

# Fraunhofer

The magazine for people shaping the future

**"I believe  
in hydrogen"**  
An interview with  
Nico Rosberg

## Climate stress

Heavy rain, storms, high temperatures: How we are making our towns and cities more resilient

**What, as Chancellor, would  
Scholz do for research?**  
An interview with the candidate

**"Campus of the senses"**  
Whiskey & science:  
A meeting of enjoyments



# FRAUNHOFER SOLUTION DAYS 2021

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## Editorial

# A spring of new beginnings

We are leaving behind a time that has demanded so much of so many, before us lies a spring of new beginnings. At the very start of the year, the TMP branch of Fraunhofer IME became the independent Fraunhofer Institute for Translational Medicine and Pharmacology ITMP, headquartered in Frankfurt am Main with locations in Hamburg and Göttingen. The key scientific objective of this new institute, which currently employs over 120 people, is to transfer innovative ideas, technologies and methods from biomedical research for use in medical applications and industry.

**Transfer is the backbone** of the German innovation system and the envy of so many other countries worldwide. Our innovative strength has remained intact. The European Patent Office EPO recently reported that last year, German companies and German inventors registered more patents than any other country in Europe. The EPO registered almost 26,000 patent applications for the year 2020. But this is also about getting the ideas into the markets. The Fraunhofer-Gesellschaft is set apart by its mind transfer, by its expertise and knowledge when researchers move into industry, when they patent, license and create spin-offs.

We have seen **480 successful spin-offs** since the year 2000. Each year, we have registered 600 high-tech patents in our Fraunhofer Institutes, more than two per working day on average. When our Fraunhofer Venture celebrates its 20th anniversary this April, it will also be applauding 20 years of practical support for young companies and enterprise founders through access to Fraunhofer technologies, infrastructure and knowledge. The Fraunhofer-Gesellschaft has committed to technology transfer with a passion. Spin-offs also feature in this edition of the Fraunhofer magazine. The first quantum technology spin-off from Fraunhofer, Quantum Optics Jena, is about to start (p. 68) making



Prof. Reimund Neugebauer

our communication networks more secure with quantum encryption. In the spin-off Volucap, researchers from Fraunhofer HHI are creating undreamed of 3D possibilities for film production (p. 72). And it's surely no coincidence when former Formula One world champion turned investor Nico Rosberg categorically states in an interview with this magazine that the Fraunhofer-Gesellschaft, with its strategy papers and studies, had been extremely valuable to his investment decisions in sustainable startups (p. 92).

Combining research and applications is what Fraunhofer does best. It is our intention to steadfastly keep to this path. Only by doing so can we address the key challenges, such as the coronavirus pandemic, digitalization, the climate and mobility crisis, global trade conflicts and the regional structural transformation, that face our society today. And only then will we hold our own in the international competition. Outstanding research and technology are key to our shaping a positive future. Let us work towards this together.

Sincerely,

Reimund Neugebauer  
President of the Fraunhofer-Gesellschaft

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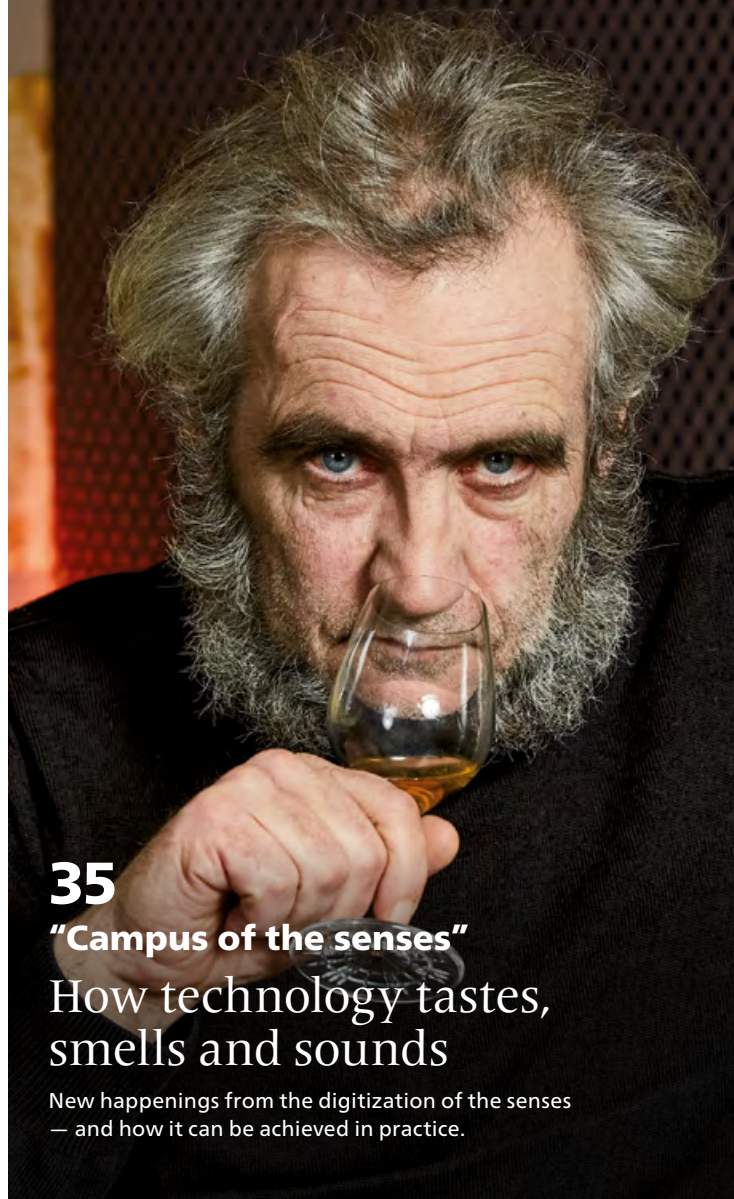
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**#homeoffice** Requests are piling up at Fraunhofer Institute for Industrial Engineering IAO (p. 60): What will work look like? What will the coronavirus have changed forever? Let’s start with the comforting news: 43 percent of people are just as productive working from home as they are in the office.

**43%**

## Brief report



Spectators in the stadium see the real perimeter advertising, the TV viewers see what the broadcaster wants them to see.

## Refined audience targeting for advertisements

It's the European Football Championship final, are French TV viewers seeing different perimeter advertising to German ones? An innovative technology developed by the Fraunhofer Institute for Intelligent Analysis and Information Systems IAIS makes this possible.

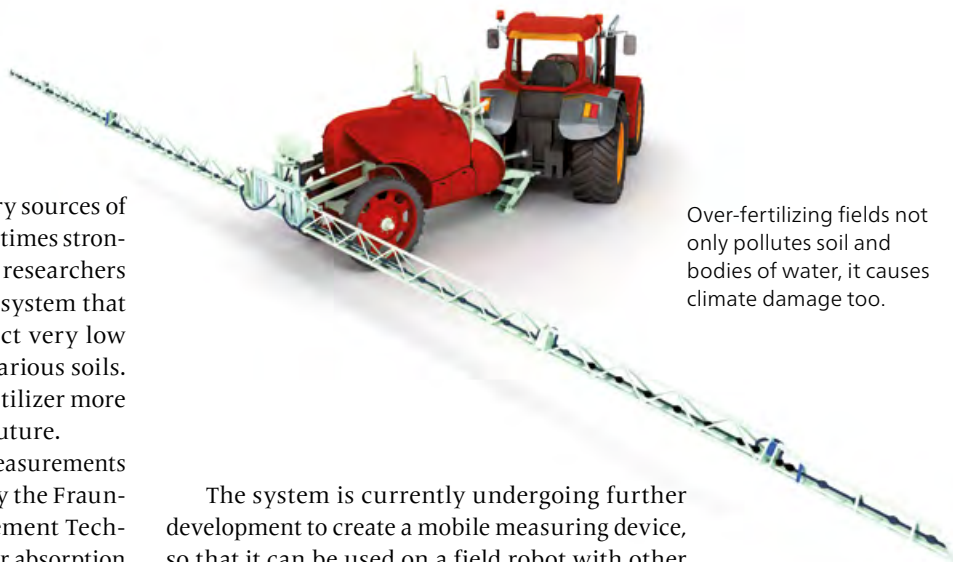
This is how it works: The advert is displayed on the LED boards for two milliseconds less, and a magenta-colored surface is shown instead — too brief to be perceived by the human eye. The TV camera's recording time and duration are set so that it records only the magenta flashes. This is where the established so-called chroma keying or blue screen technology comes into play: The magenta area in the image sent to the TV studio by the camera at the stadium is overlaid with new content. This creates an advertising stream that seamlessly blends into the TV image.

"The technology is now so advanced that even when a player is standing in front of the board, there's no fringing, color distortion or blurring," says Ulrich Nütten, Head of Media Engineering at Fraunhofer IAIS. ■

## Reducing the use of fertilizer

Nitrogen fertilizer is one of the primary sources of nitrous oxide — a greenhouse gas, 300 times stronger than carbon dioxide. Fraunhofer researchers have developed a precise measuring system that can also be used to accurately detect very low concentrations of nitrous oxide on various soils. Their goal was to be able to spread fertilizer more selectively and economically in the future.

The innovative systems for field measurements of released nitrous oxide developed by the Fraunhofer Institute for Physical Measurement Techniques IPM are based on a tunable laser absorption spectroscopy technique with a quantum cascade laser (QCL). A high degree of sensitivity is achieved by a long path absorption cell measuring 7.2 meters. The evaluation software is engineered specifically for the concentration range required and the potential cross sensitivities.



Over-fertilizing fields not only pollutes soil and bodies of water, it causes climate damage too.

The system is currently undergoing further development to create a mobile measuring device, so that it can be used on a field robot with other sensors in the future. This allows a significantly higher number of field measurements to be carried out over a growth period. The data enable the user to draw conclusions about fertilizer, soil, humidity and other parameters and improve the efficiency of soil usage. ■

# The system whisperer

Avoiding production outages and optimizing maintenance routines — a mathematical model developed by experts at Fraunhofer ITWM makes this possible.

By Marina Babi

**W**ear and contamination are part and parcel of working with production system and machinery — as is the question: Is preventive maintenance better than risking an abnormal termination? The Fraunhofer Institute for Industrial Mathematics ITWM uses a model to consider this trade-off more precisely and to help cut costs. “Condition Monitoring”, meaning a permanent monitoring of a machine’s state, and “Predictive Maintenance”, a machine learning-based prognosis, support the decision with data. “Because of the immense variability of machines, systems and sensors, we have yet to see a standard product that can be conveniently used in every instance,” explains Dr. Benjamin Adrian, Project Manager in the “System Analysis, Prognosis and Control Department.” “We therefore offer custom solutions that address specific issues, which we then devise together with our customers.”

A project with Berger Holding GmbH & Co. KG, a manufacturer of turned and milled parts, is focusing on the ball screw. These components are typically installed in machine tools. Ball screws are designed to last for an average of 10,000 operating hours, though their life span can be much more or less depending on the intensity of usage. Adrian, Project Manager: “A company that leases machine tools wants to calculate the wear on the ball screw caused by actual usage. A tool machine supplier can use this analysis to bill against usage intensity rather than intensity duration, for example.”

**No matter what the project requirements, the procedure is similar.** The number of individual steps required depends on the issue being addressed. “The data watering can principle does not work here. Our procedure instead is focused and hypothesis-based. In other words, we make assumptions and check whether the data can support them,” explains Adrian. He and his team examine and process the data until an interpretable system status emerges, i.e. until all those involved understand exactly what the displayed values mean.



If we have well-founded prognoses, we can plan the service and maintenance schedules for systems in line with requirements.

Various analyses are used to determine which variables are relevant to the issue being addressed. The next step is to build a condition monitor, which uses the characteristics identified to monitor the condition of the system at the current operating point. As a result, critical events can be recognized instantly and the cause of the problem rectified. “Our great advantage here, being a mathematical institute, is that we have a very broad knowledge of the most diverse new and also long-standing processes. This helps us find the best possible evaluation methods for each project, so in the end we have a very well-functioning condition monitor,” says Adrian summing up. In yet another step, the constantly collected data are searched for trends in order to derive prognoses for the rest of the operation. ■

“Our calculations clearly showed that we would have been better off with a hard but short lockdown.”

Prof. Anita Schöbel turned to various areas of applied mathematics to find the formulas for her mask.

## A year of coronavirus:

# “Immunization is effective, social distancing will still remain important throughout 2021”

We have been living with the pandemic for over a year now: An interview with Prof. Anita Schöbel, Head of the Fraunhofer Institute for Industrial Mathematics ITWM in Kaiserslautern, to talk about predictions and data.

Interview: Mandy Bartel

\_\_\_\_\_ **Predictions are notoriously difficult, especially when they concern the future. What has been your experience?**

Back in April and October 2020, we were able to make surprisingly good predictions on the progression of the epidemic and on the effectiveness of various measures using our prediction tool EpidemSE. As a result, we also predicted a second wave at a very early stage. When the government decided on a partial lockdown in October, I was

really disappointed because our calculations clearly showed that we would have been better off with a hard but short lockdown. We are constantly refining this mathematical model, at the moment with simulations for vaccination quotas. We are using model calculations like these to support the city of Kaiserslautern, for example, with its crisis management strategy and to provide the scientific basis for political decisions to be made.

\_\_\_\_\_ **What do you know about 2021?**

Immunization is effective, but social distancing still remains important until summer 2021 as we currently see high infection rates. Limiting social contact and testing is something we will have to live with for some time. Here’s the good news: The death rate will fall as we vaccinate because we are prioritizing the risk groups. Nevertheless we now have to protect the non-vaccinated population.

\_\_\_\_\_ **Reliable predictions depend on resilient data. You have been a member of Nationalen Forschungsdateninfrastruktur e.V. (National Research Data Infrastructure) since 2020: What is your goal?**

We want to structure and systemize data so they can be used in a piratical way. We are guided by the FAIR principle: Data have to be “findable, accessible, interoperable and reusable”. Until now, most available data have been decentralized, related to a project, linked to non-specific metadata or temporary. The goal is a kind of digital knowledge store based on unified standards for data, algorithms and mathematical models in order to also better network them across several disciplines. ■





**Editorial notes**

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**Free subscription:**

Phone +49 89 1205 1301  
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**Editorial team:**

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

**Editorial assistants:**

Dr. Janine van Ackeren, Marina Babl,  
Mandy Bartel, Christine Broll, Meike  
Grewe, Sirka Henning, Dr. Monika  
Offenberger, Andrea Pletz, Stefan  
Ruzas, Moritz Schmerbeck, Tim  
Schröder, Franziska Sell, Beate Strobel,  
Mehmet Toprak, Britta Widmann

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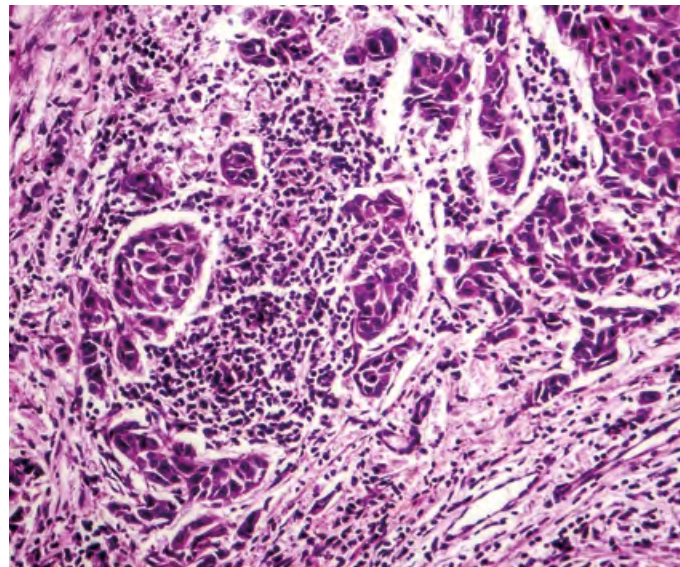
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Until now, individual cells have had to be extracted from tissue samples by hand using enzymes, which leave behind traces on the surface of the cell.

## Effortless extraction of living cells

The TissueGrinder is able to extract living cells from a sample of tissue by an automated process.

**T**he technology was originally developed by Fraunhofer Institute for Manufacturing Engineering and Automation IPA. A spin-off has now placed the product on the market ready for production.

Because no two tumors are alike, an optimal treatment regime has to be tailored to each individual patient. But to be able to test which chemotherapeutic agent is best on a case-by-case basis, we need living cells. So far, it has not been possible to isolate these cells from a tissue sample undamaged and largely unchanged. "Recovering individual cells from tissue samples remains one of the barriers to personalized tumor diagnosis and treatment," says Jens Langejürgen, Head of the Biomedical Sensors and Microsystems Group at Fraunhofer IPA and co-founder of the start-up Fast Forward Discoveries GmbH.

In an automated, enzyme-free process, the TissueGrinder quickly extracts living cells from tissue samples. It works similar to a spice mill: Thanks to specially shaped blades, which are rotated by a grinding mechanism, it gently breaks up the tissue without destroying or damaging any cells.

The miniature mill is no bigger than a shoe box and is able to process four tissue samples at once. One cycle takes less than five minutes. After the milling operation, tissue remnants and blood are automatically filtered off, and the isolated cells migrate to a separate container. The device is controlled by a touchscreen, on which the laboratory staff can select from the presets for various types of tissue — lymph nodes, bladder tumors, melanomas or cartilage, for instance. At the push of a button, the device then delivers the living cells from fresh tissue samples or extracts cells from archived histological excisions. ■



**Title**

# Under the stress of climate change

Floods and heavy rains, droughts and storms: How can we make our cities more resilient to the threats of climate change?

By Dr. Janine van Ackeren  
Photos: Heinz Heiss



Flooding as a climate problem: Sophie Mok from the Fraunhofer IAO knows that there are no panaceas. Intelligent water management, however, can help many cities.

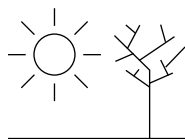
**E**xtrême weather conditions are on the rise: The number of climate-related disasters has more than tripled since 1980. In Germany too, the effect is being clearly felt. Now in spring, but in autumn too, heavy rainfall often causes rivers and streams to burst their banks, overloads sewerage systems and send basements under water. Summer sees the threat of droughts and water shortages — and their effects on agriculture and industry.

It is high time we prepared our cities for the impacts of climate change. The coronavirus crisis has shown just how quickly and profoundly lifestyle habits can be altered. And as harsh as it might sound, times of crisis make us better able to cope. “Never let a good crisis go to waste!”, observed Winston Churchill. Here’s the good news: The measures that make our cities more resilient to climate change have a crucial advantage — they also make them more livable.

### Capable against heavy rains and droughts

Resilience researchers at the Fraunhofer Institute for Systems and Innovation Research ISI show how this is possible. “When we focus on droughts and heavy rainfall, the key question is: how do we design the urban hydrological cycles?”, says Dr. Susanne Bieker, Head of the “Transformation and innovation systems in urban spaces” cross-cutting topic at Fraunhofer ISI. Until now, urban districts have been highly compressed, rainwater on roofs, streets and squares cannot seep away. Instead, the majority of it flows into the sewerage system. Being designed first and foremost for waste water, though, this system is quickly overloaded by heavy rain. Consequently, roads and basements become flooded. In dry spells too, introducing rainwater into the sewerage system proves inefficient. In nature, the water balance is equalized — in forests, 50 percent of rainwater seeps away, and only five percent of water percent of water drains off. In industrial regions, the seepage quota is just 20 percent, while 60 percent of the

water flows into the sewerage system. If rainwater is held wherever it falls, it can evaporate there and create cooling effects. This is made possible by green spaces, green roofs or facades — we also refer to these as green infrastructures. According to studies, an extensive green roof covering — mosses, grasses and similar plants — is able to retain 30 to



**The air on the earth’s surface** has warmed up compared to the pre-industrial era on a global average by **one degree Celsius.** **Never before in the course of human civilization** have we seen temperatures such as these.

70 percent of the annual precipitation, green roof coverings densely populated with trees, bushes and shrubs as much as 100 percent. Blue infrastructures are a good idea too: Ponds, lakes and canals. Also reservoir areas, large meadows for example, where 20 to 30 centimeters of water can collect after a heavy downpour. And cisterns: large underground water reservoirs that store rainwater during dry spells — and then repeatedly serve as a source of drinking water in dry regions.

The “Leipzig Blue-Green” project, sponsored by the German Federal Ministry of Education and Research (BMBF), is developing such blue-green structures. The plan over the next few years is to use the former open-air railway station in Eutritzsch as the site for 2100 new apartments, a school campus and an industrial building — including green roofs, green areas, cisterns and so on. At the core of the project is the robust and efficient control of the blue-green technologies. “Our intelligent control combines certain data, such as the fill level of cisterns, water quality or even data from soil moisture sensors, with externally available data like the weather forecast,” explains Dr. Marius Mohr, Head of Innovation Field Water Technologies and Resource Recovery at the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB. If the weather forecast announces heavy rain for the region, reservoirs such as cisterns are emptied automatically to make room for the new rain. Also the blind drains in a retention green roof, which the Fraunhofer researchers are currently constructing on a carport of the center for environmental research in a pilot test along with the company OptiGrün. Not only can plants grow on this roof, water can also be stored temporarily in integrated blind drains. Software has been controlling these blind roof drains since March 2021 and the project results are being integrated into the plans at the old open-air railway station in Eutritzsch in parallel.

### Near-nature hydrological cycles for 16,000 square meters of development area

A research team at Fraunhofer ISI is investigating what a near-nature hydrological cycle in an urban development might look like in the i.WET project, short for integrated water energy transition concept. The project is currently being realized in the area occupied by the Coers-Fläche in Lünen in North Rhine-Westphalia, on a former industrial estate covering almost 16,000 square meters, which is now being developed ►



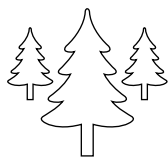
“Our newly developed system not only allows water to seep away, it also stores it, mainly in underground blind drains.”

Michael Würth,  
Project Manager for Climate  
Simulation at Fraunhofer IBP

Michael Würth  
is planning to  
integrate water  
storage facilities  
into roads.

“How can we designing the urban hydrological circuit?”

Dr. Susanne Bieker is seeking the answer at Fraunhofer ISI.



In forests, some

**50%**

of rain seeps away, only **five** percent of the water runs off.

with seven residential blocks. The gray water from washbasins, bathtubs and showers is fed through a heat exchanger in order to recover the heat for other applications. This water is then collected in a reservoir together with the rainwater and used for toilet flushing – in this way, valuable water can be saved, especially during dry spells. Further rainwater is stored in three cisterns and used for watering green areas. Any gray water and rainwater accumulating beyond this runs into the core of the near-nature hydraulic circuit: a planted “green avenue,” in which the water is cleaned and retained. Here, it first seeps through a green planted soil filter, or rather a cleaning layer containing a special grain of sand. Located below this layer of soil is a channel, through which the water discharges into an open ditch and then onward into a small river. “Even when the rain is torrential, we can completely separate the rainwater from the sewerage system and ease its load,” says Dr. Thomas Hillenbrand, Head of the Water Management business unit. The vegetation in the energy avenue also ensures pleasant cool temperatures during the summer and enhances the surrounding area.

**Where does the road of the future lead?**

Optimizing the hydrological cycle is also an area of focus in the “Road of the future” project currently underway at Fraunhofer IGB and the Fraunhofer Institute for Industrial Engineering IAO. In one of two associated living laboratories in Ludwigsburg, Mohr and his team have built and commissioned a cistern below the road – the rainwater that drips from roofs and cars collects in this cistern.

Another starting point for counteracting heavy rainfall and droughts lies in the road surface. Instead of sealing roads, cycle paths and sidewalks with asphalt or paving stones, teams of experts involved in the project “Building physics of urban areas” at the Fraunhofer Institute for Building Physics IBP are experimenting with a hydroactive road surface design. ▶



○  
★  
Dr. Susanne Bieker, Head of the “Transformation and innovation systems in urban spaces” cross-cutting topic at Fraunhofer ISI.



“Our newly developed system not only allows the water to seep out, it stores it mainly in underground stormwater detention layer — cavities in the ground that are enclosed by a watertight material,” explains Michael Wuerth, Project Manager for climate simulation. When it rains, these buffers fill up and counteract flooding, rather like any dry spell that might follow. For over the course of the next few weeks, wicking elements integrated into the underground stormwater detention layer transport the stored water back to the surface and emit it into the environment by means of evaporation. This also develops a cooling effect. Unlike commercially available underground stormwater detention boxes, which are interconnected as cubic underground reservoirs with a storage capacity of several thousand liters and therefore require a large ditch, the innovative, flat system can be integrated into the road without any notable additional work. “We are simply replacing one or more of the substructure layers required with our planar blind drain system,” explains Wuerth. The researchers are planning on the systems being able to take up to 200 liters of water per square meter. They are currently in the experimental phase.

### Cooling heating islands

2020 was the hottest year in Europe on record. Especially in the cities, so-called heat islands are a cause for concern: Heat-retaining building materials, dark facades and roof surfaces, as well as sealed surfaces, cause a temperature rise of up to ten degrees Celsius. “While a deep red facade can reach 80 degrees Celsius when the sun shines, a yellow facade heats up to only around 65 degrees Celsius”, explains Dr. Susanne Bieker from Fraunhofer ISI. “There are now facade paints with special additives that are better able to reflect thermal radiation, ensuring that buildings do not heat up too much during the summer months. And an innovative new paint with an admixture of calcium carbonate even promises a cooling effect.” Generally speaking, the approaches applied to eradicate heat islands resemble those used to

counter the effects of drought and heavy rain: Blue infrastructures such as lakes or spring wells increase evaporation rates and cool the area that surrounds them. Green infrastructures likewise reduce the temperature. Avenues and tree-lined roads can lower the perceived temperature by up to 15 degrees Celsius. The cooling effect of green facades and roofs



The number of days when the temperature remains **below 0 degrees Celsius** has been decreasing since the 1950s in Germany **from 28 to 19 days per year.**

can be felt even inside the building: A ground-based green facade, for example, reduces the surface temperature of the interior walls by up to 1.7 degrees Celsius.

### Green roofs, green facades — and a robot tends the surfaces

Using the Abu Dhabi example, Dr. Afshin Afshari investigated the effect of green exterior walls on the urban climate in a model-based analysis. The researcher is currently establishing the “Urban Physics Modeling” working group at Fraunhofer IBP. “The study in Abu Dhabi revealed: If we were to cover all facades with plants with average foliage, the temperature rise in the city would drop by 25 percent.

And by using plants with a greater density of foliage, we could almost half the heat island effect,” says Afshari. The researcher is presently working on a similar study for Berlin: This centers around the effect of greened roofs. “In Berlin, the effect is likely to be less because the city already has a lot of green areas,” presumes Afshari. However, green facades are difficult to maintain and normally require the use of scaffolding, lifting platforms or industrial climbers. In their “Green Wall Robot” feasibility study, researchers at the Fraunhofer Institute for Manufacturing Engineering and Automation IPA have devised a simpler method. “On a rail-based facade system, a robot moves fully automatically and performs all planting, tending and maintenance work — from cutting the plants to exchanging individual plant modules,” explains Kevin Bregler from Fraunhofer IPA.

Urban green, then, is one of the primary approaches being taken to protect cities against the effects of climate change. In the “Urban Nature Labs” project, a consortium with ten cities is investigating exactly what nature-based solutions are capable of. The Fraunhofer IAO is also involved. “Some measures have already been implemented in three of the cities: in Eindhoven in the Netherlands, Tampere in Finland and Genoa in Italy,” Sophie Mok, scientist at the Fraunhofer IAO, explains. In Eindhoven, the measures are spread across the entire city: Roads and squares have been greened and equipped with underground water storages, built-up rivers have been “daylighted” and renaturated. In Tampere, two districts have been greened, including an old industrial site. Biofilters are being used to absorb harmful substances and to clean water and soil. Intensive green roofs and urban gardens have also been created. In Genoa, a former military site has been re-developed into a green area, the focus here being on drainage, flood protection and landscaping.

### Success only when all stakeholders are involved

The Fraunhofer IAO is investigating: How can we replicate successful measures to other cities? There is no “one size fits



all” solution. Our experience shows: It is important to bring all stakeholders together and jointly develop, locally adapted and knowledge-based solutions. To achieve this aim, the Fraunhofer experts have compiled municipal governance guidelines and alternative financing options for nature-based solutions. They have also collaborated with five other cities to develop individual roadmaps for improving resilience to climate change.

What is the local vision for a climate-resilient future in 2050? Where does the city stand right now – and which nature-based solutions would help reach the set goals? “Of course, a city in Finland faces different challenges than one in Spain,” explains Mok. “Therefore, we have different problems to address, the visions also differ. However, most cities do face the important challenges in the areas of water management, urban heat islands and biodiversity.” In a further step, the researchers are planning to compile their results in an online database that will provide cities and municipalities with targeted knowledge about nature-based solutions and urban greening.

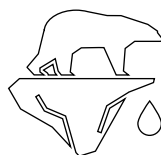
### How will room climates develop through to the year 2100?

If we want to prevent heat stress for city dwellers, making streets of houses and squares prettier by urban greening is not enough. Another important aspect is the room climate inside buildings. A multidisciplinary team involving 27 partners from Europe and Egypt have been working on the “Climate for Culture” project, funded by the EU and coordinated by Fraunhofer IBP, to deliver a solid basis for assessing this issue.

“We have coupled the hygrothermal building simulation model WUFI®Plus to climate models,” explains Dr. Johanna Leissner, the Fraunhofer-Gesellschaft representative in the research consortium. “This will allow us to simulate the room climate inside buildings through to the year 2100 and to analyze how climate change, but structural measures such as new windows, doors or shading too, is affecting the indoor climate and how much

energy will be needed in the future for climate control in the building.”

Coupling climate models to building simulation systems in this way has never been done before anywhere in the world – and has required a great deal of research work. First of all, the researchers had to define the parameters needed for the building simulation, and then calculate



### The research status on climate change in 20 words:

1. It is real.
2. We are the cause.
3. It is dangerous.
4. The experts are in agreement.
5. What else can we do.

Klima wissen, Sept. 2020, published by the German Climate Consortium

them out of the climate models. To achieve this, they needed to calculate the climate parameters with a resolution of ten by ten kilometers throughout Europe up to the year 2100. In fact, for two different scenarios since the true greenhouse gas emissions in the future can only be estimated.

“There was a huge volume of data to process before we could feed it into the building simulation,” recalls Leissner. The research team validated the parameters


they had identified using climate data from the past. Although the project focused on historical buildings and cultural heritage, the simulation does lend itself to all kinds of buildings.

### Hurricanes and strong winds

Although less sensational than droughts, heavy rain and rising temperatures, hurricanes and strong winds are other relevant effects of climate change. The aim here is to systematically break through wind swaths without reducing the positive effects of ventilation used for cooling during the summer months. “Besides topography, the way the wind works its way through cities is also largely down to the man-made obstacles – in other words the buildings,” says Matthias Winkler from Fraunhofer IBP. “Meaning, there are only a few options open to us for buffering wind swaths because we cannot alter the existing building structure that much.” One such possibility is not to close gaps between buildings flush with other houses, but instead to erect the new building slightly higher. Another one is trees, shrubbery or works of art that are positioned at the start of a wind swath and break through the unimpeded wind passage.

The urban climate model PALM-4U can be used to pinpoint the streets of houses in a city down which the wind whistles the strongest, and analyze the effects of such measures in especially windy corners in certain cities. The model is being developed in the “Urban Climat Under Change” project by a research consortium, also belonging to Fraunhofer IBP. “PALM-4U will help us map temperature profiles up to building level and also to simulate wind swaths,” explains Winkler.

The city of Berlin has already been simulated: We will be able to use this model in the future to reveal wind hotspots and examine approaches to counteract their effect. Will they have the desired effect? The researchers are also creating a model for Stuttgart, which they expect to be ready by the end of 2021. In the subproject ProPolis, the Fraunhofer researchers want to put the urban ►

A photograph of a man in a dark suit and glasses, identified as Dr. Marius Mohr, filling a white bucket with water from a large, ornate brass faucet. The faucet is mounted on a light blue backdrop. The background shows a laboratory or industrial setting with various pipes, valves, and equipment. The man is smiling and looking towards the camera. The faucet has a wooden handle and a large, curved spout. The water is flowing from the spout into the bucket. The man is wearing a watch on his left wrist and dark shoes. The overall scene is brightly lit, suggesting an indoor laboratory environment.

Collecting water? Dr. Marius Mohr from Fraunhofer IGB is advocating a "robust and efficient control of blue-green technologies".



climate model into practice and refine it so it meets the needs of municipalities and other users from practice. This includes developing a graphical user interface and training concepts. After all, the more practical and easier to use the model is, the more likely municipalities, cities and local communities are to take it on board. In the UCare4Citizen project, researchers are preparing the simulation results so that we can experience the complex information by wearing augmented reality glasses. In the KERES project, researchers are investigating the effects of extreme storms on cultural assets, focusing on both historical buildings and garden areas in the process.

### **The technologies themselves? They are not the problem!**

A challenge running through most projects for adapting to climate change like a common thread: For the most part, the technologies are in place. “The difficulty lies in getting them implemented,” says Dr. Susanne Bieker from Fraunhofer ISI. We would often hear the argument that the measures are too expensive. For Bieker, though, this does not hold: “There are numerous sources of funding. The ‘Water in the city of the future’ initiative, for example, covers up to 100 percent of the costs in some cases. Many cities also offer a ‘Green roofs program.’ Habits combined with ignorance and the will to create myths often stops the funding getting to where it needs to be,” Bieker knows only too well. As one such myth would have it: Photovoltaics and green roofs can’t be combined. Complete nonsense, in Bieker’s opinion. In fact, the exact opposite is true: Green roofs cool the photovoltaic elements from below, improving their performance by four to five percent.

An important lever for climate-resilient urban planning, therefore, is allaying the fears of the decision makers, communicating more information about the individual measures and unraveling the host of possible remedies. Researchers at Fraunhofer ISI are pursuing this goal in a feasibility study in Bochum. The team approached a large housing association ►

“The solutions are intertwined. If we save some of the water the monsoon season brings, it will be available in the dry spells.”

Dr. Marius Mohr, Head of Innovation Field Water Technologies and Resource Recovery at Fraunhofer IGB

### **The proportion**

of hurricanes in the strongest categories 3, 4 und 5

**increased**

from 1979 to 2017

**by around a quarter, from 32 percent to 40 percent.**



that looks after various districts. “If we understand exactly what’s needed here, we have wholly different possibilities for a scale-up than through private individuals,” says Bieker.

The researchers focused on a district with around 50 existing buildings which now however — just like many districts in the Ruhr region — is facing densification. In other words: In large gardens or in gaps between buildings, new houses are to be erected and existing buildings are to be made higher. But because, as a result, open spaces can disappear, we have to keep an eye on the hydrological cycles. In the feasibility study, the research team examined which measures would lend themselves to densification initiatives and under which framework conditions.

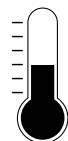
**200 square meters of green roof can save 500 euros**

To give the partners a chance to better estimate the costs involved, the researchers broke the figures down. “Our example calculation showed: In Bochum, just one green roof of 200 square meters is able to save 450 to 500 euros per year,” says Bieker. “Then there are the unquantifiable advantages such as improved weather protection for the facade and the cooling effect for the environment and interior spaces.”

Here’s what the project brought to light: Major synergies exist between the housing sector and the municipalities, the interests are much more similar than we expected on many levels. The municipalities, for example, offered to feed surplus rainwater from the district to a cased stream — which would then in turn carry enough water for it to be uncovered. “Getting all stakeholders around one table often bears a lot of fruit,” says Bieker summing up.

Researchers working on the SMARTilience project — in which the University of Stuttgart, a close collaborator of Fraunhofer IOA, is also involved — are pursuing a similar approach. Other project participants are Drees & Sommer, malik, the HafenCity University of Hamburg, and also the cities of Mannheim and Halle an der Saale.

“We are developing a control model which comprises all the process steps of planning, implementation and evaluation and which supports the local decision makers as they plan their forward-looking, efficient actions on tackling climate change,” says Rebecca Nell from Fraunhofer IAO. “The model will contain descriptions of possible measures such as roof greening,



The rate at which **temperatures are rising** has increased dramatically in Germany, and also globally, in the last 50 years: **Nine of the ten hottest years we have seen since 1881 occurred after the year 2000.**

links, data for contacts, references to similar projects and other things — the aim being to win over the government employees who matter.”

A peer-to-peer process that will allow the municipalities to share information has also been initiated. In the “City of the Future Constance” project, Fraunhofer IAO is collaborating with the city of Constance and local partners from science and industry to develop a district for the future. True to the motto of QUALITY NOT SQUARE

METERS, a new quality of life is emerging from the interplay between living space, sharing, mobility, greening, energy and digitalization.

**Adapting to climate change — a global issue**

Of course, the effects of climate change are not limited to just Europe — and neither are the Fraunhofer approaches to tackling climate change. Cities such as Kochi in India and Saltillo in Mexico are being severely impacted by climate change. In the project called “Morgenstadt Global Smart Cities Initiative”, researchers from Fraunhofer IAO, Fraunhofer IGB, Fraunhofer ISI and Fraunhofer IBP are therefore devising precise courses of action. The project is being financed by the International Climate Protection Initiative (IKI) of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). “We are making use of the experience we gained from the Morgenstadt network with 40 partners from industry, research and the municipalities, as well as the Morgenstadt tools,” says Dr. Markus Schwegler. The work involves three essential steps: The first one is to analyze the interactions within the city. What are the problems? Second, the researchers will be discussing co-creation — working with all partners and associates, they will work out and prioritize the first project ideas. And in the third and final step, they will set the ideas in motion.

Kochi, one of the most important ports on India’s west coast with a population of 600,000, has first and foremost water problems. “The recent monsoons caused severe flooding, claiming many lives and disrupting public life; around half of the airports had to close,” explains Dr. Marius Mohr from Fraunhofer IGB. For the remaining months of the year, though, the city faces serious water shortages. “The solutions to these two problems are intertwined,” says Mohr. “If we save some of the water the monsoon season brings, it will be available in the dry spells. “Roof gardens would appear to be a good solution for Kochi. Another efficient way of dis-

charging the bodies of water would be to use the open channels that were created during the colonization period but are now clogged with garbage. “We want to experiment with the approach on a small district — our hope is that the city will embrace the idea and roll it out in other districts too,” says Mohr.

Turning to Saltillo, Mexico — the second city lab. Defined by the automotive industry, this prosperous city lies in the Chihuahuan desert and is by nature very arid. Due to the effects of climate change, however, water scarcity is a growing problem. Water efficiency is therefore becoming an important subject, especially for

industry. Together with partners and associates, the researchers will decide in summer 2021 which projects are to be realized. “Research projects are often halted when recommended actions are devised for the customer. I think it’s wonderful that in the context of the city labs, we can implement tangible approaches in the form of pilot projects,” enthuses Jose Antonio Ordonez, scientist at Fraunhofer ISI and project manager. “We can then see whether the approach is reaping the desired successes, sort out the teething troubles and then replicate it or scale it up.” And by doing so, gradually better counteract the effects of climate change in the cities. ■

“It is important to bring all stakeholders together and develop common, locally adapted and knowledge-based solutions.”

Sophie Mok, scientist at Fraunhofer IAO

Photographer Heinz Heiss traveled to the researchers for the pictures in this edition of the Fraunhofer Magazine with his specially designed photo wallpaper. To adjust the light, the award-winning photojournalist took hold of the umbrella himself.



## Interview

# “Schmidt. Schröder. Scholz.”

The first candidate to declare his plan for power. Olaf Scholz is planning on becoming Germany’s chancellor. The finance minister and vice chancellor promises to be a point of contact for research and science who really cares.

Interview: Josef Oskar Seitz

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Olaf Scholz, 62, positions himself among the successful SPD chancellorship candidates.

\_\_\_\_\_ **Schmidt. Scharping. Schröder. Steinmeier. Steinbrück. Schulz. And the new chancellor hopeful is called Scholz: What does the "S" in SPD stand for again?**

**Scholz:** For a social democratic policy that is shaped by respect, that has a clear plan for the 2020s and that stands for a strong and sovereign Europe. As the SPD, we are fighting for a strong result that will allow me to become chancellor. If you like, then: Schmidt. Schröder. Scholz.

\_\_\_\_\_ **The coronavirus has changed our lives, and perhaps our society as well. Is solidarity more than just a nostalgic reminder for social democratic romantics?**

The pandemic is highlighting the importance of mutual respect and strong social cohesion. The only way to successfully overcome this historic challenge is to be there for one another, and support and help one other. Giving up social contact and restricting public life and business activities to protect people's lives and health is solidarity through action. Solidarity also involves us, as a state, assisting employees and organizations with massive rescue packages in this difficult time to make sure we all come through the crisis in the best possible shape.

\_\_\_\_\_ **Indonesia decided to prioritize the younger population in its vaccination drive: Key players first. Is an economically powerful Germany squandering significant competitive advantages by protecting its older generation first — being expected to share its vaccines equally with other European countries as well?**

I am pleased that Germany is seeing a broad consensus for the decision by the Standing Committee on Immunization to vaccinate the most vulnerable first: The very old. And those exposed to a very high risk of infection because of their work in hospitals and care homes. We have a duty to protect the weakest members of society. And I wholly agree with the EU's centralized approach to procuring the vaccines. However, I believe that the process could have been faster and more organized. Our only way out of this pandemic is to vaccinate — and I do understand the growing sense of impatience we are all feeling. Now it's important for us to organize as much vaccine as possible, carry out mass testing and roll out the vaccine as quickly as we can.

\_\_\_\_\_ **Which vulnerabilities has the coronavirus exposed in our economy?**

For a start, it has shown just how robust our economy is as a whole, despite the pandemic.

"I plan to help our public research institutions, which includes those of the Fraunhofer-Gesellschaft, bring their ideas and innovations to the market."

Economic development last year did not turn out as bad as feared. This being in part due to the resolute financial steps we took early on. Thanks to a strong rescue package and an extensive economic program, we have held firm. Europe too has found a powerful joint response to the crisis.

\_\_\_\_\_ **We engineered a vaccine in Germany and developed it in record time. Where do our country's true strengths lie — and what brings you hope for the future?**

Our country is strong, united and has many capable and bright minds. The development of the coronavirus vaccine is a fine example. We have a sound industrial basis, competitive companies, a highly trained workforce, an extensive and superb research landscape and a solid, dependable welfare state. All this builds an excellent foundation for successfully overcoming the challenges of climate change and digitalization we are facing. What we now need is a clear plan, bold decisions and determined effort.

\_\_\_\_\_ **What could research and science expect from a Chancellor Scholz?**

Excellent science and research are key to our prosperity. We intend to successfully shape the transformation to a climate-neutral society and ▶

the digitalization process. For that we need groundbreaking innovations. The policymakers have to ensure good research conditions, adequate freedom and reliable financial support. Taking BioNTech as an example, it's clear that targeted and sustainable support for innovation reaps success. I plan to help our public research institutions, which include those of the Fraunhofer-Gesellschaft, bring their ideas and innovations to the market. And in Chancellor Olaf Scholz, research and science will always have a point of contact who really cares about them and their concerns.

\_\_\_\_\_ **Germany plans to be spending 3.5 percent of its gross domestic product on research and development by 2025. Is this too much for a finance minister amidst the crisis and too little for a candidate for the future chancellorship?**

As finance minister, I am firmly convinced that such investments in our future can reap twice the reward. As chancellor, I will do my utmost to raise this level even further. Over 60 billion euros of the stimulus package that we pledged last summer will be spent on education, research and innovation. This will be another strong boost for innovation in Germany.

\_\_\_\_\_ **China is investing ten billion dollars in its quantum research center. The USA is to spend 1.2 billion dollars on quantum computing through a five-year program. The EU is intending to find a billion euros over ten years for its quantum flagship initiative. The IBM quantum computer has just gone into operation on German soil. But still, are we taking a risk by not driving a key future technology with the necessary vigor?**

Quantum technology is the next great technological leap. It's important that both Germany and Europe are up at the front. The Fraunhofer-Gesellschaft is playing a key role in this. The German federal government is promoting the development and production of quantum technologies. We are using an additional two billion euros from the stimulus package to support, among other initiatives, the building of at least two quantum computers.

\_\_\_\_\_ **How will the government claw back the 180 billion euros of new debt planned for the 2021 election year alone?**

Our budgetary policy of recent years has secured the financial strength we need to overcome this major crisis. Accordingly, Germany will have a lower debt-to-GDP ratio than that of all other G7 states before the pandemic. And our economic

“Over 60 billion euros of the stimulus package will be spent on education, research and innovation.”



A difficult role: As vice chancellor, Olaf Scholz has a shared responsibility for the policies of the Grand Coalition — as a candidate for the chancellorship, he needs to raise his profile vis-à-vis the European Union.

growth will enable us to emerge from the debt just as successfully as we did after the 2009 financial crisis.

\_\_\_\_\_ **Climate issues have dropped down the agenda somewhat, yet the problem still remains. What appeals to you most: Conventional electromobility or hydrogen?**

We should be able to have one without forsaking the other. I consider the fight against man-made climate change to be one of the most pressing issues of our time. It hasn't gone away just because of the pandemic. The stimulus package introduced last summer rigorously addressed the fight against climate change, having put together in 2019 the most ambitious climate protection package Germany had ever seen. My focus is this: Over the next few years, we will take the key decisions to ensure that Germany, as planned, can be climate neutral by 2050 and thereafter continue to offer good jobs, strong industries and a robust national economy. In terms of mobility, this means we will resolutely drive forward the switch to green propulsion and focus on both: Electromobility and hydrogen. We need to



“Quantum technology is the next great technological leap. The Fraunhofer-Gesellschaft is playing a key role in this.”

solve the chicken and egg situation facing electric cars: There are too few electric cars because we do not have enough charging points. And there are not enough charging points because there are too few electric cars to make operation commercially viable. And if we are to have CO<sub>2</sub>-free heavy goods vehicles, we need to establish a network of hydrogen gas stations. We also need much more power from renewable energies and a far more efficient supply grid. Not only that, we should be focusing on hydrogen technology big time.

\_\_\_\_\_ **The “Handelsblatt” newspaper, not usually considered a forum for lay psychology, has analyzed a German state of mind: “After 16 years of Angela Merkel, citizens see themselves as a male version of the long-standing chancellor.” Will the winning formula Merkel used in her election campaign: “You know me” be any help to you?”** As people well know, I don’t tend to psychoanalyze. However, it’s no bad thing that people know who I am and that, as Lord Mayor of Hamburg, German federal minister and vice chancellor, I know how to govern and lead. ■

## The comeback guy

### Hopes for a tailwind 2020

Comeback Scholz strikes again: The SPD elects him as chancellor candidate. Nine months before, he was still in the runoff election for party chairman.

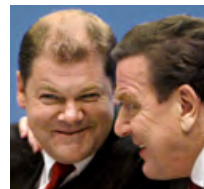
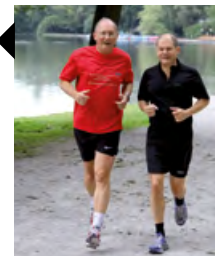


### 2015 On the way to the top

Olaf Scholz after the Hamburg council election together with his wife Britta Ernst, then minister of education, now Brandenburg minister of education, youth and sport.

### He runs and runs and runs 2003

German Federal Minister of Labor Olaf Scholz spends time during his visit to Munich jogging in the Englischen Garten with Franz Maget, the then Group Chairman of the Bavarian SPD.



### 2003 Comeback Scholz

Despite having lost the election in Hamburg, Gerhard Schröder made him General Secretary of the SPD. The comeback qualities remain: In 2004, he stepped down due to the agenda reforms, but in 2007 became federal minister of labor who can turn the financial crisis into a chance to raise his profile as crisis manager.



### 2001 Well-armed

As senator of the interior in Hamburg, Olaf Scholz faces the police dog team well-armed.

### Ruffling not only his hair 1982

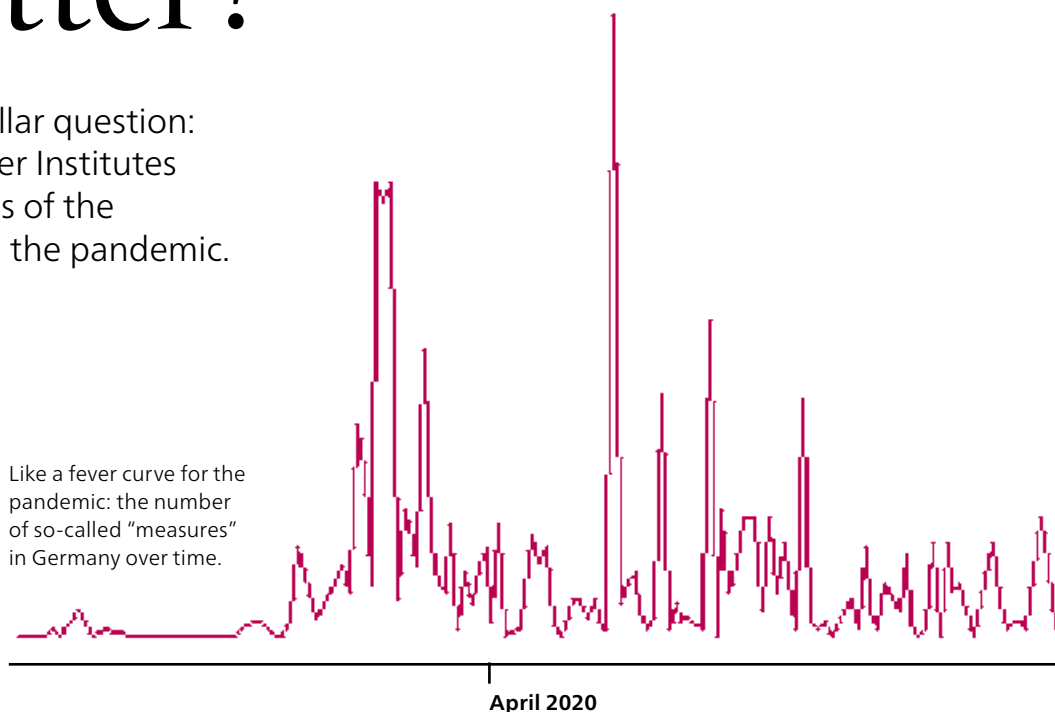
From 1982 to 1984, Olaf Scholz was Deputy Jusos Chair, criticizing the “aggressive imperialistic NATO” and the Federal Republic as a “European stronghold of big business.”



# What could we have done better?

Coronavirus and the million dollar question: In a joint project, five Fraunhofer Institutes are analyzing the consequences of the political decisions made during the pandemic.

By Stefan Ruzas



In her New Year’s speech, Angela Merkel gave out a message of courage and hope, before turning to the challenges facing the economy and society. An address by her Austrian counterpart Sebastian Kurz made an obvious comparison between Austria’s achievements and those of other countries. Planned measures were Giuseppe Conte’s favorite topic during his time as Italy’s prime minister.

The Fraunhofer Institute for Systems and Innovation Research ISI is currently using its own “codebook” with 13 parent categories and 125 individual codices to record and categorize addresses by heads of government and state during the COVID-19 pandemic. It contains more general aspects such as “statements of alarm” or

“justification of the measures with case numbers”, and also specific topics.

## Deriving potentials for improvement

On November 25, Fraunhofer ISI began work on the KResCo (crisis management and resilience against corona) with four other Fraunhofer Institutes. For one year, they will work as a team analyzing political decisions and crisis communication during the pandemic, taking a close look at the consequences of such decisions.

The institutes and centers of the Fraunhofer Group for Innovation Research are working together on the project. Alongside the Fraunhofer Institute for Technological Trend Analysis INT as the overall coordi-

nator and Fraunhofer ISI, the collaboration involves: The Fraunhofer Institute for Industrial Engineering IAO, the Fraunhofer Center for International Management and Knowledge Economy IMW and also the Fraunhofer Information Center for Planning and Building IRB. Each organization contributes its own view of things for the total of eight work packages.

“We want to derive improvement potentials for various areas of our company — for future pandemics as well: What could we have done better?,” Larissa Müller, Project Manager at Fraunhofer INT, explains one of the goals. The team is comparing, in particular, five countries with COVID-19 cases, namely Germany, Austria, Switzerland, Italy and Sweden. All kinds of questions arise: How does a federal system best

Angela Merkel, 66,  
German Chancellor



Stefan Löfven, 63,  
Prime Minister of Sweden



Sebastian Kurz, 34,  
Austrian Chancellor



# 294

Measures for  
making masks  
mandatory  
in Germany

# 13

Measures for  
making masks  
mandatory  
in Sweden

# 138

Measures for  
restricting local  
public transport



deal with pandemics? Are there standards that demonstrably help? How can we get organizations such as the Federal Agency for Technical Relief involved?

Müller: “The results could help build a higher resilience by helping the policy-makers better understand the implications of their decisions, and ultimately bolstering the crisis management system.”

Data from various sources, including the Oxford COVID-19 Government Response Tracker or the CoronaNet, the world’s largest database containing over 50,000 coronavirus-containing measures from 195 states, are set to be merged to create one standardized pool, which can then be used for analytical purposes. “Taken as a whole, our project delivers great added value. We are looking at consequences in all areas

— from health, society and the economy to the feedback effects for the political system through to innovation, crisis management and research institutions. We are also breaking new ground in terms of research data management,” explains Daniela Beyer from Fraunhofer ISI.

### “State of disbelief”

The first evaluations of the political decisions show that Germany, having introduced 1848 official measures, is behind the USA (4020) in the world ranking but still ahead of China (1703). And while Sweden has implemented 13 measures to make mask wearing compulsory since the start of the coronavirus pandemic, the figure here in Germany is 294. Conversely, Germany

has implemented 51 measures to restrict local public transport whereas 138 such measures have been counted in Austria.

A Fraunhofer study from 2013 shows that this kind of research work loses none of its relevance. The study reads like a blueprint for the present day. It reports millions of infections, tens of thousands of fatalities and the closure of schools and vaccination quotas. “Influenza pandemic in Germany 2020 — Scenarios and action options” is the title of the paper, written at Fraunhofer INT in Euskirchen. “The study was never really forgotten, but when the first lockdown came, we studied once again what our colleagues had described”, reports Larissa Müller. “So much was relevant. Once the coronavirus outbreak happened, we were rubbing our eyes in disbelief.” ■

# Big Data — Big Privacy

Data privacy is important, rightly so — and not necessarily at the expense of the quality of big data analyses, confirms a study by the Fraunhofer Institute for Secure Information Technology SIT.

By Franziska Sell

**W**ithin Europe, all aspects are in fact clearly regulated: Any party processing personal data in compliance with the law in big data environments has to consider data privacy when developing its solution. Clear so far — as far as the security of a person's privacy is concerned.

The fact that this issue always deserves a closer look is shown in the context of machine learning: Because the algorithms are usually trained and evaluated on data sets that have no common element, it has long been assumed that it is not possible to draw conclusions about the data used for training from the final model. Some security experts, however, such as Prof. Martin Steinebach, Head of IT Forensics at Fraunhofer SIT in Darmstadt, have been able to prove that certain technologies unexpectedly clearly recall the individual pieces of information and react more strongly to known data. We are also seeing more and more new processes that allow specific data to be extracted from the networks.

Steinebach uses a fictitious example to outline the risks: A disease can be diagnosed by looking at a person's face. There is now an app that can show people whether they are sick or vulnerable. The system used in the app is trained with portraits of sick people with a confirmed diagnosis. "If I want to release the app, I have to make the knowledge taken from this network available," explains Steinebach. He believes there is a very real danger of the latest technology being able to trace the photos back to the patients and their data. Steinebach: If a system designed to provide people with more medical security on the basis of machine learning were to suddenly become a mechanism that could expose them, "we would have a catastrophe on our hands."

### How can we link big data analyses with data privacy?

Privacy-preserving Machine Learning (PPML) is the name given to the relatively young research field that conveys the importance of this issue. It has set itself the goal of protecting the privacy of the individual, while allowing models to be

trained on the data of large groups of people. The approaches already masterminded by the researchers are being applied in the "Privacy and Big Data" study being conducted by Fraunhofer SIT. "What strategies will allow me to anonymize data to such an extent that I can still run big data analyses on them while preserving privacy at the same time?", asks Martin Steinebach, as one of the authors, getting to the heart of the research work.

In the study, the authors are evaluating the key encryption technologies using the processing sequences in big data systems: From secure transmission channels, "data in transit", to secure storage, "data at rest" — through to secure processing, "data in use".

Steinebach generally believes developments in big data and data security to be on the right track: "All those involved have learned a lot and companies have become more candid. The General Data Protection Regulation has made it very clear to many that they cannot continue to ignore the issue. Those responsible are taking the issue far more seriously merely because data privacy violations are now quantifiable."

### What do data lose in terms of value when they are anonymized?

To what extent does privacy influence the results of big data analyses in reality? "To have a well-founded basis for making decisions, a company has to see in no uncertain terms: If I can no longer distinguish between individual users, only groups of ten for example, how does this impact my analysis mechanisms? Do they become one percent less accurate, ten percent or are we in the order of ppm? Only if I know this can I also know what the cost will be. I can then deliberate over whether a business model, which is data-based but which calls for anonymization, is viable in its intended form."

In a current research project, the security expert and his team are therefore examining how much value data do actually lose when they are anonymized. Steinebach is convinced that the results of the study will be able to dispel current concerns: "I am very confident that in many cases, the implications of anonymization are far less serious than feared." ■



"If a system designed to provide more medical security were to suddenly become a mechanism that could expose them, we would have a catastrophe on our hands."

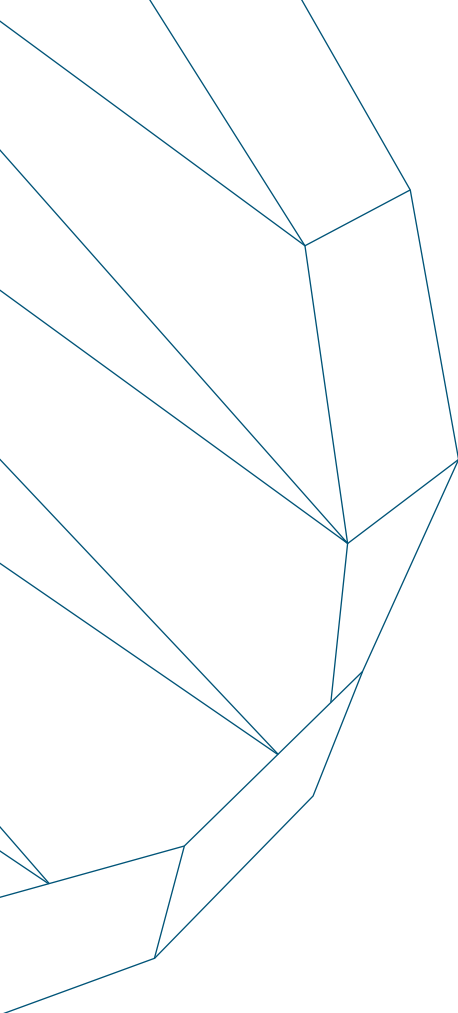
Prof. Martin Steinebach

# DNA origami to fight infection

Our DNA is capable of more than just storing genetic information. It is also an ideal building material for tiny intricate scaffolds. These constructs are forming the basis of new therapies for viruses and antibiotic-resistant microbes.

By Christine Broll

DNA is shaped like a double helix and wound in a spiral — rather like a spiral staircase.



The DNA origami with the initials of the Fraunhofer IZI consists of a structure of DNA strands. Attached to the structure at selected places are proteins, which form the logo.

**W**hen the Japanese practice the art of origami, they fold fine quality paper into beautiful objects of nature like cranes or delicate blossoms. When Dr. David M. Smith takes to origami, he uses an even more noble material. He folds DNA to make three-armed star shapes, tubes or rings. At times, he aligns the DNA strands so exquisitely that they form a microscopic carpet, which he then adorns with proteins or sugar molecules. The physicist at the Fraunhofer Institute for Cell Therapy and Immunology IZI in Leipzig is using these scaffolds to create the basis for a new class of drug. Drugs that have the ability to effectively disarm pathogenic, even antibiotic-resistant microbes.

Smith and his team have already demonstrated that this principle works — first on the influenza virus and latterly on the respiratory syncytial virus, RSV for short. The RSV is one of the most significant

The origami measures just **70 by 100 nanometers**, equivalent to **1 thousandth** of the diameter of a hair.

pathogens causing respiratory diseases in babies and small children, although infections occur in all age groups. Laboratory experiments conducted together with Dr. Thomas Grunwald, Head of the Preclinical Validation Working Group at Fraunhofer IZI, demonstrated a remarkable effect. The peptides that are bound to the three-armed DNA constructs are much better at fighting RSV viruses than individual peptides. The first experiments are currently underway, in order to test the effect on mice. In the CoronaSense project, supported as part of the Fraunhofer vs. Corona program, the working group headed by David M. Smith is also developing three-armed DNA constructs to fight SARS-CoV-2. The logic is that the receptors on the coronavirus spike protein are also made up of three sub-units.

US biochemist Ned Seemann came up with the idea of using DNA as the building material as early as 1982. However, it ►

# DNA — a special kind of building material

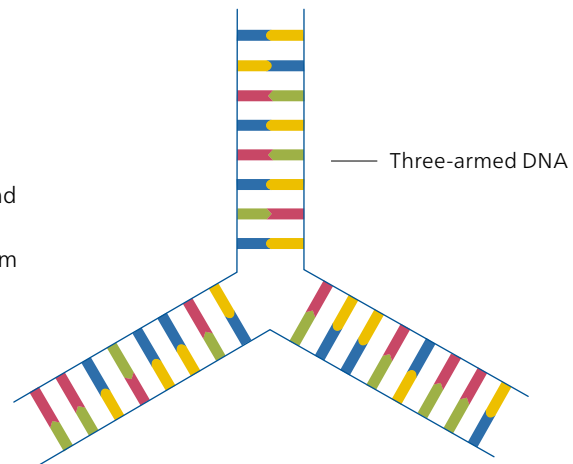
Life would not exist without DNA. It contains every single piece of genetic information. And it can be used to build three-arm scaffolds, which attach themselves to viruses and render them harmless.



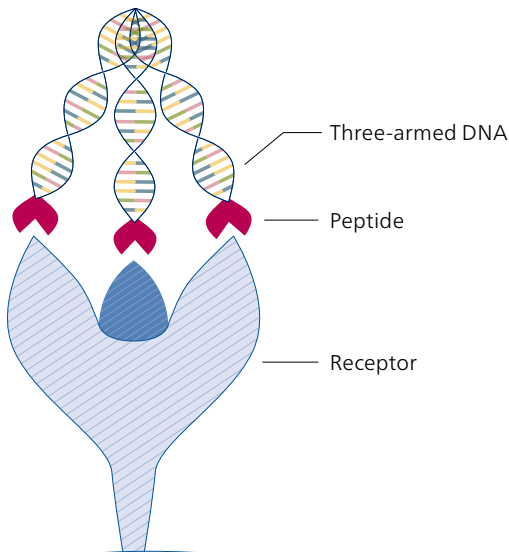
Adenine	<span style="color: green;">█</span>	Thymine	<span style="color: red;">█</span>
Guanine	<span style="color: yellow;">█</span>	Cytosine	<span style="color: blue;">█</span>

Natural DNA consists of two individual strands. Sitting on each strand like fine teeth are the four bases — adenine, thymine, guanine and cytosine. These bases form the alphabet of letters that are used to write the genetic code. They also make sure that the two DNA strands bond to one another. Adenine bonds with thymine and guanine with cytosine. This preordained base pairing makes the two strands complementary to one another.

It's the mechanism that causes the complementary bases to join together that makes the DNA an ideal building material. We produce individual strands and select a sequence that will allow complementary strands to automatically join up into the desired form like a zip fastener.



— Three-armed DNA



The three-armed DNA latches onto the receptor of an influenza virus like a harpoon. Because it tethers itself to three places at the same time, the bond is particularly strong. The receptor on the virus is blocked and cannot infect any more cells.



was nine years before he actually managed to build the first intricate scaffold structures. “Back then, producing DNA in the lab was a highly complex matter,” explains David M. Smith. It would take weeks or even months to synthesize just one single, short strand. Nowadays, specialized firms deliver DNA strands with any desired genome sequence to order within a matter of days.

It goes without saying that Smith does not use the naturally occurring DNA, which consists of two strands bonded to one another, for his origamis. Instead, he takes individual strands of DNA and structures them in such a way that they can be assembled to create the desired form according to his blueprint (see graphic). In practice, this is quickly done. The pre-built DNA strands arrive in a test tube, are heated to 90 degrees and then cooled down again very slowly. During this process, individual complementary strands pair up to form a double stranded structure.

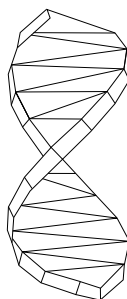
### Trident attacks viruses more effectively

“We have found three-armed structures to be highly effective in the development of anti-viral agents,” says Smith. The Texan, who joined Fraunhofer IZI in 2013, attaches small proteins called peptides to the tips of the three arms. This creates a “harpoon” which launches itself onto the receptors of viruses. “Virus receptors often consist of three sub-units,” explains Smith. “The harpoon is able to bind to all three sub-units at the same time. This is significantly more effective. We have already protected this technology with two patents.” In principle, the harpoons act like antibodies. They stop the virus penetrating cells by bonding themselves to the receptors.

While three-armed DNA scaffolds are relatively easy to produce, structures formed from several hundred individual strands are accredited to the fine art of DNA origami. David M. Smith demonstrated his prowess in this area too at the tenth anniversary of Fraunhofer IZI. He created a DNA origami bearing the initials of the institute. To do so, he used one



**Dr. David M. Smith** studied physics and philosophy at the University of Texas. He joined Fraunhofer IZI in Leipzig in 2013, where he now heads the DNA Nanosystems Working Group.



### DNA origami making your own paper model

Simply download the PDF with the template, print it out and follow the detailed video instruction to fashion a colorful DNA double helix.



You can find the instruction here: [www.yourgenome.org/activities/origami-dna](http://www.yourgenome.org/activities/origami-dna)

extremely long strand of DNA, which he bonded to short strands to create a fine carpet. He then attached proteins to this structure at selected points to form the “IZI” logo. To bring the work of art to life, it had to be photographed using a special atomic force microscope — the origami measures just 70 by 100 nanometers, equivalent to one thousandth of the diameter of a hair. This is how the origami made it onto the cover page of the 2014 annual report.

### New weapon in the fight against antibiotic-resistant microbes

In a project called Glyco3Display, Smith is working in collaboration with the Max Planck Institute of Colloids and Interfaces to develop a new class of antimicrobial agents. He is approaching this by attaching various types of sugar to his DNA scaffolds. He looks for sugars that bind to bacteria, more or less neutralizing them in the process. To ensure that the processes involved are executed with military precision, the project team has set up a screening platform. It is designed to answer two questions: Which sugars bind to which bacteria? And the second: What is the optimal geometric arrangement for the sugars on the DNA scaffold? The first tests were ran using the intestinal bacterium E.coli and look very promising. Next, the team will test respiratory viruses such as Influenza A, RSV and of course SARS-CoV-2. “We could administer the therapeutic agent as a spray or for patients to inhale,” reasons Smith. “That way, we reach the throat and the lungs at the same time.”

The application of the sugar DNA constructs for diagnostic purposes is more advanced. The specific binding of the sugar to the surface of viruses can also be used to detect viruses. Smith wants to market the technology through a spin-off. “With the AHEAD program designed to promote start-ups, Fraunhofer Venture is helping us conduct market research and develop a blueprint,” says excitedly, adding with a wink: “The platform we are developing now will allow us to react to the next platform at speed.” ■

# “Attack surfaces have got bigger”

Cybersecurity researcher Dr. Haya Shulman from the Fraunhofer Institute for Secure Information Technology SIT wins the eighth German IT Security Award. Her “Cache Test” protects sensitive internet infrastructures.

Interview: Franziska Sell

\_\_\_\_\_ **Mrs. Shulman, has the surge in digitalization caused by the coronavirus changed cyber attacks?**

With so many people working from home, the attack surface has grown much bigger. The firewalls used by employees at home do not meet the standards in place for companies. These firewalls are not configured by system administrators. This makes it much easier for hackers to penetrate company networks. There’s quite a need to upgrade here.

\_\_\_\_\_ **You have just won the German IT Security Award. Where does your solution come in?**

It addresses the known issue of being able to redirect communication over the internet. To send anything, you need an IP address. The communication is then sent to the recipient through various nodes. Their IP address is provided by Domain Name Service, DNS for short, servers. Basically, they are the Yellow Pages of the internet. You open a page, search for the address by name, drive by and deliver your bouquet of flowers. Hackers attack these very DNS servers and give out fake IP addresses. Without knowing it, you could be sending sensitive data, from your password to your PIN code, to criminals instead of to you bank for example. My tool checks DNS infrastructures for vulnerabilities by an automated process.

\_\_\_\_\_ **What sets your “Cache Test” apart?**

This is truly a solution for anyone who moves around the internet - from end users to government departments. Anyone can examine their service

## Interview



Dr. Haya Shulman

provider for security vulnerabilities, the provider itself likewise — the process is quick, easy and can be done on a regular basis. My tool does this by specifying fake IP addresses — for various services I have set up. I carry out attacks for these services. At the end, you get a report that highlights the vulnerabilities and recommends counter measures.

\_\_\_\_\_ **How are the opportunities for the market looking?**

Very good. I always try to make the tools I develop as automated as possible. This eliminates human errors. And the process must be as painless as possible for the user. The Cache Test needs just one click to run the check. And the tool also achieves something brand new: It checks servers to confirm whether they will accept fake IP addresses or whether fake addresses can be entered. This is a real chance to make the internet much more secure.

\_\_\_\_\_ **You are one of the world’s leading cybersecurity researchers, present lectures at the university as a visiting professor, run your own business — and have developed an award-winning solution for solving fundamental IT problems. And you are also mother to three children. How do you manage it all?**

I am fortunate to be doing something that fascinates me. Work is such a big part of our lives, you know. It’s tremendously important that we enjoy it. Before I had children, I needed peace and quiet to be productive. Now, I can write papers and develop solutions with my children on my lap. That’s amazing!

Over many months, corona has made us aware of just how precious our senses are: smell, taste — all under threat because of the coronavirus.

**Enjoyment** has become a rare experience in the lockdown. The plan being deployed to fight the pandemic **is** endangering enjoyment as a way of life. Fraunhofer researchers are working on digitalizing the senses. We'll be discussing how technology sounds, smells and tastes in an **encounter** with professionals from the industry.

Whiskey &  
science  
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cuisine  
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Technology &  
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## “Campus of the senses”

Column,  
aroma expert

---

The glass capillary, 30 meters long and wound into a handy loop unravels aromatic substances into the readily soluble and the barely soluble. What hits the nose as floral and honey simply becomes 2-phenylethanol, cloves become 4-allyl-2-methoxyphenol.

# Whiskey, keeping the sober perspective

The distillate is an indulgence, plays a cult role in countless films, connoisseurs outdo one another in poetic analogies. In the “Campus of the senses”, Fraunhofer is getting to work on deciphering aroma and taste. Dream or nightmare? A meeting of experts.

By Josef Oskar Seitz  
Photography: Michela Morosini

**Stefan Gabányi,  
Whiskey connoisseur**

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Author of "Schumann's Whisk(e)y Lexicon", the definitive work for whiskey aficionados. He worked with bar legend Charles Schumann for 23 years. Stefan Gabányi has been running his own bar in Munich since 2012.



**Dr. Tilman Sauerwald,  
Physicist**

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Since 2020, the gas measurement technology expert has been working at Fraunhofer IVV on the detection of complex gas mixtures by sensor systems. In the "Campus of the senses", Sauerwald as Project Manager is currently focusing on deciphering whiskey aromas.





**L** eading the way to indulgence, descending ten steps, into the bar. Soles squeal on the fresh black surface, the floor has just been repainted. Deep, dark brown leather chairs await. Right at the back a piano, this boss plays here himself too. Now he reaches for the bottle. Stefan Gabányi pours a whiskey. A Longrow Single Malt. The incidence rate is still too high to welcome guests. So these are the only glasses the host will be filling in his bar in Munich this evening.

Indulgence is becoming an endangered way of life. Restaurants, pubs and bars — all long since locked down. For the moment, he's the homemaker, says Gabányi. The barman is being modest. For 23 years, he worked night after night in the legendary Schumann's bar in Munich as a recognized whiskey expert. Since 2012, he has been running his own bar, open until five in the morning, when life was normal, with live music once a week. His definitive work "Schumann's Whisk(e)y Lexicon", has just been published, translated into English for the international whiskey aficionados. Gabányi pours, just for nosing. But what does that actually mean: Just for nosing? If the nose doesn't react to this whiskey, it's high time for a coronavirus test.

"First the peat note," explains Gabányi. "For some, this is also akin to a medicine, reminiscent of iodine. Then we get the fruit. Cloves too. A touch of salt or pepper..." Dr. Tilman Sauerwald sniffs, concentrating. "There's a hint of sweetness too," the expert from the Fraunhofer Institute for Process Engineering and Packaging IVV wracks his brains: "Pear?"

**While ever we are breathing, we can smell.** 350 receptor types work around the clock, day and night. No matter whether asleep or awake, scent molecules excite the olfactory cells, produce a current that's directed through the nerve fibers into the brain, reach the brain areas of the limbic system, responsible for emotion and mood, and the hippocampus, responsible for memory and recall. This dedicated circuit makes smelling so immediate — and so difficult for us humans. To express the unfathomable, experts resort to word crutches. Gabányi recounts whiskey tastings in Scotland, where the connoisseurs passionately try to find the best superlatives to describe the bouquet. "Like a wet horse blanket," he's even heard. Or even: "This one smells like a seagull's armpit."

Dr. Tilman Sauerwald takes a different approach. The physicist and expert for gas measurement technology is the Project Manager in the "Campus of the senses". Under this initiative, sponsored by the Bavarian Ministry of Economic Affairs, Regional Development and Energy, experts from Fraunhofer IVV and

**350**  
**receptor**  
**types**  
**work**  
**24**  
**hours,**  
**day and**  
**night.**

the Fraunhofer Institute for Integrated Circuits IIS, working in cooperation with the Friedrich-Alexander-Universität Erlangen-Nürnberg, are researching the sense of smell and taste — and are planning to translate these chemosensory perceptions into machine and digital concepts. Together with his team, Sauerwald chose whiskey as the research subject. As a scientist, he is fascinated by the diversity, the wealth of variants, the complexity.



These are the aromas that people like in a whiskey: pear and citrus, ginger and mint.



600 pages of palatable reading for connoisseurs. The English version has just been published.

**"You have your work cut out there!"**, says Gabányi in amazement. "A very complex task indeed," agrees Sauerwald.

In his bar, the whiskey man explains the diversity of aromas. "The water, that's very important!", says Gabányi. As an example, he describes Islay, the Hebrides island battered by storms and famous for the most Scottish of all Scottish whiskeys. The island is covered in peat, which turns the water pale yellow — and alters its taste. This increases the whiskey's phenol content. Ten ppm in the malt creates a slightly smoky taste, 40 ppm and upwards make it a concoction for specialists. Gabányi also talks about the Scottish pot stills, which would be too impure for German distillers. Precisely why they are able to impart more complex aromas. Then he turns to the casks, for many experts quite simply "the mother of the whiskey", because this is where 60 to 80 percent of the aroma ►



Two opposites get close up: Stefan Gabányi as a seasoned expert and Dr. Tilman Sauerwald as a natural scientist.

develops. He talks about the varieties that are left to mature for their last years in specially imported port or sherry casks before being decanted. He describes the differences between European barrel oak, which contains more tannins, and the American oak with its vanilla aroma. He goes on to explain why connoisseurs are so fascinated by individual barrel filling events, because they are so unique, so exclusive and offer an unrepeatable pleasure. After all, every barrel is a limited edition that yields just 300 bottles — sometimes fewer. At the end of February, a 0.75 liter bottle of “The Macallan 1926 Fine and Rare” was auctioned in Scotland, it fetched 1,157,000 euros. In 1986, just 40 bottles were decanted from the barrel, only 14 of these were labeled Fine and Rare. The world record for a bottle of whiskey is still around half more, at a palatable 1.5 million pounds.

**Keeping the sober perspective, the art** consists of around 40 flavoring agents. It sounds straightforward. 2-phenylethanol has a floral, honey-like aroma. 2-methoxyphenol smells slightly smoky, burnt. Gamma-Nonalactone is reminiscent of coco, 4-allyl-2-methoxyphenol of cloves. Quercus lactones are produced by the constituents of the oak wood. The interactions between these substances cause the com-

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plexity. Furthermore, even closely related chemicals perplex again and again with their dissimilarities. The nose perceives one substance as: Wood. Another as: Rubber.

Dr. Sauerwald brought one of his tools to the bar this evening. A column. A glass capillary, wafer thin and 30 meters in length, is wound to form a loop of 30 centimeters in diameter. Inside is plastic that is almost liquid. This column is placed in an oven at a temperature of 250 to 300 degrees. Gas is introduced, the readily soluble separates from the barely soluble and can be smelled and measured in parallel at different times via a Y-shaped end piece. Deciphering the concert of flavoring agents requires a concert of experts. Sauerwald’s team of engineers and psychologists, food chemists and neuroscientists are working to crack the whiskey aroma code. “We need this interdisciplinarity, especially when it comes to the senses,” explains the Project Manager. “It is indeed a massive challenge, even to get everyone speaking the same language, but it will without any doubt become increasingly important in science — and certainly at Fraunhofer due to the diversity of the institutes.”

**The measurement data from the gas chromatograph** add up to aroma profiles. Automating this task, still largely a manual one, is one of Tilman Sauerwald’s goals. So far, the scientists have analyzed scotch blends. The data basis of the elected Scottish whiskeys is currently being expanded by selected Germany whiskey varieties. The plan, using this basis, is to have a classification trained by a human sensory panel, that is to say by human testers, by the end of the year. This will show whether the machine is able to class new blends just like a human. Sauerwald puts it in a nutshell: “We are trying to make the senses of smell and taste measurable by machine and in doing so support the creative process of blending.” The ultimate goal is to give the blend masters who mix the major whiskey brands for the reliability of their taste an instrument to support aroma predictions — and a tool for detecting and avoiding off-aromas in good time. 90 percent of scotch is sold over the counter as blended whiskey. Reliability is important here: A Johnny Walker always has to taste like Johnny Walker and a Chivas Regal like Chivas Regal.

“My vision,” says Dr. Tilman Sauerwald, “is to one day measure smell and taste as accurately as the other senses like sounds and colors.”

A nightmare for Stefan Gabányi, the whiskey man? “This would be a great help to the manufacturers,” he replies. “It’s really very exciting for the industry.” And he adds: “The exclusivity, the creativity, will always remain.” ■

# Nose for whiskey

Process development of an automated aroma evaluation

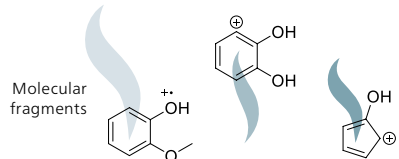


## Human sensory evaluation

Trained testers determine an aroma profile for the whiskey against which the mechanical evaluation has to be "measured".

## Example of a flavoring agent 2-methoxyphenol: smoky, phenolic, burnt

**Automated evaluation**  
Because of its mass spectrum and other characteristics, every molecule possesses a unique **fingerprint**.  
Fraunhofer IVV is developing a new method for the automated detection of the molecules from this fingerprint.

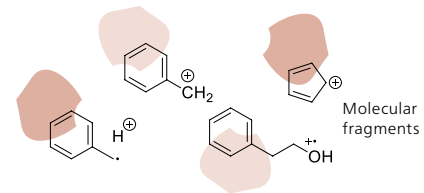


The evaluation is performed using the characteristic mass spectra of the molecules, which emerge from the molecular fragments.

## Example of an aroma 2-phenylethanol: floral, honey-like

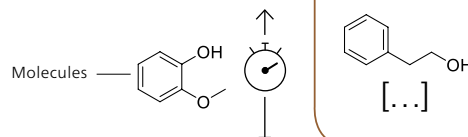
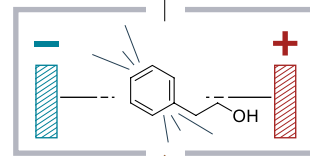
### Automated result

All the molecules identified by the **fingerprint** are used to carry out a holistic aroma assessment of the complex mixture. **Artificial Intelligence** is used to determine the whiskey's aroma profile.



## Mass spectrometer

The molecules are ionized in the detector. During the electron impact ionization process, they are pounded with electronics, causing them to disintegrate into fragments that are in turn unraveled according to mass.



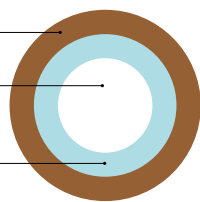
## Physical separation principle

The aromas interact with the polymer film. They condense and evaporate. At the same time, the molecules are separated from one another and exit the column at different times.

## Cross section of the capillary

Length: 30 m (wound)

Glass capillary  
Carrier gas as mobile phase  
Stationary phase from thin, almost liquid polymer film



## Gas chromatograph

heats up under control from room temperature to approx. 250°C.

## Sampling

Aromas are extracted from the whiskey and transferred to the gas chromatograph.


Whiskey sample



# Easily combustible

Currently, smoke detection devices are lacking at the most vulnerable places in the apartment. Odor experts at Fraunhofer IIS and Fraunhofer IVV are working on a solution — with sense and the senses.

By Josef Oskar Seitz



Our noses recognize cigarette smoke spontaneously. But how can technology learn how to differentiate between enjoyment and danger? Sebastian Hettner, mathematician at Fraunhofer IIS, wants to teach machines to categorize burning odors.

**C**an we smell the first charcoal grill on a warm spring day? The last welcoming open fire, there's still quite a chill towards evening time? Or is a cable on fire in our neighbor's kitchen? Humans are a good sort. They decide spontaneously, quickly and with absolute certainty — they simply have a good nose for knowing what to do when it comes to life and survival: Pleasure and danger. And the technology?

Smoke alarms are mandatory in all 16 states for private dwellings. Only in Saxony does the law still apply only to new buildings. Smoke alarms are installed in hallways and living rooms, nurseries and bedrooms. But not in kitchens. In 2020, the "Vereinigung zur Förderung des Deutschen Brandschutzes" (German Fire Protection Association) published very clear figures from the statistics on fire damage. The major risk factor in private dwellings is the kitchen. 48 percent of fires in homes break out around the stove and the oven. In 24 percent of cases, fires run rampant from trash cans. In those places where the fire risk is greatest, then, there is currently a dearth of automatic warning devices — even though, another finding from the study, the fires would not have spread as far had the alert been raised by an alarm system. The amount of loss would also remain lower.

**For smoke alarms to be able to raise the alert in the most dangerous places too,** they have to learn to distinguish between a chop burning in the pan and a kitchen curtain that gets caught in the gas flame. At the moment, however, the vast majority of warning devices do not detect the various concentrations of the different gases. The Fraunhofer Institute for Integrated Circuits IIS and the Fraunhofer Institute for Process Engineering and Packaging IVV are working on a solution in a joint project called "Campus of the senses". They want to improve safety in the home and reduce the number of false alarms using technical sensors and AI-based evaluations. Sebastian Hettenkofer is fascinated by the idea of teaching a machine to understand the complex world of molecules — and open the door to a machine learning system for detecting fires from odors.

The mathematician at Fraunhofer IIS in Erlangen comes from image processing. In this work, he experienced how far technology has come in terms of replicating — or even surpassing the potential of the human eye. "Analyzing odors is a far more difficult field," he learned. Yet: "Even smoke holds an unbelievable latent potential."

But the problems are also daunting. Smoke is volatile. There is no data basis. To be able to measure the

Human error, such as dropping a cigar on the carpet, is a common cause of fire.



### Causes of fire in Germany

**32%**  
Electricity

**17%**  
Human error

**9%**  
Arson

Germany:  
2002 to 2019

Source: Statista 2021

target gases and create comparability frameworks, fires have to be simulated in special fire rooms, and this takes great effort. The areas, after all, are highly individualized: Where is there an apartment, with its fabrics, floor coverings and furnishings, that is wholly comparable with the neighbor's one?

Despite all the problems still to be solved, Sebastian Hettenkofer is firmly convinced about the advantages of an innovative technical solution over the time-honored smoke detector, the nose. "Technology," he says, is incredibly powerful in terms of objectivity, reproducibility and continuity." His hope is that he and his team will be presenting for Fraunhofer a prototype that promises to deliver real safety benefits within one to two years. The Fraunhofer man from IIS: "This will be a genuine benefit to society." ■

# Could we imagine a world without aromas?

The coronavirus has exposed the vulnerability of our senses. Two experts — one bringing the theory and the other with plenty of experience — meet to talk about fragrance and aroma, and about enjoyment.

By Josef Oskar Seitz

"We are constantly discovering new aromas that the world has no idea about."

Prof. Andrea Büttner, food chemist and aroma researcher, has been director of the Fraunhofer Institute for Process Engineering and Packaging IVV since 2019.



[www.ivv.fraunhofer.de](http://www.ivv.fraunhofer.de)

## An encounter



“All the important things in life involve smelling, eating and drinking.”

Tohru Nakamura, 37, earned his second Michelin star in 2016.



[www.tohrunakamura.de](http://www.tohrunakamura.de)

How do you envisage a world without aromas?

**Büttner:** Frightful! I once lost my sense of smell because of an infection — I was full of dread! Mr. Nakamura, as a chef you are presumably just as anxious over your olfactory epithelium.

**Nakamura:** Indeed. Early last year, I lost my sense of taste completely — fortunately I tested negative for Covid. In my profession, this is just like a skier breaking his leg. But for restaurant clientèle too, there’s no pleasure without a sense of smell. Their passion disappears. They no longer have a subjective experience. After all, we associate so many aromas and fragrances with our subconscious!

What is your first memory of a scent as a child?

**Nakamura:** The fragrance of Nabe, this Japanese hotpot. With dashi, the classic broth made from kombu algae and bonito dried fish, vegetables and tofu added in, the delicate essence of soya beans — all simmered together in the middle of the table, with the smell of the log fire burning in our fireplace to boot: The nose evokes memories like these in all of us. We build ourselves a world around them. All the important things in life involve smelling, eating and drinking. Without this direct association, days on which we would normally celebrate are not so easy to recall. Ascension day? No idea. Christmas then? Of course. Roast goose? Ditto.

Ms. Büttner, which childhood memory does a particular scent evoke for you?

**Büttner:** My Dad was a carpenter, actually quite a famous one — he made the bed and the swing ship for the fictional character Pumuckl. I played in the wood shavings. My bedroom was all stone pine. This has always been an unbelievable scent for me. Incidentally, we are analyzing wood odors at my Fraunhofer Institute at the moment. It’s astonishing how little we know about them. We are constantly discovering new aromas that the world has no idea about. I am always delighted when we are able to synthesize them — suddenly, you are standing in a cloud of scent that nobody else has ever experienced before.

About 15 percent of people have no sense of smell, or a very poor sense of smell. How many of them are taste dyslexic, so to speak?

**Büttner:** Many, an alarming number. And it’s not only a coronavirus issue. Other infections could also harm our sense of smell and taste: Alzheimer’s, Parkinson’s, neuro-degenerative diseases, including the aging process in itself — the quota is astonishingly high. In our institute, therefore, we do more than just investigate aromas, we analyze people too. We take individual aromas and test the



Prof. Andrea Büttner and Tohru Nakamura in his "Salon Rouge" in Munich's Altstadt.

"How will we achieve safe and enjoyable cuisine in the post-corona period?"

Prof. Andrea Büttner

variance. You would be shocked if you saw the difference in people's thresholds for smell detection, these thresholds can be many powers of ten apart.

**Nakamura:** When I cook for 30 guests, each and every one of them has a different perception. And yet evening after evening, we are met with a basic consensus in our restaurant — and everyone has a joyful culinary experience.

**Büttner:** Fascinating.

**Nakamura:** The question remains though — how can we steer this towards an even more dependable result? How much of the effort we make behind the scenes do our guests actually perceive: In terms of taste, appearance, sound? How crispy should things be? How should they sound as we eat them? We have so many variables, so many unknowns!

———— **What do you think you can learn from the research Ms. Büttner is doing?**

**Nakamura:** A great deal. Our kind of cuisine thrives on consistency. It's incredibly important that we not only create the sensual, the emotional, the pleasure for our guests, but that we can keep reproducing these moments too. And so we do need to ask ourselves: Which multi-sensory effects can we use to put our guests even more at ease and to make sure they leave with a long-lasting memory of an even more positive experience. The fragrance in the room, the aromas from the dishes — I believe that we in gastronomy are still at the very early stages here. And I am sure we can learn much more in the award-winning kitchen of science.

**Büttner:** Welcome to Fraunhofer! I'm plagued by questions like these right now: How will we achieve safe and enjoyable cuisine in the post-corona period? It will require more than creating a healthier indoor climate. We also have to look at air conditioning and air circulation systems, aerosol dispersion, proactive hygiene, disinfection and decontamination, odors and the cleanliness of interior surfaces, kitchen utensils and the items we use to serve food such as crockery, glasses, table settings and much more as everything interacts. But how will this affect our sensory perception? I do not believe that people really understand that there's only one ideal temperature to get the perfect enjoyment from certain dishes. In our team, there are also psychologists and neuroscientists — a broad range of disciplines actually — working on such issues. And many are drawn to the main topic of multi-sensory integration processes.

———— **Mr. Nakamura, if we were to break down enjoyment into molecules and aroma into individual components, do you think we are destroying the magic?**

**Nakamura:** On the contrary — this would be very exciting for us in gastronomy. We too need to understand and be able to explain what we do and how we can best entice our clientèle. For all the technical consideration, what ultimately remains is the emotion — I might know it's all just molecules, but I still feel the magic at the end.

———— **Ms. Büttner, you are working on pushing the boundaries of technical sensors.**

**Büttner:** And not just that ... the human being is a multi-sensory system with all their strengths and weaknesses. In parallel, we are developing the multi-sensory aspects of technical systems too. It's elementary for us to understand the weaknesses of humans as well as the technical systems. In the vast majority of cases, simply building a sensor that can detect smells does not make sense. We sometimes need a few tricks up our sleeves as well. Let's take an example: When we conch chocolate, we all want to find that perfect time at which acid and unpleasant and astringent tasting notes disappear, but the desired aromas remain or intensify and the optimum balance of bitterness, sweetness and sense arrives on the palette. Many of us would like to have an electronic nose that can reliably determine the optimum point. It can be far more practical to observe the chocolate mass during the conching process and have an optical or mechanical sensor indicate when this time has occurred. And although there are many who would like to solve the problem using artificial intelligence, what we really need is the human



mind, an understanding of the basic process and of what makes most “sense”.

\_\_\_\_\_ **Ms. Büttner, you are developing new foods and seeking alternatives to meat. You grew up in Maxvorstadt in Munich. How do you like roast pork?**

**Büttner:** I love it! But the crackling has to be perfect. If we're having meat, let's have good meat! And of course excellent dumplings.

\_\_\_\_\_ **Mr. Nakamura, could you imagine your kitchen without meat?**

**Nakamura:** In my kitchen, we have the same quality expectation of a beetroot as we do of a fillet steak — essentially, then, the answer is yes. No fish, however, would be a different matter. A kitchen without dairy products would be very, very difficult. And without any eggs? These items simply play a monumental role in the kitchen. Incidentally, I eat very little meat personally. So the idea of wanting to recreate meat from plant-based raw materials is a difficult one for me to understand. So this vegetarian mincemeat burger ...

\_\_\_\_\_ **...is the work of the devil for you?**

**Nakamura:** Let's say it goes beyond my culinary powers of imagination at the moment. But I do admit: 20 years ago, I could not have imagined a smartphone either.

\_\_\_\_\_ **You do believe, then, in technical advancements in the food world?**

**Nakamura:** I find food from insects extremely exciting, because this source of protein could solve many of mankind's problems. Perhaps we just need to skip a generation. We are not quite that rational: Why do we splash out so much on a lobster, while many people find grasshoppers simply abhorrent?

**Büttner:** We are currently working on the KERBSE project. This is a Camembert from pea protein.

\_\_\_\_\_ **Mr. Nakamura, I can see you cringing a little there!**

**Nakamura:** As a chef, I tend to go for the most natural products, the ones created with the most care. I like to do business with those farm producers who pour passion and appreciation into making the things that impress us. The pea Camembert sounds rather like painting by numbers.

**Büttner:** You shouldn't view this as an either/or situation. We're simply seeking to unlock additional sources of food.

**Nakamura:** You are right there. We have to differentiate between haute cuisine and our day-to-day diet, which might have us eating a high proportion of meat and animal products, often unwittingly.

\_\_\_\_\_ **You're making me very curious, Mr.**

**Nakamura. Your first Michelin star in 2013, a second Michelin star in 2016, two-time “Chef of the**

**Year”, ambassador of Japanese cuisine since 2020”:  
What does this man cook on an average day in his kitchen at home?**

**Nakamura:** First of all I have to say — I love to cook, even when I'm at home and not working. Once a week, I need conventionally cooked Japanese rice for my inner harmony, otherwise my yin and yang are out of balance. Served with a generous helping of vegetables. Of course, it's easier to come by good quality vegetables than good quality meat or fish.

\_\_\_\_\_ **What would be your advice when speed is of the essence?**

**Nakamura:** Toast some bread, pop a wedge of vacherin in the oven, add a salad — and there you have a superb dish. Just on that, Ms. Büttner, do you see a way of transferring the aroma we get from a tomato vine to the fruit itself? We know they are toxic, of course, but the fragrance...

**Büttner:** A scientist at our institute has just found from an analysis that tomatoes retain their taste better if they arrive at the shop on the vine. I'm confident we can answer to your question too.

\_\_\_\_\_ **Ms. Büttner, Mr. Nakamura, thank you very much for talking to us. Before my very eyes, I am seeing the third Michelin star unfold for Mr. Nakamura in the interplay between the practice and the theory of enjoyment.** ■



Fragrance and aroma samples on the table: Tohru Nakamura, Prof. Büttner and Josef Oskar Seitz comparing notes.

#### Successful encounters

Just one week after the interview with the Fraunhofer Magazine, Michelin two star chef Tohru Nakamura and Institute Director Andrea Büttner agreed to collaborate on five definitive projects for research into the senses at Fraunhofer IVV in Freising.

# 3x3 Questions

## Human hearing is extremely individual

**Bernhard Fiedler,**  
Fraunhofer IDMT in Ilmenau



\_\_\_\_\_ **1** What for you personally is especially fascinating about digitizing the senses?

As an acoustician, I'm intrigued by how we can understand human hearing and digitize it in models. The more precise this model is, the more realistically a digital sound scene can be reproduced.

\_\_\_\_\_ **2** What are you hoping for in terms of a result?

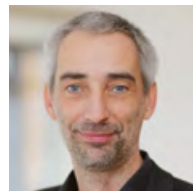
I hope that in the future we will be able to achieve an artificial acoustic immersion that can barely be distinguished from reality. This will go a long way towards being able to better simulate, understand and ultimately modify everyday sources of noise. After all, lower noise emissions protect our health as well as the environment.

\_\_\_\_\_ **3** What is it that makes human perception so unique in comparison to technology – and where will technology play to its strengths?

Human perception is not only highly adaptive, it's also highly individual. When it comes to how we hear for example: What sounds pleasant for one person can be annoying for another. At this point, I believe that AI-based technologies, for instance, are better at objectively evaluating everyday things than humans. ■

## Intelligent ears for our daily lives

**Dr. Jens-E. Appell,**  
Fraunhofer IDMT in Oldenburg



\_\_\_\_\_ **1** What for you personally is especially fascinating about digitizing the senses?

For me as a hearing researcher, the way it helps people is a key aspect. The true fascination here is, how technology can support the human sense of hearing that has evolved superbly well over time. Conversely, we can also teach machines how to hear, allowing them to acoustically detect themselves and their environment, identify malfunctions or be voice-controlled for instance.

\_\_\_\_\_ **2** What are you hoping for in terms of a result?

I am convinced that AI-supported hearing systems will significantly change the way we communicate with each other and interact with our environment, and that these "intelligent ears" will in the future be part and parcel of our everyday routine – be that in industry, mobility, health care or in our private lives. They will acoustically detect speech or dangerous situations and mask out unwanted noises. They will perceive our environment and our health, warning us as required, and provide us with information about areas of interest.

\_\_\_\_\_ **3** What is it that makes human perception so unique in comparison to technology – and where will technology play to its strengths?

Of all the senses, our sense of hearing is perhaps the one most able to instantaneously trigger our emotions. Human beings not only perceive speech per se, they can also make out voices, moods and nuances. It will be a long time before technology is able to convey an emotional connection. Thanks to the use of AI, however, technology is getting better and better at supporting our perception, avoiding unpleasant circumstances such as noise, and bringing important events to our attention. ■



Non-smoker Sebastian Hettenkofer, Fraunhofer IIS, is more fascinated by smoke and its composition than he is by cigars.

## Research “over the counter”

**Sebastian Hettenkofer,**  
Fraunhofer IIS, headquartered in Erlangen

### 1 What for you personally is especially fascinating about digitizing the senses?

For many years, my research focused on how we can capture the emotional or affective impact of our sensory impressions. I collaborated especially on processes for analyzing facial expressions. Part of this involved getting machines to be empathetic so that they can adapt to human feelings. As a researcher, of course, my curiosity grew: How does a person actually process various sensory impressions? And how can I emulate this using artificial intelligence?

### 2 What are you hoping for in terms of a result?

I work in applied research and in the past, have collaborated on a number of successful product developments. I find it particularly gratifying when the result of years of research and development becomes available “over the counter” so-to-speak. I have similar hopes for our research into the digitization of the senses: If, for example, we could translate some of the spectacular aspects of our sense of smell to an AI-supported sensor. Not only would the sensor be able to detect a fire in a room, it could also identify the type of fire to ensure the correct extinguishing agent is used.

### 3 What is it that makes human perception so unique in comparison to technology — and where will technology play to its strengths?

Human beings are able to adapt to situations and specialize in what is important to them (safety for example). Technology, on the other hand, scores in terms of objectivity and continuity and is not necessarily limited to what a human being instantly perceives as important or rational. The aim, of course, is to combine these strengths with one another. ■

# Listen up!

In pursuit of hearing: How acoustic perception is making our lives safer and more relaxed — and how it can even open up completely new horizons.

By Moritz Schmerbeck



Drone hazard for aircraft on approach: These small unmanned flying machines go largely undetected by conventional radar systems.

## Under the threat of drones

Drones caused more than 120 obstructions at German airports during 2019. With increasingly regularity, airports are disrupted, flights are prevented from taking off and landings are delayed. These small unmanned flying machines go largely undetected by conventional radar systems. All the more important, then, to introduce new approaches to reliably monitoring the air space over airports, in order to minimize the hazards posed to aircraft and their passengers. The Fraunhofer Institute for Digital Media Technology IDMT in Oldenburg has developed a mobile sensor system, which equipped with eight microphones can localize even three-dimensional noises, for use at airports.

The detection system is based on an “acoustic fingerprint”, a specific pattern within the acoustic

signal that is identified by a diverse range of drone models and stored in a database. Sound recordings are taken of various drones over a 25-hour period. This is enough to ensure that even drones never “heard” before are reliably identified.

**The biggest challenge** facing the researchers at the Hearing, Speech and Audio Technology branch is background noise — the noise aircrafts make as they take off and land, for example. To localize the drones in real time, the sensors make use of the effect that sound travels slowly in air and hence arrives at the various microphones with a time delay. This is how the exact position in space can be calculated. ■

## Who can still believe the spoken word?

Disinformation and fakes are representing a great menace. Is the audio recording genuine? To expose audio manipulation, scientists at the Fraunhofer Institute for Digital Media Technology IDMT are making use of forensic audio analysis: Special processes detect traces left by recording and editing and, as a result, are able to provide information about the creation and processing of the content.

**Many a sound recording contains**, for example, a humming that exposes characteristic fluctuations and is due to supply and demand changes within the electrical power supply system over time. If this humming shows “glitches” or does not match the

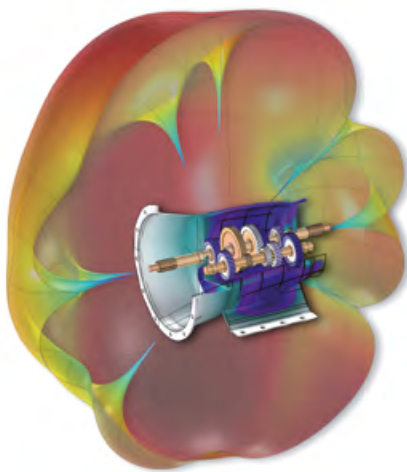
claimed recording time, these can be indications of modifications. Beyond that, there are many other forensic approaches, including tools for detecting partial overlaps to identify reuse, which is very common to fake creation.

“Ultimately, forensic audio analysis is a cat-and-mouse game”, says Patrick Aichroth, who leads the team of experts responsible for the technology at Fraunhofer IDMT. “There are innumerable ‘attack variants’ and any new type of attack requires new detectors to be developed.”

In Digger, a joint research project of Deutsche Welle and the Greek company ATC, the audio forensics technologies are being adapted for journalistic workflows and being integrated into the content verification platform TrulyMedia. In the future, this will provide journalists with further possibilities to detect disinformation. ■



**Digger website:** <https://digger-project.com>



## Auralization improves the shopping experience

Corona times are record-breaking times for online retail. For customers, internet shopping is becoming increasingly convenient — and now also increasingly sensual. To ensure the best possible appeal of products, we should also consider their sounds. The Fraunhofer Institute for Digital Media Technology IDMT in Ilmenau is developing a revolutionary software solution for this very purpose.

**The Fraunhofer researchers combine spatial simulation data** with measurement data in a virtual space to create an authentic sound experience. This process of making something acoustically perceptible is called auralization. It allows us to experience the acoustic

behavior of products or components in different virtual environments. Fraunhofer IDMT successfully creates a realistic 3D audio experience. Unlike conventional reproduction methods, this system is able to replicate the acoustic directivity of a virtual object. Based on simulation and measurement data, Fraunhofer scientists generate sound that our senses perceive from the correct direction.

The new software VIPRA is also accelerating the development process. It is now possible to assess both virtual and real prototypes in an understandable way and easily compare them with one another based on their product sound. “For the first time, VIPRA is allowing us to experience the sound of numerical simulation data — long before a real prototype is created,” explains Bernhard Fiedler, the expert in charge at Fraunhofer IDMT. “This makes our tool the perfect complement to virtual product development. It will allow us to experience 3D with our eyes and ears.” ■



**The realistic sound of numerous virtual everyday appliances:** <https://auralization.idmt.fraunhofer.de>

Hearing a new product in 3D as early as the development stage: This is the aim of VIPRA.

## Connecting co-workers

“Please God, give us ear lids!” Kurt Tucholsky, bemoaning in his book “Castle Gripsholm. A Summer Story”. Of course, we can close our eyes, look away. But we can’t close our ears — until now that is. The Fraunhofer Institute for Digital Media Technology IDMT in Oldenburg is using AI-supported technology to develop intelligent ear protection the size of an earbud.

Blind source separation algorithms are already capable of differentiating noise from speech. A hearable will then be able to tune speech and background noise to one another in such a way that the spoken word remains intelligible and the ambient noises are audible, but not too loud. For natural sound in the ear, sound will also be reproduced in the correct direction in a way we can perceive. As a result, the orientation in the room will be preserved.

The Fraunhofer scientists envisage the device being used in places such as noisy working environments, loud workshops for example. In such applications, the hearable is also able to connect together co-workers who may, for example, be situated on different sides of a machine and cannot hear each other at all. ■

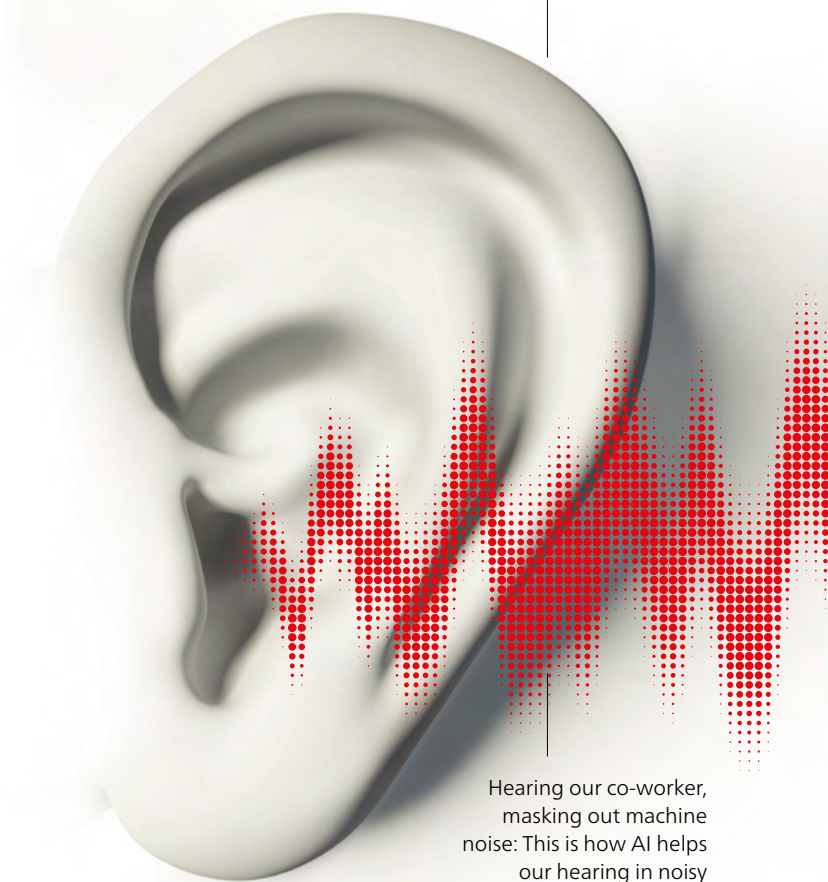
## Understanding TV better

It’s Sunday. The popular series “Tatort” is showing. It’s a viewership record. A good fifth of viewers find listening difficult because their hearing is impaired. A recurrent theme of complaints made to the TV stations is that music and background sounds are too loud and the speech being broadcast too faint. Researchers at the Fraunhofer Institute for Integrated Circuits IIS have therefore developed an AI-based solution that makes dialog more intelligible — and alleviates this persistent annoyance that plagues some viewers.

An algorithm examines the audio material and distinguishes between speech and sounds, ambience

and music. The AI detects when someone is speaking, separates dialog from background noises and reduces the latter if they are too loud. In a study in cooperation with a public service broadcaster, 2000 viewers were asked about the new, more intelligible sound mixing.

**Even the younger interviewees** liked the idea of being able to choose between two audio tracks (normal mix and Dialog+). 46 percent of all those interviewed preferred the more intelligible audio track, only one fifth the original mix. ■



Hearing our co-worker, masking out machine noise: This is how AI helps our hearing in noisy working environments.

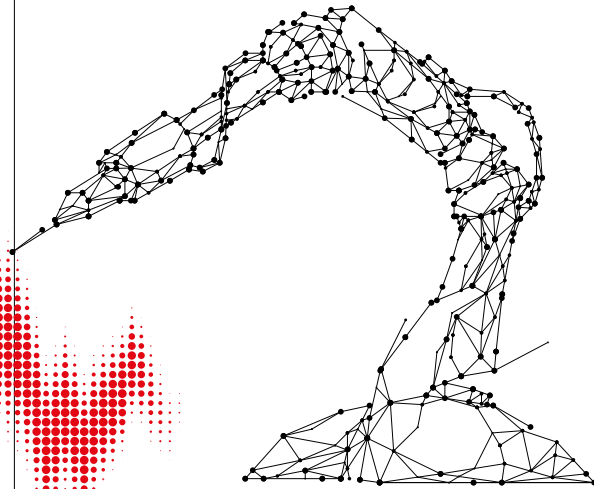
## If robots had ears

Welding is becoming increasingly automated — body construction in the automotive industry is already almost 100% automated. However: An experienced welder hears whether they have successfully produced a seam or weld spot during the welding process itself. Robots lack this acoustic response — until now.

Researchers at the Fraunhofer Institute for Digital Media Technology IDMT in Ilmenau are working on a “sensical” solution. The Fraunhofer scientists are forerunners in establishing artificial intelligence on the basis of acoustic sensor data and machine learning algorithms — especially when it comes to data on airborne sound.

In the AKoS project, sponsored by the BMBF, a microphone was mounted to the arm of a welding robot just a short distance away from the electrode. Acoustic abnormalities are recognized immediately, the production process can be stopped and rectified as required.

The researchers at Fraunhofer IDMT have already tested the technology on the final inspection of electrically adjustable vehicle seats, in order to test installed servomotors in a non-destructive manner. ■



## How a car hears sirens

In autonomous driving, computers conduct an entire orchestra of sensors — the new first violin: The acoustics. Modern cars see pretty much everything — with six cameras, four radars and a LIDAR, which works

with a light beam instead of radar beams. They do not hear a thing. Instead, with increasing comfort and constantly improving acoustic insulation, vehicle occupants are perceiving less and less noise from their surroundings.

And to realize the “hearing car”, researchers at Fraunhofer Institute for Digital Media Technology IDMT in Oldenburg are developing AI-based technologies that can recognize individual acoustic events. The idea is that a sensor will be able to perceive, categorize and localize background noises in a split second. This would enable future autonomous guided vehicles to move out of the way of their own accord whenever a siren approaches. The system makes sense even for vehicles steered by the human hand: It could make the driver, isolated from the outside world, aware at an early stage by a message in the head-up display.

**The AI-based acoustic sensor system** developed by the scientists at the Hearing, Speech and Audio Technology branch comprises acoustic sensors, computing units and modular software components. Besides sirens, it could also detect children playing on the side of the road, a cyclist ringing their bell or a train approaching an unguarded railway crossing. ■

A fast reaction can save human lives. At the same, the AI-based acoustic event recognition system developed by Fraunhofer IDMT helps localize all manner of sound events.



## A voice from the business world



Peter Körte, 45, joins Siemens to drive the company's strategies for digitalization and the Internet of Things.

# Welcome to a new age!

The Internet of Things has immense potential — but it also calls for data sovereignty. It is the key to unlocking knowledge and data silos in a way we can control.

**A viewpoint of Peter Körte, Chief Technology & Strategy Officer at Siemens AG**



**T**he digital transformation in the 2010s first and foremost connected people. The 2020s herald the start of the Internet of Things era: Intuitive buildings that react to the needs of the people living in them. Autonomous vehicles that can draw on a sea of data. Critical infrastructures such as decentralized, intelligent networks that will autonomously manage renewable energy sources.

**The merging of the physical and the digital world** holds immense potential. Billions of devices and appliances are already interconnected. They generate a valuable data pool which remains untapped in many areas. At the same time, we are seeing new forms of collaborations between partners (we call these ecosystems) that are opening the door to completely new business models. There is also a huge potential in efficiency increase, sustainability and energy saving initiatives. We can, for example, increase the capacity of public transport by 20 percent without having to build any new physical structures!

But I do see challenges here too. Around 60 percent of industrial companies have yet to implement any notable industrial technologies for the Internet of Things. In many sectors, production IT and the internet still tend to be separate entities. The question “what will happen to my data if I share them?” creates a lot of uncertainty, as shown by the recently published “Data economy in Germany” study conducted by the BDI. In addition to absolute data security, the question of data sovereignty also comes into play. For end customers, data sovereignty means that each and every person, as a consumer, can actively control and autonomously decide the use of their personal data. Similarly, in B2B sectors it means that companies can access and use their data through an autonomous management procedure. In other words, decide who gets which data for which purposes.

It’s not easy to strike a good balance between data sovereignty of the stakeholders and practicability in terms of cooperation.

“The German and European economies can boost their innovative strength and competitiveness.”

## Peter Körte

- ▶ Chief Strategy Officer of Siemens AG since February 2020 and Chief Technology Officer in addition since October 2020.
- ▶ Began his career at Siemens in Group Strategy in 2007. In 2011, he transferred to Medical Engineering, where he was engaged in a number of managerial roles in the Diagnostics Division.
- ▶ Graduate Industrial Engineer, University of Karlsruhe, Doctoral Program in Strategy and International Management at the WHU Otto Beisheim School of Management and graduate of the General Management Program of the Harvard Business School.

### The key aspects:

#### 1. Infrastructure

A robust infrastructure with the highest data security requirements must be provided (see also our “Charter of Trust” initiative).

#### 2. Data sovereignty

Contracts between the cooperation partners are the method of choice. They must appropriately consider the interests of all, very often complex, industrial frameworks for data use. Siemens works on the principle of responsible data management. For example, we are collaborating with a number of partners to devise, on our industrial IoT platform, standardized contract templates for Shared Data Pools.

#### 3. Legal and political frameworks

I welcome in principle the latest political initiatives of the European Commission and the German federal government for improving the use of data and creating support frameworks in order to do so. We need to be empowering the stakeholders and dispelling the legal uncertainties caused, for example, by the unsurmountable hurdles to B2B data cooperations under cartel law or concerning anonymization and pseudonymization. Another step forward is to create cross-industry infrastructures and ecosystems, such as the ones in the European initiative GAIA-X.

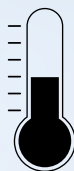
If industry, the policymakers and society act smart and work together here, the German and European economies will be able to boost their innovation strength and competitiveness. And this is not just about economic prosperity, it also involves sustainability, efficiency and resource conservation! We need to unlock knowledge and data silos in a way we can control so that all industrial partners can create value and innovation together in ecosystems. Data security and data sovereignty of all stakeholders are the basis that will allow this to happen. Trust in the idea must grow and be earned through the right decisions! ■



# The treasure that rests in the cold

The German Environmental Specimen Bank documents how the chemical load on the environment changes over the course of time — in plants, animals and human beings too.

By Christine Broll



# -130°

Cold temperatures prevail in the 70 cryogenic tanks used to store the environmental specimens.

**W**e do still hear good news sometimes. The lead burden on people in Germany has fallen by 87 percent since 1985. The amount of mercury detectable in the environment is dropping continuously and the burden on fish in the Elbe caused by the toxic pickling and wood protection agent hexachlorobenzene is 90 percent less than in the 1990s. “The load caused by environmental pollutants, the use of which was regulated by law, is falling significantly,” says Dr. Heinz Rüdél from the Fraunhofer Institute for Molecular Biology and Applied Ecology IME. The data for this piece of good news came from studies of the German Environmental Specimen Bank. It provides the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety with scientific facts for political decisions. For there is still a lot to be done to protect the environment against chemicals.

Over 70 round stainless steel tanks stand in rank and file in the storage halls of Fraunhofer IME in Schmalleberg in the Sauerland region. The environmental specimens of the Environmental Specimen Bank are stored here at minus 130 degrees Celsius. The cryogenic tanks in Schmalleberg hold more than 400,000 tubes which contain specimens collected in the environment from plants, animals and the soil. Equipped with special thick gloves and face protection, Sonja Uhlig steps onto a ladder, lifts the lid of a tank and pulls out a long, narrow metal frame containing specimen tubes. Cold mist rises and a white layer of frost instantly forms on the frame. “The specimens are stored in the gaseous phase over liquid nitrogen, which stays at the bottom of the tank,” explains the chemical technical assistant. “This makes it possible to keep them unchanged at a low temperature.”

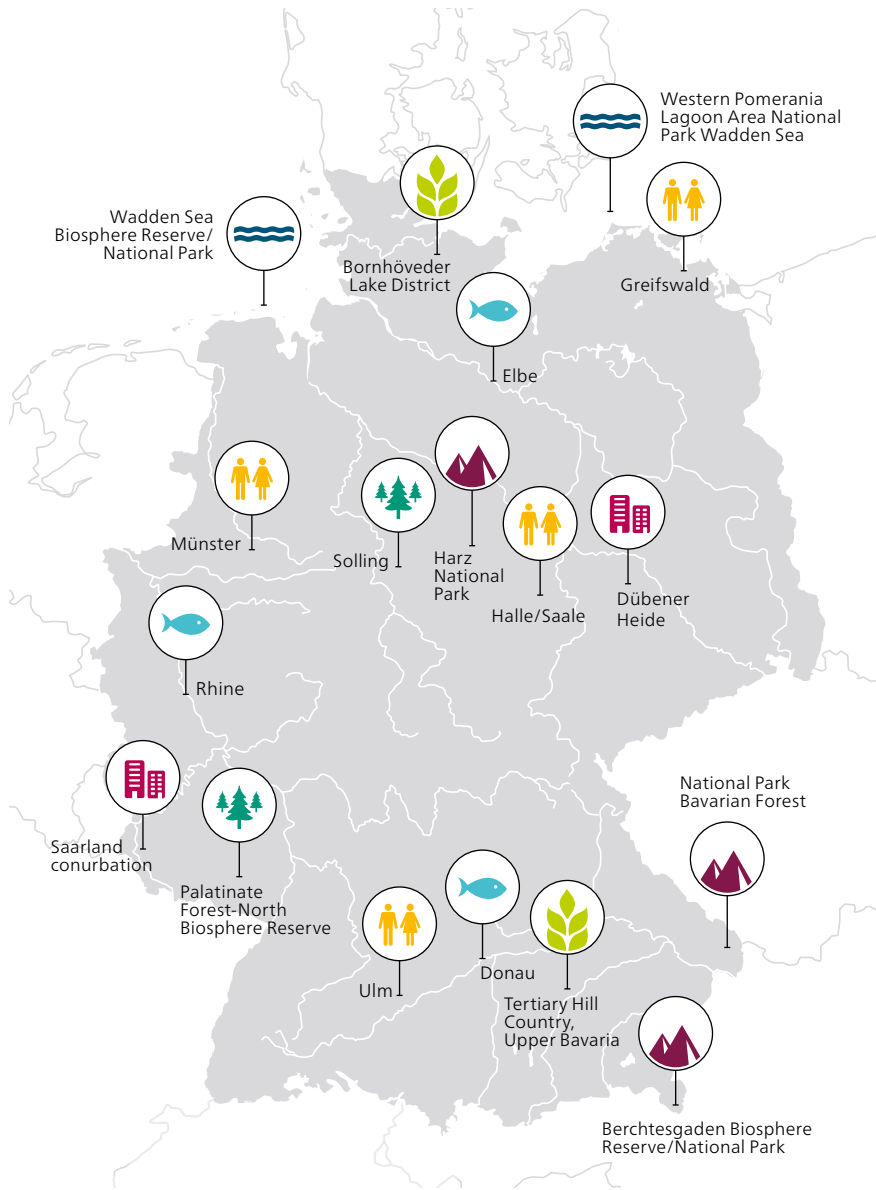
In Münster, the Environmental Specimen Bank even has a second archive. This holds over 300,000 human specimens in the form of whole blood, blood plasma and urine. This part of the Environmental Specimen Bank is under the care of the Fraunhofer Institute for Biomedical Engineering IBMT and is located in a former medical supply store of the German Federal Armed Forces.

The Environmental Specimen Bank is a unique treasure for scientific studies. It provides an insight into the past, right back to 1985. By analyzing specimens, it is possible to see how the chemical load on the environment and on human beings too has changed over the course of time.

### Environmental monitoring since 1985

The idea of archiving environmental specimens emerged back in the 1970s when people in Germany were protesting against nuclear power, forest ►

# Sampling areas in Germany



## LEGEND

- |   |                                   |   |                                     |
|---|-----------------------------------|---|-------------------------------------|
|  | Marine ecosystems                 |  | Forestry ecosystems                 |
|  | Flowing water ecosystems          |  | Agricultural ecosystems             |
|  | Human sample collection locations |  | Semi-natural terrestrial ecosystems |
|   |                                   |  | Ecosystems close to conurbations    |

Source: German Federal Environment Agency

“Samples from the sampling site Münster represent the longest time series of the Environmental Specimen Bank. This time series covers a period of more than 40 years without interruption.”

Dr. Dominik Lermen,  
Head of the Biomonitoring and Biobanks  
Working Group at Fraunhofer IBMT

dieback and water pollution. There was a need to create a reliable instrument to ensure continuous environmental monitoring.

After detailed planning and pilot studies ongoing since the end of the 1970s, work started on setting up the German Environmental Specimen Bank in the early 1980s. Since 1985, the German Federal Environment Agency has been coordinating the operation as a standing government task that engages various institutions to collect, archive and characterize the specimens. The Fraunhofer-Gesellschaft, with its IBMT and IME institutes, is a long-standing partner.

The specimen types and sampling sites for the environmental sector are selected in a way that enables them to precisely depict the state of the environment throughout the whole of Germany. Specimens are collected close to cities, just as they are from nature conservation areas. These sampling sites were clearly defined at the outset to ensure the comparability of the results from the various analyses. On the North and Baltic Seas, samples of bladder wrack, common mussels and the eggs of herring gulls are collected. Inland, the interest is in beech leaves, spruce shoots and earthworms. In rivers and lakes, we go for zebra mussels and sea bream, a whitefish resembling carp.

The Environmental Specimen Bank project group of the University of Trier has taken on the task of collecting the environmental specimens. The team around Prof. Martin Paulus and Prof. Roland Klein prepares the specimens in a mobile laboratory and

freezes them there and then over liquid nitrogen. In this state, they are taken to Fraunhofer IME in Schmalenberg where they are crushed without breaching the cold chain and then milled to a fine powder in a special cryogenic mill. Afterwards, they are decanted into small test tubes and lowered into the stainless steel tanks. Around 12,000 new specimens are added every year.

### Human specimens collected by the mobile lab

A similar quantity of new human specimens are added to the specimen store of the Environmental Specimen Bank in Münster year on year. Fraunhofer IBMT was assigned to collect the samples in 2012 and developed a special mobile safety lab for this purpose: a 20 meter long semitrailer. In the lab, the team takes blood samples, records dental status and also characterizes and processes the full blood, blood plasma and urine samples there and then, before freezing them over liquid nitrogen. Since 2020, Fraunhofer IBMT has generated as many as 52,000 individual specimens per year for analytical purposes in standardized format. The institute has partially automated and digitized processes for this purpose. Specimens are collected once a year at four locations: Münster, Halle an der Saale, Greifswald and Ulm. At least 120 young adults, usually medical students, take part. They arrive at the appointment with a urine specimen collected over 24 hours, having filled out a questionnaire online beforehand, providing information about their eating habits, the medicines they take and their living arrangements. Once their blood has been taken, a dentist examines their teeth in order to record any braces or fillings. "Fillings made of amalgam, for example, are a source of pollution and we therefore have to take them into account when analyzing the data," explains Dr. Dominik Lermen, Head of the Biomonitoring and Biobanks working group at Fraunhofer IBMT.

### Even the coronavirus has not halted the process

After the specimen collections in Halle, Greifswald and Ulm were rendered useless by the coronavirus, the sampling

started in Münster at the end of January this year with a comprehensive safety concept. "We upgraded the ventilation system in the mobile lab to meet the requirements of the Robert Koch Institute," reports Markus Michel, Head of the Laboratory Technology and Mobile Business Units at Fraunhofer IBMT. The rectification of the schedule, partition walls and antigen rapid tests also ensured the safety of personnel and test subjects. Dominik Lermen is delighted that the sampling procedure was able to take place in Münster in this way. "Samples from the sampling site Münster represent the longest time series of the Environmental Specimen Bank. This time series covers a period of more than 40 years without interruption."

The specimens from the Environmental Specimen Bank are used primarily for studies assigned by the German Federal Environment Agency and published in scientific journals. One of the focal points here is the retrospective examination of substitutes for chemicals already legally regulated, softening agents for example. "Our specimens show that the load of newly introduced plasticizers in humans is increasing.

As we do not yet precisely understand how this impacts health, the development in human exposure to these substances has to be examined in closer detail," emphasizes Dominik Lermen.

He is also concerned about the increasing load of the pesticide glyphosate in humans. In a random sample of around 400 urine specimens, an increase in the frequency of glyphosate load was established over a 15 year investigation period. In 2013, the substance was detected in the urine of just under 60 percent of the student test subjects.

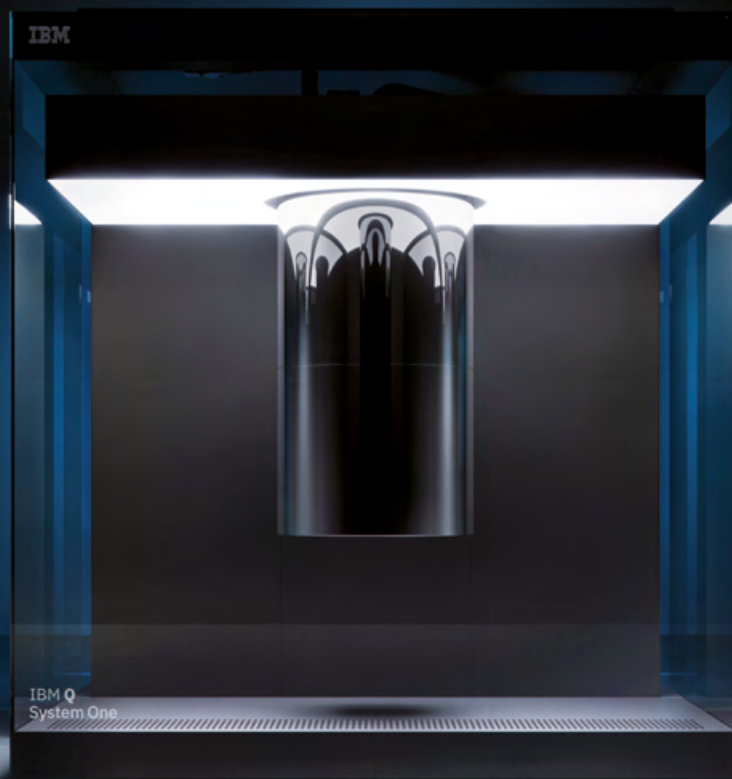
Another similar case is that of the perfluorinated compounds which are used, among other substances, to impregnate outdoor jackets or to coat food packaging. "Now that some of these substances have been banned, we are seeing a rise in the concentrations of the substitutes in the environmental specimens," reports Heinz Rüdell. "This is like a game of cat and mouse." The EU is considering a general regulation on the perfluorinated compounds which, due to their persistence, are also referred to as 'forever chemicals'. This would be another success at political level, to which the Environmental Specimen Bank has contributed with its data. ■

**87 %**  
less lead poisoning,  
the concentration has fallen dropped continuously since 1985.



Precision work forever:  
Specimens, crushed and deep frozen.

# “A tremendously exciting journey”



Establishing quantum computing in this country is tantamount to a lunar landing program for Germany. The first universal quantum computer for research and industry in Germany is now operational — initiated by Fraunhofer in collaboration with IBM.

By Mandy Bartel

With its glass enclosure from Milan, the IBM Q System One is a sight to be seen. All you need to work with it is a web browser and a user agreement with Fraunhofer.

Jürgen Winkler does not see himself as another Neil Armstrong, but rather as “part of a team on a tremendously exciting journey”. The Head of IT at the Fraunhofer Institute for Open Communication Systems FOKUS is the first Fraunhofer employee to have worked with the IBM Q System One, the first of its kind in Germany, and has been putting it through its paces since the start of the year. Indeed, this is one of the small steps for man that could lead to a great step for mankind. The potential of quantum computers may soon be expanding our knowledge in many areas and answering those questions that have remained difficult or uneven unsolvable to date.

As an open research platform, the IBM quantum computer will lay the foundation stone for building up knowledge bases in this country and networking important areas of expertise. Both tasks are the prerequisites for developing our own national quantum computer, a goal the German federal government has set itself ten years to achieve, and in which it has invested billions. We now have to make the most of the time until then. “Companies and research institutions can already use the quantum computer to test use cases and algorithms and shape technology in this way,” explains Winkler. Here’s the thing about the computer: The data stay local in Germany. This data locality and the highest possible data protection standard it achieves are especially important to external project partners who handle sensitive data and calculations, and also to protecting intellectual property.

### The system is up and running

After an intense test phase, the system is now operational and the first projects of Fraunhofer Institutes in collaboration with universities and industrial partners are underway. What astounded Winkler was just how the quantum computer resonated: “Many could hardly wait to work with the computer and there was

already a huge amount of expertise in this relatively young technology. It was also heartening to see that many people already had very specific ideas about which problems they wanted to solve, be they mathematical, chemical, physical or optimization issues.”

Before the quantum computer was linked up to the network, it first had to clear the coronavirus hurdle. The fragile system, dismantled into its component parts, did indeed arrive punctually by ship from the USA. But the specialists from IBM who were supposed to be setting it

“It’s a privilege to be helping drive this promising technology forward.”



Jürgen Winkler, Head of IT Fraunhofer Institute for Open Communication Systems FOKUS

up were not allowed to travel. The complex quantum computer therefore had to be built by local experts, a first for them, in countless video conferences. Besides that, some of the components had suffered damage on their journey across the Atlantic. But replacement parts were delivered immediately and, once successfully installed, the system was hooked up to the network.

This is where Jürgen Winkler’s work started: “Because a quantum computer operates on a completely different set of principles, we had to run tests to check whether all 27 Qubits work properly in the desired parameters,” he reports. The IT expert was able to do this sitting comfortably in Berlin via a web interface. The very moment he had been working towards for eighteen months had arrived.

The first operation Winkler was to perform on the IBM Q System One was the so-called Bernstein-Vazirani algorithm: “It does an impressive job of showing a quantum computer’s supremacy over standard ones. This algorithm allows us to guess a random number combination of numbers very quickly in just one attempt. As if we were to crack a bike combination lock at the first go. A normal computer would try out every possibility in succession and cough up the result sooner or later. Because the quantum computer calculates the numerous possible combinations in succession, it is much faster,” says the expert, explaining how this technology works.

### The effort pays off

Even though, as an IT man, Jürgen Winkler is responsible mainly for ensuring the system operates trouble free in terms of technology, he is fascinated by the applications that quantum computing makes possible. If he has to explain to someone the potential of this technology, he quickly becomes a process engineer: “My favorite example is the synthesis of ammonia for fertilizer. This is already possible, but only through a highly inefficient and energy-guzzling process. We could use quantum computing to optimize this process, increasing the output for minimum energy consumption. Quantum technology could make sure, for example, that we grow enough food for the entire world.”

The IT Director currently spends three quarters of his working hours dealing with the technical, legal and organizational issues concerning quantum computers. Just like a Qubit, he wants to assume multiple states at the same time to be able to accomplish all tasks very quickly, he explains. “And my team often thinks I’m a little unpredictable,” he says, tongue in cheek, alluding to Heisenberg’s uncertainty relation. But all the effort is paying off — in both big and small ways: “We are living in a very exciting time and it’s a privilege to be helping drive this promising technology forward.” ■

# Team work post-corona

How can we organize teamwork in the post-pandemic era? How will we return to a new normal in the digitalized world of work? These are the questions that are keeping many companies occupied at the moment. The Fraunhofer Institute for Industrial Engineering IAO has the answers.

By Mehmet Toprak



**K**atharina Dienes has many inquiries to answer at the moment. Companies are seeking advice on how to proceed with their employees if and when the pandemic is defeated. Should they and could they simply send all the employees who have been working from home back to the office? How do we organize and structure teamwork in the post-corona era in order to remain competitive with innovative products or business ideas? How do we return to a new normal in the digitalized world of work and what actually gives a team its edge? Researchers at the Fraunhofer Institute for Industrial Engineering IAO in Stuttgart have been seeking the answers to such questions — for many years, and even before the pandemic.

Some of the answers Katharina Dienes came up with can be found in the study called “Teamwork and its working environment,” on which she worked as the

author. For this study, around 1200 employees from various companies were interviewed between May and October 2019. The current study “Homeoffice Experience” focuses on working from home during the coronavirus pandemic. The Fraunhofer IAO team interviewed around 2100 employees from various sectors between May and July 2020.

Here’s the good news: “People organized their working day at home around making sure their performance doesn’t suffer. Even if it might have been evening time before they actually got down to work or had to set up their laptop in the kitchen,” observes Dienes.

And these are the figures: 43 percent of those interviewed said they are just as productive working from home as they are in the office. Almost 40 percent of those interviewed even believed they were more productive at home. Working from home, then, proved successful especially when

# 43%

of those interviewed said they are just as productive working from home as they are in the office.

employees are required to concentrate on their own work. But the study also highlights the pitfalls. The information flow between the office and home, for example, is often problematic. Although 63 percent of those interviewed do feel well-informed, in actual fact only 40 percent get important news from the company straightaway.





“Physical presence in the office helps us come up with creative ideas and improves how employees identify with the team, the project and the company.”

Katharina Dienes,  
Fraunhofer Institute for Industrial Engineering IAO

Currently, employees spend 50 percent more time working as a team than 20 years ago.

Even worse, the team’s creativity suffers when colleagues are sat working from home and can exchange ideas only via video conference or emails. In the study, only a third of those interviewed said they are able to develop new ideas and solutions at home. “Physical presence in the office helps us come up with creative ideas. And almost incidentally, it also improves how employees identify with the team, the project and the company,” explains Dienes.

### Prerequisites for the coexistence between working from home and at the office

Home when we need to concentrate on our own work and the office for creative teamwork? It’s not quite that simple. The scientists at Fraunhofer IAO believe that the successful coexistence between working from home and at the office depends on two things: First, there must be an

interface between home and the office. This includes, for example, virtual white boards in meetings on which all employees can make notes or sketch out ideas — no matter where they are. The video conference tools should be used to set up breakout sessions, in which team members can talk in small groups without everyone being present. The benefit here is that the physical distance between the employees can be compensated at least in part.

Second, the surroundings have to suit the task at hand. There are clear recommendations for the office life of the future. Long distances between employees are a barrier to productive teamwork. Dienes even measures this in meters: “Our investigations have shown that distances of greater than 15 meters makes informal and spontaneous exchanges between employees difficult. Creativity then suffers. In this context, it is also important for employees to be able to maintain eye contact.” The

findings of the Fraunhofer researchers show that variable, creatively crafted spaces are an indispensable prerequisite for successful teamwork.

This is where the coronavirus presents an opportunity. Many of those interviewed in the study are presuming that post-corona, they will work from the office only 10.8 days per month, that’s around 26 percent less time than before the pandemic. “Now is the time to make the office as attractive as possible and make the advantages clearly visible to everyone,” advises Dienes. It will pay off: Teams that master the on-the-fly switchover between working from home and office, supported by IT equipment and their work environment, are able to respond to unexpected situations with speed and flexibility. An agile work culture not only benefits the next project. In the medium to long-term, it also helps the company to remain competitive and innovative. ■

# New emergence from the forest

Higher, faster, further: Timber construction is booming. Tokyo wants a 350 meter high skyscraper — and there are plans for the world's biggest urban district on the former Berlin-Tegel airport site.

By Beate Strobel

**P**rof. Holger Kohl first realized he had more or less hit the jackpot with the topic of wood three years ago. At the time, the deputy director of the Fraunhofer Institute for Production Systems and Design Technology IPK was trying to get representatives from various sectors around the table to discuss a timber construction project: Architects and planners, politicians, construction companies, foresters. "I was amazed at the response. Timber construction is currently making waves in society, in the economy and in the political world," says the industrial engineer. But what astounded him also: "Everyone works only within their own profession. As yet, nobody has considered the issue as systemically as we do here."

**Efficient, affordable and above all sustainable:** Wood as a raw material is well on its way to becoming the plank into the city of the future. Standing 65 meters high, the tallest timber skyscraper in Germany is currently being constructed in the ▶

Visualization: Nikken Sekkei



90 percent wood, only ten percent steel — the eco-variant of a skyscraper set to materialize in Tokyo by 2041.



port of Hamburg. Rotterdam is planning a 140 meter tower in a timber-hybrid technology, Sydney wants to go even higher to 180 meters. And Tokyo? Working on a 350 meter high skyscraper made from the natural building material timber. Estimated completion: 2041.

But wood can go wide, as well as high. On the site of the former Berlin-Tegel airport (TXL), an entire city district, named the Schumacher Quarter, is to be constructed largely from this raw material, which will come from the forests of Brandenburg. With upwards of 5000 homes, this development will not only be many times larger than Germany's current record holder in this field — Prinz-Eugen-Park in Munich with just on 6000 units — it will be the world's largest city district to be constructed from wood.

**Also being planned on the TXL site** is a research and industrial park for future technologies. This "Urban Tech Republic" will then become home to Bauhütte 4.0: A cluster for innovative wood construction being developed by IPK, TU Berlin and Tegel Projekt GmbH. Just like its historical namesake — the Dombauhütte (cathedral works) as an association of workshops — Bauhütte 4.0 is planning to be a kind of think tank, as well as a highly innovative shop floor for wood construction: It will be a place where experts from the worlds of research and forestry and from the software, construction and urban development sectors come together to industrialize sustainable timber construction, making it the new must-have for local communities. Or as Holger Kohl puts it: "We are bringing the forest to the city."

In the last twenty five years, the proportion of new residential buildings built from spruce, larch, beech, etc. in Germany has grown by 18.7 percent. Revenues for the cottage industries in this sector rose by a good 16 percent between 2016 and 2019. Indeed, the Swedish lakeside log cabin and the architect designed villa for eco-conscious professionals are no longer enough. Experts agree that unless there is a rethink in urban residential development, the EU will not reach its ambitious goal of climate neutrality by 2050. For around 38 percent of global carbon dioxide emissions are accounted for by the construction and building

sector. Cement production is responsible for around eight percent, another six to eight percent come from steel production. Despite this, says Holger Kohl, "the industry continues to build pretty much as it did 100 years ago".

Building with trees is actually nothing but advantageous: Wood does not take a lot of energy to produce like steel, brick or concrete, it simply grows aloft with light, air, soil and water. And at the same time, it draws the greenhouse gas carbon dioxide out of the atmosphere. Every cubic meter of wood can permanently store one ton of CO<sub>2</sub>. When the wood is installed, it retains the CO<sub>2</sub>, and space is made for new trees. If we build using wood, we are effectively planting a second forest. Just in cities and in the form of houses.

There should be no concern that the housing shortage in the megacities is growing faster than German forests: According to the German wood-working industry, the Brandenburg forests alone produce, within 50 days, enough wood for 17,000 new dwellings every year. The intractable concern that timber houses are, literally, a fire hazard, was also scientifically debunked long ago. Prof. Stefan

Winter, for example, who specialized in fire protection at the Technical University of Munich, attests the fact that timber constructions have "exactly the same level of safety" as any other building. Researchers at the Fraunhofer Institute for Wood Research, Wilhelm-Klauditz-Institut, WKI have also been able to demonstrate that timber constructions will even withstand climate change: Considering the predicted climatic conditions up to 2115, the

scientists conclude "that the changes in the climate are not having any negative impact on timber construction", says project manager Norbert Rüter. Moreover, the material is durable: The oldest timber dwelling in Europe, a log cabin in Switzerland, was built in 1175 and habited until 1980.

**That trees as a building material**, despite all these benefits, have been slow to catch on is mainly down to the price: Timber construction is still around ten percent more expensive than conventional methods. Those responsible for Bauhütte-4.0, however, are hoping that increasing digitalization, automation and standardization in timber construction will change the situation.

Standing 65 meters high, the tallest timber skyscraper in Germany is currently being constructed in the port of Hamburg.



**38%**

of global carbon dioxide emissions are accounted for by the construction and building sector.

"We are bringing the forest to the city."

Prof. Holger Kohl,  
Deputy Director  
of Fraunhofer IPK

Just as Industrie 2.0 once made cars affordable for all, Holzbau 4.0 could make vegetable raw materials more economical and therefore more appealing to developers and local communities. And perhaps even revolutionize social housing: Tree houses instead of prefabs.

**The timber construction sector in Germany,** however, is still dominated by small specialist companies and cottage industry-like structures. They lack the high-tech knowledge and the financial strength to start bringing about real change. The cooperation partners of Bauhütte 4.0 therefore consider their most pressing task to be taking timber construction into the digital age. As Holger Kohl puts it, “we want to orchestrate the entire value creation chain.” And this starts in the forests: How does tree cultivation need to be controlled to ensure that in 30 years’ time, there is enough forest available regionally to meet requirements? How can we employ digital technologies, from the planning stage through to

the realization of the buildings? How much modular preconstruction is possible when the goal is a variable architecture rather than a uniform prefab? How can the intelligent preconstruction and preassembly of wood components relieve the weather-reliant daily routine on the building site, and make the construction phase itself faster and more efficient in the process? And ultimately, what might a secondary or tertiary utilization of timber construction be like?

In 2019, the Berlin City Parliament declared its commitment “Berlin builds with wood”. Holger Kohls, however, has been looking beyond the city boundaries for a long time: “We will be able to scale Bauhütte 4.0” very well.” he says — first for Germany, but also worldwide. Fraunhofer IPK is already planning a project in Vietnam on the basis of Bauhütte 4.0 — this time not with the Brandenburg pine as the raw material, but with bamboo. The use of timber on a building, of course, is only elemental if it hasn’t been carted half way around the world first. ■

Urban life for young families. The promise: “Berlin builds with wood” — also on the site of the former Tegel airport.





Series: **Founding companies with Fraunhofer**

# Plug-in quantum communication

With Quantum Optics Jena, the first quantum technology spin-off from Fraunhofer is due to launch. The young team wants to use entangled light photons to revolutionize the security of communication and make quantum communication an everyday commodity.

By Mandy Bartel

**F**or start-ups, the right timing is one of the most important factors for success — this applies in particular to future technologies. If we are too early, there is no market, and if we are too late, it has already been divided out. “There’s plenty going on with quantum technologies at the moment. The structure of the

start-up ecosystem is now forging its way out,” explains Kevin Füchsel, one of the masterminds and commercial director of Quantum Optics Jena. The time appears to be exactly right, then, for the spin-off from the Fraunhofer Institute for Applied Optics and Precision Engineering IOF in Jena, with its focus on quantum communication.

## Tracking spies with entangled photons

The start-up team's idea is based on a complex process: The company uses entangled light particles to make communication networks more secure through quantum encryption. Sets of twins of these so-called photons, linked in terms of their properties, are produced in a quantum cell using a crystal. If the polarization of one photon is measured, that of the other is also known — no matter what its position. On this basis, it is possible to create two keys, which tell sender and receiver instantly if third parties try intercept the communication.

Oliver de Vries, the company's technical mastermind, developed such quantum sources with his team for several years at Fraunhofer IOF through to technological maturity. "Fraunhofer gave us the opportunity — both professionally and personally — to become an independent entity, allowing us to create jobs and take Germany further in this future technology. Even in the spin-off process too, we received immense support," says the electrical engineer and Doctor of physics looking back.

"Our original idea was to simply to offer an entangled photon source as a product. However, we soon realized that companies want to have a plug-in solution, connected to the network structure and containing all the necessary components," explains his brother in arms Kevin Füchsel, physicist and communication strategist. "Our vision is to offer a kind of quantum router as a complete package, which you simply plug in and the communication is quantum-cryptographically encrypted, in well under five years." The solution this young company is offering is independent of the transmission pathways. It works via free space, through satellites in outer space over great distances and also terrestrially over fiber optic networks without repeater nodes.

The potential customer base is correspondingly broad: From satellite provid-



Kevin Füchsel (top) and Oliver de Vries: founders of Quantum Optics Jena.

"Fraunhofer gave us the opportunity — both professionally and personally — to become an independent entity, allowing us to create jobs and take Germany further in this future technology."

ers, which equip their satellites with photon sources, to network suppliers, industrial companies with their high security requirements, in the financial or medical sectors or government organizations for example. And the demand is huge. "We are in talks with a number of companies that want to have fast solutions. The dynamic development of high-performance quantum computers is increasingly putting conventional encryption processes at risk of being quickly cracked. Speed is therefore our top priority," emphasizes Füchsel.

Everything moved fast, from the initial idea for the spin-off just barely a year ago to founding the company. By summer 2020, there were enough co-founders, the due diligence on the business model was completed within three months and investors quickly came forward. On that note, the start-up team consciously decided on a smaller consortium of three investors, that way a lot could still be achieved on a personal level.

## Doer qualities and courage

The work of Quantum Optics Jena is still very research-intensive. After all, the declared aim is to "raise the technology above the threshold of commercialization," says de Vries. Joint strategic projects with former colleagues at the Fraunhofer Institute, under which the photon sources are optimized, still help in this regard. In order to meet the tight schedule through to product launch the spin-off set for itself, however, it needs even more bright minds. "These people are actually hard to come by. Not only do they need to bring along a technical understanding, they also need the doer qualities and the courage a spin-off like this demands," says de Vries. There cannot be too many ideas. Together with Fraunhofer IOF, the team is also toying with a new idea for quantum imaging, which could soon be used for medical engineering or materials analysis applications. ■

# Nerve cells off the production line

1.6 million people in Germany suffer from dementia. We are short on drugs for this disease. The StemCellFactory processes blood samples into body cells, the aim being to test the effects of certain drugs in a faster time.

By Dr. Monika Offenberger

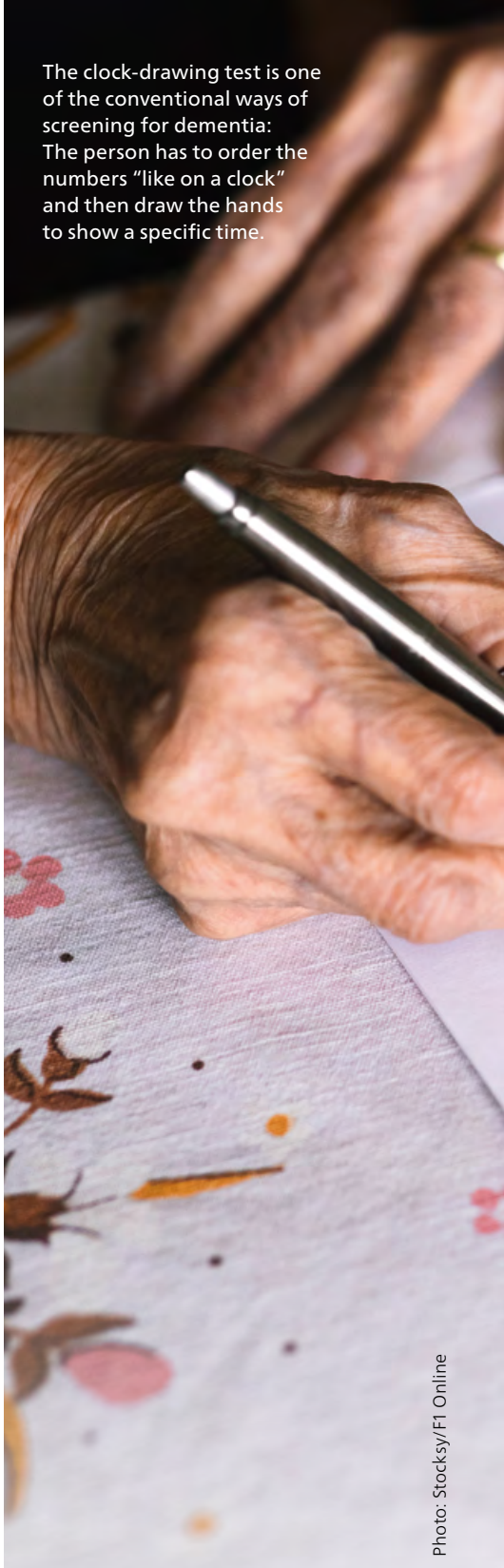
**W**hen grandma no longer finds her way home by herself, when she mistakes one grandchild for another, the case is clear: The lady has dementia. Last year, the German Alzheimer Society reported that 1.6 million people in Germany suffer from dementia. Prediction: By 2050, the number of those affected will have risen by 2.4 to 2.8 million people. What can be done? Currently, various preparations support the function of nerve cells or alleviate the psychological accessory symptoms. We are short on drugs that halt the loss of mental faculties. The search for potent active ingredients takes years and is often in vain. “We can significantly shorten this process by testing the drugs on the pathologically altered nerve cells at an early stage rather than on the patient themselves,” says Bastian Nießing from the Fraunhofer Institute for Production Technology IPT in Aachen: “This would allow us to find out, within just a few weeks, which active ingredient positively impacts these changes and in what dosage — and then investigate the findings more closely in other test systems down the line.”

The idea might sound convincing. But how do the researchers get to grandma’s

nerve cells? The answer to this question is through her blood. Special biomolecules can be used to reprogram mature red blood cells to become immature stem cells and subsequently to nerve cells or any other body cells. The recipe for these induced pluripotent stem cells, iPS cells for short, won its inventor Shinya Yamanaka the 2012 Nobel Prize in Medicine. “The detour through iPS cells is now allowing research into specific diseases of organs from which it is difficult to take samples and grow cell cultures,” emphasizes Oliver Brüstle, Professor at the Institute of Reconstructive Neurobiology at the University Hospital of Bonn.

## How a gene repairs itself

The brain as an example. All gene mutations that lead to dementia can also be found in the nerve cells recovered from reprogrammed blood cells. “An ideal solution would be to compare diseased cells of a person with healthy cells of the same person,” says Prof. Brüstle, going on to explain how this might work: “We know of several genes that are associated with neurological or psychiatric conditions. And we are able to repair an individual faulty gene in cultivated cells. This allows



The clock-drawing test is one of the conventional ways of screening for dementia: The person has to order the numbers “like on a clock” and then draw the hands to show a specific time.





“We can significantly shorten the drug development pathway by testing the pathologically altered nerve cells at an early stage.”

Bastian Nießing, Fraunhofer IPT

us to compare, in the same patient, two cells lines that have either the faulty or the repaired gene and that are otherwise identical. This works the other way round too: We take the cell of a healthy person and replace one specific gene with its diseased counterpart.”

Such precise interventions into the genetic make-up are possible using the CRISPR/Cas9 genetic scissors. Developed originally for bacteria, this enzyme system was adapted by Emmanuelle Charpentier and Jennifer Doudna for genome editing in the lab — a masterly achievement honored by the 2020 Nobel Prize for Chemistry. iPS cell production and genome editing have revolutionized the life sciences. In combination, these techniques are opening up a host of new possibilities for medical research and application. Fraunhofer IPT recognized this potential very early on and sought the cooperation with the LIFE & BRAIN translation platform at the University of Bonn: “By 2010, shortly after the iPS cells became available, we came up with the idea of also manufacturing such a fantastic product in automated fashion. This was the starting signal for the StemCellFactory,” relates Bastian Nießing, who has played a key role in developing the system since 2017.

The German Federal Institute for Drugs and Medical Devices, Lead Discovery Center GmbH in Dortmund, umlaut consulting GmbH in Aachen and the University Hospitals of Aachen and Bonn are also involved in the project. In the beginning, skin cells of a particular type, referred to as fibroblasts, were used as the primary material for the stem cell induction process. Now, we can also reprogram and genetically modify blood cells, before allowing them to mature into the body cells we want.

### Some relief for dementia — and cancer

The entire procedure takes just under ten weeks and — apart from a small number of steps — is fully automated and always

performed to a consistent quality. The StemCellFactory functions as a large platform with combinable modules: First, the prepared blood samples are separated into their constituent parts in a centrifuge. A robotic arm passes them from here to the camera station, which pinpoints the location of the red blood cells, and transfers them to the pipetting station. The blood cells we want are now aspirated, treated with culture medium and placed in the incubator where they grow and propagate. The reprogramming of these cells to stem cells is initiated by special viruses and therefore carried out in a lab with heightened biological safety precautions. The conversion is completed back in the StemCellFactory, where the genomes of the stem cells just created are also edited. The disease being researched dictates which genes are modified. This also decides the destiny of the iPS cells: In a suitable culture medium, they can be converted into numerous different body cells.

The StemCellFactory still mainly provides tailor-made cells for disease research and active ingredient testing. Cancer sufferers could also benefit in the near future. We are basing this hope on a special class of immune cell, the CAR-T cell. Targeted genetic modification makes them able to recognize the cancer cells of individual patients and set about destroying them. Currently, these specific immune cells are extremely expensive to produce. Furthermore, sufferers have to wait for long periods and lose valuable time. An automated process would speed up the production of CAR-T cells and significantly reduce costs. The Fraunhofer team is currently working on a solution with medical professionals from the University Clinic of Würzburg in a project called AIDPATH, which received a four-year funding package from the EU in January 2021. Bastian Nießing describing his vision: “I envisage our systems being operated decentrally in various hospitals and the individually tailored immune cells for cancer sufferers being produced there and then.” ■

# It feels like I'm in the film!

A volumetric studio in Babelsberg is creating lifelike, three-dimensional film images — using technology developed by the Fraunhofer spin-off Volucap.

By Stefan Ruzas

**T**he cinema of the future is diametrically opposite the Marlene-Dietrich-Halle which, covering 5400 square meters of space, used to be Europe's largest film studio. In 1927, the legendary Fritz Lang directed his science fiction movie "Metropolis" here. His production, involving multiple exposures and stop motion technology, is still considered revolutionary.

Today, the Babelsberg-based company Volucap needs no more than 170 square meters to transform media production. At the heart of the studio is a four meter high rotunda, 16 pairs of stereo cameras are installed on three levels on the white walls, and there are almost 250 LED panels. In the room, special software and film technology is employed to create scans of people and objects. Three-dimensional images are then generated from these scans almost in real time. Even in the 360 degree perspective, every facial expression, every gesture and every wrinkle appear lifelike. "Until now, 3D figures have always looked like 3D figures, because our brain knows instantly whether they are real or not," explains Volucap CEO Sven Bliedung. "Now, the volumetric process allows us to capture a person or an object using a normal camera without any of their naturalness or movement being lost."

Volumetry is a spatial measuring method. A volumetric video, then, is hologram-based technology that allows viewers to simply "walk into"

A photograph of two men in suits posing in a white, circular rotunda. The man on the left is wearing a light blue suit and has his arms outstretched. The man on the right is wearing a dark grey suit and is also posing with his arms outstretched. The background is a plain white wall with several black circular marks, likely camera lenses or sensors. The floor is a light-colored, circular platform.

"For us as a start-up, the cooperation with Fraunhofer is very productive."

Sven Bliedung,  
Volucap CEO

the set. Whether in the entertainment industry, in medicine, fashion or machine technology, sport or automotive engineering. “Technically speaking, we capture the depth in the room from the various camera positions,” explains Bliedung. “Thanks to artificial Intelligence, it’s possible to use these data to generate a surface figure, onto which the video signal is projected as photographic texture. We map that which is real by an automated process and do not copy it because our studio works like a new camera.” Virtual Reality (VR) is finally resembling real life.

In the first trial runs in 2018, the Volucap team barely managed a minute due to the colossal volumes of data, and then needed two months to process it. Now, recordings of 90 minutes at a time are no problem at all and the data are ready for use by the next day. We are currently able to process two terabytes a minute, by the end of the year, we should be able to manage four. Anyway: From the very start, the Volucap studio has been booked out: by Telekom, “Tagesschau” or customers from industry. “Around 125 years ago, the Lumière brothers had the cinematograph patented under their name and invented the cinema,” says Bliedung. “With this new world of images, we are once again on the cusp of a new era.”

Babelsberg has already seen Hollywood producing blockbusters, reports Bliedung. Over the next few years Apple, Google and Microsoft will have more and more of us replacing our two-dimensional smartphones with three-dimensional glasses.

### Invite to the Microsoft headquarters

Microsoft was the start of many things for Volucap. The group invited us to its headquarters in Redmond in the USA. They had, they said in early 2017, developed something new for filming in 3D. Sven Bliedung and his colleagues flew over to test it out. Back in Germany, the team realized: At the time, the Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institute, HHI, in Berlin, was exploring so many solutions for 3D filming — from depth acquisition to the algorithms to data compression — that its own project emerged. In collaboration with Fraunhofer and media compa-

nies Studio Babelsberg, UFA and ARRI, as well as the software developers from Interlake, a start-up now considered to be world leading was created.

“We are extremely proud that a technology we were instrumental in developing is advancing the film industry,” says Ralf Schäfer, Director of the Video Division at Fraunhofer HHI. “The volumetric studio is testimony to the fact that Germany can be an innovation driver.” Fraunhofer HHI developed not only the “3D Human Body Reconstruction” software for Volucap, but also the dynamic 360 degree lighting concept and the custom audio surround system.

“For us as a start-up, the cooperation with Fraunhofer is very productive,” commends Bliedung, the media and computing graduate who was toying with the idea of structured and animated 3D surfaces over 20 years ago. Back then, he was still an intern at the Fraunhofer Institute for Computer Graphics Research IGD in Rostock. At the end of 2020, the Volucap studio won the Innovation Award Berlin-Brandenburg. In addition, the Fraunhofer HHI researchers were also awarded the Joseph von Fraunhofer Prize for the innovative video reconstruction.

As an innovation cluster, Volucap works with a number of universities all the time. And still with Microsoft too, of course. The next step now is to build mobile volumetric studios. Bliedung explains: “There are immense learning opportunities to be had, by filming the inside of an operating theater in a clinic, for example. One person wants to know how to administer the anesthesia, another is interested in the intricacies of the surgery and a third in the documentation required in operations. All this is possible at the same time. In the future, we will be able to walk into this room as viewers.”

The same applies to training on machines for workers in the automotive industry, in the gaming sector or for diagnostic investigations in competitive sports — and all without “motion capture”, the name given to the conventional 3D process, where people are filmed in sensor suits and modeled on the computer. The clothes always looked artificial. Even the fashion industry can now benefit from the volumetric studio, walking around the model hologram and appraising how the fabric falls where. ■

The Executive Board of Volucap: Thomas Ebner, Sven Bliedung and Torsten Schimmer (f.l.).



16  
pairs of cameras  
and almost  
250  
LED panels

**T**he news came one Friday afternoon. Dr. Simon Fichtner was sat working from his home office looking through his emails. “When I read the news that the Hugo Geiger Prize jury had awarded first place to my dissertation, I grinned from ear to ear.”

Fichtner received the prize in recognition of his discovery that aluminum scandium nitride (AlScN) thin film has ferroelectric properties. Fichtner wrote his dissertation at the Christian-Albrechts University of Kiel (CAU) — closely aligned with projects of the Fraunhofer Institute for Silicon Technology ISIT. The intense collaboration between CAU and Fraunhofer ISIT made this possible.

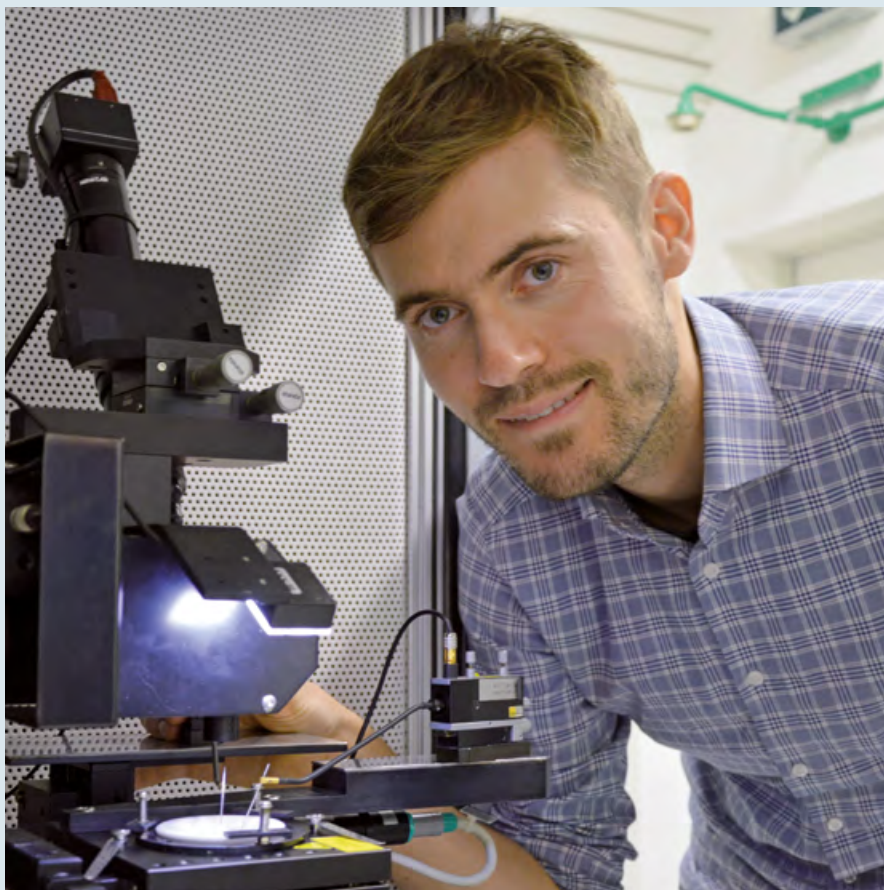
“Our original goal was to enhance the performance of the piezoelectric material AlScN,” explains Fichtner. Piezoelectric materials have the ability to convert mechanical movements into electrical energy and, vice versa, generate a movement pulse when electrical energy is applied. The components are used in hearing aids, microphones, cellphone speakers and headphones, for instance. The researchers saw AlScN as a promising candidate for enhancing performance. In the laboratory, Fichtner and his team therefore repeatedly altered the chemical composition of AlScN and then applied electrical voltages. They wanted to see whether the expansion this caused in AlScN increases linearly with voltage and whether the material remains controllable — especially under very high voltages.

**An unexpected reaction occurred** when the Fraunhofer ISIT researchers increased the scandium fraction in AlScN to above 40 percent. From a specific voltage level, the expansion was suddenly no longer linear to the applied voltage. “This anomaly, a small one at first, piqued our interest immediately. We had, however, floated ferroelectricity as a possible theory at a relatively early stage,” recalls Fichtner. Numerous further independent tests finally supported this theory unequivocally. The theory had been proven: When voltage is applied, AlScN crystals change

## 1st prize: Dr. Simon Fichtner

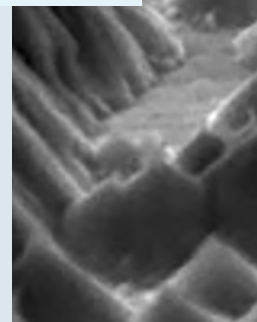
# Ferroelectric material for Next Generation Computing

The discovery that aluminum scandium nitride has ferroelectric properties caused a stir among the experts. The research project headed by Dr. Simon Fichtner could herald the start of a significant performance boost in electronic components for Next Generation Computing.



Initially, experts believed Dr. Simon Fichtner had delivered false measurement results.

Photos: Julia Siekmann, CAU  
Microscopic image: Simon Fichtner

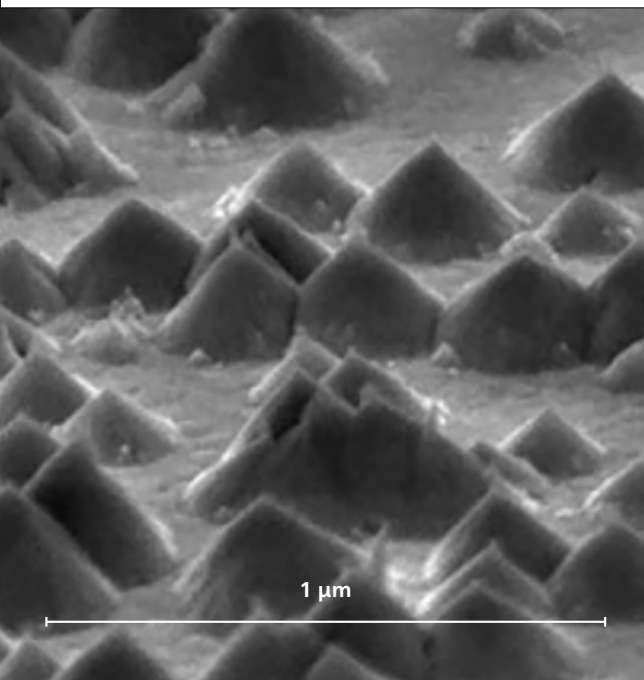


## Hugo Geiger Prize

# Prize for talented young scientists

The Bavarian Ministry of Economic Affairs and Media, Energy and Technology awards the Hugo Geiger Prize in recognition of three outstanding PhD theses. The criteria assessed are: Scientific quality, economic relevance, novelty and interdisciplinarity of the approaches.

By Mehmet Toprak



The crystalline structure of ferroelectric materials can be altered by electrical signals. Once immersed in an acid, the difference becomes visible in the scanning electron microscope.

their electrical direction — their atomic structure is electrically switchable, as it were. They become ferroelectric and, as a result, able to store certain states.

Ferroelectric components promise major advances, for Next Generation Computing or performance electronics for example. As supposedly intelligent materials, they aid speed and energy efficiency through a much higher degree of precision. Their piezoelectric properties also makes them ideal actuators or sensors.

The researchers were surprised at how pronounced the ferroelectric properties are. “The polarization effect is twice what we imagined, almost all calculations done by the experts had been based on much lower values,” says Fichtner. This was another reason why, in the beginning, Fichtner and his team were met by skepticism from the experts. “When we presented our results at a convention in 2018, we received critical comments from the floor. Some thought we had misinterpreted our measurements. Others demanded that we provide additional proof. As scientists, we sometimes meet with resistance,” recounts Fichtner.

But the Fraunhofer ISIT team was confident that the results it had presented were correct. Fichtner was finally able to convince the experts of his discovery by publishing more detailed measurement results.

The level of interest has increased ever since. The US research authority DARPA is promoting research into the application of AIsCN through its own call for tender. The German Federal Ministry of Education and Research has also recognized the potential of the ferroelectric material and is supporting the follow-up research to the tune of 2.3 billion euros. “Besides that, we have secured industrial contracts for AIsCN-based components valued at around four million euros,” says Fichtner, clearly delighted. ■

To the second and third prize: ►

## 2nd prize: Dr. Annelie Schiller

# Holographic measurement of moving objects

Fraunhofer researcher Dr. Annelie Schiller has succeeded in measuring objects in motion using holography. This project is opening the door to new fields of application in quality control: The test specimens no longer need to be stopped during the measurement as before.

**D**igital holography is already used as a method of quality control in industrial manufacturing. Until now, however, the part being tested had to be completely still. A project of the Fraunhofer Institute for Physical Measurement Techniques IPM in Freiburg is set to change this and make it possible to measure objects in motion – either moving linearly or rotating. Annelie Schiller, straight from the Albert Ludwigs University of Freiburg, is involved in the project. The result of the scientist's work won second place in the Hugo Geiger Prize.

To measure an object using digital holography, the object is illuminated all over by coherent laser light. Reference light overlays the light reflected or scattered from there. The result is a two-dimensional interference image, which is captured by a digital camera. The topography information of the surface can be calculated from this image. This is done not only very precisely, but also very quickly: Up to ten million 3D dots can be captured with micrometer precision within 100 milliseconds. "Me and my team believed from the beginning that it's also possible to measure objects in motion," recalls Annelie Schiller. "First of all we measured moving coins and other objects moved in a straight line. We then turned our focus to rotating cyl-



Dr. Annelie Schiller, Research Fellow at Fraunhofer IPM.

"Up to ten million 3D dots can be captured with micrometer precision within 100 milliseconds."

inders." The scientists described the project in detail in her PhD thesis, which she submitted in January 2020.

Step by step, Schiller investigated how the motion of an object influences a measurement and worked with her team to develop a measurement concept. The key to this is the direction of motion: During the measurement, the object can be moved in the lateral direction, but motion in the axial direction is troublesome to start with. The sensor developed by the team allows Schiller to reconstruct the height information from a single camera image, and also to eliminate the disruptive axial motion component by means of an active compensation. As the object no longer needs to be stopped during the measurement, illuminating and capturing just a small area of the object suffices. The individual measurements are then combined to form one overall measurement. And with success: "We managed to measure both linearly moving and rotating objects using holography. The concept works," explains Schiller.

**Schiller was able to demonstrate a surprising correlation for rotating movements:** The disruptive axial motion component is independent of the object's radius. It depends solely on two variables: The rotational speed and the position of the sensor. This is essential to the measurement of complex parts, such as gear wheels for example.

Straight gearwheels are important and safety-relevant components in machines where optimized quality is paramount, aircraft engines or transmissions of electric cars for instance. The gearwheels installed here must be manufactured to precise standards in order to guarantee functional capability, efficiency and low noise emission. The research being conducted at Fraunhofer IPM makes it possible to measure products to within one micrometer: Quickly, precisely and extensively. For industry, the holographic measurement of objects in motion is creating new opportunities for quality control in production: New developments will be able to increase throughputs and tap new application potentials. ■

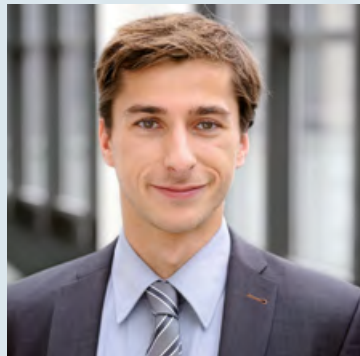
## 3rd prize: Dr. Christian Kalupka

# Ultrashort pulsed laser in glass: The perfect cut

What happens when a laser beam penetrates glass? Dr. Christian Kalupka has been finding out. He started by observing at microscopic level processes that occur within the order of femtoseconds. The project led to innovative methods for the processing of glass and other materials accurate to the micrometer. The technology could also be used in quantum computing one day.

**L**aser technology is already used for cutting or processing glass, cellphone screens being one example. In order to further develop the technology and open the door to new applications, Dr. Christian Kalupka from the Fraunhofer Institute for Laser Technology ILT and his team wanted to understand precisely what happens when the laser penetrates glass. They knew that a highly dynamic interplay occurs between light and matter on a microscopic scale. All this takes place in an extremely short space of time, in a matter of picto or femtoseconds. To capture these processes, the researchers used a pump-and-probe microscope. The instrument was specially developed at the institute and achieves resolution with femtosecond precision. "The exposures then create a kind of flip book that shows how the laser perpetrates the glass and how the glass warps the focus of the light beam."

**Kalupka's work on the behavior of laser beams in glass** has now been recognized by the Hugo Geiger Prize. "Energy deposition of ultrashort pulsed laser radiation in glasses" is the title of the dissertation written by the scientist between 2015 and 2019 at RWTH Aachen University LTT - Chair for Laser Technology. Thanks



Dr. Christian Kalupka, Team Manager Glass Processing, Fraunhofer ILT.

to the close cooperation between the university and Fraunhofer ILT, he was a team leader at the institute at the same time.

However, the prize honors not only the better understanding of laser technology achieved by Kalupka, but also the practical results from the laboratory. Backed by his findings, the team around Kalupka set itself an ambitious goal: High-speed precision

cutting of glass using ultrashort pulsed laser radiation. Although the test setup had already been established and the simulations had delivered all the settings and parameters the laser required, this was definitely the most difficult phase of the project. "To achieve glass processing with this degree of precision, the lasers, lenses and attendant mirrors have to be positioned with micrometer precision. The adjustment mechanism for the components is now automated, but this required months of trial and error until we got everything just right," recalls Kalupka. Researchers also need to demonstrate a good deal of patience and perseverance. "Holding a piece of glass in my hand for the first time knowing we had succeeded was a real wow moment," says Kalupka.

**The researchers at Fraunhofer ILT have passed a milestone.** They have developed a process that is capable of processing various type of glass very quickly and with micrometer precision. No microfissures, no brittle edges, no flaws. The perfect cut. Besides all that, the technology is scalable. It can be used to process even large glass objects of up to a meter in length. "Having understood the ins and outs of how glass and laser interact, we can design a process tailored to any application," explains Kalupka. True innovations and new business models are within reach for use by industry.

Kalupka is already envisaging the next goals. This glass processing technology can also be transferred to other materials such as silicon or applied in a modified form. It could be possible to develop components for the high-performance electronics used in 5G technology. In the development of the quantum computer too, there is tremendous demand for components and materials. One promising candidate is lithium niobate. "This is a crystalline solid inside which individual photons can be generated using laser light. This is a fascinating field of application for our ultrashort pulsed laser," says Kalupka. And one that will demand, once again, a great deal of patience and perseverance from the Hugo Geiger Prize winner. ■

# Economical wireless communication

Nowadays, billions of small electrical appliances are linked together by radio in the "Internet of Things." They consume an enormous amount of energy.

By Tim Schröder



Urgently needed: Energy-efficient sensor nodes. Eight Fraunhofer Institutes are researching this together.



**T**he electronics of the future are small, intelligent and omnipresent. Although nobody knows the exact number, experts estimate that all around the world, we are already surrounded by 10 billion tiny sensors or measuring devices that exchange their data via radio and over the internet. Measuring sensors that automatically measure the nutrient content of a field, home security cameras whose images we access while on holiday to check that everything at home is in order, or sensors for detecting when a machine is idling and squandering energy. Given the growing number of these devices, referred to as sensor nodes, experts have been talking about the Internet of Things (IoT) for several years now. Sensor nodes tell us when something has gone awry, are able to control machines and help us stay abreast of a situation. No wonder, then, that they are so popular. Statista, the statistics portal, estimates that these canny electrical accessories could well have doubled in number to around 20 billion devices by the year 2030.

However, the numerous sensor nodes used so far are consuming huge quantities of energy. By 2013, the energy consumption of all networked devices globally was already equal to the total demand in Germany as a whole, according to a study conducted by the International Energy Agency. In response to this, eight Fraunhofer Institutes teamed up three years ago under the lighthouse project ZEPOWEL, short for Towards Zero Power Electronics, to develop especially energy-efficient sensor nodes. This year will see the introduction of two solutions to meet the challenge presented by energy consumption from two different perspectives. One of these, the “smart city node”, a small self-sufficient sensor node that supplies itself with energy and collects environmental data on air quality for example. The other involves a sensor node that records the operating state of machines, motors or pumps in order to dramatically reduce their energy consumption.

### Controllers in deep sleep mode

At the core of these sensor nodes is a central computer module, the IoT core, which works very economically and contains the new developments from all participating Fraunhofer Institutes. These include efficient micro-controllers, batteries and high-performance control electronics or energy converters. Added to this is the expertise in all matters concerning secure radio protocols. The smart city node gets along without any

energy source at all, because it supplies itself with power. It features an energy converter that recovers energy from movements and vibrations. And as soon as the sensor node is not required, it falls into a deep sleep mode. In this state, it consumes just a few nanowatts.

### Smart nodes — for medical engineering too

The first smart city nodes, the size of a matchbox, are expected to come into use within the next few months on cars or buses to measure the particulate matter in the city air. “These nodes are minute, maintenance-free and cost-effective and can be used in numerous places — so what we get is a very finely meshed network,” says Erik Jung, project manager at the Fraunhofer Institute for Reliability and Micro-integration IZM, which merged the developments from the participating institutes to create a complete solution that is good to go. In the future, smart energy-saving nodes like these could also be used for marking medical devices in hospitals — mobile ultrasound devices for example. In an emergency, the current location of the devices could be requested and the nearest one quickly located.

The sensor nodes for the machine control developed in ZEPOWEL are significantly larger than the smart city nodes when combined with the required power electronics. Depending on the point of use, they bring it up to the size of a half-liter can of beer or milk carton. In addition, they do not necessarily have to be energy self-sufficient because, as a control module, they are linked to the machines. Their key task is to reduce the power consumption of the machines — and use the smallest amount of energy themselves in the process.

After all, machines that have to be started and stopped manually are still in use today. Once an order has been completed, they continue to idle until someone presses the button. The new sensor node now contains, in addition to the radio and measuring technology, power converters that power the machine up or down as needed and bring it to the speed required at the time. “Instead of a simple on and off switch, the machines containing our power converters and the intelligent control in the IoT core have a gas pedal, so-to-speak, which adapts it to the current requirement and regulates voltage and current accordingly. As a result, they are seamlessly integrated into a digitally controlled production process,” explains Jung. ■

“These nodes are minute, maintenance-free and cost-effective.”

Erik Jung,  
Fraunhofer IZM

These electrical accessories could well have doubled in number to around **20** billion devices by the year 2030.



CHILE

## Sustainable waste disposal on salmon farms

Every year, Chile's water bodies are polluted by 300,000 tons of excreta, food remains and antibiotics from aquacultures.

A spin-off from Fraunhofer Chile has developed in collaboration with Novatech the Biolift system for sustainable waste disposal in the salmon farming industry.

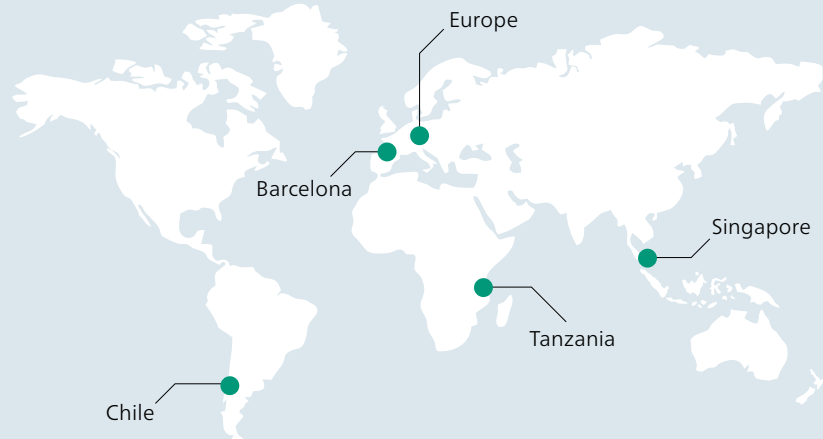
Biolift intercepts the bigger part of the organic waste and prevents sediments from accumulating on the beds of oceans and lakes. Allowed to collect, this debris leads to over-fertilization, increased bacterial growth and, ultimately, to oxygen deficiency and dead water beds. The system also reliably filters residues of pharmaceutical substances.

Installed on the bottom of the aquaculture cage, Biolift uses suction to gently elevate the organic waste to the surface before it has chance to reach the water bed. The slurry retained in this way is dehydrated in situ and taken to dry land. Energy can be recovered from the dehydrated waste. It can also be a source of new products, fertilizer being one example. Only a fraction of the sediment ends up in the land fill.



After Norway, Chile is one of the world's biggest exporters of farmed salmon.

# Fraunhofer worldwide



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Dr. Natalia Sandetskaya from Fraunhofer IZI (I.) and a field nurse from KCMC working on the field study in Tanzania.



TANZANIA

## Rapid test for trachoma eye infection

Trachoma is the leading cause of blindness worldwide. Fraunhofer researchers have now developed a chip-based test that allows rapid diagnosis and early treatment.

No laboratory infrastructure is required for the molecular biological DjinniChip developed by the Fraunhofer Institute for Cell Therapy and Immunology IZI. The analysis can be performed device-free, with the naked eye. Trachoma is caused by bacteria and is highly infectious. The disease is most widespread in tropical regions. The Fraunhofer team developed the test in cooperation with the Kiliman-

jaro Christian Medical Centre in Tanzania, which has an extensive specimen collection of eye swabs at its disposal. The DjinniChip rapidly delivered the results from the specimens. In addition, it comes at only a fraction of the cost of conventional test methods.

Until now, the approximately 40 million trachoma sufferers have generally been treated with mass medication. If the incidence of the disease in a particular village increases, antibiotics are given to all residents as a precaution. This causes, among other conditions, preventable antibiotic resistances.



## EUROPE

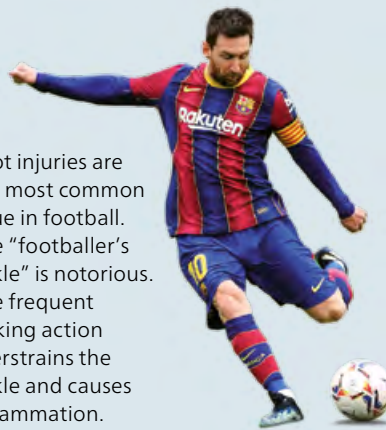
## Foot implants from a 3D printer

Together with eleven European partners, including FC Barcelona, the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB, is developing a method for manufacturing personalized implants for injuries to the foot, the tendons and joints in particular.

The researchers want to halve the convalescence time, and are also aiming to increase tissue functionality by ten to 15 percent. Precisely tailored to the patient's foot, the implants will be made, using innovative 3D printing processes, from biopolymers like the ones naturally occurring in the body. "Because we want to be able to process these biopolymers together with the growth factors and the cells using a 3D printer, they have to be free-flow-

ing," explains Dr. Achim Weber from Fraunhofer IGB. "We are therefore formulating and developing collagen-based and gelatin-based bioINKS. These are cross-linked to make solid biopolymers only after the printing process."

Foot injuries are the most common issue in football. The "footballer's ankle" is notorious. The frequent kicking action overstrains the ankle and causes inflammation.



Volocopter completed a test flight over Marina Bay in Singapore as early as October 2019.



## SINGAPORE

## Air taxis — they will fly!

Dorothee Bär, CSU State Minister for Digital Affairs once faced ridicule for her vision of air taxis. The dream of urban air mobility is about to become reality. Volocopter, the German air taxi pioneer from Bruchsal, will offer this service in Singapore — within the next three years and in cooperation with local institutions, starting with Fraunhofer Singapore at Nanyang Technological University.

"The research institutes in the city will also play a key role. Topics such as route validation for autonomous operation, material science and research for battery technology are very important to our long-term business success," says Florian Reuter, Managing Director of Volocopter.

Volocopter air taxis are emission-free, electrically powered aircraft that take off and land vertically. They are intended as a complement to urban mobility and fly up to two passengers to their destination directly and quietly. The company is aiming to establish affordable air taxi services in the megacities around the world.



## EUROPE

## Recycling metals instead of destroying natural resources

In Europe, with few natural resources, recycling is the most important source of chromium, nickel, copper and so on. To boost the competitiveness of the local industry, the Fraunhofer Institute for Laser Technology ILT and Cronimet Ferroleq. GmbH developed a new sensor technology that detects the alloys

in metal scrap much faster and with greater precision than conventional methods. A process called Laser Emission Spectroscopy (LIBS) is used to identify over 20 special alloys in even small pieces of scrap — automatically, quickly and without any contact.

As a result, bigger quantities are processed and a higher degree of sorting accuracy is achieved. Fraunhofer ILT is now contributing this expertise to the EU project REVaMP. The idea is to develop a sensor for installation in existing industrial facilities.

A new sensor makes the recycling of metallic raw materials far much efficient.



# Too good to throw away

A world without waste, where everything is continuously reused in an endless cycle — utopia or a realistic vision?

By Dr. Sonja Endres



**N**ature knows no waste. Man is now learning what nature masters to perfection. German chemist Michael Braungart and US architect William McDonough had developed the “Cradle to Cradle” concept of a consistent circular economy by the end of the 1990s. Their concept states that products are to be either completely biodegradable or endlessly recyclable — from cradle to cradle rather than cradle to gate. This is not, wrote Braungart in Die ZEIT newspaper in 2009, about doing without. Today, the circular economy is considered a key strategy for safeguarding prosperity, conserving resources and achieving the climate targets. In March 2020, the European Union adopted a Circular Economy Action Plan, one of the main building blocks of the Green Deal.

Fraunhofer scientists are showing in the EVOBIO project that the transformation from the linear economy of “take — make — dispose” to a circular, biobased one does not have to remain the stuff of dreams. 19 institutes from various areas of research are involved in the project — from bioprocess engineering to building physics and microtechnology to applied polymer research. Numerous subprojects are interlinked. “We want to rethink the industrial value creation chain”, says Dr. Markus Wolperdinger, Director of the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB in Stuttgart, the institute coordinating EVOBIO. The Fraunhofer-Gesellschaft provided funding for the project off-plan during the 2020 coronavirus crisis year. The goal: To pool the expertise of the institutes to create a modernization drive that will force the ►

In the early 1960s, around 220 to 255 kilograms of household waste was produced per capita. At 457 kilograms, the amount had approximately doubled by 2109.





Lettuce grown using wastewater. Sensors constantly monitor the nitrogen content.



The sewage sludge is converted in a digestion tank from bacteria to biogas, which can then be used to generate power and heat.

“We need to reduce material flows and implement a rigorous product policy in order to get more raw materials into the cycle.”

Prof. Vera Susanne Rotter, Advisory Council of the German Federal Government for Environmental Issues, May 2020

structural transformation. Within six months, the researchers had developed new ideas, concepts and technical solutions — continuation guaranteed.

### When the wastewater treatment plant is transformed into a vegetable farm

At the core of the largest EVOBIO sub-project, the “Wastewater treatment plant of the future”, is of course wastewater. Germany sees around ten billion cubic meters of wastewater every year. “Until now, the wastewater treatment plants have simply decomposed the constituents of the wastewater without putting them to use. We see the constituents as reusable materials and are trying to convert them into products,” explains Dr.-Ing. Ursula Schließmann, Head of Business Area Environment at Fraunhofer IGB.

On the site of the municipal wastewater treatment plant in Ulm, the researchers built a pilot plant for the high-load digestion of sewage sludge. The sludge contains not only pollutants, but also nutrients such as phosphorous and ammonium-nitrogen. Today, most sewage sludge in Germany is burned. “Our plant is very efficient at biodegrading the organic fraction and therefore, in addition to biogas, solid digestate and nutrient-rich sludge liquor are available for further use,” says Dr. Marius Mohr, Head of the Water Technologies and Resource Recovery Innovation Field at Fraunhofer IGB.

Schließmann and her team are experimenting with microalgae, which filter the nutrients out of the sludge liquor and use them for their growth. “The challenge lies in finding suitable organisms that are capable of drawing the nutrients from the sludge liquor and producing reusable materials as well,” says Schließmann. Her search was successful: The microalgae *Monodopsis subterranea* and *Phaeodactylum tricornerum* are not only good at filtering, they also produce a biostimulant that boosts the immune system of plants. In agricultural cultivation, this substance

“We want to rethink the industrial value creation chain.”

Dr. Markus Wolperdinger, Fraunhofer IGB



helps reduce the use of fungicides and keep the groundwater clean.

The nutrient-rich sludge liquor is also suitable for hydroponic vegetable cultivation without soil — a pioneering idea in times of increasing droughts and water shortage, in Germany too.

Fraunhofer IGB was able to garner experience from the previous project HypoWave. Using various technologies, the researchers managed to reliably remove pollutants and pathogens from the wastewater and cultivate lettuce. Researchers at the Fraunhofer Research Institution for Marine Biotechnology and Cell Technology EMB in Lübeck are working on using the water cleaned by plant cultivation to breed edible fish. Dung and food remains enrich the water with nutrients once more, allowing it to be reused for plant cultivation — an innovative link between agriculture and aquaculture.

The researchers are able to recover biochar and bio-oil even from the dewatered

sewage sludge. It is also possible to produce hydrogen from the wastewater using bioelectrical systems. The first laboratory tests show that, in this way, wastewater treatment plants can be operated in an energy self-sufficient manner.

The more recycling pathways we dock to the overall “wastewater treatment plant of the future” system, the more important sophisticated process monitoring and control becomes. If something fails to work at this point, this has a direct impact on other steps in the process. If, for example, the concentration of certain micronutrients in the sludge liquor is too high, algae growth can be inhibited. Schließmann emphasizes: “The equilibrium that nature manages to maintain by and large is a very sensitive one. We only have to create it.” A sensor technology recently developed by the Fraunhofer Institute for Microelectronic Circuits and Systems IMS will lend a helping hand. The sensors continuously record numerous parameters such as nitrogen and pH values, various light intensities, flow velocity or pressure. The researchers feed the data they have gathered into self-learning systems that will ultimately control the complex plant.

### Today's waste — tomorrow's raw material

The EVOBIO team also wants to unlock the potential of biobased waste as alternative resources. For example, researchers at the Fraunhofer Institute for Process Engineering and Packaging IVV use residues from rapeseed oil production to create a protective coating for food packaging. They do this by extracting proteins from coarse colza meal and applying them to cellulose film. As soon as the proteins dry out, they form a dense network that makes it very difficult for oxygen to penetrate the packaging. This stops the food from oxidizing, its quality and shelf-life remain guaranteed. In the case of vacuum-packed foods, the barrier layer ensures that the partial pressure gradient is maintained and that oxygen cannot penetrate. “Food production ▶

causes significant CO<sub>2</sub> emissions and guzzles a great deal of energy. This is where the effort for effective packaging is certainly justified," says Dr. Cornelia Stramm, Head of the Material Development Department at Fraunhofer IVV. She and her team are convinced that waste materials can be used to produce high-quality packaging, and replace fossil materials at the same time. Stramm has already experimented with rapeseed, as well as dairy and potato proteins. Fava beans are next on the agenda. "In principle, all proteins have a barrier effect against oxygen, but they are not easy to extract from the waste materials," she explains. The team is now planning to use plant wax to create an additional water vapor barrier in the packaging. Eugenol, a constituent of thyme oil, is supposed to protect food from bacteria and deterioration. But essential oils are highly volatile. Before eugenol can be introduced into the packaging materials, it has to be micro-encapsulated.

### Thyme oil in plastics

Dr. Alexandra Latnikova and her colleagues from the Fraunhofer Institute for Applied Polymer Research IAP are lending a helping hand. They are specialists in the micro-encapsulation of additives, which influence the properties of the carrier material. Additives ensure, for example, that a plastic is especially flexible or less readily flammable. In many cases, additives cannot be introduced into the polymer in their raw form — they need a protective coating because they are often unstable or released too quickly. The release process can be controlled by the material and the composition of the capsule. Latnikova and her team are working on a concept for replacing synthetic additives with natural ones. They are experimenting with essential oils, enzymes and phenols which occur in the "Wastewater treatment plant of the future" as by-products of winemaking and also in the production of bio-oils, for example. "Additives are not on many people's radars

"The willingness to explore new ways is there."

Dr.-Ing. Ursula Schließmann,  
Fraunhofer IGB



when it comes to finding a sustainable alternative to mineral oil-based plastics. Additives can account for up to 50 percent of the material. Without biobased additive, no biobased plastics", says Latnikova categorically.

Dr. Michaela Müller from Fraunhofer IGB also wants to replace synthetic substances with natural ones. She is investigating ways of making functional textiles water-repellent and breathable without using conventional, environmentally harmful fluorocarbons. She and her team are successfully experimenting with chitosan, a biopolymer that can be produced from the shells of crustaceans, for example. The EU sees around 250,000 tons of crustacean shell waste every year, over 6 million tons accumulate annually worldwide — a natural resource in abundance. Insect cuticles and exoskeletons, a common residue from animal foodstuff production, contain chitin, from which chitosan is made.

Müller applies chitosan to the fabric in combination with a special protein which. Named hydrophobin due to its special water-repellent property, this protein occurs in fungal spores, for example. "We have been able to gather a certain degree of experience with chitosan over the last few years. Thanks to a physical trick, we have now managed to make the fabric hydrophobic while still guaranteeing its breathability. This cannot be done using plant waxes, they are not water vapor-permeable", explains Müller. She and her colleagues are currently working on optimizing the chemical bond between chitosan and hydrophobin. The hope is that this combination will not only improve the water-repellent properties, but make the fabric highly oil-repellent as well.

Green fashion has become a trend — the interest of textile companies in sustainable alternatives is immense. In a survey by Statista from 2019, 57 percent of consumers said that sustainability/recyclability is important to them when they buy fashion items. Once the EVOBIO funding period had expired at the end of December 2020, Müller and her team continued their research with funds from industry.

That the "wastewater treatment plant of the future" will also continue is already clear. Numerous companies from various sectors want to get involved — plant constructors, food and animal feed manufacturers, chemical and energy companies, sensor, automation and IT start-ups. "The willingness to explore new ways is there. Companies can see a market," Dr.-Ing. Ursula Schließmann from Fraunhofer IGB is convinced. ■

### 10. International Conference "Life Cycle Management"

Virtual Event, Sep. 5–8, 2021  
Organizer: Fraunhofer IBP, University of Stuttgart, Festo and DGNB.



Further info: [www.lcm2021.org](http://www.lcm2021.org)



Only **9%**  
of the over eight billion of  
tons of plastic generated  
since the 1950s  
worldwide have  
been recycled.

## Packaging waste

in Germany in  
millions of tons

1998: 14.1

2018: 18.9

**+25%**



Sources of the facts and figures:  
German Federal Statistical Office,  
Deutsches Museum München, German Federal  
Environment Agency, Heinrich Böll Foundation,  
Circularity Gap Report 2020, Conversio Study  
"Stoffstrombild Kunststoffe 2019" (Substance Flow Plastics)

In the year  
2020 only  
**8.6%**  
of the global  
economy was circular.

Half of the **76 kg**  
of plastic waste per person  
in Germany in 2019 was  
accounted for by packaging waste.

# Reducing food waste with AI

**T**he biggest proportion of food waste is accounted for by private households, though a considerable amount occurs during production. There are various reasons for this: Processing chains are complex, fluctuating requirements are difficult to predict, and our inadequate knowledge of consumer demand results in surplus production. In the REIF (Resource-efficient, Economic and Intelligent Foodchain) project, Fraunhofer is seeking solutions. "The real challenge is to create a link between farmer, production and consumer to reduce food waste while maintaining or even increasing profitability at the same time," explains Philipp Theumer from the Fraunhofer Institute for Casting, Composite and Processing Technology IGCV.

As many as 30 partners from research and industry are working to achieve this. The common goal is to develop an AI ecosystem with a networking platform for curbing food waste. This includes the AI-based calculation of sales forecasts, which are important to both the food trade and the upstream production process. The aim for the future is to optimize the production systems using AI. REIF is focusing on three value creation networks: the manufacture of bakery, dairy and meat products. The production processes here are complex ones, all the more important due to their high loss rates and cause a relatively large ecological footprint.

In Germany alone, around 12 million tons of food end up in the trash every year. Intelligent algorithms help to put an end to waste.

By Andrea Pletz



# 52%

of food waste is accounted for by private households.

Baked goods are among those foods most frequently thrown away.

“The real challenge is to create a link between farmer, production and consumer.”

Philipp Theumer, Fraunhofer IGCV

The REIF team from Fraunhofer IGCV is responsible for standardizing data structures, the idea being to simplify and accelerate the integration of AI into systems and business processes. In the dairy scenario, a dynamic adjustment to the product quantity would prove ideal. The system-specific framework conditions deserve special consideration here. AI-based decision-making aids, which come into play as early as the production process, provide the solution. A prototype that predicts the ability of cheese mass to be pumped is already developed.

### Sensors for preventing substandard products

How to make perfect dough while reducing the start-up time of machines is a question asked in the production of baked goods. AI processes are designed to determine, check and control the quality of raw materials and additives. Sensors allow conclusions to be drawn about the quality of the cake base, for example, are being developed for this purpose. Consequently, the optimum machine parameters can be found more quickly, and substandard products can be avoided.

In the third application field, meat processing, the focus is on extending the shelf life — another important way of reducing waste. The project is complex: The shelf life of the individual products must be constantly measured and assigned to a batch. In the raw meat mixing process, cooling and mixing time are among the parameters to be considered. From animal delivery from the slaughterhouse through to the packaging operation, all steps must be capable of being assigned to a data record.

Collecting the data relevant to the AI algorithms is a huge challenge. Considerable effort is required to collect and check specific data over a prolonged period. At the core of the AI ecosystem is a communication and service platform. One of the aims is to compare the customer's demand against the farmer's supply and optimize production capacities. The algorithms, already trained, are supplied and combined with the company data. The data and forecasts along the entire value creation chain are linked to one another. This could allow fluctuations to be predicted and brought close to zero, with overproduction being avoided. ■

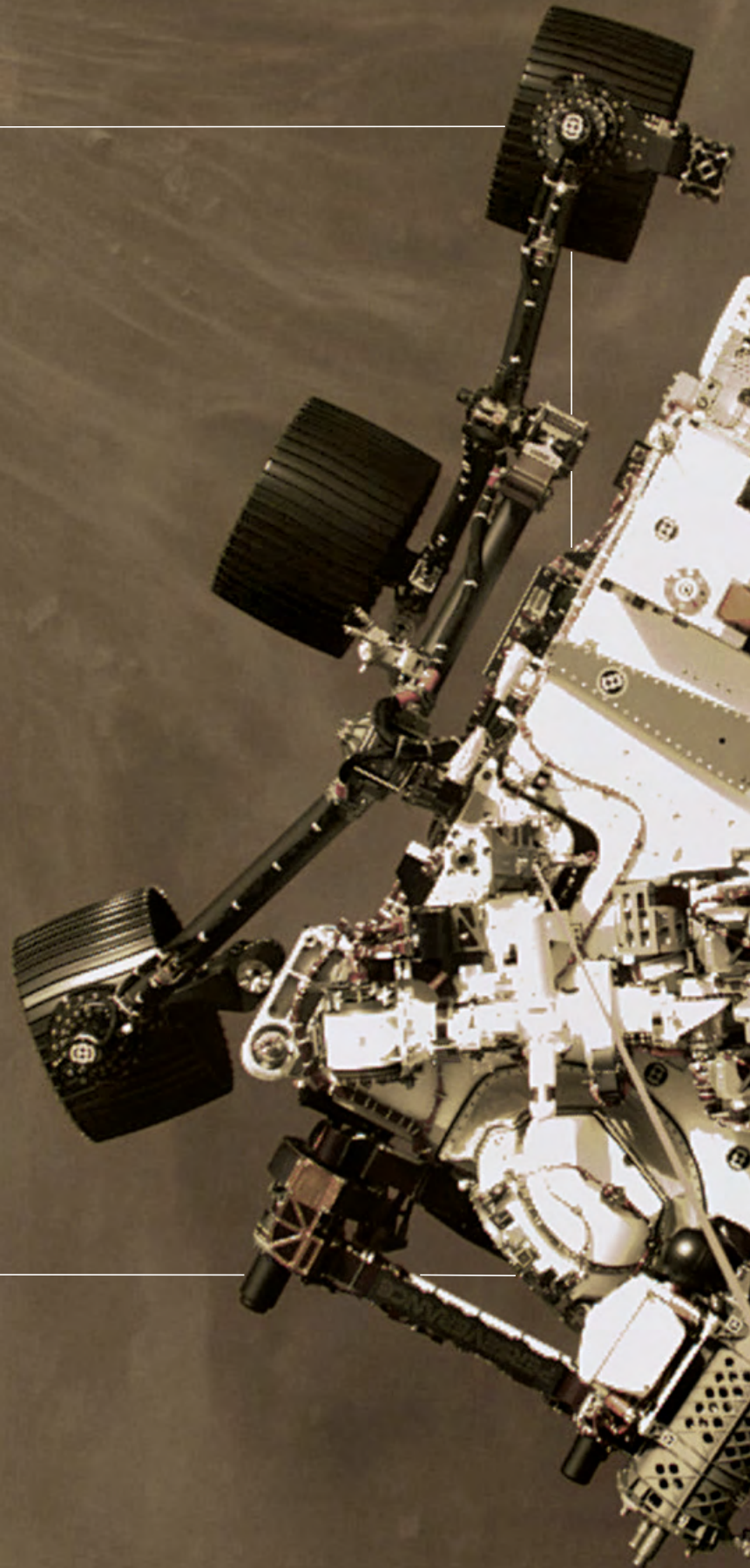


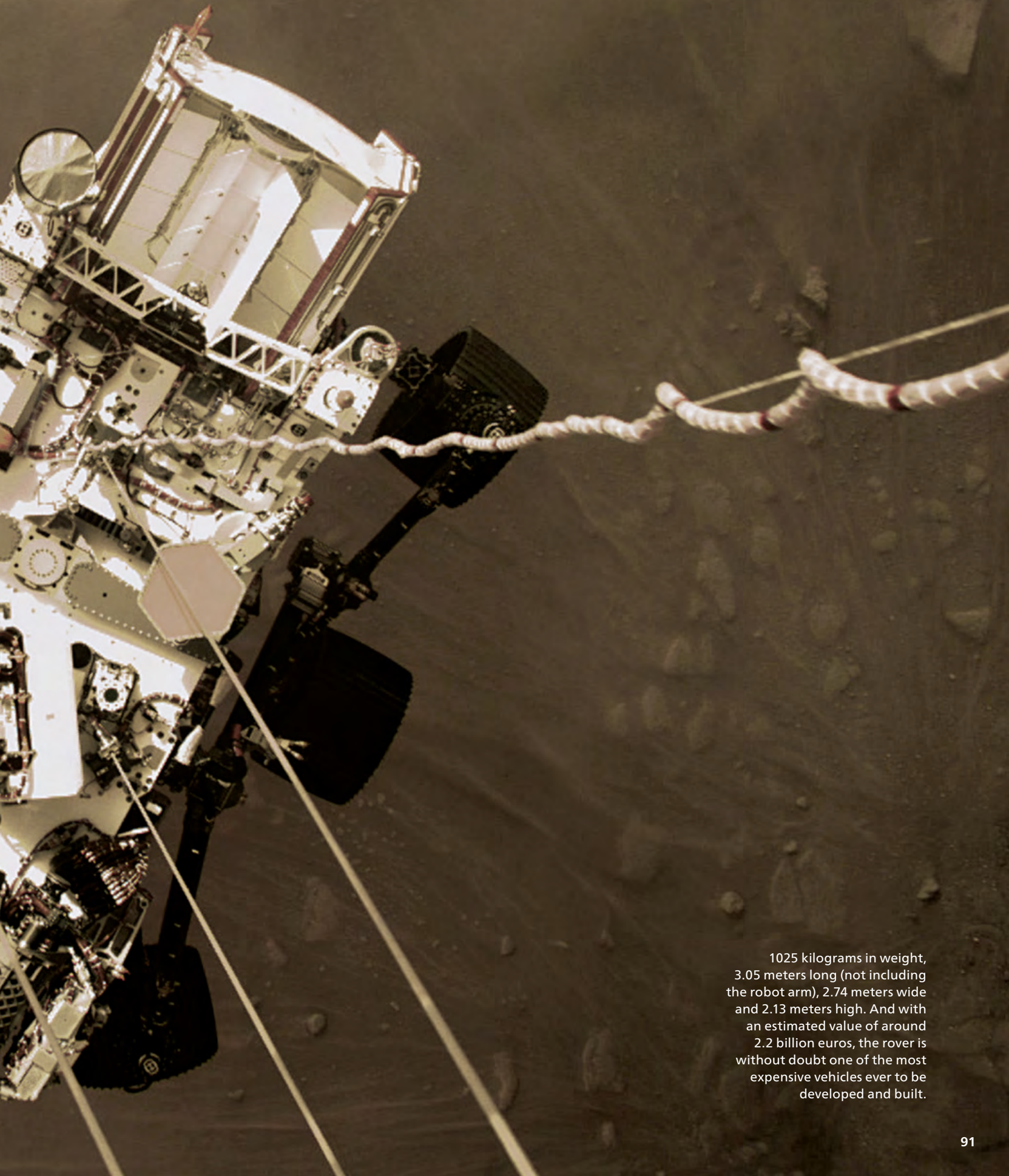
## Photo & Fraunhofer

# Fraunhofer on Mars

472 million kilometer journey. 205 days of travel time. Landing site: Jezero crater. This is where the Mars Perseverance rover began its work in the dust on Mars. The Mars mission sends fascinating impressions back down to earth using 23 cameras and two microphones. Aboard: An optical interference filter from the Fraunhofer Institute for Surface Engineering and Thin Films IST. The filter works inside a sensor designed to characterize dust. Ahead of the mission, the filter was subjected to a rapid temperature change 3000 times to ensure that it would also work reliably on Mars at temperatures of down to minus 120 degrees Celsius. The sensors that detect radiation exposure and dust are positioned on the top of the rover. "The filter is designed to let only light in the 'near' infrared range pass through," explains Project Manager Stefan Bruns. "The aim here is to detect dust on the surface of Mars."

Photo: NASA/JPL-Caltech/USGS





1025 kilograms in weight, 3.05 meters long (not including the robot arm), 2.74 meters wide and 2.13 meters high. And with an estimated value of around 2.2 billion euros, the rover is without doubt one of the most expensive vehicles ever to be developed and built.

## Interview

**Nico Rosberg, 35**

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became the Formula One World Champion in 2016 with Mercedes. Just a few days after winning the title, he announced his retirement from motor racing. Now, he is pushing for Formula One to switch to electric engines — and campaigning as an investor for sustainability and e-mobility.

# “I believe in hydrogen!”

Combustion engines made him Formula One World Champion. Nico Rosberg now champions sustainability and new drive concepts. And is more than happy to hand over the wheel — for autonomous driving and even flying.

Interview: Josef Oskar Seitz

\_\_\_\_\_ **Mr. Rosberg, ten years as a Formula One racing driver, 2016 world champion — how much have you personally contributed to global warming?**

Rosberg: Do I have a guilty conscience, you mean? To that I can say no. I am, of course, aware that the CO<sub>2</sub> emissions from Formula One were not insignificant. But if we look at the figures in detail, more down to the movements of the teams and the fans. And we should not forget the enjoyment this sport brings — or at least did bring — to many millions of people all over the world.

\_\_\_\_\_ **Has the fascination remained with you?**

I can still relate to it. But I lead a completely different life now.

\_\_\_\_\_ **You have developed a passion for different kinds of mobility — e-mobility, hydrogen propulsion. You like to invest your money in sustainability projects? How do you see the future?**

I believe in hydrogen, I have hopes for hydrogen. And what I want is for the politicians to set the right course for the future. I am, however, painfully aware that future processes and election periods are not a good match. If we really do want to shape the

future, we have to think long-term and way beyond the four-year election cycle. That said: The effort is worth it — for everyone's future. “Many thanks by the way, the strategy papers and studies from Fraunhofer point me in the right direction.”

\_\_\_\_\_ **Will autonomous driving always be a dream?**

I believe it will. The danger remains that of the interaction between man and machine. I am convinced we need full driving automation, level five, where the vehicle occupants are nothing but passengers and the technology is able to handle all traffic situations.

\_\_\_\_\_ **How hard is it for a famous professional driver to suddenly hand over the wheel?**

I'm enjoying it. I welcome the improvement to my quality of life. All I want is to drive the roads myself that bring true joy — in a fantastic car with beautiful weather, on a windy mountain road.

\_\_\_\_\_ **Do you make a bad passenger, when it's another person rather than the machine controlling the car?**

My wife Vivian is usually quite happy with that. ▶



He has already bought his ticket: Investor Nico Rosberg in front of an air taxi, about to take to the air in Singapore.

“Many thanks by the way, the strategy papers and studies from Fraunhofer point me in the right direction.”

**As an investor, are you looking at high-flying adventures?**

Air taxis, you mean? Actually, I have invested in Volocopter and Lilium, two promising German start-ups in this sector. Autonomous air taxis will, and of this I’m absolutely convinced, not only turn urban traffic on its head. They are set to revolutionize the way we inhabit cities — and will open up new possibilities for commuting, take the pressure off the roads, increase mobility and ultimately make our cities more livable.

**Our Fraunhofer Institute for Industrial Engineering IAO has created an acceptance study on this in cooperation with Volocopter GmbH. The vast majority of those interviewed in a prototype welcome the alternative to automobile traffic — although 72 percent still see the emergency landing function as “very important”. Autonomous urban traffic in an air taxi, then, is not just science fiction?**

I have already bought my ticket for Singapore. I am convinced that the first air taxis will be taking off here in Germany within the next few years.

**If we want to do good for our society as a whole, we have to show that there’s big money to be made as well. What are the factors?**

It’s really about economic success. But for this, you need to create the biggest possible benefit for as many people as possible. You know, I invested early in TIER, the electric scooters that have changed our cities. They opened the door to a new kind of mobility that perfectly combines enjoyment and usefulness. This, incidentally, is our next great step forward. In the future, TIER users will be able to charge their batteries themselves in charging stations, and receive a credit voucher in return. This advantage benefits the customers. As a result, the company is also better off because his costs reduce accordingly. Ultimately, it also eases the environmental burden as there is no need for diesel-powered transporters to collect the scooters at night.

**How does the life of Rosberg the entrepreneur differ from his time as an elite athlete?**

I’m learning to be more patient. Of course, the unbelievably intense exertion over a race weekend has now gone. Instead I negotiate contracts, over weeks and months. Whereas: The attention to detail and the knowledge that true success can only be achieved in a team — that stayed with me when I turned entrepreneur.

**What is it that’s motivating you today?**

My belief in a better world. The prominence, which I owe to my time in Formula One, helps builds this belief as well. It is opening doors for me and forging relationships — racing, then, is bringing my concerns about sustainability to the fore.

**Many fans surely see you as Saul who became Paul with gasoline running through your veins. Do you often come under fire as a result?**

It does happen, of course. But I’m used to being up against it. I know how it is from my time as racing driver.

**You now experience a completely different kind of speed.**

You are into speed reading? Actually I’m fascinated by methods that make you read faster and assimilate knowledge more effectively. Incidentally: This kind of speed is completely climate-neutral. ■



## Fraunhofer on the road

**Last updated: End of March.**  
Changes may occur due to the current situation. Please keep an eye out for information from the event organizers.



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“It’s important to bring together all stakeholders to devise knowledge-based solutions.”

Sophie Mok, Fraunhofer IAO