

Fraunhofer

magazine

3/19

Using AI to fight cancer

When does the electric car really become ecological?

What Fraunhofer does to ensure data security

Hitler's prototype - revealing the secrets of the Me 163

Employee at
Fraunhofer IGD,
Darmstadt

A portrait of a woman, likely Josephine, with dark hair and a high collar, set against a background of colorful bokeh lights in shades of blue, green, and purple.

HELLO JOSEPH!

#WHATSNEXT

Take a trip down memory lane with Joseph.



Acceptance comes from transparency



Prof. Reimund Neugebauer
© Fraunhofer/Bernhard Huber

“Hey, Siri, what’s artificial intelligence?” The answer comes promptly. “I’ve found this!” says Apple’s intelligent assistant and refers to the Wikipedia page for AI. Asked the same question, Google Assistant immediately begins to read out the entry from the aforementioned online encyclopedia. Alexa from Amazon tries to go one better: “Artificial intelligence is a field of IT concerned with the automation of intelligent behavior.”

Whether in cellphones, laptops or other devices, virtual assistants are now part of everyday life. But their actual capabilities remain modest. “In the end, we humans have learned how best to communicate with them in order to get the answers we’re looking for,” says Prof. Ulrich Schade from Fraunhofer FKIE in an interview (p. 24). If anything, the current generation of assistants can be more of a hindrance to human intelligence than offering any substantial help. Yet artificial intelligence promises much, much more than this. All the signs are that AI will revolutionize our lives. But will it do so in a manner comparable to the invention of the wheel? Or the Internet? Current advances in artificial intelligence are so exciting and so complex and multifaceted that it is still impossible to say just what changes it will bring. “We’re seeing new developments on practically a weekly basis,” says Prof. Stefan Wrobel from Fraunhofer IAIS in an interview on the myths of AI and its genuine potential (p. 22).

It’s when progress becomes disruptive that fears arise. Medicine is one area where such worries are particularly acute. Will computers make clinical decisions in the future? The answer here is no. Increasingly, however, doctors will be able to use artificial intelligence to help them make decisions. The lead article of the latest Fraunhofer magazine takes a closer look at the exciting work being done by Fraunhofer researchers as they look to harness the power of artificial intelligence for tomorrow’s healthcare. One in five men and one in six women are diagnosed with cancer at some point during their life. This year, Germany has launched a National Decade against Cancer. The goal is to pool resources in a push to conquer a disease that affects so many people. Researchers

from Fraunhofer have already joined forces. The lighthouse project MED²ICIN brings together seven Fraunhofer Institutes under the leadership of Fraunhofer IGD. The aim is to turn artificial intelligence into an effective weapon in the fight against cancer. The current issue of Fraunhofer magazine devotes 18 pages to this vital work, the methods used, the results already achieved and the challenges ahead.

Human ingenuity lies in versatility. Throughout history, the advances of technology have successively relieved us of certain tasks and provided us with newer and more varied and attractive opportunities to make use of this free time. The past has proved again and again that humans and machines complement one another. And, in the future, human and artificial intelligence will mutually reinforce each other. There is no cause for concern here, even if technology is already capable of replacing certain aspects of human thought. We still have a wealth of opportunities to occupy our minds, with our unique and uniquely versatile capabilities.

Should we be afraid of AI? People certainly need to be better informed about artificial intelligence. After all, acceptance will only come from transparency. But rest assured: human intelligence has served us well in the past and will continue to do so in the future.

I hope you enjoy reading this issue of Fraunhofer magazine.

Yours sincerely,

Reimund Neugebauer
President of the Fraunhofer-Gesellschaft

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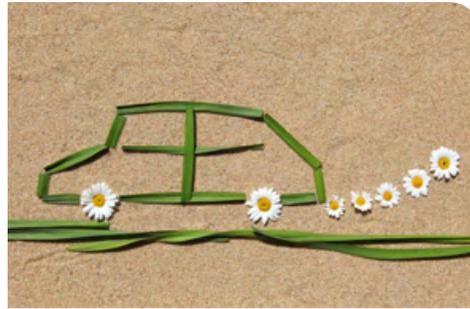
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Trade shows, conferences, events – pick the topic and location that interests you most

In a representative survey (sample size 1012) conducted by the German Association for the Digital Economy (BVDW), more than half the respondents were in favor of introducing rules obligating doctors to accept **second opinions based on artificial intelligence**. Learn more about **medical applications of AI** starting on p. 10.

57%

To scoot or not to scoot?

This summer's crop of e-scooters is rolling in on big cities. They are fast. They are fun. But are they eco-friendly? We put **three questions to Stefan Blume**, project manager for Sustainable Factory Systems and Life Cycle Management at Fraunhofer IST.

1 Are e-scooters eco-friendly?

It depends, and the same goes for electric mobility in general. It would certainly do the environment good to leave the car parked and hop on an electric scooter for those daily commutes. However, if droves of public transportation users switch to e-scooters, the overall environmental effect is more likely to be negative. If a habitual walker or cyclist switches over to an e-scooter, this will actually have an added adverse effect on the environment due to the resources and energy needed to manufacture and operate an e-scooter. This is what we call the rebound effect. We have been seeing this phenomenon for quite some time with e-bikes and pedelecs as electrically powered bikes are increasingly replacing the classic bicycle.

2 Are you aware of any robust studies on the environmental impact of e-scooters? Several studies shed light on the full

life cycle of electrically powered two-wheelers. In 2014, the German Environment Agency found that riding a pedelec emits up to 40 times less CO₂ per kilometer than driving a car powered by a combustion engine. Much the same can be said of e-scooters, even if their energy requirements are somewhat higher than that of the pedelec, where muscle power provides at least some of the propulsion.

3 What would you recommend to eco-minded customers?

The best way to protect the environment is to steer clear of consumption. Walking or classic cycling is always going to be the eco-friendlier alternative. Energy has to be generated to run the scooter, and battery production also has a significant environmental impact. Ecologically speaking, buying a scooter only makes sense if that prompts you to leave your car or motorcycle parked more often.



When e-scooters zipped onto the scene this summer, that trend soon changed the way urbanites get around big cities. They are hip, but whether or not they are good for the environment depends on the circumstances. By the way, sharing a ride is strictly prohibited in Germany. Read more about e-mobility on page 58. © dpa



Andreas Turnwald comes through in a clutch to clinch gold.
© Andreas Turnwald

Fraunhofer employee garners Golden Lola

Andreas Turnwald defied extreme conditions during the filming of *Styx* to take home the German Film Award for best sound design.

Shooting on a small boat, constantly buffeted by waves on the open sea, was a challenge for Andreas Turnwald and everyone else on location. The audio engineer braved the elements to capture the original sound for every scene.

Born in 1975, Turnwald has been with the Audio and Media Technologies division of the Fraunhofer Institute for Integrated Circuits IIS in Erlangen for two years now, developing interactive 3D sound using the new audio format MPEG-H.

Styx tells the story of Rike, an avid yachtswoman, and her encounter with a floundering boat full of refugees. When her calls for help go unanswered, Rike has a choice to make – rescue the refugees or stand idly by.

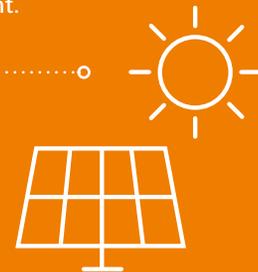
Fraunhofer employee Andreas Turnwald's **Golden Lola** for the best sound design is not the only award to *Styx*'s credit. It also took gold for best actress and best cinematography, and silver for best film. Bestowed since 1951 by the German Film Academy, the Lola award is widely held to be the domestic movie industry's most prestigious accolade.

7.17

terawatt hours

is the amount of energy that solar systems in Germany fed into the public grid in June, as calculated by the Fraunhofer Institute for Solar Energy Systems ISE. This month, for the very first time, the sun was the number one source of electricity generated in Germany, edging out coal-fired energy for the top spot. Wind power took third place.

That makes June 2019 a milestone in the history of Germany's power industry; a month where solar power furnished 19 percent of the net electricity generated, accounting for nearly one fifth of the energy piped to wall sockets and consumed by households. Prof. Bruno Burger and his team calculated that the collective market share of all renewable forms of energy came to 48 percent for the first six months. By comparison, last year's total just barely topped the 40 percent mark. Ten years ago, the share was a mere 18 percent.



Smarter skin care with AI

Fraunhofer researchers have come up with a way to make small batches of skin cream in a tiny retail outlet. No larger than a wardrobe, these micro-factories are already doing business in Douglas perfumery chain stores in Frankfurt am Main, Hamburg and Sindelfingen, with more to follow by the end of the year.

Seven minutes – that's all it takes to mix a 30-milliliter jar's worth of daycare product. Every blend is personalized, formulated individually to suit the customer's specific skin type. Measurements are taken on the spot to determine

the skin's elasticity, moisture, fat content and other factors. Self-learning algorithms and specially programmed neural networks assess the results of these measurements and calculate which ingredients in what concentrations are best for the individual's skin condition and stress and hormone levels, as well as the current season. Viktor Balzer and his fellow scientists at the Fraunhofer Institute for Manufacturing Engineering and Automation IPA prepared the data needed to train the artificial intelligence. A cloud-based solution controls the entire cyber-physical production system.



© Michael May

Crash-testing drones

The only collision test of its kind, it goes to enhance air traffic safety.

The Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut, EMI aims to set up a test rig to simulate collisions between drones and aircraft. Aircraft are only licensed to fly if they have been proven to withstand bird strikes, but drones are not birds. There are no regulations governing collisions with unmanned aerial vehicles, which can cause much more severe damage.

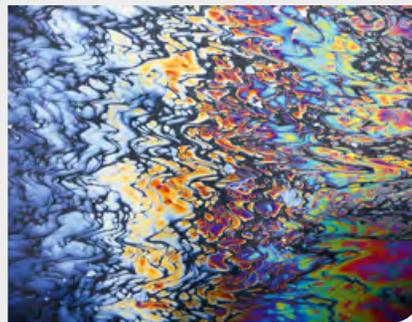
Initial impact tests have confirmed that drones are an airborne hazard. "We used a compressed air accelerator to bring the batteries and motors of a commercially available quadcopter up to various speeds ranging from 115 to 255 meters per second and crash them into flat aluminum panels up to eight millimeters thick. The impact left the panels heavily deformed and dented, and the drone components completely destroyed," explains Dr. Sebastian Schopferer, a scientist at Fraunhofer EMI.

The innovative test rig is designed to accelerate entire drones weighing up to three kilograms to speeds of up to 150 meters per second. "This will enable us to investigate their behavior in collisions with rigid and flexible targets. Tests in this weight class of drone have never been carried out before."

Well-oiled with water

Smoother motion for machine bearings helps protect the environment – and prevents corrosion.

Researchers at the Fraunhofer Institute for Mechanics of Materials IWM have succeeded in modifying water with additives for use as a lubricant. The new blend not only lubricates better than conventional mineral-oil-based substances; it also prevents corrosion. And it is far more eco-friendly.



An oil film is dazzling, but dangerous, environmentally speaking. Lubrication with water is an eco-friendly alternative. © Adobe Stock

Dr. Tobias Amann and his team at Fraunhofer IWM developed their new lubricant using a slide bearing. Vaguely resembling a ring, this bearing is a rotating steel shaft made up of several layers. A sleeve surrounds the bearing; a layer of aluminum and a layer of sintered metal surround the shaft. What makes this design special is that a small channel runs down the sintered inner layer to allow water to flow between the rotating shaft and the aluminum layer. An electric charge builds up inside the bearing between the aluminum, a base metal, and the steel, a more noble metal, with no need to apply an external electric field.

The researchers take advantage of this electric charge to transform the water into a lubricant. "We mix what are called ionic liquids into the water," says Amann. The ions in the electric field align and collect on the inside of the sintered metal ring with their ends pointing upward toward the rotating shaft. This creates a sort of protective layer on which the shaft can glide. The electric field also prevents the steel from rusting. "The shaft glides more easily when wet with water, so it consumes far less energy than when operated with far more viscous oil."

Editorial notes

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Germany's electrical grids are growing ever more complex and therefore more prone to disruption. Artificial intelligence can help here. © dpa

AI for greater power-grid safety

Fraunhofer researchers are working to gear up Germany's grid for the future.

Power grids are growing more complex as demand for green electricity soars. In the past, large power plants furnished practically all our electricity. These days, more and more distributed power sources such as wind turbines and photovoltaic cells are plugging into the grid. This poses tricky challenges for transmission grid operators. Are we losing control of relevant grid parameters such as phase and angle? Are we having to cope with power fluctuations? Have any lines or power plants dropped out of the grid? Conventional measuring equipment lacks the insight to answer such questions. But a new breed of measuring systems can provide that intelligence, sampling current and voltage amplitudes up to 50 times per second. On the downside, they generate vast amounts of data, collecting several gigabytes worth every day.

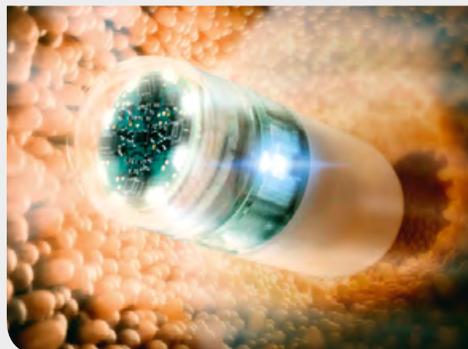
To make molehills out of these mountains of data, researchers at the Advanced Systems Technology (AST) branch of the Fraunhofer Institute for Optronics, System Technologies and Image Exploitation IOSB in Ilmenau developed compression techniques that can shrink this data by as much as 80 percent. Though this is just a first step, this streamlined data is already easier to store and can be assessed that much faster and more efficiently. The scientists then fed examples of typical malfunctions into neural networks, the building blocks of artificial intelligence. With the benefit of these lessons, the algorithms learned to distinguish disruptions from normal operating data and properly categorize incidents.

In a real-world trial, the algorithm spotted an anomaly or an error within milliseconds, and provided information about the location and type of malfunction to boot. The researchers are now working on automated routines to launch countermeasures.

Interior bodyscapes

A new technology developed by Fraunhofer researchers gives doctors the means to fast-track their efforts to spot diseases of the small intestine. The patient swallows a pill-sized encapsulated camera. Having proven its merits in other medical applications, it can explore areas of the body that are otherwise difficult to access. One such elusive organ is the small intestine, a six-meter tract that winds its way through the abdominal cavity. The drawback of capsule cameras is that they record images continuously, regardless of whether the capsule endoscope has moved or not. This produces strings of identical shots that a human has to look at to filter out the duplicates.

The new capsule camera developed by a team at the Fraunhofer Institute for Reliability and Microintegration IZM in Berlin is different. It takes pictures only when the capsule has moved. Its computer memory will not receive the signal that triggers a snapshot until the camera detects changes in the intestinal villi. Reducing the amount of imaging data by more than half, this feature certainly lightens the assessment workload.



The Fraunhofer IZM pill camera brings light into the darkness.
© Fraunhofer IZM/
Volker Mei

80 %
less data
means a lot
more efficiency

How a digital twin can save lives

Diagnostic hypotheses and personalized therapies: artificial intelligence has begun to revolutionize the fight against cancer.

Text: Janine van Ackeren / photography: Peter Gransee

LET
THE
AI
SHOW BEGIN

It's considered the epidemic of our time: 18 million people will be stricken with cancer this year. Statistics show that Germany alone sees 500,000 new cases every year. Each year, around 200,000 Germans die of

cancer. The World Health Organization's (WHO) International Agency for Research on Cancer (IARC) calculated that nearly one in four cancer diagnoses worldwide concerns a European – as does one in five tumor-related deaths.

Artificial intelligence is considered the hope of our time. Although AI scares some people, it is now the case that

artificial intelligence is assisting humans more and more, especially in medicine. Artificial intelligence in the medical field isn't science fiction. Based on his experience, Prof. Jörn Kohlhammer, department head at the Fraunhofer Institute for Computer Graphics Research IGD, is quite certain: "AI can benefit physicians by comparing the course of a disease in a large number of patients and offering the doctor suggestions as to the best possible personalized treatment."

This year, Germany launched a National Decade against Cancer. Kicking off the initiative, Anja Karliczek, German Federal Minister of Education and Research (BMBF), said, "Research is the most important tool in the fight against cancer." In May, she added, "Over the coming ten years, we will pool all our strengths in the National Decade against Cancer." ▶

people
worldwide
are stricken
with cancer
every year.

18,100,100

Estimate of the International Agency for Research on Cancer (IARC) for 2018

AI

New possibilities require new rules in order to build trust. Under the aegis of Fraunhofer IAIS and in partnership with Germany's Federal Office for Information Security (BSI), the Universities of Cologne and Bonn have used an interdisciplinary approach to identify seven priority issues for a process to certify the trustworthy use of artificial intelligence. In some areas, this certification project goes beyond the principles of the EU Commission.

#1

Ethics and law

Does the AI application respect the laws and values of society?

Translucent 3D print from Fraunhofer IGD Darmstadt overlaid with fireproof cables.



One in every **5** men and one in every **6** women
will be diagnosed with cancer at some point in their life.

► Fraunhofer has already pooled its strengths. Led by Fraunhofer IGD, researchers from seven Fraunhofer Institutes are now participating in the MED²ICIN lighthouse project with the aim of predicting how well any given treatment will work on any given patient. One person may respond very well to one treatment, while another doesn't respond at all. When this happens, not only does it burden the patient both physically and emotionally, it also incurs unnecessary costs for health insurance companies.

"To make this prediction, we use a digital patient model," explains Dr. Stefan Wesarg, a department head at Fraunhofer IGD. "It summarizes all the data available on a patient – data acquired from tests and data relating to prior illnesses – as well as lifestyle information, such as whether the patient smokes. The costs incurred and data on general healthcare costs are also fed into the model." In other words, one of the aims of the project is to create a digital twin of the patient.

What interests physicians attending to a patient is whether there are similar therapeutic cases and what can be learned from them in order to improve the current treatment. To this end, they classify groups of people with similar clinical pictures and disease progression into cohorts.

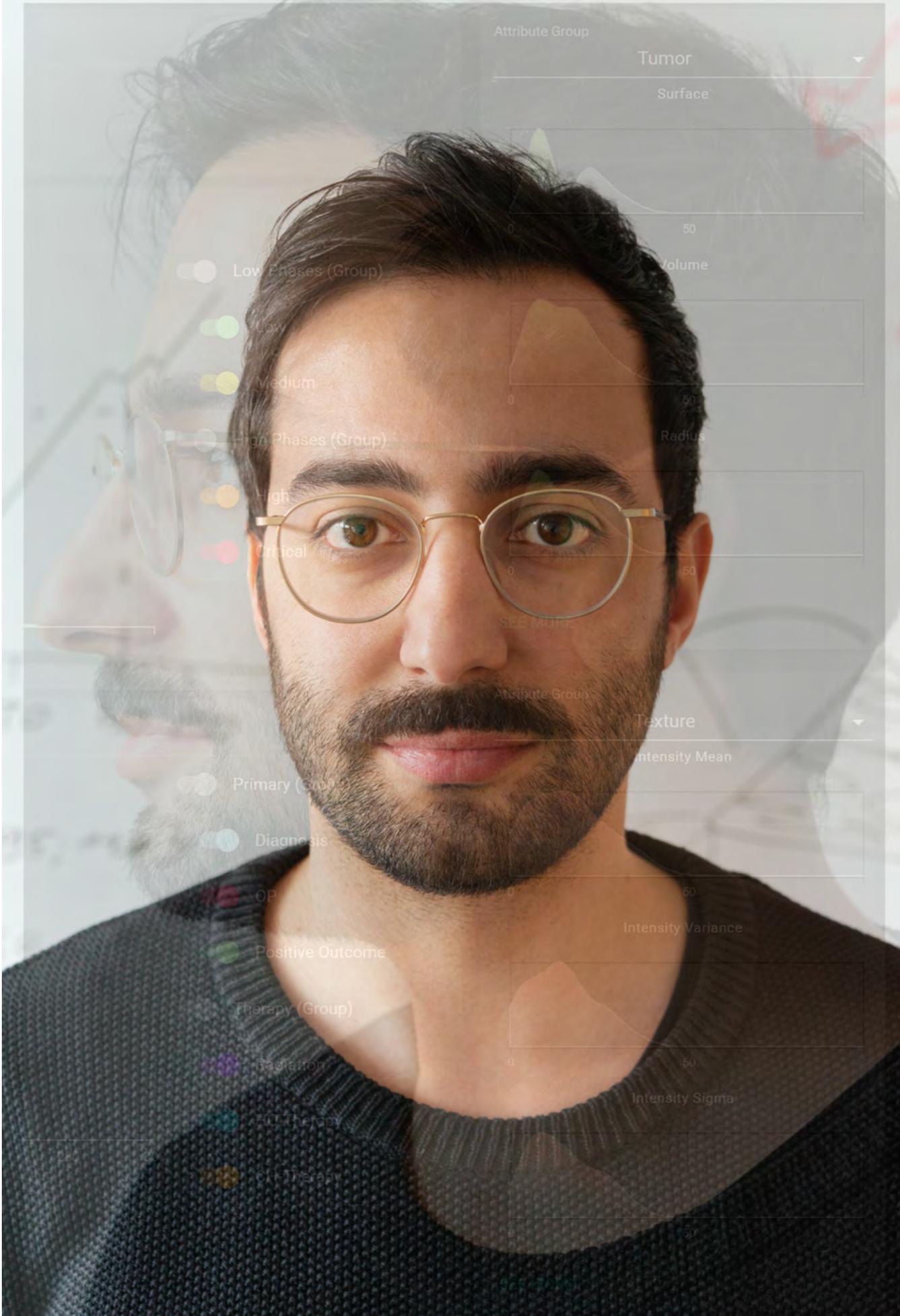
However, examining these cohorts for significant similarities or differences is extremely time-consuming and therefore currently impractical. This is precisely where artificial intelligence comes into play: it scours the volumes of data for important matches, visualizes them and determines which treatments are promising for a particular patient. "In this way,

doctors can also compare patients they would never meet in person – because, for instance, some diseases are extremely rare," Kohlhammer adds. In the long run, this tool could help predict which form of treatment would be best for treating a patient's specific illness.

If it were up to the researchers, these findings would then also feed into the guidelines that prescribe which diagnostic methods and treatment options are to be used for various indications – for instance, which form of chemotherapy should be used for colorectal cancer, or whether and how chemotherapy, radiation and surgery can be combined. "We need to start with the guidelines," says Kohlhammer, "because they are what provide the recommendations. By using the data from our system, we can reinforce the expert knowledge of doctors and optimize the guidelines in order to provide a more personalized treatment." For patients, this would mean that they would no longer be treated according to general standards, but rather with the treatment method that promises the best prospects for them personally.

Sending artificial intelligence to work in the "text mines"

Colon cancer continues to be treated largely on the basis of these guidelines. In some patients, however, tumors continue to spread in the body. Particularly in these cases, alternative treatment methods that are not yet included in the guidelines may be of interest. For the doctors treating these patients, this would mean scouring scientific publications on clinical studies in order to track down more-expedient therapies. ►



#2

Autonomy and control

Does the user retain full and effective autonomy over the AI application?

Ivan Iovine, a research fellow in the Geoinformation Management department at Fraunhofer IGD.

► This is a complex undertaking – and another area where artificial intelligence can provide targeted support. In the BMBF-funded Electronic Patient Path (EPP) research project, Jil Sander, business unit manager at the Fraunhofer Institute for Intelligent Analysis and Information Systems IAIS, is part of a team working to create a suitable text-mining solution: “AI searches public abstracts of medical publications for therapies whose effectiveness for patient groups can be estimated on the basis of certain biomarkers. The relevant publications are then recommended to the doctor as reading material for potential treatments for colorectal cancer.” A biomarker might be a gene that has mutated in the tumor cells of some, but not all, patients. And it may be that chemotherapy works well for the group with the mutated gene but has hardly any effect in the second group. In this way, doctors can form specific patient groups and search for the best treatment options for a particular group.

But the program doesn’t just search for keywords – a simple search algorithm could do that. Instead, it learns to use context in order to identify certain classifiers, known as entities, and their relationships. This makes it possible, for instance, to identify whether a certain therapy has actually been used for a clinical picture – rather than merely listing the therapies and clinical pictures within a text. The system can also recognize entirely new entities, such as novel treatment options that have not yet been recorded in any database and thus have not yet been keyworded. But the project encompasses more than just these text-mining solutions. Its goal is to develop an Electronic Patient Path (EPP) – an integrated system for therapy guidance for colorectal

cancer that extends beyond the guidelines. This is why the scientific partners – Ruhr-Universität Bochum, University of Bonn, Hamm-Lippstadt University of Applied Sciences and Fraunhofer IAIS – are collaborating with a clinical partner, the Universität zu Lübeck and the University Medical Center Schleswig-Holstein, Lübeck campus. The final results are still out. In the long term, however, it is hoped that the program goals will help doctors pinpoint the most relevant new studies and thereby drive up the treatment success rate for cancers – by, for example, continuously refining the EPP method in the MED²ICIN lighthouse project, both for colorectal cancer and for other clinical pictures. But here, too, the artificial intelligence behind the integrated system is meant to support doctors, not replace them.

The head and neck region is particularly challenging

Tumors that develop in the area of the head and neck pose particular challenges for doctors. Because many different structures lie next to one another in a relatively small area, using radiation and other treatments on these kinds of tumors is particularly tricky. The high-energy beams must destroy the tumor while keeping damage to the sensitive organs in its immediate vicinity to a minimum. An AI system that researchers at Fraunhofer IGD already developed several years ago is able to identify anatomical structures, such as the spinal cord, blood vessels and larynx, in computer tomography image data and present the results graphically. AI can do in just four minutes what it takes humans several hours to complete. ►

One in every **8** men and one in every **11** women die of cancer.

#3

Fairness

Does the application treat all participants fairly?



IGD dummy. The glasses enable the doctor to see, in augmented reality, the exact position of the lymph node.

The IARC estimates the yearly increase in the number of new cancer diagnoses worldwide at

4,000,000

► Now, however, artificial intelligence can also automatically detect the tumor. As Wesarg explains, “Our software tool localizes and labels the tumor in the computer tomography images, presents it in 3D and analyzes the corresponding image data.” The system is based on neural networks and was trained with data in which the tumor was labeled manually. It then used this data to generate a model. Additional data is added from the head and neck atlas, such as the information that the larynx is completely healthy-looking, so the system doesn’t need to look for the tumor there. The results of the head and neck atlas thus provide a preselection.

How is brightness distributed within the tumor? Is there anything that isn’t noticeable when a human looks at it? The tool uses various descriptive parameters to answer these questions. In total, with the appropriate software, more than a hundred parameters of this kind can be extracted from the images of a head and neck tumor.

Faster, cheaper and gentler than a biopsy

Initial results show that, with this approach, CT images can even provide information that once could only be obtained through a surgical procedure followed by laboratory analysis of the extracted tumor tissue. “So it’s conceivable, for instance, that a correlation could be found between the intensity pattern within the tumor region and a cell abnormality detected in the lab. With enough patients, it could one day be possible to infer – with statistical certainty – pathological cell changes on the basis of the appearance of the tumor in the image data.” Thus, so the theory goes, it will soon be possible to use artificial intelligence to draw conclusions regarding tissue markers, obviating the need for an actual biopsy. This is easier not only on patients but also on health insurance companies’ budgets. On top of that, the

results are available much more quickly than they would be for a biopsy with a lab analysis of the extracted tissue.

Parts of this technology are already being used in initial test runs at the HNO clinic of the University Hospital of Düsseldorf. The doctors there are using the technology to retroactively analyze patient data and review cohort assignments. In the months ahead, this test is expected to reveal how the AI findings correlate with empirical knowledge, thus marking the first step toward cohorting – and onward toward treatment tailored to the individual patient.

The long-term aim is to personalize medical care – to identify the therapy with the highest probability of success for each patient. To achieve this, the algorithms developed for the head and neck region could also be extended to other types of cancer. For this, however, the algorithm needs to have the relevant information as to which structures it should look for in the image data. This is because tumors in the head and neck region have different markers than, say, lung tumors. ►



#4

Transparency
Does the AI application function and make decisions in a way that is transparent and comprehensible?

Veneta Ivanova, a research fellow in the Geoinformation Management department at IGD

The photographs on the topic of AI

were created by Peter Granser for Fraunhofer magazine. A self-taught photographer, he has published ten photography books to date. Granser's works have been shown in numerous international exhibitions.



Three questions for the photographer

1 Everyone takes photos today, so why still create photographs?

Because a carefully considered photograph can be much more than a snapshot taken with a smartphone. With the flood of images we are exposed to today, we have to take care that we don't forget how to appreciate artistic photography.

2 What appealed to you about the overlays you created for Fraunhofer?

AI isn't immediately visible. I had to find a format for making areas in which AI is used visible. It was important to me to create compositions that convey the issue and attract people to look at them.

3 AI: should we fear it or be delighted by it?

If the ethical principles were to be internalized and respected worldwide, my curiosity would turn into delight. Unfortunately, history often shows us that the opposite is true.

► In collaboration with MedCom GmbH in Darmstadt, a Fraunhofer IGD spin-off, the researchers also want to begin this process as early as the initial diagnosis. In the BMBF ECHOMICS project, they are using artificial intelligence to analyze ultrasound images of the lymph nodes in a process analogous to a biopsy. This is because a permanent enlargement of the lymph nodes may indicate the presence of a tumor in the body. This would enable doctors to detect tumors much sooner than is currently possible, thus facilitating swifter treatment and improving the chances of success.

Predicting complications following bone marrow transplants

When radiation or chemotherapy is not successful in treating leukemia or lymphoma, there is usually only one chance for recovery: a bone marrow or blood stem cell transplant. But here, too, the chances of success are slim. Currently, many patients die despite the transplant. This is because all the blood stem cells are killed off before the transplant – including all the white blood cells that make up our immune system. In a transplant, the patient then “inherits” the donor's immune system – but this may turn against the patient. It is also possible that the new immune system doesn't recognize latent pathogens in the patient's body, allowing severe infections to erupt.

In the XplOit project, researchers from the Fraunhofer Institute for Biomedical Engineering IBMT, together with their partners from Saarland University, the University of

Tübingen, Essen University Hospital and analytics company Averbis, now aim to use artificial intelligence to predict whether the new immune system will give rise to these kinds of problems. Was the transplant successful? Will dangerous viral infections occur, or will the new immune system react badly to the patient's body? What is the probability that the patient will survive? What is the probability that their cancer will spread again? “Our XplOit platform enables earlier detection and treatment of life-threatening complications than is currently possible,” says project coordinator Stephan Kiefer from Fraunhofer IBMT.

To teach the prediction procedures what to look for, the scientists trained them with representative clinical data from the participating stem cell transplant centers in Essen and Saarland. With their prediction tools now trained, the researchers have been working on clinical validation since March 2019. For one year, they will feed in the data of patients currently being treated, compare the predictions with the doctors' assessments and the actual course of the disease, and thus evaluate and refine the prediction models. “We are certain that these models can offer physicians solid indications of probable complications,” says Kiefer, summarizing their findings to date. Then, so the researchers hope, significantly more people might survive this type of transplant. ►

9,600,000 people worldwide die of cancer each year.

Estimate of the International Agency for Research on Cancer (IARC) for 2018

#5

Reliability

Is the AI application reliable and robust?



Matthias Noll, research fellow in the Visual Healthcare Technologies department at IGD

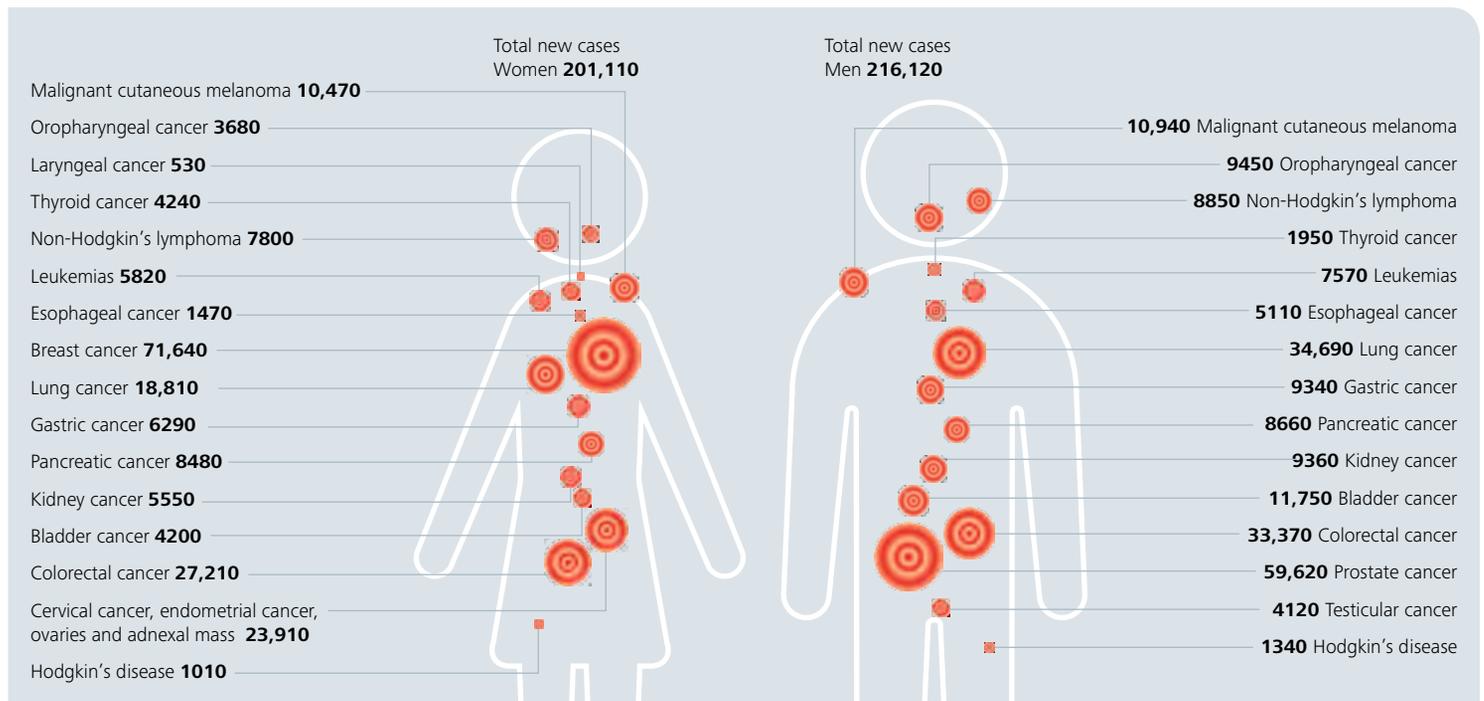
Europe accounts for just **9%** of the world population, but

23% of cancer diagnoses worldwide.

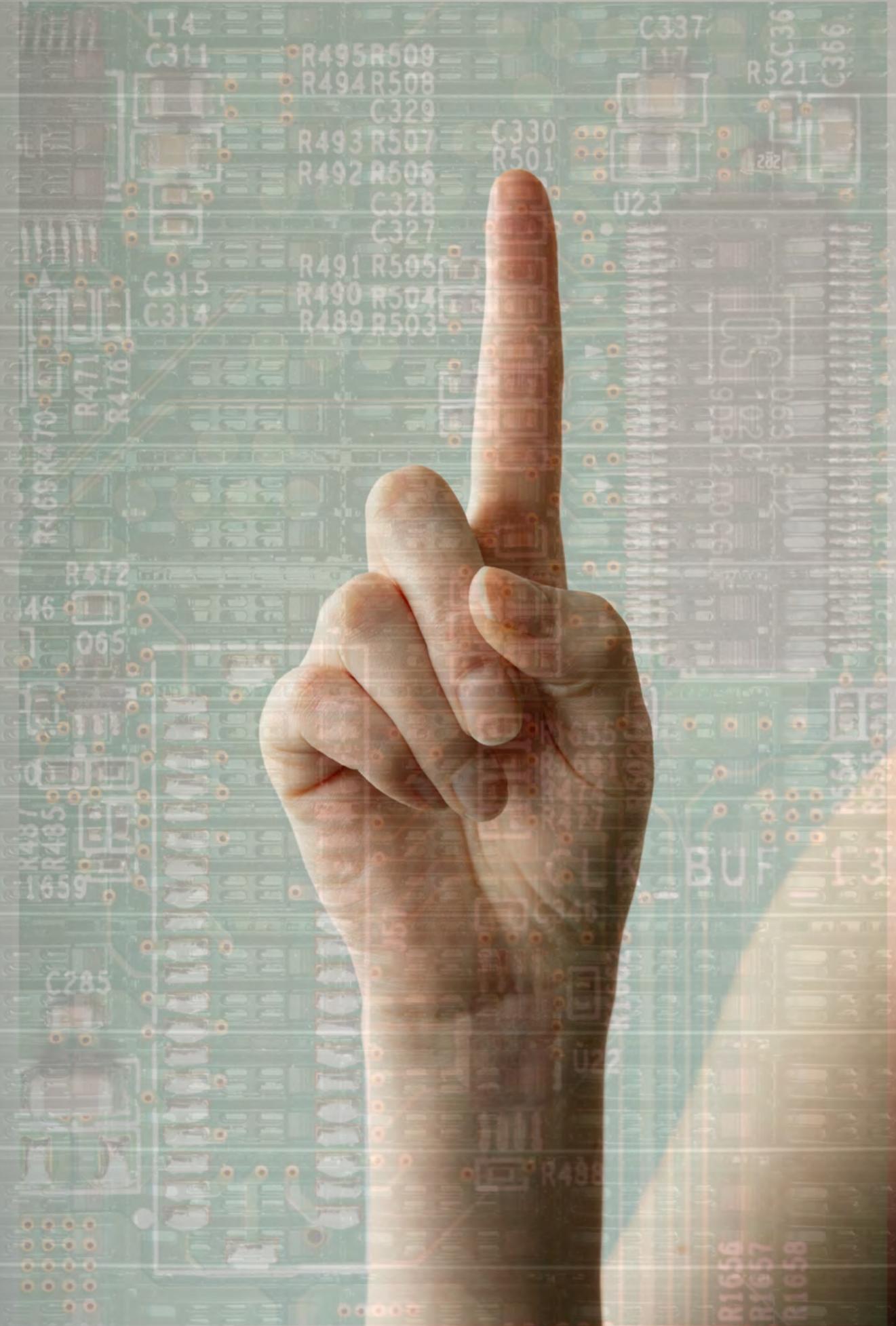
► One of the keys to the treatment of cancer – perhaps the most important of all – is the early detection of tumors. Optical coherence tomography (OCT) could play a major role here. Its resolution is between ten and 100 times that of ultrasound. But there is a drawback: the lack of suitable expertise in the day-to-day clinical work in many medical disciplines. Researchers at the Fraunhofer Institute for Production Technology IPT and at Tokyo Women’s Medical University (TWMU) are now hoping to change that with their OCTmapp research alliance. “It is hoped that artificial intelligence will assist doctors with analysis, as well as helping them better understand signal generation – especially the formation of artifacts,” says Niels König, department head at Fraunhofer IPT.

Early diagnosis reduces the number of deaths

In June, the researchers at Fraunhofer IPT took two OCT systems to Japan, where the preclinical study – testing the technology in relevant applications – will take place. Their aim is to determine what is feasible and how the technology can be used for joint research with Japanese partners. König expects that it will be possible to integrate the system into TWMU’s Hyper Smart Cyber Operating Theater (HyperSCOT) in around five years – and, in the long term, that it will help diagnose cancer earlier and reduce the number of cancer-related deaths. ■



Number of new cancer cases each year in Germany in women and men
 Source: German Center for Cancer Registry Data at the Robert Koch Institute, for the year 2013



#6

Security
Is the AI application secure against attacks, accidents and errors?

“We see advances almost weekly”

Will artificial intelligence replace the human intellect? Prof. Stefan Wrobel from Fraunhofer IAIS tackles the numerous myths.

Interview: Janine van Ackeren



Prof. Stefan Wrobel is the director of the Fraunhofer Institute for Intelligent Analysis and Information Systems IAIS and spokesperson for the Fraunhofer Big Data and Artificial Intelligence Alliance. The German Informatics Society recently named him one of the ten “most influential minds in German AI history.”
© Intuitive Fotografie Köln

Everyone is talking about AI, but what exactly is artificial intelligence?

We humans see and hear, we make plans and we adapt them to changes. AI is when we replicate these kinds of cognitive achievements using machines or computers. We still don't know exactly how the human brain actually does these things, but in some areas we can devise mathematical processes that produce similar results. A machine uses algorithms to analyze sample data from which it then derives models and thus gradually improves its behavior.

So that's the reality. Where do the myths begin?

Many fears stem from one assumption: that artificial intelligence thinks the way humans do. We see how AI beats humans at chess and Go, or how it translates human language from German to Italian and calls the hairdresser to make an appointment, and we conclude that if AI can do all that, then it can also do everything else we humans can do. But that's precisely where we're wrong. Artificial intelligence today still lacks the integrated understanding that we humans possess when it comes to certain processes.

What can AI do?

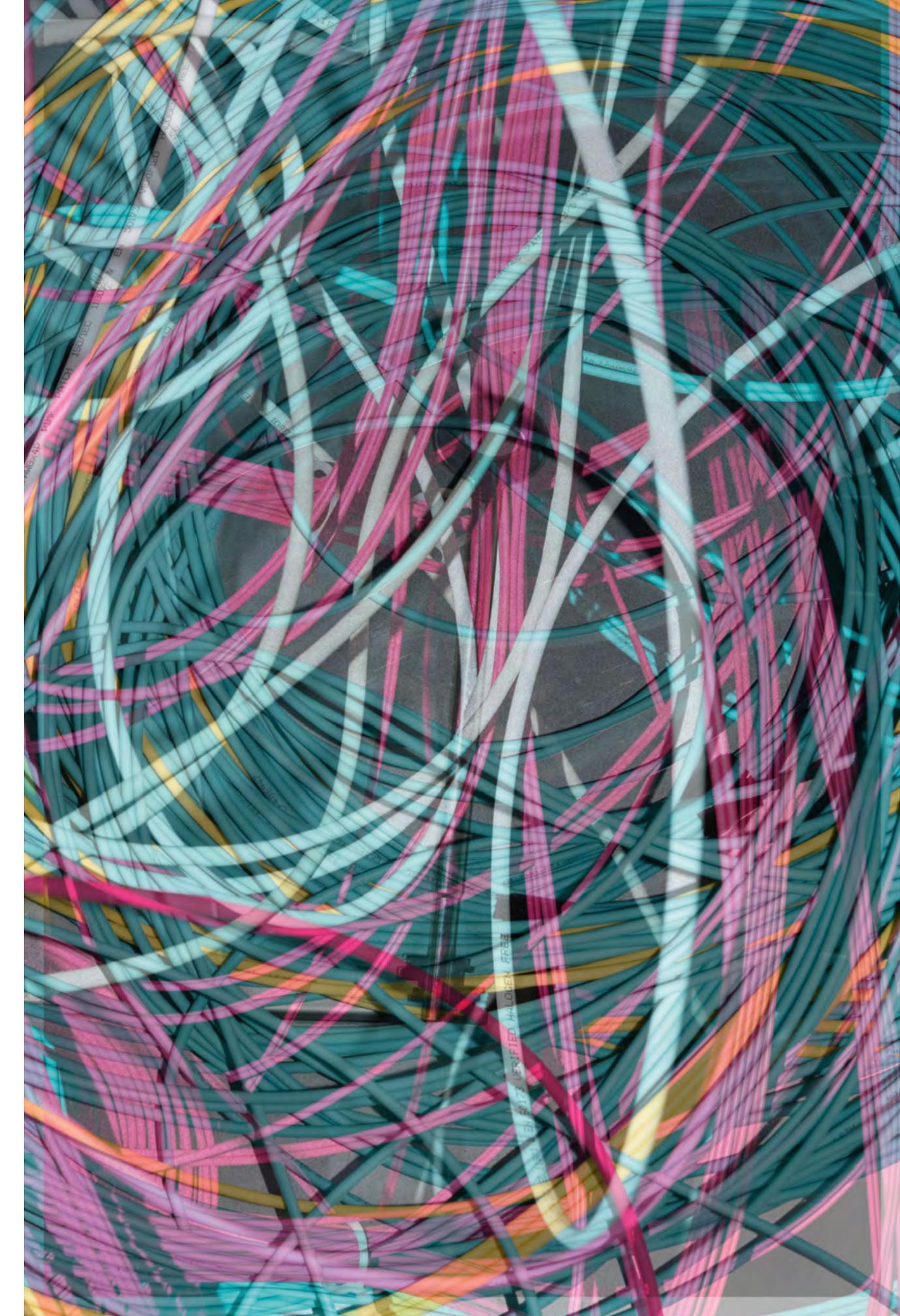
It's definitely not a myth that AI can replace humans in certain domains. If a task is clearly defined and delimited and there is sufficient data or human knowledge available, artificial intelligence can accomplish feats that rival those of human experts. It may even exceed them.

And what can AI not do?

Each artificial intelligence system is developed for a specific purpose. It's currently not possible to automatically apply these systems to other purposes. For example, if a system has been trained to translate sentences from German to Italian, it can't automatically also answer questions in German or Italian. Another fundamental issue concerns self-reflection: artificial intelligence doesn't yet know what it cannot do. If an AI system for diagnosing milling machines is suddenly asked to analyze a punch machine, it won't refuse – but it also won't produce any meaningful results.

When will AI overcome these limits?

Everyone wants to know what the future will bring and when. Much in the field of AI has happened faster than even we imagined possible. Other things, however, are taking longer. What we can say is that we are seeing advances monthly, almost even weekly. Even next year's AI systems won't be like the ones we have today. But there's no way to reliably predict when artificial intelligence will have come far enough that it can use global knowledge and context the way we do. It may be ten or 20 years or more before AI is generally as flexible as human intelligence. It's important not to get caught up in thinking about the future possibilities of AI. Rather, we should take advantage of the opportunities it already offers. Only by using AI today can we remain competitive! ■



#7

Data protection
Does the AI application protect privacy and other sensitive information?

Server cables, including pink fiber optic cables, with integrated safe key, in the server room at IGD.

“Ours is a kind society”

Fake news or real news? Why we are so prone to manipulation and what democracy needs to do to protect itself: a chat with Prof. Ulrich Schade, Fraunhofer FKIE.

Interview: Josef Seitz



“AI will not rule the world,” of that Prof. Ulrich Schade is sure. But he does have a caveat: “At least not in our lifetime.” Schade has headed up the Information Analysis research group at Fraunhofer FKIE in Wachtberg near Bonn since 2002. © Fraunhofer FKIE/Petra Kaiser

A lie or the truth – which travels faster, Prof. Schade?

With modern technology, there is practically no limit to the speed of a lie. Human fact-checking has no hope of keeping up. Our tool doesn't perform a fact check; instead, it spots news that might be fake in real time. (See chart to the right.) Sometimes just finding the source of a message is enough to treat it with caution.

Are you fascinated by the relationship between humans and artificial intelligence?

Some of these systems' intelligence does not actually reside within the systems themselves. It is in the minds of us humans. After all, we're the ones who adapt to the programs. Take the language assistants Alexa and Siri. We're the ones who have gradually learned how to communicate with them to get the answers we seek. If we want the user to get a better idea of how dumb these systems really are, we have to look at their constraints to see where they don't work. This is what fascinates me – searching for these limits of machine-based processes.

Let's get back to the search for human limits. Has the power shifted in the digital era?

Ours is a kind society. We believe in the good. This makes us much easier to manipulate than authoritarian states. We have to respond to this threat.

Are democracies jeopardized by manipulation?

We should at least be wary. I recently read about an interesting thought experiment in “Aus Politik und Zeitgeschichte” by Maximilian Steinbeis: It takes a two-thirds majority to amend our Basic Law, the 70th anniversary of which we celebrated in May. This is a good line of defense. The same goes for our

constitutional judges – they are appointed only upon gaining a two-thirds majority. That, too, is a good line of defense. But there is no cause to be overconfident. The law stipulating that a constitutional judge may only be appointed with a two-thirds majority can be amended far more easily, with a simple majority. Closing this kind of gateway for manipulators in order to better defend our constitutional state is a relatively small matter with a huge impact.

So you're pessimistic about the future?

Not when it comes to artificial intelligence. A machine is always good in its one specialty field, but its skills extend no further than that. A program either plays chess or the board game Go. A person can learn both, and would then apply ideas and strategies from one game to the other. The machine can't do that. AI is not going to rule the world, at least not in our lifetime. Of that I am sure.

A machine does one thing perfectly. People do many things well. That sounds comforting. How does human thinking differ from artificial intelligence?

Let's stick with chess. A human can think about the goal at hand and work backward to figure out which steps are needed to win. A computer doesn't think about the goal, it merely calculates the potential consequences moving forward – quickly, but with no imagination.*

Do you see an inclination in humans to surrender their thinking to the machine?

Complacency is always a risk. We have to encourage children, young people and, yes, adults to think for themselves again. And we need much stronger media skills to protect ourselves and our views against manipulation. ■

* For more on this, please refer to: “Schomann, Conrad (2019). Inoffizielle Engine-WM TCEC – Finale: LCO vs. Stockfish. Rochade Europa, 4, 42-43.”

Tracking down the lie

Basic steps for developing an AI tool to spot fake news



Time-consuming preparations
First create two corpora, **GOOD** and **BAD**.



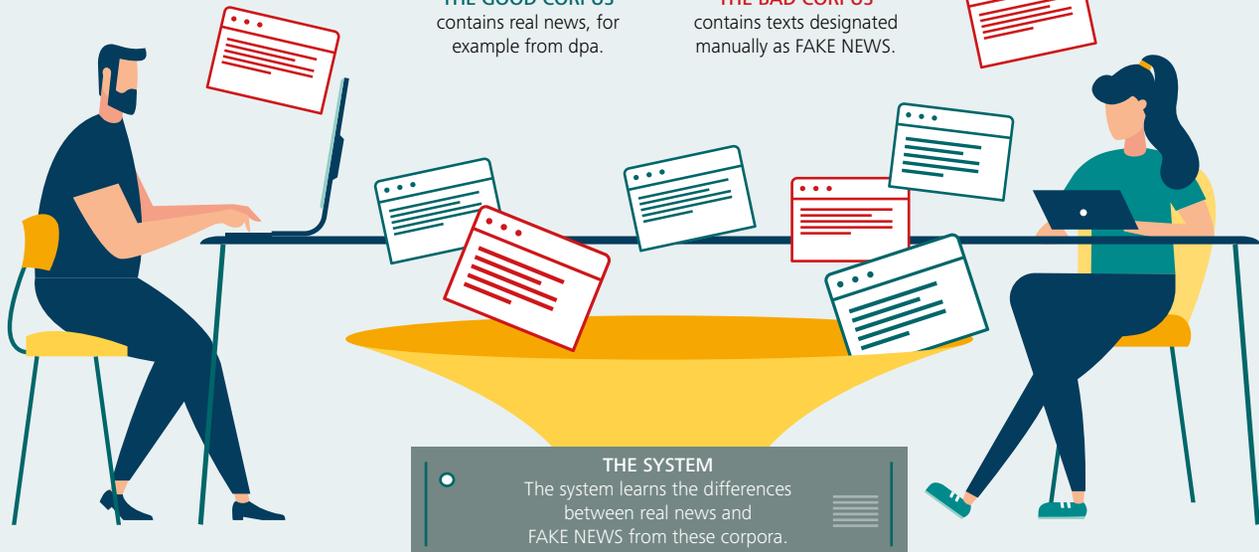
THE GOOD CORPUS
contains real news, for example from dpa.



THE BAD CORPUS
contains texts designated manually as FAKE NEWS.



Humans review the contents of the texts for the corpora, which then serve to train the system.



These are differences learned from metadata and linguistic characteristics. The AI created in the course of this learning process compares new texts based on learned differences and classifies them accordingly.



Fast processing
The AI classifies news in real time.

www.deutschetageszeitung.de/politik

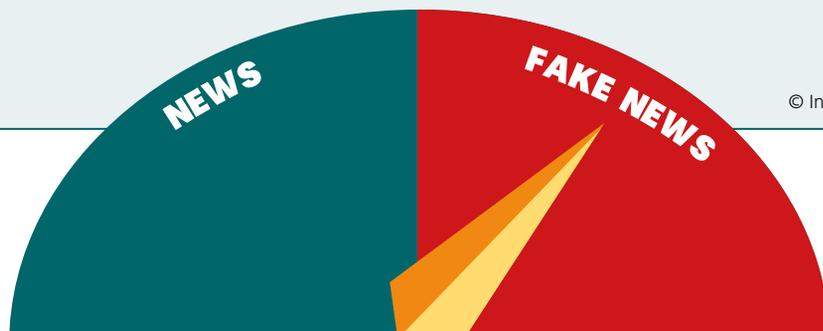
Feb. 18, 2017, 07:38 a.m.

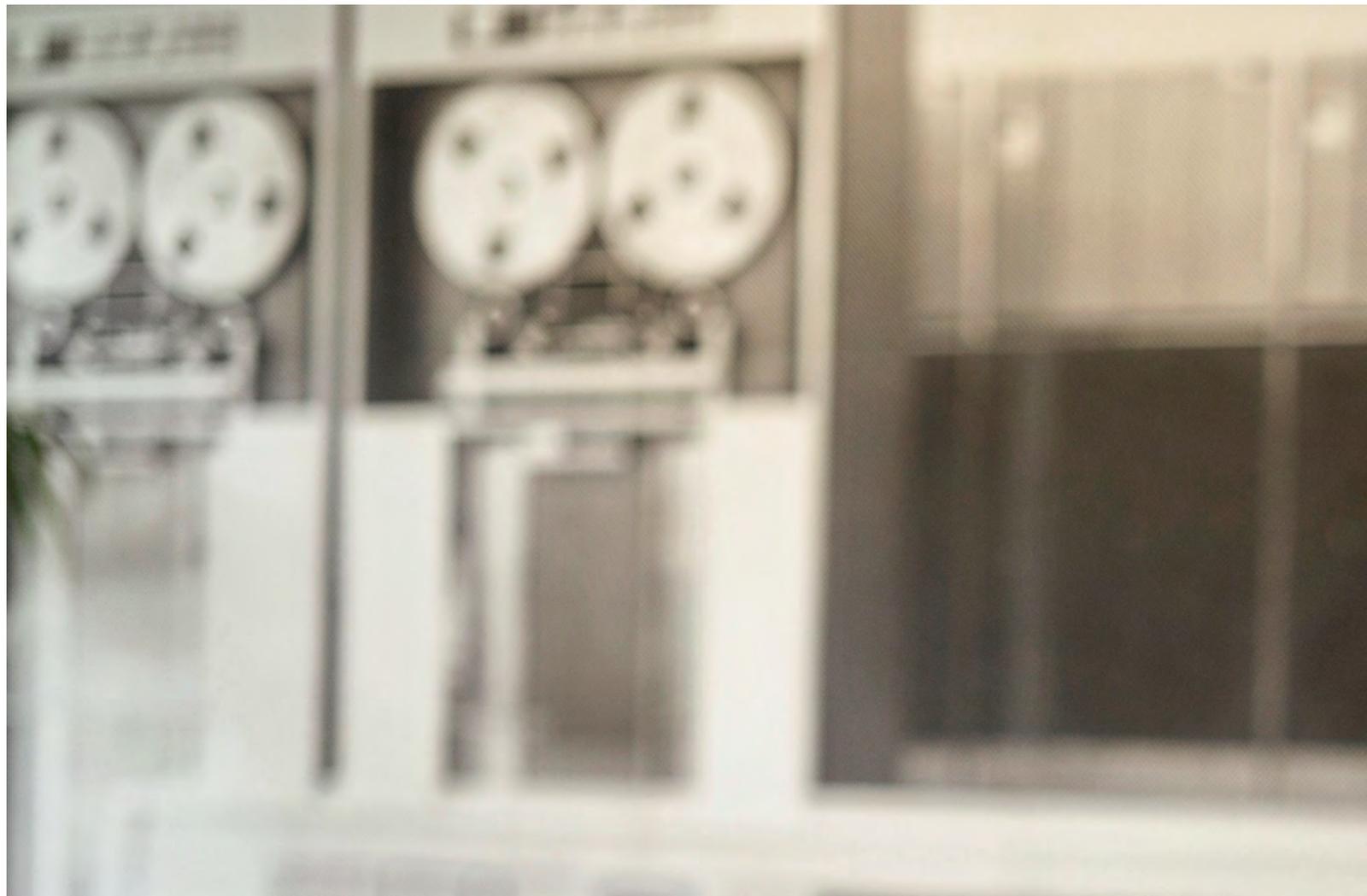
The Christian Democratic Union's poor showing in current polls are probably because the current chancellor Angela Merkel and her ruling CDU/CSU coalition bear "the political responsibility for the mass murder committed by the murdering refugee and asylum seeker Anis Amri – he murdered over 12 people and injured 50 more at the Breitscheidplatz Christmas market in Berlin (Dec. 10, 2016)" – as citizens on the streets of several German cities told the German daily Deutsche Tageszeitung, not to mention Angela Merkel's evidently dismal stewardship of Germany's intelligence services, as was recently revealed... (I.W.Urgyanjin--BTZ)

METADATA includes the source (URL), date, time and author.

LINGUISTIC CHARACTERISTICS include use of buzzwords (asylum seekers, etc.), inaccurate information, errors and misplaced dashes.

RESULT OF THE AI SOFTWARE'S ASSESSMENT





“Information can be a weapon”

The so-called Ibiza tape plunged Austria's government into crisis. Experts from Fraunhofer SIT checked the video for authenticity. Afterwards, they were left wondering why so few media outlets take the trouble to have their material verified.

Text: Josef Seitz





Unbelievable but true: under the leadership of Prof. Martin Steinebach, a five-person team from Fraunhofer SIT in Darmstadt verified the authenticity of the so-called Ibiza tape. Our photo pictures him in front of an image of a 1960's mainframe computer in the Deutsches Rechenzentrum datacenter. © Josef Seitz

The impact of the Ibiza tape



May 17: German media organizations Spiegel and Süddeutsche Zeitung release a secretly filmed video in which senior Austrian politicians Heinz-Christian Strache (right) and Johann Gudenus discuss granting state contracts in return for major political donations. They also discuss the possibility of exercising political control over Kronenzeitung, an Austrian newspaper. © YouTube



May 18: The day after the video was made public, Heinz-Christian Strache (pictured) resigns as Austrian vice-chancellor, and Johann Gudenus as speaker of the parliamentary group of the FPÖ. The remaining FPÖ ministers also resign. © ddp



May 26: Austria's 6.4 million voters are called to the polling stations for the European elections. The ÖVP, party of Federal Chancellor Sebastian Kurz, makes substantial gains, increasing its share of the vote by 7.57 percent compared to 2014. The FPÖ's share of the vote falls by 2.52 percent. © imago images

Prof. Steinebach, you describe one of your methods as "camera ballistics." Are videos really a form of weapon? And, if so, do we need to trace their origin as though their images were bullets from a gun?

"I'm amazed that the media still seem so unconcerned about the origin of the material they publish."

Prof. Martin Steinebach

"Videos can definitely act as weapons," says Martin Steinebach. "We're in the information age, and information can certainly serve as ammunition." Steinebach, head of Media Security and IT Forensics at Fraunhofer SIT in Darmstadt, has witnessed the explosive impact that video material can have on political life. His team had barely finished verifying the authenticity of the so-called Ibiza tapes when the Austrian government began to unravel before his very eyes: first the vice-chancellor resigned, and then various government ministers, all followed by a vote of no confidence in the federal chancellor. The whole affair had been triggered by a secretly filmed video of FPÖ politician Heinz-Christian Strache chatting idly about how he proposed to exercise control over sections of the Austrian media and reward those who helped him with state contracts. To ensure the video was genuine and eliminate the possibility of it being an instance of deepfake, Spiegel magazine contacted Fraunhofer SIT and asked them to carry out a technical appraisal of the ten-minute clip.

Both of the media organizations involved in releasing the Ibiza tape had already experienced fake journalism firsthand. Spiegel had only recently published a closing report, 17 pages in length, documenting a whole series of fraudulent articles written by its star journalist Claas Relotius. And, at one time, Süddeutsche Zeitung had erroneously published a

series of bogus Hollywood celebrity interviews, either entirely fabricated or comprising a montage of set pieces, that writer Tom Kummer had never actually conducted. Another German media outlet, Stern magazine, had almost foundered on the disgrace surrounding its publication of the forged Hitler Diaries. A satirical German movie was made on the back of the scandal.

"I'm amazed that the media still seem so unconcerned about the origin of the material they publish," says Martin Steinebach. For the last 20 years, he has witnessed how digital media have come to assume an ever greater importance in the information society. "Yet the information society still doesn't know how to answer the question of whether we can trust digital media." For a start, today's image editing programs are so sophisticated that manipulation is extremely hard to spot. Nonetheless, Steinebach is convinced that it would be easy to filter out many fake videos with the right technology.

Five specialists from Fraunhofer SIT worked for a whole week evaluating the material. At that point, Steinebach wasn't interested in the clip's explosive nature: "When I look at a video, I don't focus on the actual content. I rather perceive it as noise with certain energy peaks." To begin with, the team from Fraunhofer SIT ran an automated check. Using algorithms they had programmed themselves, they looked for any data anomalies in terms of resolution, sample rate and frequency response. In addition, Spiegel had commissioned the team to verify that the footage of the interior of the villa on Ibiza matched still images of the property. To achieve this, the team checked the camera angles and compared objects in the room. Steinebach is confident in his



May 27: Following a motion of no confidence in Austria's National Council, votes from the SPÖ, FPÖ and Liste Jetzt ensure the removal from power of Federal Chancellor Sebastian Kurz (pictured). He will enter history as the Austrian chancellor with the shortest period in office.
© APA/LUKAS HUTER

and his team's capabilities: "There are certainly other experts in this field. But essentially they're not any better than us. We use all the latest research and develop special tools that you can't get anywhere else."

Steinebach is certain that these kinds of checks are going to become increasingly important. With more and more digital data being distributed across a growing number of platforms, the opportunities to falsify them are on the up. As Steinebach says, it's high time that people start looking at precautionary measures.

"A rough check is very easy," Steinebach says. A simple re-upload filter, as employed by YouTube, can often be enough to prevent material that has already been used in a previous case from being recycled in a new context. Steinebach recalls the images posted following the 9/11 attack on the Twin Towers in New York. The pictures showed Arab crowds hailing some joyous event. The implication was that the Arabian world was celebrating the victory of terrorism. In fact, the images were archive material and predated 9/11. "When somebody knowingly uses images to stir up emotions such as hatred, that's when things are really getting dangerous," Steinebach says. "It can be explosive."

This is why he is calling for media organizations to create the infrastructure required to detect fake content in real time. "It's no great challenge to identify whether existing material has been reused for manipulatory purposes. It would be perfectly possible to run an automatic check in the background while the video material is being loaded into an editing program. And while the material is being viewed and

cut, the system can check whether any or all of it is already in the database. If so, the system issues a warning that the images have been used in the past in a completely different context." Steinebach would also like to see the establishment of a new infrastructure in the media industry that would render the entire process – from initial recording to final broadcast – fully transparent. In other words, the camera would in effect confer a digital signature on the content provided by journalists. As soon as such an infrastructure is in place, media organizations will be able to access that signature and thereby verify that the material is authentic.

Steinebach is also convinced that deepfake will soon become an issue for the business world. Today, a well-known scam is the fake company e-mail in which the CEO seemingly asks an employee to transfer a large sum of money to a secret account overseas. In the future, increasingly simplified technology will enable criminals to use Skype for similar purposes. This will make it possible to create thoroughly authentic video images of the CEO speaking directly into the camera and with a convincing expression and voice, ordering an employee to transfer ten million bitcoins to an account in Singapore. "And with one click," says Steinebach, "the ten million will be gone!" ■

"When somebody knowingly uses images to stir up emotions such as hatred, that's when things are really getting dangerous. It can be explosive."

Prof. Martin Steinebach, Media Security and IT Forensics



© Josef Seitz



Magnetocalorics “for Future”

A discovery made in 1917 may save our future: Fraunhofer IPM is developing cooling systems that protect the climate - and is aiming for a new world record!

Text: Christine Broll

Only very few researchers are privileged to experience moments like this. When Pierre Weiss and Auguste Piccard pointed their electromagnet at a piece of nickel, they observed a phenomenon that nobody before them had ever described: the metal grew hot. And when the two physicists deactivated the magnetic field, the nickel cooled down. Weiss and Piccard named the phenomenon “magnetocaloric effect.” The year is 1917. The First World War was ravaging Europe. Comedian Buster Keaton appeared in his first movie role. And the November Revolution put an end to the reign of the Czars in Russia.

One hundred years later, thousands of school-aged students gather every Friday at their “Fridays for Future” demonstrations to fight for more climate protection. At the same time, the magnetocaloric effect observed by Pierre Weiss and Auguste Piccard is well on the way to becoming a climate-friendly technology. The heating and cooling cycle generated by magnetization is excellently suited for cooling and eliminates the need for environmentally damaging refrigerants. Many research groups around the world are



“Protect our planet:” school students call for better climate protection at a “Fridays for Future” demonstration in Munich. © ddp

working on refrigerators, industrial cooling systems and air conditioners that use magnetocaloric materials.

Physicist Dr. Kilian Bartholomé and his team at the Fraunhofer Institute for Physical Measurement Techniques IPM in Freiburg, Germany, have developed an extremely efficient thermal conductivity concept. Their achievement puts them at the forefront of international climate protection efforts.

There is great demand for an innovative cooling technology that functions without refrigerants, since the conventional hydrofluorocarbons (HFCs) used today are powerful greenhouse gases. This is what led the EU to significantly restricting the use of HFCs. Several of these refrigerants will be banned within the next few years, while a “phase-down” is in process for others. This measure will gradually reduce the total quantity of HFCs that are allowed to be brought into circulation. The resulting supply shortage has led to skyrocketing prices for HFC-based refrigerants. Natural-gas refrigerants such as butane and propane provide an alternative to HFCs. These gases are already used in today’s household refrigerators. But, apart from being derived from fossil fuels, they have one serious disadvantage: they’re flammable. The amounts of these gases

used in household refrigerators is not considered hazardous, but they are not a viable option for larger cooling systems such as those found in supermarkets. The industry is working on alternative refrigerants but has yet to come up with convincing solutions. Kilian Bartholomé’s cooling system needs no harmful refrigerants at all. The system uses an environmentally friendly lanthanum-iron-silicon alloy as a magnetocaloric material, which heats up when a magnetic field is applied and cools down when the field is removed. Kilian Bartholomé has already developed and patented a special procedure for diffusion of the heat produced. Bartholomé’s refrigeration machine makes use of latent heat to make a liquid evaporate: “This is the energy absorbed when a substance changes from a liquid to a gaseous state. We use the evaporation process to transfer the heat,” the physicist says. “This is a highly efficient means of transferring the thermal energy.”

In deciding to use the evaporation process for heat transport, Kilian Bartholomé and his colleague Jan König were inspired by the heat pipes used as pipe collectors in solar power systems and for cooling computers. Heat pipes consist of an evacuated tube in which a small amount of fluid has been enclosed. If one side of the pipe is heated, the fluid ►

Refrigerant phase-down: supply shortage leads to skyrocketing prices.

Sights set on a new world record for magnetocaloric cooling systems: Dr. Kilian Bartholomé at Fraunhofer IPM. © Fraunhofer IPM



“Magnetocaloric technology has huge disruptive potential. We see this as an emerging market that we can easily penetrate.”

Jochen Kopitzke, CEO of Philipp Kirsch GmbH, a manufacturer of specialist cooling systems

► evaporates on this heated side and condenses again on the cold side. This process achieves very high heat transfer rates, but the magnetocaloric heat pipe being developed at Fraunhofer IPM is significantly more complex. It consists of many small chambers containing the magnetocaloric material. The alloy has a finely porous structure so that it can be optimally penetrated by the water vapor. The method for producing the porous alloy is the work of Dr. Sandra Wieland and Dr. Martin Dressler at the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM.

In order to even further increase efficiency, Bartholomé arranges the segments of the heat pipe in a circular pattern and places a rotating magnet in the middle. It is expected that the demonstrator will generate 300 watts of power by the time it is finished at the end of the year. By comparison, the compressor in a domestic refrigerator has an output of 50 to 100 watts. The new system is already capable of operating at a very high electromagnetic frequency. Accordingly, the researchers in Freiburg plan to use the demonstrator to break a world record for magnetocaloric cooling systems in the category of performance. The objective is to achieve 50 percent of the theoretical maximum efficiency level. Today comparable systems reach a level of approximately 30 percent.

Industry players are already expressing great interest, for example Philipp Kirsch GmbH, which manufactures special refrigerators for medical laboratories, pharmacies and hospitals. The long-established German company is working together with Fraunhofer IPM in a project sponsored by the German Federal Ministry of Economics and Technology (BMWi). “We want to bring a minus-86-degree freezer based on magnetocaloric cooling to the market,” says CEO Jochen Kopitzke. “Magnetocaloric technology has huge disruptive potential and could be capable of replacing compressor-based cooling in the medium term. We see this as an emerging market that we can easily penetrate.” ■



Structure of a magnetocaloric cooling system: The gray segments contain the magnetocaloric material. This material is then alternately heated and cooled by the rotating magnet. Similar to the process in a classic compressor system, on the right gaseous hot fluid from the magnetocaloric system flows into the condenser on the back of the refrigerator. There the fluid condenses, transferring heat to the ambient air. The fluid in liquid form then runs through the pipe inside the refrigerator. Here it evaporates, withdrawing heat from the interior of the appliance. The cold gaseous fluid is then returned to the magnetocaloric system. © Fraunhofer IPM



Prof. Auguste Piccard, co-discoverer of the magnetocaloric effect, in the aluminum pressurized capsule he designed himself. He flew up into the stratosphere inside this capsule on May 27, 1931. © dpa

The magnetocaloric effect – or how scientific discoveries from long ago can be relevant to our future

Auguste Piccard, the co-discoverer of the magnetocaloric effect, not only went down in the history of physics; the Swiss adventurer made world history as well. On May 27, 1931 in the Bavarian city of Augsburg he and an assistant climbed into an aluminum sphere measuring 2.10 meters in diameter, which a gas balloon then flew to an altitude of 15,781 meters. From high in the stratosphere he was the first human to see the curvature of Earth with his own eyes. Prof. Piccard had calculated he would return to Earth seven hours later somewhere in Germany’s Black Forest. Already presumed dead, the physicist and his assistant landed 17 hours after takeoff in the Ötztal valley in Tyrol, Austria.

The reason why the magnetocaloric effect is still not in widespread application over one hundred years after its discovery is the complex physics involved. Only materials that are themselves magnetic can be heated using magnetization. And this is only possible within a narrow temperature range that is specific to each material. When a magnetic field is applied at these temperatures, the elementary particles of the material are arranged in the direction of the magnetic field. This generates thermal energy. The metal grows hot.

Iron exhibits the magnetocaloric effect at approximately 750°C, and nickel at around 360°C. There is only one element that can be heated using the magnetocaloric effect at room temperature: gadolinium, a very rare and therefore extremely expensive metal. It wasn’t until the end of the 1990s that alloys were developed that are magnetocaloric at room temperature and that can be produced cost-effectively on an industrial scale. One of these is the lanthanum-iron-silicon alloy being used by the working group at Fraunhofer IPM.

AI: easing the way for sea trout

Once a year, sea trout leave their home in the ocean and swim upstream in rivers to spawn. But at numerous spots along the way, their path is blocked by dams or weirs. In many rivers, the fish have already been driven to extinction. High time for action, then. Artificial intelligence can help evaluate and make adjustments to river restoration measures.

Text: Janine van Ackeren

Sea trout are a very special kind of fish. Once every year, *Salmo trutta morpha trutta* – as the experts call it – leaves the salt water of the Baltic Sea and battles its way upstream into freshwater, where it forms hollows in sandy riverbeds to lay its eggs. The journey is a real obstacle course and may even meet an abrupt end at a hydroelectric power plant. Artificial intelligence is currently being used to help these up to 130-centimeter-long fish complete their annual journey. It might just help save them from extinction as well as enable scientists to assess the effectiveness of fish ladders and river restoration measures.

Researchers at the Fraunhofer Institute for Computer Graphics Research IGD in Rostock have used video clips to train artificial intelligence (AI) to distinguish sea trout from floating leaves and other types of fish. Now, AI can help in the first wide-scale analysis of the sea trout's peregrinations. The state government of Mecklenburg-Vorpommern has commissioned the Institute for Fish and the Environment (Institut für Fisch und Umwelt) to monitor sea trout numbers. Along the rivers, employees of the institute are constructing pinch points that sea trout have to traverse and are monitoring them with video cameras. But evaluating the images is a work-intensive process: an employee needs three months to perform counts at all of the pinch points.

Shortening a lengthy process. "We are using artificial intelligence to evaluate the video data," explains Matthias Vahl, group manager at Fraunhofer IGD. "The system takes just five days to evaluate the data instead of the three months required by a human operative: automatic classifica-

tion is performed in three to five hours, while the employees then need a further three to four days for post-processing." Another advantage of deploying AI is that it makes genuine wide-scale surveillance of sea trout stocks possible, whereas previously only five or six rivers could be monitored. The data collected is considerably more comprehensive and the researchers have used it to train the system further and make it even more reliable. "Artificial intelligence is often able to detect differences that the human eye cannot. For example, the water in newly analyzed rivers may be marginally cloudier than in previous ones. The more varied the training data, the lower the risk of the system learning something it wasn't meant to," says Vahl. The researchers took a few random samples from the current stock of data and labeled them manually. Of the original data, 10 percent was deployed for post-training, while 90 percent was subjected to a second test.

The results are impressive: the system didn't overlook a single fish, making for 100 percent sensitivity. The specificity level is also high, at 97 percent – meaning that the tool mistakenly classified a leaf or other object as a sea trout in only 3 percent of cases. And the employees at the Institute for Fish and the Environment need just three or four days to sort through that remaining 3 percent. With the help of artificial intelligence, they can evaluate the river restoration measures not only much faster, but also in much greater detail – and help raise sea trout numbers by making corresponding adjustments. ■

© Adobe Stock





Going out with a bang

Vacation time is when airports are at their busiest. As the only independent German test center authorized to work with explosives in the service of aviation security, Fraunhofer ICT helps smooth the flow of traffic.

Text: Mehmet Toprak

Increasing passenger volumes present a challenge for security checks at airports.
© Flughafen München



When Dr. Dirk Rösling submits a report, he is not allowed to use mail, electronic or regular. He must travel to Paris and personally hand it over to the European Civil Aviation Conference (ECAC). That's because the contents are, quite literally, explosive.

Rösling is head of the Test Center for the Evaluation of Detection Systems for Explosives at the Fraunhofer Institute for Chemical Technology ICT. The institute is in a secluded location on the side of a hill in Pfinztal, not far from Karlsruhe. That seclusion is really a coincidence, but it's highly appropriate. Fraunhofer ICT operates the only independent test center in Germany allowed to use real explosives in its work. "We're also the only facility in Germany authorized to produce liquid explosives for test purposes," Rösling adds.

Aviation security is one of the principal concerns at the Fraunhofer ICT test center. Last year, 122.6 million passengers passed through Germany's 24 largest airports. Vacation time is when airports are at their busiest. According to DFS Deutsche Flugsicherung GmbH, the organization responsible for air traffic control in Germany, the busiest day in 2018 was September 7, with 3,079,093 passengers arriving and departing on commercial flights at German airports. Even on other days outside the peak period, it is common to see long lines of passengers waiting to have hand luggage screened. ▶



Suspect substances in luggage are marked on the scanner display.
© All photographs: Fraunhofer ICT



A test center worker places items of hand luggage in plastic trays.

► As soon as any stray water bottles have been disposed of, all electronic devices and metallic objects must be placed in a separate tray. This is because they interfere with today's scanner technology. According to Röseling, however, smart algorithms, greater computing power and, above all, better software mean that the latest generation of this technology is able to reliably scan luggage containing liquids and electronic appliances. This will speed up security checks for passengers and make things easier for airport operators, because they can now dispense with all the extra trays for laptops and mobile phones, etc.

Sarah Steinert packs a bag, first with items of clothing, then a toiletry bag containing toothbrush, toothpaste, perfume and various tubes of cream. Next comes a phone charger, insect-repellent spray and a travel alarm clock. Finally, she takes a gray-brown plastic bag containing 500 grams of nitroglycerin and slides it carefully between her iPad and a layer of T-shirts. Steinert is one of a team of 17 at the test center. She is used to dealing with high explosives such as nitroglycerin, TNT and Semtex. Her job is to test whether the scanner systems at airport baggage control are able to discover the explosives in her luggage. "I really enjoy my job," she says. "We're a great team, and the work is very varied."

Baggage scanners that pass all the tests at Fraunhofer ICT receive certification from the European Civil Aviation Conference (ECAC). Röseling helped develop the protocol

that forms the basis for tests throughout Europe. He also works regularly with Germany's federal police, who supply him with details of new explosives or new combinations of explosives. Fraunhofer ICT then builds this information into its testing routines.

Visitors to the test center are immediately struck by the scale of the tests. Across the vast testing hall are mock baggage scanners with 100 or more cases, bags and rucksacks of varying shapes and sizes. Large steel shelves hold a huge array of bottles and cans. And a large table is crammed with jars of cosmetics, tubes of cream, aerosols and cleaning products. Steinert approaches with a trolley carrying various explosives. She and her colleagues will check whether the software of the scanner being tested is able to detect the explosives. Or whether any slip through the net. The test report will also refer to any false alarms.

More and more new explosives

Yet the test center is more than just a highly qualified service provider to the security industry. Much of its work also flows directly into research. In today's world, where terrorist organizations are always working to develop new explosives for bomb-making purposes, Röseling and his team are regularly required to analyze new chemical combinations or modified formulations of known substances. Their job is to find out whether today's scanning systems can detect them.

TNT?
Semtex?
Nitro-
glycerin?
"I really
enjoy my
job!"



The team at Fraunhofer ICT checks whether scanner systems are able to detect hidden explosives in luggage.



A vast array of liquids and beverages is available for placing in luggage used to test the scanner.



Greater
efficiency and
lower costs
for baggage
control

An employee mixes
liquid explosives.

A major research project in this field goes by the name of Accelerated Checkpoint Design Integration Test and Evaluation (XP Dite). Sponsored by the EU to the tune of 14.6 million euros, its objective is to incorporate all the various security technologies in this field within one integrated system, thereby enhancing safety while also increasing passenger throughput and convenience. In the future, the idea is that the security authorities will prescribe the level of security that airport operators must deliver. How they do that will be their own business. They will be at liberty to choose which technology and equipment they wish to install and to combine and connect different systems. XP Dite will provide a suite of planning tools and evaluation methods to assist with this process. The system-based approach will create greater efficiency and thus save airport operators money. By the same token, passengers will find the check-in procedure more convenient, with fewer steps and less waiting time.

At Fraunhofer ICT, each day goes out with a bang. Once testing has finished, the team must dispose of any unused explosives. A detonation chamber weighing 20 metric tons is used for this purpose. The explosives are placed within the chamber and detonated remotely. A dull thump is all that emanates from within. ■



Unused explosives are disposed of in a detonation chamber weighing 20 metric tons.

Sharp for steak, blunt for butter

Will tomorrow's knife be a blade that adapts to purpose? Programmable materials may one day be fixtures in our lives. Here's a look at where they stand today.

Text: Mehmet Toprak

Small things often herald bigger things to come. Chris Eberl is holding a nondescript plank of hard plastic. He brings his finger down, pressing on one end. The slab springs to life, a wave rippling down its surface from one end to the other before going rigid again. This change is reversible. When the pressure on the 20-centimeter slab lets up, the material changes back as if it had a built-in reset switch. It does, but rather than a single master switch, it is an array of many small switches spliced into the material's very structure.

What at first glance looks like a nifty parlor trick could be the seed that sows a technical revolution. Chris Eberl, professor and deputy director of the Fraunhofer Institute for Mechanics of Materials IWM, prefers the term "paradigm shift." He believes the same technology that conjured a wave on a piece of plastic in the Fraunhofer lab at Freiburg will be instrumental in developing products the likes of which we have never seen before.

Step by step, from notional to actual

The idea behind this tech is not new. Scientists have been kicking proposals around since the '70s. Back in the day, programmable materials were a distant prospect, but the science is gradually catching up with the speculation. These materials have a unique ability encoded in their DNA – the means to process information like a computer and respond to it like a machine. But rather than processing information in the form of electrical signals, they physically change shape. This 'genetic' encoding enables scientists to design the inner structure of a material so that compression triggers a wave at a predetermined point, and further compression sends it forward. The structure of the material also determines its properties.

For example, a material could be soft at one point and hard at another. A car seat could be designed to bear-hug the passenger when the vehicle accelerates, and ease off its firm embrace to allow greater freedom of movement when the car slows down. Malleable properties include permeability, hardness, density, and thermal and electrical conductivity.

But this is just the beginning. As Chris Eberl puts it, "The second step is to create adaptive materials that autonomously adjust their properties to changes in environmental conditions such as pressure, temperature and humidity."

The potential applications are many and diverse. Researchers at the Fraunhofer Institute for Applied Polymer Research IAP are also exploring filters that close when a liquid heats up and open when it cools down. Another prospective application is sheathing for batteries in electric cars. Heat buildup can be a problem, especially for lithium-ion batteries. The thermal conductivity of a housing composed of programmable material could be made to increase at a certain temperature to let heat escape. Conversely, the housing could transform itself into a protective layer of insulation when the car is parked outdoors on cold days.

Pointing out the benefits of this technology, Prof. Peter Gumbsch, director of the IWM Institute, says, "Integrating two or more functions into a material without requiring external components such as joints, cables, switches or sensors saves on material and resources." In the best-case scenario, consumers will benefit from products that are easy to handle and work efficiently. Also, waste management is a lot easier for a product made up of fewer different materials. However, developers and industrial manufacturers will have to rethink their practices to put concepts like these into



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action. “This is less a matter of finding the right material for a function and more a matter of finding the right way to integrate desired functions into materials,” notes Gumbsch.

A Cluster of Excellence to pool skills

Programmable materials present such towering challenges for researchers that Fraunhofer set up a Cluster of Excellence in 2018 for scientists across Germany to scale those heights in a collective effort. The Fraunhofer Institutes for Applied Polymer Research IAP, for Building Physics IBP, for Chemical Technology ICT, for Mechanics of Materials IWM, and for Machine Tools and Forming Technology IWU are all on board. It marshals experts – chemical engineers, mathematicians, physicists, process engineers, product developers – in a wide range of disciplines.

One of the priorities for the research teams is to design a component that can do more than merely toggle between two states. They aim to encode a more complex if/then logic into the material: when environmental condition A occurs, then property A changes into property B, but only when environmental condition B reaches value X. This will serve to create products and components that can execute complex functions despite consisting of just a few materials. “The better we master the materials, the more complex functions we will be able to incorporate,” says, Gumbsch. “The finesse is in the internal structure,” adds Eberl.

One of the trickiest tasks will be to ramp up these materials for industrial manufacturing so as to deliver full-fledged products rather than just small components. The difficulty is one of scale: It still takes high-tech tools such as laser lithographs or 3D printers to process the materials and build up the demonstrators’ internal structures layer by layer on a nano or micro scale. This limits the range of manufacturable products – for the time being, that is.

Fraunhofer experts Gumbsch and Eberl are confident that they are on the path to profitable production: “We are already developing demonstrators and prototypes. The technology works; the concepts are viable.”

They expect to see the first products on the market in just a few years, for example, filter systems for cleaning water or other liquids, shape-shifting aerodynamic components, and soft robotics grabber claws and arms that can also handle heavy loads. ■

Fraunhofer experts are confident: “The technology works; the concepts are viable.”

The gleaming foundation of the scanning probe quantum magnetometer from Fraunhofer IAF is an artificial diamond that uses a positioned electron as a magnetic sensor.
© Achim Käflein

Quantum sensors: ready for practical application

The Fraunhofer Lighthouse project QMag

The QMag project will run through 2024 and is being funded with a total of ten million euros split evenly between the Fraunhofer-Gesellschaft and the German state of Baden-Württemberg. QMag consolidates the research work of the Freiburg-based Fraunhofer Institutes for Applied Solid State Physics IAF, for Physical Measurement Techniques IPM and for Mechanics of Materials IWM as well as the Fraunhofer Centre for Applied Photonics CAP in Glasgow and the Fraunhofer Institutes for Microengineering and Microsystems IMM and for Integrated Systems and Device Technology IISB. The University of Stuttgart and the University of Colorado Boulder are also associated with the project, which forms part of the Fraunhofer-Gesellschaft's key strategic initiative "Quantum Technology."

A single electron in a diamond can be turned into a highly sensitive magnetic sensor. This opens up new fields of application in micro- and nanoelectronics, medical technologies and process analysis.

Text: Mandy Bartel

They are all around us in the digital world, but we usually aren't aware of them until they stop working: nanoelectronic circuits, processors and data storage devices. Installed in smartphones and computers with an increasing number of functions and unbelievable data densities, they are constantly growing smaller and more complex. But this rise in complexity also means a higher error rate, with the nanoscale geometrical dimensions adding to the challenge of reliable and non-destructive testing: a task for quantum sensors.

Quantum sensors, or quantum magnetometers to be exact, can precisely detect even the smallest of magnetic fields caused by power distribution in nanoelectronic circuits. They

can bring to light the smallest bits on storage media such as hard drives, allowing quick detection of defective elements. Such image-based proof of power distribution makes troubleshooting, developing and producing storage media and electronic circuits in the semiconductor industry considerably more efficient.

The crux of the matter is that industrial use of the magnetic field sensors available to date is subject to serious limitations. They are very expensive to operate and are technically complex, requiring for example extreme cooling. Working at room temperature, today's sensors are not sensitive enough or are lacking the necessary spatial resolution, especially when it comes to confirming fields generated by the magnetic moment of elementary particles.

The electron as a digital compass

Fraunhofer launched the lighthouse project QMag, short for quantum magnetometry, with the objective of making quantum sensors ready for practical application. As part of the project, scientists at six Fraunhofer Institutes and two universities are working together to further develop quantum sensors to make them ready for use in industrial applications in the near future.

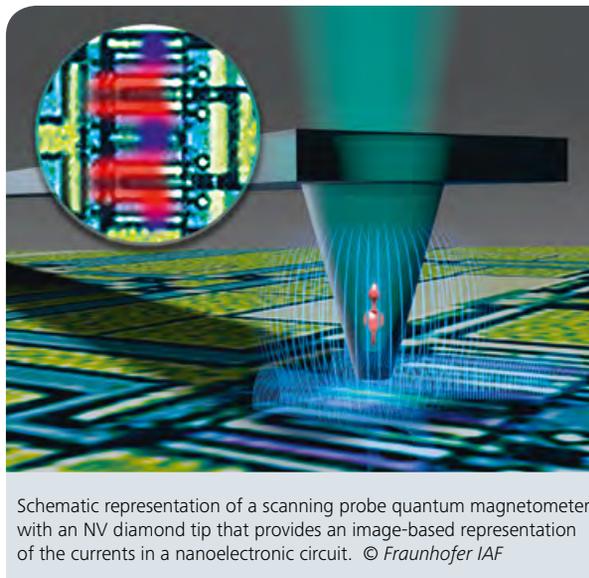
By its completion in 2024, the QMag project will have created two complementary quantum magnetometer systems that can detect tiny magnetic fields created by only a few moving electrons or nuclear spins. The two systems will both work at room temperature and are intended to open up fundamentally new applications to industry. "The objective of the QMag lighthouse project is to create image-based representations of magnetic fields with a previously unprecedented spatial resolution and the highest sensitivity for applications in electronics and medical technologies," says Oliver Ambacher, head of the Fraunhofer Institute for Applied Solid State Physics IAF in Freiburg, the lead Fraunhofer Institute in the project.

Researchers at his institute are working on what are called "scanning probe quantum magnetometers," the gleaming foundation of which is an artificial diamond with an electron positioned at its tip. This is achieved by removing two adjacent carbon atoms and replacing one with a nitrogen atom. The leftover electron from the nitrogen atom falls into the adjacent gap. This electron then has a magnetic moment, the orientation of which is used to demonstrate the presence of the magnetic field, turning the electron into a digital compass.

The hardness of the diamond crystal makes it possible to orient this electron and thus also allows weak magnetic fields to be measured over relatively long periods of time, even at room temperature. The main applications for the diamond-based quantum magnetometer are in micro- and nanoelectronics, where the image-based and non-destructive demonstration of power distribution is of great importance.

Alkali atoms as highly sensitive magnetic field sensors

In addition to the diamond sensor, the project partners are working in parallel on a second approach based on the same measurement principle, but intended for use in other sectors: highly sensitive optically pumped magnetometers ("OPMs") are under construction at the Fraunhofer Institute for Physical Measurement Techniques IPM. Based on gas cells, the system is suited for use in process analysis as well as production and materials control, since it, too, can operate without the need for cooling.



Schematic representation of a scanning probe quantum magnetometer with an NV diamond tip that provides an image-based representation of the currents in a nanoelectronic circuit. © Fraunhofer IAF

OPMs make use of the magnetic field dependency of electronic transitions in alkali atoms. The principle is as follows: In the magnetometers, a laser beam prepares the alkali atoms in the gas phase in such a way that their magnetic moments all have the same orientation. When a magnetic field is present, the electrons in these atoms begin to rotate in a synchronous circular motion. This motion can be measured with great precision based on the absorption of a laser beam at the appropriate wavelength.

Precisely detecting the smallest defects

This makes it possible to detect the most minute magnetic fields, for example to expose the smallest cracks and cavities in materials during production control. A magnetic stray field surrounds every microscopic material defect, which this kind of sensitive magnetic field sensor can identify precisely and without contact. Thus for example steel can be inspected for quality while still in production. Non-destructive material testing of high-strength steels is of enormous significance for lightweight automobile construction in particular.

As part of the QMag lighthouse project, the Fraunhofer experts are furthering the technological development of OPMs for use in low-field magnetic resonance systems, especially for chemical analysis and material characterization. And the process can be used in medical applications as well. Here the highly sensitive magnetometers will provide previously unattainable insights into brain function and will help in the diagnosis of illnesses. Furthermore, their compact size will make medical examinations much more comfortable for patients in the future. ■

New hope also for medicine: quantum sensors could provide novel insights into brain function

Fraunhofer worldwide

Fraunhofer technology praised by top U.S. animation studio

 Is there an intermediate species between our shaggy ape cousins and us humans? There is in the movies. In the animated feature *Missing Link*, released on May 30, researcher Sir Lionel Frost stumbles across such a hirsute creature. Part human, part animal, this Sasquatch is eloquent, funny and kind-hearted. U.S. production company Laika tapped into Fraunhofer know-how to make this stop-motion movie.

A 3D printer driver called Cuttlefish helped bring these figures to life. Developed by researchers at the Fraunhofer Institute for Computer Graphics Research IGD in Darmstadt, this software furnished commands to control the printer that fabricated the animated protagonists' faces – in thousands of variations with ever so slightly different expressions. The moviemakers' standards for 3D print quality were rigorous indeed.

Every shade of each color in a facial expression had to match that of the previous image. Cuttlefish has the technical wherewithal for that kind of precision. Supporting various 3D printing technologies, it enables animators to work with many materials simultaneously, while ensuring the accuracy of reproduced shapes and colors. It even lends itself to printing translucent objects – that is, materials that are partially or wholly transparent.

Brian McLean, Laika's director of rapid prototype, has nothing but praise for this tech: "For our current production, *Missing Link*, we used Fraunhofer IGD's technology because it has made it possible to achieve one-of-a-kind color consistency and geometric accuracy. By combining the Cuttlefish software with the Stratasys J750 hardware, we were able to create the most complex color 3D prints that have ever been produced."

Quick comeback and victory thanks to carbon-fiber brace from Fraunhofer

 What do you do when an injury benches one of your key players? The coach of the Michigan State University (MSU) basketball team came up with a novel idea when power forward Nick Ward fractured his left hand: he called the university's engineers to the rescue.

These researchers set out to develop a brace for Ward. First, they scanned the injured hand and computed a 3D model that would provide the blueprint for a heat-resistant, carbon-fiber brace. The researchers at MSU's Fraunhofer USA Center for Coatings and Diamond Technologies CCD then fabricated it with a 3D printer. The brace not only speeded Ward's return to training, it also got him back on the court in time for the Big Ten tournament. The Spartans took home the title.

Fraunhofer coordinates clean-water initiative for Africa



More than 130 million people south of the Sahara have no access to clean water. African and European partners have joined forces in an EU project called SafeWaterAfrica to develop a distributed system for purifying water from wells and rivers. The Fraunhofer Institute for Surface Engineering and Thin Films IST in Braunschweig is coordinating the project.

The first trial with a demonstrator system is underway in South Africa; a second unit has been installed in Mozambique. Powered by solar collectors and batteries, these off-grid systems

run without mains power. With a capacity of 1000 liters per hour, each plant can cover the needs of around 300 people.

Fraunhofer IST developed the technology for electrochemical water purification: a low-voltage charge applied to electrodes coated with thin diamond layers generates hydroxyl and ozone radicals in the flowing water. These radicals kill germs and break down organic impurities.

This disinfection unit is just one of several modules. Other purifiers remove heavy metals, sediments and nitrogen compounds.



Fraunhofer puts down roots in Shanghai as a cooperation partner



Shanghai is growing. The city at the mouth of the Yangtze River is China's hub of business. Leading automakers, machine manufacturers and steel companies call it home. A new district, the Lingang area, also offers an attractive abode for companies from all over the world.

Fraunhofer is putting down stakes here. The Sino-German Project Center for Smart Manufacturing arose from a contract signed on March 26. A team from the Fraunhofer Institute for Manufacturing Engineering and Automation IPA in Stuttgart and Shanghai Jiao Tong University

(SJTU) have set up camp here to develop new processes for production management, human-machine collaboration and digitally connected manufacturing. The district's governing body, the Shanghai Lingang Area Development Administration, is supporting the project.

The researchers have already gotten a first demonstrator production line up and running. It shows how digitally connected machines can help optimize manufacturing. The Sino-German team aims to put Industrie 4.0 solutions into practice in a joint effort with industrial companies that use this tech.

Fraunhofer develops micro dosing pump for medical applications



A German-Japanese research team has harnessed printing technology to fabricate a quiet, light and inexpensive pump that dispenses liquids with exacting accuracy. "Not much larger than a two-euro coin, this pump is perfect for medical applications, for example, to deliver precise doses of liquids such as insulin or antibiotics," says Ivica Kolaric by way of explanation.

His team at the Fraunhofer Institute for Manufacturing Engineering and Automation IPA in Stuttgart and scientists at the National Institute of Advanced Industrial Science and Technology (AIST) in Osaka, Japan, have developed a prototype. Both research groups contributed their particular skills. The Stuttgart-based researchers specialize in process technology; their Japanese colleagues excel at developing materials.

At the heart of the pump is an electrically controlled membrane. It consists of an ionic electroactive polymer, a conductive plastic containing ionic liquids. The ion density changes in response to an electrical charge, moving the membrane. It stretches and contracts much like a stimulated muscle. It takes the 3D printer but a few minutes to fabricate the pump housings. All components are made of plastics applied in precisely the right amounts and blends during the printing process.

Fraunhofer and Australian partners research more durable and efficient solar panels



How do defects and impurities in the crystal affect solar cells' efficiency? How do we boost efficiency? And how do we extend solar cells' life? Scientists at the Fraunhofer Institute for Solar Energy Systems ISE in Freiburg have teamed up with researchers at the Australian National University and the University of New South Wales to answer these questions.

"We have a lot in common," says Dr. Martin Schubert, head of the Quality Assurance, Characterization and Simulation department. "All facilities specialize in measurement techniques for analyzing solar cells, but use different methods. A combination of these methods should help us achieve our goal."

This desk is poised to make India more livable

From 2030 onward, Indians will outnumber Chinese - it's a huge future market. Working here for Fraunhofer is a petite woman with a great love for Germany: Anandi Iyer.

Text: Christine Broll

Anandi Iyer lights a tea candle in front of the image of spiritual master Sai Baba of Shirdi every morning. Sai Baba dedicated himself to working toward the equality of all sections of society. © Christof Blumberger



India and Germany meet on Anandi Iyer's desk. This is where the director of Fraunhofer India coordinates the German institutes' projects with their Indian partners.

“Maybe I was
German in a
previous life.
We Indians
believe in
reincarnation,
you know.”

Anandi Iyer

Two coins lie before the holy man's
image as a symbolic sacrifice. Sacrifice
plays a central role in Hinduism.

Looking at India can be quite depressing. Dr. Marius Mohr experienced just that at Valankulam Lake near Coimbatore, a city with more than a million inhabitants in South India. The shore is littered with trash and a foul odor emanates from the turbid water. And the lake's great history? Gone. Finished. And polluted.

Some 1200 years ago, Valankulam Lake was part of a complex rainwater management system that was built by the powerful rulers of the Chola dynasty to store the excess water from the Northeast Monsoon in October and November and harness it for agriculture. Together with German and Indian partners, Dr. Marius Mohr traveled from the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB in Stuttgart to examine this historical irrigation system. All around Coimbatore, the same scene presents itself: instead of clear rainwater, foul effluent fills the lakes and canals. Only one in every three of the city's 1.6 million inhabitants has access to the sewer system. There is currently only one functioning sewage treatment plant for the entire city.

The team of experts is conducting their survey in connection with the Smart Water Future India project, which is funded by the German Federal Ministry for the Environment (BMU). Their aim is to develop a sustainable water management strategy for Coimbatore, one of India's fastest-growing cities. And this isn't the only Fraunhofer project in the most populous democracy on earth. Since 2018, Fraunhofer has also been working on improving the traffic situation in Coimbatore as part of a project spearheaded by the Fraunhofer Institute for Industrial Engineering IAO and financed by the German state-owned development bank Kreditanstalt für Wiederaufbau. On the southwest coast, in the port city of Kochi, Fraunhofer is helping improve the infrastructure with a smart city project led by the IAO.

Fraunhofer and India: All threads come together in Bangalore – India's third-largest city – in the Fraunhofer office on the fourth floor of a gray commercial high-rise in the city center, at a desk bearing closely crossed German and Indian flags flanked by an Indian shrine. This is where Anandi Iyer works.

The director of Fraunhofer India greets her visitors in perfect German. She learned the language by taking courses at the Goethe Institute in Delhi, and she read Goethe and Schiller after passing the test for the Major German Language Certificate (Großes Deutsches Sprachdiplom). “I have a great fondness for Germany, for the orderliness there, and for its people,” she says. Winking, she adds: “Maybe I was German in a previous life. We Indians believe in reincarnation, you know.”



India is expected to have 1,500,000,000 inhabitants in 2030, superseding China as the most populous country on earth

► **Her affinity for Germany** makes it easier for her to bridge the gap between the Indian and German mentality in her daily work. It isn't always a simple task, especially when it comes to planning and organization – for delegation visits, for example. The German partners would prefer to know who's coming six months in advance, while the Indians don't decide who might join the trip until a week before departure, at the earliest.

Anandi Iyer has further improved her knowledge of German over the course of her career – first at GIZ, the German society for international cooperation in Delhi, and later in connection with a German Federal Ministry for Economic Affairs project in which she helped German SMEs establish operations in India. That's where she first encountered the Fraunhofer-Gesellschaft – or, to be more precise, a delegation sent to evaluate whether Fraunhofer should become involved in India.

Anandi Iyer still remembers that meeting very clearly. "Back then, I was asked whether Fraunhofer can afford to go to India. I answered with another question: Can Fraunhofer afford not to go to India?" After all, with a population of 1.3 billion, the Indian market is gigantic. And India continues to grow. According to UN estimates, India will surpass China, becoming the most populous country on earth – with 1.5 billion inhabitants – in 2030.

The decision was finalized in 2008: Fraunhofer will become involved in India. And Anandi Iyer was tasked with setting up an office there. "Ten years ago, hardly anyone in India had heard of Fraunhofer," Iyer recalls. "As contract research was still at a nascent stage in India, we were faced with the question of whether the Indian industry would even be willing to pay for research activities."

Step by step, Iyer made the Fraunhofer name known. She went to companies, government agencies and ministries. She organized delegation visits and technology workshops. To date, more than 50 Fraunhofer Institutes have participated in a broad array of projects in India. Anandi Iyer's office, where she is supported by four managers, generates an order volume of nearly four and a half million euros per year. Of that amount, 70 percent comes from Indian industry and about 30 percent from Indian and German funding sources. Fraunhofer is now so well known in India that Fraunhofer co-organized the Official Business Summit for the visit of the German Chancellor and Indian Prime Minister Narendra Modi to Bangalore in 2016, and signed a memorandum of understanding with the Indian Ministry of Production – and Anandi Iyer was invited to a dinner with Angela Merkel afterwards.

Better quality of life for India's cities

One of Iyer's main areas of focus involves smart city projects aimed at making Indian cities livable again. Today, India's metropolises are being choked by chaotic traffic, they lack clean drinking water, and they are drowning in sewage because there is no functioning waste management. To tackle these problems, the Indian government launched the Smart Cities Mission, which is supporting hundreds of Indian cities in their development. Germany is sponsoring three of these cities: Bhubaneshwar, Kochi and Coimbatore.



Clean India. Indian authorities appeal to citizens using signs featuring Mahatma Gandhi's iconic glasses. © *Christof Blumberger*



Mopeds, motorized rickshaws and trucks edge their way through India's cities amid a deafening chorus of honking horns. © *Christof Blumberger*



Waste and sewage pollute India's waters, as seen here in Mumbai.

Dr. Marius Mohr from Fraunhofer IGB became acquainted with Coimbatore, which is located around 350 kilometers south of Bangalore, in March 2018. He traveled together with project partners Dr. Stefan Liehr from the Institute for Social-Ecological Research in Frankfurt am Main and Alyssa Weskamp from consulting firm Drees & Sommer to analyze the city's overall situation. Locally, Aditya Fuke from the Fraunhofer office in Bangalore supports the team by establishing contacts and providing data.

When Mohr entered the Coimbatore city administration office for the first time, he immediately understood why he hadn't been able to reach anyone here by e-mail. "There were neither laptops nor monitors on any of the desks – only stacks and stacks of files."

The project team presented some initial ideas for solving the wastewater problems at a workshop in Coimbatore last July. One possibility is semi-decentralized, modular sewage treatment plants that can grow in step with the population. Under the guidance of Fraunhofer India, a "Water Innovation Hub" is being set up in Coimbatore to devise sustainable solutions. German companies will be able to build pilot plants there to demonstrate their expertise for the Indian market.

Fraunhofer's commitment to India is also awakening international interest and recognition. At the World Corporate Social Responsibility Congress (World CSR Congress) in Mumbai in February, Anandi Iyer was honored with the "Global Top 51 Smart City Leaders Award" – one more brick in the foundation of Fraunhofer's strong reputation in India.

In this male-dominated country, it is by no means a given for a woman to be this successful. "Upon first meeting me, Indian men are often surprised that I hold this position," says the mother of two. She also draws strength and inspiration for her work from Hinduism. On her desk is an image of spiritual master Sai Baba of Shirdi. She has adorned it with a floral garland, and every morning she lights a tea candle stationed in front of it. "Sai Baba advocated humanity, the reconciliation of Muslims and Hindus, and the rights of women and the lower castes," says Anandi Iyer, explaining her admiration for her role model. The spiritual leader died in 1918.

Door opener for German industry

Anandi Iyer sees great potential for future synergies in the cooperation between India and Germany. Here, too, she considers Fraunhofer India to be a door opener for German industry. Cooperation particularly lends itself to Industrie 4.0. Germany is a leader in production technology, while India has strong IT expertise. Another field is solar energy, which is currently being promoted extensively in India.

"But we can't adopt these technologies one to one," warns Anandi Iyer. Many things are different in India – the infrastructure, the climate. But above all the dimensions. Dr. Marius Mohr also experienced this when searching for solutions to the wastewater problem in Coimbatore. "The city's population is expected to increase by another million in the next 30 years," says Mohr. "That's a huge challenge and it goes well beyond the dimensions we work with in Germany. We need technologies that are adapted for India. That's the only way we will be able to sustainably improve the water quality of the lakes and rivers." ■

"I was asked whether Fraunhofer can afford to go to India. I replied: Can Fraunhofer afford not to go to India?"

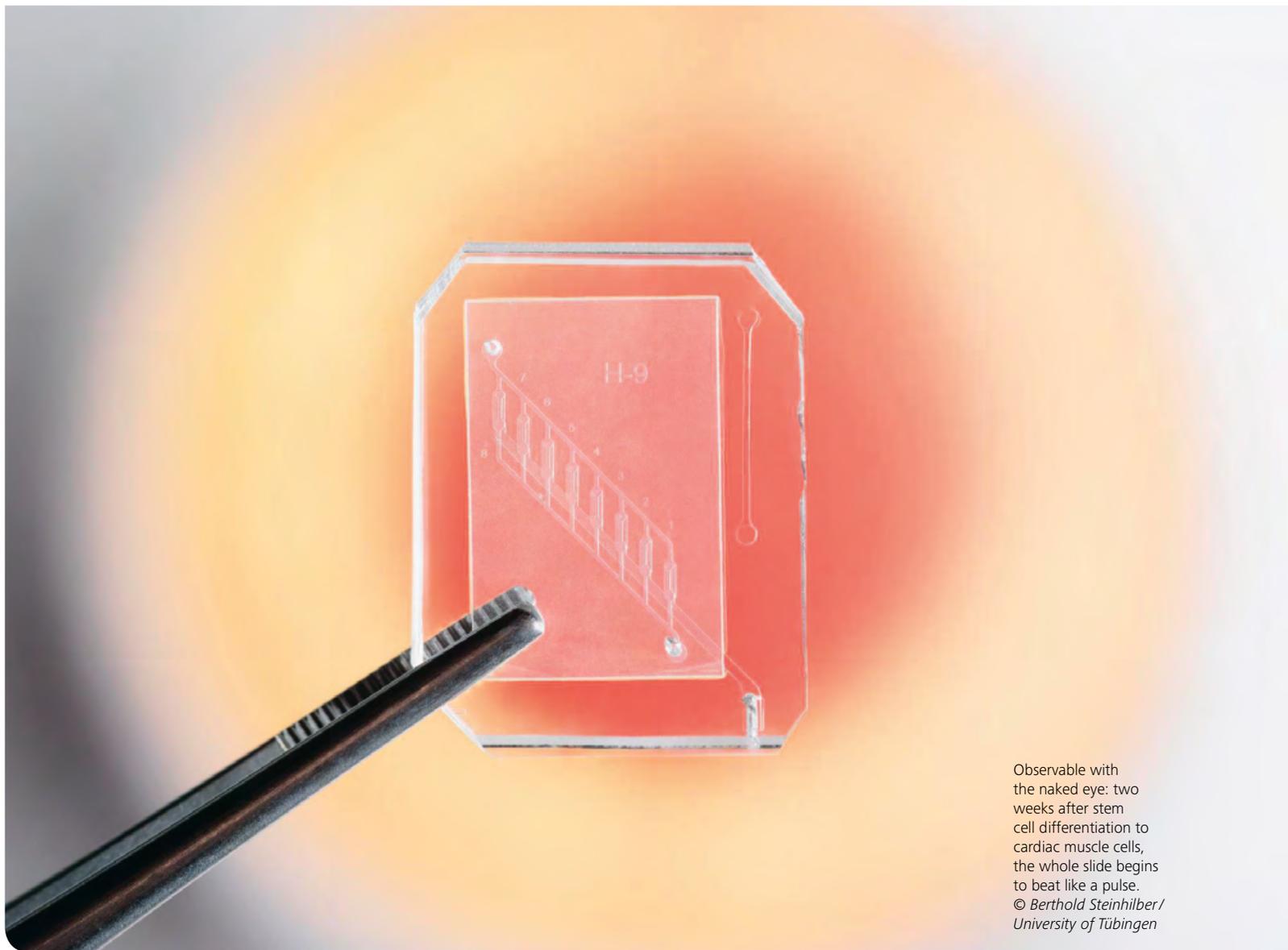
Anandi Iyer



Anandi Iyer cultivates contacts with political figures, such as Svenja Schulze, the German Federal Minister for the Environment. © Fraunhofer India



Speaking with Indian Prime Minister Narendra Modi at a reception at the Indian embassy in Berlin. © Andreas Amann



Observable with the naked eye: two weeks after stem cell differentiation to cardiac muscle cells, the whole slide begins to beat like a pulse.
© Berthold Steinhilber / University of Tübingen

Cells that beat like a heart

More than meets the eye: organ-on-a-chip technology could lead drug research toward the development of gender-specific medicine.

Text: Christine Broll

It seems like an act of creation. For Dr. Christopher Probst, however, it's all part of the job. Probst has just taken a dish with cell cultures from the incubator. He slides the cultures carefully under the microscope and observes how the thin tissue of transparent cells pulsates. The stem cells have differentiated to cardiac muscle cells. "By the time the cells are two weeks old," Probst explains, "you can see, with the naked eye, the whole slide beating like a pulse!"

Probst is a research fellow at the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB in Stuttgart. He is part of the Attract working group, which is led by Prof. Peter Loskill. If successful, the group's research may well substantially reduce the number of animal experiments.

(see interview, right).

Doctoral student Oliver Schneider will use the cardiac muscle cells to create a so-called organ-on-a-chip (OOC): postage-stamp-sized polymer chambers in which minuscule tissue cultures and organoids are fed with nutrients via a system of microchannels. Back in 2016, OOC was declared one of the top emerging technologies by the World Economic Forum. Today, there are OOC systems for a whole range of tissue types, including cardiac muscle, liver, kidney and even brain tissue. The working group at Fraunhofer IGB has helped spearhead this technology in Europe, pioneering a number of unique developments that include the recreation of human fatty tissue and human retinal tissue on a chip.

Loskill is pursuing an ambitious goal. He first began working on OOC technology in the USA back in 2013, where a huge funding program had just been launched. This saw a number of research organizations team up with federal and public bodies for a variety of projects. The Food and Drug Administration (FDA), for example, saw OOC as a means of speeding up drug development, whereas the U.S. Department of Defense was interested in tests for chemical and biological weapons. The Environmental Protection Agency (EPA), meanwhile, wanted ways of investigating pollutants. Buoyed by hundreds of millions of dollars in funding, U.S. researchers soon forged ahead of the rest of the world, including Europe. Loskill is now seeking to redress the balance. Together with three fellow researchers from the Netherlands, he set up the European Organ-on-Chip Society in November 2018. This was followed by an inaugural conference in Stuttgart. Furthermore, EU funding has now been secured for two undertakings: a Marie Curie project involving 21 European partners, and an initiative to draw up a road map for OOC technology in Europe.

This collaboration between European research groups will help pave the way for a broad-based application of this technology. And now that scientists have mastered the



"Many diseases manifest themselves in different ways in male and female patients," Prof. Peter Loskill explains. His research may well lead to the development of gender-specific therapies. © Bernd Müller/Fraunhofer IGB

technique of placing a whole variety of tissue cultures on a chip, the next challenge will be to increase the throughput of the various substances being tested. Doctoral student Schneider is already working on ways of scaling up this technology. In the future, so-called organ-on-a-disc systems will combine hundreds of human tissue samples in one handy format, thereby helping to turn this technology into a routine procedure.

Teaching a chip how to see

The latest breakthrough to emerge from Loskill's lab is a retina-on-a-chip system, featuring the complex stratified tissue of the human retina as an organoid. Right now, Loskill and his team – which includes doctoral student Johanna Chuchuy – is busy endowing it with the capacity to see. Working with partners from the University of Tübingen, they have been able to differentiate stem cells and incorporate them in a chip in such a way that they recreate a multilayer tissue. This tissue comprises, among other things, light-sensitive rods and cones, retinal pigment epithelium and ganglion cells, which make up the optic nerve. "When we shine light on the retina-on-a-chip, we register an electrophysiological signal in the rods and cones," Loskill explains. "And now we're working on a system with which we can quantitatively measure this signal."

Such a system will make it possible to measure the extent to which a substance influences the "visual capacity" of the retina-on-a-chip. "The pharmaceutical industry is showing a big interest in retina-on-a-chip technology," Loskill adds. "Lots of modern drugs have retinopathic side effects." To date, model systems are rare in this field. Animal models, for example, are of only limited use since the retina of animals has a different structure than that of the human retina. Moreover, retina-on-a-chip technology will also facilitate research into diseases of the retina and the development of drugs to treat conditions such as age-related macular degeneration and diabetic retinopathy. ▶

"Substantially fewer animal experiments"

Prof. Loskill, will organ-on-a-chip technology help reduce large-scale animal experimentation? For sure.

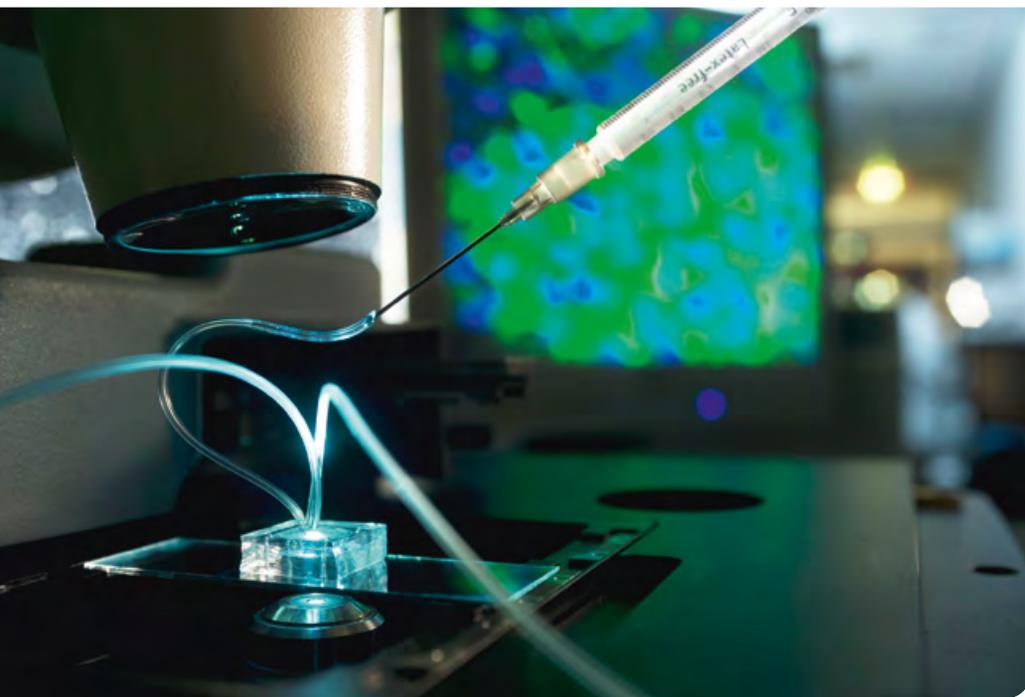
We're already seeing a big interest on the part of the pharmaceutical industry. The technology can be used right across the board: screening for new active ingredients, carrying out toxicity tests and backing up clinical studies.

Will the regulatory authorities accept organ-on-a-chip data in place of results from animal experiments? The

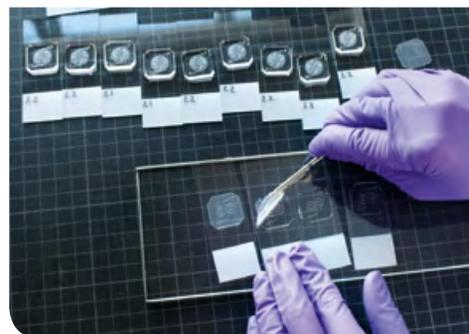
regulatory authorities are very open to this new technology. I'm currently working with regulatory bodies on two EU projects. These include the German Federal Institute for Drugs and Medical Devices (BfArM).

Will the technology make animal experiments completely redundant in the long term? No

technology alone will ever be able to completely replace animal experimentation. But our chips do provide a source of data that will enable us to gain requisite certainty with significantly fewer animal experiments.



WAT-on-a-chip, under a microscope: a syringe is used to introduce an active ingredient in order to investigate how the tissue reacts. © Bernd Müller/Fraunhofer IGB



WAT-on-a-chip preparation at Fraunhofer IGB in Stuttgart. © Berthold Steinhilber/University of Tübingen (top), Bernd Müller/Fraunhofer IGB (bottom)

Fat makes up one quarter of the weight of a healthy person – but we're only just beginning to understand its role in the body.

► **Of even greater medical significance** are so-called WAT-on-a-chip systems. WAT is the abbreviation for white adipose tissue – a key factor in human health, not least because it makes up such a significant proportion of body mass. Adipose tissue comprises a quarter of the body mass of a healthy person and up to half the body mass of a clinically obese person. It has only recently become clear that adipose tissue is responsible for secreting a whole variety of hormones and other chemical messengers into the blood stream. Much of this field is still not properly understood, but WAT-on-a-chip systems should help deepen our understanding of the role that white adipose tissue plays in the body and enable researchers to develop more selective treatment for associated diseases such as diabetes.

In addition, WAT-on-a-chip systems help reveal the processes by which substances are stored in adipose cells. To demonstrate this, doctoral student Julia Rogal uses a fatty acid marked with a green fluorescent dye. She injects the fatty acid into the chip and places it under the microscope. Within a few minutes, the green fatty acid can be observed penetrating and accumulating in the round adipose cell. Similar methods can be used to investigate whether herbicides, for example, or microplastics accumulate in fatty tissue.

Loskill also expects OOC technology to open up a further field of research – that of sex-specific medicine. “Many diseases manifest themselves in different ways in male

and female patients,” he explains. “It’s an aspect that has not yet received enough attention in medical research and drug development.” In the future, OOC systems will enable researchers to investigate male and female tissue separately. For example, it would be possible to use a female organ-on-a-chip system to simulate the menstrual cycle and observe whether it has an impact on a specific disease and potential drug therapies. Such projects form part of his work as junior professor at the Institut für Frauengesundheit (Institute for Women’s Health) at the University of Tübingen, where he is also producing chips containing the tissue of breast and cervical tumors.

Collaboration with a working group under the leadership of Dr. Frank Sonntag at the Fraunhofer Institute for Material and Beam Technology IWS in Dresden has yielded further breakthroughs. Building on Fraunhofer IWS’ expertise in microfluidics, the team has developed a multi-organ chip that simulates the way in which the organs in the human body are supplied with blood. Using a smart combination of pumps, valves and control technology, the chip is able to replicate the differing rates of blood flow to the organs. Last October, the multi-organ chip from Fraunhofer IWS was presented with an Innovation Award from the European Association of Research and Technology Organisations in Brussels. The two Fraunhofer research groups have now submitted a joint patent application with a view to combining the two systems. ■

An ultra-secure network

Major initiative for quantum communication: German research organizations collaborate on infrastructure designed to make sensitive content proof against eavesdropping.

Text: Mandy Bartel

Quantum objects have a very special property: they never reveal the entire information about their current state. This is because any attempt to capture that information irrevocably modifies the quantum object in that very instant, such that this original state can never be recovered. Which of the countless, superposed quantum states is captured in that precise instant is subject entirely to the principle of quantum indeterminacy.

Researchers from the Fraunhofer-Gesellschaft, the Max Planck Society and the German Aerospace Center (DLR) are now collaborating on the QuNET project to develop an ultra-secure communications network based on quantum cryptography – i.e., quantum key distribution. Any attempt to eavesdrop on a communication encrypted in light particles – photons – alters the quantum state of the encryption key and is therefore immediately detected.

The goal: data sovereignty for the whole of Europe

A major drive to develop quantum communication was announced back in May by the participating research bodies along with the German Federal Ministry of Education and Research (BMBF). The primary goal of QuNET is to develop technology to enable ultra-secure communications between government organizations. At the same time, it is hoped that this technology will provide the cornerstone for a future German quantum communications infrastructure.

According to Fraunhofer President Prof. Reimund Neugebauer, Europe is seeking to combine the highest levels of data sovereignty and data security. To achieve this, the long-term goal will be to link a quantum network with so-called international data spaces. These are created by the International Data Spaces Association, an initiative founded by Fraunhofer to enable the secure exchange of data between mutually trustworthy members of the business community.

At the same time, QuNET is set to play a pioneering role in the creation of the quantum Internet. This will enable quantum computers to exchange information in the form of so-called

qubits. Since quantum information cannot be copied, it is impossible to transmit it over a classic network. Instead, the quantum state must be transferred from one node to another. In order to handle longer distances, this transfer can be accomplished by satellite or over a terrestrial fiber-optic network by means of quantum repeaters.

QuNET is a consortium project initiated and led by the Fraunhofer Institute for Applied Optics and Precision Engineering IOF in Jena. Further partners include the Berlin-based Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institut, HHI, the German Aerospace Center (DLR) and the Max Planck Institute for the Science of Light. The project also involves partners from the following sectors of industry: telecommunications, systems and component development, security and satellite operation. This cooperation will ensure that solutions quickly find their way into industrial applications.

The project is scheduled to start this fall and will comprise three phases. Over the coming two years, the partners will initially be working to develop the hardware components. Then, in a second phase, they will establish the technological basis for multiuser operation in heterogeneous networks. In the third phase, they will work with industry and federal network operators to scale up the technology and take it to the product stage, thereby laying the foundation for the creation of a quantum-based network for government agencies. ■

QuNET is expected to pave the way for a German and European communications infrastructure that is proof against eavesdropping.



With quantum communications, any attempt to eavesdrop can be immediately traced. © action press

Brilliant insights from outside the box

An instant dental prosthesis, delivered chairside? Dr. Bernhard Durschang and Dr. Jörn Probst from Fraunhofer ISC discovered how to do just that with a material few believed had any potential left to exploit. They took home a Fraunhofer Prize for Human-Centered Technology for their efforts.

Texts by Janine van Ackeren

Dentists and patients want the same thing in chairside care – colorfast, bespoke dental prostheses delivered straight to the dentist’s chair. Dr. Bernhard Durschang and Dr. Jörn Probst from the Fraunhofer Institute for Silicate Research ISC in Würzburg found a solution based on glass ceramics, a material thought to have little left to offer in the way of technical advances.

Teaming up with the two companies VITA Zahnfabrik H. Rauter GmbH & Co. KG and DeguDent GmbH, they have given this material a new lease on life in tomorrow’s dentistry. “Our glass ceramic offers several benefits in one: First, it is much stronger and more robust with 450 to 500 megapascals compared to just around 350 megapascals for conventional glass ceramics,” says Probst. “What’s more, it needs no post-curing in a furnace. On top of that, the glass ceramic looks great in all the various hues, and that does not change in the further course of processing. This way, the dental prosthesis can be selected to perfectly match the color of the patient’s teeth.”

The two scientists defied conventional wisdom to come up with these improvements. Glass ceramics consist of an amorphous glass component with an atomic arrangement much like a liquid. Individual crystals form as their atoms take up precisely defined positions relative to one another. They endow the material with entirely different properties, such as enhanced strength. To date, researchers have tried to vary the type of crystal or increase the relative proportion of crystalline phases as high as it would go. The amorphous glass phase was merely an unwelcome leftover.

“What we did instead was modify the properties of the glass phase – and achieved astonishing results in doing so,” says Bernhard Durschang, who has been developing glasses and glass ceramics at Fraunhofer ISC since 1996. “Adding various metal oxides to the amorphous portion increases its strength. This changes the amorphous portion of an undesirable residual glass, which you really wanted to be rid of, into a useful portion that has the added benefit of enhancing overall strength. The two researchers also adjusted

the material’s color by modifying the glass phase.

Although developing the material was the greatest challenge, it took more than that to turn the inceptive idea for a solution into a CI-certified production plant. “The industry customer gets everything from a single source – that is unique,” says Durschang. Many dentists are now using this new type of glass ceramic. The two partner companies’ annual revenue from this material has already climbed to eight figures, with annual growth rates of around 20 percent expected for the years ahead.

Dr. Bernhard Durschang and Dr. Jörn Probst garnered the Fraunhofer Human-Centered Technology prize for their remarkable success in developing an ultra-robust ceramic for state-of-the-art chairside dental care. Explaining its rationale for singling out this achievement, the jury pointed to the project’s “multiple development criteria encompassing medical parameters and efficient manufacturing technology.” ■



This red-hot crucible holds the molten mass of the glass-to-be, the base material for the dental prosthesis.



Casting and cooling the molten glass in graphite molds.



A cast glass block as used by the researchers to characterize the material.

With up to 500 megapascals, the new dental prosthesis is more robust than earlier glass ceramics.

The long wait for prostheses to cure in a furnace is over.

Not even a subtle change of hue occurs during processing.

Dr. Bernhard Durschang (left) and Dr. Jörn Probst from Fraunhofer ISC.
© All pictures of Fraunhofer prizes: Piotr Banczerowski

Accelerating the installation of cable for fast broadband

Prof. Alexander Reiterer inspects a laser scanner that is used to map street environments.



Germany is planning to roll out gigabit networks nationwide, but telecom companies lack the necessary human resources to install the infrastructure. A tool from Fraunhofer IPM - with 3D mapping and machine learning - is now providing the solution.

Germany's federal government is committed to improving bandwidth. The target is nationwide access to fast gigabit networks by the end of 2025. This will require a massive rollout of optical fiber. Currently, however, the project is mired in planning issues. Where best to lay the cable? Will the earthwork damage trees? Will expensive paving need replacing? To date, telecom companies have sent out employees to measure every street and take photos. All this data must then be evaluated without the help of digital technology. Mapping out a nationwide fiber-optic network would require in excess of 1000 new employees - way more than are available in the current market. Now, however, Prof. Alexander Reiterer, Dominik Störk and Dr. Katharina Wäschle from the Fraunhofer Institute for Physical Measurement Techniques IPM in Freiburg have come up with a solution so promising that it promptly landed them the Joseph von Fraunhofer Prize. In explaining its decision, the jury highlighted the new development's impact on society as a whole and its high public profile.

As Germany gears up for fiber, a new Fraunhofer tool is slashing the time required to plan cable routes

A highly practical solution

"We've come up with a unique process chain that analyzes 2D and 3D data fully automatically, recognizes objects relevant to the application and then incorporates them in a digital planning map," says Prof. Reiterer, head of the project at Fraunhofer IPM. "It's a tool that can be used wherever you need to identify and map, right down to the last centimeter, the surface of a particular area, including the type of paving as well as objects such as street lamps."

Deutsche Telekom, the first company to adopt the new tool, now requires just a couple of days to plan the rollout of fiber

in a small town. In the past, this would have taken several weeks. "Initial tests show that the data from our tool has made the whole planning process up to 70 times faster for Deutsche Telekom," says Störk, an IT expert at Fraunhofer IPM. "And, what's more, it's all fully automated."

The process is based on extremely precise positional data provided by survey vehicles equipped with cameras, laser scanners and spatial-location systems. Machine-learning methods mean that the system can automatically recognize whether an object is, for example, a deciduous or coniferous tree. The biggest challenge was to assemble the dataset required to train the system. "When a person looks at a picture, they bring along a wealth of knowledge about the world; they know, for example, if they are looking at a real car or merely a billboard with a picture of a car," explains Dr. Wäschle, a research associate at Fraunhofer IPM. "A neural network, which only knows the world in terms of segmented images, can't recognize the difference."

Some 100,000 representative images were selected from almost two million mapping images. These were then manually evaluated and annotated in 30 object classes by a team of 50 employees working over a period of 12 months. In terms of both quality and variation - differing weather conditions, for example - the dataset is better than anything currently available worldwide.

A tool from Fraunhofer with major potential

When it comes to expanding Germany's fiber-optic network, there are more than 1800 earthwork companies in Germany eager to make use of the data generated by the Fraunhofer tool. Construction company Strabag, for example, which presently uses drones to monitor roadworks on freeways and other roads, will soon be turning to the Fraunhofer tool for this purpose. Likewise, Germany's Federal Highway Research Institute (BASt) is currently using the technology in a pilot project to update its mapping of street furniture. Finally, for Deutsche Telekom, there are plenty more jobs that will require the use of intelligent algorithms, not least the rollout of wireless-to-the-home (WTTN) and 5G technology. ■

Hybrid analysis saves resources

Manufacturing chemicals consumes a lot of energy. However, a new software solution is now bringing savings of 10 percent and more. Developed by Dr. Michael Bortz and Prof. Karl-Heinz Küfer from the Fraunhofer Institute for Industrial Mathematics ITWM, this analytic tool has won them this year's Joseph von Fraunhofer Prize.

Plastics, detergents and fertilizers have one thing in common: they are all made of mass-produced feedstocks. It takes a lot of energy to produce these basic chemicals – so much so, in fact, that chemical production accounts for 20 percent of commercial energy requirements in Europe. Cutting this energy consumption would therefore reduce the burden on the environment and save companies money. Yet trial and error is not an option here. Chemical companies operate huge plants producing many tons of product a day. Were an engineer to turn the wrong valve in an attempt to make the process more energy efficient, it is quite possible that the product would no longer meet the required quality standards. In short, it would be unfit for sale.

Significant savings

A team led by Dr. Michael Bortz and Prof. Karl-Heinz Küfer at the Fraunhofer Institute for Industrial Mathematics ITWM in Kaiserslautern has now developed a model that describes all the complex processes involved. "Our algorithms replicate the various processes in a realistic way, which means we can describe a production operation over its entire lifecycle," explains Bortz, a physicist and head of department at Fraunhofer ITWM. "We've already achieved energy savings of 10 percent at an operational production plant." The software is now being used by German chemicals company BASF and Swiss chemicals and pharmaceuticals company Lonza. Hundreds of process engineers thus have access to it for routine production.

A hybrid approach

"Our software tool brings together two aspects for analysis: expert knowledge about physical laws and the thermodynamic and chemical processes involved in the production of chemicals – this is what our model describes; and then the data collected by various sensors during the production process, including readings such as temperature and pressure. We use these values in situations where there are no physical data available," explains Küfer, division director at Fraunhofer ITWM. Normally, such sensor readings are merely used to monitor the various processes. Now, however, the research team has used machine-learning methods to

tap this valuable data resource. The result is a hybrid tool that successfully combines a theoretical model with process data, thereby compensating for the inherent shortcomings of each approach. For, on the one hand, a physical model is unable to depict a real process in its entirety, since not all the relevant data are known; and, on the other, it is impossible to collect all the data required during an ongoing production process, because the conditions in the reactor are generally extremely hostile.

The tool has applications beyond the chemical industry. Indeed, it will bring benefits wherever there is a need to control a process with a large number of parameters – and a process that cannot be completely described in terms of readings and process data. In the long term, the researchers hope to make the tool real-time capable. At present, it requires a couple of minutes to deliver a decision.

In recognition of the development of their hybrid analysis tool, Dr. Michael Bortz and Prof. Karl-Heinz Küfer have been awarded this year's Joseph von Fraunhofer Prize. In explanation of their decision, the jury highlighted the solution's demonstration of energy savings in the chemical industry. ■

Chemicals account for 20 percent of Europe's energy needs. A new tool from Fraunhofer helps increase energy efficiency in chemical production.



Dr. Michael Bortz and Prof. Karl-Heinz Küfer (4th and 6th from left) together with their team from Fraunhofer ITWM.



Fraunhofer HHI's three prize winners in the volumetric studio at Babelsberg.

Science dives into immersive movies

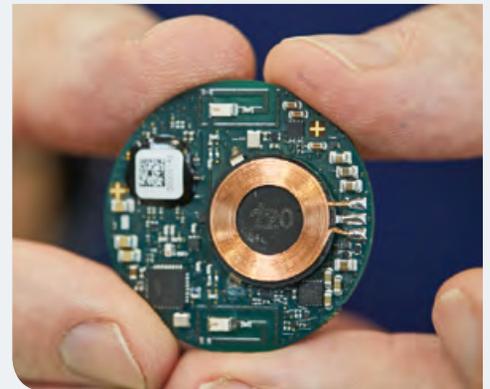
Ingo Feldmann, Dr. Oliver Schreer and Peter Kauff from Fraunhofer HHI have opened the door to usher in the walk-through movie experience.

Volumetric videos put the viewer in the middle of the action. Spectators can stroll through the scenes, but their avatars still look artificial and the way they move feels unnatural. Beard stubble, birthmarks, textures like the woven fabric of a dress – all this is still a far cry from photorealism. That is about to change.

Ingo Feldmann, Dr. Oliver Schreer and Peter Kauff from the Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institut, HHI have developed technology to put those problems to right. "We can insert into the VR environment virtual people that look lifelike and move through the artificial world with the same fluid, natural motion we are used to

As tough as ice hockey is rough

A research team from Fraunhofer IIS defied the sport's extreme conditions to measure the game's every move. This tech wowed the audience at its premiere showing in the North American NHL and won the 2019 Joseph von Fraunhofer Prize.



A chip like this inside the puck enables real-time analysis.

The 2019 Honda NHL All-Star Weekend in San Jose, USA, treated ice hockey fans and experts to a radically different way of experiencing the action of a game. The organizers deployed new tech to analyze the movements of players and the puck with unprecedented depth and precision.

A team of 20 researchers at Nürnberg's Fraunhofer Institute for Integrated Circuits IIS developed this technology. Thomas von der Grün, Norbert Franke and Thomas Pellkofer received the Joseph von Fraunhofer Prize on behalf of this team. In the jurors' statement, the jury praised the "robust technology that works loss-free under high loads during the game."

seeing in the real world,” says Ingo Feldmann, head of the Immersive Media & Communication group at Fraunhofer HHI. “And textures seen by the viewer look like they do in real life.”

To make that happen, the researchers film actors with cameras arranged in pairs and distributed throughout the room’s best vantage points. These cameras capture up to 30 frames a second, which the software uses to determine the depths of vision. It calculates the distance of each body part from the camera and then merges the data of paired cameras. This yields lifelike, three-dimensional images of people and their motions – a volumetric video that may then be rendered for any viewing angle. The researchers translate this three-dimensional model into the virtual world, including every move a person makes. The conventional approach has been to scan people and then animate their avatars on a computer.

A European premiere

For their new approach, the Fraunhofer HHI researchers purpose-built a studio. It consists of LED lighting elements that provide the backdrop for the shots as well as all-around lighting. Thirty-two camera eyes peer from these wall elements, four pairs at the bottom, eight in the middle and four more in the ceiling. With 20 megapixels definition each, these cameras are ten times as sharp as HD. And at 1.6 terabytes per minute, the data they produce is more deluge

than stream. When the researchers set up their studio at the Babelsberg movie production lot in summer of 2018, it was the only one of its kind in continental Europe. Fraunhofer-Gesellschaft partnered with Studio Babelsberg, ARRI, Interlake and UFA in a joint-venture production company that now offers digitalization and other services to the studio’s clientele.

The Fraunhofer HHI researchers aim to deploy this technology for other applications. For example, a remote expert’s avatar could join surgeons performing a difficult procedure, seeing the patient in real time and providing assistance in VR. The technology also looks to be a promising proposition for history documentaries. A project is underway to recreate historical scenes such as speeches given by Cicero at the Forum Romanum. “Essentially, our technology can be applied wherever authenticity matters,” says Kauff, with its commercial exploitation in mind. His colleague Schreer, who developed the algorithms with Ingo Feldmann, adds, “Our process opens the door to a huge new field of applications.”

The human body in 3D

Ingo Feldmann, Dr. Oliver Schreer and Peter Kauff garnered the Joseph von Fraunhofer Prize for their success in developing this 3D Human Body Reconstruction technology. Citing its reasons for acknowledging this project, the jury hailed the “broad scope of the application and of the technological, scientific development.” ■

Thirty-two camera eyes, each with ten times the definition of HD, generate 1.6 terabytes of data a minute.

Ice hockey is fast. Fraunhofer keeps pace by measuring the puck’s position up to 2000 times a second

“We installed a transmitter in the puck that sends a signal to 16 receivers distributed throughout the arena,” says von der Grün, head of department at Fraunhofer IIS. “The system determines the exact position by measuring the time it takes for the signal to reach the respective receivers. Basically, we flipped the GPS system around.” Another special feature is the high sampling rate. It tracks the puck’s position 2000 times a second. At a puck speed of 140 kilometers per hour, that comes to one measurement every two centimeters. The system tracks the player’s position 200 times a second.

The toughest use case

The challenges were daunting. The system has to be small enough to fit inside the puck. It has to withstand the hard knocks of sticks hitting slap shots and banking the puck off the boards. It has to work reliably at low temperatures of -11°C. And the version with integrated electronics has to feel and respond to players’ touch just like a regular puck. Fraunhofer IIS had what it takes – the skills to build it and the place to test it. A large hall with an artificial ice surface and a lab with absorbers on walls and ceilings provided the perfect proving grounds for investigating the transmitter’s performance and reach.



From left to right: Franke, von der Grün and Pellkofer on the “ice”

The system lends itself to many more applications beyond sports. “We chose the most demanding use case by going for the fastest team sport, and an indoor one at that,” says Pellkofer. “Ice hockey is the most challenging showcase for us, so we can certainly handle other challenging tracking tasks.” ■

Angela Merkel at the opening of an offshore wind farm in the Baltic Sea, off the island of Rügen. With 60 wind generators, it is designed to provide 385 megawatts of power, enough for 200,000 households. For the photo shoot, Chancellor Merkel failed to move the pinwheel by blowing on it - and so had to help with her finger.

© action press



Harvesting the wind...

... means being able to store energy. Everyone talks about generation, but let's focus on battery technology and its role in the transition to a sustainable energy system. We look at three current approaches.

Text: Mehmet Toprak

Ceramic is a wonderful material. It is strong and hard and holds its shape. It is highly resistant to wear and tear and doesn't corrode. It is weatherproof and can withstand high temperatures. That's why engineers love ceramic materials and use them in a host of applications. And now specialists from the Fraunhofer Institute for Ceramic Technologies and Systems IKTS have developed cerenergy®, a new ceramic battery.

The target: 65 percent renewable energy by the year 2030

This sodium-nickel chloride battery is the latest exciting development to emerge from Fraunhofer IKTS, which has locations in Dresden and Hermsdorf. The chief application for this technology will be stationary energy storage systems such as standby power systems for hospitals or care homes. It could also be used to store surplus power produced by photovoltaic systems on the roof of private homes, where the sodium battery could be housed in the basement, much like a freezer. Germany's transition to a sustainable energy system based on wind and solar power is badly in need of fresh impetus. The construction of new wind turbines, for example, has faltered in recent years. Nevertheless, the federal government is still aiming to increase the share of renewable energy in the current electricity mix from 38 percent to 65 percent by 2030. The problem, as ever, is that when the wind drops and the sun disappears, power generation comes to a halt. Ideally, there is then a battery on standby to take up the slack – for example, the low-maintenance sodium-nickel chloride battery from Fraunhofer IKTS.

The special ceramic used for the battery is conductive and doubles as an electrolyte in solid – rather than liquid – form. The battery uses sodium chloride (table salt) and nickel, both in powder form. Important from a strategic point of view is that both of these natural resources are readily available in Europe. In other words, no lithium from Asia or Africa, no cobalt from the Democratic Republic of the Congo, and no tacit support for child labor.

Disposal is also unproblematic. For example, spent batteries can be used in furnaces to produce slag as a byproduct of steel production. Dr. Roland Weidl, head of the System Integration and Technology Transfer department at Fraunhofer IKTS, lists further advantages of cerenergy®: "Unlike lithium-ion batteries, there is no danger of our battery overheating or catching fire. We've chosen a very stable mixture of materials. So, there's no problem with housing it in the basement." Despite the ceramic battery reaching an internal temperature of 300°C, it is well insulated, just like any domestic oven, and remains perfectly cool on the outside. "Besides, 300 degrees is not especially hot," says Weidl. Researchers at Fraunhofer IKTS have already built a 30-centimeter battery cell with a capacity of 100 ampere hours. This is a world record for a sodium battery.

Many questions had to be answered when developing the new battery. One was how to produce the ceramic electrolyte. The conventional method is to press ceramic powder into the required shape and then fire in a kiln. The first part of this process is very expensive. Instead, the developers opted to use an extruder, which functions much like a machine for making spaghetti: a viscous or paste-like material is pressed slowly through a die under high pressure. The shape of the hole in the extruder die determines the shape of finished product – in this instance, a tube made of ceramic. "Once you know how to do it, it's really rather simple," says Weidl with a smile.

Patents for the new technology have been filed

With a working prototype already built, various patent applications have now been submitted. The sodium battery is to be manufactured by the company Alumina Systems GmbH, based in Upper Franconia, with an expected product launch date three years from now.

Fraunhofer researchers are also investigating the use of another material for battery technology – one, however, that is not quite as innocuous as sodium chloride and nickel: hydrogen. For decades now, scientists have been seeking to tap the potential of this, for all intents and purposes, ►

5 premises from Prof. Stelter

1 For the next ten years, at least, lithium batteries will be the only technology that can support electromobility on a large scale.

2 There's not enough lithium and cobalt on the planet to supply everyone with an automobile battery while also providing stationary systems to store electricity. We need alternative types of batteries.

3 Sodium batteries and hydrogen fuel cells will not displace lithium batteries, but they will complement them.

4 Lithium batteries will remain the prime technology for smaller cars over the next two vehicle generations. Hydrogen can play a complementary role for heavy vehicles, particularly commercial vehicles.

5 Sodium batteries do take longer to charge, but they are made from materials sourced in Europe and are ideal for the stationary storage of wind and solar power.

► limitless resource. The problem, however, is that hydrogen is explosive and highly combustible – properties that compromise easy tank storage in the car or home.

At the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM in Dresden, Dr. Lars Röntzsch and a team of engineers, physicists and chemists have been working on a solution to this problem since 2012. Their idea is to bind hydrogen in a chemical compound that can then be safely used to generate energy.

Dubbed "powerpaste," the product they came up with is made of magnesium hydride (MgH_2) mixed with metallic salts and a nontoxic ester. It can be stored in a tube or cartridge. When magnesium hydride is combined with water, hydrogen is produced. In a fuel cell, this hydrogen can then be added to oxygen in a controlled reaction, generating electricity.

Fuel cells have a higher power density than lithium-ion batteries and can rapidly deliver power in order to cover peak loads. They also have a substantial energy density – i.e., the amount of energy that can be stored in a given volume. This translates into a high range and long service life when used in mobile applications. And once the cell is out of fuel, simply insert a new powerpaste cartridge, and it is ready, once again, to supply energy. The chemical reaction within the fuel cell produces nothing but water vapor, and the disposal of the spent cartridges, which contain remnants of magnesium hydroxide, is similarly unproblematic from an environmental perspective. This substance can be disposed of safely in the household garbage can.

Three solutions for three problems

Fuel cells are ideal as standby stationary power sources for situations when the existing electricity supply temporarily fails. "Obviously, we're targeting the international market as well," says Röntzsch. And mobile applications are also an option. Prof. Michael Stelter, deputy director of Fraunhofer IKTS, is responsible for strategy in the field of battery research. As he explains, "Hydrogen can complement lithium batteries in automotive applications, especially in the case of large, heavy vehicles that have to travel long distances nonstop – such as trucks."

Left: Powerpaste, which delivers hydrogen, can be safely stored in cartridges or tubes.
© Fraunhofer IFAM

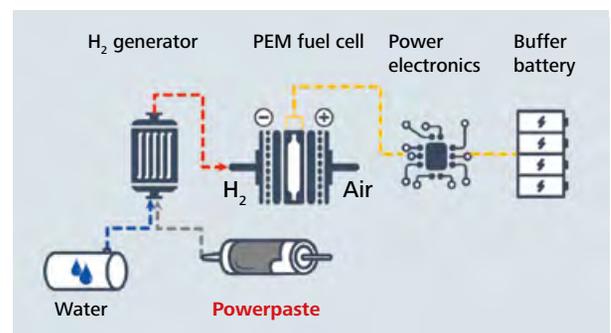
Right: Diagram of a typical fuel cell system.
© Fraunhofer IFAM



Are sodium batteries and hydrogen-powered fuel cells about to storm the market for energy storage and supply systems? Neither of them is likely to displace the lithium-ion battery, though both can complement it in a range of scenarios: the sodium battery as a reliable stationary energy source, and the more nimble fuel cell for use in both stationary and mobile applications.

For the purposes of electromobility, the lithium-battery will remain the technology of choice for the foreseeable future. And here, too, Fraunhofer is investing substantially – for example, in the Fraunhofer Project Center for Energy Storage and Management Systems ZESS in Braunschweig, which was opened in February. This facility brings together institutes such as Fraunhofer IKTS, Fraunhofer IFAM and the Fraunhofer Institute for Surface Engineering and Thin Films IST. Together with the Technical University of Braunschweig, researchers from Fraunhofer will be developing battery prototypes for industrial applications and demonstrating their viability. At the same time, complementary technologies are also set to play a vital role. As Stelter explains, "There's not enough lithium and cobalt on the planet to supply everyone with an automobile battery and also provide stationary systems to store large quantities of electricity." ■

The cerenergy® cell with a capacity of 100 Ah – a world record for this type of battery. © Fraunhofer IKTS



When does the electric car really become ecological?

Fraunhofer researchers have considered all the factors. Now they've determined the minimum distance after which electromobility really benefits the climate.

Text: Mehmet Toprak



There are typically three phases in the introduction of a new technology. It all starts with the hype. This is then followed by the skepticism phase. Finally, in phase three, the technology gradually starts to take hold. Right now the electric vehicle appears to be in phase two: its ecological benefits are frequently called into question.

Experts like Stefan Blume from the Fraunhofer Institute for Surface Engineering and Thin Films IST in Braunschweig are working to bring objectivity to the discussion. Blume is project manager in the Sustainable Factory Systems and Life Cycle Management working group, which is concerned with the sustainable manufacture of the batteries of today and tomorrow. He knows how to correctly calculate the CO₂ footprint and ecological impact of a vehicle, a significantly more complex task for electric cars than for vehicles equipped with internal combustion engines.

From raw materials to disposal, what are the advantages of the electric car?

The Fraunhofer researchers use an approach in their calculations governed by a specific ISO standard. According to the ISO standard 14040, a life cycle assessment (LCA) "covers all relevant inputs and outputs of a product throughout its life cycle and makes it possible to calculate potential environmental impact," says the institute's director, Prof. Christoph Herrmann. This means calculations factor in not only CO₂ emissions, but also other local and global effects such as raw materials consumption and the impact of toxic substances on humans and nature.

The ISO standard and additional guidelines only define a framework. The Fraunhofer experts themselves determine and document which aspects are given the highest priorities, which specific scenarios are created and what calculation procedures are to be used. All the relevant factors are taken into account, from obtaining raw materials to daily driving operations and finally to disposing of the vehicle. The resulting assessments vary considerably depending on the vehicle in question, the operator's driving behavior and basic external parameters.

Fundamental differences come to light in the ecological contest between electric and conventional vehicles. "The results for cars with internal combustion engines are for the most part independent of the location or field of use; here approximately 80 percent of the CO₂ emissions are generated while driving," Blume explains. Calculations are significantly more complex for the electric car. CO₂ emissions depend more heavily on regional factors such as outside temperatures and the electricity fuel mix at the respective place of operation. An electric car operated in a region where the electricity provider uses renewable energies is much more environmentally friendly than the same electric car running on electricity generated with brown coal. That means vehicle owners should choose an energy provider that generates electricity from renewable sources. Stefan Blume sums this up perfectly: "The greener the electricity, the greener the car." The outside temperatures where the vehicle is operated play an essential role as well. The more extreme the temperature, the higher the amount of additional energy needed to heat or cool the vehicle. In contrast to combustion engine vehicles, this energy has to be provided by the car battery, and the more electricity consumed, the poorer the environmental performance.

Conclusion: The electric car has time on its side

Previous investigations have found that, in terms of CO₂ emissions, at moderate latitudes and with the European fuel mix for electricity, the electric car typically performs the same as the diesel or gasoline engine car up to a driving distance of 50,000 to 100,000 kilometers. After that point, however, the electric car can be considered more environmentally friendly than the combustion engine car. Furthermore, the electric car has time on its side. After 100 years of development, the possibilities of combustion engine technologies have for the most part been exhausted. In contrast, an enormous amount of potential is expected from electrically powered vehicles. Blume continues: "With energy storage in particular, we'll be seeing some major advances in the years to come. This will mean longer ranges for electric vehicles and generally more attractive electromobility. At the same time, electricity and thus the operation of the vehicles will become more environmentally friendly due to the increased share of electricity from renewable sources." ■

Electric cars: the facts

Saving: The purchase price of electric cars is significantly higher, but they are less expensive to operate and require less maintenance and service. What's more, the electric car costs an average of two-thirds less to drive 100 kilometers when compared with conventional fuel prices.

Charging: There are 16,100 public charging points in Germany, 12 percent of which are fast-charging stations.

Driving: According to tests by German automobile association ADAC, electric cars have an average range of 253 kilometers. The average distance travelled by a passenger car in Germany is 38 kilometers per day.

A toast to the trigeminal nerve

Our fifth cranial nerve has a say in what tastes good or bad to us. Fraunhofer IVV is refining the recipe for non-alcoholic beer to cater to this nerve's receptors and treat our palates to a tastier brew.

Text: Prof. Jessica Freiherr

When the summer heat gets unbearable, a cool refreshment is what everybody wants. Alcohol-free beers, shandy and other beer-and-fruit-drink blends are all the rage these days. Lower in calories, they are also healthier than their alcoholic counterparts.

Summertime is beer time, and non-alcoholic beer is in vogue. Fraunhofer wants to deliver a flavor very close to the original in two years.

On the downside, they are not quite as tasty. Alcohol is a flavor enhancer. Reducing the alcohol content by halting fermentation or heating the brew can leave beer tasting too sweet or unpleasantly bitter. Researchers at the Freising-based Fraunhofer Institute for Process Engineering and Packaging IVV, scientists at the Technical University of Munich's Chair of Brewing and Beverage Technology, and various industry partners have set out in pursuit of a tasty goal. They aim to improve the flavor of non-alcoholic and reduced-alcohol beers and mixed beer drinks within the next two years using trigeminal substances that stimulate the trigeminal nerve. This nerve's fibers branch out over the face, reaching into the oral cavity and to the masticatory muscles. The refreshing cool of menthol, the scorching sting of chili peppers, the tickly tingling of carbonated water, the spicy sting of ginger and mustard oils, and temperature in general – all this we experience via the trigeminal nerve.

Testing for taste: What part of the brain likes beer?

To find out what we like, the researchers first have to characterize the taste of pure non-alcoholic beer and of beers mixed with lemonade, limeade or grapefruitade. They then add varying concentrations of trigeminal substances to the drinks for test subjects to assess in a questionnaire. The





Germans consumed 77.7 million hectoliters of beer in 2018, 0.6 percent more than in the previous year. This figure does not include the 3.6 million hectoliters of non-alcoholic beer brewed in Germany last year. © dpa

scientists also track human responses with biofeedback and functional imaging methods. This data gives some indication of how areas of the brain that play a role in emotional and memory response and in reward processes react to the beer. Scientists thus gain insight from both perspectives – conscious perceptions and the unconscious reactions that also inform our judgment of the drink's appeal.

Aroma – it's all in the nose

Eating and drinking engages not just our sense of taste, but also our sense of smell. It is this blend that makes up a drink or dish's flavor. The tongue can only distinguish between sweetness, sourness, bitterness, saltiness and umami. All other perceptions are a matter of olfaction. French gastronome Brillat-Savarin was onto something back in 1820 when he declared, "Smell and taste are in fact but a single composite sense, whose laboratory is the mouth and its chimney the nose." A glass of beer imbibed while holding your nose just tastes bitter. Its full-bodied aroma is not revealed until you stop pinching your nose. Trigeminal influences such as tongue-tingling carbon dioxide – those bubbles in beer – also influence perceptions.

How we rate a beverage is not just down to chemistry, though. Other sensory perceptions matter, such as how the shape of a glass or bottle feels and looks, as does the sound made when you open a container. Does the cork shoot out with a resounding bang, the lid flip off with a satisfying pop, or the carbon escape with a soft hiss? The brain blends all these sensory perceptions, influencing our response, but leaving us unaware of its workings. All this has to be factored into the equation to formulate a successful product. Keen to obtain the most comprehensive picture, the scientists at Fraunhofer IVV are drawing on a wide range of methods to take so many different sensory perceptions into account in their investigations. With this big toolset at their fingertips, they can gain a better understanding of how people perceive products and learn how to fine-tune the flavor formula. ■

Hitler's prototype

Fraunhofer researchers are using a unique XXL X-ray facility to reveal the secrets of the Nazi's Me 163 fighter plane. It was the first ever rocket-powered production aircraft – and, in the early 1940s, the world's fastest flying object, with a top speed of around 1000 kilometers per hour.

Text: Sonja Endres

Flying with the Me 163 was not for the faint-hearted. For a start, the pilot had to perch between two tanks full of highly explosive fuel. What's more, the jet engine was temperamental and would often splutter to a halt shortly after takeoff. The aircraft, when fully laden with fuel, was almost impossible to land – not least because it also lacked any landing gear. This is because the undercarriage was jettisoned 50 to 100 meters after takeoff in order to save weight and space. Instead, pilots had to land the fighter on a 30-centimeter-wide skid, preferably in a grassy field. At a landing speed of 170 km/h, the impact was so hard that it was not unknown for pilots to sustain serious back injuries. And, finally, there were no brakes, so the aircraft was pretty much uncontrollable once it had touched down.





Reims and his team scanned the aircraft in an upright position, thus reducing the distance the X-rays had to penetrate. This ensured that more radiation reached the detector, thereby substantially improving the quality of the scan.
© Fraunhofer IIS

XXL-CT

The X-rays can penetrate steel walls up to 20 centimeters in thickness.

| | |
|--------------------------------------|----------|
| 1-Beam source [radiation energy*] | 9000 KeV |
| 2-Detector [width] | 4 m |
| 3-Towers [height] | 5 m |
| 4-Turntable [diameter] | 3 m |

* kiloelectronvolts

Despite everything, a small number of experienced pilots managed to tame this hellish machine and fly it unscathed through to the end of the Second World War. Worldwide, there are ten examples of this historic aircraft still in existence, one of them in the Deutsches Museum in Munich. For over 30 years, it has hung from the ceiling of the aeronautics exhibition. Experts have long suspected that the Munich Me 163 was a special prototype, designed as part of a last push to help Germany seize back control of the skies from the Allies.

Revealing the secrets of Munich's Me 163

In order to take a closer look inside the Me 163, the Deutsches Museum commissioned the Development Center

for X-Ray Technology (EZRT), located at the Fraunhofer Institute for Integrated Circuits IIS in Fürth, to produce an XXL computed-tomography scan of the aircraft. The X-rays produced by this unique high-energy facility are able to penetrate massive objects weighing several tons and deliver high-resolution, high-contrast images of unparalleled quality. "Medical CT equipment operates at energies in the 100-kiloelectronvolt range when scanning, say, a broken bone. Our beam source – which is a linear accelerator – operates at 9000 kiloelectronvolts," explains Nils Reims, who together with his colleagues Michael Salamon and Dr. Michael Böhnelt was awarded the Joseph von Fraunhofer Prize in 2018. A person directly exposed to such radiation would be dead within 30 seconds. For safety reasons, the system can only be activated from outside the facility. ►

The scan took a month, but it produced a highly detailed picture.

► **“The principle is really very simple:** we shine X-rays through the object, and a detector – basically a camera – captures the shadow it casts,” Reims explains. The linear accelerator and detector are mounted on opposing towers that slowly ascend in parallel. This produces a layer-by-layer scan of the object, which sits on a turntable in front of the detector. When scanning the Me 163, the turntable was rotated in increments of less than one degree. “We scan the object from very many different angles and then use an algorithm to construct a 3D model.” As a rule, it takes several days to complete the scan. In the case of the Me 163, however, it took a whole month. This was because extremely high-quality images were required and the fuselage, tail and wings had to be scanned separately, on account of the plane’s size.

Yet the effort was worth it: the scan delivered images with a resolution as high as 350 micrometers. A human hair, by comparison, is 50 to 80 micrometers in diameter, on average. “We produced 2500 individual images from every possible angle,” Reims explains. “The data is so detailed that we could even use it to 3D-print replacement parts for the aircraft.”

Me 163 pilots wore a special flying suit. This, however, offered at best psychological comfort and was powerless to protect against leaking fuel, a toxic chemical mixture.

All photographs: © dpa



The walls of the two fuel tanks to the left and right of the pilot were made of very thin metal. In a hard landing, the remnants of the highly corrosive fuel often leaked.



Reims and his team have provided scientists at the Deutsches Museum with an initial series of images. It will still take some time to evaluate all the data. That’s not surprising, given a total data volume of around one terabyte. “At present, we’re still evaluating the images largely by hand,” Reims explains, “but we’re also working on algorithms that will automate this process.”

The images reveal the fighter’s unique nature

A comparison of the CT scans with the original design blueprints of the Me 163 has shown that the model on display in the Deutsches Museum diverges from other models in numerous respects. Andreas Hempfer, curator for historic aircraft, strongly suspects that it is a prototype, and his colleagues agree.

Their hunch was reinforced by another discovery: the Luftwaffe’s characteristic triangular plate bearing the aircraft’s serial number, which Hempfer discovered in the nose of the Me 163, was blank. “I’d never seen that before,” he says. “Normally, the serial number identifies the aircraft and serves to reconstruct its history.” Hempfer therefore hopes that the CT scan will reveal another plate somewhere in the inaccessible tail of the aircraft. “A plate with the serial number was normally mounted in a number of places, one or more of which would be expected to survive in the event of an accident – in the nose, for example, should the tail explode; or in the tail, in the event of a crash, nose first.”

Another unusual feature of this particular example of the “power egg,” as the Me 163 was dubbed on account of its ovoid fuselage, is a fixture on the roof of the aircraft, just behind the cockpit. This may well have been used to fit a pressurized cabin, which would have enabled the aircraft to fly at a higher altitude without the pilot needing to wear an oxygen mask. “We know there were ideas to fit the Me 163 with a kind of airtight canopy, but this is the only case in which something like this was actually built,” says

Jet fighters: military aircraft after 1945

In 1947, the U.S. Air Force's Bell X-1 was the first aircraft to break the sound barrier. Like the Me 163, it was rocket-propelled, but there the similarities end.



The XB-70 Valkyrie, a U.S. test plane, flew at three times the speed of sound.



The North American F-100 belonged to the first generation of jet-engine, supersonic production aircraft and saw active service in, for example, the Vietnam War. A key advantage of the jet engine over the rocket engine is that the oxygen it requires for fuel combustion can be taken simply from the surrounding atmosphere.



The Lockheed Martin F-35 Lightning II has been in service since 2015. It has stealth capabilities that render it largely invisible to enemy reconnaissance systems.

Hempfer. Experts are now using the CT images to investigate whether the fixture was merely for attaching instruments for aerodynamic measurements or it was a mechanism for fitting a pressurized cabin.

Clear signs of a design departure from the original

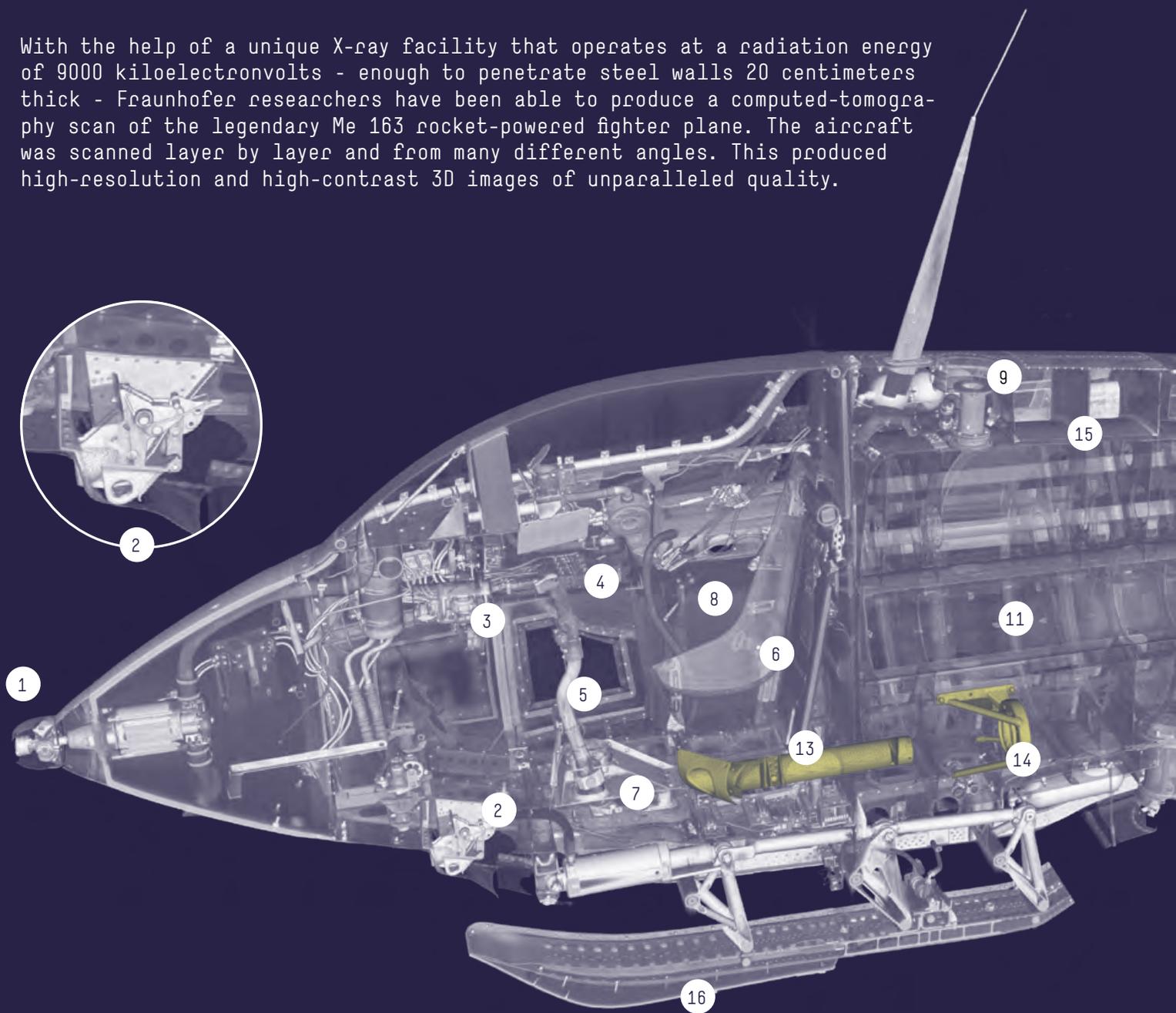
What the images already reveal is that the structure and geometry of the cockpit floor have been subject to a redesign. "There were obviously lessons learned from earlier crashes. The floor has been modified in order to reduce the shock of impact during landing." And the scan also clearly shows that the aerotow hook is much more firmly anchored. Unlike in earlier models, this is now attached to the floor structure rather than the metal plates of the fuselage. This would have made it possible to tow the Me 163 into the air, like a glider. This was less hazardous than a direct takeoff from the ground. However, it was only ever used for transfer flights of unfueled Me 163s.

The beauty of the Me 163 was that it could ascend almost vertically and extremely rapidly to extreme altitudes. In a mere two to three minutes, it could climb to 10,000 meters, the cruising altitude of enemy bombers. The downside was that its fuel tanks were empty within seven minutes, after which the aircraft had to glide back to the ground. This proved way too short to intercept and shoot down allied bombers, particularly as these would fly diversionary maneuvers and their flight path was unknown. "There are only nine confirmed cases of aircraft being shot down by the Me 163," says Hempfer, "which is about the daily output of a U.S. bomber factory. So, it certainly wasn't a wonder weapon. If anything, it was a technological flop. If you compare its limited impact with the huge development costs, never mind all the people who got killed, it's completely crazy. It just shows the inhumanity and ruthlessness of the Nazis and, at the same time, their growing desperation in the face of Allied superiority." ■

»The Me 163 shows the Nazi's ruthlessness and their growing desperation.»

XXL-CT: the Me 163 reveals its secrets

With the help of a unique X-ray facility that operates at a radiation energy of 9000 kiloelectronvolts - enough to penetrate steel walls 20 centimeters thick - Fraunhofer researchers have been able to produce a computed-tomography scan of the legendary Me 163 rocket-powered fighter plane. The aircraft was scanned layer by layer and from many different angles. This produced high-resolution and high-contrast 3D images of unparalleled quality.



The Me 163 in detail

01_Propellor-driven generator

02_Aerotow hook

03_Instrument panel

04_Weaponry console

05_Control column

06_Pilot's seat

07_Cockpit tank, left (for T-Stoff oxidizer)

08_Cockpit tank, right

09_Filler cap for T-Stoff

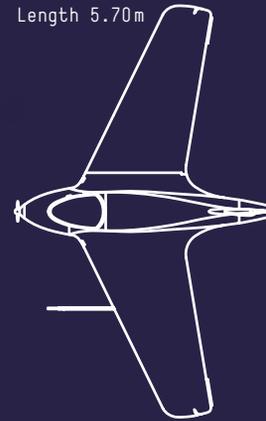
10_Starter tank

11_Fuselage tank

12_Rocket-engine combustion chamber

Messerschmitt Me 163 B

Length 5.70m

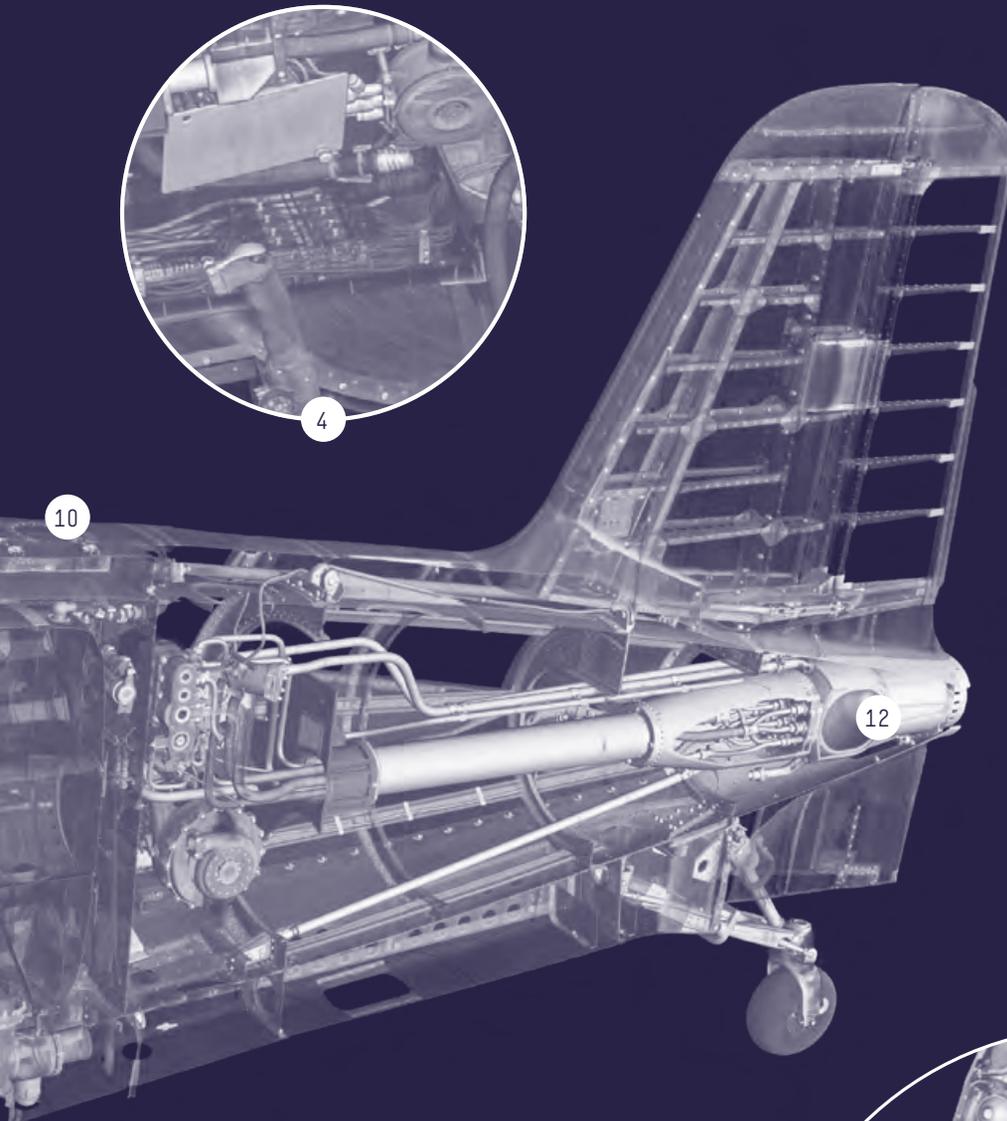


Wingspan 9.30m



Height 2.75m

| | |
|---------------|---------------------|
| Wing area | 19.60m ² |
| Engine | HWK 109-509 A-1 |
| Thrust | 1600 kp |
| Empty weight | 1980 kg |
| Top speed | 1000 km/h |
| Peak altitude | 12,000 m |



Weaponry

Two Mk 108 cannons (cannon ports, 13) were mounted in the wing root, right and left. The short barrel is enclosed within the aircraft body. As such, the cannons were practically invisible from the outside. The cannons are missing on the Me 163 displayed in the Deutsches Museum.

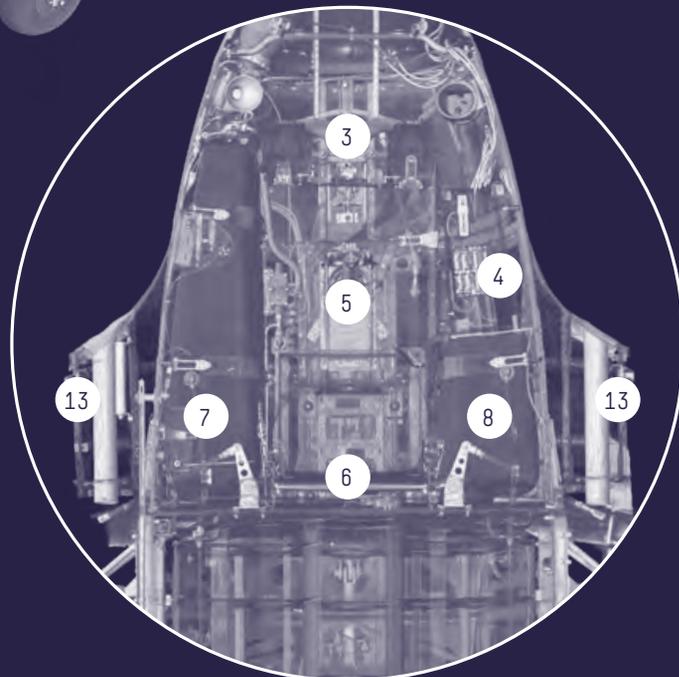


13. Port for Mk 108 cannon

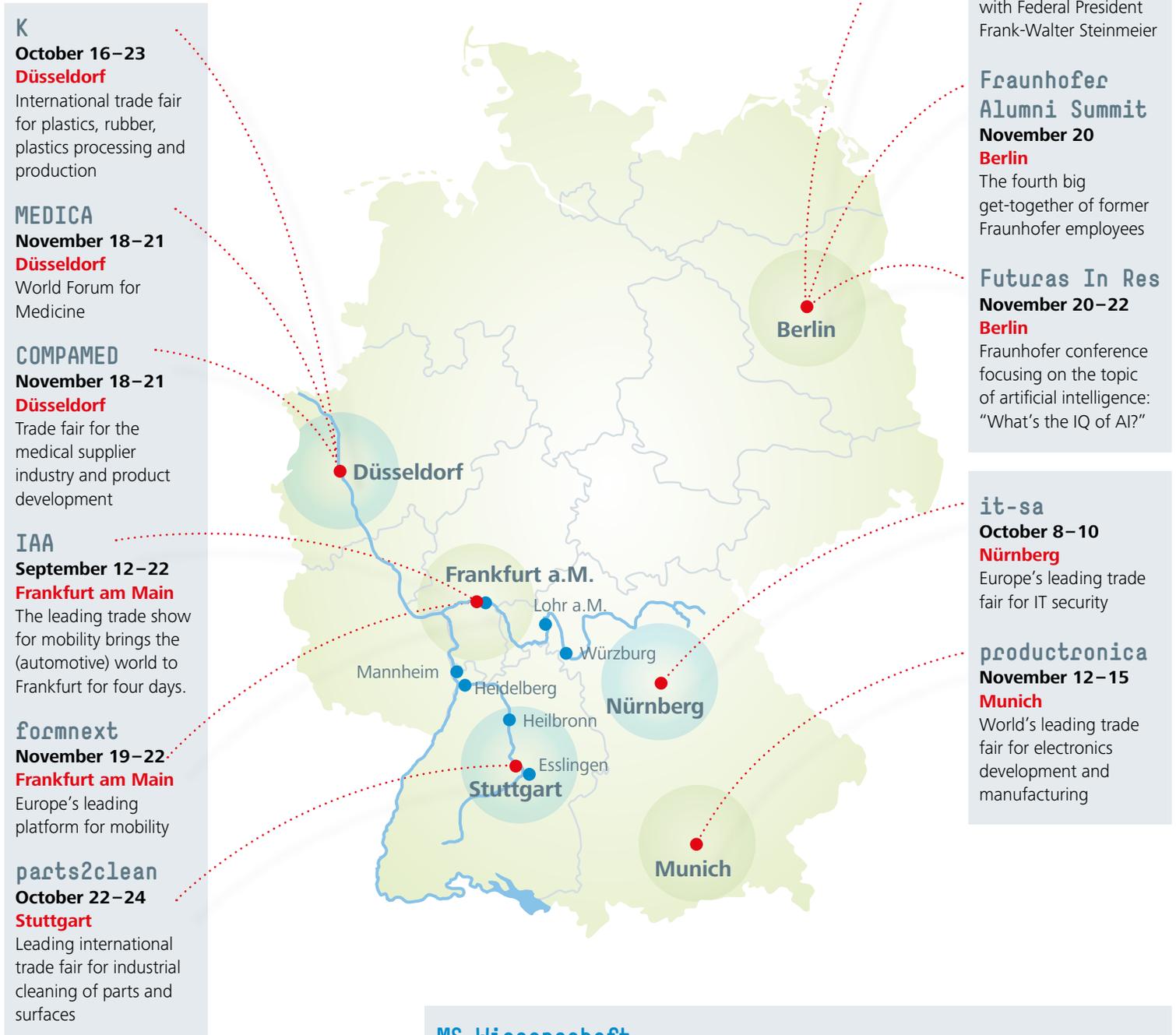
14. Mounting for Mk 108 cannon

15. Ammunition depot (2 x 60 shells)

16. Landing skid



Places to be in Q4: Fraunhofer in Germany



MS-Wissenschaft

A five-month journey starting in September will take this exhibition ship to the following destinations in Germany on its journey through the world of AI: Heidelberg (until Sep. 1) | Mannheim (Sep. 2–5) | Heilbronn (Sep. 7–10) | Esslingen (Sep. 12–16) | Frankfurt a.M. (Sep. 19–22) | Lohr am Main (Sep. 24–27) | Würzburg (Sep. 28–Oct. 3)

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