Fraunhofer magazine

1/16 special issue

Making it lighter

Information Technology
Sustainable smart cities

Life Sciences
Plasma makes wounds heal quicker

Energy
Charged in motion

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to promote industry-oriented environmental, process, and energy technology

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Sculpture designed by Hans-Dieter Godolt.

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Living in a digital world

Prof. Dr. Reimund Neugebauer. © *Stefanie Aumiller*

Modern information technologies are gradually becoming a ubiquitous feature of our working and private lives. They are changing the way we communicate, how we work, our shopping habits, and the media through which we listen to music or watch movies. But the issue of the day is the emerging digital economy, in which cloud computing, industry 4.0, smart data and the Internet of Things are beginning to revolutionize business processes.

In the future, more and more manufacturing plants, machines, cars, private homes, smartphones and even domestic appliances such as heating systems and washing machines will be digitally connected. These examples show how profoundly this development is about to affect our everyday lives – with an impact that extends to almost every sector of the economy from the manufacturing industry, the retail and service industries to supply chain logistics. This is why we refer to them as disruptive technologies, because they are about to overthrow our conventional business models, products and services and replace them with new ones.

What consequences can we expect from this new industrial revolution? Connected solutions make data a central production factor, just as important as capital, labor and raw materials. That's why it is all the more essential for companies to safeguard the sovereignty of their data – secure and reliable access to information will be of prime importance in tomorrow's digital economy.

With the support of the German federal government, the Fraunhofer-Gesellschaft and its industrial partners have set up a task force whose mission is to work together toward the goal of creating an open Industrial Data Space. Open access to and the free utilization of this resource will be granted to all companies that agree to apply the defined common standards. The objective is to develop secure solutions that will enable users to adapt their manufacturing and business processes to the rapid pace of industrial progress in this age of all-encompassing digitalization.

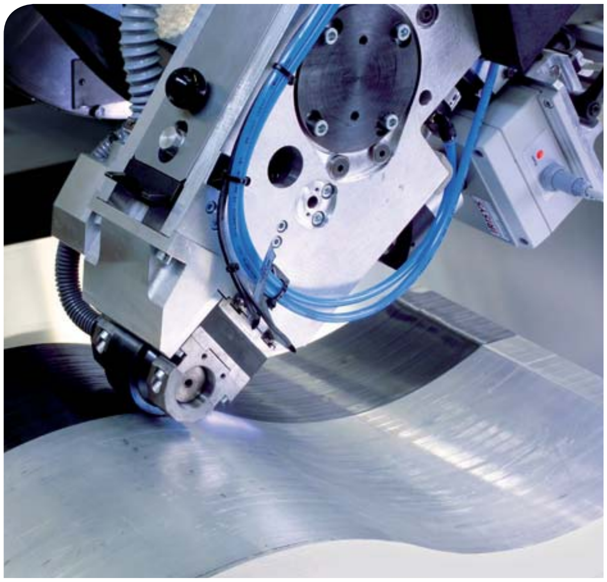
While digitalization opens up many opportunities, it also presents companies with new challenges. Take industry 4.0, for example: the ability to connect machines, components, and the like to the Internet makes manufacturing systems vulnerable to abuse by hackers. Fraunhofer researchers have set up an IT security laboratory that serves as a test environment in which such attacks can be simulated in order to identify gaps in security (page 16).

Contemporary applications of information technology also play an increasingly important role in urban development. They can help to create smart cities and improve their inhabitants' quality of life. One recent example is the EU-funded Triangulum project, in which researchers are devising pioneering concepts for sustainable energy supplies, mobility and IT solutions. The central element of this project is an architecture designed by Fraunhofer researchers (page 26).

Medicine is another of the many areas in which the trend toward digitalization is opening up new opportunities. Fraunhofer researchers are working on a software solution that enables endoscopic images to be merged to provide a panoramic view. In a few years' time, this technology may assist physicians when carrying out endoscopic examinations (page 36).

To shape tomorrow's digital world to our advantage, we need to act now to create the necessary foundations. Fraunhofer is working determinedly toward this goal.

Yours,

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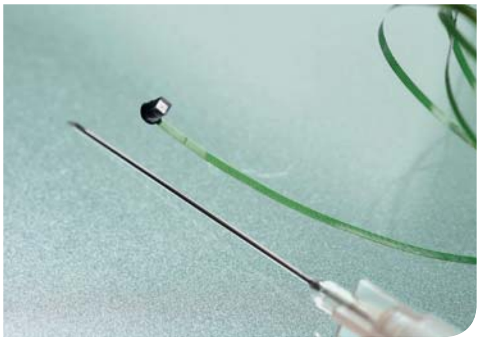
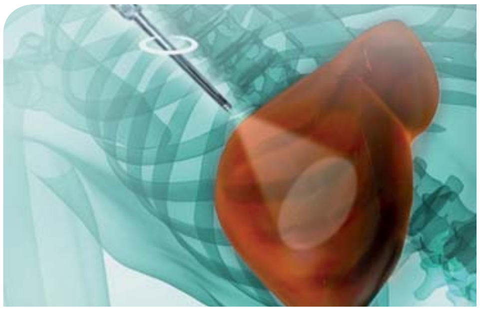
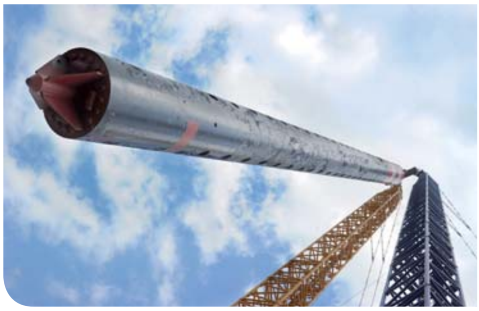
DATA







Content

Reducing imports of raw material

Until recently, valuable metals and minerals have been lying unnoticed in the iron and steel industry's metallurgical dumps. Buried beneath the dust, debris, rubble and other remnants of the iron and steel industry, these sources could reduce Germany's dependence on the import of raw materials. But for now they often go unused because of a lack of comprehensive data regarding their precise potential.

This is where the REStrateGIS project, funded by the German Federal Ministry for Education and Research, comes in. Its focus is twofold: one, to use geographic information technology to design and develop a resource registry for metallurgical dumps; and two, to develop a strategy for reusing valuable raw materials. The project is coordinated by experts at the Fraunhofer Institute for Environmental, Safety, and Energy Technology UMSICHT.

The researchers have begun to create a Germany-wide registry that catalogs the possible reserves of raw materials in dumps, making it easier to estimate which material is to be found where in Germany. Furthermore, the researchers will review under what conditions retrieving the materials is profitable.

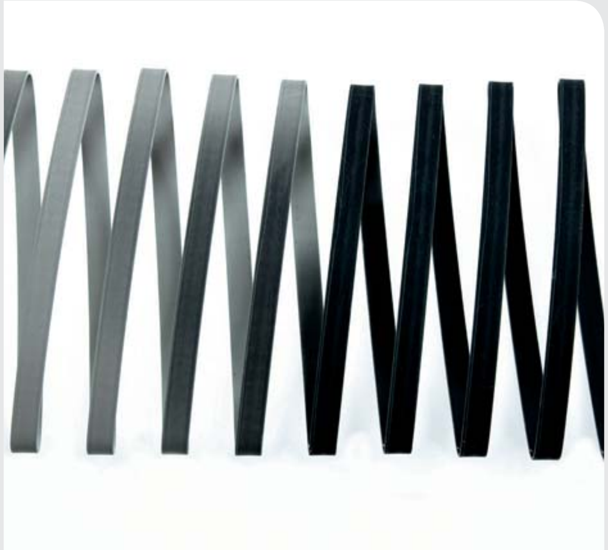
Until now raw materials in metallurgical dumps are hardly used. © *Fraunhofer UMSICHT*

Nano-coatings for heat regulation

The dimensions are tiny, but the effects are tremendous: nanoparticles featue ra particularly large ratio of surface area to volume, which makes them exceptionally efficient and reactive. Researchers at the Fraunhofer Institute for Chemical Technology ICT in Pfinztal near Karlsruhe are capitalizing on this effect to develop new types of coatings. In addition, they are incorporating active nanomaterials into polymer systems. These coatings can be applied simply like paint or varnish.

As part of a project funded by the German Federal Ministry for Education and Research and in conjunction with industry partners, the ICT researchers developed an adjustable, thermochromic nano-coating for metal wires and strips. The coating changes color in response to temperature, which means it is able either to absorb heat or reflect it. "Below 30 °C, the black coating absorbs heat. But if the temperature rises, the color changes, and the now transparent coating reflects infrared radiation," explains Helmut Schmid from the ICT. Strips and wires coated in this way are well-suited for use in building projects. They can be woven together and used as "heat-regulating" cladding for walls and façades, where they help cool the building passively and contribute to lower utility costs.

Metal strip with thermochromic nano-coating. Above 30 °C, the outer layer is transparent and reflects heat. At colder temperatures, the coating darkens and absorbs infrared radiation. © *Fraunhofer ICT*



New glass façades

Glass-enclosed office buildings are among the biggest consumers of energy, since they require complex cooling systems. To reduce this energy consumption, researchers at the Fraunhofer Institute for Machine Tools and Forming Technology IWU in Dresden, together with the Department of Textiles and Surface Design at the Weissensee School of Art in Berlin, developed façade components that react autonomously to sunshine and the resulting heat. They require no electricity, instead relying solely on the energy provided by the warmth of the sun.

The demonstrator is composed of a matrix of 72 individual fabric components resembling flower petals. Each textile module has shape-memory actuators integrated into it: thin 80-millimeter-long wires of nickel-titanium alloy that remember their original shape when exposed to heat. If the façade heats up, these wires are activated and contract, causing the fabric components to silently unfold. The exposed part of the façade element closes and the building is shaded from sunlight. If clouds block the sun, the elements close and the façade is once again transparent.

Designed for extensive glass surfaces, this sun protection can be placed either on the outer window pane or, in the case of a multi-panel glass façade, in between the panes. As such, it offers a multitude of design possibilities.

The façade element requires no external energy source. It functions on the basis of integrated wires with a shape-memory alloy.
© Bára Finnsdóttir | Weißensee Kunsthochschule Berlin

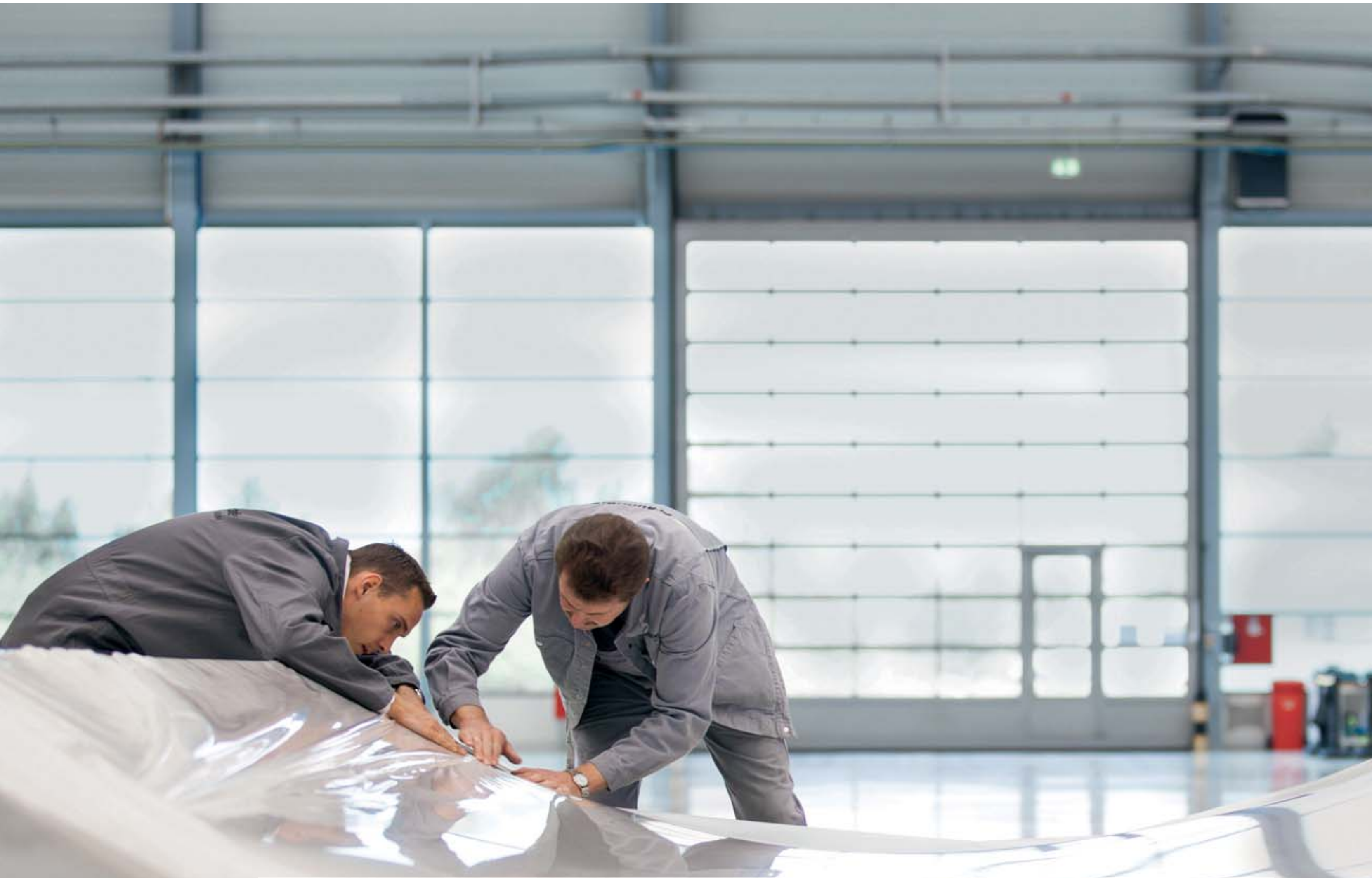
Quick check for drinks

Thanks to a new type of polymer powder, producers of beer, milk, juice and wine will now be able to check more quickly and easily for pathogens, which can have a serious adverse effect on their product's taste and smell. Conventional microbiological methods require five to seven days to conduct an analysis. Researchers at the Fraunhofer Institute for Applied Polymer Research IAP in Potsdam, together with the company GEN-IAL in Troisdorf, have developed a process that cuts the time needed for these tests down to two to three days.

A polymer powder is added to the fluid sample, where the functionalized surface of the polymer binds the bacteria. Once the pathogens have attached themselves to the powder particles, which measure 100 to 200 microns, these can be easily extracted – and the microbes with them – using the system developed by the IAP, then analyzed directly with microbiological methods.

The system for functionalizing the surface of the powder particles was also developed by researchers at the IAP, and is being used by GEN-IAL in the pilot production phase.

The functionalized surface of the polymer powder binds the bacteria.
© Fraunhofer IAP



Lightweight carbon composites are being used to a growing extent in the construction of aircrafts.
© *Fraunhofer IFAM*

Fraunhofer Lightweight Design Alliance

In order to develop new materials, manufacturing and joining technologies, as well as test procedures for lightweight design, 15 Fraunhofer Institutes have joined forces in the Lightweight Design Alliance. The alliance addresses the entire development chain – from material and product development to mass production and certification, all the way through to recycling. Fraunhofer Institutes taking part include:

- Structural Durability and System Reliability LBF
- Chemical Technology ICT
- Manufacturing Technology and Advanced Materials IFAM
- Integrated Circuits IIS
- High-Speed Dynamics, Ernst-Mach-Institut, EMI
- Laser Technology ILT
- Production Technology IPT
- Silicate Research ISC
- Industrial Mathematics ITWM
- Environmental, Safety and Energy Technology UMSICHT
- Ceramic Technologies and Systems IKTS
- Mechanics of Materials IWM
- Material and Beam Technology IWS
- Machine Tools and Forming Technology IWU
- Nondestructive Testing IZFP

Making it lighter

Lower carbon dioxide emission is one of the significant goals of the future. Not only for Germany, but also for the EU and all industrialized nations. Trimming down the weight of cars, planes and trains offers a potential solution for saving energy and raw material.

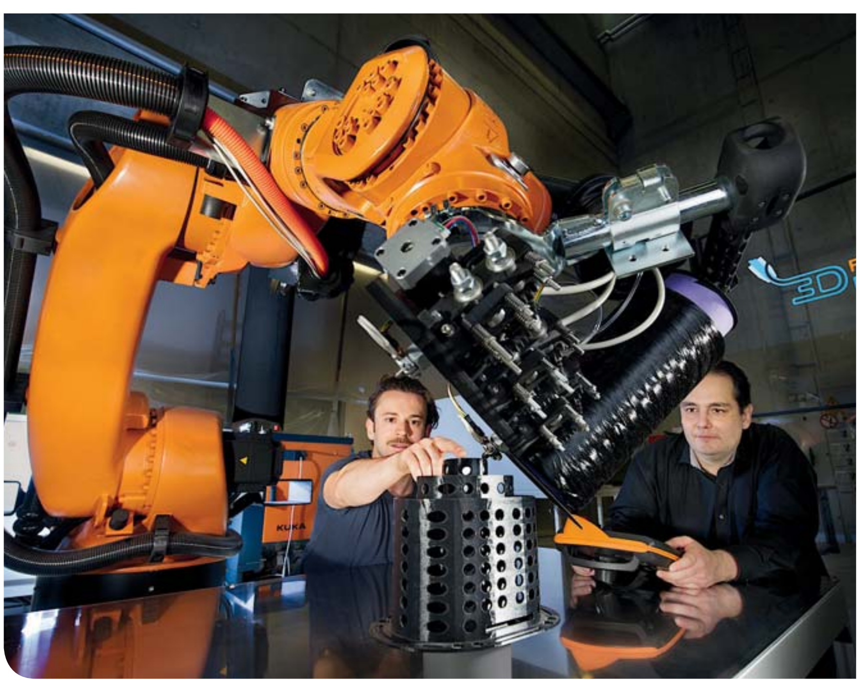
Text: Birgit Niesing

Parking assistance systems, airbags, anti-lock braking systems, heated seats – as cars gain in comfort and safety, they also gain in weight. The popular sport utility vehicles (SUVs) tip the scales at 2 metric tons or more. But even small and medium-sized cars usually weigh in at over 1.2 metric tons. Now is the time to start trimming it down, though: as of 2020, Europe will apply more stringent limits for vehicle emissions of carbon dioxide. From then on, new cars are to emit an average of no more than 95 grams of CO_2 per kilometer; the current limit is still 130 grams.

To meet this requirement, cars have to get lighter. Reducing a car's weight by 100 kilograms cuts its fuel consumption by 0.4 liters per 100 kilometers and its carbon dioxide emissions by up to 10 grams. The car body offers one way to save weight. Car manufacturers still make it using steel, but this is set to change according to a study by Berylls Strategy Advisors entitled "Lightweight Body Design – Coming Out Of The Niche". In the future, lightweight materials – such as high-strength steel, aluminum, magnesium or composite materials – will be used more frequently. In fact, the global market for lightweight body construction is expected to grow by an average of 15 percent per year, reaching 100 billion euros by 2025. But lightweight construction offers opportunities to more than just automakers: manufacturers of aircraft, trains, wind power plants, machinery and systems want to reduce the weight of their products too. The McKinsey study "Lightweight, heavy impact" predicts that the global market for lightweight materials will grow by 8 percent annually to more than 300 billion euros in 2030.

"In times of dwindling resources and growing environmental awareness, lightweight construction is one of the key technologies," emphasizes Professor Andreas Büter, spokesman of the Fraunhofer Lightweight Design Alliance (see box). Yet while engineers have many years of experience in working with steel, manufacturing with alloys, metal foams and composite materials is still in an early stage. More research and development is needed in this area. "It is important to find a good compromise between weight reduction on the one hand and sufficient rigidity, stability and durability on the other," states Büter. "The cShallenge is to use the right material in the right place."

Carbon makes aircraft lighter. © Airbus



The 3D fiber printer enables additive manufacturing of thermoplastic parts with integrated continuous carbon fibers.
© *Wolfram Scheible*

At BMW: the first car with a passenger cell of carbon fiber to be mass-produced.
© *bimmertoday.de*

Fiber-reinforced plastics FRP – in which fibers made of glass, carbon, or other materials are embedded in a plastic matrix – are especially light yet still stable. Depending on the requirements, the fibers can be arranged in multiple layers oriented in different directions. This way, the properties of the component can be optimally tailored to where it will be used. For example, carbon-fiber-reinforced plastics CFRP have great potential for use in lightweight construction. These components, also commonly referred to as carbon components, are often only half as heavy as steel but equally as impact-resistant. Formula 1 race cars have been using this ultralight material for years. CFRP is also slowly beginning to replace metal as a material in commercial aircraft; it already comprises more than half of the weight of the material in the new Boeing 787 and Airbus A350 airplanes. It's a different story for automotive applications, as this lightweight material is rarely used in production vehicles. There are a couple of reasons for this: CFRP components are still significantly more expensive than the same components made of steel, and their production is complex. Nevertheless, a few automakers are also starting to use carbon fiber. Some luxury cars already contain CFRP components, and in the BMW I3 electric car, the passenger cell is made of carbon fiber.

Fraunhofer researchers are working to see that even more vehicle components can be mass-produced using these materials in the future. Experts from the Fraunhofer Institute for Structural Durability and System Reliability LBF in Darmstadt have developed a transverse control arm made of carbon fibers, which is 35 percent lighter than one made of steel. In order to specifically deflect the forces acting on the component, the reinforcing fibers are arranged in the load direction. Integrated piezoelectric transducers prevent the lightweight component from vibrating. The researchers are already planning ahead: They want to continuously monitor the cross-member with fiber optic sensors and a fiber optic cable. Built into a vehicle, this "measurement transverse control arm" makes it possible to record and compare all loads with the design specifications. In an operationally stable design with verified load data, the weight of a component can be reduced by up to 40 percent. A load monitoring system such as this also makes it possible, by means of an online service life estimate, to warn the operator of potential operating damage and thus ensure the timely replacement of critical components.

"Innovative lightweight construction solutions can do more than just reduce weight," stresses Professor Frank Henning, head of the Polymer Engineering department at the Fraunhofer Institute for Chemical Technology ICT in Pfinztal (near Karlsruhe, Germany). He also heads the Chair for Lightweight Construction at the Institute of Vehicle System Technology at the Karlsruhe Institute of Technology KIT. "Thanks to the new manufacturing methods, even complex components that unite various functions can be completely manufactured in one piece," enthuses Henning. ICT researchers combined two production methods in order to manufacture a crash-relevant car seat cross-member, including cable ducts and integrated seat mounts, using fiber-reinforced plastics in mass production.

The component can be manufactured in less than four minutes. First, fibers are woven together to create a blank. "Structures made using a weaving technique absorb a great deal of energy and ensure enormous resistance to damage," explains Michael Karcher, project manager at the ICT. Another plus: The highly automated robot-assisted process yields reproducible components and hardly any waste. The woven blank is then filled with resin and cured in a press under heat and pressure. "This high-pressure resin transfer molding (RTM) technology is suitable for the mass production of large and complex component geometries. The finished components have a good surface finish, a low cavity and pore content and have excellent material and component properties," emphasizes Karcher. The ICT scientists jointly developed the lightweight car seat cross-members in cooperation with partners from research and industry in the Technology Cluster Composites (TC²) research cluster in Baden-Wuerttemberg. Also on board was the Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut EMI, and the Fraunhofer Institute for Manufacturing Engineering and Automation IPA.

Carbon-reinforced components from the printer

One method is particularly well suited for the resource-efficient production of complex components: additive manufacturing. This entails building up components layer by layer directly from powders, liquids or extrusion material, based on data models. Experts at the Fraunhofer Institute for Laser Technology ILT in Aachen developed an additive laser process years ago for manufacturing metallic components – selective laser melting (SLM). It allows the manufacture of complex components that are much lighter than conventional metallic components and which are given, for example, a bionic structure that is unobtainable with conventional methods. Plastic components can also be manufactured with additive methods. However, the number of materials suitable for selective laser sintering is still limited. Experts from the Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT in Oberhausen are working on new materials.

But are carbon fibers also suitable for additive manufacturing? IPA scientists in Stuttgart developed a 3D fiber printer with which thermoplastic components can be quickly and cost-effectively manufactured in top quality from fiber-reinforced plastic. Using a special printer jet, carbon fibers are injected directly into the molten plastic during the printing process – continuously and just exactly where needed.

Carbon fibers.
© *Bernd Müller*

Robot-controlled non-destructive ultrasonic testing of a CFRP component (right image).
© *Andreas Schlichter*

Even engines could be lighter in the future. Together with the Sumitomo Bakelite business unit SBHPP, researchers of the ICT Project Group New Drive Systems and the Fraunhofer Institute for Mechanics of Materials IWM in Freiburg have joined forces to construct a research engine with a fiber composite cylinder block. This makes it possible to reduce the weight by up to 20 percent. Another plus: The component can be produced cost-effectively by injection molding.

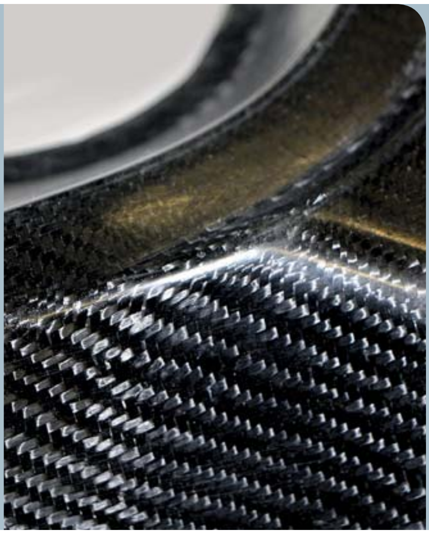
New tools for mass production

Despite all the advantages, complex components made of fiber-reinforced plastics are still rarely used in mass production. A major reason is that manufacturing costs are often too high – but this is about to change. Fraunhofer researchers are working on new manufacturing processes that are also suitable for high-volume production. One example is the EU's FibreChain project, "Integrative process chain for the automated and flexible production of components made of fiber-reinforced plastics". This project brought together partners from 18 European countries, including the Fraunhofer Institute for Production Technology IPT, which coordinating the work, and the ILT, to develop new systems technology and tools for the mass production of high-performance, recyclable lightweight components made of continuous fiber-reinforced thermoplastics.

Fraunhofer researchers are currently working on other approaches to automate the production of fiber composite components. For example, IPT engineers are driving development of a laser-assisted tape placement technique. The fiber-reinforced plastic bands, or tapes, are welded by laser by laser and formed into a compact structure. To make the method useful to small and medium-sized enterprises as well, the researchers developed the multi-material-head (MMH), a novel tape placement head. This makes it possible to process different fiber materials – such as glass and carbon fibers or various matrix materials – in the same system, assisted by laser or other heat sources. This development earned the experts at the IPT.

If lightweight components are to prevail on the market in the future, they must not only be inexpensive to mass produce, but must also function safely and reliably. Fraunhofer scientists therefore calculate models that make it possible to ascertain the damage tolerance of the materials and, using special methods, they analyze the stability of the components with respect to the heavy, fluctuating mechanical and thermal stresses of day-to-day use. With the LBF MultiTester, a new type of probe for testing internal pressure, unreinforced and reinforced plastics can be tested for stress, for example. For this test, diverse flammable and non-flammable liquids – such as oils, fuels, acids or alkali solutions – are fed into the probe and pressure is increased from the inside. The most highly stressed areas enter a multiaxial load state, as is found with lightweight structural components. The material is stressed from all spatial directions. One of the things captured by measuring systems is how the component's shape changes. The researchers can use calculations to estimate the durability for internal pressure loads and apply this to other structural components.

Experts currently rely on ultrasound techniques to test the quality of components made of fiber-reinforced plastics FRP. Researchers at the Fraunhofer Institute for Nondestructive Testing IZFP have refined the process. With sampling phased array technology (SPA), even complex fiber composite components can be examined for possible flaws quickly and reliably. First, the robot-guided ultrasonic sensor scans the components. Then the volume data generated by the ultrasound signals can be assessed largely automatically by applying specially developed algorithms.



Component reinforced with carbon and hemp fibers – body made of cotton, hemp and wood. © *Manuela Lingnau*

Blue Train: The innovative aluminum foam made it possible to reduce the weight by 20 percent compared to conventionally manufactured locomotives. Tooling costs are cut by 60 percent as well. © *Fraunhofer IWU*

A further challenge for lightweight design is that the components and materials should not only help save energy during operation, but also be recyclable when no longer in use. "Innovative lightweight construction must be viewed in terms of the entire lifecycle – from the design through production, testing and usage on to recycling," emphasizes Prof. Büter. Just how FRP can be designed to be more environmentally friendly is demonstrated by researchers at the Application Center for Wood Fiber Research HOFZET of the Fraunhofer Institute for Wood Research, Wilhelm-Klauditz-Institut, WKI. There they combine carbon fibers with different bio-based fibers made of hemp, flax, cotton or wood. The result: The components are inexpensive and very strong, have good acoustic properties, and are much more ecological than pure carbon-fiber components.

High-strength steels, light metals and metal foams

Fiber composites are lightweight materials with a future. But the potential of metals has not yet been exhausted. High-strength steels, aluminum and magnesium help substantially reduce the weight of vehicles and structures. Car manufacturers in particular will increasingly rely on high-strength steel in the future. The Berylls study predicts that by 2025, this steel will account for 45 percent of the market. However, new joining techniques are needed; the material is too brittle for mechanical methods such as clinching or self-piercing riveting. In the collaborative project "KLasse" funded by the German Federal Ministry of Education and Research (BMBF), ILT experts are working on a combined process for laser cutting and localized laser softening of components made of high-strength, press-hardened steels. Light metals can also help manufacturers reduce the weight of their products, though. An example is a rear seat backrest made of magnesium, developed by researchers at the Fraunhofer Institute for Machine Tools and Forming Technology IWU. It weighs 48 percent less than conventionally manufactured rear seat backrests. Metal foams, which can be made into lightweight and stable components, open up a new range of possibilities. These foams have a structure similar to that of bones. A pioneer in the development of foamed metals is the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM in Bremen. Today, numerous groups – including the IWU – are working on the airy materials. In most cases the metal foams are rendered as a foam core sandwiched between two solid "slices" of sheet metal. Such structures are not only lighter than strictly solid sheets, they also have a higher flexural strength. Just how this material helps reduce weight is shown by IWU researchers collaborating with Voith Engineering Services on the "Blue Train" project, which aims to develop a lightweight design and production concept for a high-speed train. There, aluminum foam is employed as an essential material for the front cab. "This lets us reduce the weight by 20 percent compared to conventional production using fiberglass composite materials or aluminum – with the same rigidity," explains Dr. Thomas Hipke, head of the IWU's Function-Integrated Lightweight Design department.

An increasing number of different materials will go into new products in the future. Creating robust bonds between components made of fiber composite materials, light metals or metal foams calls for optimized joining methods that are also economical to implement. Adhesive technology experts are pursuing this at the IFAM in Bremen. New laser processes, such as those being developed by researchers at the ILT, IPT and the Fraunhofer Institute for Material and Beam Technology IWS in Dresden, are also gaining in importance.

Fraunhofer researchers are laying important groundwork so that cars, aircraft, machinery and plants can use less energy in the future. They also help make lightweight design feasible for mass production. ■

Joined together forever

Joining aluminum and steel has always been a notoriously difficult task. Two new techniques now enable a reliable bond to be formed between these dissimilar metals.

Text: Katja Lüers

Sometimes it takes a little bit of outside help to create a reliable partnership. Aluminum and steel, for instance, can rarely be persuaded to enter into a durable relationship. And yet precisely this combination of materials is of huge interest for lightweight construction, especially in the automotive industry where aluminum is a highly prized lightweight metal. But car bodies cannot be built entirely without steel. In other words, combinations of the two dissimilar materials are necessary and, indeed, are being used to an increasing extent. The main problem lies in the joining zones because, until now, parts made of the two different materials have been either riveted or clinched together or adhesively bonded. The disadvantage of these methods is that they require a certain overlap between the parts to be joined. It is better if the two parts meet edge to edge in a butt joint. This would not only reduce or even eliminate the need for overlap flanges but also guarantee a higher joint strength.

Nonetheless, the direct joining of steel and aluminum is anything but simple. Before the metals can be joined, the stable oxide layer on the surface of the aluminum first has to be broken down. This is done either by heating the surface to an extremely high temperature or by applying chemical solvents. Neither of these solutions is ideal. Exposure to excessively high temperatures results in the formation of a hard but brittle intermetallic phase, which reduces the load-bearing capacity of the joint. This is why the use of conventional thermal welding techniques is out of the question. And the problem with chemical solvents is that they often present a danger to human health or to the environment, and in certain cases can negatively affect the surface quality of the finished component.

Seams of perfect surface quality

Scientists at the Fraunhofer Institutes for Material and Beam Technology IWS in Dresden and for Production Technology IPT in Aachen have solved the dilemma by developing two different methods for use in different joining applications. The IPT team led by Dr.-Ing. Kristian Arntz has based its solution on a dual-beam laser welding technique that produces strong, high-quality joints between steel and aluminum parts. This result is obtained by combining a pulsed and a continuous-wave laser beam.

As in conventional laser welding processes, a continuous beam of light is used to heat the surface of the two materials to be joined. Then the second, pulsed laser is used to destroy the dense, heat-resistant oxide layer on the surface of the aluminum. This makes it possible to wet the metal surface using filler materials such as aluminum or zinc alloys. “In this way, the aluminum can be rapidly joined to the steel at a relatively low temperature without the use of environmentally dangerous solvents,” Arntz explains.

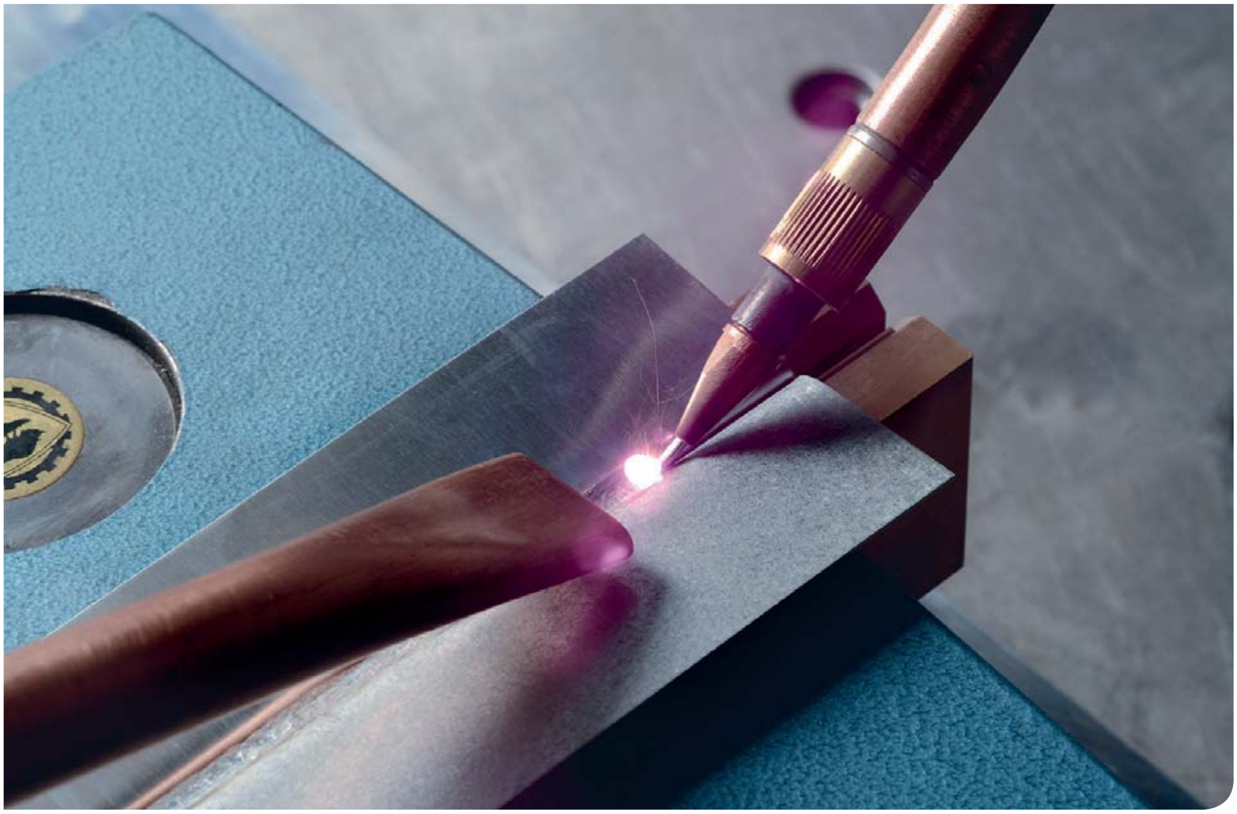
This technology is especially well suited to sheet metal joining applications that demand high-quality seam surfaces, a strong permanent bond, and minimal post-processing. “For example, once a car has been painted, the weld seams are no longer visible,” says Arntz . For this achievement, he was recently presented with the biennial Erlangen Innovation Award Optical Technologies, which is donated by the Association for the Promotion of Laser Technology at the Friedrich-Alexander University of Erlangen-Nürnberg. His colleagues at the Fraunhofer IWS in Dresden have found an alternative method of joining steel and aluminum. Here the key to success is a two-step manufacturing process. The first step involves producing a bimetallic strip which is subsequently welded to the aluminum or steel substrate in a second step. “In this way, we can create joints with excellent mechanical properties,” says Dr. Axel Jahn, who heads the institute’s Component Design group.

Joining with the help of a bimetallic strip

To produce the bimetallic strip, the researchers start by heating the two raw materials by induction, using a specially formed laser beam that brings them up to an intermediate joining temperature. Then they undergo a roll-to-roll plating process in which the two surfaces are joined. “This produces a a strong but also ductile bond between the two metals that contains hardly any brittle intermetallic phases,” says Jahn. Then the researchers weld the steel component to the steel side of the bimetallic strip and the aluminum component to the light-metal side. “We can even make butt joints, such as those required when producing tailored blanks,” says Jahn.

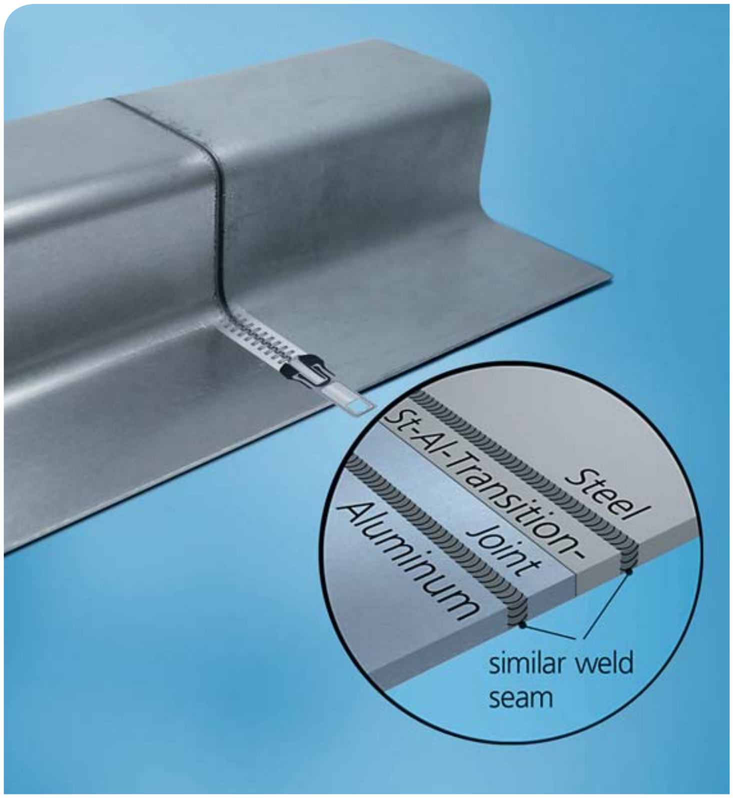
The new technology can also be used to manufacture semi-finished products consisting of aluminum and steel, which can be formed into hybrid products without the need for additional processing steps. A further advantage of this approach is that it reduces component weight without compromising crash safety. “Despite its lower weight, the component’s crash resistance is not impaired thanks to its improved mechanical properties,” Jahn concludes.

The teams of Fraunhofer researchers in Aachen and Dresden are now working together with industrial partners to develop commercial applications for these new technologies. For the lightweight construction industry, the message is clear: steel and aluminum are now inseparable partners. ■



Fraunhofer has developed a dual-beam laser processing method ... © *Fraunhofer IPT*

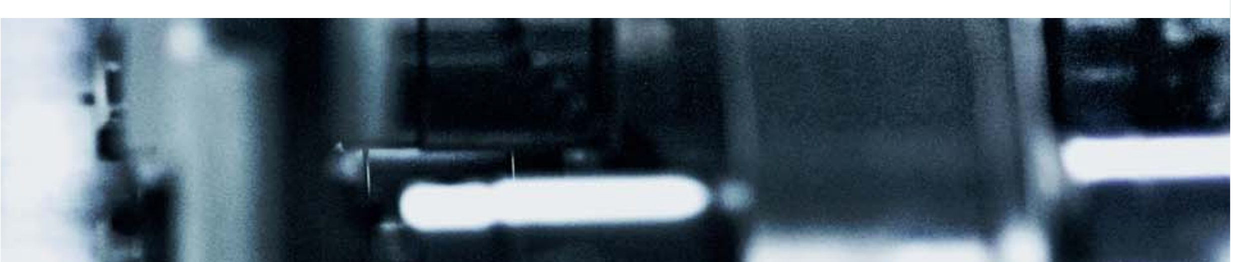
... that allows strong, high-quality joints to be created between steel and aluminum parts. © *Fraunhofer IPT*



A transition joint between steel and aluminum was used to connect the two parts of this U-profile. © *Fraunhofer IWS*

The Internet and modern technology are increasingly shaping manufacturing industry. The digitalization of manufacturing also harbors new risks. Industry 4.0 networks require extra protection.
© Fraunhofer IOSB

Secure production in industry 4.0



Industry 4.0 production facilities and components are connected to each other and linked via the Internet. The digitalization of production opens up new opportunities, yet also renders these systems vulnerable to attacks from outside. Fraunhofer researchers offer an IT security laboratory as a test environment in which to simulate attacks and detect any gaps.

Text: Britta Widmann

A wonderful new world of production sees machines, robots, system components, mini computers in components, and sensors all networked with each other to deliver the multi-site value chains of industry 4.0. These various devices exchange data, carry out condition monitoring, forecast and calculate the optimum sequence of process steps, plan equipment usage and much, much more. Yet as communication via Internet technologies makes its way into factories, it pushes up the security risks. In addition to known viruses, networked production facilities must face new threats in the form of customized malware. These programs are able to collect information on system parameters, remotely control machinery, manipulate controls or paralyze production processes. This means industry 4.0 networks require special protective measures, sophisticated network technology and effective testing methods to uncover vulnerabilities in the system and reliably eliminate them. The IT security laboratory at the Fraunhofer Institute for Optronics, System Technologies and Image Exploitation IOSB in Karlsruhe is specially equipped for production and automation technology. This lab serves as a secure test environment in which to simulate potential attacks on production networks, examine the implications of such attacks and develop suitable countermeasures and strategies. It also enables the researchers to assess the security features of the current communication standards and protocols for industrial automation systems. Among other things, these cover data encryption against product piracy, industrial espionage and sabotage.

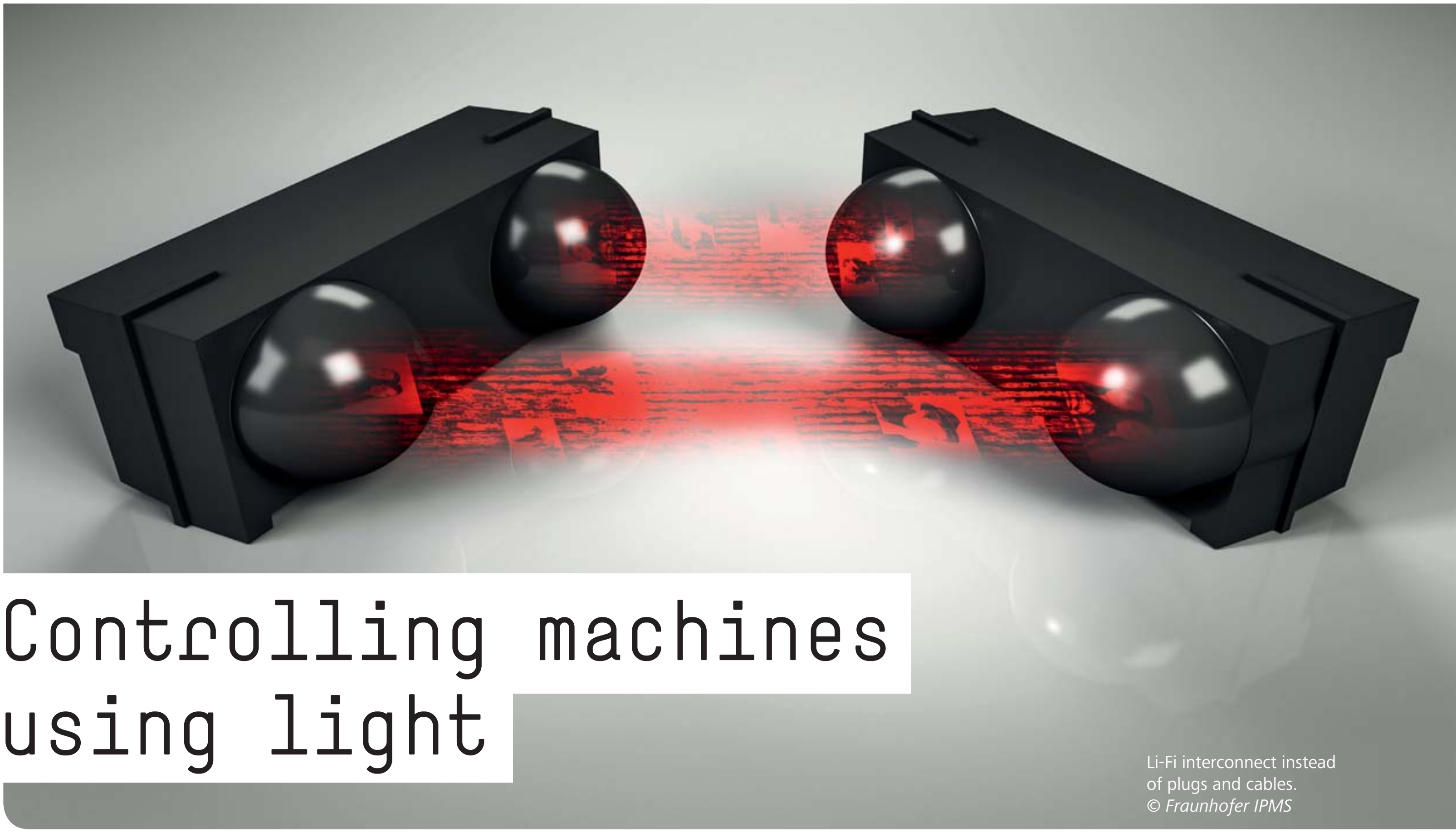
Different than office IT

"IT security in industrial production has a very different set of conditions to deal with – it's just not the same as office IT," says Birger Krägelin, a computer scientist and project manager of the IT security laboratory at the IOSB. Control of production facilities requires the kind of real-time interventions that make it difficult to apply changes to the systems. The very act of installing available software patches, monitoring software, malware scanners and antivirus programs affects the stability of the carefully coordinated processes. Conversely, the production processes themselves determine when updates are feasible. Any firewalls present on the network and any encrypted connections between systems can affect the real-time requirements. "If we incorporate known security measures from the normal office environment between machines, for example, this could delay the sending of messages. This in turn might cause conveyor belts to run slower, valves to delay their closing, photoelectric sensors to falsely trigger, motors to run faster, or control components to fail," explains Krägelin. Another major difference between production and other IT environments is the comparatively long period that hardware and software remain in use.

In order to come up with and set up IT protection mechanisms that are adapted to production environments, the research team comprising automation technology and IT security specialists made sure the lab has the equipment it needs: It has its own model factory with real automation components that control a simulated production facility featuring conveyor belts, electric motors, robots and lifting equipment. All a factory's network levels are present with typical components including firewalls, circuits and components for wireless units. With their own private cloud, the IOSB experts can install different customizable configurations and set the model factory to run various scenarios.

"Thanks to the cloud, we can patch in virtual firewalls, PCs, or client computers and change entire network structures with the click of a mouse. This enables us to install a virtual firewall or analysis systems between two components, for example a machine and a higher-level manufacturing execution system MES. Then we can launch malware detection from the cloud to check controls and plant visualization for infections," says Krägelin. "We can create new factory environments and simulate cyberattacks with no need to purchase any components or lay any cables."

Companies can use the IT security lab to obtain advice on the planning and commissioning of secure industrial network structures. In addition, they can benefit from the know-how of the IOSB experts when it comes to the analysis of their existing networks and components. In the future, the researchers also want to showcase the lab as a training and learning platform. "One thing engineers often lack is the knowledge of how to deal with cyber threats," explains Krägelin. ■



Controlling machines using light

Li-Fi interconnect instead of plugs and cables.
© *Fraunhofer IPMS*

Today, industrial machines are connected to the control center almost exclusively via cables. However, cables and plug connectors can suffer wear and tear over time. This is why researchers have developed a wireless transmitter system that uses infrared light.

Text: Tim Schröder

Many products nowadays are made on assembly lines where the workpieces travel from one station to the next. These could be metallic parts that are sequentially machined, bored and then polished, or they may be foodstuff items or car bodies, which move from one robot to the next on the assembly line. Typically, all machines on such a production line are connected by cables to a control center that governs the entire production process, and this type of setup normally works very well. However, things become difficult if the product is changed, or if the assembly line is modernized or has to be otherwise altered for some reason. In such cases, the data cables must be relaid and securely fastened, and all the plug connectors have to be put back into place before production can start again.

Transmitting data using infrared light

"The current system not only takes a lot of time, it is also prone to errors," says Dr. Frank Deicke of the Fraunhofer Institute for Photonic Microsystems IPMS in Dresden. "This is because cables can be damaged and plug connectors can come loose." For this reason, Deicke and his team have developed an alternative method for the transfer of data in industrial settings. Their system transmits information via infrared light – the same technology used in television remote controls. However, Deicke's system is far more powerful than the good old TV remote, as the data used for controlling production machines must be transferred at much higher rates. For example, the industrial Ethernet systems frequently used in modern production environments operate at a data transfer rate of up to 1.25 gigabits, or 1.25 billion computational signals, per second. For a long time, cables were the only way to achieve such speeds, as no other industrial application allowed for such rapid transfer of data. WLAN, Bluetooth, infrared light – none worked as well as cables.

But the IPMS researchers have managed to change that. "With our wireless optical transceiver module, even large amounts of data can be exchanged in real time," says Deicke. This is essential in applications that involve complex machine control data, such as when a computer sends detailed componeSnt blueprints to a milling machine. Furthermore, the light signals can travel distances of up to 20 meters. This too is of critical importance for industrial applications, as there are often substantial distances between the production machines and the control center in a manufacturing facility.

To simplify the installation of this new technology, the IPMS has developed a plug-and-play system that can be easily integrated into existing control systems and machine infrastructures. Users do not need to install any software; instead, they simply connect the transceiver module to the Ethernet. One environment where manufacturers are already employing this technology is the production line, where it is used to transfer data such as on-board software to the vehicles on the line. Previously this was usually done by attaching a cable to the vehicle's on-board computer by hand. However, this meant either slowing down or completely halting the assembly line. Such delays can now be eliminated through the use of light-based communication. "With our system, even large data packets can be transmitted without cables in seconds. This makes it possible to achieve faster production cycle times," says Deicke.

New communication methods for industry 4.0

Deicke is convinced that his new "Multi-Gigabit Communication Module" has great potential in other application areas as well. As the industry 4.0 era advances and more machines are connected to the Internet, the need for data interfaces will increase considerably. A cable-free option could help reduce the time and cost of installation. Not only that, such solutions are also beneficial in applications involving robots, which today are usually connected to a control center via trailing cables, cable chains or sliding contacts. Because these cables constantly move back and forth, they will exhibit wear and tear over time. The same is true for surveillance cameras that travel on sliding rails along the assembly line. With an infrared system using an optical receiver there is no wear involved, and in addition the camera can move faster on the rails without cables.

The researchers have already demonstrated that infrared technology is reliable. For three years now, an infrared system they created has been available that allows data to be transferred between electronic devices such as smartphones, camcorders and computers over distances of a few centimeters. It operates flawlessly. In order to make it suitable for the greater distances found in industrial applications, Deicke and his colleagues had to make a few modifications, paying particular attention to the lenses, infrared sensors and receivers. In the interest of protecting his innovation, Deicke would prefer not to share any further details.

Transmitting information using LEDs

However, the researchers at the IPMS are not the only ones working on light-based data transfer applications. For instance, at the Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institut, HHI in Berlin, experts are working on methods for transferring data using common LED indoor lamps. The trick to this "visible light communication" lies in sending bits of information by switching the LEDs on and off for fractions of a second. Light sensors on laptops or smartphones are able to detect the ultrafast flickering of the LEDs and convert this back into a stream of data. The human eye, on the other hand, is unable to perceive such ultra-rapid light signals.

Experts at the Fraunhofer Institute for Reliability and Microintegration IZM in Berlin are also working on new technological advancements involving light-based communications. Together with a number of other German and European research groups, the engineers of the PhoxTroT project are working to perfect data transfer methods that use optical fibers for mainframes and server farms. Currently, optical fibers are mostly used only in isolated subsections, such as for transferring data between two single computers. However, PhoxTroT project members are now working to introduce optical communications throughout the entire data processing chain. They are developing circuit boards on which bits of data are transmitted by light between individual processors. In addition, they are using optical technology to connect the various circuit boards inside a mainframe with one another, and to optimize the communication between different individual computers. All told, this will cut the energy consumption of mainframe systems in half while allowing data transfer rates that are several times higher than what is possible with copper cables. ■

The illusion of driving

Simulations are an important development tool in the automotive and commercial vehicle industry. But to obtain meaningful results, it's important to take the human factor into account. Researchers have developed an interactive driving simulator that allows realistic analysis of the interaction between humans and vehicles.

Text: Klaus Jacob

What small – or perhaps not so small – boy hasn't dreamt of sitting at the controls of an excavator? Researchers at the Fraunhofer Institute for Industrial Mathematics ITWM in Kaiserslautern make this dream come true in the service of science and with absolutely no risks. Headed by Michael Kleer, an interdisciplinary team of engineers, mathematicians, computer scientists and psychologists has built a simulator at one of the institute's laboratories. The facility is currently equipped with a wheeled excavator cabin in which the test subject can operate joysticks, the gas or the brakes just as in real life. Beyond the cabin windows, a view of a giant virtual construction site is projected onto the interior surface of a large dome. Two joysticks operate a simulated excavator: when the heavy shovel digs into the sand, it gives the cabin a jolt.

Simulating flying and driving

Simulators have been around for over a century. In 1910, pilots were trained in simple cockpit mock-ups. Helpers stationed outside would wait for the command to lift or shake the box. Later on, six-legged cabins were developed that could move in all directions with the aid of motors; this has remained the standard solution to this day. These models have even managed to break into the world of entertainment

– you can have yourself shaken about in one at a local fair or an amusement park. However, the ITWM simulator differs substantially from the conventional systems in that rather than standing on six legs, the driver's cabin is connected to a robotic system. This configuration gives users a real sense of what it feels like to perform hard stops or negotiate tight curves. "Our robot enables a much greater range of movement than the system of parallel kinematics usually used these days," says project manager Kleer. Such robot-based devices are still quite rare. "There are just a handful of them worldwide," says Kleer.

Excellent simulation

The system in Kaiserslautern has another special feature: its articulation system is exceedingly powerful and can support cabins of up to one metric ton. That's enough payload to bolt on a real excavator cabin. The team can also realistically simulate a tractor; it takes just four hours to attach the corresponding cabin and change out the simulation software. The scientists even plan to have a passenger car simulation up and running in the near time. To ensure that the simulation will feel like driving a real car, the institute is sending a measuring vehicle along selected road sections. Its sensors will visually record the roadway, environment and road surface to create an immersive backdrop to the simulator's virtual reality.

To make sure that the test drivers behave naturally, they must feel as though they are actually in a moving car. Simulator movements that fail to match the driver's visual impressions influence reactions and can even lead to symptoms such as dizziness and nausea. Just like car sickness or sea sickness, "simulator sickness" is caused by conflicting sensory perceptions. To prevent such unpleasant side effects, the Fraunhofer experts are working with cognition researchers on new motion-cueing algorithms to generate the control signals for the simulator.

Kleer designed the "Robot-based driving and operation simulator," or "RODOS," for his doctoral thesis. "As the institute building happened to be due for expansion at the time, it was very easy to integrate the simulator into the new building extension," says Kleer. The domed projection surface for the images takes up a good bit of space; its diameter of ten meters is large enough to easily deceive the eye. If the distance to the projection were too close, the driver's pupils would instinctively focus on the foreground. Since the pictures suggest greater distances, however, this would confuse the brain and the illusion would be lost. Eighteen projectors arranged around the dome generate a daylight landscape that, thanks to 120 Hertz technology, stays free of interference. The top of the projection dome is also an architectural highlight: it passes up through the ceiling and to the ground floor, where it acts as a visual centerpiece in the broad atrium above.

Testing assistance systems

And why is such an elaborate device needed? "It can provide valuable help in developing and testing new vehicle models or assistance systems – areas where the driver's behavior plays a vital role. Even the most sophisticated technology falls short if it causes the driver to act incorrectly," explains Kleer. For instance, the simulator makes it possible to test in advance how a dashboard can be arranged to encourage the motorist to drive in a way that saves fuel. It also helps researchers figure out how an assistance system needs to function. How fast should the car be moving at the time and how close should it be allowed to get to the neighboring car so that the driver doesn't instinctively grab hold of the steering wheel?

Future scenarios, such as situations involving a driverless car, can also be played out. What happens when the human decides to reassume control of the vehicle? Excavator manufacturers are investigating how to configure a driving aid so that it helps trainees, but does not interfere in the well-honed reflexes of experienced operators. The answers can be provided via the simulator by having a representative selection of drivers perform the respective maneuvers. Naturally, these tests could be conducted using a prototype vehicle or application, but this would be more expensive and dangerous as well as more time-consuming. "What we can test in two hours on the simulator would take far more time and effort with a prototype," reports Patrick Schuhmacher from the construction machine manufacturer Volvo CE, which uses the ITWM simulation facility.

Drivers have to feel as though they are sitting in a real vehicle so that the tests don't deliver erroneous results. The institute's own psychologists in Kaiserslautern are helping to find out how the illusion can be perfected. They are also ensuring that nobody gets seasick. Experienced excavator drivers working on the ITWM simulator are definitely impressed; they estimate that the simulator has attained "80 percent reality." ■

Driving simulators are an important tool for developing new vehicle assistance systems. The one at Fraunhofer ITWM can even simulate excavator operation. © *Fraunhofer ITWM*

A protected data space

In today's increasingly digital world, data security and data sovereignty are existential issues. In collaboration with industrial partners and in cooperation with the German federal government, Fraunhofer has launched an initiative to create an international data space that combines open access and security: the Industrial Data Space. In this issue of Fraunhofer magazine, Birgit Niesing talks with the President of the Fraunhofer-Gesellschaft, Professor Reimund Neugebauer, about the planned Industrial Data Space.

The interview was conducted by Birgit Niesing.

Prof. Dr. Reimund Neugebauer.
© *Axel Griesch*

Industry has started to go digital. What does this imply?

Digitalization is a social, economic, and technological trend that that is spreading to all sectors of industry and is about to permanently change our conventional business models. Industry 4.0, for example, merges manufacturing with advanced information and communication technology. It links together the various components of a manufacturing process, such as machinery, operating equipment, order processing and warehouse systems, via sensors, integrated processors and data networks, enabling them to communicate with one another. This calls for complex software solutions to interconnect systems at all levels of the supply chain.

What challenges arise as a result of this?

The sheer volume of stored and interconnected data, and the value it represents, is multiplying at a rapid pace. In the future, data will rank as a major economic factor on the same level as capital, labor and raw materials. Data security and data sovereignty are therefore existential issues. Companies will need assurance that their sovereign data rights are respected, even when they are sharing information with others. Hence we need to create a protected, virtually connected space for industrial data: an Industrial Data Space. High-speed data connections are another indispensable requirement. A further important aspect is the establishment of internationally applicable quality assurance standards.

What exactly is meant by an Industrial Data Space?

The Industrial Data Space is a concept that Fraunhofer aims to realize in collaboration with industrial partners and with the support of the German federal government. The aim of the initiative is to create an international data space that combines open access and security. This coordinated approach to information processing will help companies to generate added value while at the same time protecting and controlling access to their proprietary data. Small and medium-sized enterprises, in particular, need a protected environment in which they can share or exchange information according to self-defined rules without ceding control of their data. We have already won the support of major companies such as Allianz, Daimler, Deutsche Bahn, Linde, Schaeffler, Salzgitter and Siemens for the Industrial Data Space project. A key issue paper was presented to the German Federal Minister of Education and Research, Johanna Wanka, outlining the main points of this concept as agreed with our partners in industry and government.

What are the next steps?

Fraunhofer researchers are currently working on the development of a new software architecture specifically designed to ensure security in shared digital networks, based on established standards and vocabularies. The next step is to enhance the Industrial Data Space on the basis of selected use cases chosen by a joint task force including representatives from all sectors of industry and experts in the fields of information technology, software, logistics and infrastructure management. A team of researchers coordinated by the Fraunhofer Institute for Material Flow and Logistics IML is currently preparing the first use cases, initially focusing on the logistics, automotive, food and pharmaceutical industries. Meanwhile, work has started on the technical development aspects under the supervision of the Fraunhofer Institute for Intelligent Analysis and Information Systems IAIS. The focal areas of this work include data storage and networking, data security and semantic integration, in addition to the conceptual design of the software architecture. Various Fraunhofer Institutes are participating in these activities.

Will companies outside Germany be able to use the Industrial Data Space?

Data security is not a question of geography. Any company that agrees to apply the defined common standards will be granted access to the Industrial Data Space and authorized to use it. The group of companies developing the actual Industrial Data Space is also required to present a business model for operating the data space.

The Industrial Data Space has been integrated in the industry 4.0 platform promoted by the German Federal Ministry for Economic Affairs and Energy. How did this come about?

The proliferation of connected devices and mass data transfer – the hallmark of industry 4.0 – has made it necessary to tighten up security measures. When discussing this issue with the economics minister, Sigmar Gabriel, the research minister, Johanna Wanka, and industry representatives, it became clear to Fraunhofer that the Industrial Data Space plays an important role in realizing the goals of industry 4.0. That is why it forms part of the new platform. Germany's industry 4.0 initiative involves numerous players from the domains of politics, business, trade unions and science. I myself am a member of the steering committee, representing the research community. Moreover, Fraunhofer IML has been entrusted with the task of constructing and operating the communications platform for industry 4.0, in collaboration with IFOK GmbH.

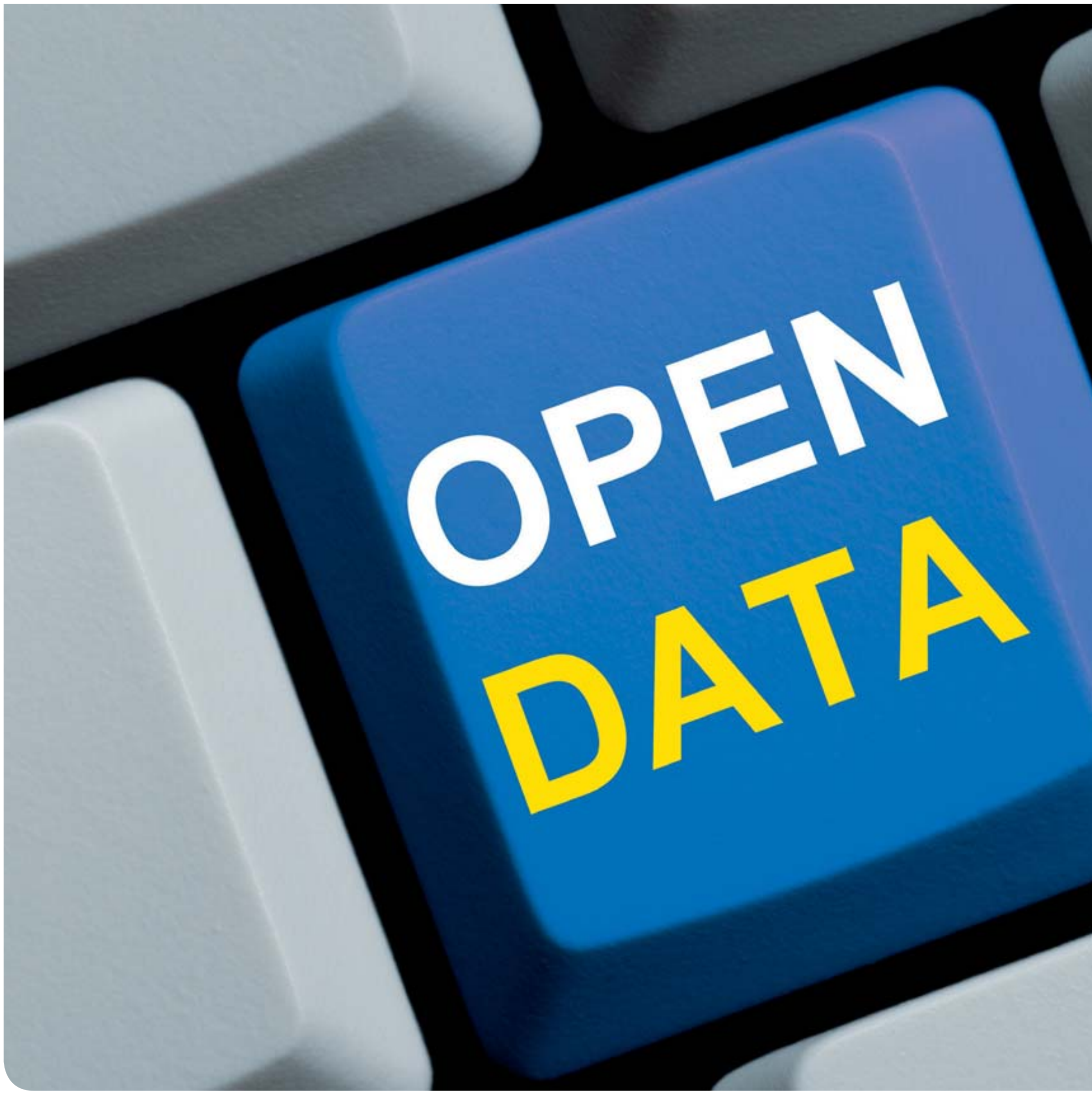
What opportunities does digitalization offer?

The increasing use of digital technologies opens up many new opportunities. For instance, innovative products and business processes can be developed with the help of collaborative, data-sharing networks and associated software engineering tools. In the future, the market success of many products – from electric toothbrushes to cars – will be determined by the availability of associated digital services. The decisive factor in this context will be the ability of industry to generate added value by integrating connected data and derived software in the development of innovative products and business services.

Is European industry ready for this change?

Many European companies are international leaders in their respective fields, typically in the automotive industry, the manufacture of plant and machinery, and the design of embedded systems. These companies also possess wide-ranging skills and experience in machine control systems. European companies are among the global leaders in the field of industrial software. But it is still the case that many innovative IT solutions are largely developed in countries outside Europe. Swift action and concerted efforts will be needed to fully equip European industry to meet the challenges of the digital age. ■

Open for everyone



With their stores of geodata, official resolutions, ordinances, and statistics, government agencies have valuable data at their disposal. However, this treasure trove of information is typically very difficult to access – for now. Fraunhofer researchers are developing open data platforms so that everyone can utilize these types of information. The economic potential of this is considerable.

Text: Chris Löwer

How high are ozone pollution levels? Where is construction taking place, and what is being built? How are tax revenues being spent? Answers to these and many other questions could be found easily with a few clicks if government agencies made their enormous repositories of nonpersonalized data available to their citizens. However, doing so not only requires a readiness to make the information public, it also entails having the right technological solution in place. Across several projects, Fraunhofer researchers are working on ways to reutilize information such as official statistics, geodata, traffic information, environmental data, scientific publications, judgments, ordinances and parliamentary decisions. "Public data is far easier to use when it is prepared and packaged in a suitable fashion. Otherwise users won't be able to do very much with it," says Jens Klessmann of the Fraunhofer Institute for Open Communications Systems FOKUS in Berlin.

Fraunhofer researchers in Berlin are working on a number of open data projects so that users not only in German cities but also across Europe can tap into these valuable stores of knowledge. As one of the main technical partners, the experts at Fraunhofer FOKUS are developing core components of an official European open data platform, which combines data from 39 countries and is above all intended to be accessible to laypersons.

"The pan-European Data Portal is likely to be the world's most ambitious Open Data project, and it will be a milestone for the cross-border and cross-sector reuse of public datasets across Europe," says Dr. Matthias Flügge, director of the Fraunhofer FOKUS Fraunhofer FOKUS Digital Public Services Competence Center. "A beta version is already online and will now be filled in with data," continues Klessmann, who is heading the FOKUS side of the EU project together with Dr. Yuri Glikman. One challenge along the way involves the objective of locating


© Fotolia

suitable public datasets, ensuring their quality, and setting up an accurate data repository. Fraunhofer experts are developing the necessary technologies, making use among other things of harvesting mechanisms: a type of electronic bloodhound that searches member countries' data portals at regular intervals for new public data material. This data is then translated into a unified descriptive format as required, which permits information from varying sources to be integrated into the open data platform in an automated fashion.

One fundamental problem with this is the multitude of different data formats, as well as varying document records and data descriptions. “Providing data records in a modern machine-interpretable format is still a new thing for many governments,” says Prof. Ina Schieferdecker, institute director at FOKUS. For this reason, a key objective is to turn these disjointed groupings of data into something that is more organized and systematic. To this end, researchers are planning a parent directory that will provide centralized access to datasets from a multitude of European information systems.

This is an investment that will pay off in the future. With the Open Data Portal, the European Commission expects to help leverage previously unexploited economic potential. The EU estimates that member countries with public data will see economic benefits of 40 billion euros annually, be it due to new business sectors created as a result of improved information availability, better educational offerings, or more efficient institutional administration. In one study, management consultants at McKinsey foresee economic growth of 3 trillion US dollars worldwide if public data is utilized to its full potential.

Open data platforms make new business models possible

Some practical uses of public geodata include the development of low-cost mobile navigation applications, journalistic data visualization services, and risk assessments using weather data. One particular case study from Paris shows how appealing service offerings can be created with data repositories from government agencies.

By utilizing the seemingly humdrum data material of the Paris tree registry, one company developed an app to assist house-hunting allergy sufferers. The company's app cross-references information on housing vacancies from real estate websites with the locations and blossoming times of trees located near the property in question. In this way, allergy sufferers can determine at a glance whether or not a particular property would be suitable for their needs.

“This application demonstrates how new services offerings can be created using government datasets,” says Klessmann. A city government could never afford to implement something like this on its own. But then again, the development of information-based business models is not a part of their job description. This is why it's all the more important to make this data available to developers, innovative startups and motivated citizens.

Extensive experience in design and implementation

“Information is increasingly being viewed not only as an economic commodity, but also as a public good. Oftentimes, added value is created only once datasets from a multitude of sources are interlinked,” says Schieferdecker. In such matters she speaks from experience, as FOKUS has already initiated open data platforms or strategies for the cities of Berlin, Hamburg, Cologne, Frankfurt am Main and Amsterdam, and has also developed the GovData.de data portal for Germany.

On the Berlin open data portal there are currently more than 800 datasets in 22 categories, from which several applications have already been created. Examples include the Low Emission Zone app, which allows drivers to quickly see which streets they can use, the Ozon Sonar app, which displays current ozone levels, or Wann (German for “when”), which tells users in real time when and where they can find the next bus or streetcar. Active participation from citizens is very much encouraged here, as all users can provide suggestions for apps, or create their own datasets to be integrated. In this way, government agencies can improve data quality, particularly when they are made aware of errors or gaps in the data.

On the Berlin open data website, one can also find user-friendly statistics on population development and unemployment, political transcripts and resolutions, budget planning as well as public tenders. “At daten.berlin.de, data originating from the Berlin state and district governments is made accessible in a manner that is centralized, structured, machine-readable and open licensed,” explains Klessmann. The GovData portal provides this on a larger scale. Here, federal, state and local governments have supplied more than 10,000 datasets, including traffic statistics, climate data, budget figures as well as laws and court rulings. FOKUS developed the platform and is managing the beta version. This “digital lost-and-found for public data” will go into regular operation this fall. ■

Sustainable smart cities

What will life be like for tomorrow's city dwellers? In a major joint project funded by the EU, researchers are developing concepts for sustainable, livable and future-ready cities.

Text: Chris Löwer

Cities have always set the pace of progress. As if under a magnifying glass, the central challenges of our coexistence as people are revealed here: from mobility to codetermination to modern energy supply. Today is when we must set the course for the sustainable, smart cities of tomorrow.

As for what the city of the future will look like, researchers in the Triangulum project intend not only to theorize but to also put theory into practice. Under the direction of the Fraunhofer Institute for Industrial Engineering IAO, innovative ideas for intelligent urban living areas are being implemented in Manchester, Eindhoven and Stavanger, to be later followed by Leipzig, Prague and Sabadell in Spain. The project originated from the Fraunhofer-Gesellschaft's Morgenstadt initiative and is supported by the Steinbeis-Europa-Zentrum SEZ. The European Commission has declared it to be a pilot project as part of the Smart Cities and Communities initiative. A broad base of 23 European partners – from municipalities, the scientific community and industry – are taking part in the project.

"Our goal is to find workable solutions to make cities smart and livable in the future. To this end, we first implemented pioneering concepts for sustainable energy supply, mobility and information technology in three selected cities," relates Alanus von Radecki of the IAO, who is coordinating the project. "An information and communications technology architecture forms the core of this in all three landmark cities."

"It provides the foundation for ensuring that the individual technologies are networked and coordinated with one another in each city," explains von Radecki. The scientists relied on a standardized architecture for information and communications technology developed by the Fraunhofer Institute for Open Communication Systems FOKUS. This way, the concepts can be adapted by other cities with relative ease – even if the conditions and concerns are different in each situation.

"This is made possible by the project's modular approach," says von Radecki. All of the employed technologies are implemented module by module, in order to establish a comparable information platform. "Essentially, all the key issues facing future-ready cities are rooted in information, communication, exchanging data and networking in real time," stresses von Radecki. What is important in this context is to converge existing separate communications infrastructures – whether sensor, information or mobile communications networks.

Information technology plays a decisive role

The plans for the Norwegian city of Stavanger illustrate why information technology plays such a key role. Here, the plan is to provide consistent links between companies, residents, research institutes and doctors through IT networks in order to plan better, more efficient use of energy and even to perform remote medical diagnoses. Thanks to an extensive fiber-optic network already in place, high-resolution videos and the like will soon be able to aid telemedicine professionals in their work, for example, or enable further innovative public services. The

infrastructure is also set to be used to open up further channels for civic involvement. For example, when it comes to helping blaze the trail to the Smart City.

Stavanger has the most electric vehicles on the road

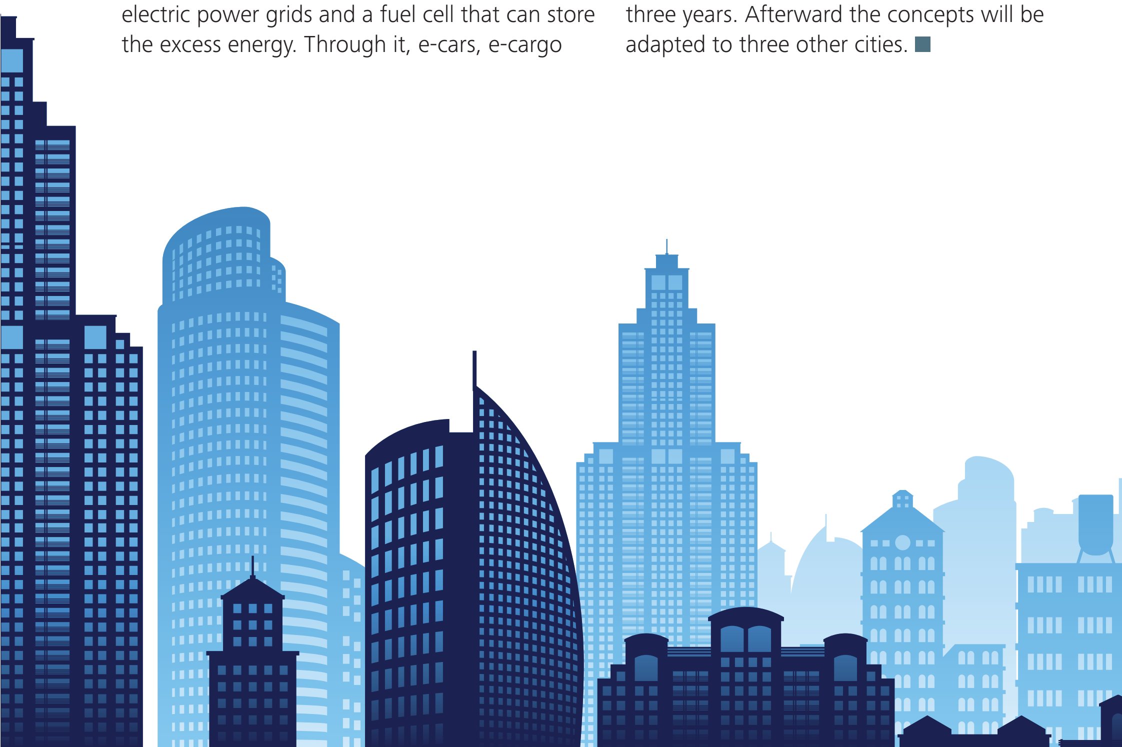
Stavanger is distinguished by another notable aspect: the city has the highest density of electric vehicles in Europe. "This and the existing high-speed information and communication technology (ICT) infrastructures form the basis for better networking of energy and mobility solutions," explains von Radecki. New solutions will also help to supply energy more efficiently. Thus, a combined heat and power plant is slated to provide public buildings with energy, with the municipal swimming pool serving as an energy storage unit. This means that during the day the pool temperature may rise several degrees Celsius over the temperature setting, and then cool down again over night.

The project partners also have ambitious plans for Manchester. Here the „Manchester Corridor" student district, home to some 72,000 students, will be transformed into a Smart City community. "Historical buildings are to be renovated as a part of this. Also, a self-sufficient energy network is to be built, to supply the entire city quarter with heat and electric power," reports von Radecki. The energy network will not only supply geothermal and long-distance heating, but will also include two separately operating electric power grids and a fuel cell that can store the excess energy. Through it, e-cars, e-cargo bikes and the Metrolink e-tram can be supplied with electric power – vehicles with internal-combustion engines will be completely banned from the district.

Eindhoven's future will also be electric. Urban transportation is to be provided by e-buses, and residents will be able to access various parts of the infrastructure – such as booking electric car-sharing vehicles or utilizing intelligent parking concepts – by means of an ICT solution. Sensors – installed in street lamps, for example – will among other things capture motion data so that the street lighting, public transportation or car-sharing can be managed on an as-needed basis. All of this is initially planned for the former industrial site of the company Philips in the Strijp district. This is also where the innovative Sanergy concept for cleaning up contaminated soil will be implemented. It entails a closed system in which energy is gained by filtering and circulating contaminated groundwater. In addition, a biomass-fueled combined heat and power plant is to be built.

A further district, Eckhart Vaartbroek, will also join this leap into the future. It is dominated by older public housing projects, which are to be renovated to become more energy-efficient. "In order to calculate the energy savings, we use an IT-based tool that can reflect the expenditures and yield in a 3D visualization of the district," reports the project manager.

The ambitious plans are to be achieved within three years. Afterward the concepts will be adapted to three other cities. ■



European Commission

Triangulum

The Triangulum project is one of three Horizon 2020 landmark projects relating to the Smart City. The European Commission is providing 25 million euros for the necessary research. The goal is to design and test concepts for sustainable, intelligent urban development. For this, innovative solutions will first be implemented in the cities of Manchester, Eindhoven and Stavanger. In the next step these concepts will then be adapted to three additional cities. The project was launched in February of 2015. Total project costs amount to more than 29 million euros. Under the scientific guidance of the IAO, the following cities have joined forces in the project consortium along with other research institutions and industrial companies.

- Steinbeis-Europa-Zentrum
- The University of Stuttgart's Institute of Human Factors and Technology Management IAT
- Fraunhofer FOKUS

Participating partners in Manchester (UK)
Manchester City Council | The University of Manchester | The Manchester Metropolitan University | Siemens plc | Clicks and Links LTD

Participating partners in Eindhoven (the Netherlands): Municipality of Eindhoven | Park Strijp Beheer B.V. | Stichting Woonbedrijf SWS.Hhvl | Technische Universiteit Eindhoven | Strijp S. Ontwikkeling B.V. | Koninklijke KPN N.V.

Participating partners in Stavanger (Norway): Stavanger Kommune | Greater Stavanger Economic Development AS | Rogaland Fylkeskommune | The University of Stavanger | Lyse Energi AS

Participating partners in the subsequent cities: Prague Institute of Planning and Development (Czech Republic) | Ajuntament de Sabadell (Spain) | City of Leipzig (Germany) | TÜV SÜD AG (Germany)

Thinking holistically - from the get-go

Supported by the EU, researchers at the Fraunhofer AdaptSys Center are hard at work creating the microelectronics applications of tomorrow. For them, the notion of developing individual components that are then merged with great difficulty into a final smart product is a thing of the past - as is the kind of silo mentality that discourages innovation. Instead, the scientists are helping to revolutionize the production process by integrating electronic systems into products as they are being made.

Text: Chris Löwer

Even the smallest micro-camera for disposable endoscopes currently available will soon be made even tinier in the future, thanks to the latest technologies.
© Awaiba GmbH

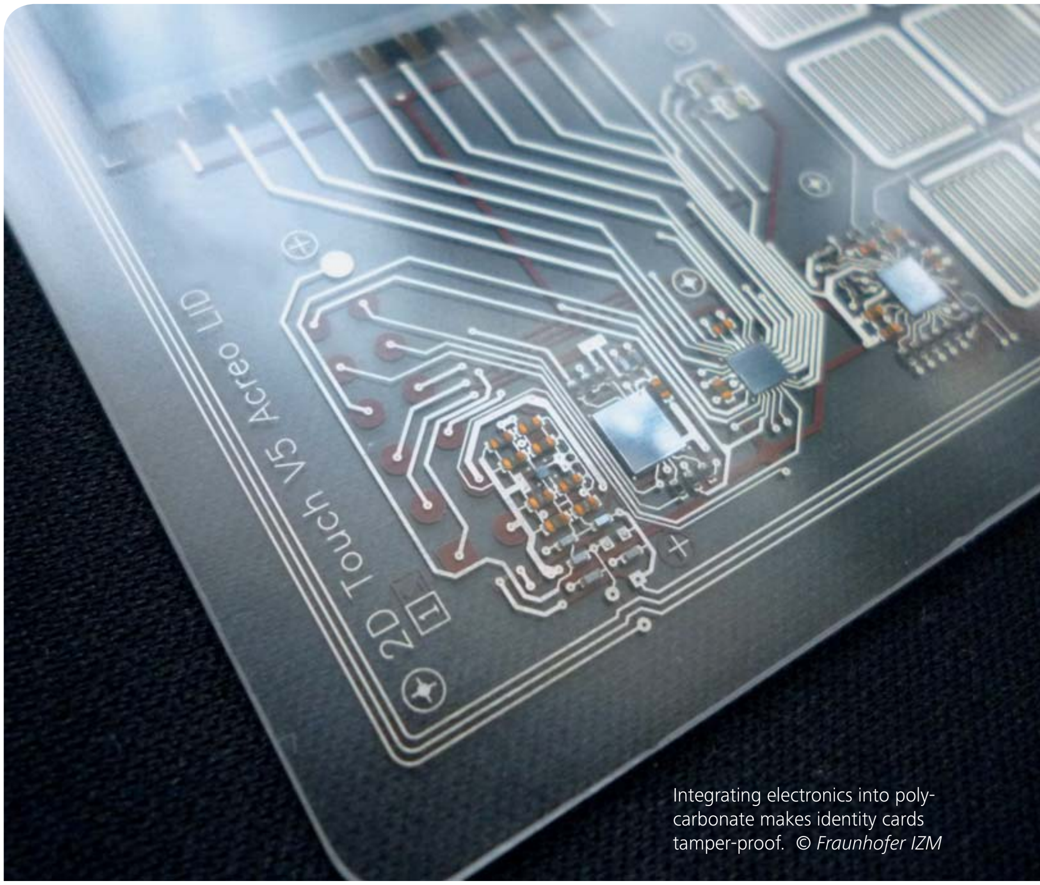
Everyone's talking about the Internet of Things, about how computers are fusing with objects to produce smart products whose services we take for granted. But to date, the road to embedding microelectronics as products are being manufactured is still a complicated and costly one. For example, incorporating radar and infrared sensors into driver assistance systems for use in cars requires each sensor unit to be individually designed, developed, manufactured, integrated and assembled. This is time consuming, and comes at a cost - both in monetary terms and in the form of clever ideas that never see the light of day because the unit cannot be conceived as a whole, limiting the possibilities open to the designer.

Scientists at the Fraunhofer Institute for Reliability and Microintegration IZM in Berlin are out to change this. A center for microelectronics applications of the future – the Fraunhofer AdaptSys Center – is currently being set up to provide a facility for designing fully integrated electronic systems. The aim is to integrate electronics into products as part of the production process rather than assembling sensor systems subsequently, as has been the practice until now. “To ensure that innovations don't fall by the wayside in the future, designers can use embedding technologies developed at the AdaptSys Center to directly integrate sensors into the vehicle,” says Rolf Aschenbrenner of the IZM, who is coordinating the establishment of the center. “This dispenses with additional installation steps, reduces production costs by up to one third and enables manufacturers and suppliers to offer a higher quality and more reliable product.”

Integration into the product

Whether for the automotive industry, medical technology applications, mechanical engineering purposes or use in smart textiles, the Fraunhofer researchers want to fit microelectronic systems into products from the very first stage of their development, instead of adapting them subsequently. This does away with the previous model that saw work divided between component manufacturers, assembly producers and providers of electronic systems. “We want to help bring specific new technological developments to the market,” says Aschenbrenner. For a long time, microelectronics innovation processes barely took into account the applications for which they would later be used – so semiconductor companies, for example, would supply chip structures without having considered the specific needs of their users. “This technology push was solely geared towards technological progress in the semiconductor industry. The final products had to follow the terms dictated by the electronics industry,” Aschenbrenner explains. It stands to reason that it then took end-product manufacturers a long time to implement their ideas or even be able to develop them in the first place.

All that is set to change. It has to. “The main driver of progress and a unique market position



Integrating electronics into polycarbonate makes identity cards tamper-proof. *© Fraunhofer IZM*

is not so much the technology per se, but rather the application it is used for. In the future, electronics will merge with and become part of the material and shape of the product. Electronic systems must be reliable and cost-effective to produce," says Aschenbrenner, describing the various challenges involved. That's why the user and the product are the focal point for researchers at the AdaptSys Center, which has material scientists, chemists, electrical engineers specializing in system design, physicists, mechanical engineers and even biologists working together under one roof.

When developing a new product, the first thing the team does is put their heads together with industry partners to consider from the outset what the end product is required to do. Following this initial brainstorming, a list of specifications is drawn up. The experts use this list to develop a preliminary concept, which then undergoes feasibility tests before the idea is turned into a prototype. The process takes into account the end product's entire life cycle, right through to how it could be recycled.

"For us, it's about combining specific technological advantages from different disciplines in a targeted manner," explains Aschenbrenner. The Fraunhofer researchers are convinced that this approach opens up completely new innovative pathways. "Manufacturers and product developers can specify which properties they require electronic structures to possess," explains Professor Klaus-Dieter Lang, Director of both the Center and the IZM. "Our experts then work with them and the semiconductor companies to develop technologies that enable electronics to be stretched, washed and ironed, to function reliably even during extreme temperature fluctuations of up to 400 °C, or to be shrunk to the size of a grain."

Working together allows value chains to be more closely interlinked, and makes synergies possible between industries that are fairly dissimilar. As a result, in the future we will see development times shorten, even though the complexity of integrated and miniaturized electronics will continue to increase.

A total of 40 million euros was invested in the AdaptSys Center by the European Union (ERDF), the State of Berlin, the BMBF and the Fraunhofer-Gesellschaft, marking a further expansion of the science hub Berlin in the field of high-quality system integration. Initially, the researchers want to focus on sensors for industrial electronics and developments for use in the fields of medical, energy and security technology, which are all highly relevant for the German capital. Thanks to their work, it won't be long before flexible sensor bandages will be commercially available that significantly shorten wound-healing times, or 3D solar cells that can be molded into whatever shape is required and thus integrated in the best and most unobtrusive way possible. ■

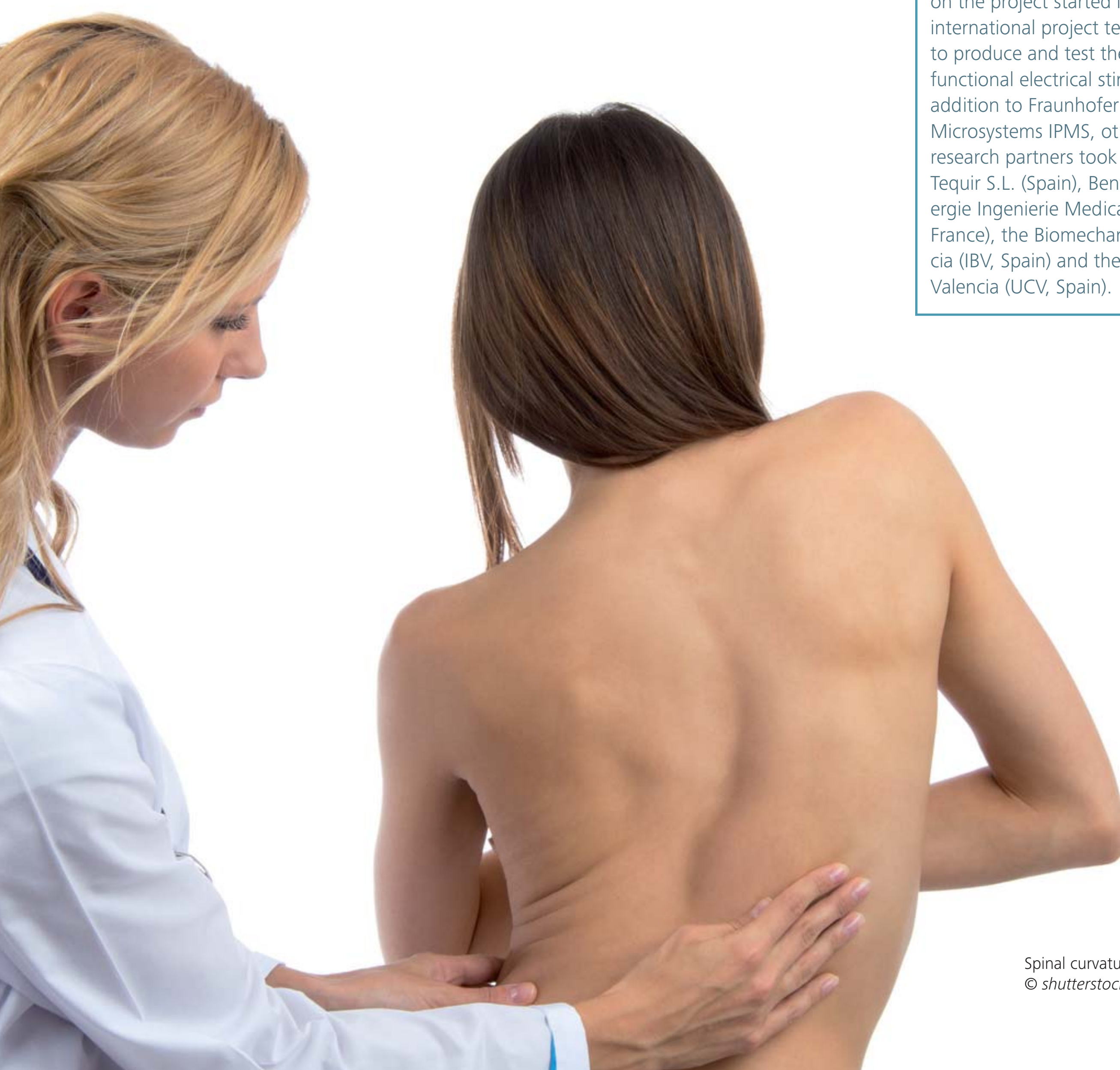
Using electrical pulses to improve posture

To provide better treatment for young patients suffering from spinal curvature, the EU-funded StimulAIS project aims to devise a solution based on muscular electrostimulation. A prototype implant has been developed by the researchers.

Text: Monika Offenberger

StimulAIS

The StimulAIS project to develop a minimally invasive treatment for spinal curvature in children was funded by the EU as part of the European Commission's 7th Framework Programme for research, technological development and demonstration. Work on the project started in 2013. It took the international project team only two years to produce and test the prototype of their functional electrical stimulation system. In addition to Fraunhofer Institute for Photonic Microsystems IPMS, other industrial and research partners took part in the project: Tequir S.L. (Spain), Bentronic (Germany), Synergie Ingenierie Medicale SARL (SYNIMED, France), the Biomechanics Institute of Valencia (IBV, Spain) and the Catholic University of Valencia (UCV, Spain).



Spinal curvature of an AIS patient.
© *shutterstock*

"Sit up straight!" Almost every child has heard this at one time or another, but for certain children it is a physical impossibility. Adolescent idiopathic scoliosis AIS is a disease that affects two out of a hundred children during their growing period between the ages of 10 and 18 and results in lifelong spinal deformity. The severity of the curvature is all the more pronounced the lower the patient's age at onset and the faster their physical development. As a general rule, the deformity does not give rise to any serious health problems such as backache, constricted blood flow or shortness of breath. But it is plainly visible and many patients therefore suffer psychologically as a result of their disfigured appearance. The condition occurs four times more frequently in girls than in boys. It would appear to be partially inherited, because the relatives of scoliosis patients have a greater probability of developing the disorder than members of unaffected families.

Stimulation with electrical impulses

In nine cases out of ten, the exact cause of spinal curvature is unknown. In these cases the condition is said to be idiopathic. Recent studies suggest that adolescent idiopathic scoliosis may be causally linked to a disorder of the central nervous system. "According to this theory, the transmission of nerve impulses to the muscles supporting the spine is impaired, but only on one side of the body. When the muscles on the healthy side contract, the muscles on the opposite side fail to receive a corresponding impulse to relax. As a result, the spinal column becomes bent or twisted," explains Dr. Heinig of the Fraunhofer Institute for Photonic Microsystems IPMS in Dresden. Following on from this theory, Heinig's team has joined forces with research and industrial partners in Spain and France to develop a novel approach to the treatment of AIS (see box text). It is based on the use of a technique known as functional electrical stimulation (FES), in which an implantable device delivers targeted electrical impulses as a substitute for the natural nerve stimulation that is absent or impaired due to the disorder. The aim is to stimulate the deep-lying muscles along the spine – the paraspinal rotator muscles – so as to balance their contraction and relaxation, and in this way encourage the spine to grow symmetrically.

After just two years of interdisciplinary research and development, the European consortium presented the first prototype of the new implant. Dr. Carlos Barrios of the Catholic University of Valencia in Spain, who has been treating children suffering from AIS for decades, contributed his medical experience. "Dr. Barrios gave us a list of requirements for the functions of the new device, which we then implemented," reports Heinig. "The main function of the implant is to generate impulses in a defined pattern consisting of active and inactive phases, which the treating physician can then continuously adapt to the specific requirements of individual patients." The central controlling device is implanted in the patient's groin. It contains a microchip with eight outputs connected to millimeter-thin wires leading to electrodes at selected points along the length of the spine. These electrodes stimulate the weakened muscles on the side of the body that is not receiving signals from the brain, and also measure the activity of these muscles. Similar electrodes are connected to the healthy side of the body to measure normal muscle activity – as a comparative reference. These two sets of data are compared by an internal regulating mechanism to enable the level of muscle stimulation to be continuously adapted over the course of treatment.

Depending on the severity and nature of the spinal curvature, the number of electrodes placed on the dysfunctional side of the body can vary between two and five, with the remainder being placed on the intact side. The prototype implant offers the necessary flexibility. All eight electrodes are capable of measuring muscle activity, and six of them are capable of delivering stimulation impulses. The electrical intensity of these impulses, which have a maximum amplitude of 25 milliamperes, is around a thousand times higher than that of a heart pacemaker. To excite the rotator muscles, a pulse rate of at least 50 pulses per second must be maintained over an extended period of time. A typical training program involves six to eight hours of therapy each day, preferable during the night or other rest periods. Ideally, the muscles should be stimulated for no longer than ten seconds at a time, with an interval of at least ten minutes between sessions. If only the stimulation periods are counted, the total energy consumption corresponds to an operating time of less than two hours per day.

In a standard treatment program, the battery incorporated in the implant lasts about nine days before it needs to be recharged. The charging process takes around 90 minutes, using an external, wireless inductive charging circuit. Wireless technology is also used to transfer the data recorded by the implant to an external reading device and vice versa. This allows the muscle activity in the body to be monitored. The periods of stimulation and inactivity can be continuously adapted to the state of each AIS patient's muscles. "Our partners in Valencia have worked out the details of the system designed to do this. If the implant is some day used to treat AIS in children, the treating physician will operate the external reading device," says Heinig. In the necessary tests, the researchers were able to demonstrate that the technology works in principle. Data were successfully transmitted in both directions, and the muscles could be electrically activated. The spinal curvature in animal test subjects could be corrected in the desired direction.

French company Synimed, one of the partners in the consortium, developed special precision surgical instruments to accurately place the fine wire electrodes in the muscular system near the spine. These instruments may one day also be used in human surgery. The new treatment could bring tremendous relief to the many young people worldwide who suffer from AIS. With current forms of therapy, the best that can normally be hoped for is to slow the progression of early-stage spinal curvature and prevent further deterioration until the child stops growing. The most commonly used method is bracing, in which the child or adolescent is required to wear a special brace or corset, often for many years. In particularly severe cases, the curvature may be surgically corrected using metal implants connected by screws to one or more rods to fix the vertebral column in place. Both methods have a considerable impact on the patient's everyday life and limit their mobility.

Concept remains to be proved in practice

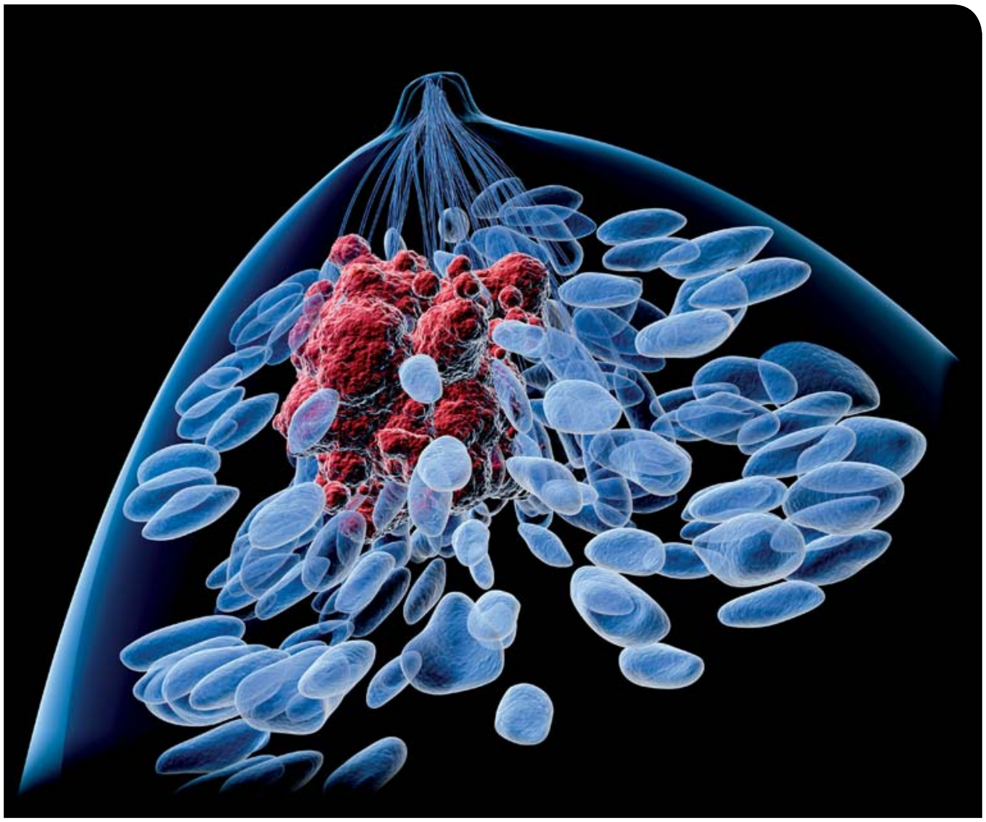
The concept of functional electrical stimulation is superior to the existing therapies. Minimally invasive treatment using implantable devices not only promises to prevent the condition from getting worse but also offers a possible means of permanently correcting deformities – at least in theory.

Only time will tell whether the theory can be proved in practice. "We have provided clear evidence that this form of therapy is technically feasible," stresses Heinig. "Now clinical studies need to be conducted to prove that it is an effective and reasonable medical treatment and that it is capable of healing or at least alleviating scoliosis." ■

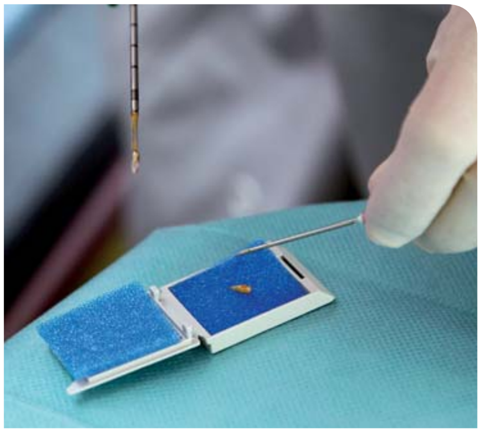
Better biopsies

Fraunhofer scientists have developed a way of speeding up and reducing the discomfort of biopsies in suspected cases of breast cancer.

Text: Frank Grotelüschen



Breast cancer, which often develops in the mammary gland, is one of the most frequent cancers observed in women. © *iStockphoto*



Sample of breast tissue removed during a biopsy. © *ASTIER – CHRU LILLE, BSIP/Science Photo Library/Agentur Focus*

Ultrasound images are recorded during the MRI scan. © *Fraunhofer IBMT*

The magnetic resonance MR scan reveals a suspicious dark area in the breast tissue – could it be a tumor? The doctor decides a more thorough examination is necessary, and orders a biopsy – a procedure that involves extracting a tissue sample with a fine needle. The precise insertion of the needle is usually guided using ultrasound. But what if the abnormal structure is undetectable by ultrasound? This is where a joint research project by the name of MaRIUS aims to provide help. The Fraunhofer Institutes for Biomedical Engineering IBMT and for Medical Image Computing MEVIS have developed a method that utilizes a novel ultrasound imaging technique to speed up the biopsy. The basic technology could also be of interest in other areas of application, for example: enabling more precisely targeted and less traumatic radiation therapy, or delivering sharper MR images of the heart, liver and kidneys, or paving the way to entirely new ultrasound imaging techniques.

In the standard procedure for an ultrasound-guided biopsy of breast tissue, the doctor tracks the position of the needle on the screen of an ultrasound scanner while it is being inserted. But in some cases this method cannot be used because the suspected tumor isn't visible in the ultrasound images – a problem experienced with one in three patients. The doctor then has to resort to the more costly alternative of magnetic resonance imaging MRI, a technique that delivers images in which abnormal changes in the breast tissue are much easier to detect. While this method delivers good results, it also increases the complexity of the procedure. To obtain the required images, the patient must first be examined in the MR scanner, while the biopsy can only be performed outside of this confined space. "So each time the doctor needs to verify the position of the needle, the patient has to undergo another MRI scan," explains MEVIS project manager Matthias Günther. "This makes the procedure longer, more expensive, and extremely trying for the patient."

In order to find a simpler and faster solution, two Fraunhofer Institutes, IBMT and MEVIS, launched the MaRIUS (Magnetic Resonance Imaging using Ultrasound) project. In their novel approach, the patient need only to undergo one MR scan before the doctor performs the actual biopsy. The important difference is that the MR and ultrasound images are recorded at the same time. Once this has been done, the ultrasound-guided biopsy can proceed in a normal examination room. The key to this solution is a computer algorithm which uses the tissue deformation retrieved in real-time from the ultrasound data to recompute the MR image. This enables a new MR image that takes into account the deformation induced by the patient´s motion - creating the impression that the patient has remained inside the MR scanner throughout the biopsy. "This gives doctors two sources of information to guide the biopsy procedure," says IBMT project manager Steffen Tretbar. "They not only have the ultrasound images but also the computerized MR images in which the suspected tumor is more clearly visible."

The Fraunhofer scientists had to overcome a number of challenges in order to build up the necessary technological base. The IBMT team was tasked with developing a new ultrasound scanner capable of operating in the conditions imposed by an MR scanner. To allow the two systems to function in parallel, the size of the ultrasound transducer has to be as small as possible, to allow it to be integrated in the limited space available. The device must also be capable of operating reliably in the strong magnetic field generated inside the scanner without affecting the quality of the MR images. "The solution involved designing a system adapted to the MR environment in which small ultrasound probes are attached to the patient's skin, similar to the electrodes used in ECG examinations" relates Tretbar.

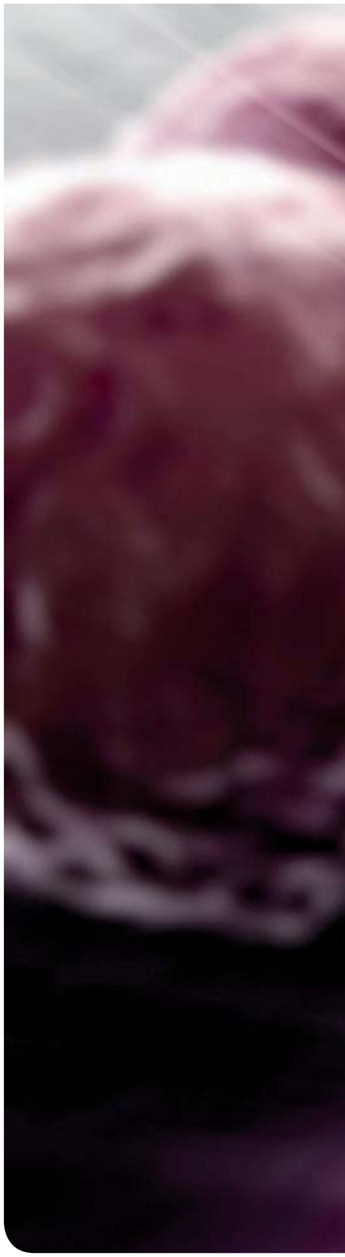
"This system can be rotated mechanically to obtain three-dimensional ultrasound images." Another advantage of the new system is its high speed, which enables it to record ultrasound waves reflected by the tissue at a rate of up to three thousand images per second. By comparison, the devices normally used in doctors' offices cannot process more than 50 images per second.

The MEVIS IT experts developed new tracking software to support the ultrasound imaging process. This was necessary because the MRI scanner requires the patient to lie face down whereas the biopsy is taken while the patient is lying on her back. This change of position alters the shape of the patient's breast and the relative location of the tumor. The ultrasound probes record the displacement of the tumor due to the change in body position in real time, and the tracking software analyzes these movements and uses them to update the original MR images. "As a result," explains Matthias Günther, "the MR image can be adapted in real time to the patient's changed position, enabling the needle to be guided to the site of the tumor with much greater accuracy than using ultrasound images alone."

The team has meanwhile built a technology demonstrator in which the new method is applied to an imitation breast made of silicone gel to simulate a real clinical setting. An ultrasound probe monitors changes in the shape of the breast as it is moved into different positions, and the software uses this information to modify a previously recorded MR image. The researchers have thus accomplished the goal they set out to achieve through the MaRIUS project. The next stage is to enhance the procedure and test it in clinical studies. "We will be collaborating with hospital staff to prove that this technology is reliable. But until then, we obviously have a lot more work to do," says Günther.

The technologies developed for the MaRIUS project are likely to be of benefit in other applications. For instance, the ultrasound tracking software could be used to enhance the images delivered by relatively slow techniques such as MRI or PET (positron emission tomography) when examining organs that move within the thoracic or abdominal cavity such as the heart, liver, and kidneys. The pulsations of a beating heart, for example, often result in a blurred image of this organ in MRI scans. Sharper images could be obtained more rapidly if its movements were tracked using ultrasound. Radiation therapy is another area that could benefit from this technology, especially in the case of tumors that move with the patient's breathing or heartbeat. "In the ideal case, by using ultrasound to track the motion of the tumor, the focus of the particle beam or X-ray beam could be adjusted in real time to target the tumor more precisely," explains Steffen Tretbar.

The ultrasound system itself could also open the way to new applications. With its ability to collect echo signals at a rate of several thousand per second, it is capable of significantly improving the contrast of ultrasound images. The IBMT specialists intend to use their new technology to track single particles as a means of visualizing flow profiles in the bloodstream. Very high flow stress can cause irremediable damage to blood vessels, a risk factor for many cardiovascular conditions. The technology is also suitable for a new form of ultrasound known as shear wave elastography, in which the probe sends high-energy pulses into the tissue. This creates a specific waveform that allows lumps and other hard structures to be easily detected. ■



Lab-on-a-chip solutions for everyone

Chlamydia bacteria can cause urinary tract infections. A team of molecular biologists is currently working on a lab-on-a-chip diagnostic solution for home use. But don't rush to the pharmacy – it will be a year or two before the home testing kit goes on sale.

Text: Janine van Ackeren

Chlamydia are bacteria that can cause urinary tract infections or inflammation of the genital organs.
© *Science Picture Co / SCIENCE PHOTO LIBRARY / Agentur Focus*

According to World Health Organization (WHO) statistics, more than 100 million people around the world become infected with chlamydia every year. The pathogenic bacteria are transmitted during unprotected sexual intercourse. In Germany, there are an estimated 300,000 new cases of chlamydia infection each year, and it is particularly prevalent among the younger age groups. An itching or burning sensation or pain during urination are often the first signs of a chlamydia infection, but in many cases there are no detectable symptoms in the early stages. If the infection isn't detected in time and remains untreated, it can lead to further, more serious complications such as inflammation of the endometrium, ovaries, fallopian tubes, urethral passage or, in men, the epididymis. If it spreads to the eyes, it can even cause blindness. With early diagnosis, the infection responds extremely well to antibiotic treatment, but many patients are too embarrassed to consult a doctor.

A pocket-sized laboratory at home

In future it will be possible for anyone to test for chlamydia infection in the privacy of their own home thanks to an easy-to-use kit. The advantage of this particular test is that the diagnosis is equally as reliable as that provided by a doctor utilizing the services of a molecular biology laboratory, whereas the currently available home testing kits tend to be less accurate. This is because many of these tests take an indirect route. Instead of detecting the pathogen on the basis of highly specific nucleic acid sequences in its DNA, they detect antigens on the surface of the pathogenic bacterium that bind to antibodies in the patient's fluid sample. But tests for bacterial antigens generally have a low sensitivity. This means that they can produce a false negative result, leading the patient to believe that all is well when in fact they are infected.

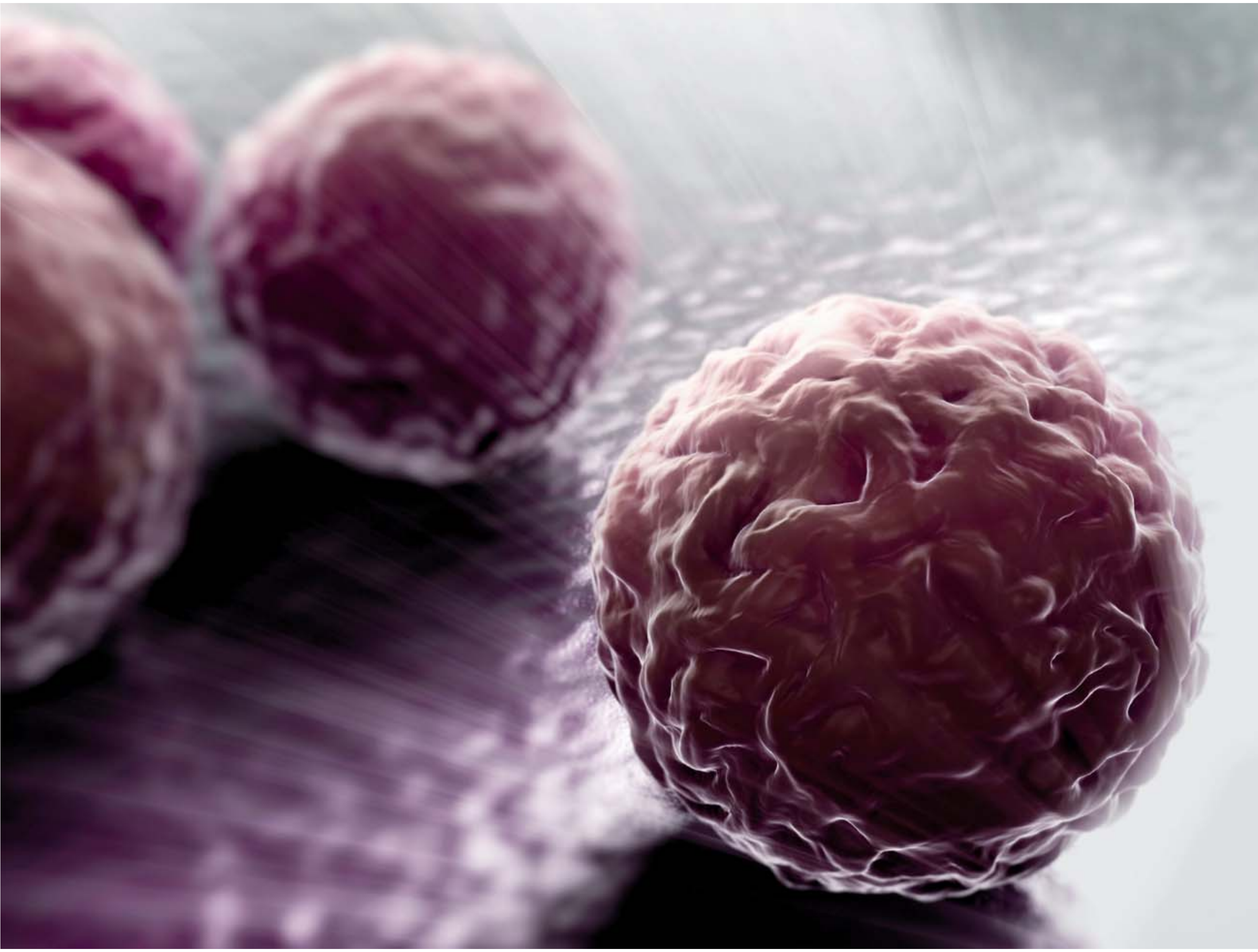
This problem is avoided by the home test developed by researchers at the Fraunhofer Institute for Cell Therapy and Immunology IZI in Leipzig, in collaboration with SelfD Technologie GmbH. Established as a subsidiary of Selfdiagnostics OÜ, Estonia, the company operates from premises in Leipzig only a few hundred meters away from the Fraunhofer Institute.

So how exactly does this home lab-on-a-chip system work? "The particularity of our test system is that it detects the actual bacteria, using molecular biology techniques," explains IZI project manager Dr. Dirk Kuhlmeier. "We isolate and then amplify the DNA of the chlamydia bacteria in the urine sample." In other words, the home test uses the same technique to analyze the sample as that employed by specialized staff in medical laboratories.

There is however one minor difference. In conventional laboratory tests, prescribed by the patient's physician, the lab technicians isolate DNA from the urine sample or swab and amplify it using a polymerase chain reaction PCR. The PCR technique enables the characteristic strands of chlamydial DNA to be specifically replicated and then detected. But this process involves successively heating and cooling the sample to three different temperatures. "This is almost impossible to implement in a home testing kit," says Kuhlmeier. So the researchers decided to use a method known as isothermal amplification instead. This method replicates strands of DNA in the same way as PCR, but the whole process takes place at the same temperature. "Our highly sensitive lab-on-a-chip solution is the only molecular biology analysis system in the world that lends itself to home testing applications," emphasizes Kuhlmeier. "Our aim was to obtain results that are equally as reliable as those of tests carried out in professional laboratories. And yet users with no medical background can perform the diagnosis, without the need for any other equipment or specialized knowledge."

Collect urine sample, start test

If someone wants to check that they haven't caught a chlamydia infection, all they have to

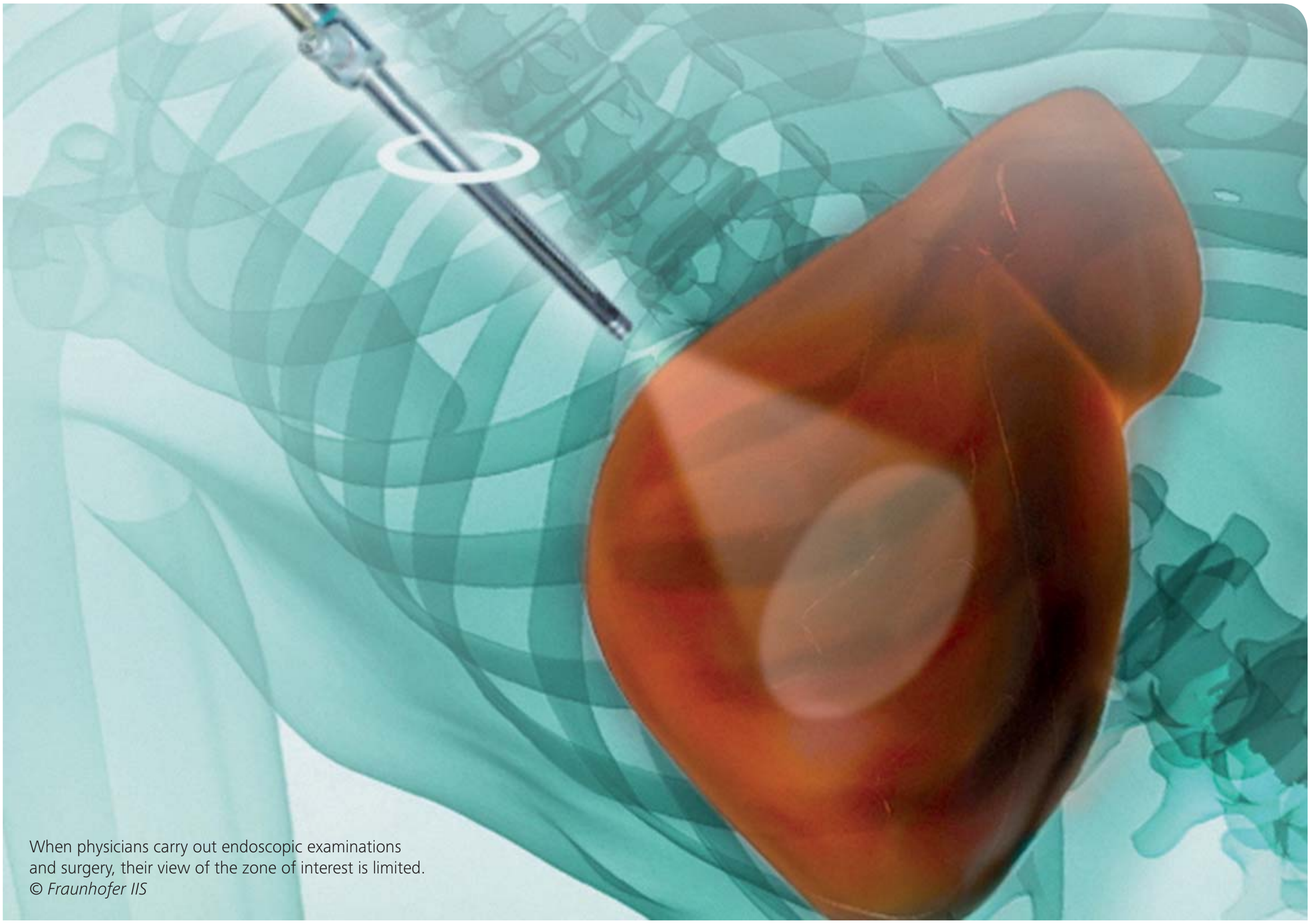


do is urinate into the collection vessel integrated in the test kit and wait 30 minutes or so. Inside the device, unseen by the user, a complex reaction takes place. The urine sample is sucked through a fine capillary tube into a reaction chamber containing the test reagents. These are dissolved by the urine and any chlamydial DNA present in the sample is replicated. When the reaction is complete, the liquid in the reaction chamber is fed onto an indicator strip, similar to that used in home pregnancy tests. The strip changes color to indicate the presence or absence of infection.

To ensure that the kit works perfectly and delivers reliable results, the researchers had to deal with a number of challenges. "The biggest difficulty was preparing the test reagents for this particular application, because the product is expected to have a shelf life of at least two years when stored at room temperature. Another sticky issue concerned the solubility of the DNA extracted from the urine sample in the reagent mixture. These two points represent the essence of the know-how that makes this test system so unique," says Dirk Kuhlmeier.

The team composed of industrial researchers and Fraunhofer scientists has successfully overcome many of these hurdles. They have now reached the stage at which their system can be used to test samples in a real clinical environment, i.e. on real patients. By comparing the results of these tests with those obtained in the laboratory, they will be able to optimize the home testing kit. The packaging to house the entire "pocket-sized laboratory", complete with capillary tube and reaction chamber, is already being manufactured on a small scale using an injection molding process.

The researchers' next goal, which they hope to achieve within the next two-and-a-half years, is to detect other pathogens responsible for sexually transmitted diseases, in addition to chlamydia bacteria, using one and the same diagnostic device. But it will still be another four or five years before people who are worried they might be infected can buy this type of all-in-one test in their local pharmacy or via the Internet. ■



When physicians carry out endoscopic examinations and surgery, their view of the zone of interest is limited.
© *Fraunhofer IIS*

Endoscopy with a panoramic view

When doctors use an endoscope to examine or operate on the bladder wall, they can only see a tiny section of the organ at any one time – as if they were peering through a keyhole. A new software solution that provides a wider, panoramic view may be available in a few years' time to support endoscopic procedures.

Text: Janine van Ackeren

Painful urination or traces of blood in the urine are symptoms that could indicate anything from cystitis to a malignant tumor of the bladder. The best way to be sure is to undergo an endoscopic examination. The physician introduces the endoscope into the patient's bladder through the urethra and looks at the images captured by the camera to check for abnormal changes in the examined tissue. While such minimally invasive procedures are virtually painless for the patient, they pose certain problems for the physician, whose view of the bladder wall is limited to the tiny area of tissue on which the camera lens is focused at any particular instant in time. To examine a wider area of surrounding tissue, the tip of the endoscope has to be repeatedly repositioned to obtain more imaging data. Even so, this series of isolated images doesn't provide a complete picture of the bladder wall, and the physician cannot be sure that he/she has carried out a thorough examination.

Widening the keyhole perspective to a panoramic view

Future endoscopic cameras will be able to provide a panoramic view. "The Endorama software that our researchers have developed merges the separate images into a single picture – in close to real time," reports Dr. Thomas Wittenberg, chief scientific officer at the Fraunhofer Institute for Integrated Circuits IIS. In this way, the physician has a complete view of all examined areas of the bladder at a single glance. The software displays the most recently recorded image in the center of the screen. If there are any blank spaces in the panoramic view, this informs the physician that this area of the bladder wall has not yet been examined. Endorama also simplifies the preparation of case records. Instead of inserting individual images in the patient's medical file, the physician can attach a panoramic image that contains all of the results of the medical examination and, moreover, proves that every area of the bladder was examined.

Most smartphone cameras these days are capable of producing panoramic photos. To do this, a software program looks for distinctive structural features in each frame and uses them as reference points for joining consecutive images to create the full picture. It is more difficult to produce a panoramic view from endoscopic images. The video camera at the tip of the endoscope captures around 20 to 25 overlapping frames per second, but the image quality is comparatively poor. The images usually suffer from optical distortion, they have a low resolution, and their contrast is marred by uneven lighting. Moreover, the structural features of the bladder are relatively indistinct, which makes it difficult to find reliable reference points that could be used to align the overlapping images.

Endorama – Enhanced Endoscopy Vision

Endorama solves all of these problems. The software starts by applying algorithms to correct for optical distortion and eliminate the shadow effects caused by uneven lighting. Then a number of different computing processes are used to join the images. While one process looks for suitable anatomical features that could be used as reference points, such as the blood vessels in the bladder wall, another process uses this information to align the images. The mathematical models on which these processes are based were designed to take into account the complex geometry of the bladder.

Endorama has already passed initial tests with flying colors. In the first software review, the researchers used a phantom configuration consisting of a hollow plastic ball measuring ten centimeters in diameter onto which the vascular structure of the bladder was imprinted on the inner surface. The Fraunhofer experts also used their algorithms to assemble a panoramic view from video sequences recorded during conventional cystoscopy examinations. Wittenberg estimates that Endorama could be launched as a commercial product within the next two or three years.

The same method can be applied when examining other human body cavities. For instance, in the case of a suspected tumor in the pituitary gland, the physician performs a biopsy by inserting an endoscope through the nose into the sinus cavity and extracting a tissue sample. The resulting hole allows the endoscope to penetrate the brain, creating a passage through which surgical instruments can be introduced to remove the tumor. This is an extremely delicate operation, because the surgeon has to be very careful not to damage any nerves or compromise healthy brain tissue. Conventional techniques using a rigid endoscope provide no more than a partial view of the nasal cavity, as in bladder inspections. Here too, Endorama provides a wider view. "But such neurosurgical applications are still at the development stage," comments Wittenberg.

Esophageal endoscopy: no longer limited to a tunnel view

Another of the researchers' objectives is to facilitate endoscopic examinations of the digestive system. To do so, they are working on a software solution that they call TubeStitching. The problem is similar to that encountered by trains when passing through a tunnel. "When the train enters a tunnel, the driver's range of vision decreases exponentially as a function of the light intensity. But a bright ring of light illuminates the tunnel wall within a defined distance of the train's headlamps, providing perfect lighting conditions in this section of the tunnel," explains Wittenberg.

A similar principle applies during endoscopic examinations of the esophagus. In the ideal case, the light source illuminates ring-shaped sections of the esophageal wall. As the physician gradually withdraws the endoscope, successive rings become visible. The TubeStitching program selects images of the well-lit segments and "stitches" them together to produce a two-dimensional picture of the length of esophagus that has been examined. The system could be ready for commercialization within about two or three years.

The researchers also intend to use the new technique in industrial applications. "We envisage using it to examine complex hollow spaces in an engineering context, for instance in cars or aircraft," Wittenberg tells us. Automated procedures for inspecting cylindrical openings such as brake cylinders using a rigid endoscope have been in use for many years. But winding cavities are quite a different matter. It is for this type of situation that the scientists want to develop solutions. "We are already engaged in discussions about this with industrial customers," reveals Wittenberg, who originally worked in the field of technical endoscopy. ■

Plasma makes wounds heal quicker

Skin disorders are a common problem. But there is a solution. For the development of the new PlasmaDerm technology now available all over Europe researchers were honored with a prize for Human-Centered Technology.

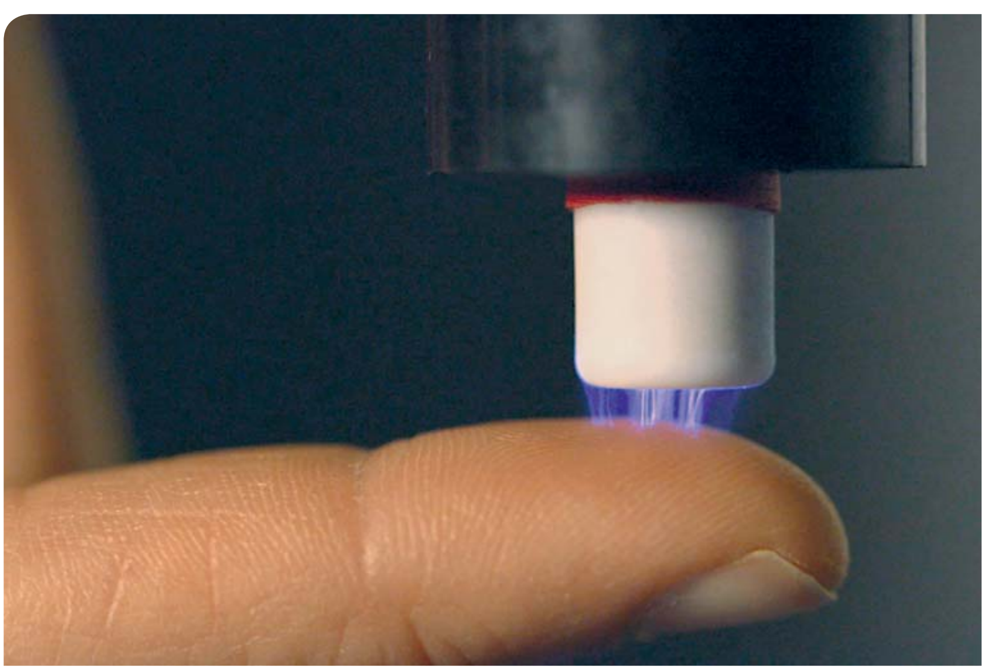
Text: Martin Kern

Skin disorders are a common problem in this part of the world. Atopic dermatitis, psoriasis and chronic venous leg ulcers – typically caused by diabetes or varicose veins – can cause patients years of suffering. Working in collaboration with the company Cinogy and the Department of Dermatology, Venereology and Allergology at the University Medical Center Göttingen, the Fraunhofer Institute for Surface Engineering and Thin Films IST has successfully developed a new medical technology solution for treating wounds and skin disorders known as "PlasmaDerm". Plasma promotes wound healing when it is generated directly on the skin.

"All you feel is a slight tingling sensation," says Prof. Wolfgang Viöl from Fraunhofer IST, moving a device approximately the size and shape of a pocket flashlight in small circles over the back of his hand. Holding the device just over the skin, a faint purple mist can just barely be seen at the device's tip. That's plasma, he explains – an ionized gas.

PlasmaDerm – which was developed by a team consisting of medical professionals, biologists, physicists and engineers – is a novel solution. For the first time, the device generates a non-thermal or "cold" plasma directly on the skin at atmospheric pressure. The patented method involves placing the electrode of the device close to the skin, with the skin itself acting as the second electrode. A high voltage is then applied across the gap, and the resulting electric fields convert the area between the electrode and the skin into non-thermal plasma.

PlasmaDerm is a new medical technology solution for treating wounds and skin disorders. © *Fraunhofer*



PlasmaDerm is safe and painless

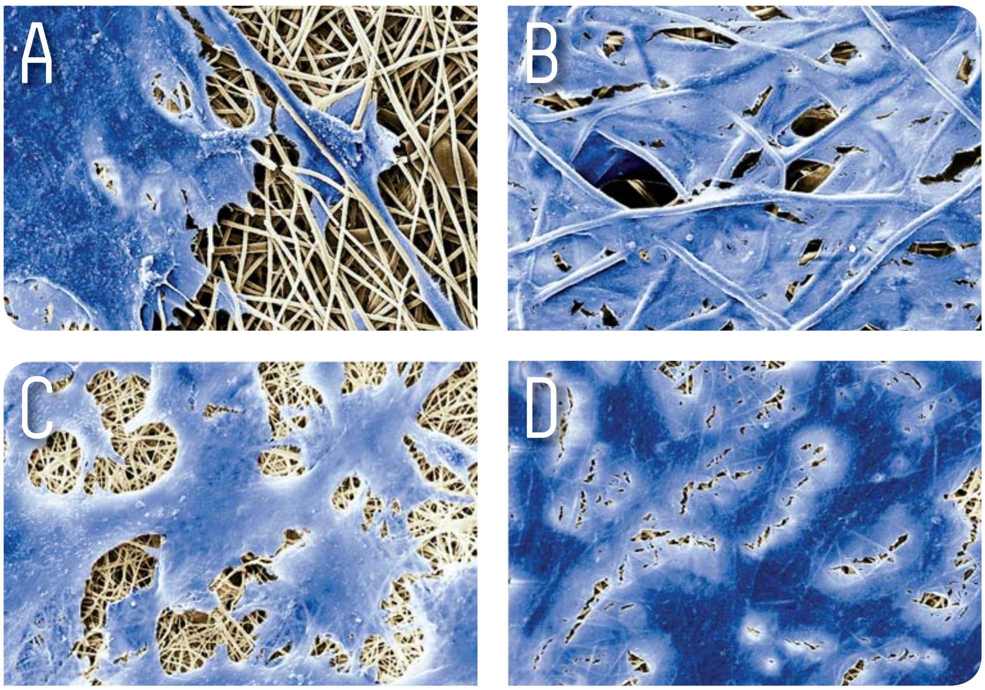
Since cold plasma has not been used on human beings before, the top priority of the Fraunhofer IST was to evaluate the safety of the solution. "We carried out a risk-benefit analysis to evaluate all the chemical and physical parameters and concluded that there is no reason to be concerned about using plasma on people," says Dr. Andreas Helmke, describing how Fraunhofer IST went about the process.

A clinical study conducted by Prof. Steffen Emmert at the Department of Dermatology, Venereology and Allergology at the University Medical Center Göttingen revealed an antiseptic effect and improved wound healing. But Prof. Emmert explains that the greatest benefit of the application is the fact that "non-thermal plasma actually combines the mechanisms of different therapies. UV, ozone and electrotherapy are already available, but plasma achieves a better effect in a shorter period of time." Plasma reduces the bacteria count on the skin's surface, while the electric field simultaneously boosts the skin's microcirculation by allowing more oxygen to be delivered. These are both decisive factors in improving wound healing.

To enable the new method to be applied more flexibly, the researchers needed to develop a portable device. To do this, the Fraunhofer IST worked together with the company Cinogy. "We had to develop a device that was small but capable of generating high voltages. The result is only about the size of a laptop and can be plugged into a normal socket between 100 and 230 V," says Dr. Dirk Wandke, managing director of Cinogy, describing how they tackled the project's biggest challenge. PlasmaDerm is now available all over Europe.

For Prof. Viöl, PlasmaDerm has inspired a vision. But the researcher has an even more ambitious vision. "I anticipate that in the future, a child who falls off a skateboard could be treated at home. Parents could care for the wound using a small PlasmaDerm stick instead of iodine. And I could even imagine the device itself being able to measure what's wrong with somebody's skin and then adjust the dose accordingly and start the physical treatment." ■

Novel tissue substitute made of high-tech fibers



The high-tech fibrous material can be used to replace human tissue. These images taken with a scanning electron microscope show cells adhering to the electrospun substrate. *© Fraunhofer IGB*

Regenerative medicine uses cells harvested from the patient's own body to heal damaged tissue.

Text: Britta Widmann

Donor organs or synthetic implants are usually the only treatment option for patients who have suffered irreparable damage to internal organs or body tissue. But such transplants are often rejected rejected by the body. Implants based on autologous cells are more likely to be accepted by the human organism. But in order to grow, these cells require a compatible structural framework. Researchers at the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB in Stuttgart are working on a project to develop suitable substrates – known as scaffolds – in collaboration with the university hospital in Tübingen and the University of California, Los Angeles (UCLA). Their solution is based on electrospinning, a process in which synthetic and biodegradable polymers such as polylactides are spun into fibers using an electrical charge. These fibers are then used to create a three-dimensional non-woven fabric.

The scientists have chosen a novel approach in which proteins are added to the polymeric material during the electrospinning process, and become incorporated in the resulting hair-thin fibers. In this way, the material serves as a substrate to which the patient's own cells will bind after it has been implanted. "Electrospinning enables us to create a cell-free substrate on which cells can grow after it has been implanted in the patient's body. Each type of protein attracts specific cells, which adhere to the scaffold and grow there. By selecting the appropriate protein, we can build up heart tissue or regenerate other damaged organs," explains Dr. Svenja Hinderer, one of the research scientists working on this project at Fraunhofer IGB in Stuttgart.

The substrate is spun into a fine sheet and cut to the required size. To repair damage to the heart muscle, for instance, a scaffold corresponding to the extent of the damaged area is placed like a blanket over the muscular tissue. The polymeric fibers gradually degrade in the human organism over a period of approximately 48 months. During this time, the cells that bind to the proteins find an environment that is conducive to their growth. They construct their own matrix and restore the functions of the original tissue.

Successful bioreactor test results

The results of initial laboratory experiments and bioreactor tests have been very successful so far. The researchers have been able to demonstrate that esophageal/tracheal cells, which are difficult to culture in-vitro, are capable of binding to decorin protein fibers in the substrate and growing there. Another protein – the stromal-cell derived growth factor SDF-1 – binds with progenitor cells, a special type of stem cell necessary for constructing heart valves and for regenerating heart muscle cells after an infarction. "The implants we have fabricated using electrospinning demonstrate the same mechanical and structural properties as a normal heart valve. Like the original version, they close and open at a blood pressure of 120 to 80 mmHg during tests in a bioreactor," says Hinderer. The next step for the researcher and her colleagues is to test the protein-coated scaffolds in animal models.

The hybrid materials composed of polymeric and protein fibers can be produced and stored in large quantities. The IGB team is working to bring the novel substrate to market as a rapidly implementable alternative to conventional heart valve replacements. "We can't yet say how long this will take, though," comments the researcher. One of the advantages of cell-free implants is that they are classified as medical devices and not as novel therapeutic drugs, which means less time waiting for approval. "Even so, the process of obtaining approval for medical devices that are populated with human cells prior to implantation is very long and expensive," explains Hinderer. ■

Loading of steel pipes for an offshore wind farm. © Wolfhard Scheer / *Fraunhofer IWES*

By hook or by crook

In Hannover, the test center for support structures has commenced operations. Research is done there on how well wind turbines withstand wind, rain, waves and salt water.

Text: Frank Grotelüschen

Violent gusts, heavy rain – and sometimes even lightning strikes: Wind energy facilities can find themselves exposed to severe conditions. It's even rougher on the high seas, where offshore wind farms are beset by storms, waves and aggressive salt water. In order for wind power plants to operate safely and reliably, their technology must first undergo exhaustive testing. To do this, the state of Lower Saxony in Germany recently inaugurated one of the largest and most modern test rigs in the world – the Test Center for Structures in Hannover (TTH). There, experts from the Fraunhofer Institute for Wind Energy and Energy System Technology IWES closely examine components or entire wind turbines under defined laboratory conditions. The facility was built by Leibniz Universität Hannover at a cost of 26 million euros.

The test center has two large test facilities: In the "foundation engineering test trench", new concepts for anchoring wind turbines in the seabed can be tested on 1:10 scale models. And, on the "field testbed", experts subject tower sections and support structures to severe forces to simulate the effects of wind and waves in an accelerated scenario. The results provide important findings on how components can be constructed to be more stable and durable. "These are key issues, particularly for offshore wind energy, because maintenance and repair on the high seas are very expensive," explains Maik Wefer, director of the Fraunhofer IWES Structural Components division.

It is absolutely crucial that the wind energy turbines are anchored as safely and efficiently as possible in the seabed. At the Hannover test center, various construction methods can be simulated in a giant "sandbox": The "foundation engineering test trench" is a rectangular hole in the hall floor 14 meters long, nine meters wide and ten meters deep and filled with 1,250 cubic meters of sand. Four wells provide the necessary moisture and an extreme density ensures that the conditions are similar to those in the seabed.

Fraunhofer engineer Martin Kohlmeier uses the sandpit for the collaborative project entitled UnderwaterINSPECT, which is developing technologies for reliably and efficiently testing underwa-

Seabed in the model layout: Construction methods, such as the gentle vibrating in of steel piles, are examined in the test center. © *Fraunhofer IWES*

ter support structures for offshore wind energy turbines. First, a special backhoe presses a metal pile, which is 7.5 meters long and thick as a tree trunk, into the wet sand. “This isn’t a case of ramming the pile into the ground,” points out Kohlmeier. “Instead, a special mechanical technique applies vibration so that it vibrates itself into the ground.”

In the end, only about a meter of the pile is left protruding from the pit. On top of it the experts will screw on a six-meter high tower section – essentially a wind turbine model scaled at 1:10, but without a nacelle and rotor. Next to be mounted will be a “shaker” to shake the structure back and forth over a period of several weeks. Strong jolts from a hydraulic cylinder will simulate extreme wind gusts and breakers.

In order to determine whether the support structure can withstand these extreme loads, Kohlmeier’s team fitted the model with sensors that measure the elongation, angular tilt and acceleration. They will detect how the model tower reacts to the onslaught from the shaker and the hydraulic cylinder.

“We want to know how much we can deduce from the sensor data about what’s going on in the sand pit – or on the seabed, so to speak,” says Kohlmeier. “If the support structure undergoes any changes during the course of the experiment, will this result in damage?” The results should help industry to examine and improve its sensor systems – with the hope that this can help reduce costly inspections by divers and underwater robots.

Later the engineers want to try out new design concepts. “It’s our aim to develop low-noise foundation systems that cause the least amount of construction noise and are thus less disruptive to marine mammals,” explains Wefer. The idea: Instead of ramming the foundations loudly into the seabed with pile drivers, a wind turbine could also be anchored with what are known as suction buckets. Put simply, they are like inverted buckets that attach to the seabed by a vacuum process.

Long-term trials

The long-term trials in Hannover will show whether these suction buckets can withstand the loads to which wind turbines are typically exposed. How do they have to be arranged to ensure sufficient stability? It is quite a balancing act: If the components are made too small, stability could be at risk. If they are made too large, high material and logistics costs make them too expensive and thus uneconomical. “Our trials also help to verify the results of computer simulations,” says Wefer. “These computer programs are among manufacturers’ most important tools; our trials will make them even more reliable.”

This also applies to the experiments in the second large TTH setup, on the field testbed: A massive, 200 square meter concrete slab is boxed in on two sides by a high, perpendicular concrete wall. Between the base and the wall a test piece is clamped in place, for example a tower section. Then, the 14 hydraulic cylinders go into action – applying up to 200 metric tons of force on the test object. They pull, tug and press with enormous intensity, comparable to the effects of extreme waves or gale winds.

During the trials, measurement sensors monitor the condition of the components; periodically the researchers scan with ultrasound. Upon request, before components are challenged on the field testbed, they can be artificially aged in the “climatic chamber” by applying a series of temperature cycles, salt spray mist treatment and intense exposure to UV radiation to accelerate material fatigue. Here, the experts can set the weather to mimic a wide range of conditions – from cold fog to a warm tropical rain; the salt content can also be adjusted.

Endurance tests are planned with an often destructive finale: At the end of the battery of tests, the IWES experts increase the forces to the point that the test specimen bursts, breaks or bends. Because: “Only if the boundary limits are known,” says Wefer, “can a system be designed to be truly safe and economical.” ■

Hybrid storage for the new energy economy

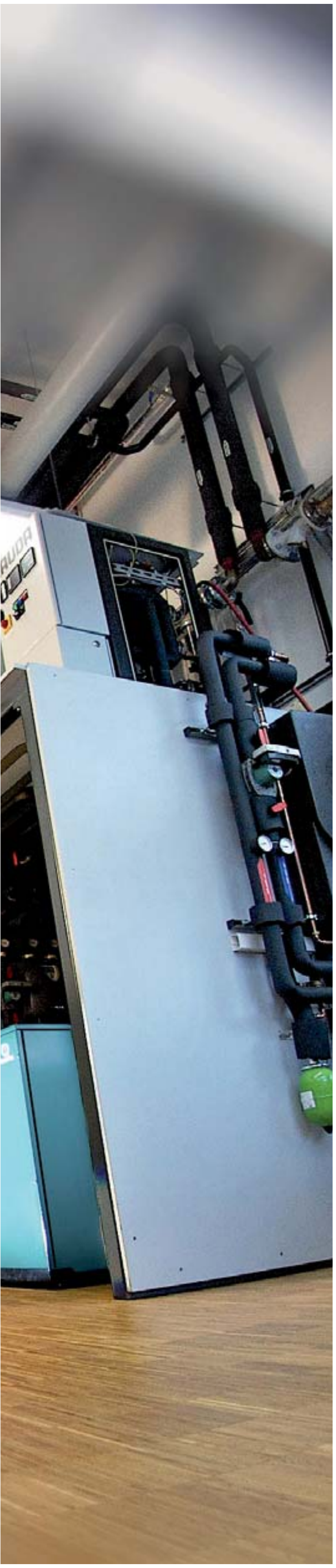
Researchers at Fraunhofer ISE's Smart-EnergyLab have tested the way many small energy storage devices can interact, and are now developing software to enable decentralized management of such a system.

Text: Brigitte Röthlein

Wind farms, biogas plants, solar cells and hydroelectric power stations already provide more than a quarter of the electricity we need. In the future, even more power and heat is expected to be generated from renewable sources. Yet the supply of sun and wind is not constant, and adjustments have to be made for seasonal variations. This calls for efficient energy storage devices and smart energy management solutions.

Decentralized power generation

"Our new energy system is increasingly moving away from big power plants that control everything with a top-down approach, and toward many small units that have to be integrated into the grid," says Prof. Christof Wittwer, head of the Intelligent Energy Systems department at the Fraunhofer Institute for Solar Energy Systems ISE in Freiburg. "We now need to bring lots of small and medium-sized energy providers in line with the needs of consumers, and that will become even more important in the future. Doing so requires a smart energy management approach that incorporates a large variety of storage devices." There's no shortage of potential: the ISE's Renewable Energy Model – Germany (REMod-D) predicts that, when set up for the grid, small battery and heat storage systems alone could provide around 340 GWh to the German energy system in 2050. Power can be stored temporarily in batteries, for example – such as batteries in cars currently standing unused in the garage. Water tanks



A view into the SmartEnergyLab. The yellow cabinets house the decentralized agents. © *Fraunhofer ISE*

or latent heat storage systems – and buildings, too, with their large mass – can absorb heat and feed it into the grid when required. In comparison, the anticipated capacity of all pumped-storage plants in that same year is 60 GWh.

The idea of a virtual storage system

Still, this sort of networked system must first be developed and tested. That's why Fraunhofer has its SmartEnergyLab, in which researchers can carry out realistic simulations of the interplay between energy suppliers and consumers in homes or housing developments. The lab is equipped with renewable as well as electric and thermal production units and storage devices for tomorrow's single-family homes and apartment buildings. It boasts a five kilowatt combined heat and power plant, a two-cubic-meter water tank, a photovoltaic simulator, various inverters, a lithium-ion battery pack, a lead battery bank, charging infrastructure for electric vehicles, and more. The combination of virtual and real components means researchers can artificially simulate almost any energy system. In addition, all external parameters, such as weather patterns, can be set right down to the second. In this way, the lab can test and compare a variety of operating systems under exactly the same conditions.

In a three-year project entitled "Storage City" – carried out in collaboration with the Fraunhofer Institutes for Environmental, Safety, and Energy Technology UMSICHT and for Optronics, System Technologies and Image Exploitation IOSB in Ilmenau – Wittwer and his team developed an energy management system that interconnects thousands of small batteries and heat storage systems in its central control unit. The result is a large, decentralized virtual storage system that they call "hybrid storage." Whenever there is a shortage of power or heat, the operating system is able to supply consumers with the energy they require by drawing it from the appropriate storage units. If more energy is generated than the consumers need at that time, the storage units recharge themselves. All this takes place locally – perhaps within an apartment building, a housing development or an industrial site. "We have developed special programs, called intelligent agents, that access local storage capacity, aggregate it, and make it available on the distribution network," explains Wittwer. "The agents perform most of the control tasks directly with their neighbors – through unofficial channels, you might say – thereby reducing the workload of the centralized structures." In practice, you could visualize it as follows: when a man living in an apartment building is out at work, his neighbors can buy the power or heat that he doesn't need during the day directly from him. An agent acting as an intermediary can broker deals like this directly, since it knows the neighborhood and the agreements that have been made there. In addition, it factors the current state of the network and local considerations into its calculations – for instance information about who is on vacation at the moment. If agents make sure that energy is supplied at the cheapest possible price every time, one of the most important elements of the new concept could also be the cost of energy.

Digital agents for the electricity grid

At the moment, the ISE researchers are working on software that will implement completely new management strategies for the power grid. "It's an agent-based management technology that links together many local components in a completely automated way," says Wittwer. "You can think of it as similar to the Internet, in the sense that individual users don't really know which pathways their information is being routed through." Of course, security – both of access and of data – must be the top priority in energy distribution networks as well.

The advantage of such a structure is that it is very resistant to disruptions and so has a high level of resilience. Wittwer stresses that "in an emergency, such a system can usually continue to operate in a stable manner. This is because local islands are able to form in the neighborhoods, supplying themselves and balancing each other out. That is an excellent feature of the new, decentralized power system, and one that we should not pass up by reimposing a centralized control structure." Of course, the link with the transregional power grid must still be maintained. "That is a balancing act, and we need to find the optimum mix." A prototype for the new software already exists; currently the ISE researchers are seeking hardware partners from industry who are willing to use the software to optimize their energy system. ■

Charged in motion

"Filling up" with electricity while driving.
© *Fraunhofer IFAM*

Recharging electric vehicles (EVs) is still an inconvenient process, but this may soon change. In a joint project with industrial partners, Fraunhofer researchers have developed a system that enables EVs to recharge their batteries while in motion on the road through the inductive transfer of electricity - a technology that numerous Fraunhofer teams are helping to advance.

Text: Tim Schröder

Electric cars are silent and don't emit offensive exhaust fumes. And they are miles ahead of conventional gasoline or diesel vehicles in terms of environmental impact, as long as the electricity is generated from renewable resources. The German government offers tax reductions and other incentives to encourage people to buy electric cars. And yet in 2014 only 21,000 electric vehicles were registered in Germany. This is a drop in the ocean compared with the 43 million conventionally powered vehicles circulating on German roads: electric vehicles have still not achieved the hoped-for breakthrough. This is partly due to their high price but also to their restricted range, which has been a problem from the outset, and the inconvenience of existing charging methods. To "fill up", drivers have to plug in a special cable and arm themselves with patience.

If electric cars could be liberated from their charging cables and their range extended this would represent a huge step forward for e-mobility. This may sound like trying to square the circle, but one such solution has already been demonstrated on a test track. A number of companies have joined forces with researchers from the Fraunhofer Institutes for Manufacturing Technology and Advanced Materials IFAM in Bremen and for Transportation and Infrastructure Systems IVI in Dresden to change the way electric cars are supplied with electricity. Their solution is to recharge the vehicle while it is in motion.

Their groundbreaking approach is based on a technology known as inductive or wireless charging, an already widely researched solution for charging stationary vehicles. In inductive charging, electricity is transferred to the vehicle through the air by means of a magnetic field created between electromagnetic coils mounted on the underside of the vehicle and coils embedded in the road. Physicists have known about the principles of induction, in which a magnetic field generates a flow of current in an electrical conductor, since the mid-19th century. It is only in recent years that these principles have been applied in technical applications such as induction hobs or charging stations for electric toothbrushes.

"Filling up" while driving

It has been barely two years since the project was launched, but it has already taken inductive charging a decisive step further. With the support of the German Federal Ministry of Transport and Digital Infrastructure BMVI and the National Organization for Hydrogen and Fuel Cell Technology NOW, a 25-meter test track with integrated induction loops has been constructed on the premises of the engineering services company INTIS in Lathen, Emsland. The IFAM researchers' role in this project was to integrate the necessary inductive charging technology in the vehicle. To conduct the tests, they fitted a sports car with an electric engine to create a demonstrator named FreccO – short for Fraunhofer electric concept car, generation 0.

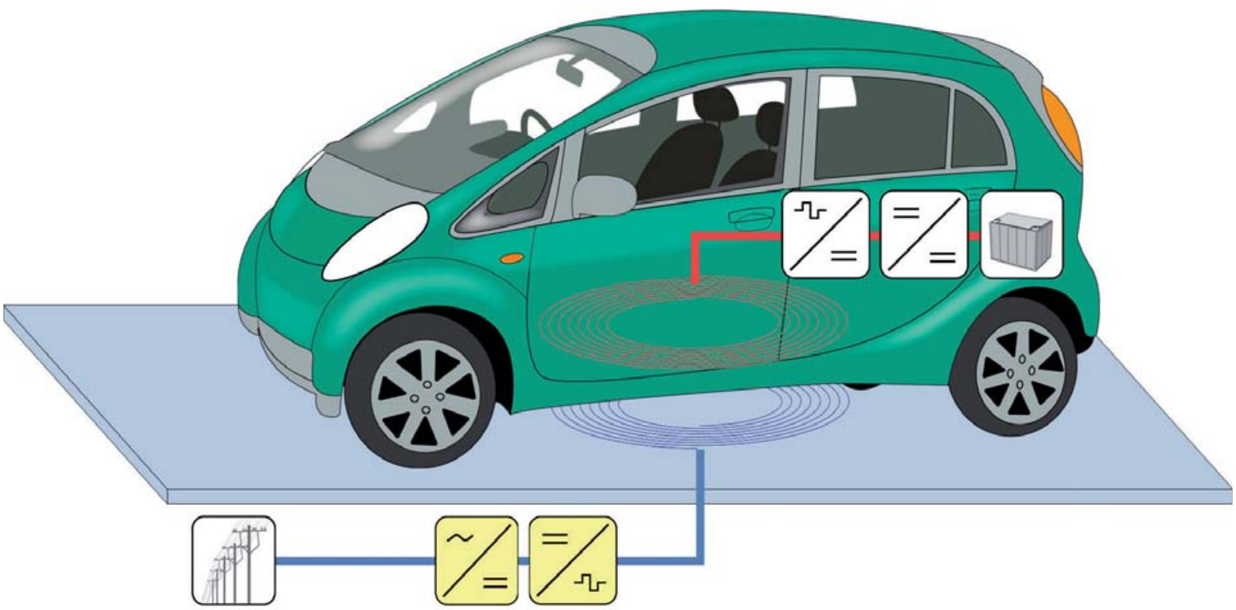
"We showed that it is possible to charge the battery while driving round the circuit at a moderate speed," reports project manager Bartels of the institute's Electrical Systems department. "This is proof that the concept of dynamic charging, i.e. recharging the vehicle while it is in motion, is technically viable."

The researchers went to huge efforts to create a realistic test environment. One major requirement was that the road surface should closely resemble that encountered in real-life driving situations. This task was entrusted to two project partners: a road construction company integrated the induction loops in the test track and Alcatel provided the electronic control system. Another important component was the vehicle detection system, which ensures that a current is induced in the loops only when a vehicle drives over them.

Inductive energy transfer

The IFAM researchers were responsible for integrating the inductive charging system in the electric vehicle. "The challenge was to find the best compromise between vertical clearance, required mounting space in the vehicle, and system efficiency," says Bartels. The distance between the charging coil in the vehicle and the induction loop in the road plays a major role in this respect. The shorter the distance between the charging coil and the road surface, the simpler and more efficient the transfer of energy.

The IFAM engineers added a voltage converter to adapt the high-frequency alternating current supplied by the induction loop to the onboard DC network. They also installed a charging regulator in the vehicle, together with the necessary electronics. And finally they integrated all of these components in the electric powertrain and



In this highly efficient inductive charging system for electric vehicles, energy is transferred wirelessly to the car battery by means of a magnetic field generated by a pair of induction coils. © *Fraunhofer ISE*

linked them into the vehicle's electronic communication system.

The IFAM researchers have demonstrated that this sophisticated technology works on the indoor test track. Their concept car charged its batteries from the induction coils in the ground as it traveled from one end of the building to the other at a speed of 35 kilometers per hour. "If the track was longer, I'm sure that we could charge the battery at higher speeds," says Bartels. The researchers envisage that it would perfectly possible to recharge vehicles even when traveling in the fast lane of the freeway. But this would mean installing induction coils over long stretches of road. Christian Rüther, who heads Fraunhofer IFAM's strategic project management team, is convinced that this might one day be possible. "Obviously, it would be impossible to equip all existing freeways with this technology in one go. But there is no reason why it couldn't be incorporated in new roads or sections of freeway already scheduled for major reconstruction." Another of the project's objectives was to ensure that the induction loops embedded in the road would have an insignificant impact on overall construction costs.

Rüther sees the introduction of dynamic charging as a gradual process, starting with small-scale applications in places such as bus stops or taxi stands, where vehicles move slowly up the waiting line. The contribution by the Fraunhofer IVI research team focuses on precisely this type of application. They have installed the inductive charging system not in a car but in their AutoTram. This cross between a bus and a streetcar with rubber tires was developed by the institute as a research platform. Up to now, it has been used to demonstrate various drive technologies including batteries, supercapacitors and fuel cells. In the future it will also be able to top up its batteries on the go by means of dynamic inductive charging.

Stationary systems

The big advantage of both stationary and dynamic inductive charging is that it does away with the need for cables. Cables can accumulate dirt, and charging stations are susceptible to damage by vandals. Wireless charging by means of induction loops gets rid of these problems. Stationary inductive charging generally involves immobilizing the vehicle in a parking bay for a significant length of time. And because the charging pads transfer high levels of energy, there is an increased risk that objects underneath the car could overheat or even burst into flames. The resulting high-intensity electromagnetic field also presents a danger to cats and other family pets who might be tempted to take a snooze under the warm engine.

To solve these problems, researchers at the Fraunhofer Institute for Integrated Systems and Device Technology IISB in Erlangen have developed an alternative to charging coils mounted in the floor of the vehicle. In their novel solution, the receiving coil is situated in the nose of the vehicle, near the number plate. The key to this innovative solution is a charging bay that allows the car to park within a very short distance of the pillar. By reducing the distance between the transmitting coil and the vehicle, it is possible to use coils with a much smaller diameter than those needed when the transmitting coil is installed at ground level: ten instead of 80 centimeters. And if the driver accidentally bumps into the pillar, it automatically folds away to prevent damage to the vehicle.

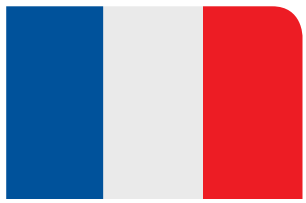
Inductive charging is also an interesting proposition for car sharing. The six Fraunhofer Institutes participating in the GeMo project (shared use of e-mobility: vehicles, data and infrastructure) have chosen to implement a range of future-oriented technologies including an infrastructure consisting of inductive charging stations and cloud-based charging management. The inductive charging system for electric cars was developed by researchers at the Fraunhofer Institute for Solar Energy Systems ISE in Freiburg. The first prototypes of this charging system are capable of transmitting up to 22 kilowatts of power. This level of efficiency is sufficient to charge the batteries of a conventional electric car to 80 percent of their rated capacity in less than one hour.

In either case, wireless solutions for recharging electric vehicles without pesky cables will soon be commercially available, thanks to Fraunhofer research. "Both dynamic and stationary solutions are necessary to improve the acceptance of e-mobility. For this reason we intend to reinforce collaboration between Fraunhofer Institutes in the months to come," says Christian Rüther. ■

Joint research

In the future, the Fraunhofer Institute for Material Flow and Logistics IML in Dortmund and the Arab Academy for Science Technology & Maritime Transport (AASTMT) plan to work together in the fields of transport, logistics and supply chain management. Professor Uwe Clausen, Director of Fraunhofer IML, and Professor Atalla Hashad, Vice President for Education and Students Affairs at AASTMT, signed a memorandum of understanding to this effect in the House of Logistics and Mobility (HOLM).

Founded in 1970 and based in Alexandria, AASTMT is one of the leading scientific institutions in Egypt in the fields of general and maritime transport. As well as carrying out research, it also offers a comprehensive education and further training program for students.



Virtual laboratory

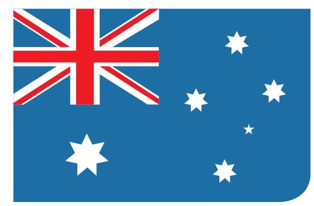
Germany and France are among the leading European nations in semiconductor technology and solar cell research. The CEA Tech research group in Grenoble und Chambéry, which is part of the French Alternative Energies and Atomic Energy Commission (CEA), and the German Fraunhofer Institute for Solar Energy Systems ISE in Freiburg have been working together for several years now. In order to strengthen this cooperation, the two partners have now signed an agreement concerning a "virtual laboratory," where the experts want to train scientists, work on prototypes for the solar cells of the future, and create synergies in industry-oriented research for ultra-efficient multiple solar cells.

"We're looking forward to working with our colleagues from CEA Tech to develop new ultra-efficient solar cells and to bring these products to market," says Dr. Frank Dimroth, head of the III-V Epitaxy and Solar Cells department at ISE. "We're convinced that the collaboration represents the best possible research outcome for industry," adds his French colleague Dr. Thomas Signamarcheix, who heads the Advanced Substrate Laboratory at CEA Tech.

New energy for Europe

To reach its ambitious climate targets, half the European Union's electricity needs must be covered by renewable sources by the year 2030. A substantial portion of the power generated – roughly a third – will therefore come from wind and solar energy. However, the amount of energy supplied by the wind and the sun fluctuates. A closer networking of the central western European power systems of France, Switzerland, Austria, the Benelux countries and Germany (CWE region) can help to significantly reduce the costs of balancing out weather-dependent wind and solar energy. This was the conclusion of a study carried out on behalf of Agora Energiewende by researchers at the Fraunhofer Institute for Wind Energy and Energy System Technology IWES in Kassel.

Another positive effect is that closer networking enables surpluses in one region to balance out lower energy generation in others. Because this has not been possible before now, electricity from renewables has often not been fed into the grid on very sunny and windy days. In 90% of cases, this curtailment could be avoided. Yet even with better networking of the central western European power systems, flexible power plants (pump storage, gas-fired power stations) and energy storage solutions are needed to carry out back-up and balancing roles – albeit only to a fraction of the capacity required today.



Additive manufacturing

A new cooperation center for innovative production technology has been established in Melbourne. The mission of the Innovative Manufacturing Cooperative Research Centre (IMCRC) is to promote collaboration between science and business in the field of additive manufacturing. Its work will focus on research and development into additive manufacturing techniques such as 3D printing, developing automated and supporting technologies, and manufacturing high-quality products.

The initiative brings together 18 international manufacturing companies and 16 universities and research institutions. This includes the Fraunhofer Institute for Laser Technology ILT in Aachen, which is the only German research and development organization taking part in the IMCRC.

Pothole and rut analysis

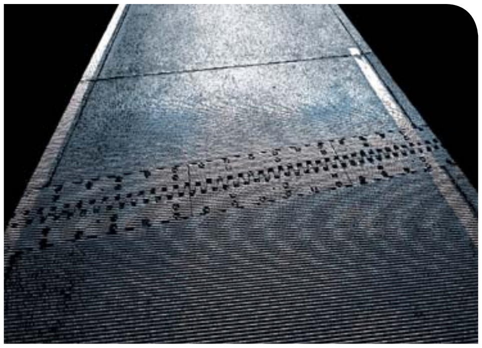
How good are the highways? Road quality is a question that concerns not only motorists, but also administrations and governments. A new laser scanner has already enabled surveys in Germany, Austria and India.

Text: Janine van Ackeren

RoadSTAR has been surveying Austrian roads since 1991. Since 2013, it has been doing so using the PPS measuring system (left).

The laser scanner (top right) is attached to the front of the measuring vehicle.

High-resolution road surface model using data from 3D laser scan (lower right).
Photos © AIT Austrian Institute of Technology GmbH



Rain pours down on the car roof. Despite the windshield wipers working at full speed, visibility is still poor. Meanwhile, ruts in the road fill with water, increasing the safety risk even further. But how badly affected are roads by damage such as ruts or potholes? This question is of interest not only to motorists, but also to the authorities responsible for the upkeep of the highways in question, because they have a vested interest in maintaining and preserving the road network as a valuable asset. In Germany, the public authorities commission surveys on a regular basis to give them an overview of which roads are in good condition, and which are in need of repair. To what extent are they damaged? Which sections of road pose a heightened safety risk because of ruts in the surface that collect standing water?

Until now, the companies commissioned to conduct these surveys have typically used several measurement devices mounted on a beam to examine the condition of the roads. This device, which is over three meters wide, is mounted on the front of a car, and positioned some 20 to 30 centimeters above the road surface. But such massive survey vehicles can obstruct the flow of traffic and cause jams. What's more, the system does not come cheap: the scanner contains some 30 to 40 distance sensors, each of which costs several thousand euros.

Barely the size of a shoe box

Researchers at the Fraunhofer Institute for Physical Measurement Techniques IPM in Freiburg have come up with a compact alternative. "We use a laser instead of the unwieldy measuring beam," explains Dr. Heinrich Höfler, Head of Department and Deputy Director of the IPM. "The special feature of this laser unit is that it's not much bigger in size than a shoe box."

The principle is as follows: The box is attached to a vehicle at a height of three meters above the ground. Inside the box is a laser, a deflector, a detector and the corresponding evaluation electronics. The laser emits its light pulses onto the road surface, which reflects them back to be received by the detector. The further the distance the light has to travel, the longer it takes to return to the detector. So if the beam of light travels into a pothole or a rut in the road, it reaches the detector later than any light reflected off flat road surfaces. To ensure that the laser can measure the entire width of the road - four and a half meters - a deflection unit controls the light, guiding the beam so that it flits from one side of the road to the other. This all happens at incredibly high speed: the laser beams sends out two million laser pulses per second, and passes over the entire width of the road approximately eight hundred times a second. Despite this, the accuracy is impressive, with each "line" that the laser draws across the road comprising between 900 and 1800 measurement points. Measurement accuracy is to within 0.2 millimeters. And the system has yet another advantage: it even works at speeds of up to 80 kilometers per hour.

Eye safety guaranteed despite high laser power

Any laser-based measuring system intended for use on the road must first meet two essential requirements. First, the laser beam must not pose a danger to the eyes of passers-by, which means that only Class 1 laser systems approved for use in the public domain can be used. Nevertheless, the laser has to be powerful enough for the system to work on roads, which are usually very dark and fairly unreflective – far from ideal surveying conditions. The problem is that as soon as you increase the laser's power so that good results can be obtained even on very dark surfaces, eye safety is reduced and becomes a limiting factor.

Researchers at the IPM found a neat solution that allows them to fulfill both requirements. "We took the wavelength so far into the infrared that the laser poses no danger to eyes, even at high power," says Höfler. This is because the wavelength of the laser light is so far outside the spectrum of visible light that the human eye is no longer able to focus it. Thus the retina is not damaged by the beam.

Already on the roads

"Our laser system is the first to be approved by the Federal Highway Research Institute to date," Höfler is delighted to report. The system is already in action on the roads: it has been used in many German cities, and played an important part in the final acceptance of construction work for the A5 highway. Staff from service provider Lehmann + Partner GmbH also used the laser scanner to analyze different road surfaces in India. In Austria, the system has even been used to scan the country's entire highway network, which adds up to more than 4000 km of road.

Currently, the researchers are working to expand the system so that it could also act as a kind of camera in the future. "Until now, we've only used the laser to determine distance from the road. In a further step, we also consider the amount of backscattered light, in the same way that a conventional camera does," explains Höfler. To increase the resolution, the scientists have integrated a second laser. They plan to take their extended system out onto the road in 2016. When used for measuring roads, the new camera feature has one great advantage over the existing system: it is independent of external lighting conditions. Regardless of whether the sun is beating down or it is pitch dark, the laser beam still provides a high-resolution, well-lit camera image. An external light source, as required by conventional cameras, is not necessary. "This combination of cross-profile imaging and high-resolution camera pictures would allow us to detect even the finest of cracks in the road surface, of that I am sure," says Höfler.

Useful on tracks, too

The scanner's use is not just limited to roads – it's equally useful on rails, for example when it comes to measuring the track bed. Switzerland has already put the technology to use in this way. Another area of application is the trains themselves, to prevent the risk of serious accidents caused by displaced loads on freight trains – when the train enters a tunnel, for example. Italian railway officials are currently testing different systems that can measure trains three dimensionally and identify any dimensions that don't correspond to the target values. The solutions being trialed include several laser systems from the IPM, which each feature four lasers that analyze the three-dimensional shape of the train. In the future, the plan is for one of these scanning systems to be placed in front of each tunnel in the Italian rail network to help prevent accidents. ■

The dish of the radio telescope installed at the Yebes observatory in Spain measures over 13 meters in diameter. It will serve as the proving ground for the researchers' high-performance radio-wave receiver. © *Instituto Geográfico Nacional*

Surveying Earth from space

Researchers at the Fraunhofer Institute for Applied Solid State Physics IAF in Freiburg have been working together with partners in Spain – the Instituto Geográfico Nacional and the University of Cantabria – on a project to develop a sensitive high-frequency amplifier for radio telescopes used in scientific research. The extremely low-noise amplifier, which operates at a temperature of minus 251 degrees Celsius, will make it possible to obtain Earth survey data of greater accuracy than ever before. Scientists use Earth-based radio telescopes to capture radio waves emitted by quasars.

Quasars are luminous objects powered by supermassive black holes surrounded by a glowing disc of material, situated at the heart of the galaxy several billions of light years distant from our home planet. They are so far away that, when observed from Earth, they appear as a motionless point of light, which makes them ideal reference objects to serve as a point source in Earth surveys.

Radio-telescope measurements make it possible to obtain highly precise Earth-sensing data including day length, the movement of tectonic plates and the magnetic poles, and changes in Earth's axis. Among other purposes, this information serves to define the orbital path of satellites more accurately. The IAF's amplifier technology has been implemented in a recently constructed radio telescope at the Yebes astronomical observatory in Spain, operated by the Instituto Geográfico Nacional.

Capturing energy from the Nordic sun

The Stenbråtlia housing complex on the outskirts of Oslo is equipped with novel, roof-integrated polymer solar thermal panels supplied by Norwegian company Aventa. They provide the occupants of the 34 row houses, built to passive house standards, with over 60 percent of the energy they need for space heating and hot water. This real-life test demonstrates the functionality of these low-cost modules. Another advantage is that they are easy to install and harmonize with the aesthetics of the building.

The innovative solar collectors are the result of a joint European research project named SCOOP (short for Solar Collectors Made of Polymers). A total of 12 partners collaborated on the project, which was coordinated by researchers from the Fraunhofer Institute for Solar Energy Systems ISE.

Solar Collectors made of Polymers. © *Aventa*

Royal visit

Danish royal couple visits Fraunhofer headquarters: (from left:) HRH Crown Prince Frederik, former Fraunhofer Executive Vice President Professor Alexander Verl, Raoul Klingner, Director International Business Development, HRH Crown Princess Mary. © *Jörg Koch / Fraunhofer*

Their Royal Highnesses Crown Prince Frederik of Denmark and Crown Princess Mary paid a visit to the Fraunhofer-Gesellschaft's headquarters in Munich where they were welcomed by Professor Alexander Verl, former Executive Vice President, Technology Marketing and Business Models. The Danish royal couple was accompanied by a delegation of 50 business representatives interested in learning about Fraunhofer's healthcare research activities. HRH Crown Princess Mary is the patron of Healthcare Denmark, a public-private consortium created with the aim of promoting international awareness of Danish healthcare excellence.

Plastic parts for internal combustion engines

To build lighter cars, the weight of engine components also has to be reduced, for instance by manufacturing them from fiber-reinforced composites. Plastic cylinder housings weigh around 20 percent less than the equivalent aluminum component, and cost the same. They can be mass-produced using an injection molding process.

An engine of this type was developed by the Fraunhofer project group for new drive systems NAS, which forms part of the Fraunhofer Institute for Chemical Technology ICT, in collaboration with SBHPP, the high-performance plastics unit of Sumitomo Bakelite Co. Ltd., Japan. To construct their single-cylinder experimental engine, they opted to use a cylinder case made of a fiber-reinforced composite. The materials used have to be able to withstand extreme temperatures, high pressure and vibrations without suffering damage. The researchers use metal inserts to strengthen areas subject to high thermal and mechanical loads. One example is the cylinder lining, inside which the piston moves up and down millions of times during the lifetime of the vehicle. The researchers also modified the geometry of these parts to ensure that the plastic is exposed to as little heat as possible.

The material needs to be sufficiently hard and rigid, be resistant to oil, gasoline and glycol-based coolants, and adhere well to the metal inserts. A glass-fiber-reinforced phenolic resin fulfills all of these requirements. It comprises 55 percent fibers and 45 percent resin.

Experimental engine built using the new, lightweight cylinder housing. © *Fraunhofer ICT*

Editorial notes

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