges before commissioning.

Photo: German Space Agency at the German Aerospace Center (DLR)

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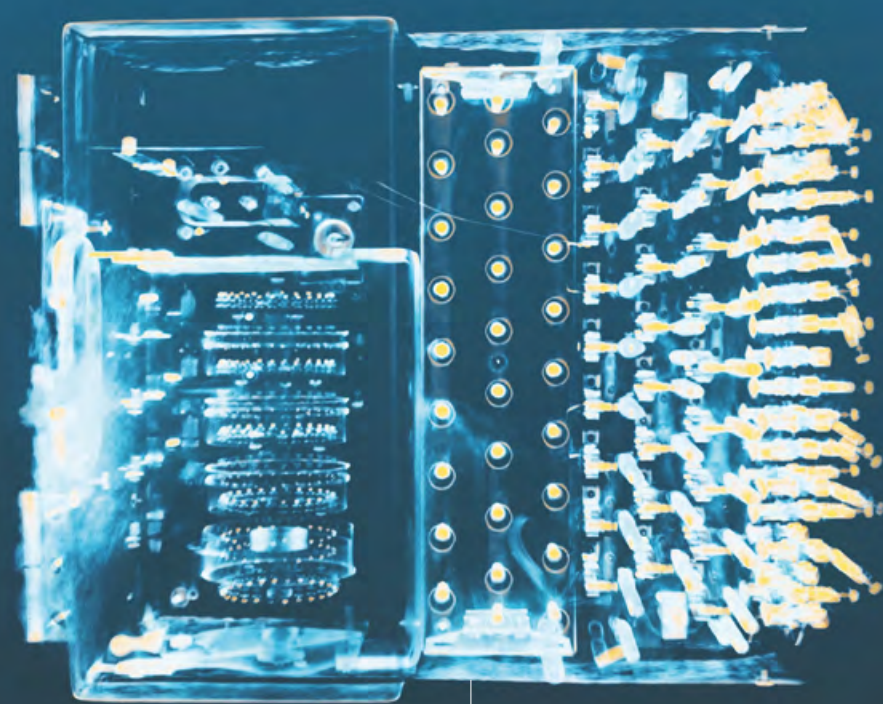
The Nazi relic in the ghost net

Seven Enigma machines have been recovered from the Baltic Sea and are puzzling historians. With a high-resolution CT scan, Fraunhofer IMTE is helping to solve the mystery.

By Dr. Sonja Endres



The CT scan clearly shows the heart of the Nazi cipher machine Enigma: the rotating rollers, so-called rotors, each with the 26 letters of the alphabet. The invention by German engineer Arthur Scherbius was the first to combine different encryption methods and was therefore considered particularly secure.

The beams penetrated the Enigma with

520

kiloelectronvolts.

The divers in the Geltinger Bay near Flensburg were actually looking for abandoned fishing nets, so-called ghost nets, which often become deadly traps for fish, seals or diving birds, but this time, something else had gotten caught in the net. Most people would have mistaken it for an old typewriter and paid no further attention to it. But this wasn't the case for the team from Submaris, a company that offers research diving as a service to scientific institutes, associations and the media. In addition to marine biologists, an underwater archaeologist was also present that day. It was immediately clear to him that this was an Enigma! Shortly afterwards, a colleague found six more nearby in the Sly Firth, a narrow inlet of the Baltic Sea.

Enigma, Greek for riddle, was the name given by the German engineer Arthur Scherbius to his cipher machine, which he patented in 1918 and which the Wehrmacht used to encrypt its communications during the Second World War. It did not remain a mystery for long, however — its code was first cracked in January 1940 by a team of experts from the British intelligence service MI6. But the Germans didn't notice. The decryption enabled the Royal Navy to sink German supply ships for Erwin Rommel's Afrika Korps in large numbers and made the work of British air defense in the Battle of Britain much easier because they were informed in advance about attack targets and even the number of German aircraft involved.

Some 75 years later, the seven Enigmas from the Baltic Sea are every restorer's nightmare: full of sediment, rusty, even with seashells living inside. Add to that the material mix of metal, wood and plastics. The solution is a high-resolution CT scan from the Fraunhofer Research Institution for Individualized and Cell-Based Medical Engineering IMTE in Lübeck, which makes the intricate structures in the Enigma visible. "We normally use our technology to guide surgeons through the body, for example, when they want to place an electrical implant deep in the brain at a specific location to treat Parkinson's," explains Prof. Thorsten Buzug, director of Fraunhofer IMTE. "Now we are showing restorers how they can navigate through the Enigma in a non-destructive way."

To accomplish this, the Fraunhofer researchers placed the cipher machine on a turntable between the X-ray source and the detector, i.e., the camera, and moved it step by step through a total of 360 degrees. The beams penetrated the Enigma with an energy of 520 kiloelectronvolts — about five times as much as is used in medicine to examine a broken bone. To capture the complete capacity and achieve the best image quality, the researchers scanned the Enigma section by section at different heights. "We captured about 4000 images from all directions, a total of 170 gigabytes of raw data," says Maximilian Wattenberg, a research fellow in the Department of Individualized Diagnostics.

In the process, Wattenberg and his colleagues worked under high pressure. They had little time for the scans because the Enigma could only be taken out of its preserving water bath for a short time. "It rusts very quickly when it comes into contact with oxygen," he explains. The researchers had to place it on its side so that the X-rays did not have to penetrate the full length of the solid block. This allowed much more radiation to reach the detector, which significantly improved the image quality but made it more difficult to fix the Enigma on the turntable. It was essential not to tip the machine over under any circumstances. Fixings could only be attached with extreme care because of the corroded, extremely sensitive surface. The mixture of materials also made tomography challenging due to the considerable differences in density. To meet the high quality requirements, Wattenberg and his team used a method that involved serially scanning sections of the Enigma. They then reconstructed these sections into a whole.

The result of the effort: razor-sharp images with a resolution of 139 micrometers. By comparison: A human hair has an average diameter of 50 to 80 micrometers. The rest of the Enigmas will soon have their turn. "This would allow us to see, for example, which of the devices is best preserved and where restoration is most likely to be worthwhile," Buzug says. Due to a lack of money and personnel, restoring them all is not an option. Dr. Ulf Ickerodt, director of the Schleswig-Holstein State Archaeological Office, emphasizes, "Of course, as an archaeologist and historian, you always want to conserve and save all the findings, but that's just not possible. ▶

"We took around 4000 images from all directions, a total of 170 gigabytes of raw data."

Maximilian Wattenberg, research fellow at Fraunhofer IMTE

Photo: Fraunhofer IMTE

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For 75 years, the Enigmas lay dormant at the bottom of the Baltic Sea before research divers discovered them by chance. The Nazi encryption machines are currently being stored in large tubs of water, where they will have to desalinate for a year.

"We hope that, with Fraunhofer's help, we will find a way to digitalize and store the findings in the future in a way that preserves the data in the long term."

Dr. Ulf Ickerodt, Director of the Schleswig-Holstein State Archaeological Office

There are too many for that." Up to 500 findings of all sorts are reported to the office each year — not including objects from rescue excavations, which are often necessary due to civil engineering work.

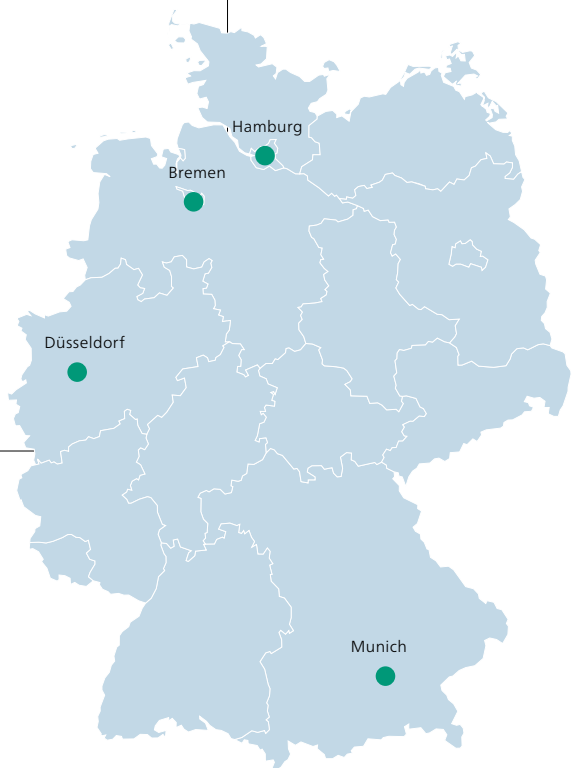
The history of the Enigma, its technical development and decryption is well researched. The Wehrmacht had up to 200,000 of these compact, battery-powered devices produced, and dozens have been preserved and are on display in various museums around the world. "In contrast, a unique Stone Age item certainly has a higher archaeological value," Ickerodt explains. Nevertheless, the finds are valuable to historians because they could provide important information about the last days of the war on the Baltic Sea. Ickerodt suspects that the cipher machines were disposed of in the sea as part of the so-called Rainbow Order: German crews were to sink their ships and submarines themselves in the first days of May 1945 so that they would not fall into the hands of the victorious powers. One of the locations for this, among others, was the Geltinger Bay — the place where the first Enigma was found. Using the serial numbers of the devices that naval historians hope to discover on the CT images from the Fraunhofer IMTE, they could possibly be assigned to specific ships or submarines.

"The Enigma scans were just the starting point; we want to continue and expand our cooperation with Fraunhofer IMTE in the future," says Ickerodt. He sees digitalization as a great opportunity to preserve findings for future generations where conservation and restoration are not possible. The digital object could also find a place in (virtual) exhibitions. "Especially with complex technical devices like the Enigma, it's exciting for visitors to be able to look inside of it instead of just looking at it from the outside," he is convinced. The digital recording via high-resolution computer tomography also greatly facilitates research — scientists worldwide can easily access the detailed 3D models. "We hope that, with Fraunhofer's help, we will find a way to digitalize and store the findings in the future in a way that preserves the data in the long term." ■

Photo: Florian Huber

Fraunhofer on the road

As of: mid-June. Changes may occur due to the pandemic. Please keep an eye out for information from the event organizers.



Amsterdam, NL
December 3 – 6, 2021
IBC
Worldwide trade fair for film, television and radio production.
www.show.ibc.org

Munich, September 7 – 12, 2021
IAA mobility
Changing focus to integrated mobility, smart traffic solutions and a visionary mind-set — everything that defines and allows us to experience the future of mobility.
www.iaa.de/en/mobility

Hamburg, October 11 – 15, 2021
ITS World Congress
World congress for promoting smart mobility and the transportation digitalization.
www.itsworldcongress.com

Bremen, November 16 – 18, 2021
Space Tech Expo
Trade fair for technology and innovation in the aerospace sector.
www.spacetechexpo.eu

Düsseldorf, November 15 – 18, 2021
Medica/Compamed
Worldwide leaders in information and communication platforms for the medical technology industry.
www.medica-tradefair.com

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“I think play is simply something that should always be taken very seriously.”

Jan von Holleben, photographer

Berlin native Jan von Holleben posed and photographed the founders and their ideas for this Fraunhofer magazine. He admits, “It might have been a little uncomfortable at times.” But both photographer and subject had fun all the same.

Fraunhofer