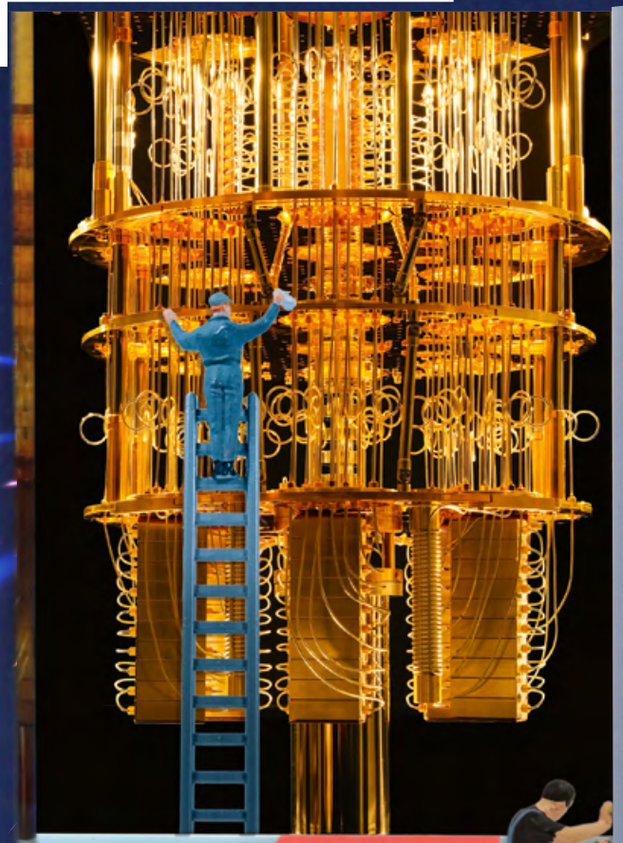
Fraunhofer

magazine 4/20

What lies ahead in 2021

Open up the New Year!



Quantum computers

Neuromorphic chips

Trusted computing

Series ---> Founders ----> Spin-offs
---------> Reasons for Fraunhofer

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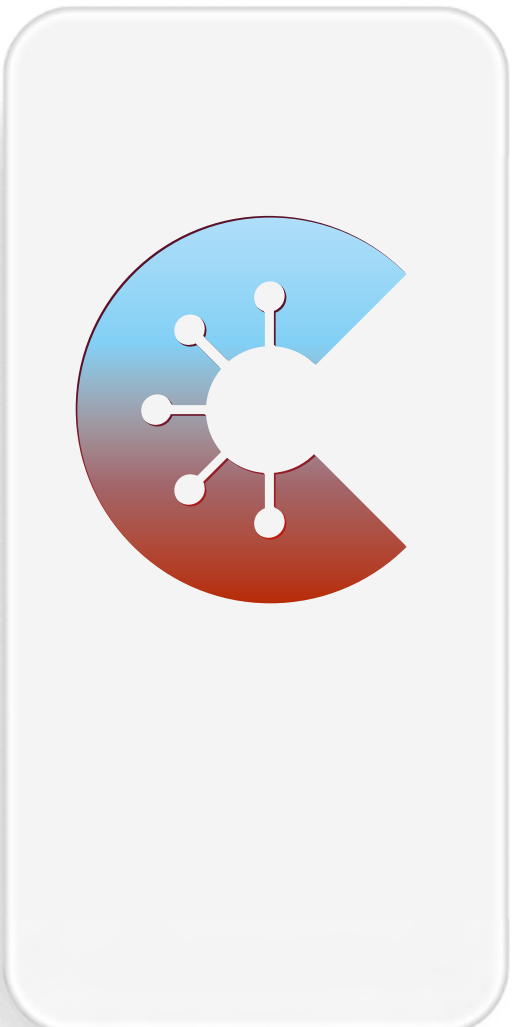
FRAUNHOFER VS. CORONA



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The Federal Government

Let us face our challenges head on!

Prof. Reimund Neugebauer
© *Fraunhofer/Bernhard Huber*

"What does the future hold?" The Editorial for this magazine opened with the same question precisely one year ago. At the time, nobody knew or could even have imagined how 2020 was set to change under the fallout of COVID-19. Given everything we have come to realize as this year draws to a close, the Fraunhofer-Gesellschaft has emerged extremely well from the year of the pandemic. I would like to thank all our employees, researchers, institute directors for the discipline and judgment they have shown. Even in this difficult time, together we have successfully generated fresh momentum with our innovation push and coronavirus program.

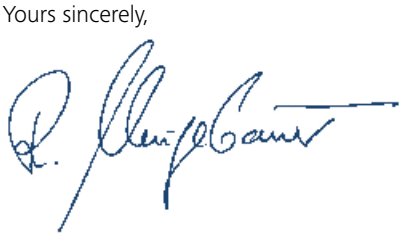
The contribution to the development of EUV lithography made by Dr. Sergiy Yulin and his team from the Fraunhofer Institute for Applied Optics and Precision Engineering IOF has made sure we are able to close the year with an extremely positive result. Together with fellow researchers from ZEISS and TRUMPF, Dr. Yulin won the German Future Prize on November 25 (see page 62). Fraunhofer IOF has won this award, presented by the Federal President, for the third time, and Fraunhofer as a whole nine times. For the Fraunhofer-Gesellschaft, it is not the only positive to come out of 2020, a "year in which we have talked about science more than ever before," as Frank-Walter Steinmeier puts in a nutshell.

As unexpectedly as this year has developed, the Fraunhofer-Gesellschaft has resolutely stuck to its goals. The first quantum computer, which Fraunhofer wanted to bring to Germany together with IBM, is about to go into operation. Reaching Germany by ship in November, it will be available in the town of Ehningen in Baden-Württemberg from January 2021 – for the Fraunhofer Quantum Computing Competence Network, but also dedicated to the German economy as a whole. The first projects are about to get underway. This Fraunhofer magazine takes a look at what computing of the future can and will do. One thing is already clear: The association between quantum and artificial intelligence will be nothing short of a future key technology for safeguarding Germany's competitive ability in international high-tech markets.

Quantum computing is set to become one of the strong pillars for building the future – alongside trusted computing, set to achieve digital security, and neuromorphic computing, which models itself on the marvel of the human brain.

Science has played no small part in our fresh optimism as we step into 2021. The record time in which corona vaccines have been developed and pushed to the approval stage is impressive testimony to the true value of research. The challenges are not about to get easier. But if this last year has taught us one thing, it's this: We have the strength to face them head on.

Yours sincerely,



Reimund Neugebauer
President of the Fraunhofer-Gesellschaft

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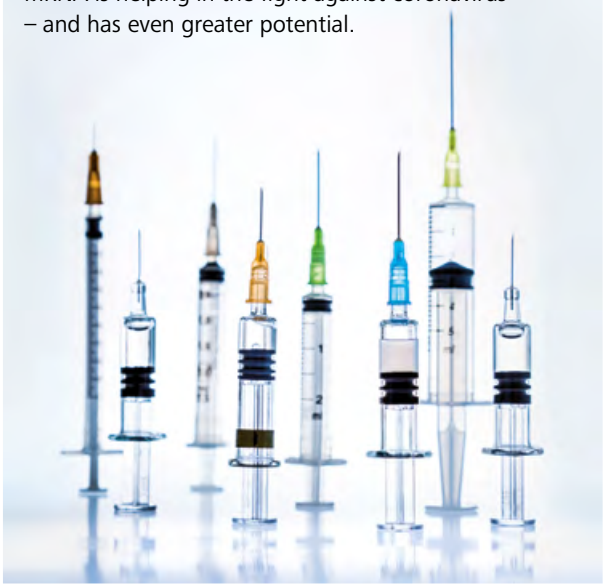
Fraunhofer brought the first quantum computers to Germany in November. It's now putting them into operation. Neuromorphic computing, trusted computing and quantum computing are the three pillars for building a future.

62 A threesome that saw the – ultraviolet – light
milestone in the production of microchips: German Future Prize for EUV lithography – and for Fraunhofer.



Coronavirus is keeping people off the shopping streets, online retailing is exploding with Christmas business. In the five weeks before Christmas, Deutsche Post DHL delivered **1.6 billion packages**, more than it did in the whole of 2019: **100 percent in November,** 100 percent ahead of the usual high season. Customers and companies can feel it: the challenges for the logistics of tomorrow are on the rise. Fraunhofer connects AI to swarm intelligence for its LoadRunner solution (see p. 64).

100%

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Enjoy without a care

Christmas is a time for enjoyment. But almonds can sometimes pose a health risk. © *iStockphoto*

Almonds, the delicious ingredient in gingerbread and spiced cookies, are often colonized by salmonella. A new process developed by the Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT gives these germs no chance.

According to the German Federal Office for Consumer Protection and Food Safety (BLV), nuts, nut products and seeds are among those foods that most frequently had to be recalled from retailers in 2019.

"Salmonella go dormant to survive on almonds. If water enters the picture, salmonella then proliferate explosively. But it only takes between ten and a hundred of these bacteria to cause food poisoning. Contaminated almonds that make their way into production facilities after harvesting can also contaminate other batches," explains Karen Fuchs, a researcher at the Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT in Oberhausen. In a joint project with researchers at the University of Alberta in Canada called MiDeCO2, the scientist and her team investigated technologies that could serve to decontaminate almonds. "It is common knowledge that pressurized carbon dioxide can kill pathogenic bacteria in liquids such as orange juice. Our research has shown that under certain conditions this also works with dry food," says Fuchs. Carbon dioxide is not harmful to the environment or health and can be separated from almonds without any trace of residuals. This does not involve any energy-intensive steps for purification.

The almonds are decontaminated and impregnated with antimicrobial oils using compressed carbon dioxide in a high-pressure autoclave. The oil extract coats the almond, making it difficult for germs to recontaminate the fruit. The advantages of this process are these: the almonds retain their characteristic flavor and quality. The process does not adversely affect their shelf life or lipid composition.

Precisely printed heaters

Fraunhofer researchers have developed, for satellites and spaceships, especially reliable ceramic-silver heaters that can be seamlessly applied to components.

Earthly applications are also conceivable: when condensation is to be kept away from the camera lenses of automated guided vehicles using heat, for example. Pipe systems with precisely printed heaters could also open doors in the chemical, semiconductor and food industries, which often require precisely controlled temperatures for their processes.

Until now, polymer heating foils, bonded by hand, have been used for components with complicated shapes. "This is not only time-consuming, but also prone to errors," explains Lukas Stepien, Group Manager for Printing at the Fraunhofer Institute for Material and Beam Technology IWS in Dresden. "During the bonding process, small gas bubbles can go unnoticed and become trapped. These bubbles expand in the vacuum of space. This ultimately reduces the heat output." In space, even minor problems such as an iced battery can have dramatic consequences. The new heaters from Fraunhofer IWS are far more fail-safe.

First, the components are insulated with a thin ceramic coating and the heating elements are then applied using a dispenser printing machine. These elements resemble the shape of a meander. If an electrical current later flows through the metallic meander, it will release heat.

To create these heating patterns, the scientists fill a cartridge with a special paste containing small silver particles. Compressed air then drives the viscous material through the cartridge towards a fine cannula. This hollow needle finally prints the heating pattern, about ten microns thick, onto the ceramic-insulated tubes, which rotate on a shaft.

The Fraunhofer engineers are also expecting their printed heaters to be produced more cost-effectively and with greater flexibly than the conventional heating foils used for bonding today. They will last longer and function more reliably, especially at high operating temperatures.

One in two young people in Germany wear a brace – often for many years. © *F1 online/Stocksy*

Healthy teeth despite a fixed brace

Brace wearers face an increased risk of caries. Wires and fasteners make it difficult to clean the teeth. A combination of a special peptide and fluoride helps to protect the enamel.

This is shown in a study by the Philipps University of Marburg and the Fraunhofer Institute for Microstructure of Materials and Systems IMWS. The research results were recognized with the Oral-B Award for Pediatric Dentistry and Prevention 2020.

The enamel may demineralize, especially at the edges of the surfaces where the braces are attached to the tooth. Such damage, which occurs with fixed braces in almost half of all cases, can lead to the formation of caries. Damage to the enamel can cause bacteria to settle, multiply and penetrate further into the tooth.

If the damage is still at an early stage (initial lesion), a novel treatment method can stop the process and even help the tooth to repair itself: The peptide P11-4 is applied to the tooth as a liquid, fills the lesion and ensures that calcium ions and other minerals are deposited in the tooth structure. "By using P11-4 in combination with a fluoride varnish, we were able to observe a significantly improved remineralization of the enamel compared to the use of fluorides alone," says Prof. Anahita Jablonski-Momeni from the Philipps University of Marburg, summarizing the results of the study.

Peptide P11-4

On the International Space Station, the lives of the astronauts depend on the onboard technology working. © *NASA Images*

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Under EU law, animal testing is now permitted to only a limited extent. For example, new substances intended for use in cosmetics may no longer be tested on animals. © *AdobeStock*

New test procedure to replace animal experimentation

How irritating are chemical substances for the eyes? Until now, this has been assessed by the Draize test on rabbits. Fraunhofer researchers are working on an alternative.

Since 1944, the damage potential of new chemicals has been assessed and classified by the Draize eye irritation test. This method, used as the standard worldwide, involves dripping chemical substances into the eyes of live rabbits. In an effort to do away with this troublesome procedure, scientists have cultivated tissue models of the human cornea in the test tube and used them as test systems. However, as current tissue models do not allow the distinction between irreversible and reversible damage, animal experiments have so far only been reduced, not replaced.

Researchers at the Translational Center for Regenerative Therapies of the Fraunhofer Institute for Silicate Research ISC are now drawing on their many years of experience in the field of human tissue models to develop a powerful test system in collaboration with various partners. The ImAi project aims not only to replace the Draize test completely, but also allow more reliable results to be obtained. ImAi is financed by the Federal Ministry of Education and Research as part of the "Alternatives to animal testing" program.

Identifying illegal cultural property by app

Customs officers and the police find it difficult to know whether an antique sculpture or vase was acquired illegally or has come from an illicit dig. An app developed by the Fraunhofer Institute for Secure Information Technology SIT will help.

In 2018, some 223,000 items of cultural property worldwide were seized by law enforcement authorities, among them antique coins, ceramics, historical weapons and fossils. Most of these items came from illegal digs and should have passed through customs on their way out of the country. To track down such cultural treasures, customs officers carry out targeted inspections at airports or comb through online auctions.

In the KIKu project, meaning artificial intelligence for cultural property, experts from the Fraunhofer SIT are working with software developer cosee on an app that uses artificial intelligence to identify cultural property. All investigators need to do is take a few photos of the object from different perspectives on a smartphone. They send these pictures via the KIKu app to a server where a deep learning network compares the images to known cultural treasures. If the object is recognized as stolen, the investigator receives a warning. The similarity detection feature means that even cultural property taken from illegal digs which is still unknown can be assessed. If this AI finds similar objects, it selects the data records concerned and sends this information to the officials. So within a matter of seconds, customs officers and the police get, via the app, an initial assessment of the object's region and era and a lead as to whether its origin has to be investigated further.

The sword with the diamond handle is among the valuable objects spectacularly stolen from the Green Vault Museum in Dresden around one year ago. The new app was easily able to identify the treasure. © *Green Vault, State collection of treasures, Dresden, photo: Jürgen Karpinski*

Editorial notes

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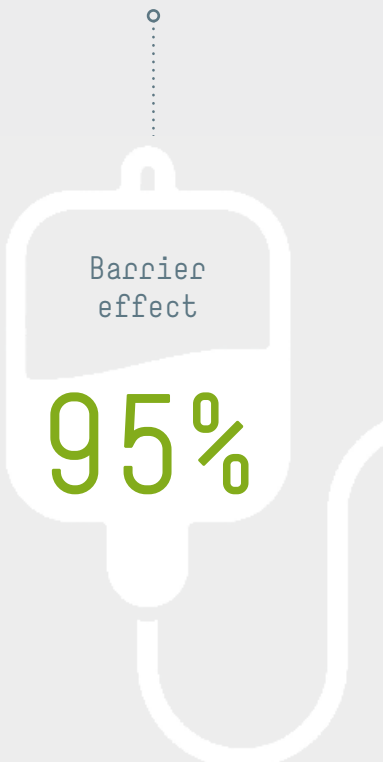
Reliable protection against plasticizers

Harmful plasticizers are found not only in plastic toys or packaging, but also in blood bags and intravenous tubes. A new process being developed at the Fraunhofer Institute for Surface Engineering and Thin Films IST prevents these dangerous substances getting into the body.



Banned from children's toys, allowed in blood bags: the PVC additive DEHP. © *iStockphoto*

Plasticizers are added to plastics to make them more flexible. Because they are not permanently bound to the polymer, these plasticizers can easily release themselves again. Blood bags and medical tubes often contain the PVC additive DEHP (diethylhexylphthalate). The EU has classified DEHP, which belongs to the phthalates class of substances, as toxic. The substance is banned from cosmetics and children's toys because of its toxic effects on the reproductive organs.

Dr. Thomas Neubert and his colleagues at Fraunhofer IST in Braunschweig use atmospheric pressure plasma processes to modify the DEHP's molecular structure on the plastic surface and to crosslink the molecules in a way that prevents the harmful substance from passing through the crosslinked lattice. The PVC itself is not modified, its mechanical properties are preserved.

The researchers' tests showed that plasticizer migration from soft PVC could be reduced by 95 percent. To test the long-term stability of the barriers, the treated soft PVC films were stored in air for four months. The result: The molecular meshwork produced does not dissolve, and the 95 percent barrier effect is preserved. The tests were conducted with PVC films that are used to manufacture blood bags. These results can also be extrapolated to other phthalate plasticizers.

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NEXT GENERATION COMPUTING

Problem in,
solution out:

“The future of computing is hybrid”

Digitalization is causing a torrent of data and the computer systems we use today are about to reach the limits of their efficiency. The time has come for a new hybrid computing generation that’s powerful, trusted and resource-efficient.

By Mandy Bartel / Photos: Oliver Hilterhaus

Computers with super powers? Many hopes are resting on quantum computers being able to better solve simulation and optimization problems in the future. They will demonstrate their superiority in the computer center of the future in combination with other technologies.

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NEXT

Creating something new from the ground up: It's still impossible to simulate larger molecules well. Quantum-based computer strategies could change this, and create new potentials in the development of medicines, chemicals and materials.

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NEXT

Computers for the future: In future hybrid computer architectures, quantum processes could solve complex, physical equations more quickly, optimizing in turn climate models and weather predictions. More precise modeling techniques will ultimately improve planning procedures, in the energy sector too.

"A new world from one square meter"

For many of us, the coronavirus has made the world small. This hasn't hindered the work of the photographer working on the cover story for this Fraunhofer magazine. "Sometimes, I take just a few steps through my apartment or photo studio," he says. "If I have just one square meter, I can create a new world."

Oliver Hilterhaus, born in 1963 in Mülheim an der Ruhr, where he runs a small gallery, discovered his passion as a photographer of miniature worlds ten years ago. For this Fraunhofer magazine, he built a skyline from staples, fashioned high-tech medical equipment from screws and nuts and used pieces of a jigsaw puzzle to recreate the arctic. The lonesomeness of the bear cub on the ice floe is his personal favorite motif. He now has a collection of some 2000 figures, "figurines" as he fondly calls them. And through his constantly shifting perspective, he has gained a new perception of the world – of the bigger world that is. He does find, though, that many big things have a very irrational effect on him today. www.oliverhilterhaus.de

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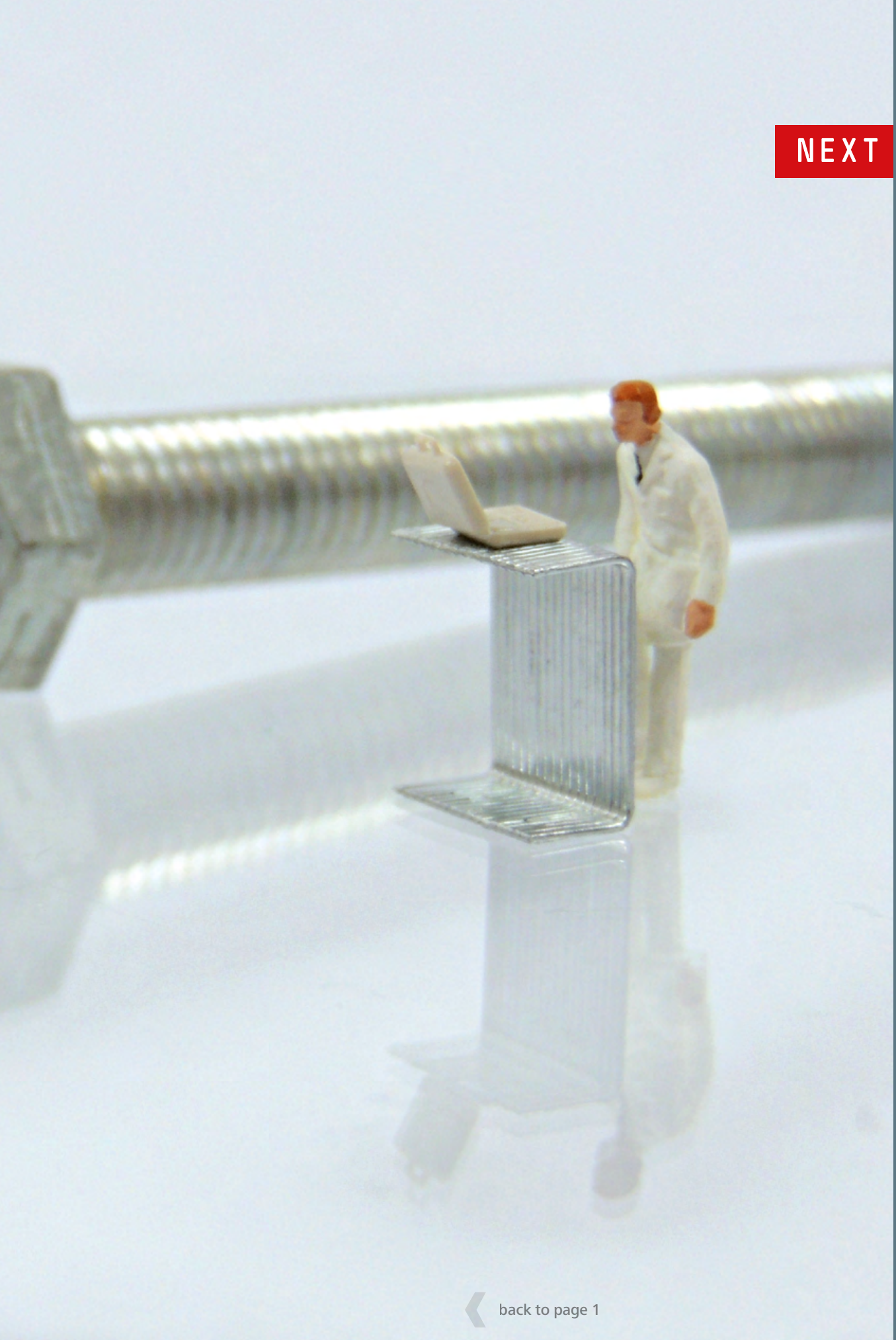

NEXT

Artificial synapses and neurons: Researchers have looked deep into the human brain to help in the development of neuromorphic chips. Based on neural networks, the circuitry of these chips is highly energy efficient and fast.

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Statisticians are predicting a five-fold increase to 175 zettabytes of data for the year 2025. That's 175,000,000,000,000,000,000,000 bytes.

"To successfully meet these challenges, we need to develop trusted, high-performance and resource-efficient hardware and software."

Prof. Albert Heuberger, Head of the Fraunhofer Institute for Integrated Circuits IIS

Not only in terms of health 2020 has set a turning point. The year has also seen unprecedented data usage. In October, market analysts at the VATM (Trade Association of Telecommunications and Value-Added Services Providers) estimated that this year, 5.2 billion gigabytes of data will be transmitted across the German mobile radio networks alone – an increase of 52.9 percent on the previous year. Just five years ago, mobile data traffic amounted to just on 600 million gigabytes. In 2020, an estimated 72 billion gigabytes are whooshing through Germany's fixed network lines – that's an increase of 28.6 percent.

According to the Federal Statistical Office, some 33 zettabytes of digital data were generated worldwide even in 2018. Statisticians are predicting more than a five-fold increase to 175 zettabytes for the year 2025. That's 175,000,000,000,000,000,000,000 bytes. As a comparison: All of Shakespeare's works, as once calculated by the Computer Weekly magazine, comprised 5 MB, or 5,000,000 bytes in total. The next, and last, known unit is the yottabyte. And our digital society is moving ever closer to this limit.

Especially sensor data from the Internet of Things – besides video streaming – will drive forward data growth in the future. Artificial Intelligence, Industry 4.0, autonomous driving. All of these digital developments need increasing amounts of data, and that means more computing power and energy. In 2020, some 80 percent of all data generated were still processed in centralized systems and 20 percent in systems at the edge. It is likely that this ratio will have reversed by 2025. And as we watch the data mountain grow, we approach the limits of our existing computer technologies. Soon, they will barely be able to meet the new requirements for energy consumption, data processing and transfer times.

And the torrent of data is not the only challenge. As we become more and more reliant on digital networks and data, the demands for a secure and resilient digital society grow. Especially technological sovereignty, meaning the self-determination and control over systems and data, is playing a key role in Germany and in the EU. Until now, the market power of American IT giants like Microsoft and Google in particular has led to almost complete dependencies.

"To successfully rise to these challenges, we need to develop trusted, high-performance and resource-efficient hardware and software," says Prof. Albert Heuberger, Head of the Fraunhofer Institute for Integrated Circuits IIS in Erlangen. Together with his colleague Prof. Anita Schöbel from the Fraunhofer Institute for Industrial Mathematics ITWM in Kaiserslautern, he is responsible for Next Generation Computing, an area the Fraunhofer-Gesellschaft has defined as one of seven strategic research fields. In the computer center of the future, there will be more ways to solve problems. As Heuberger explains: "The future is in hybrid, secure computer technologies that can be used in their own right or as a complement to other solutions, depending on the nature of the problem. We investigate which approach would be best for which problem – and adapt the architecture to the application concerned." Three technologies are key to Next Generation Computing: neuromorphic hardware, trusted computing and quantum computing.

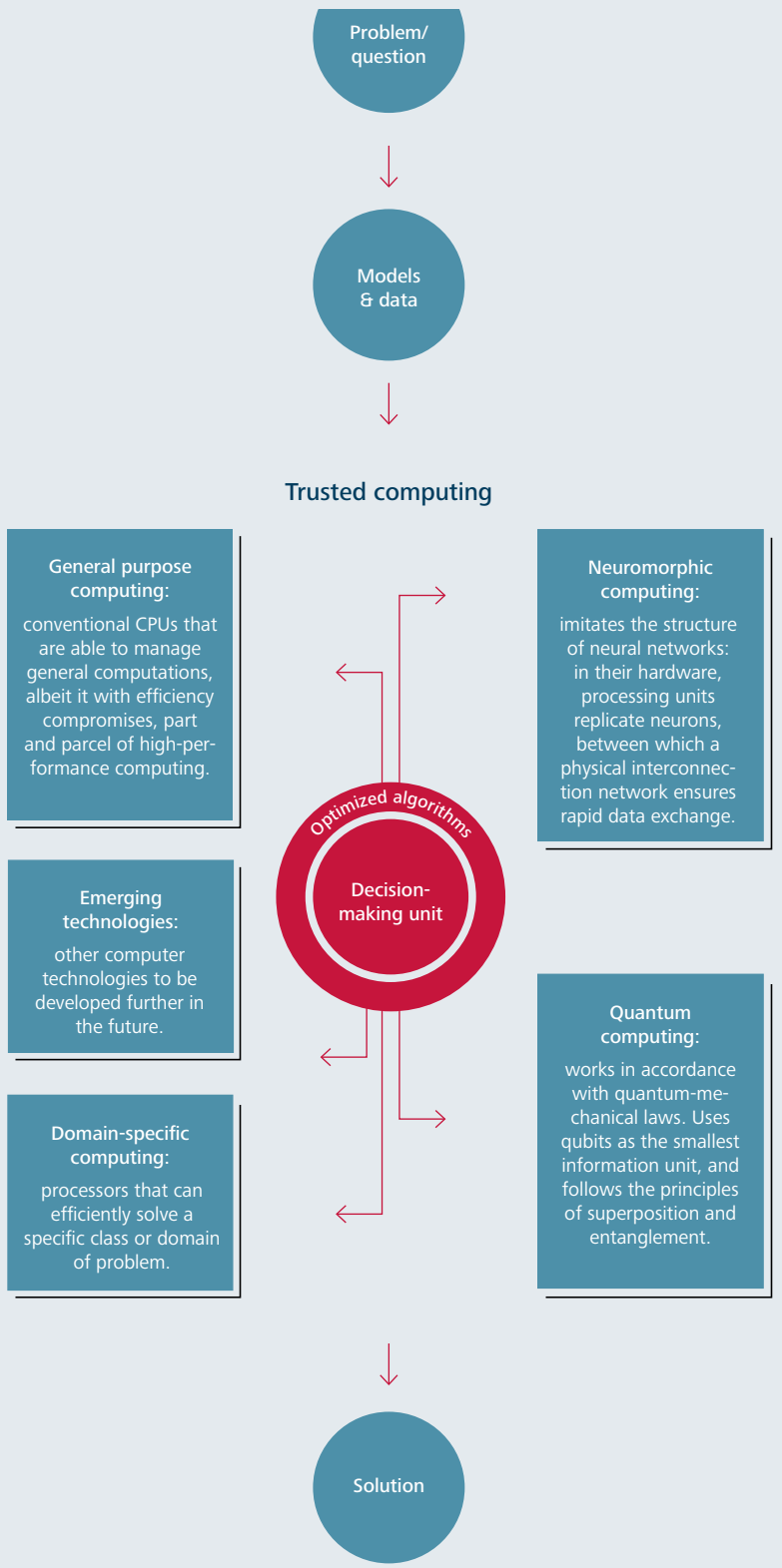
Pillar of the future number one: Neuromorphic computing

Our brain is an incredible phenomenon. It can process and store huge amounts of information. While doing so, it uses no more energy than a 20 watt light bulb. The neural networks, to which millions of nerve cells connect using synapses, are permanently flexibly adapting to new learning processes and experiences. This plasticity makes the human brain more than just a paradigm of efficiency. It is superior to today's AI systems, in the main highly specialized and inefficient.

Researchers have taken this success model, the special structure of the brain, as their archetype for mapping to the

circuits of neuromorphic chips. “Neuromorphic hardware is a new approach to design,” explains Dr. Loreto Mateu who is coordinating neuromorphic activities across several projects at Fraunhofer IIS. Neural networks are being used as algorithms for integrated circuits in order to imitate neuro-biological architectures. And here's the most exciting thing: “Data are processed in parallel in distributed memories, not centrally like in conventional central processing units (CPUs). So there's less transfer between memory and CPU, such that the job can be done much faster and more efficiently by neuromorphic chips than by current processors.”

In Erlangen, Munich and Dresden, but at other locations too, researchers at Fraunhofer IIS, the Fraunhofer Research Institution for Microsystems and Solid State Technologies EMFT and the Fraunhofer Institute for Photonic Microsystems IPMS are developing new neuromorphic systems for semiconductor chips that are set to allow neuromorphic computing on mobile, battery operated devices directly. “This will do away with the time-consuming transfer of data between processor and memory, and that in itself will minimize the power consumption for complex computing and transfer procedures, and reduce the latency times as well,” explains Dr. Mateu. So the technology could prove to be an asset for AI applications in particular. Such applications currently need huge amounts of energy because machine learning involves parallelizing tasks in a complex matrix multiplication operation, and fast reaction times are required as well. ▶



Problem in, solution out, but one thing is for sure: the technology used in Next Generation Computing depends on the nature of the problem to be solved. © *Infographic: 2issue*

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"In terms of energy-saving potential, we are between a hundred and a thousand times more efficient than established AI hardware."

Dr. Thomas Kempfe, Fraunhofer IPMS

▶ "If the information is saved and processed in the system itself, a neural processing unit in a smartphone for example, the energy efficiency of such applications increases," the researcher explains. Her colleague Dr. Thomas Kämpfe at Fraunhofer IPMS, also working on the technology, adds: "According to circuit simulations, we can perform individual computing operations with a latency of just one nanosecond. In terms of energy-saving potential, this makes us 100 to 1000 times more efficient than established AI hardware, and compared to conventional hardware, the gap is even wider. The low latency of the individual operations means that even very deep neural networks can be computed in realtime."

This technology, then, has what it takes to tackle one of the most pressing challenges of digitization: the enormous energy consumption of computer centers. As early as 2014, the IT sector was producing as much CO_2 worldwide as the aviation industry as a whole, reports the German Federal Environment Agency. A study recently presented by the EU commission shows that the energy consumption of computer centers in EU member states will rise from 2.7 percent of the energy demand in 2018 to 3.2 percent by 2030. "As well as looking at local data processing, we are designing the electronics with intelligent standby and low-power circuit architecture to ensure minimum energy consumption," explains Dr. Mateu. And she reveals: "The first chips with a neuromorphic design are set to go into production in 2021."

And in the EU-funded NeurONN project, Fraunhofer EMFT is working with six European partners to develop a neurologically inspired computer architecture not based on common silicon technology. In this architecture, information is encrypted in the phase of coupled oscillating elements that are interconnected to form a neural network. "Just like the brain, the two key components in neuromorphic computing are called neuron and synapse – they replicate the distributed computing and memory units," explains Dr. Armin Klumpp, Project Manager at the Fraunhofer Research Institution. "The neurons used in the project are novel elements based on vanadium dioxide, which can be 250 times more efficient than state-of-the-art digital oscillators. The synapses are memristors – a word made up from memory and resistor – based on innovative 2D-dichalcogenide materials." In terms of switching speed, lifespan and energy consumption, these minute elements are set to be up to 330 times more efficient than current technologies.

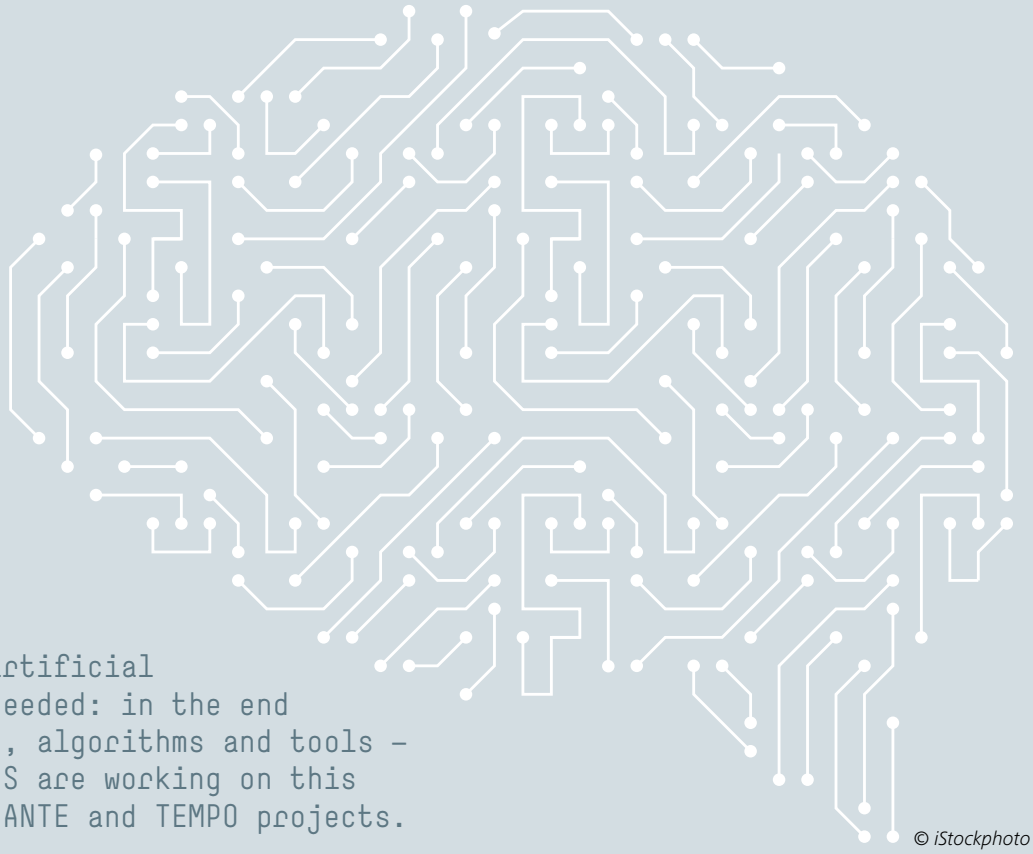
The neuromorphic chips will be used wherever energy efficiency and low latency times are key, because devices may be battery-operated or there's no time left to send data to the cloud and wait for a response. For example, to analyze biosignals during an ECG or EEC, as "electronic noses" for gas and odor detection, when processing signals for voice recognition or anomaly detection, or for hearing aids. Signal processing by mobile and portable sensor systems can also be much more energy-efficient when processing sensor data – relevant for autonomous driving, in satellite applications, predictive maintenance or condition monitoring in Industry 4.0. One major advantage of neuromorphic hardware is that information is stored locally, not in a cloud, making the devices more secure and improving the degree of data protection. Last but not least, neuromorphic chips provide the basis of Edge AI applications (see also Page 21).

Pillar of the future number two: Trusted computing

Trusted computing is the second element of Next Generation Computing and the one which, technologically, has flourished the most. "Trusted electronics and data security form the basis of all digital, networked systems, for the Internet of Things in particular, but also for AI," says Prof. Albert Heuberger from Fraunhofer IIS. ▶

"Just like the brain, the two key components in neuromorphic computing are called neuron and synapse – they replicate the distributed computing and memory units."

Dr. Armin Klumpp, Project Manager at the Fraunhofer Research Institution EMFT



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Shrewd end devices save energy

Edge AI is designed to get artificial intelligence to where it's needed: in the end device. This calls for chips, algorithms and tools – researchers at Fraunhofer IIS are working on this future technology in the ANDANTE and TEMPO projects.

By Dr. Janine van Ackeren

Thinking is hard work. And it's no different for computers. If they are to make decisions using artificial intelligence, they actually need far more power than people and animals. A specialist AI processor, then, needs 7000 times more energy than a bee's brain to recognize a flower in a picture, for example. This high energy consumption is especially problematic if the artificial intelligence is to be moved to the end devices – so to sensors which, installed in a bridge, are supposed to detect whether the tension of the structure changes, or in portable devices that can be switched on and off by voice commands. We also call this Edge AI.

This kind of artificial intelligence especially offers a host of advantages: it will work even in places where no Internet connection is available. It is much faster than conventional AI, which sends the data to a cloud and analyzes it there. And it protects privacy, data sovereignty, security and safety, because the data is never surrendered, or disclosed only to the extent absolutely necessary. Until now though, its weakness is the huge energy consumption of the components. So how can we reduce the energy consumed by artificial intelligence to a level that opens the door to Edge AI applications? At Fraunhofer IIS, Dr. Marco Breiling and Dr. Loreto Mateu and their teams are now facing this challenge in two projects: in the TEMPO and ANDANTE projects, in which, alongside numerous other partners, the Fraunhofer Research Institution for Microsystems and Solid State Technologies EMFT and the Fraunhofer Institute for Photonic Microsystems IPMS are involved. "We are developing the energy-saving chips, hardware-aware algorithms and the associated tools that Edge AI needs. With these tools, we are already keeping an eye on the limits of the hardware for developing the algorithms and are considering them in the optimization process," says Dr. Marco Breiling, Chief Scientist for Communication Systems Research. In the TEMPO project, the research team is building on the Radar and Lidar application examples. In ANDANTE, its focus is on speech activity detection.

The chief attraction in both projects is the mix of digital and analog technologies that combines the advantages of both. "Multiplications and additions are no problem for analog computing – so for these applications we can bypass a complex digital circuit that would consume a lot of energy," reveals Dr. Loreto Mateu, Group Manager for Smart Sensing and Electronics Research, who is responsible for the development of analog components. For the control, on the other hand, digital circuits are required, and these come from Breiling's team. Analog and digital circuits developed specifically for certain AI applications are what make Edge AI possible.

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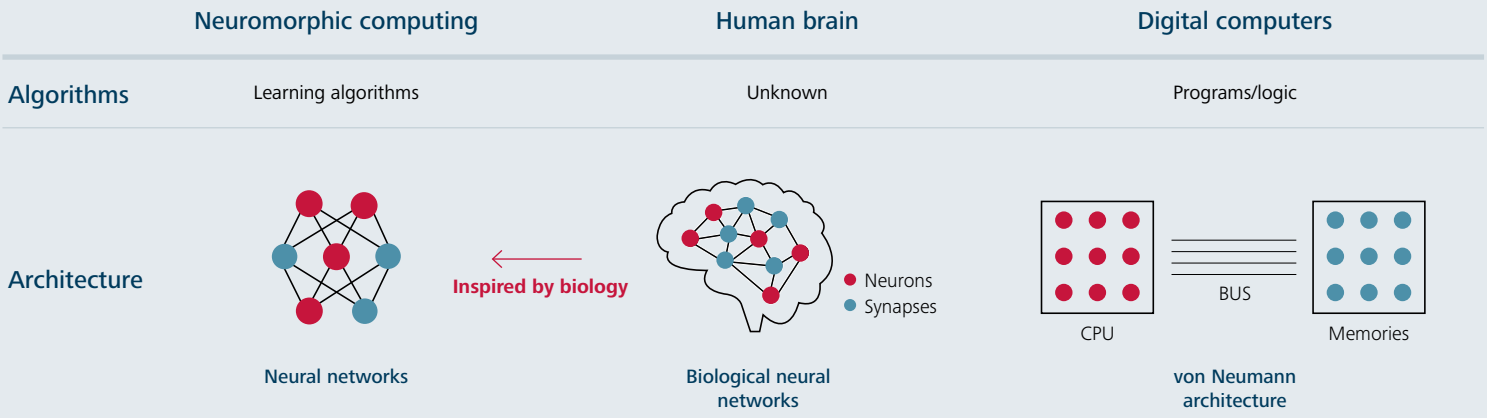
Description of the technologies



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"Trusted electronics and data security are the basis of all digital, networked systems."

Prof. Albert Heuberger, Fraunhofer IIS

▶ Especially wherever personal or security-critical data are processed, like for medical engineering and autonomous driving purposes, or where infrastructures are critical, it is essential for owners to have complete control over their ICT systems and for users to be informed about the properties of the systems they're using.

The entire data flow – from the end customer to the actual hardware that does the data processing – has to be considered. Time and time again in the past, hardware in particular had security vulnerabilities that allowed sensitive information to be read. Only in spring 2020 did it become a known fact that many Intel and AMD chips were permitting unauthorized access to protected data. The fault was in the design of the processors. Vulnerabilities can also often be undocumented interfaces or implementation faults. "Trusted computing, then, is not only about fail-safe hardware and trusted software. It comprises, starting with secure semiconductor production, non-readable memory contents and secure identities of computers through to the secure embedded systems," explains Prof. Heuberger.

Dr. Patrick Bressler, head of Central Office, the Fraunhofer Group for Microelectronics, addresses another crucial issue: "Many critical components of digital technologies are today produced outside Europe, and foreign suppliers hold quasi-monopoly market positions in many areas of the digital value added chain. This creates a heavy reliance, and it could be used to Germany's disadvantage." As also recognized by the politicians: The "Trusted electronics – Made in Germany" initiative, financed by the German Federal Ministry of Education and Research (BMBF), will develop and apply the relevant standards, norms and processes on the basis of a national and European chip security architecture. The declared aim: to strengthen Germany's technical sovereignty over the long term.

In the TRAICT innovation program (TrustedResource-Aware ICT), 18 Fraunhofer Institutes work together to create framework conditions to ensure that information and communication technology is trusted and compliant, and can be used in a self-determined and secure way. The key question is: How can the reliability of critical electronic components and systems in globally interwoven supply and value-added chains be validated and guaranteed?

The higher-level system in TRAICT is a 5F mobile radio scenario, which can also be transmitted to other applications. The participating research teams are examining system architectures and their components for their trustworthiness and energy efficiency. They want to make it easier for users to better examine the hardware, and they do this through a

transparent design and disclosed specifications. The aim is to maintain an overview of exactly what is implemented and how, and hence of functionality monitoring.

The use of open-source platforms, which offer more transparency and allow user-specific modification and precise examination of the design, plays a key role here. An ecosystem with open-source RISC-V processors will allow companies to build their own hardware, even in small quantities. The project also investigates analysis methods for chips in order to uncover any unwanted functions, such as hardware Trojans for example. It also seeks to optimize energy efficiency – both locally in components and assemblies, using new semiconductor materials and so on, and also with the distributed computing strategy in the system through predictive maintenance or AI.

III Pillar of the future number three: Quantum computing

The third pillar of future computer architecture is quantum computing. It is this technology more than any other that has become the benchmark for high hopes in recent years. Many states are promoting the research with billions of euros, large companies and start-ups are competing for the qubits. Quantum computers are expected to take just seconds to solve problems for which computers today need years. Quantum-based computers are much faster than their normal counterparts because their information units are elementary particles, like electrons or photos, with quantum entanglement: Qubits.

We can think of qubits as rotating particles that decide on a rotational direction or polarization only when measured. Until such time as they are measured, they remain in a mixed state, called a superposition. As a result of this effect, the individual quantum states can not only have a value of 0 or 1, like conventional bits, they can also have any combination of the two. In this superposition, the particles can be entangled with one another and used like this for logical computing operations. This way, complex tasks are computed in parallel rather than in linear fashion. Adding one qubit doubles the system's performance.

"But quantum computers are not expected to be able to solve every problem," warns Anita Schöbel, Head of Fraunhofer ITWM. "Success hinges on having an algorithm which is able to use the effects of quantum mechanics. An exponential improvement of quantum computing in contrast to classic computing is possible in some applications, but for most applications this is still under research. We are in the process of investigating what kind of problems we can better solve in future with quantum computers and which using alternative architectures."

To find the answers, Fraunhofer has recently collaborated with IBM to bring a quantum computer, the IBM Q System One, to Germany – the first of its kind in Europe. The fragile freight arrived in Germany by ship in November. The quantum computer is currently being installed and is scheduled to go into operation in Ehningen in Baden-Württemberg in January 2021. "The aim is to test the first applications directly. That way, we will be expanding not only our in-house expertise, but those of the German economy as a whole. We now need access to the quantum computer, to enable us to build and operate the next generation," Prof. Oliver Ambacher is convinced. He is head of the Fraunhofer Institute for Applied Solid State Physics IAF in Freiburg and one of the spokespersons for the Fraunhofer Competence Center Quantum Computing. The Center was established as a central point of contact for anyone wanting to research on and with the quantum computer together with Fraunhofer Institutes. ▶

Facts

Fast processing

Data security and protection

Flexible

Energy-saving

"We now need access to the quantum computer so we can build and operate the next generation."

Prof. Oliver Ambacher, Fraunhofer IAF

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▶ **The key questions,** to which the scientists are seeking answers, are: How do we need to condition problems to be able to solve them efficiently using quantum computers? What is the procedure for building the algorithms for this? And how will we formulate computing methods on these computers so that they can achieve their full potential? Ambacher makes a comparison with early PCs: "Back then, Microsoft provided conventional computers with software that enabled users to easily write letters or process images without any in-depth IT knowledge. We now need to do the same for quantum computers to make them usable for a broad range of applications."

Another area of research is the hardware. To master quantum computers and keep the qubits stable, they have to be cooled down to extremely low temperatures close to the absolute zero point of -273 °C. This cryogenic operation makes it difficult to connect the qubits to the power management, readout and electronic systems that are needed for the computing processes.

In the EU-funded project SEQUENCE, nine consortium partners, including Ambacher's Fraunhofer Institute IAF and IBM, are investigating how cryogenic applications in 3D nanoelectronics can help improve key technologies for quantum computers. Another challenging problem is the error-proneness of the hardware: even the most advanced quantum processors threw an error in approximately one in a hundred to one in a thousand operations.

The experts agree that quantum computers will come into their own in three main areas, as shown just recently in a study conducted by the Fraunhofer Big Data and Artificial Intelligence Alliance on the multifaceted range of market and specific potentials of quantum computing:

» They reliably solve complex systems of equations and, because of that, are better able to predict dynamic systems. This is key to more trustworthy climate models and weather predictions, but also to fraud detection or risk analyses in the financial sector.

» They are faster at finding solutions for so-called problems of combinatorial optimization. This bodes well for making tremendous progress in machine learning. Logistics can be enhanced by optimizing delivery routes, resources in industry can be used with greater care.

» They are able to simulate quantum-mechanical systems with greater precision, since they follow the same laws. And in the medical and chemical sectors, structures at the lowest possible level can be investigated and novel material properties can be predicted.

This will all become reality in January 2021 in Baden-Württemberg, when the first projects with the IBM Q system kick-off. The focal points are the design of innovative materials and quantum-chemical reactions, the optimization of complex state systems and the development of powerful

From A to B and C with greater efficiency: Future computer systems with quantum power will ensure optimal distribution of limited resources in logistics.

quantum memories and scalable quantum processors. The application fields under examination include the modeling of batteries and fuel cells, stability analyses of critical infrastructure networks, as well as applications and algorithms for manufacturing, development, logistics, energy and finance.

In Rhineland-Palatinate, researchers at Fraunhofer ITWM are aiming, in the research project "EnerQuant: Fundamental Modeling in Energy Economics With Quantum Algorithms," to use the advantages of quantum computing to solve a major optimization problem from energy economics. The designated fundamental model can be used to answer questions such as: Which power plants are needed with which capacities to generate energy or which energy tariffs are appearing on the stock exchange? The aim is an adequately accurate stochastic modeling of the German energy market. This is being made increasingly complex by the expansion and associated growing supply of renewable energies and therefore calls for new approaches.

And the research team hopes that, in the future, quantum computing will be able to solve this problem of combinatorial optimization with greater speed and precision. Fraunhofer ITWM and its partners are therefore developing algorithms for quantum computers and quantum simulators. The first step is to define a simple fundamental model that can be translated into a quantum-mechanical problem and mapped on a quantum simulator. Then, the model and the quantum simulator will be developed step-by-step until such time as the German energy market can be precisely modeled. A comparison of the results on conventional high-performance computing systems acts as a benchmark. At the end of the project, the results from EnerQuant will be available for use in industry, especially in the capital and energy sectors.

Problem solved

High-performance computing, neuromorphic chips, quantum processors, all in one trusted infrastructure – how will we solve problems in the future? Prof. Anita Schöbel is convinced that current universal computers are not about to become obsolete anytime soon, instead they will be optimized by the new technologies: "The computer center of the future will be a heterogeneous one. For every special application, a decision unit assigns the application to the hardware which can solve it most efficiently (see figure on page 19). And it will still need conventional high-performance computing, to control quantum processors for example."

In all likelihood, the new technologies will in future be used in a complementary capacity as accelerators and to solve specific problems in existing computers. So neuromorphic hardware will be used to design energy-efficient neural networks for artificial intelligence applications. Quantum processors will get their chance later for simulation and optimization processes. "But ultimately, users are not interested in how their problem can be solved. All they want to know is that it will be solved to the best of the computer's ability," emphases the Fraunhofer scientists, and she promises: "That's the true aim of our research." ■

> "But ultimately, users will be less interested in how precisely their problem can be solved. All they want to know is that it will be solved to the best of the computer's ability."
>
> Prof. Anita Schöbel, Fraunhofer ITWM

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A voice from the business world

Quantum technology makes it to the market

This technology will push firmly anchored technical boundaries and enter a new dimension – including, but not only, in the field of measuring precision.

A guest editorial by Dr. Robert Bauer, Chairman of the Executive Board of SICK AG

Sensors are the key to the industry of today and tomorrow. In logistics, production and process automation: Sensors monitor, detect, measure, secure and save data. Sensor solutions are driving digitization and innovation. The fast-paced development of software, like Augmented Reality or Deep Learning for example, is opening new doors for Industrie 4.0. Industrial applications make exacting demands on sensor systems. To meet those demands, sensor hardware has been consistently further developed and refined. The dramatic increase in processor performance in particular is creating completely new solutions time and time again.

"Quantum technology will lead to major changes in practically all sectors and industries."

Quantum technology will lead to major changes in practically all sectors and industries – from the automotive sector to the chemical industry to the financial markets. The commercialization of quantum technology is a marathon to be run over the next few decades. Key players such as applied research, industry and politics will therefore need to take a deep breath. Together with the TRUMPF subsidiary Q.ANT, SICK is now in the race to get industrial quantum sensors ready for mass production.

Quantum effects are opening the doors to entirely new measuring processes by using the relationships between the individual quanta. Quantum technology, then, is pushing firmly anchored technical boundaries: Where it has not been possible to measure specific signals as yet, quantum effects from signal noises are able to provide additional details. Quanta can assume various states at the same time ("superposition") or even be in several positions at more or less the same time. And thanks to digitization, statistical evaluations at the level of the individual quanta are possible. In this combination in particular, the precision of the measurement reaches a new dimension. This makes quantum sensors a key technology for the future of industry and delivers a solution to meet existing challenges.

Quantum sensors are a key technology

With quantum sensors, SICK will is operating in an area that belongs to the company's early historical roots; an area that created its initial success and which has never been more important than it is today. In the nineteen fifties, Erwin Sick invented a device for measuring the density of smoke in chimneys. This was an important foundation for introducing the upper limits for the emission of harmful particles and gases and, consequently, being able to reduce the impact on the environment.

Dr. Robert Bauer

... has been the Chairman of the Executive Board of SICK AG since October 1, 2006. He is also responsible for the Products & Technology department. Dr. Bauer joined the company in 1994 as Head of Research & Development for Automation Technology. In 1998, he assumed overall responsibility for research and development. He was appointed to the Executive Board on January 1, 2000.

... born in Munich in 1960, Dr. Bauer studied electrical engineering with core modules on electrophysics/optics at the Technical University of Munich from 1979 to 1985. In 1990, Robert Bauer earned his doctorate in the field of semiconductor-based integrated optics.

SICK is currently producing sensor solutions for dust measurement technology in Dresden. The project group for the quantum sensor is also located there. The proximity is important for drawing on existing knowledge about industrial applications and incorporating that knowledge into the development work. In combination with digital sensor solutions, additional information about evaluating sensor data is provided. This makes it possible to classify extremely small, extremely low density particles under realtime conditions.

Entry into existing markets

With this technology and the improvements it brings to measurement processes, SICK will initially enter markets with which it is already familiar. This is primarily about providing users with data to add value to processes and improve the handling of resources. The quantum sensor will be able to measure particles that are a fifth of a micron in size.

The sensor records information about particle size, distribution, concentration, speed and direction. In the semiconductor industry, these sensors can identify contamination produced by the machines themselves which has so far been undetectable online. Quantum sensors are able to record such contamination and hence prevent yield problems. In addition, continuous realtime measurement of even the tiniest particles in powder production, in the cement industry for example, is also possible. The grain size is crucial to the end product. If the grain size is wrong, concrete will not achieve the strength it needs at a later time. So until now, samples have been taken on a regular basis and analyzed in the lab. This can take hours. If the result is unsatisfactory, the product may even need to be disposed of. Quantum sensors are able to run an analysis in realtime. So there's no waste of resources.

And the data can be retrieved from anywhere in the world at any time As well as the semiconductor and cement industries, public buildings are also promising areas of application: As an example, quantum sensors will be used in subways to check compliance with the particulate threshold values and control the ventilation systems to optimum effect. And many other applications are conceivable too.

The competition will help achieve the all-important implementation in the market. If only one company creates a market, it will be very limited. Competition is good for business, even today. ■

"Quantum sensors can help prevent a waste of resources."

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The car as a living space on wheels.
A dream that dates back to the nineteen fifties: to travel in comfort while leaving the mind, hands and feet free for the important things in life. "Highways will be made safe – by electricity," they said, back then. Today, the dream is becoming a reality, like in the cockpit of the BMW Vision iNEXT (top), which was made tangible last year at the Consumer Electronics Show CES in Las Vegas.
© alamy/F1 Online, BMW, Composing: Vierthaler & Braun

Autonomous and safe

The dream of a traveling in perfect comfort in the car is an old one – and has never been as close to reality as it is today. Yet risks remain. An onboard electrical system failure could have fatal consequences. Fraunhofer IZM and IISB guarantee safety with a unique electronic module.

By Olga Putsykina, Britta Widmann

Danger on the road – and we can't stop the car! A nightmare scenario. With autonomous driving, an electric short circuit can cause the brakes and the steering system to fail. Autonomous electric vehicles draw power from two sources: a high-voltage battery and a conventional 12-volt battery. So safety-critical systems, such as steering and brakes, are connected to two sources of power at all times. To safeguard against a complete failure of the batteries caused by a short circuit, research teams at the Fraunhofer Institute for Reliability and Microintegration IZM and at the Fraunhofer Institute for Integrated Systems and Device Technology IISB have developed a disconnect device. This electronic module isolates the fault in the onboard electrical system and ensures that the electric vehicle reacts reliably in case of need.

Partial shutdown only

In today's onboard electrical system architecture of highly and fully automated vehicles, isolating the affected area by means of an overload safety device is common practice. This arrangement, however, leads to a complete deactivation if a fault occurs. For highly and fully automated driving, such a procedure is possible only if all components and the onboard electrical system are designed redundant, meaning they exist in duplicate. This costs money, space and weight. The disconnect element developed by Fraunhofer researchers, however, fully guarantees safety during the journey even without a second onboard electrical system by deactivating the faulty components in the system and maintaining a supply of power to safety-relevant components.

Recovery on the hard shoulder

Phillip Arnold, research associate at Fraunhofer IZM, explains: "In conventional systems, any undervoltage while on the road can trigger a sudden and uncontrolled failure of the entire onboard electronics – including the braking and steering systems. This presents an unacceptable risk, particularly when traveling at high speeds. But with our new module, part of the onboard electrical system continues to function as before, so that a fully automated vehicle would still have enough time to get its passengers to safety, onto the emergency lane of the freeway, for example, or a parking lot."

In the field of power electronics, engineers use so-called MOSFETs – Metal Oxide Semiconductor Field-Effect Transistors – to switch or block large electric currents or voltages. Equipped with 16 of these MOSFET switches, the newly developed disconnect device is capable of switching up to 180 amperes of current. If this threshold value is exceeded – in the event of a short circuit, for example – the electrical switch opens and thereby shuts off the power. And given that the MOSFET switches are capable of handling up to 300 amperes and therefore operate well below their maximum permissible load, they have a significantly longer lifespan than conventional solutions.

Sixty times faster than conventional fuse systems

In tests where researchers intentionally triggered short circuits, results showed that the module is capable of reliably isolating a current of up to 700 amperes without there being any propagation of the initial short circuit. There are also clear advantages over conventional systems in terms of switching speeds. While a conventional fuse takes some 20 milliseconds to trip, the disconnect device detects a fault within 10 microseconds and only requires a further 300 microseconds before tripping. This makes it more than 60 times faster than current fuse systems.

The finished module has already been successfully tested in an electrically powered BMW i3 demonstrator vehicle and is designed in such a way that it can, in principle, be used in any electric vehicle. By protecting against a complete failure following sudden problems with the onboard electrical system, this new development marks a groundbreaking step towards safe and reliable autonomous driving. ■

Until now, onboard electrical systems and components have had to exist in duplicate. A small electronic module can save a lot of time, space and weight.

Small: the electronic module. Great: the degree of safety. © *Volker Mai*

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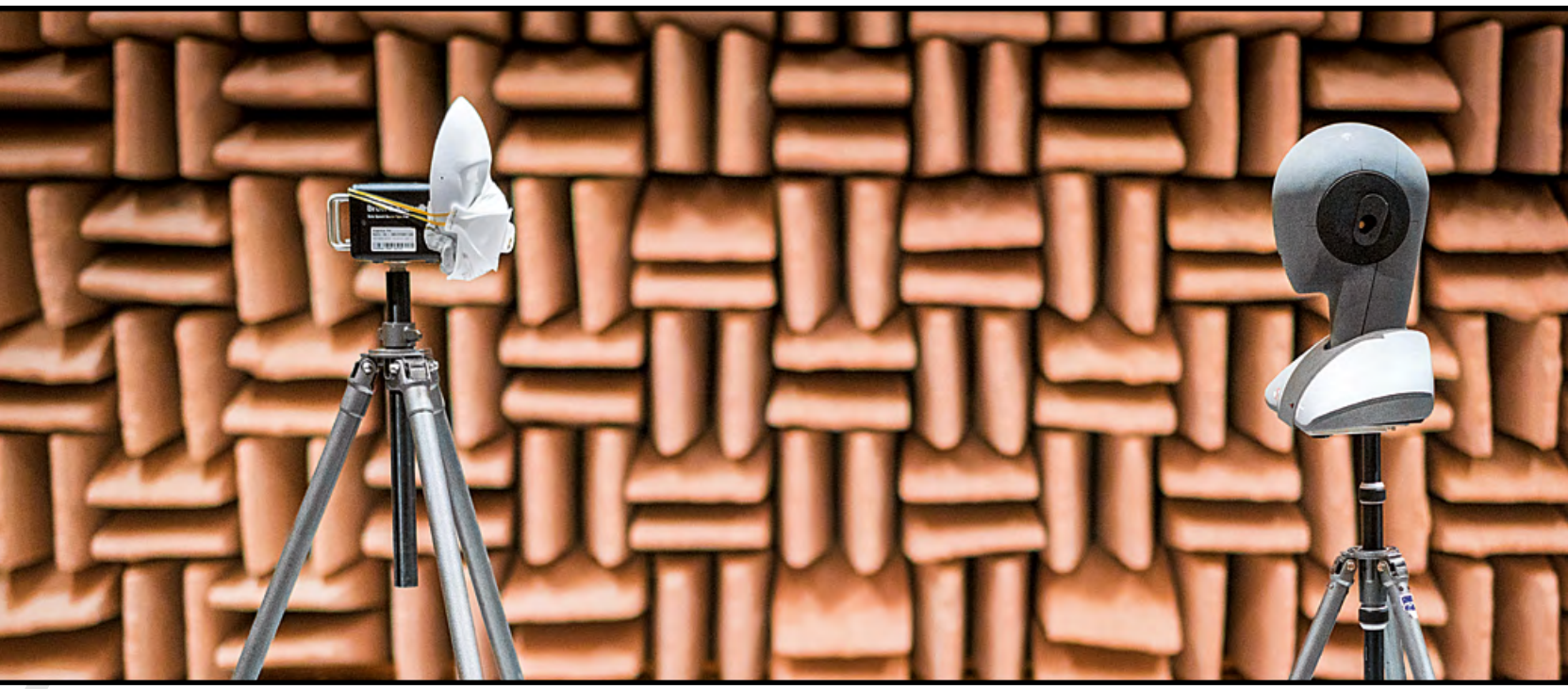

Tech dialog: The dummy transmits through the mask with its artificial mouth. © *Fraunhofer IBP*

Excuse me?!

We live, we talk, we negotiate with masks over our mouth and nose. A Fraunhofer research team has now quantified how this affects speech intelligibility – and suggested some workarounds.

By Dr. Janine van Ackeren

Fabric masks reduce speech intelligibility by up to 15 percent.

If we were to rank the phrases that have snowballed due to the coronavirus crisis, "Excuse me?" would certainly be topping the list. Mandatory mask wearing is immunologically effective, but causes a problem with speech intelligibility. How many times do we need to repeat things like "200 grams of cottage cheese, please!" before the shop assistant works out what it is we want from the mutterings that tumble out of the mask? This reduced speech intelligibility is a particular concern for those who are hard of hearing – masks cover the lips as well, hindering understanding even more. Coronavirus aside, mask mutterings can cause discomfort: When all said and done, masks belong in the daily routines of physicians, care workers and rescue teams.

How speech intelligibility actually suffers – and how this differs from mask to mask – has been examined by scientists from the Acoustics Department of the Fraunhofer Institute for Building Physics IBP. Not only did they find what each and everyone of us fathoms from everyday experiences, the scientists also delivered quantifiable results. For the first time, these results are giving mask development and production a scientific foundation in terms of speech intelligibility. "If all around us is quite still, in controlled laboratory conditions for example, masks have barely any effect on speech intelligibility when worn at the recommended safety distance of 1.5 meters," says Maria Zaglauer, Psychologist at Fraunhofer IBP. "If, however, we add a background noise of 35 deci-

bels, fabric masks reduce speech intelligibility by up to 15 percent." Medical single-use masks do much better: These masks reduce speech intelligibility by just five percent. FFP2 masks sit somewhere between at about ten percent. The "heavyweights" in terms of speech intelligibility are the half and full masks like the ones worn by firemen for example, who have to search for people in a building full of smoke caused by a blaze. This design makes the spoken word 26 percent less intelligible.

Test series with a talking dummy

The team decided to carry out the tests using an artificial speaker. A dummy with an artificial mouth gave out a defined signal, perceived by the human ear as an unintelligible whooshing. Yet this noise is well-defined: it expresses spectrum and volume of the human voice in a precise, and most importantly, reproducible way. Once the artificial mouth had released this noise into the acoustic anechoic chamber at Fraunhofer IBP, it was covered with a number of different masks. The signal was recorded by measuring microphones at defined distances. "We also had the face speak in sentences, so that the effect was also perceptible for non-acousticians who are less able to understand the readings," explains Benjamin Müller, the engineer who carried out the tests.

The research team analyzed the signals that arrived at the microphone in two different ways. First, it used an evaluation algorithm to compare the individual frequencies of the "voice," uttered by the face with and without a mask – in a range of 63 to 8000 Hertz. Conclusions were then drawn on which tones penetrate the mask well, which not as well, and how the mask changes the timbre. The results show that masks dull the speech and "light" tones are more adversely affected – including, and especially, the frequencies that are important to speech intelligibility. The team also found how masks impact the volume of the overall signal, meaning the speech level actually perceived. "Masks absorb between 5 and 15 decibels of sound. That is equivalent, on average, to a doubling of the perceived distance to the person speaking," says Müller summing up.

In a second analysis, the scientists calculated the "Speech Transmission Index" (STI), a measurement of speech intelligibility. This index can have values of between "zero" and "one", "one" being optimum speech intelligibility. It works on a number of different variables: the volume of the surrounding area, the volume at which a person speaks and the room acoustics, such as reverberation for example.

To replicate speech intelligibility with a mask in the form of the STI, the researchers varied not only the mask types, but also the rooms, for all their tests. They performed their investigations, just like in the first analysis, in an anechoic chamber, the walls of which absorb all sound through their special coverings. This approach allowed the scientists to precisely measure and understand which noises come from the acoustic source itself – without distorting echoes. As valuable as this might be, the HiPIE lab has even better news: the room is not, as its name suggests, decorated with bright-colored cushions, peace graffiti and flowers. The name HiPIE actually stands for "High Performance Indoor Environment" and means: Any acoustic environment can be staged here – and within seconds, we can switch from the acoustics of a classroom to those of a church.

Hundreds of speakers embedded in the walls make this possible. For their tests, the researchers created an acoustic office environment, once with typical background noise and once with the loud background noise that might occur in open-plan offices. They took the final measurements in the institute's organ laboratory – a lab for musical acoustics. The acoustics here are like those of a large meeting room which is known to echo.

Better understanding thanks to transparent masks?

But what shall we do with all the knowledge we have about speech intelligibility with various kinds of masks? "Our findings are intended mainly to produce masks that improve speech intelligibility," says Zaglauer. And Müller adds: "These masks will make it easier to maintain the social distances that are important to controlling the coronavirus pandemic. It stands to reason, if you can't understand someone, you move closer." The scientists have therefore already held the first talks with potential industrial partners. Areas of focus include development of the system and the material. Fraunhofer IBP is able to examine non-woven fabrics, which have an equivalent immunological effect, for their impact on speech intelligibility and compare them with one another.

To complement the measurements, the research team is aiming to address the issue of speech intelligibility using test subjects and surveys as well. Although the readings from artificial mouth and ears are second to none in terms of accuracy and comparability, they are unable to cover every single scenario and replicate the multimodal perception of a human being. Does speech become more intelligible if a person wears a transparent mask and we can see both their lip movements and their facial expressions? The masks that will need to be worn in future could help answer that question – and spare us the unintelligible "Excuse me?" in many settings. ■

"Masks absorb between 5 and 15 decibels. That corresponds, on average, to a doubling of the perceived distance."

Benjamin Müller, Fraunhofer IBP

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Fraunhofer worldwide

Step by step to a correct posture

Wrong posture, standing for long periods and repetitive movements pose the greatest health risks at the workplace. In order to prevent musculoskeletal disorders, a research team at the Fraunhofer Center for Assistive Information and Communication Solutions AICOS in Portugal has collaborated with Luxembourg's IEE S.A. to develop "ErgoFeet": a shoe inlay uses sensors to detect pressure on the sole of the foot and draw conclusions about postural disorders.

This AI-based technology determines the severity and the duration of the poor posture to allow countermeasures, tailored specifically to the person, to be taken at an early stage to prevent damage to health.

Until now, similar devices have been used only in competitive sports or for rehabilitation purposes. "The ErgoFeet project has demonstrated that this technology can be applied in demanding work environments too," explains Project Manager Diana Gomes. According to the European Agency for Safety and Health at Work OSHA, three in five employees in the EU suffer from musculoskeletal disorders.

Portugal

Reducing mortality with an electronically controlled infusion set

Many diseases require intravenous infusion therapy. However, incorrect dosing can lead to severe complications or even death. Infusion pumps that provide controlled, safe dosing are expensive and need a lot of maintenance, so they are generally not used in developing countries. A team from the Uganda Industrial Research Institute has succeeded in developing a low-cost and safe alternative. A first prototype of the ECGF-IS ("Electronically Controlled Gravity Feed Infusion Set") has already been tested successfully in a clinical setting. The device will be improved in collaboration with the Fraunhofer Project Group for Automation in Medicine and Biotechnology PAMB.

In Ugandan hospitals, gravity-feed infusion by an elevated bag is standard of care. The flow rate is adjusted manually using a roller clamp on the tube, and this often leads to incorrect dosing. "The new system includes a drip sensor that automatically counts the number of drops of IV fluid," explains Tobias Behr, engineer at Fraunhofer PAMB. The drip rate remains constant, but can be readjusted. This system can simply be attached to existing bags or tubes. The ECGF-IS device is battery-powered and the researchers are currently developing a solar-powered charging station. The collaboration has received the 2020 German-African Innovation Incentive Award.

Uganda

The battery of the future made in Europe

For the change to a climate-friendly society to succeed, batteries have to store more energy, last for longer, and be safer and more environmentally acceptable. The European Commission has launched the "Battery-2030plus" initiative to coordinate these research endeavors. "Battery2030plus" is being led by Prof. Kristina Edström, University of Uppsala in Sweden. The Fraunhofer R&D Center for Electromobility Bavaria of the Fraunhofer Institute for Silicate Research ISC is playing a key role.

One main focus of the initiative is the computer-aided modeling and material development. The BIG-MAP ("Battery Interface Genome – Materials Acceleration Platform") project aims to achieve a better understanding of the complex reactions inside batteries and develop a completely new cell chemistry. An AI technology works out the combination of electrode materials and electrolytes that best allows the battery to store as much energy as possible or can be charged faster in various settings.

Fraunhofer ISC is heading the "Modular robot" project. Taking digital experiments as a basis, one aim is for autonomous robot systems to synthesize protective coatings in order to significantly accelerate the development of longer-lasting and more powerful batteries.

Hunting down pancreatic tumors

Insidious, aggressive and fairly invincible: Pancreatic cancer is one of the most deadly forms of the disease. The clinical picture is heterogeneous, the molecular biology of the carcinoma is largely unexplored. Working on the European project NExT, scientists at the Fraunhofer Institute for Biomedical Engineering IBMT have set themselves the task of identifying the specific biomarkers of pancreatic neuroendocrine tumors (PNETs). It will then be possible to detect the disease at an early stage.

Fraunhofer IBMT is heading the research consortium of six European partners. An international team of biologists, oncologists, pathologists, endocrinologists and engineers is setting up a tissue bank with genetically characterized PNET specimens and analyzing in detail their molecular properties and metastatic patterns. And Fraunhofer IBMT is developing a microfluid chip system with a special microhole structure for sorting and characterizing cancer cells. Circulating tumor cells are considered attractive biomarkers for fluid biopsies. This is because they identify blood-transmitted metastasis at an early stage. So not only could the cancer be diagnosed earlier, this technology also has the potential to increase the success of surgical intervention and improve survival rates.

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What the breath reveals

Cancer, diabetes, kidney problems – a special ion mobility spectrometer from Fraunhofer Project Hub MEOS will make it possible to detect diseases by analyzing the breath in future. Even before symptoms appear.

By Britta Widmann

© Stocksy/F1online

"And we can well imagine that our technology might one day be used to screen airline passengers to determine whether they are infected with the coronavirus."

Dr. Jessy Schönfelder, Fraunhofer MEOS

Sore throat, runny nose, fever – a common cold or a SARS-CoV-2 coronavirus infection? Research teams at the Fraunhofer Project Hub for Microelectronics and Optical Systems for Biomedicine MEOS are currently working on a measuring system that aims to precisely distinguish between the two diseases in the future. The innovative ion mobility spectrometer (IMS) recognizes whether people are infected with COVID-19 or a different respiratory tract disease. "The breath carries information that we use for the analysis," says Dr. Jessy Schönfelder, a scientist at Fraunhofer MEOS. A faintly sweet and fruity acetone odor, for example, can indicate diabetes. The Fraunhofer Institutes for Cell Therapy and Immunology IZI, for Photonic Microsystems IPMS and for Applied Optics and Precision Engineering IOF are collaborating on an interdisciplinary project at the Project Hub in Erfurt.

What diseases smell like

The odors that are characteristic of diseases are caused by certain volatile organic compounds (VOCs). They are emitted by diseased tissue or by the pathogen itself, even before the first symptoms become manifest.

A lot of diseases cause a change in the composition of the volatile organic trace gases in exhaled air that can be used as biomarkers. It is often a combination of several trace gases in a significantly elevated or significantly reduced concentration that is characteristic of a specific disease. "This is known as the VOC fingerprint or VOC pattern," explains Schönfelder.

There are specific marker combinations for many more diseases than was once thought. Each one of them has to be painstakingly deciphered. The chemist and her team are developing an ion mobility spectrometer with which to identify these VOC patterns. By no means an easy job given that each person exhales around 200 VOCs.

The work of the research team at Fraunhofer MEOS aims to use this new technology to detect a broad range of biomarkers. It is hoped, for example, that this method of breath gas analysis might provide the first indications of neurodegenerative diseases such as Alzheimer's – with earlier warnings than conventional methods, such as blood testing, and with also more convenience. It merely requires that the patients breathe into a tube.

"There's huge potential for sensor systems in breath gas analysis. IMS technology is noninvasive, sensitive and selective. And it is quick, inexpensive and also compact and portable, so there's no reason why it shouldn't be used in medical practices and hospitals. The finished product will be about the size of a shoe box," says Schönfelder.

Chips with alternating voltage

At the heart of this novel IMS system is a miniaturized high-field asymmetric ion mobility spectrometry (FAIMS) chip. The microelectromechanical system (MEMS) comprises an ion filter and a detector. The device also features a UV lamp. In the first instance, the VOCs – borne in a carrier gas – are pumped into the spectrometer, where they are ionized by means of UV light. In other words, they are transformed into charged molecules. The researchers feed these to the FAIMS chip, which was developed by Fraunhofer IPMS. They then apply an alternating voltage to the filter electrodes. By adjusting the voltage at the filter, you can control which VOCs get through to the detector. "This generates a VOC fingerprint, which enables us to identify the disease we're looking for," says Schönfelder explaining the process.

Dr. Jessy Schönfelder involved in analysis work at Fraunhofer MEOS.
© *Fraunhofer MEOS*

At present, the research team is working to enhance the electronic control system and to improve sample extraction and sample processing. Meanwhile, reference measurements with cell cultures have now been successfully conducted, and further investigations with clinical human samples are in the pipeline. In a project recently completed at Fraunhofer IZI, scientists using a similar technology were able to distinguish seven different bacterial strains.

Airline passenger screening

Specially developed AI algorithms are expected to simplify the evaluation of VOC fingerprints. "Each measurement generates half a million readings. So we want to use machine learning to analyze this huge volume of data," says the researcher. The algorithm is trained using samples from healthy test subjects and cancer patients. The results of such measurements are available within just a few minutes.

The measurement system is also featured in the Fraunhofer cluster project M³Infekt, which is developing a modular, multimodal and mobile monitoring system to enable rapid intervention in the event of a sudden deterioration in the condition of COVID-19 patients. "We are focusing our research on the early detection of cancer. However, at the moment, we are still working on distinguishing between Covid-19 and a common cold. In principle, this is indeed possible," explains Dr. Jessy Schönfelder. "And we can well imagine that our ion mobility spectrometer might one day be used to screen airline passengers to determine whether they are infected with the coronavirus," she says. ■

A lot of diseases cause a change in the composition of the volatile organic trace gases. A VOC fingerprint emerges.

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"Without Fraunhofer? Our spin-off would simply not exist!"

Going online to buy shoes where even the carbon footprint fits? The three founders had a most intriguing idea. The Fraunhofer-Gesellschaft provided the expertise and the start-up finance. The result: mySHOEFITTER, the auspicious spin-off.

By Dr. Janine van Ackeren

Coronavirus has changed life so much, and that includes our shopping habits. While ambling leisurely through the shops downtown was once part of most people's everyday lives, lockdowns and the reticence to venture out have boosted online sales enormously. The pre-Christmas period may well have driven the number of online orders to new record levels. Yet as practical as ordering online may be in many ways – it also has its pitfalls. When we buy shoes for example: One in two pairs of shoes ordered on the Internet ends up back with the seller – 75 percent of these returns are because the customer ordered the wrong size. All because sizes are not standardized: If we need size 41 in our favorite brand of running shoe, a pair of size 42 brogues from a different manufacturer might be a squeeze. So many online shoppers get over this problem by ordering the model they want in three or more different sizes and sending back the ones that don't fit.

But shoe returns are not without their drawbacks: 15 euros in costs, and 500 grams of carbon footprint

Markus Piebrock is the one who resolved to change all this. He's been working on the idea since 2013. As co-founder of online shops Tennis-Point and Jogging-Point, he has learned more than just the ins and outs of sensitive feet. "Although only 30 percent of shoes we sold were being returned," he recalls, "they proved a significant cost factor." If we include the postage, packaging and personnel expenses, one return costs an online shop a total of 15.18 euros. And let's not forget the environment: every shoe return creates a carbon footprint of 500 grams, then there's the packaging waste and the shoes that end up being destroyed because they can't be processed for a new shipment or the cost of doing so would be too high. Besides all that, it's time-consuming and stressful for consumers to carry the boxes containing the ill-fitting shoes back to the post office.

Piebrock's idea sounds simple – and promises clear benefits for the mail order business and for consumers: Once they find a shoe model they like, they follow a link to open an app or the technology integrated into the participating online shop, and take a photo of their foot. That's it. In the background, algorithms use the image to calculate the customer's foot size down to the last millimeter. The results are checked against the manufacturer's data for the selected model, these values having been saved in a database in millimeter or inch format. The entire process takes just a few seconds. There's nothing more for the customer to do: their shoe size is automatically displayed on the shop's online page.

Tackling development alone? No easy feat ...

Putting the idea into practice, however, turned out to be more difficult than expected: The first prototype Piebrock developed a few years ago achieved the correct results with only four out of every hundred measurements. As simple as the task might sound in principle, the algorithms required to solve it are extremely complex. The software has to recognize which parts of the photo belong to the foot, which toe is

The mySHOEFITTER team: Frederik Dürr, Claudia Ebbers and Markus Piebrock (f.l.t.r.) © *Lars Berg*

the longest and the distance to the very back of the heel. Piebrock and his colleague Frederik Dürr realized that going it alone was not an option. "That's where Fraunhofer stepped in," recalls Piebrock. "Shortly before, I had met Professor Harald Mathis from the Fraunhofer Institute for Applied Information Technology FIT at an event of the Bundesverband für mittelständische Wirtschaft (BVMW), an association for small and medium-sized businesses. We then became friends. He encouraged me to take the algorithm to the next level with the support of Fraunhofer." Or to put it more succinctly, to redevelop the algorithm, as things have turned out. "Many people can take approximate measurements, it's the last tricky five percent, though, on which it all hinges. Because there's just four to six millimeters in half a shoe size, the app has to work to an accuracy of at least three millimeters," says Piebrock explaining the challenge they face. Thanks to the cooperation with Fraunhofer FIT, founders Piebrock, Dürr and, Claudia Ebbers, their new colleague, have successfully cleared this hurdle: In the first large test studies, 95 of 100 measurements are now delivering the correct result. One of a kind, as Piebrock proudly points out.

An excellent idea, plus reliable implementation: a solid basis for a spin-off that aims to bring the development to the market. But where was the money coming from? "We needed an investor, financially, we could not have managed by ourselves. That would have been the end of our development," says Piebrock. But Fraunhofer stepped in and lent the founders a helping hand. Piebrock and partners approached Jörg Wamser from the Fraunhofer Technology Transfer Fund, FTTF for short, who supports only Fraunhofer technologies. "Our idea blew him away," recalls Piebrock, the company's managing director. In short: FTTF financed the newly founded spin-off mySHOEFITTER GmbH with a six figure sum in return for a small share of the company. "We think it's truly awesome," said the founders, delighted. "Without Fraunhofer, the technology could not have been developed and the spin-off would simply not exist."

The Fraunhofer team remains closely involved

And the collaboration continues. Working with the three founders and managing directors Piebrock, Dürr and Ebbers, the Fraunhofer team is taking a close look at how artificial intelligence can be integrated into the algorithms. The app could then find similarities between customers' foot shapes and suggest a suitable model to other customers from the non-returned purchases. And the data, anonymized of course, could help manufacturers adapt their shoe model to the actual foot size and shape of customers – ultimately conserving resources.

Despite the ongoing development, the mySHOEFITTER app has already reached pilot customer status. So that means: the founders are holding their first discussions with customers who are "testing the app down to the wire with us," Piebrock explains. The aim is to find two or three shoe manufacturers with their own online shop, with whom the currently available demo app can be refined based on the needs of both companies and customers – in terms of the app's usability for example. And from whom, sometime soon, shoppers would have to order only one model of the shoe they want – the one that fits. ■

"We think it's truly awesome," say the founders. "Without Fraunhofer, the technology could not have been developed and the spin-off would simply not exist."

Markus Piebrock

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Perfectly packed

What does eco-friendly packaging actually need to do? Its recyclability or biodegradability is not down to the material alone. The packaging's coating also plays a key role.

By Dr. Monika Offenberger

Five awards in 2020 alone – testimony to the heights demand and interest have reached.

Proud Mary", "Knockin' on Heaven's Door", "Down on the Corner": Sabine Amberg-Schwab's repertoire includes plenty of rock classics. "Mostly, we play the older genres. Ballads and groovy pieces are among our favorites" says the keen drummer. During the coronavirus pandemic, though, band practice is on hold for the time being. In any case, the doctor of chemistry finds very little time for her hobby. Her working days at the Fraunhofer Institute for Silicate Research ISC are long ones. As an expert scientist for barrier coatings and chemical coating technology, she develops new concepts for eco-friendly packaging. And she's incredibly successful at it.

The drummer is inspired beat by beat: A new class of coatings called bioORMOCER® won Sabine Amberg-Schwab five awards in 2020 alone. It all started with being ranked third for the Innovation Award as a Biobased Material of the Year, given by the nova Institute. Then came the German Packaging Award in the sustainability category and gold for the German Packaging Award. In the European-wide competition for the Sustainability Award, given every year by the Packaging Europe organization, the eco-friendly coating concept finally won the bio-based packaging category – and also the overall winner across all eight categories. In addition, she was nominated finalist – one of three – for the German Sustainability Award, Special Prize Packaging. "I felt most gratified by the award from Packaging Europe. The competitors included many companies that were able to boast fantastic products on the market. As the only research institution, we had produced only a few packaging items in the lab. The panel was made up of experts. Receiving the nomination in itself was sensational. And then to be overall winner across all categories! It's fantastic, unbelievable actually."

Her face now beams on the screen. The meeting is taking place virtually, just like so many this year, from home office to home office. Nonetheless, the lively lady manages to spread good mood and humor from her end of the line. Welcoming the other participants with a friendly smile. True joy at receiving the congratulations. A growing sense of enthusiasm as she describes the advantages of the award-winning bioORMOCER®: "This substance can be considered for every conceivable product. Above all, though, for recyclable or compostable packaging, either from paper or cardboard, from bio-materials or mineral oil-based plastics." In actual fact, the novel coatings pretty much do it all: at no more than five microns, they are ultra-thin. Yet they still form a reliable barrier against oxygen, other gases and aromatics. They also keep water vapor away from the product inside the packaging. So, even packaging made from mineral oil-based plastics can be designed suitable for recycling as mono-materials. The coatings are resistant to abrasion and are capable of being printed, coated and bonded. They can be applied in the roll-to-roll process to flat substrates, but also to trays and other surfaces with complex shapes.

A true all-rounder for the packaging of the future

How do we produce such an all-rounder? "We combine two kinds of network: an inorganic silica networks and an organic network. They then have to be linked with one another in the best possible way," explains the award-winning scientist. The result is hybrid meshworks from very different, branched chain molecules, the organically modified silica networks, otherwise known as ORMOCER®. This special class of polymers was created at Fraunhofer ISC in the late 1970s, and since then has generated a myriad of substance groups with a stream of novel properties. "Originally, Fraunhofer ISC was devoted solely to glass and ceramic research. The institute then managed to harden glass-like materials at much lower temperatures than had previously been possible. This created the first opportunity to introduce organic components and to lay the cornerstone for an abundance of new applications," says Sabine Amberg-Schwab.

A life of research into packaging – but Dr. Amberg-Schwab was inspired beat by beat more than just professionally: *© Photo Studio Schwab Remlingen / Knud Dobberke / Composing Vierthaler & Braun*

During this time, she herself laid the foundation for her own professional career. "As a child, I had biology kit and my friend had a chemistry set. We did our experiments on my parent's balcony. But we left a bad stain or two on the tiles," says the face in the screen, laughing as if she were still a girl. A science course seemed the obvious choice, "but I didn't want to study either biology or chemistry by itself. So I enrolled on a course to become a high school teacher and studied both subjects". She soon realized, however, that she would rather be researching than standing in a school classroom. So she followed her thesis with a doctorate in silicate materials – and took up a position at Fraunhofer ISC even before taking her final examination.

At Fraunhofer, she finds chemistry sets of a different dimension

As she joins the institute, she finds a much bigger size of chemistry set than the ones in her Hessian home town of Gelnhausen. She is fascinated by ORMOCER® and its special properties: "When I started at Fraunhofer in 1989, various abrasion-resistant or corrosion-resistant coatings for metals, polycarbonate and glass were already in existence. But there were no barrier coatings. So I got to thinking: This is a new field, I'm going to take a look!" Another laugh spills out of the PC, betraying her passion for experiments. Just a few months after her first day at the ISC, the newly qualified scientist goes about synthesizing the first barrier coatings: "We were able to create effective barriers very quickly. Better than anything we might need to package food products." In 2011, she presented a low-cost barrier film as a flexible encapsulating method for solar cells. Together with Fraunhofer IVV, which had developed the roll-to-roll application system for the ISC coating, she wins the Fraunhofer award for outstanding scientific achievements for this work.

At the same time, the chemist continues to puzzle over barrier coatings for packaging. "By then, packaging waste had already become a huge problem, plastic waste especially. ▶

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The Fraunhofer researcher considers the German Packaging Award to be one of her highest distinctions in 2020.

▶ I felt a need, personally, to do something about it. So we started thinking: What if we were to cover paper or biodegradable films with a barrier coating? We could then also give compostable materials made from renewable primary products the properties they lack – making them suitable for use as food packaging." This new coating didn't only have to satisfy the high barrier requirements. It also had to be just as biodegradable as the packaging material it would coat.

In 2014, Sabine Amberg-Schwab set about reducing the mineral oil-based organic components in ORMOCER®. The substitute comes in the form of the plant or animal based polymers that occur as a food byproduct. Because bio-waste such as pomace or crab shells is upgraded like this, there is no competition with cultivatable land. After countless attempts with one new formulation after another, the breakthrough came: The new bioORMOCER®s achieve a similar level of performance as their predecessor coatings, but are biodegradable. This was convincing enough for the panel of the Ellen MacArthur Foundation; in 2018, Sabine Amberg-Schwab won the New Plastics Innovation Prize in recognition of her development.

A feel for timing and tempo – both professionally and personally

How, in just a few years, did she turn a good idea into a completely new, eco-friendly material? "This isn't the work of one person alone. I had a fantastic team around me! And I'm very good at motivating people," says the Fraunhofer scientist about herself: "We always had a lot of fun doing our job." Sabine Amberg-Schwab doesn't only rely on team work in her own lab. As director of the POLO® Alliance, for ten years, until 2012, she pooled the expertise of seven Fraunhofer institutes that were working on polymer surfaces. And at the end of the working day, she rocks in the POLO band with her Fraunhofer colleagues. Team spirit is needed here, just like in the lab. As well as discipline, stamina, enthusiasm and creativity. Most especially, a true feeling for timing and tempo.

The drum kit didn't lay abandoned during lockdown. "When I finish work, it helps me relieve stress. Best of all with loud, funky rhythms," says the scientist. The fact is, her workload is higher than ever. The numerous awards have drawn much attention to the bioORMOCER® concept – not least since the amended packaging legislation of 2019 specifies significantly higher recycling quotas. Since then, Fraunhofer ISC has been approached by companies from the food, cosmetic and pharmaceutical industries, as well as paper and film manufacturers, recycling and packaging firms, component suppliers and start-ups for sustainable packaging materials. Interested parties from all over the world are seeking the expertise of Sabine Amberg-Schwab. Always with a view to solving special problems that go way beyond the properties of the barrier materials: the coating materials have to be processed, it can't cost much, and companies want to continue using the systems they have in place. "So we have to deliberate over whether, given all the framework conditions in place, our concept can be implemented or not. But I do usually manage to convince them. Anything is possible!" she says, laughing. ■

"I had a fantastic team around me," says Dr. Amberg-Schwab in praise of her colleagues from Fraunhofer ISC. © *Fraunhofer ISC*

Smart devices – a complex ecobalance

In Germany, smartphones are used only for eighteen months to two years on average. Less than 50 percent of devices are recycled or used again for other purposes. © *BSR*

The ecobalance of smartphones, tablets, printers and and so on is like a thousand piece jigsaw puzzle. Researchers at Fraunhofer IZM assemble this puzzle with aplomb.

By Dr. Katja Engel

The carbon footprint has been a key part of any purchase decision not only since the "Fridays for Future" movement. A survey conducted by statista in 2016 revealed that 61 percent of those consumers surveyed from the age of 45 believe sustainability is an important criterion, in the younger age group (18–24 year olds), the figure was still 48 percent. Leading companies like Apple, therefore, advertise with good ecobalances and publish their key indicators in comprehensive "Environmental Responsibility Reports". And the demand for reliable statements on lifecycle analyses is growing in politics too. This is essential to having meaningful legal regulations that stipulate which requirements have to be placed on longevity, material selection or repairability. So Karsten Schischke, Group Manager for Environmental Evaluation and Eco-Design at the Fraunhofer Institute for Reliability and Microintegration IZM in Berlin has a lot on his hands.

"The ecobalance of electronic devices is a very tricky matter. These devices often consist of up to 1000 components, are produced in widely ramified delivery chains and comprise a wide variety of materials," he explains. Working with his team, he has to assemble the puzzle of a thousand pieces of information in exactly the right way in order to obtain the fullest possible picture. So the scientists painstakingly track every step in the production chain. They scrutinize the entire lifecycle: from the raw material source to production, transport, use by the customer through to possible recycling. The energy efficiency of a device in use or the material from which it consists is just a tiny piece of the balance puzzle.

The more pieces of this puzzle the researches understand, the more precisely they can track down the potentials for improvement. They use the collated data and ask specific questions: How can the delivery chain be improved? Which production technology, methods and systems are used? Is there a more sustainable energy mix available? Can only a few metals be recycled? Are the components flown in or can they be sent overland?

Not all the questions are purely technical or logistical ones. Psychological aspects also play a role. As Schischke explains: "The more exclusive a product, the more people embrace it. This might be a top-quality tablet with a casing made of a fine wood, whose owner treats regularly with olive oil. This tablet will be used for a long time, for sure."

Natural raw materials and repairability equal a good ecobalance, but it's not that easy. The results of analyses conducted by Fraunhofer researchers came as somewhat of a surprise to the manufacturer of the "Fairphone", which proactively advertised with its product's sustainability. The Fairphone is deliberately designed to be easy for even laymen to repair. The idea is to prolong its useful life, improving sustainability in the process. And to make sure any repair goes without a hitch, the connectors are provided with strong contacts made of gold. Yet even these extremely robust components tip the ecobalance the wrong way due to the high material usage. The balance is restored only if Fairphone users do actually lend a hand and replace faulty parts, for example. Schischke and his team found that such a repair benefits the environment if the life span is prolonged even by just a few months. The Fairphone manufacturers improved the situation with the next model and found an alternative solution for the connections. A good example of how, using ecobalance as a basis, products can be modified by spotting the problems in the design or product's life. ■

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Breathing thanks to moon dust

Can potentially deadly moon dust be turned into life-giving oxygen? Innovative ROXY reactors can: they could revolutionize space exploration – and open doors on earth too.

By Dr. Janine van Ackeren

"We made oxygen from a sample of simulated moon dust."

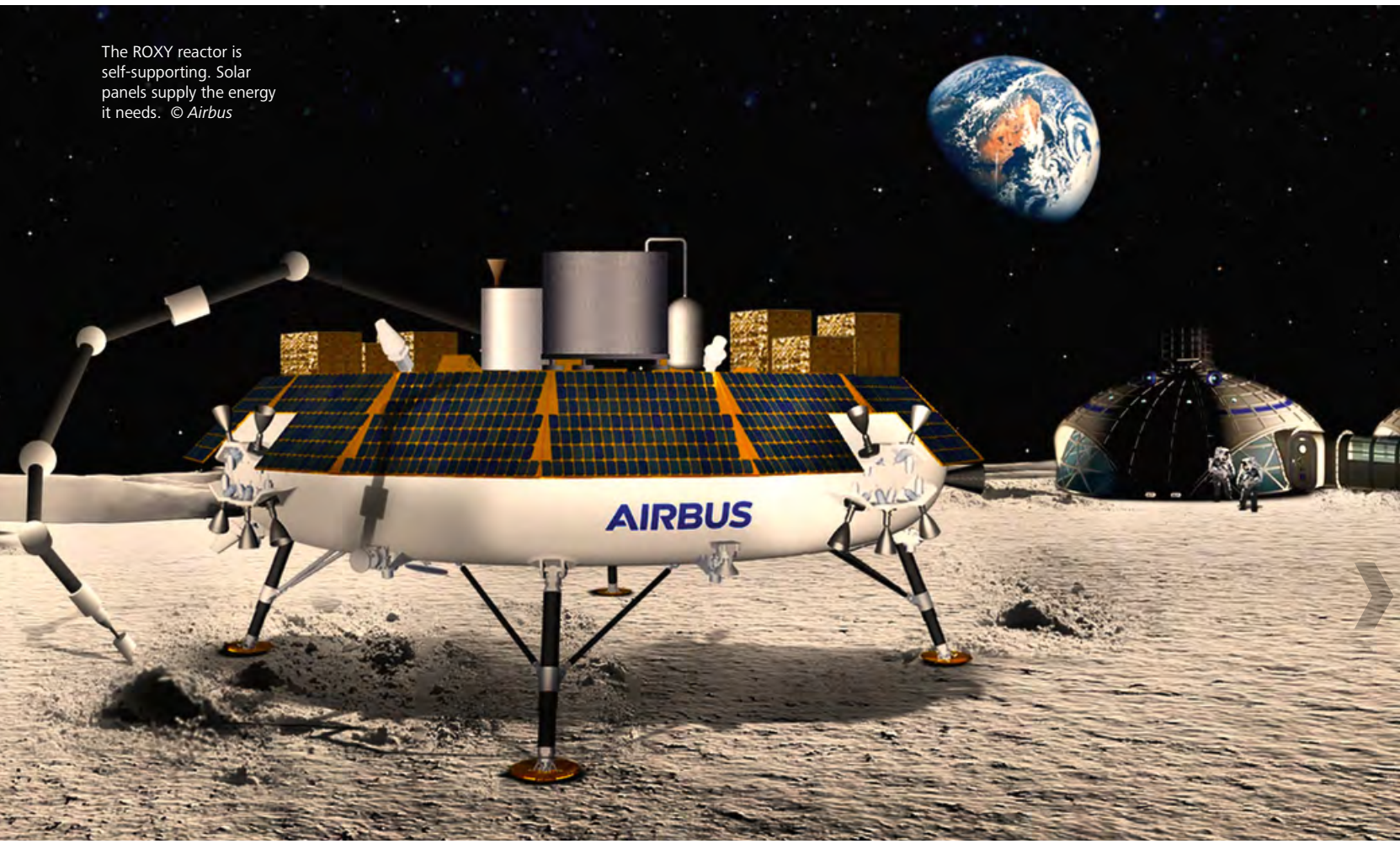
Dr. Peter Quadbeck, Group Manager Fraunhofer IFAM

Mining in outer space? It might sound like science fiction. But making this dream a reality is now high on the agenda of space travel programs. The idea is that raw materials will no longer be recovered only from mines on earth and other earthbound resources, but from asteroids in the solar system. From earth, though, each and every rocket launch engulfs huge amounts of energy, so the dream is being overshadowed by the debate about lunar bases. And the question is: How do we get oxygen to astronauts stationed on the moon?

Fraunhofer researchers took on the experimental side of things

Airbus was waiting in the wings with this idea: why not use the oxygen bound up in moon dust in the form of oxides? The colorful mix contains oxides of silicon, aluminum, iron, magnesium and other chemical elements. The separation of oxygen and metals works and is already used in a variety of ways, in certain areas of metal production for example, where the metal is freed of oxygen by an electrochemical reaction between anode and cathode.

In terms of its principle, the process of electrolysis is well-established. Like so many new applications, though, the devil is in the detail. A porous cathode is required to trigger the reaction, for example. So Airbus got the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM in Dresden involved in the project. "Not only our expertise in highly porous metals was tailored, as it were," recalls Dr. Peter Quadbeck, Group Manager at Fraunhofer IFAM. "We had also just completed a system for reducing titanium, which provided the ideal basis. The thermochemical measurement of gases – another core competence of my



The ROXY reactor is self-supporting. Solar panels supply the energy it needs. © *Airbus*

group – also came in handy." While all of the theoretical deliberations were made in the international team, the Fraunhofer researchers covered the experimental side entirely.

The process is called ROXY, short for Regolith to OXYgen and Metals Conversion: voltage is applied between the highly porous cathode and the anode, a saline solution is contained in the space between. If we now add simulated moon dust – known as Regolith – the metal detaches itself from the oxygen: The metal accumulates on the cathode, the oxygen is collected on the anode. All this at just short of a thousand degrees Celsius. "After two years of development time, the breakthrough came during a series of lab tests at Fraunhofer IFAM: we made oxygen from a sample of simulated moon dust," enthused Quadbeck. Jean-Marc Nasr, Head of Airbus Space Systems, also stressed the significance of this success: "This breakthrough is a giant leap forwards – it brings us closer to the 'holy grail' of being able to live on the moon." Apart from the ROXY reactor – no consumable materials from earth will be needed at all. Moon dust is available in abundance, solar panels supply the energy needed. And if being able to produce oxygen on the moon were not enough, the ROXY reactor is expected to deliver another "raw material" as well. The metals produced as a result can be used as fuel for the rockets that fly to the asteroids.

And the process opens doors on earth too: as an example, it could drastically reduce the emissions of greenhouse gases occurring during metal production. While the methods currently in use emit considerable quantities of environmentally harmful perfluorocarbons (PFCs), the ROXY reactor works practically emission-free. In this way, space technologies could improve life on earth in the long run – not only by alleviating bottlenecks in the production of raw materials. ■

"Closer to the dream of being able to live on the moon."

Jean-Marc Nasr,
Head of Airbus
Space Systems

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New mission as a medicine

© Science Photo Library

mRNA is causing a great furore as a vaccine against the coronavirus. In actual fact, this messenger molecule can do so much more. It is seen as a new hope for treating inflammatory diseases and cancer.

By Christine Broll

When Dr. Holger Cynis began to concentrate on mRNA four years ago, only a small number of specialists had any interest in this field of research. Now, the abbreviation appears in every news program: mRNA stands for messenger RNA. Scientists at the Fraunhofer Institute for Cell Therapy and Immunology IZI wanted to research whether it's possible to induce a patient's body to produce the medication it needs by itself. As much like science function this may sound, it had a sound scientific basis even back then: Holger Cynis wanted to use mRNA to carry the blueprint for a medicine into the human body. The idea is that the person's cells then produce the substance required.

"Drugs containing therapeutic proteins and antibodies as their active agent could be produced in patients themselves using mRNA technology," explains Cynis. These may include in particular therapeutic agents for anemia, inflammatory diseases – and cancer. Currently, these active agents are produced in giant bioreactors from cell cultures. So drugs such as these are very expensive and out of reach for many people in poorer countries. Cynis believes mRNA technology is an important alternative here. "mRNA is much easier to produce than therapeutic proteins, and so the cost of treatment would drop tremendously," says Holger Cynis describing his motivation. "We cannot keep this highly effective drug away from people in emerging and third world countries any longer."

The art of packaging

Holger Cynis took a small step in this direction with the project he started in 2016. The manager of the Working Group for Molecular Biotechnology at the Halle Branch Lab of Fraunhofer IZI collaborated on the project with Christian Reinsch and Steffen Panzner, the founders of Lipocalyx, the biotech start-up also situated in the Technology Park in Halle. Lipocalyx has developed special polymers in which the mRNA is transported to its site of action. These polymers look so promising that in January 2020, Lipocalyx was taken over by mRNA specialist BioNTech.

The polymers developed by Lipocalyx coat the mRNA to protect them from damage and decomposition as they travel through the bloodstream. The polymer arrives at the target cell and attaches itself to the membrane. It is then absorbed and afterwards, releases the mRNA into the cell. Because the designers adopted this mechanism for the influenza virus, they call their transport polymer Viromer too. "The packaging for the mRNA is an extremely important key technology for the success of the therapy as a whole," stresses Holger Cynis.

The trial by fire on the living organism took place once the viromers had demonstrated their ability to effectively carry mRNA into cells in the test tube. The research team treated mice that had suffered an inflammation. They did this using mRNA containing the blueprint for two anti-inflammatory active agents, including one for the biologically active part of Etanercept, a drug used to treat rheumatic diseases.

"The viromers delivered the mRNA primarily to macrophages, a special kind of white blood cell, also referred to as scavenger cells," reports Holger Cynis. These macrophages then produced the anti-inflammatory active agents. ▶

"We cannot keep this highly effective drug away from people in the third world any longer."

Dr. Holger Cynis, Fraunhofer IZI

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“Using the same model, we were also able to engineer mRNA-carrying viromers to treat other conditions.”

Dr. Holger Cynis, Fraunhofer IZI

▶ The fact that these agents are indeed active was demonstrated by the progression of the disease in the mice. The inflammations, which can be measured using a number of different parameters, reduced considerably.

Relief for rheumatoid arthritis

Holger Cynis considers this a major success. Because it shows that the concept works in principle. The research team wants to use further preclinical trials to test active agents against rheumatoid arthritis, the idea being to lay the foundations for getting them from the lab to the hospital. This also requires, for example, dose-ranging studies to determine which quantity of mRNA achieves which effect.

The first mRNA vaccine will accelerate development – for drugs too.

“Using the same model, we were also able to engineer mRNA-carrying viromers to treat other conditions,” explains Holger Cynis. He has in mind here certain therapeutic proteins for which patent protection has already expired. Because the blueprint of these proteins is common knowledge, it was very easy to produce a suitable mRNA. Cynis is confident that the approval of the first mRNA-based vaccine will accelerate the development of this technology considerably. Not only for vaccines, but for drugs too. ■

Vaccine against cancer – the data look promising

Internationally, three companies are considered the pioneers of mRNA technology: BioNTech in Mainz, Curevac in Tübingen and Moderna in Cambridge, USA. All three set out to establish messenger RNA as a new class of drug in medical science. Their primary focus was on drugs to treat cancer. All three companies and their technology, however, became renowned for their vaccines against SARS-CoV-2, with which they sprinted to the head of the international race. This is clear testimony to the speed at which mRNA-based agents can be developed and produced.

A glance at the research pipeline of the three companies shows which mRNA-based drugs could be launched on the market in the future. The most important field of application – besides the coronavirus vaccine – is cancer immunotherapy, a vaccination against cancer as it were. Patients are vaccinated with mRNA for marker proteins, which occur very specifically on tumor cells. Once vaccinated, the body develops an immune response to these markers and, as a result, is able to destroy the cancerous cells. All three companies are already testing such vaccines against cancer in clinical trials. In July of this year, BioNTech published in Nature, the renowned science journal, promising data from a Phase 1 study of an mRNA agent for melanoma.

BioNTech and Curevac are also developing mRNAs that act as an agent in the body’s own production of therapeutic antibodies against cancer. Currently, such antibodies are produced from cell cultures in giant bioreactors and are used to treat numerous malignant diseases.

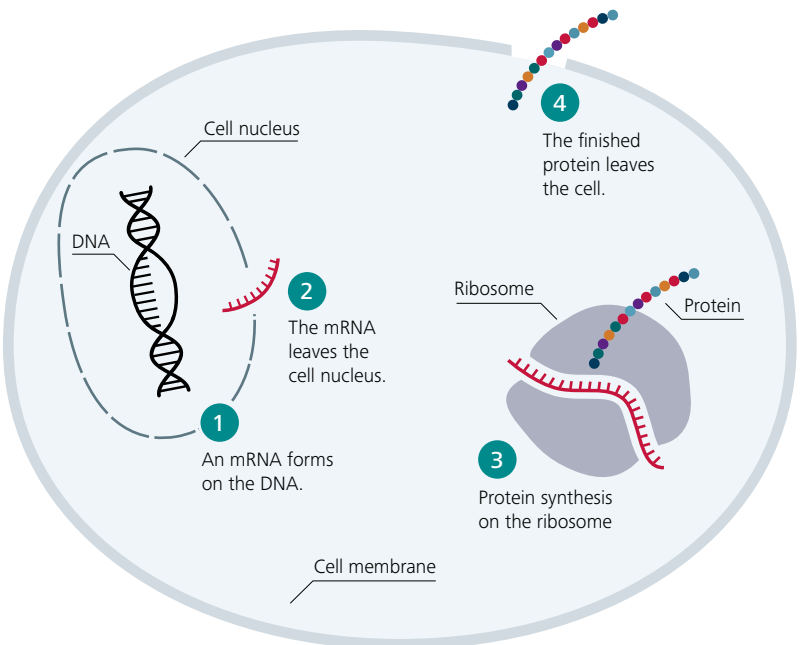
Curevac and Moderna are playing a key role in the development of mRNA-based vaccines to treat infections. In 2017, Curevac led the world’s first clinical study of an mRNA vaccine against an infectious disease – a vaccine against rabies. This is currently undergoing further development in clinical studies, just like a vaccine against influenza. As well as the SARS-CoV-2 vaccines, Moderna has another five candidates in clinical trials, against the Zika virus and the Cytomegalovirus.

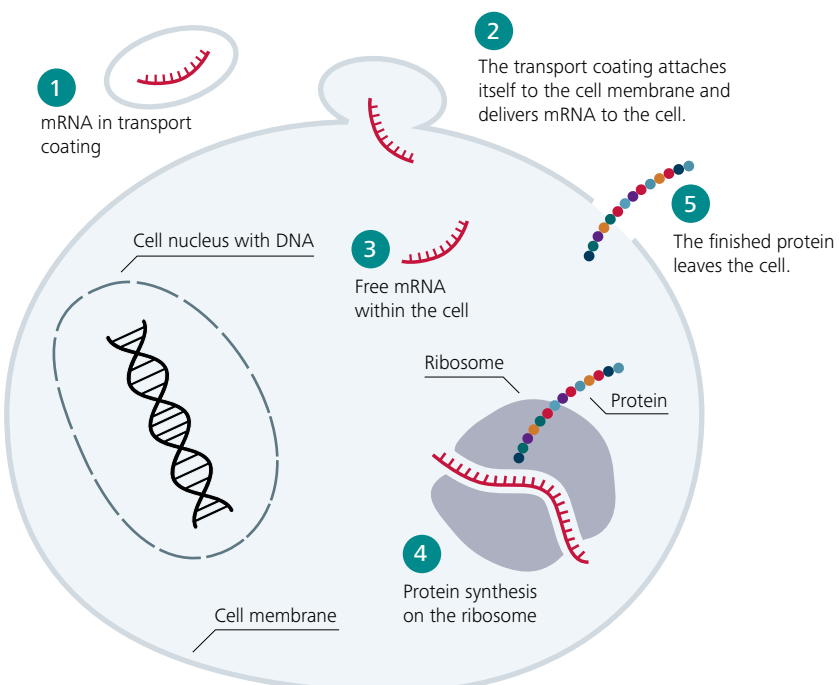
mRNA – a new class of vaccines and drugs

Messenger RNA has made a breakthrough with the first vaccines against SARS-CoV-2. These molecules occur naturally in all the body's cells. They transport the information stored in the DNA to the cell's protein factories, the ribosomes.

The role of mRNA in natural cell metabolism

The DNA contains the genetic information required to build proteins. For a cell to be able to produce a protein, it must first read the applicable gene that's stored in the DNA. For this to happen, the DNA unfolds. At this point, a mRNA forms as a copy of the DNA (1). The mRNA then leaves the cell nucleus and migrates to the ribosomes (2). Following the blueprint stored in the mRNA, the building blocks for the protein are strung together (3). Proteins consist of 21 different amino acid building blocks. The sequence of these building blocks determines the protein's structure and function. The finished protein then leaves the cell (4).





How mRNA acts as a medical agent

mRNA used in drugs carries the information for a special protein. It is produced in the lab and packaged in a transport coating (1). In the simplest case, the coating is made of special lipids. When the lipid coating meets the cell membrane, the two things fuse together and the coating releases the mRNA to the cell (2). The mRNA now migrates to the ribosomes (3) and sets the synthesis of the target protein in motion (4). The finished protein is able to leave the cell and develop its medical effect in the body (5).

If the mRNA is packaged in complex coatings, like viromers for example, getting it inside the cell is a more intricate task. The viromers, together with the mRNA, are absorbed by the cell and surrounded by a membrane vesicle (endosome). Next, the mRNA is released from this membrane vesicle.

© Infographic: 2issue

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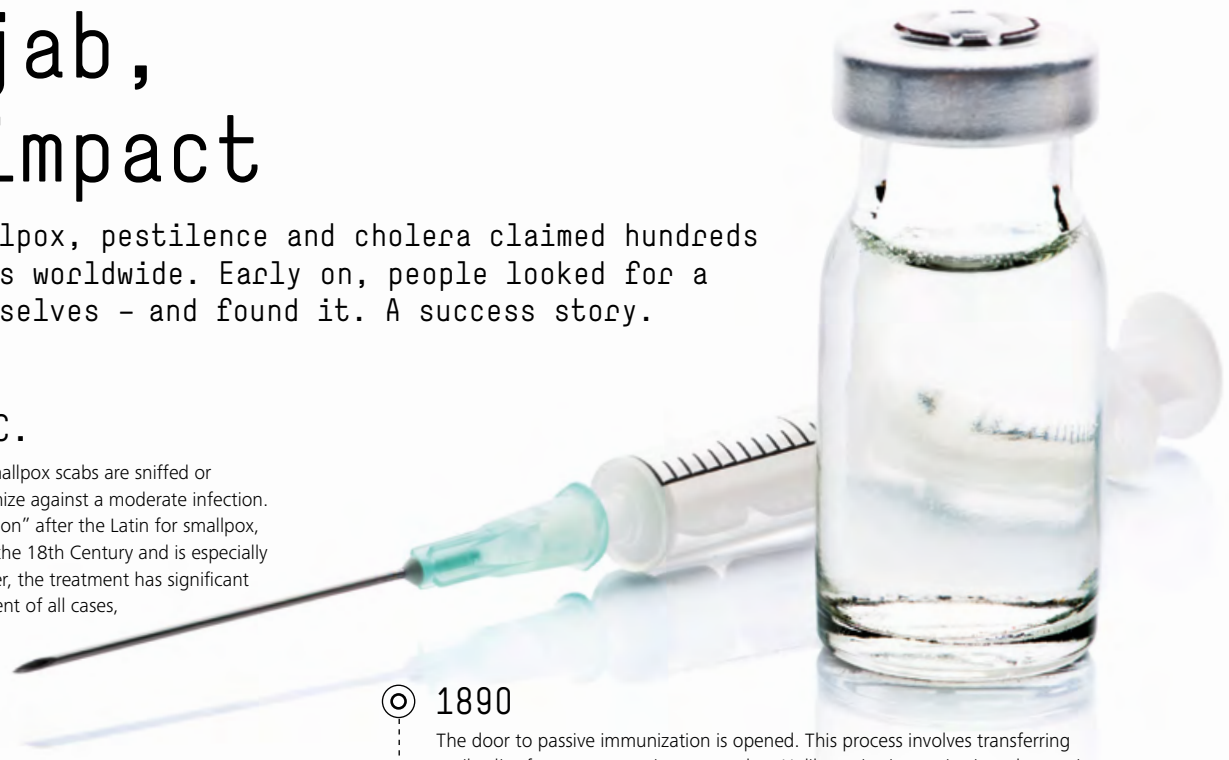
Small jab, great impact

Epidemics like smallpox, pestilence and cholera claimed hundreds of millions of lives worldwide. Early on, people looked for a way to protect themselves – and found it. A success story.



Around 200 B.C.

In China and India, infectious smallpox scabs are sniffed or scratched into the skin to immunize against a moderate infection. This technique, named "Variolation" after the Latin for smallpox, arrives in Europe by the start of the 18th Century and is especially popular in Great Britain. However, the treatment has significant side effects. In around two percent of all cases, it leads to fatality.

1796

The age of modern vaccination begins with the English country doctor Edward Jenner. It comes to his attention that although milkmaids often fell prey to cowpox, they rarely contracted smallpox. He assumes there is a correlation and checks out his theory by deliberately infecting a young boy first with cowpox and then with smallpox. The child remains free of the disease, the smallpox vaccination is created. Jenner calls his discovery "Vaccination" (vacca being the Latin for cow). Little does he know that smallpox infections are caused by viruses. These viruses are identified as pathogens only a century later.

Anti-vaxxers accuse Jenner of contaminating humans with a serum taken from a cow. This would turn humans into animals. (Etching by James Gillray, London 1802)

1874

In the newly established German Reich, compulsory vaccination is introduced to combat smallpox. The last major epidemics in 1870 and 1873 claimed 181,000 lives.

1881

Louis Pasteur (image) and Robert Koch are accredited with conclusive proof that microbiological pathogens exist. In 1876, Koch discovers the rod-shaped Bacillus anthracis and in 1882, the tuberculosis bacterium. The groundbreaking research results not only deliver an explanation for the success of the first vaccines, they also lay the foundation stone for the development of new vaccines: In 1881 against anthrax In 1885 against rabies.

1890

The door to passive immunization is opened. This process involves transferring antibodies from one organism to another. Unlike active immunization, the passive method offers immediate protection, though this lasts only for around three months. The physician Emil von Behring uses passive vaccination successfully as a treatment for diphtheria for the first time in 1890 – back then, the most common cause of death in children between three and five years of age.

1914-1918

During the first few months of the First World War, tetanus infections cause more loss of life than do grenades or rifles. In the trenches, wounds become infected with soil contaminated with tetanus bacteria. The bacterial spores multiply rapidly. They secrete various toxins that lead to seizures, heart failure or death by suffocation. So from October 1914 onwards, wounded German soldiers are given a passive vaccine as a preventive measure – with overwhelming success. The protective vaccine is effective for just a few weeks. Although the pharmaceutical industry produces liters of serum every day, it can barely meet the army's needs.

1933-1945

Many Nazi leaders like Rudolf Heß and Heinrich Himmler are advocates of natural medicine and are skeptical about immunization. The rule on the compulsory immunization against smallpox, in existence since 1874, is relaxed. It is not abolished altogether though. In light of the war, there is to be an assurance that the armed forces are immunized. The "Third Reich" withdraws from the production of vaccines and transfers the responsibility to private companies. The pharmaceutical industry skillfully uses newly emerging and increasingly professional advertising to persuade people to get immunized – one reason why the voluntary immunization programs are more successful than state compulsory vaccination.

1960s

Vaccines against measles, mumps and rubella become available. While the Federal Republic of Germany believes in people's willingness, the Democratic Republic makes makes immunization compulsory. During the Cold War, the idea was to demonstrate the supremacy of the socialist health care system. Adolescents get a total of 20 state-imposed vaccines under the "The best prevention is socialism" slogan. The infection rates drop rapidly.

End of the 1970s

The German Democratic Republic is unable to keep pace with immunization. There's no point in developing multiple vaccines, because that would delude the drug giants in the west. The vaccine fails with increasing frequency – partly because the equipment in the production facilities is outdated.

1986

The first genetically engineered vaccine, recombinant HBsAg to immunize against Hepatitis B, arrives on the USA market.

2020

Novel mRNA vaccines bring new hope in the fight against the coronavirus pandemic. They contain the messenger ribonucleic acid, the mRNA, that carries the blueprint for the viral antigen. The human body uses this instruction to produce the antigen that induces a protective immune reaction.

1955

A vaccine against polio is approved for the first time in the USA. An oral polio vaccine that protects against all three virus types is then approved in 1963. This vaccine quickly becomes a worldwide standard and is dispensed on a sugar cube. Many people can still remember the catchy Federal German advertising slogan for the vaccine: "Schluck-impfung ist süß, Kinderlähmung grausam" (Oral vaccination is sweet, polio is cruel).

1967

The process of immunization is made international, the WHO gains influence. It has launched worldwide immunization programs since 1967. The most successful so far is the smallpox program. The epidemic has been considered eradicated since 1980.

1972

The Act for establishing a federal institute for serums and vaccines makes the Paul-Ehrlich Institute (PEI) an independent federal authority. It validates the safety and efficacy of new vaccines. The Standing Committee on Vaccination (STIKO) starts work in the same year. It prepares recommendations for administering vaccinations in Germany.

2019

The Ebola vaccine is the first vector technology-based vaccine to be approved in the EU. A virus that is harmless to humans is used to deliver the information required for antibodies to be created in the body.

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Ready for mass production

The race for coronavirus vaccines is in full swing. All around the world, experts are placing their confidence in the innovative mRNA technology. Fraunhofer researchers want to make the mass production of this new hope possible.

By Dr. Sonja Endres

A ray of hope: When will the coronavirus vaccine reach the general population? © *dpa*

> “Because this process is very similar to a real infection, it triggers an especially good immune response.”
>
> Dr. Sebastian Ulbert, Fraunhofer IZI

Annika Brehmer, Biotechnologist at Fraunhofer IPK, working with mRNA molecules. © *Fraunhofer IPK / Larissa Klassen*

Anyone who wanted the flu jab this season will have some idea of how things might have looked had the coronavirus vaccine arrived: The crowds in clinics and pharmacies were huge, the waiting lists were long. Even though the German federal government had obtained over 26 million doses of the flu jab in this pandemic year – almost twice as many as last season. Flu as well as coronavirus: Many wanted to avert this risk.

The race for a coronavirus vaccine is in full swing. In November, BioNTech, headquartered in Mainz and the US drug giant Pfizer published provisional results that said their mRNA vaccine appears to be 90 percent effective against COVID-19. A short time later, the US biotech firm Moderna also reported encouraging study data: Its mRVA vaccine shows an efficacy of 94.5 percent. This was the first company to apply for approval of a coronavirus vaccine in the EU.

All manufacturers face the same challenge: producing hundreds of millions of vaccine doses in the shortest possible time. This is the only way to stop the virus. The novel mRNA vaccines have an advantage here. They can be produced much easier, faster and cost-effectively than conventional preparations. Experts also promise better efficacy and tolerability.

The EU has secured 300 million vaccine doses from BioNTech and Pfizer, and 160 million from Moderna should the mRNA-based vaccine be granted approval. And to make as many of these available as quickly as possible, the Fraunhofer Institute for Production Systems and Design Technology IPK in Berlin is laying the foundations for mass production.

Viruses from a chicken egg

The process for manufacturing conventional vaccines, which contain viral proteins, inactivated or weakened pathogens, is a complex one. Viruses for vaccine production are grown primarily using chicken eggs. Living pathogens, referred to as seed viruses, are injected into a fertilized egg and incubated for several weeks. The virus reproduces in the egg white. The manufacturing process can take up to one year, depending on the vaccine. For complex combination preparations, the time is even longer. “The pharmaceutical sector has to meet high safety and quality standards. But because the quality of natural products such as chicken eggs fluctuates, only eggs from special farms can be used. The effort involved in obtaining a sufficiently high quantity of eggs under strictly controlled conditions is huge. Besides that, the subsequent regeneration of the viruses and the formulation of the vaccine add extra costs to the process,” explains Annika Brehmer, biotechnologist at Fraunhofer IPK. ▶

> Faster, simpler, more cost-efficient – three advantages of the mRNA vaccine

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Anti-vaxxers are a vocal minority. A fear mRNA could become part of a person's genetic makeup. "That cannot happen," Christoph Hein, Fraunhofer IPK, gives his assurance. © *EPA / Shutterstock*

▶ **mRNA vaccines are based on genetic information from the antigen** that triggers the immune response in the body, not on inactivated viruses or parts of such viruses. Often, the antigen is a surface protein of the pathogen – in the case of SARS-CoV-2 the spike protein, which lends the virus is characteristic spikes. "The messenger ribonucleic acid, the mRNA, is an essential part of our cells. It is used whenever a protein is to be produced in our body. Acting as a messenger, it brings the blueprint from the cell nucleus to the protein factories in the surrounding cytoplasm, so-called ribosomes," explains Dr. Sebastian Ulbert, Virologist and Manager of the Vaccine Technologies Working Group at the the Fraunhofer Institute for Cell Therapy and Immunology IZI in Leipzig. Researchers are harnessing this mechanism for the new vaccine. They inject the mRNA, containing the blueprint of the spike protein, to ensure it gets to the ribosomes in the human cells. "The body is tricked into producing the antigen by itself. Because this process is very similar to a real infection, the body triggers an effective immune response," says Ulbert.

This technology would also enable a rapid response to new variants of the virus. "The RNA sequence is easy to alter. This would be a perfect solution, for example, for the flu vaccine, which has to be laboriously adapted to new variants and mutations every year."

Here's the problem – although mRNA is readily prepared by synthesis, it quickly decomposes in the body. To stabilize it, the team at Fraunhofer IPK is working on a lipid coating that covers, and hence, protects the messenger molecules. This coating is also the only way to get the foreign mRNA into the cell and set antigen production in motion. "Broadly speaking, then, our work is about packaging the mRNA so that once in our body, it gets to where it can do its job," says Brehmer.

mRNA does not become part of a person's genetic makeup

Despite all the measures taken to protect it, the external messenger has a short lifespan. Once it delivers the blueprint for the spike protein, it decomposes. "A fear often voiced at the moment is that the mRNA would become part of a person's genetic makeup. But that cannot happen," stresses Christoph Hein, Head of the Microproduction Technology Department at Fraunhofer IPK. "It would first have to be transformed into DNA, and introduced not only into the cell plasma, but also into the cell nucleus."

The basic production technology for the encapsulated messenger is already available. So far though, it has not been possible to produce the quantities required. Researchers at Fraunhofer IPK are working to design processes for mass production, make them effective, controlled and cost-efficient, while at the same time meeting the high quality and safety standards in the pharmaceutical industry. Besides the perfect formulation for the lipid coating, they are refining processes to make its manufacture as standardized and efficient as possible. "This presents a huge challenge, because the lipid-encapsulated mRNA molecules are much smaller than a micron," explains Brehmer. Large differences in the thickness or composition of the capsule could influence the efficiency of the vaccine, and generate large quantities of waste during mass production. ■

“There are many horses in the race”

The whole world is pinning its hopes on a coronavirus vaccine. Will we then have overcome the pandemic? Dr. Sebastian Ulbert, Virologist and Manager of the Working Group for Vaccine Technologies at the Fraunhofer Institute for Immunology IZI in Leipzig, provides some answers.

Interview by Dr. Sonja Endres

Normally, it takes several years to develop vaccines. Why so fast this time?
Because, fortunately, we didn’t have to start from scratch. The researchers were able to build on existing knowledge and the groundwork done on the known coronavirus strains, especially SARS-CoV-1 and MERS. The antigen, which triggers a protective immune reaction in the body, had already been identified.

Which vaccines are in the running?
So far, there have been eleven candidates in phase three of the clinical studies. This is the final and decisive phase ahead of approval. They are based on four different technologies. Two of these are old, and two are new.

What are the fundamental differences?
The conventional process involves weakened or inactivate pathogens that trigger an immune response in the body. This is how hepatitis, polio or flu vaccines, for example, work. The Chinese are adopting this approach for SARS-CoV-2 as well. Their inactivated vaccine is among those in phase three. The so-called protein vaccines, containing only the surface protein of the pathogen that triggers the strongest and presumably protective immune reaction, are also well established. In the case of SARS-CoV-2, this is the spike protein which lends the virus its characteristic spikes. By contrast, vector vaccines, which use a virus that is harmless to humans to get the information required to build antibodies into the body, are relatively new. In 2019, the Ebola vaccine was the first vaccine that works on the basis of this technology to be approved in the EU. mRNA vaccines are completely new. They contain the messenger ribonucleic acid, the mRNA, that carries the blueprint for the spike protein. The human body uses this instruction to produce the antigen that achieves an effective immune response.

Which candidate do you think is the most promising?
In the initial studies, all vaccines produced immune reactions and, in my opinion, have a good chance. The ideal situation would be to have as many vaccines, based on various technological platforms, approved as possible. We can draw comparisons: Which provides the best protection?

How is this measured?
The vaccine candidates are tested on thousands of test subjects, ideally in a major outbreak setting. Then we check: How many were in the placebo group, and how many in the group that actually received the vaccine? If, for example, 100 people in the placebo group contract the virus, but none in the vaccinated group, this means the vaccine is one hundred percent effective. The WHO defines the point at which the vaccine is considered effective as 50 percent. BioNTech has reported a 95 percent efficiency for its mRNA vaccine.

Can this not also be determined by the antibody values in the blood?
Unfortunately, it’s not that simple. The immune system is complex and antibodies are merely one of a host of indicators. Especially in the case of respiratory viruses like SARS-CoV-2, the T-cells, which are able to recognize and kill foreign structures, also play a key role. But they are not so easily verified. The actual degree of protection can be learned only through clinical studies, which continue to run once the vaccines have been approved.

Which questions still need to be answered by the studies?
For example: How many booster doses of the vaccine are required and when are they administered? Does the vaccine provide protection even before the virus is transmitted? Does efficacy differ between age groups? Vaccines given to the over-sixties, for example, are less effective because the immune system no longer works as efficiently. Given the shortness of time, we cannot expect one preparation to meet every need. Gradually, we will learn and make improvements. The good thing is: There are many horses in the race, and this improves our chances. Even if the vaccines protect only part of the population, or at least prevent those infected from getting worse, we have achieved success. ■

“Given the shortness of time, we cannot expect one preparation to meet every need.”

Dr. Sebastian Ulbert would himself have the vaccine. If a vaccine attains EU approval, he says reassuringly, there will be no adverse reactions to worry about. © *Fraunhofer IZI*

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Quick and reliable curbing of paper mountains

In hospitals, courtrooms and companies – documents are created all over, and they have to be sorted, analyzed and processed. Fraunhofer researchers develop systems that accomplish such tasks quickly and thoroughly through largely automated processes. This is done by deep learning algorithms – and guess what: they even recognize emotions within texts.

By Mehmet Toprak

This is a widespread affliction among many a professional group. Doctors spend time writing discharge notes and reports on diagnoses or treatments, instead of making those diagnoses and devising treatment plans. 10,000 codes for diagnoses, 5000 codes for different treatments: paperwork instead of time with the patient. The Fraunhofer Institute for Intelligent Analysis and Information Systems IAIS is applying its artificial intelligence-based software solutions for automated document and text analysis, including the text recognition tool (OCR) recognAIze and the NLU (Natural Language Understanding) suite, to find a remedy. The algorithms of these tools are able to analyze the content of texts written by doctors and then assign the codes automatically. A tricky task, not least because doctors often user different expressions and wording to mean the same thing. "The software, however, detects even the slightest differences between texts and can then assign the correct codes on this basis," explains Sven Giesselbach, Leader of the Natural Language Understanding Team.

The NLU suite works with deep learning models developed by experts at Fraunhofer IAIS. The buzz phrase deep learning refers to a sub-field of machine learning that involves initially feeding and training the software with large amounts of data. This creates neural networks, which apply what has been learned during complex decision-making processes to new information and learning what to do through an automated process. Fraunhofer IAIS in Sankt Augustin near Bonn ranks among Europe's top names when it comes to making big data and deep learning concepts into something tangible for companies.

ALI trained to pass the practical test

Quarterly reports, annual balance sheets and business reports compiled by companies or financial service providers constitute a worthwhile field of application for the deep learning systems at Fraunhofer IAIS. In collaboration with a large insurance company, the IAIS Team is currently exploring how the Automated List Inspector (ALI) tool proves itself in practice. The tool analyzes the texts and uses the result to extract the key indicators. Sales, operative profit, equity ratio, net liability or the flow of capital. "The company can then have the business

report at least partially generated or checked by the software," explains Dr. Rafet Sifa, Head of the Cognitive Business Optimization Unit.

"In the beginning, we fed and trained ALI with thousands of business reports and data from several financial service providers. So at the end, we were able to define the relevant key indicators," reports Sifa. The tool even recognizes inconsistencies or discrepancies in the key indicators and, in such cases, initiates a recheck of the figures. "This does not, in any way, make the accountant's job unnecessary," says Sifa reassuringly. "ALI is simply a very diligent and swift assistant."

Furious customers? Better respond quickly!

Codes and figures, data and factors – another step detects the emotion. Deep learning models that decipher feelings from texts are being increasingly used to analyze and channel emails received from companies to ensure appropriate customer support. These models not only analyze text or work out the customers' areas of interest. Spelling and sentence structure are also meaningful. The way someone writes says something about their emotions. "If many words appear capitalized throughout or a sentence ends with five exclamation marks, the customer is very probably upset. The software is able to flag such messages as urgent," explains Sven Giesselbach. And direct them straight to the Complaints Department.

Scanning with deep learning

Many OCR programs find paper documents that are scanned for text analysis problematic – pages may have yellowed, torn or creased. The document processing platform recognAIze is an expert in reliably recognizing text under difficult conditions. This is where deep learning algorithms come into their own and help faithfully digitize even troublesome documents. Indeed, the software can converts photos of documents taken by cellphones with a distorted perspective. The platform is already in service and can also be operated on the company's webserver.
---------- **www.recognaize.de**

Bureaucracy devours time. Especially so in the health care system. In Germany, registered practitioners and psychotherapists spend over 54 million working hours per year on paperwork, a study by the National Association of Statutory Health Insurance Physicians found in 2017. © *iStockphoto*

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Too valuable for the compost heap

A biorefinery in a shipping container was among the three finalists in the competition for the German Sustainability Award Research 2020. The waste-to-resource unit is designed to convert food waste into valuable raw materials by an automated process.

By Christine Broll

"With the waste-to-resource unit, we want to hygienically reprocess food waste and recover valuable resources from the result."

Dr. Boje Müller, Fraunhofer IME

In Berlin alone, some 2,200 tons of food rot away every day.
© *plainpicture/ Oote Boe*

One million banana skins, 62 tons of coffee grounds. 2,200 tons of food. These are the volumes of waste for Berlin – just for the city alone, every single day. Until now, discarded food has simply ended up in the garbage, and at best composted. The initiators of the German Sustainability Award Research got to thinking that there must be better solutions, and started to look among the current competition for innovative solutions for the "urban bioeconomy". Their vision: a city in which organic material flows are intelligently directed and biological resources are put to the best possible use.

Wanted: smart ideas. To develop these ideas, 80 brilliant minds from academia, business and local government met online. One of these bright people was Dr. Boje Müller, Plant Biotechnologist at the Fraunhofer Institute for Molecular Biology and Applied Ecology IME in Münster. "During the two-day Makeathon, five of us designed the concept for the waste-to-resource unit," reports Müller "The idea is to hygienically reprocess food waste and recover valuable resources from the result. Currently, we are developing the idea further and looking among industry and local government for interested parties to put the idea into practice."

The waste-to-resource unit is designed to process food waste at the very place where it occurs, in canteens or similar facilities. This cuts transport costs for disposal. The planned unit consists of a standard shipping container, which accommodates all the technology, from the preparation of the waste material through to the finished product. At the heart of the unit is a bioreactor, in which algae are cultivated.

Vitamins can be isolated from fats and oils

The project team already has a clear idea of how processing will be done. A ball mill crushes the food waste into a fine pulp, very similar to a hand blender in the kitchen at home. The fats and oils are then separated by binding them to special adsorbents. The solution to this task is being devised by Boje Müller at Fraunhofer IME, since his work too involves the reprocessing of plants. More specifically, he isolates natural rubber from the roots of the Russian dandelion. "From the separated fats and oils, we are able to isolate various raw materials, like vitamins, for example," explains Boje Müller, who is collaborating on this project with the University of Münster.

In the ball mill, the edible pulp is mixed with enzymes, which split the carbohydrates and proteins into their building blocks. All we have to do now is remove the fibers through a filter, and there we have the nutrient solution for the algae. Prof. Daniel Pleissner from the Institute for Sustainable and Environmental Chemistry of the Leuphana University Lüneburg chose a special algae for this project. It bears the name Galdieria sulfuraria, belongs to the group of red algae and can even grow in the dark – if fed with a nutrient solution. Furthermore, this algae is extremely robust and capable of producing phycocyanin, an agent considered to have anti-inflammatory and hypoallergenic properties. Dr. Sergiy Smetana from the German Institute of Food Technologies in Quakenbrück is responsible for processing the algae. The cell cycles are managed by Dr. Natalie Laibach from the University of Bonn and Wolf Raber from inter 3 GmbH.

The waste-to-resource unit could be an interesting business model for young entrepreneurs. They would make the container available to a canteen, look after the maintenance and sell the reusable materials recovered. "We have already asked food companies like Nestlé and Oetker whether they might be interested in processing the substances produced in the biorefinery," reports Boje Müller.

The motley team received a source of motivation in September when the expert panel of the German Sustainability Award selected the project from the top 3 contenders in the final round. It was then down to good marketing to win as many points as possible at the online voting stage. The other finalists were contenders to be taken seriously. In the "loopsai" project, an intelligent software solution for identifying highly complex material flows is being developed with a view to networking these flows into a closed circuit. The "Urban Pergola" project group aims to turn cities into an urban jungle using pre-grassed plant nets. The nets can be affixed between buildings and thus reduce the heating up of facades and streets. ■

On the German Sustainability Day, held for the most part online on December 4, it was the "loopsai" project that edged out the competition. Although the waste-to-resource unit wasn't among the winners, Boje Müller remains optimistic: "As finalists, we receive development advice and professional media training. And this will allow us to successfully further develop our idea."

Sustainable future

The German Sustainability Award recognizes groundbreaking contributions to a sustainable future and shows, using the best examples, how ecological and social progress can be made at a faster pace. The award is given by the German Sustainability Award Foundation (Stiftung Deutscher Nachhaltigkeitspreis e.V.) in close cooperation with the German Federal Government. In 2020, over 800 entrants competed in the categories of design, architecture, packaging, companies, local government, start-ups and research. This makes the German Sustainability Award the most extensive award of its kind in Europe.

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How can we prolong youthfulness?

Fraunhofer researchers in Hamburg have developed a test that each and every one of us can use at home to determine our biological age. They are now looking for ways to slow down the biological aging process.

By Christine Broll

As a researcher involved in the quest for therapies to treat cancer and other diseases, Dr. Sheraz Gul put things in a nutshell: "Prevention is better than cure." But even those who watch their weight and choose a healthy diet know: as we age, we are at more risk of disease. The changes occurring in the body at cellular level are the subject of intense research work – and the work of Sheraz Gul too. At Fraunhofer IME in Hamburg, and from January at Fraunhofer Institute for Translational Medicine and Pharmacology ITMP, he is seeking to find substances that influence this aging process.

130 genes reveal how we, as individuals, will age.

The big steps in a person's lifetime are obvious ones. But there are many excursions in between. © *iStockphoto*

In collaboration with Hamburg-based Cerascreen GmbH, Gul's team has developed a test that determines biological age – using a sample of saliva a person takes at home and sends off for analysis. This is an easy way to tell whether their biological age matches the data on their identity card.

Lifestyle and environmental factors have a major impact on epigenetic changes. "The genetic information coded in DNA is pretty much constant throughout a person's life," explains Sheraz Gul. But the older we get, the more frequently small molecules, methyl groups made up of one carbon atom and three hydrogen atoms, bind to our DNA. The researchers on aging call this process epigenetic change. The methyl groups have a direct influence on whether specific genes are decoded. The degree of methylation correlates with age and is influenced by diet and a host of environmental factors.

Epigeneticists like Sheraz Gul work with colossal amounts of data. His investigations have involved analyzing more than 800,000 methylation sites in the human genome. "We developed algorithms for analyzing this huge amount of data and have identified 130 genes, the methylation process of which is closely linked to aging," says Sheraz Gul. This genes are examined by the Cerascreen Genetic Age Test. The test arrived on the market at the end of 2018. The samples sent in are sequenced at the University of Kiel, and the data are analyzed using the algorithm developed by Fraunhofer. Gul's Working Group is currently developing an online tool that customers can use to find out which genes undergo abnormal methylation.

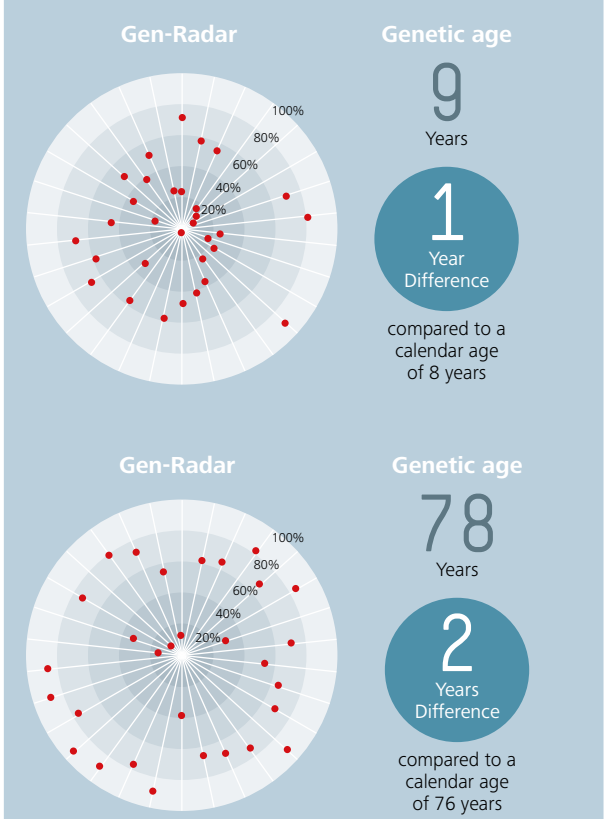
Can we halt the aging process?

Ever since we have known that the aging process involves epigenetic changes, the question has been: Can we halt or reverse this process? Is it possible to stop DNA undergoing methylation? Sheraz Gul answers this question with a resounding yes. One possibility is to fast. Studies have revealed that reducing calories extends longevity and makes us less vulnerable to a number of diseases, including cancer.

The 130 genes whose methylation processes correlate with age are currently the subject of research work at ITMP. Gul analyzes which proteins are coded by these genes. He then looks for substances that influence these proteins and, as a result, could impact the aging process. Certain substances that change the epigenetic profile are already known. Resveratrol, for example, which occurs in grape skins and hence also in red wine. The team is now developing test systems for identifying new substances that have the potential to be anti-aging remedies.

The Gen-Radar

© iStockphoto



Biological age can be depicted in a Gen-Radar. The analysis of the Cerascreen genetic test involves depicting the methylation process of 30 genes. Each red dot represents a gene. The position of the red dot shows the percentage by which its gene is methylated. The further out the dot, the greater the degree of methylation. In an eight year old child, the dots are much closer to the center than in someone who is 76 years of age. © *Fraunhofer FIT*

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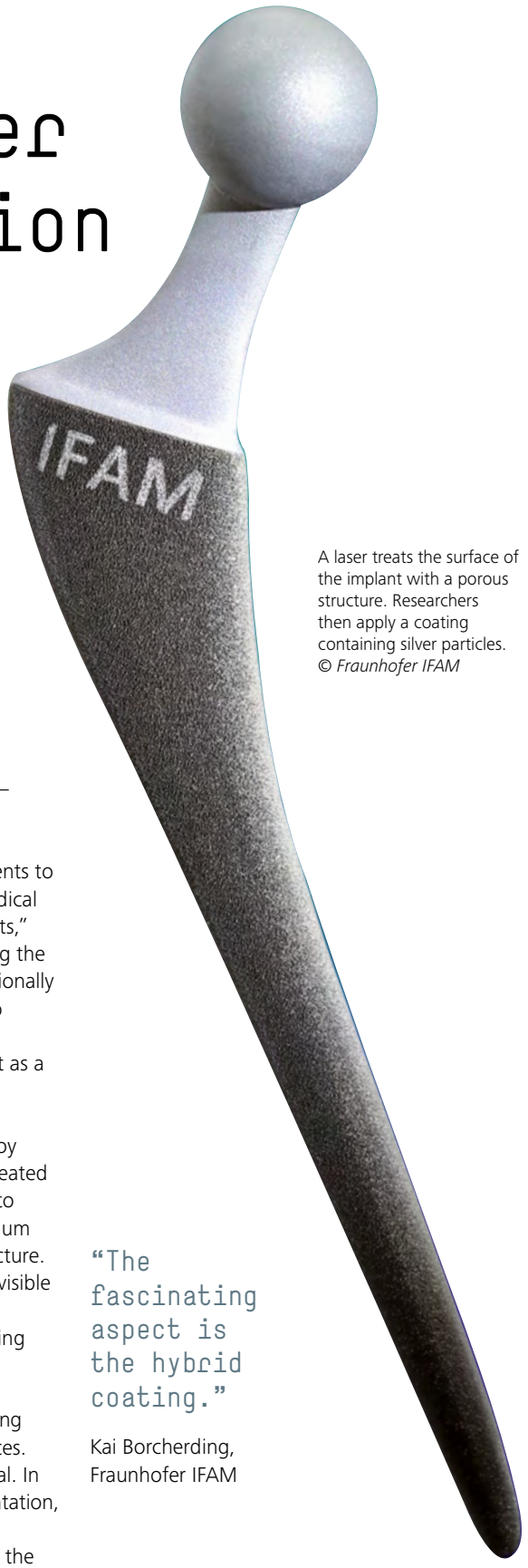
Proper healing after a hip joint operation

Hope for people who receive implants: Researchers at the Fraunhofer-Gesellschaft have developed concepts to prevent the dreaded infections once a hip prosthesis or other implant is in.

By Mehmet Toprak



A laser treats the surface of the implant with a porous structure. Researchers then apply a coating containing silver particles. *© Fraunhofer IFAM*

There are more hip operations in Germany than anywhere else in the world. The statistics show 309 implants of artificial hip joints per 100,000 inhabitants for the year 2017 alone. One to two percent of these patients develop complications. The Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM and the Fraunhofer Institute for Ceramic Technologies and Systems IKTS are working on minimizing this post-operative risk and hence aid the healing process. The institutes are attempting, through various approaches, to reach the same goal. Fraunhofer IKTS is pouring its energies into replacing metal with ceramic. Fraunhofer IFAM is working on a hybrid coating.

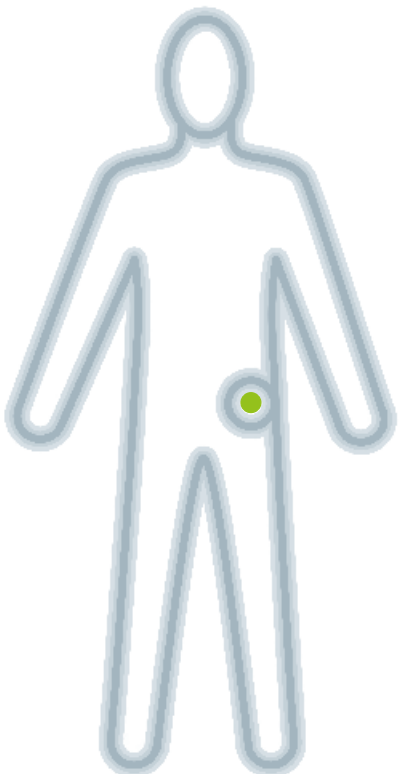
"The most fascinating aspect of the BMBF AntiSelektInfekt project is the hybrid coating. The implant can be charged with an antibiotic, tailored to the patient's unique requirements, just before the operation. This, in combination with the antimicrobial properties of silver, allows the implant to grow into the flesh with less risk of infection," explains Kai Borcherding, Manager of the Medical Engineering and Life Systems Business Unit at Fraunhofer IFAM. The project was jointly realized with researchers from the Julius-Wolff Institute and the BIH Center for Regenerative Therapies (BCRT) of Charité – Universitätsmedizin Berlin.

"Technologies that allow antibacterial agents to be administered locally, alongside the medical care, make sense especially for risk patients," says Prof. Gerhard Schmidmaier, explaining the basic concept of the project. The internationally renowned expert for trauma surgery, who specializes in bone infections and healing disorders, was involved in AntiSelektInfekt as a project mentor.

If the antibacterial agents are to deploy their local effect, the implant has to be treated beforehand. The IFAM team uses a laser to treat the surface of the implant, the titanium hip stem for example, with a porous structure. During this process, tiny pores that are invisible to the naked eye appear on the surface. Researchers then apply a coating containing silver particles.

Fraunhofer IFAM draws on its long-standing experience for treating and coating surfaces. The second step takes place in the hospital. In the operating room, so just before implantation, the surgeon immerses the implant into a solution containing antibiotic. This means the

> "The fascinating aspect is the hybrid coating."
>
> Kai Borcherding, Fraunhofer IFAM



309
Implants

/ 100,000
Population
in Germany

antibiotic can be tailored to allergies or to the patient's unique requirements.

"Once the implant is in, the antibiotic begins releasing into the surrounding tissue, and kills off any bacteria," explains Prof. Britt Wildemann. In the project, she led the studies on efficacy and biocompatibility at Charité – Universitätsmedizin Berlin. The silver, by contrast, is released much more slowly. It remains active for several days and weeks and aids the healing process.

Tests show that the hybrid coating concept is a resounding success. Wildemann says: "The preclinical studies have demonstrated that the hybrid implant coating encourages the implant to grow into the flesh and significantly reduces the rate of infection." Several companies have already indicated their interest. Service providers could handle the pre-treatment and coating phase, or implant manufacturers might take on the process as a whole.

A second approach to the same goal

Equally promising as the work at IFAM is the CERAMIC Bonepreserver research project of Fraunhofer IKTS. Its all in the name: ceramic instead of metal. Patients who receive implants made of metals such as cobalt-chromium-molybdenum often develop irritations or allergies, also known among medics as metallosis. Ceramic is a much more tolerable material.

The project partner was medical technology manufacturer Mathys Orthopädie GmbH. The project focus is the hip region. The researchers made the acetabulum, and its counterpart, the so-called femoral head. During the surgery, the acetabulum is implanted in the hip bone, and the femoral head is anchored in the femur. The surfaces that touch are completely smooth, whereas the other sections are roughened. This improves bone cell adherence.

Fraunhofer IKTS has many years of experience in ceramic materials and a great deal of expertise in the forming process used in medical engineering. For the resurfacing prosthesis, the researchers use a finely ground ATZ (Alumina Toughened Zirconia) dispersion ceramic. This creates the basis for the ultrapure suspension, from which the femoral head and the acetabulum are in turn formed by the slip casting method. Fraunhofer IKTS has developed this method from the process known from traditional porcelain manufacture. The particles need to be evenly distributed in the suspension to ensure the quality of the final product. "We work with a grain size of between 310 and 320 nanometers. The suspension needs to be entirely free of any pores or impurities," says Project Manager Martina Johannes.

Ceramic too is stable

Concerns that the ceramic material could break more easily than an implant made from metal have proved unfounded. "Our bending, pressure and load tests have revealed that the ceramic prostheses are at least as stable and robust as a product made from metal," says Johannes. The project is now complete. But it will take some time until the technology receives final approval for use in the medical world.

Meanwhile, the IKTS has the next medical project firmly in its sight. The Finger-KIT project concerns the "Remobilization of finger joints through AI-based reconstruction and generation of patient-specific ceramic implants". Fraunhofer Institutes IAPT, IKTS, ITEM, IWM and MEVIS are collaborating on the project. Its aim is to establish a continuous and automatable process chain, from the design and production of implants through to certification-compliant testing. ■

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They laid the foundation stone for innovations of the future

The Federal President awards the German Future Prize in recognition of technology and innovation with guaranteed application potential. Fraunhofer is among the prize winners for the ninth time.

By Josef Oskar Seitz

The German Future Prize, awarded for the 24th time for Technology and Innovation.

The German Future Prize – the Fraunhofer prize winners

2000
"MP3 compression of audio signals in hi-fi quality for Internet and mobile radio"
Karlheinz Brandenburg (spokesperson), Bernhard Grill, Harald Popp, Fraunhofer Institute for Integrated Circuits IIS, Erlangen

2004
"Lab on a chip – electrical biochip technology"
Rainer Hintsche (spokesperson), Walter Gumbrecht, Roland Thewes, Fraunhofer Institute for Silicon Technology ISIT, Itzehoe
Siemens AG, Power & Sensor Systems, Corporate Technology, Erlangen, Infineon, Munich

2007
"Light from crystals – light diodes are finding their way into our everyday life"
Klaus Streubel (spokesperson), Stefan Illek, Osram Opto Semiconductors GmbH, Regensburg, Andreas Bräuer, Fraunhofer Institute for Applied Optics and Precision Engineering IOF, Jena

2010
"Modeled on an elephant's trunk – a high-tech helper for industry and the home"
Peter Post (spokesperson), Markus Fischer, Andrzej Grzesiak, Festo AG & Co. KG., Esslingen am Neckar, Fraunhofer Institute for Automation and Manufacturing Engineering IPA, Stuttgart

The three winners (f.l.t.r.): Dr. Sergiy Yulin, Fraunhofer IOF, Dr. Peter Kürz, ZEISS, and Dr. Michael Kösters, TRUMPF.
© All photos: German Future Prize/Ansgar Pudenz

Research to the extreme" was the title this magazine gave to its portrait of Fraunhofer researcher Dr. Sergiy Yulin in October. Television viewers were able to experience pure joy on ZDF on November 25. In front of live cameras, Federal President Frank-Walter Steinmeier awarded the 250,000 euro German Future Prize to the scientist from the Fraunhofer Institute for Applied Optics and Precision Engineering IOF in Jena and his fellow researchers Dr. Peter Kürz from ZEISS and Dr. Michael Kösters from TRUMPF.

This is the ninth time (see below) Fraunhofer researchers have won this prize awarded by the Federal President – starting in 2000, when Karlheinz Brandenburg, Bernhard Grill and Harald Popp received the German Future Prize for their "MP3 compression of audio signals in hi-fi quality". The 24th award ceremony again honored a technology that has what it takes to change – and improve – people's everyday lives. The award-winning process for chip production will make microchips smaller, more powerful, energy-efficient and cheaper in production. Fraunhofer President Prof. Reimund Neugebauer clearly described the potential in his congratulatory speech: "They used EUV lithography to develop a technology that will cause a digitalization boost worldwide and they have thus laid the foundation for further innovations." The first smartphones with EUV-lithographically manufactured microchips have been on the market since 2019.

The research result is minute in size, the effort gigantic. Optical lithography, key technology in microchip production for over four decades, is fast approaching its limits. With EUV lithography, Fraunhofer, ZEISS and TRUMPF are once again throwing the door wide open to the future – to new potentials for digitalization, artificial intelligence, autonomous driving and Industrie 4.0. A single chip, no bigger than a finger nail, can now accommodate more than ten billion transistors.

To make this possible, researchers have pushed the boundaries of current technology. The breakthrough that is set to make EUV lithography ready for series production broke a number of records. The world's most powerful pulsed industrial laser, developed by TRUMPF AG, ignites – to generate the extreme ultraviolet light – some 50,000 tin droplets per second in a plasma source at a temperature of 220,000 degrees Celsius: that is 40 times hotter than the surface of the sun. Highly precise collector mirrors and projection optics, produced at ZEISS AG on lithographic photomasks, direct the radiation.

The nuclear precision and the high reflectance achieved by the mirrors are the result of the coating technology of Fraunhofer researcher Yulin. He explains, "In our coating system, we apply 100 nano layers, which must all be exactly the same thickness, to a mirror substrate." Let us make a comparison to get some idea of the precision involved: if we were to widen this mirror to the size of Germany, the greatest unevenness would be 0.1 millimeter. Besides Fraunhofer IOF in Jena, Fraunhofer IWS in Dresden and Fraunhofer ILT in Aachen have also been conducting research into coatings and EUV radiation sources for many years.

The perfect coating composition for mirror optics is Sergiy Yulin's life work. His route into EUV lithography and hence to winning the German Future Prize started in 1988 during his studies in his home country, the Ukraine. He even wrote his thesis on the subject. "30 years of research are not so unusual for a technology of this complexity," he says dismissively. And adds: "What has always fascinated me about the work with extremely short wavelengths is its huge application potential. It simply has to be exploited." Federal President Frank-Walter Steinmeier said on the evening of the award ceremony: "They are outstanding people, the ones whose ideas created projects and whose projects created products." ■

"They are outstanding people, the ones whose ideas created projects and whose projects created products."

Federal President Frank-Walter Steinmeier

"30 years of research are not so unusual for a technology of this complexity," says Dr. Sergiy Yulin, Fraunhofer IOF.

2011 – **"Organic electronics – more light and energy from ultra-thin molecular coatings"**
Karl Leo (spokesperson), Jan Blochwitz-Nimoth, Martin Pfeiffer, Technical University/Fraunhofer Institute for Photonic Microsystems IPMS, Dresden, Novaled AG, Dresden, Heliatek GmbH, Dresden

2012 – **"Binaural hearing aids – spatial hearing for everyone"**
Birger Kollmeier (spokesperson), Volker Hohmann, Torsten Niederdränk, Carl von Ossietzky University of Oldenburg/Fraunhofer Institute for Digital Media Technology IDMT, Ilmenau, Siemens AG, Munich

2013 – **"Ultrashort pulse lasers for industrial mass production – manufacturing with light flashes"**
Jens König (spokesperson, Bosch), Stefan Nolte, Dirk Sutter, Robert Bosch GmbH with Schwieberdingen Development Center, Friedrich-Schiller University Jena, Fraunhofer Institute for Applied Optics and Precision Engineering IOF, Jena, TRUMPF Laser GmbH + Co. KG, Schramberg

2014 – **"Food ingredients from lupines – contributing to a balanced diet and providing a richer source of protein"**
Stephanie Mittermaier (spokesperson), Peter Eisner and Katrin Petersen (Prolupin GmbH, Grimmen) and Fraunhofer Institute for Process Engineering and Packaging IVV, Freising

2020 – **"EUV lithography – new light for the digital age"**
Dr. Peter Kürz (spokesperson), Dr. Michael Kösters, Dr. Sergiy Yulin, Carl Zeiss SMT GmbH, Oberkochen, TRUMPF Lasersystems for Semiconductors Manufacturing GmbH, Ditzingen, Fraunhofer Institute for Applied Optics and Precision Engineering IOF, Jena

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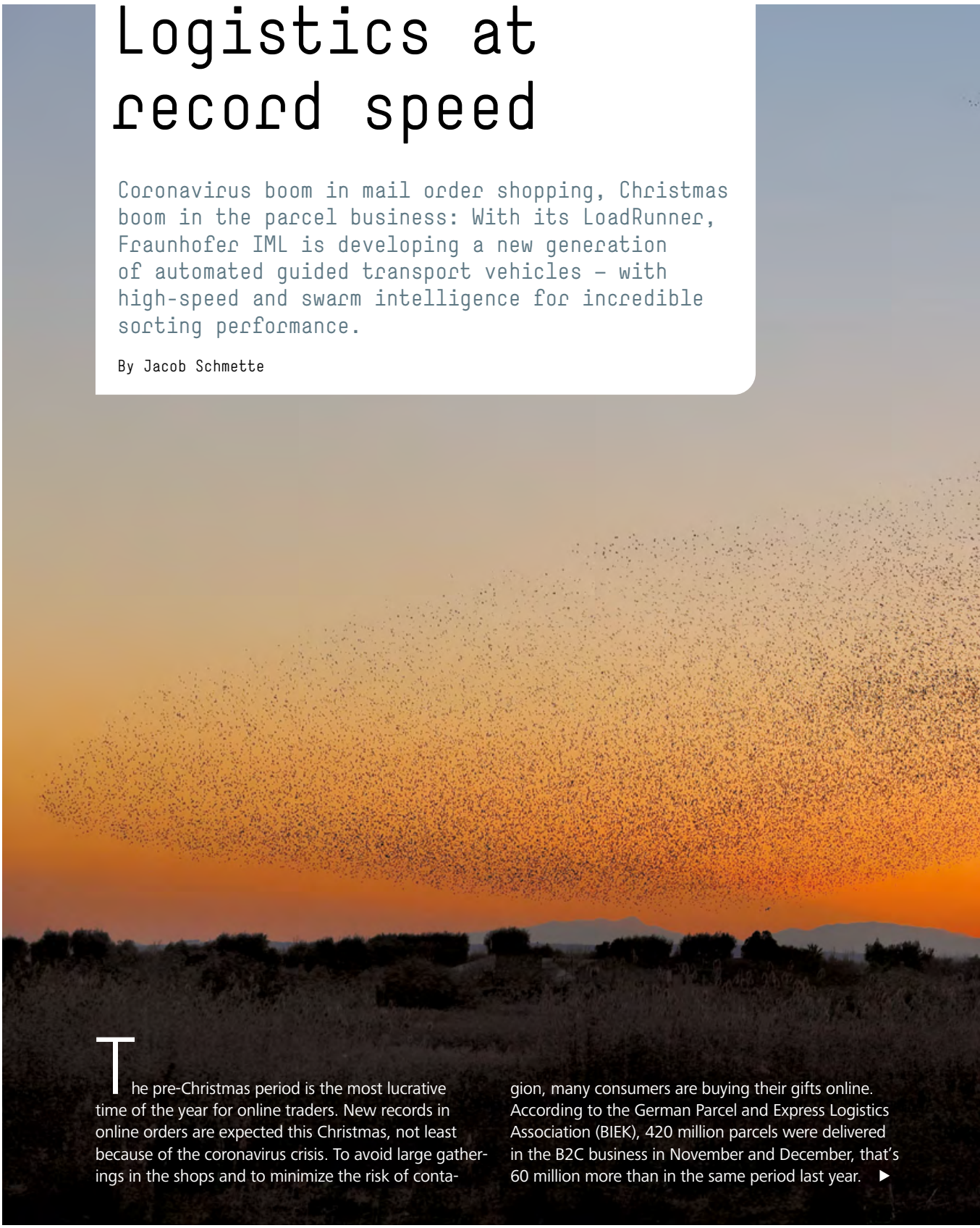
Logistics at record speed

Coronavirus boom in mail order shopping, Christmas boom in the parcel business: With its LoadRunner, Fraunhofer IML is developing a new generation of automated guided transport vehicles – with high-speed and swarm intelligence for incredible sorting performance.

By Jacob Schmette

The first half of 2020 saw at least 800,000 more consignments being transported every day than in 2019. This is the figure found by the German Parcel and Express Logistics Association (Bundesverband Paket und Expresslogistik e.V.). For 2020 as a whole, the organization is expecting more than 3.9 billion consignments – with a new parcel record at Christmas.



The pre-Christmas period is the most lucrative time of the year for online traders. New records in online orders are expected this Christmas, not least because of the coronavirus crisis. To avoid large gatherings in the shops and to minimize the risk of contagion, many consumers are buying their gifts online. According to the German Parcel and Express Logistics Association (BIEK), 420 million parcels were delivered in the B2C business in November and December, that's 60 million more than in the same period last year. ▶

Fascination Swarm intelligence.
© *Daniel Biber*

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© Fraunhofer IML

The LoadRunner as “the last piece of the puzzle for the logistics of tomorrow”.

Prof. Michael ten Hompel

▶ In future, the LoadRunner will really help traders manage these parcel mountains. The automated guided transport vehicle was developed by the Fraunhofer Institute for Material Flow and Logistics IML. It can sort items and move them from A to B at speeds of up to ten meters per second.

“These vehicles can accelerate like a sports car and are entering a whole new performance dimension,” emphasizes Prof. Michael ten Hompel, Managing Director of the Fraunhofer Institute for Material Flow and Logistics IML. He sees the LoadRunner as “the last piece of the puzzle for the logistics of tomorrow”.

Organization by swarm

The transport robot works in a swarm system. The idea was based on a swarm of drones, which the researchers at Fraunhofer IML had developed already. Twenty drones mimic the behavior of a swarm of birds. Each drone follows the behavior of its neighbor, continuously adapting their flight direction and speed. Collisions are avoided, groups are formed and the interactions between the individual decisions create a swarm intelligence that requires no central coordination. Just like the drones, the swarm system of the LoadRunner uses methods of simulation-based artificial intelligence.

“The LoadRunner has an omnidirectional chassis, its direction of travel and sense of rotation are completely independent of one another. So the new transport vehicle can turn in any direction, even as it travels, without having to maneuver,” explains Moritz Roidl from Fraunhofer IML. “The robots use an onboard ground camera to orientate themselves. This camera takes 400 pictures per second of the ground, which is memorized beforehand. As a result, the vehicle can precisely localize itself in tight formation flights even at high speeds.”

As a stand-alone vehicle, the LoadRunner is able to transport and sort parcels weighing up to 30 kilos. So it’s ideal for items of baggage at airports. For any heavy items, the AI runners work in groups. That way, even large and bulky objects can be transported. In addition, every LoadRunner can be coupled to up to four passive trailers. The LoadRunner draws its power from an electric motor. To drop off its load, the LoadRunner brakes at exactly the right moment just before its destination and bumps towards its final stop under control. The item can then slide from the robot onto the delivery surface.

13,000 consignments every hour

Fraunhofer IML investigated the use of the LoadRunner for parcel sorting. And this study delivered the first promising results: Around 60 vehicles are able to process 13,000 consignments per hour. So 60 LoadRunners achieve the performance ranges of conventional sorting systems. The huge benefit of this novel transport vehicle is that it needs far fewer permanently installed infrastructures than conventional sorting systems. The LoadRunner promises much faster commissioning and higher scalability.

Autonomous order processing

Thanks to artificial intelligence, the LoadRunner can accept and process orders by itself. So for that reason too, the vehicle is revolutionizing logistics. In future, the LoadRunner will communicate securely over 5G and conclude pay-per-use contracts independently using blockchain technology. The transport vehicle is currently undergoing further development at Fraunhofer IML. The aim is to realize an outdoor LoadRunner. “Thanks to 5G technology the vehicle can, in principle, be used outdoors as well. Applying the same technological basis as the indoor LoadRunner, the outdoor version could move, via mobile radio, between warehouses on a company’s premises for example,” explains Moritz Roidl. This will give the transport robot even more flexibility in the future. The logistics sector, which is overstretched on a regular basis, can look forward to the huge relief this AI runner will bring. ■

LoadRunner swarm in the start formation.
© Fraunhofer IML

Use in the Silicon Economy

To fully exhaust the potential of the LoadRunner technology, an open digital infrastructure like the Silicon Economy is required. In the Silicon Economy, the digital platform economy of the future, vehicle swarms will organize themselves and communicate with human beings, other swarms and platforms to complete their mission. With the “Silicon Economy Logistics Ecosystem (SELE)” research project, Fraunhofer IML wants, as a counterdraft to Silicon Valley, help a decentralized and open platform economy in Germany and in Europe to achieve a breakthrough. The Federal Ministry of Transport and Digital Infrastructure (BMVI) is supporting the project over a period of three years with a total of some 25 million euro. As well as Fraunhofer IML, project partners are the Fraunhofer Institute for Software and Systems Engineering ISST, and TU Dortmund. In future, the LoadRunner will play a key role in the Silicon Economy and usher in a new era of logistics.

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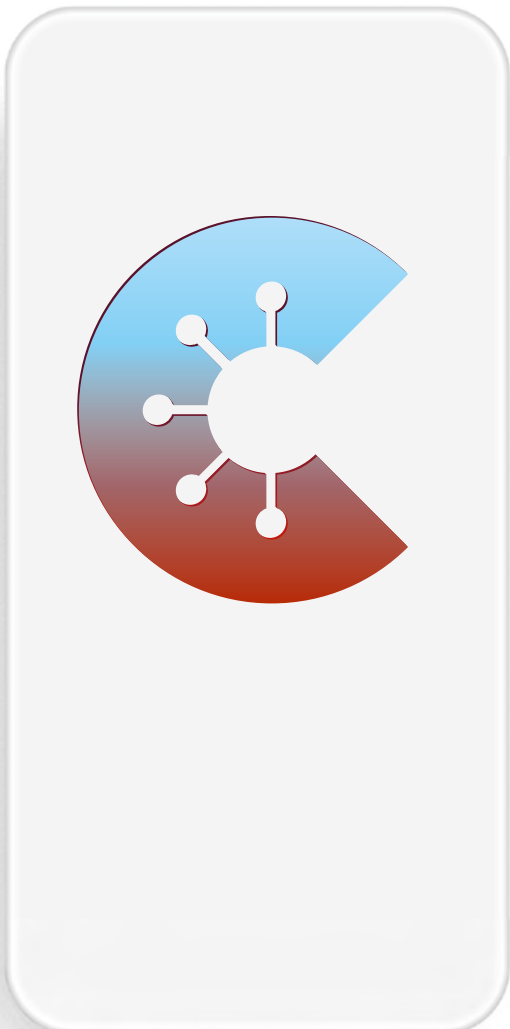
FRAUNHOFER VS. CORONA



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“BIOLOGICAL TRANSFORMATION IS SET TO BE PART OF OUR FUTURE IN PRACTICALLY EVERY AREA OF LIFE.”

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