

# Fraunhofer

2/14 special issue

# magazine

## Security in the cloud



### Information Technology

Surround sound with a smartphone

### Europe

Rescuing ruins

### Energy

Protecting the climate pays off

# Fraunhofer magazine

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# A secure digital society



Prof. Dr. Reimund Neugebauer. © Axel Griesch

Information and communication technology (ICT) is becoming an all-pervasive feature of our daily lives. It has dramatically changed the way we work, communicate, do our shopping, listen to music, watch movies, and obtain all kinds of information. At the same time, digital technologies are also the motor that drives innovation in almost every sector of industry – including automotive engineering, machine tools and, in the service sector, banks and insurance companies. Advances in ICT are bringing the real and virtual worlds together in the ever-expanding Internet of Things. The German government's Industry 4.0 initiative is based on the fusion of microelectronic systems with information and communication technologies. ICT is also helping to simplify administrative procedures involving public authorities, with concepts such as e-government and smart cities opening up further new possibilities. We live and work in a digital society. So it is no coincidence that the German Federal Ministry of Education and Research (BMBF) has chosen this theme for its Science Year 2014.

But as well as offering huge advantages and growth potential, the ubiquitous presence of ICT in our society also carries substantial risks and associated problems. According to the Cyber Security Report 2013, practically every company in Germany has been the target of hacking attempts on at least one occasion. Only 13 percent of the medium-sized and large businesses surveyed said that their IT systems had never been attacked via the Internet. Other potential targets for cyber attacks include the sensors integrated in our cars, wirelessly networked medical devices, and numerical control systems in factories. In this digital world, the possibilities for misuse and manipulation are almost endless, and hackers can steal not only confidential access codes but also a person's identity.

Our growing dependency on digital systems and the increasing use of cloud computing services – by around 40 percent of all businesses in Germany according to 2013 statistics – make it indispensable to have an efficient means of providing cyber security. The very functioning of government, industry and society depend on it; IT security is an issue that hits at

the heart of our national sovereignty. We need to protect our intellectual property and our inventions, because knowledge is the capital that will assure our future.

We need to cultivate a new mindset as regards data security, a culture in which "security by design" is seen as an integral part of every phase and development stage in the lifecycle of products, systems, infrastructures, and services. In future, data security will be one of the most important gauges of quality. Another equally important aspect is user-friendliness, because security applications will only be used consistently if they are simple to operate. This is an area that still requires a considerable research and development effort. The concrete challenges faced by researchers in the domain of IT security are described in detail in Fraunhofer's strategic agenda entitled "Cyber Security 2020."

The Industry 4.0 initiative covers more than ICT and cyber-physical systems. It also includes industrial robots, which are a vital element in smart, adaptive automation solutions. In tomorrow's factories, humans and robots will work closer together. One of the reasons for this development is demographic change. The support provided by robotic assistants will relieve workers of many tasks requiring physical strength and endurance. But it must be ensured that the robots are sufficiently intelligent to prevent all risk of injury to their human colleagues. Fraunhofer is working on various fundamental research projects dedicated to this aim. The lead article in this magazine offers an overview of the solutions we are developing together with our industrial partners.

Yours sincerely,



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Thanks to new developments it will be possible to outsource data to external servers.



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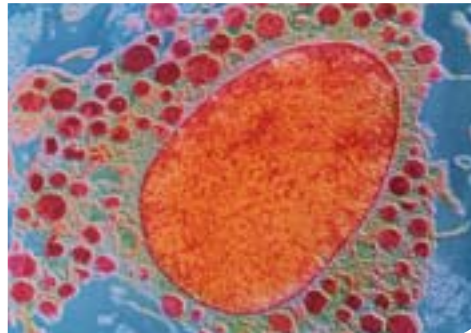
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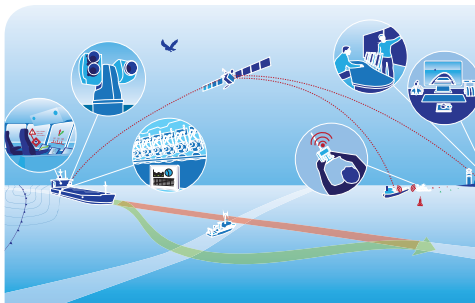
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Speaker of the future developed in an acoustically dead room.

## Special printer for 3D components

Thanks to a new printer head developed by researchers at the Fraunhofer Institute for Manufacturing Engineering and Automation IPA in Stuttgart, it is now possible to produce thermoplastics with an integrated continuous carbon fiber using additive manufacturing. Lightweight, high-quality components made using these materials are in high demand in the aerospace and automotive industries as well as in many other sectors. The IPA researchers have applied for a patent for their new printer head.

The nozzle for this printer, which was also additively produced at the IPA using selective laser melting (SLM), moves in three dimensions to build up a computer-generated workpiece. The carbon fiber is introduced into the plastic strand, which is then applied layer by layer to form the desired component in the process known as fused deposition modeling (FDM).

Production systems coordinate their work steps with each other and exchange information. © Fraunhofer IPA



## Generating less waste

Western industrialized countries throw away a lot of perfectly good food. This has been confirmed by a study conducted by researchers at the Fraunhofer project group Materials Recycling and Resource Strategies IWKS and the University of Giessen.

The experts investigated five tons of residual waste to determine its percentage of animal or plant matter. The focus of the study was on foodstuffs that were still edible at the time of disposal, which amounted to about half of the biogenic garbage. 28 percent of the weight was made up of tossed out fruits and vegetables, while baked goods made up another 20 percent. Meat and cold cuts accounted for 11 percent of the total weight; dairy products accounted for 10 percent. But how can we stop the flow of food directly into the garbage can? Researchers believe a good starting point is to improve consumer information about the proper way to store fresh products and the meaning of the sell-by date.

Manufacturers can also help by minimizing food waste. To help companies, the Fraunhofer researchers have developed the certification system called "s:lim – say: less is more." This system examines ways of optimizing manufacturing processes and material streams, identifies how manufacturers can cut environmentally damaging emissions or reduce energy and water usage, and singles out points in the current production process where unnecessary waste could be avoided.

Many packaged products end up in the garbage even though they are still edible. © Fraunhofer ISC



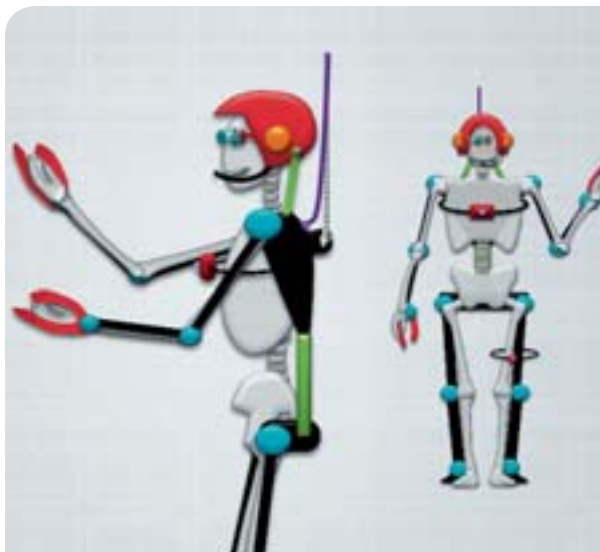
## Deft and robust

Many of the manual steps in industrial manufacturing processes are so complex that they are difficult to automate – for example the kind of assembly and disassembly work done by hand in the automotive and food processing industries. But the problem is that this sort of work carries with it a high risk of serious injury. According to the Work Foundation Alliance (Lancaster, UK), as many as 44 million workers in the European Union are currently affected by work-related musculoskeletal disorders (MSDs).

Twelve partners from seven European countries are working together on the Robo-Mate project to develop an intelligent, easy-to-manuever exoskeleton that can be worn while carrying out manual handling work. Wearing the external skeleton allows workers to combine their own manual dexterity with the technology's strength advantages. The project aims to improve working conditions in industrial environments, facilitate the lifting of heavy loads, reduce the incidence of work-related injury and disease, and increase productivity and product quality.

Scientists from the Fraunhofer Institute for Industrial Engineering IAO will begin by simulating how the exoskeleton works in a virtual factory environment. Project partners INDRA SAS (a French company in the vehicle recycling sector) and COMPA S. A. (a Romanian automotive components manufacturer) will then develop test scenarios for automotive assembly lines and carry out prototype demonstrations at their manufacturing facilities. The Centro Ricerche Fiat (CRF) – the Italian car manufacturer's research center – will carry out laboratory analyses and system evaluations of the exoskeleton. The project, which will run for three years, is funded to the tune of some 4.5 million euros by the EU's Seventh Framework Programme for Research and Technological Development (FP7).

An intelligent, portable exoskeleton will make work safer and more productive. © CRF (Centro Ricerche Fiat)



## Getting to series production more quickly

The auto industry is facing major challenges, with more and more models having to be launched in ever shorter timeframes. But before these new cars can start to roll off the line in large numbers, automakers have to test the manufacturing process by producing a pre-series.

In vehicle body manufacturing, it can currently take months to set things up for series production. To assemble each body element – a door, say, or a side panel – manufacturers have to mount its individual parts onto type-specific clamping fixtures so they can be welded together. It's essential to align the parts precisely for something like a door, because otherwise its measurements will not match up properly later.

Researchers at the Fraunhofer Institute for Machine Tools and Forming Technology IWU in Chemnitz have developed a clamping fixture that allows all the relevant parameters to be transferred directly to series production. This can greatly reduce the time it takes to set up production for new models. The method is called "try out" and is already used during forming in the press shop. The scientists have now adapted this system to work successfully in vehicle body manufacture.

New car models are initially produced in a pre-series. A new method makes it possible to transfer the parameters used there directly to series production. © dpa







Cloud computing offers the opportunity to make use of processing power, storage space or software over the internet as and when required, reducing IT costs in the process. In spite of these advantages, many companies remain skeptical about outsourcing their data to external servers. Their fear - heightened in the wake of the NSA scandal - is that unauthorized individuals could gain access to sensitive company information. Now Fraunhofer researchers are working on solutions that will make computing in the cloud a more secure affair.

Text: Bingit Niesing

Cloud computing is a practical concept that allows companies to rent storage space, processing power or software programs over the internet as part of a flexible service. This lets companies respond quickly to changes in customer requirements or developments in the marketplace. The information technology can be adapted simply and cheaply to meet their current need (see information box on p.11).

More and more companies are seeing the merits of this sort of system. According to the Cloud Monitor 2013 survey conducted by BITKOM and audit and consulting company KPMG, in 2012 37 percent of companies were making use of cloud computing in Germany alone. Among large companies (those with more than 2000 employees) this figure rose to 65 percent. Experts reckon that the cloud computing market will grow by 47 percent in 2013 to reach a value of 7.8 billion euros.

#### Data theft fears

Nevertheless, the study does clearly point to reservations about cloud computing. The majority of companies opt for in-house solutions (private cloud), simply because they want

to avoid storing important company data externally. Only around 10 percent of companies make use of the services of publicly available providers (public cloud). Reasons for not doing so include a fear of losing data and IT know-how, legal uncertainties (compliance) and the fact that integrating such solutions is difficult. Another study conducted by market research company IDC, "Cloud computing in Germany 2013," yielded similar results, with companies viewing security as the main challenge.

It's worth noting that these studies were carried out before the NSA PRISM scandal hit the news. Since then, companies have become even more skeptical - particularly concerning U.S. cloud computing services. The Information Technology & Innovation Foundation (ITIF) estimates that U.S. providers will lose as much as 35 billion dollars in turnover over the next three years. This opens up new opportunities to German and European service providers. Currently there is a particular demand for "made in Germany" cloud solutions, with German software manufacturer SAP one of the success stories. SAP provides companies with applications "on demand" and has attracted some 30 million customers to its SAP data cloud.

Germany's Federal Ministry for Economic Affairs and Energy (BMWi) was quick to appreciate how essential reliability, security, availability and data protection are to cloud computing and in 2010 launched the "Trusted Cloud" technology competition in an effort to develop and test secure solutions that meet legal requirements. From a total of 116 proposed projects, an independent expert jury selected the 14 most promising ones – among them numerous projects with Fraunhofer involvement. The total budget stands at some 100 million euros, of which 50 million is being provided by the ministry.

But how can storing data in public clouds be made secure? How do you prevent situations where the provider is given access to sensitive information? Researchers from the Fraunhofer Institute for Applied and Integrated Security AISEC have joined forces with their colleagues at Unicon GmbH and SecureNet GmbH to develop a particularly closed-off IT infrastructure, the Sealed Cloud. Here, a whole system of security precautions ensures that unauthorized individuals cannot gain access to data. "Not only are all the data encrypted, there are technical and electromechanical systems in place to protect access to the servers as well – and this is what sets it apart," explains Mario Hoffmann, who heads Service & Application Security at AISEC in Garching near Munich.

### "Sealing" servers

Up to now operators of cloud services and their employees have generally enjoyed unrestricted access to the technical infrastructure – and hence to all the information stored there. The Sealed Cloud changes all that by securing the server for each individual application from both a technical and organizational perspective. Each server is locked away in a rack. If the server requires maintenance, the system first transfers all information from the data and internal storage places to other secured computers. Only then is the administrator given an electronic token that allows him to open the rack. Once the repairs are complete, the rack is locked again and the system is started back up from a central point. An automatically triggered process verifies that all the data and programs recorded match up with the authorized, certified versions.

One important component is the "Secure Data Store" cloud service (SDS as a service). This offers a trustworthy way to administrate distributed process-relevant data. At the center of the SDS is a database that stores information as well as links to external sources. When authorized users want to access data, a personalized key is generated for them during log-in on the basis of log-in data such as username and password. Users can then use this key to locate, decrypt and process application data. After they have logged off, the data are re-encrypted and saved.

Each transfer of data from the user to the SDS is conducted over a secure channel and only once the data have been encrypted on the user's device. This prevents any unauthorized parties from gaining access to the information while data are being transferred. "The Sealed Cloud combines the economic advantages of a public cloud that you can use over the internet with the security of a sealed-off private cloud," says Hoffmann, pointing out the advantages of this solution.

### Trustworthy identification

Smartphones, tablet PCs and netbooks allow employees to access company data even when they're on the move. On the one hand, this makes work flexible and mobile. On the other, it gives unauthorized users the opportunity to steal employees' access data and to read sensitive data without permission. To prevent this from happening, what is required in the cloud are robust authentication mechanisms based on several elements. The SkiDentity project takes the kind of secure electronic identification (eID) found in the new German identity card, electronic health cards, bank cards or employee badges and applies it to cloud computing. The aim is to provide trustworthy identification and so better protect all manner of business processes for both users and companies. Researchers from the Fraunhofer Institutes for Industrial Engineering IAO in Stuttgart and for Computer Graphics Research IGD in Darmstadt are among those working on the project.

Yet mobile communication conceals still more risks. As attacks from hackers, data leaks and spying attacks show, it is especially when data are being sent between workstations and the cloud, between company servers and tablets or from smartphone to smartphone that data protection often proves to be at its least reliable. Experts in secure communication architectures from the Fraunhofer Institute of Optronics, System Technologies and Image Exploitation IOSB in Karlsruhe are now working on an extremely secure communications solution, a small additional device called "CyphWay" that provides a secured highway for data. The system is modular in construction; one module encrypts and decrypts data while a further module ensures a secure connection between the extra device and the communication hardware employed.

Researchers at the Fraunhofer Institute for Experimental Software Engineering IESE are developing data monitoring software that will keep a permanent eye on how sensitive data are used. This will allow users to remain in control of their data even once the data are "out of their hands." IND<sup>2</sup>UCE (Integrated Distributed Data Usage Control Enforcement) makes it possible to define user rights and restrictions for passing on and using data. These guidelines determine who is permitted to receive a given document, what kind of editing is possible, how often a document can be opened, or when it gets automatically deleted from the recipient's system.



## Cloud computing

In cloud computing, IT services are outsourced to an external provider. You simply rent processing power, data storage, network capacity (infrastructure-as-a-service), platforms with value-added services such as security solutions and billing services (platform-as-a-service) or programs (software-as-a-service) as required. There are various types of cloud. One particularly popular type is the private cloud, in which companies' own data centers operate cloud-style computing concepts and technologies as part of their in-house IT infrastructure. This has the advantage of keeping data within the company.



A public cloud is operated by a publicly available provider that makes its services available to any party over the internet. Customers can rent IT infrastructure and software according to their requirements. This saves money but does mean that data are stored externally.



© istockphoto

### Fraunhofer Cloud Computing Alliance

Cloud computing and virtualization count among the most important trends in IT. However, these technologies remain at a very early stage of their development and there is a considerable need for advice and development work – particularly in the areas of security, compliance, availability and data protection. In the Fraunhofer Cloud Computing Alliance, eight institutes have teamed up to promote the efficient use of cloud services in commercial applications.

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

However, cloud computing isn't just about hidden dangers. It can also help companies to secure their data in a highly reliable way. The cloud gives companies a professional back-up of their data. Data are stored on the provider's servers, and the provider takes responsibility for guaranteeing the necessary redundancy, physical security, qualified personnel and high level of availability.

#### File server with a connection to the cloud

Despite these benefits, only a few companies have begun to make use of this service. One reason for the hesitation is that companies don't want to be tied in to one cloud service provider in what is known as provider lock-in. At the moment, transferring data stored in the cloud is a very arduous process, since each service provider generally has its own interfaces. This is the issue that researchers from the Fraunhofer Institute for Secure Information Technology SIT in Darmstadt are focusing on. They have developed OmniCloud, a sort of file server that facilitates seamless access to any cloud service provider. In 2012, the system was awarded first place by the Horst Görtz Stiftung in its renowned German IT security prize. The system recognizes service providers'

various programming interfaces and offers a "migration service." This means that data can be quickly and easily transferred over to a new storage provider as and when required. The system is capable of connecting any application and back-up software with any provider.

Another advantage of OmniCloud is that it encrypts all data locally before they leave the company's network to be stored in the cloud. "This guarantees that company data remain confidential, whatever the security measures the company's storage provider might have in place," stresses Michael Herfert, who heads Cloud, Identity and Privacy at the SIT. With OmniCloud, each file is encrypted using a separate key, protecting not only the actual content of the files but the file names and directory structure as well. There is also an access control system for specifying exactly which users can access which files.

Cloud computing opens up new opportunities for government agencies. To take one example, in future you might notify the authorities of a change in address via your computer simply by using the new German identity card's eID feature. In the goBerlin project, researchers from the



Fraunhofer Institute for Open Communications Systems FOKUS in Berlin are now working to develop a secure and trustworthy services marketplace for citizens, business, and administrative bodies based on cloud technology. FOKUS is also coordinating the EU-sponsored CloudForEurope project, which aims to build up trust in European cloud computing and to create a single European market. The EU has set aside ten million euros for pre-commercial tenders to allow the demands of the public sector to be clearly defined and above all to help out small and medium-sized cloud service providers in Europe.

There are also many ways in which public authorities, schools and technical colleges can benefit from cloud services. For one thing, these services facilitate networked and flexible working even when colleagues are scattered across several different locations. Keeping data in the cloud also means that central programs can be shared and used as software-as-a-service. Yet many public agencies and medium-sized businesses still hesitate to take the step into the cloud. They are worried about getting locked in to a certain provider and concerned about the security of their data. What's more, they can't be sure that laws, guidelines and data protection regulations are being respected. The CloudCycle project wants to lay these concerns to rest and make sure government agencies and medium-sized companies have access to secure and reasonably priced cloud services. It brings together experts from Fraunhofer SIT, IBM Deutschland Research and Development, Kommunale Informationsverarbeitung Baden-Franken and the University of Stuttgart. The idea is that the system will support cloud services over their entire lifecycle: from designing a service and running it on a cloud platform to potentially migrating it to another platform and finally phasing it out.

But if companies and authorities are to be able to access cloud services and data at all, we will need secure networks with a high level of availability. This access can be impeded by technical problems or targeted attacks. At the moment there are almost weekly reports of network threats – from denial-of-service attacks to spyware and computers hijacked to form botnets. What happened in Estonia in 2007 is a reminder of how vulnerable modern societies and the economy have become now that they are all tied in to the internet. In the case of Estonia, cyber attacks forced a country-wide internet shutdown and large parts of the public apparatus were rendered helpless. What is needed are new concepts that allow for emergency operation and mean that users can continue to work even when availability is restricted.

“Cyberspace calls for its own defense strategies,” stresses Dr. Jens Tölle from the Fraunhofer Institute for Communication, Information Processing and Ergonomics FKIE in Wachtberg near Bonn. Researchers from the FKIE are working on these strategies in the “Cyber Defense Lab.” “It's a case of keeping up with the pace of advances in network infrastructure technology and the accompanying diversification of potential threats. Denial-of-service attacks, deliberate siphoning of information, manipulation of industrial control systems and targeted spying on users are all risks against which one has to take appropriate precautions,” says Tölle.

So that users don't have to rely solely on their provider's security measures when working in the cloud, researchers from the FKIE's Usable Cyber Security group are working on new techniques to store data securely in the data cloud. Existing data encryption methods such as Boxcryptor or Wuala don't offer the process integration companies need. What's more, the products can be used only in certain instances and have limited functions. The same applies to the security offered by the big, often U.S.-based cloud service providers such as Amazon. “Until now, customers have been obliged to take security measures as they come or to add encryption mechanisms of their own – assuming that they have the necessary expertise,” says Dr. Matthew Smith, the new Professor for Usable Security and Privacy at the University of Bonn. To help, researchers from the FKIE have come up with an innovative way to keep security providers and resource providers separate by combining techniques from IT security and the security-as-a-service (SecaaS) concept. This means that companies can collaborate on data storage.

### Find success in the cloud

Cloud computing really does pay off: a 2013 comparative study conducted by the IBM Center for Applied Insights shows that companies making systematic use of cloud computing grow around twice as fast and generate almost 2.5 times the gross profit of their cloud-less competitors. If we want more companies, authorities and public agencies to make use of cloud computing in the future, we need to ensure that it is reliable, secure and readily available while offering the best data protection. ■



[www.fraunhofer.de/en/press/audio.html](http://www.fraunhofer.de/en/press/audio.html)

# The car that looks round corners

Every driver dreams of being able to identify a hazardous situation ahead of time, or having the power to circumvent traffic jams and unnecessary diversions. Now modern IT and wireless technologies have brought us to the point where such a scenario no longer seems all that far-fetched - as a field test demonstrating the usefulness of car-to-x communication has just demonstrated.

Text: Tobias Steinhäuber

Out blares the familiar jingle of the traffic news: dada-dada-dadaaa-daaa! "Ten-kilometer tailback on the A8 from Munich heading toward Salzburg following an accident at the Frasdorf junction. Left lane closed - please steer clear of the accident site!" A warning that comes too late as traffic begins to back up around the next bend.

It's an experience familiar to thousands of German commuters, who get their traffic information from the radio, from in-built traffic information systems or via their GPS. The problem with these channels is that it can take some time for the relevant data to filter through from traffic information headquarters and be passed on to the drivers. This means it is often too late for them to react, and they are left to rely on their

driving skills and personal experience to identify dangerous situations in good time and bypass congestion. Traffic jams alone cost the German economy more than 17 billion euros a year - not to mention the countless liters of fuel that could be saved and the emissions that could be avoided.

## A world free of accidents and congestion

In Michael Eisenbarth's world, accidents and traffic jams are an alien concept. "In a few years' time," predicts the researcher from the Fraunhofer Institute for Experimental Software Engineering IESE in Kaiserslautern, "vehicles will be able to communicate directly with other cars and elements of the traffic infrastructure such as traffic lights, crash barriers and road signs, allowing them to warn us of danger well in advance." Having teamed up with automotive manufacturers and suppliers, communications

companies, other research institutes and public organizations, in 2013 the IESE participated in the sim<sup>TD</sup> project, which demonstrated that car-to-x communication works and is ready for everyday application. Not only that, but modern IT and wireless technologies could make using the roads safer, more comfortable and more efficient. In the initial phase of the project, Eisenbarth and his team were responsible for finding a common standard for the various solutions and approaches brought by the participating partners.

A change in scene and we are sitting admiring one of the test vehicles. In fact, there's nothing here that points to car-to-x communication. At first glance, the car looks entirely ordinary. All the technology is on the inside, tucked away inside the on-board units - computers, hard drives, WLAN and mobile communications antennas built into the cars. Then all of a sudden there is a beep and the on-board computer's display shows a brake warning - even though we appear to be a safe distance from the car in front. "That signal is to warn us that several cars nearby have braked violently. All the vehicles communicate with each other via WLAN - to a range of a couple of hundred meters. This lets us 'see' brake lights we can't actually see," explains Ilya Radosch from the Fraunhofer Institute for Open Communication Systems FOKUS in Berlin. Now the vehicle in front violently applies the brakes - but it's ok, our foot is already hovering over the brake pedal and we come to a stop at a safe distance.

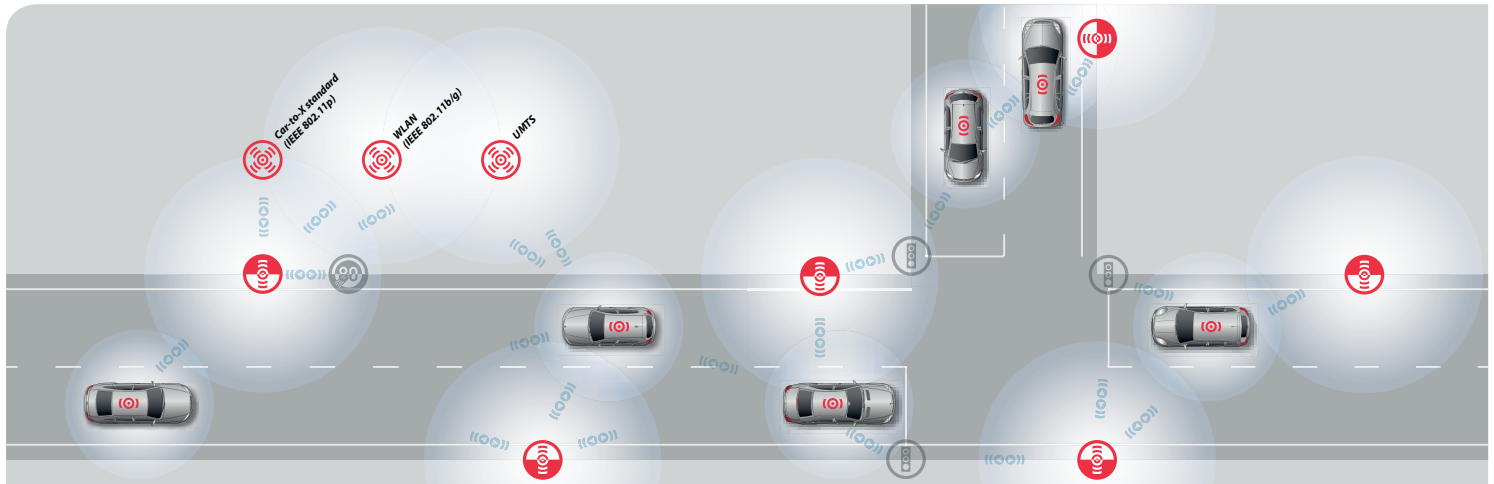
This "electronic brake light" function has won over test drivers, too, and was voted their favorite feature at the end of the project. Next came the "crossroad and traffic crossing assistant," which warns the driver of potential collisions at crossroads and junctions. Third place went to the "road sign assistant", a car-to-x function that flags up any relevant road signs even when they are hidden from view.

In all, the consortium tested 21 different driver assistance functions over a period of six months, an operation that called for 120 vehicles and over 100 roadside stations - sensors installed at the edge of the road. Testing took place on roads around Frankfurt. The job of the FOKUS

Emergency braking. © Deutsche Telekom/T-Systems



Car-to-x communication between vehicles or between a car and an ITS roadside station relies on ad hoc communication. This is based on the European standard for car-to-x communication now to be developed as well as the established WLAN. UMTS is also used. © sim<sup>TD</sup>



scientists was to ensure that all the systems were collecting the data correctly and processing it properly. "We developed the tools for taking benchmarks and recording variables, we set up the entire fail-safe cloud infrastructure featuring a capacity of more than 120 terabytes, and we supported the actual road testing with computerized tests and simulations," says Radusch, describing FOKUS's involvement. These tools will now be used in further European road testing.

When cars engage in car-to-x communication with one another, the air is often fairly thick "not because of the exhaust fumes but because of all the data being transferred via WLAN," says security expert Norbert Bißmeyer. In collaboration with Fraunhofer FOKUS, he and his colleagues from the Fraunhofer Institute for Secure Information Technology SIT in Darmstadt developed the IT security architecture for sim<sup>TD</sup>. "Unlike your laptop at home, which registers with a central router, WLAN communication between vehicles is decentralized and conducted on equal terms. That makes it more difficult to make the transfer of data secure and to protect participants' privacy," Bißmeyer says of the challenge. To ensure security, the researchers programmed a sophisticated security architecture featuring special software certificates and several cryptographic keys for each vehicle.

### Manufacturers send out a clear signal

It is no secret that current vehicles already bristle with modern information technology, but the additional services they currently offer are still mostly restricted to functions such as

### sim<sup>TD</sup> - Safe and Intelligent Mobility - Test Field Germany

**Partners:** Audi, BMW, Daimler, Ford, Opel, Volkswagen, Bosch, Continental, Deutsche Telekom, Fraunhofer FOKUS, IESE and SIT, German Research Center for Artificial Intelligence DFKI GmbH, Technische Universität Berlin, Technische Universität München, Saarland University of Applied Sciences, Julius Maximilian University of Würzburg, Hessen State Office for Roads and Transportation, City of Frankfurt am Main

**Sponsors:** Federal Ministry of Education and Research, Federal Ministry of Economics and Energy, Federal Ministry for Transport and Digital Infrastructure, State of Hessen, VDA – German Association of the Automotive Industry

**Distance covered:** 1 650 000 km, 41 000 hours

**Main outcome:** sim<sup>TD</sup> functions can help prevent accidents. If all vehicles were to be equipped in this way, it would be possible to save up to 6.5 billion euros. A reduction in the impact on the climate also means a further saving of 4.9 billion euros.

seat adjustment via smartphone or lowering the suspension using an app. Still, manufacturers are sending out a clear signal that they would like to introduce car-to-x communication at some point soon. "For instance, at the sim<sup>TD</sup> closing event in June 2013, Daimler announced it would be implementing the first tested driver assistance functions in its series-production vehicles before the end of 2013," says FOKUS researcher Radusch. Taking center stage is communication between vehicles and traffic infrastructure using the 4G/LTE mobile communications standard. Prior to this, European car manufacturers had already signed a memorandum in which they state their intention of bringing the first series-production cars to feature the WLAN ITS-G5 standard in the 5.9 GHz band to market from 2015 onwards.

Fraunhofer researchers are also working on the topic outside of the sim<sup>TD</sup> project – and Josef Jiru from the Fraunhofer Institute for Embedded Systems and Communication Technologies ESK

in Munich is one of them. "In the 'Automotive Connectivity' working group, we're working on software platforms that enable driver assistance functions for car-to-x communication to be developed and tested quickly and flexibly." Meanwhile Alexander Kiening and his colleagues at the Fraunhofer Institute for Applied and Integrated Security AISEC are working on improving standardization. Based in Garching near Munich, the scientists were involved in work on the security standard for WLAN-based car-to-x communication. They are also using the findings from sim<sup>TD</sup> on WLAN security to improve data protection when cars are communicating with traffic infrastructure. "In this instance, mobile wireless communication is better than WLAN since it has better coverage," explains Kiening. So while we may for now still have to listen in to the distinctive "dada-dada-dadadaa-daaa!" of the traffic news and rely on our driving skills to get us quickly and safely through the traffic, thanks to car-to-x communication that's sure to change soon. ■

# Surround sound from a smartphone

If you want to experience surround sound, you generally have to place a number of loudspeakers all around the room. With Cingo software, even mobile devices can wrap you in a blanket of surround sound - using nothing more than normal headphones or the device's own loudspeakers.

Text: Janine van Ackeren



Surround sound has long been a feature in movie theaters and living rooms. Now mobile devices such as smartphones and tablet PCs will be able to offer the surround sound experience, through either built-in stereo loudspeakers or normal headphones – all thanks to technology developed at the Fraunhofer Institute for Integrated Circuits IIS in Erlangen. Cingo is software that processes movie soundtracks and music to give users the impression that they are surrounded by loudspeakers – even though these are in actual fact built into the mobile device itself.

But how do the scientists achieve this effect? “As sound travels from a loudspeaker to our ears, it gets altered in many ways, for instance when sound waves reflect off walls,” explains Jan Plogsties, who heads the Semantic Audio Rendering group at the IIS. “As a result, the audio signal that reaches our ears not only carries music or speech, it also contains information about our surroundings. What’s more, differ-

ent sound waves are affected differently by the head and outer ear depending on what direction each wave is coming from. It’s these changes to sound waves that we’ve now managed to recreate using digital filters. If we apply these filters to an audio signal that is played back through a small device or headphones, the sound is altered to make it similar to what we would expect to hear from a home cinema system.”

## Good volume – even in noisy environments

Having surround sound on a tablet makes sense only if it’s loud enough to hear. But this is precisely where tablet PCs and smartphones can disappoint, since their integrated loudspeakers are small and not especially powerful. That means the sound is often too quiet, especially if there is lots of background noise. “Film soundtracks have a wide dynamic range, which means some parts are very quiet while others are really loud,” says Plogsties. But a soundtrack that

sounds great in a cinema can cause problems on a tablet PC. “What our software does is process this dynamic range to improve the volume control,” explains Plogsties. To begin with, Cingo analyzes which parts of a soundtrack are particularly quiet – and amplifies them. But it leaves louder parts essentially untouched, because otherwise they would sound distorted. This automatic volume control is good news for fans of music, too, even if the improvement in sound quality for rock and pop isn’t quite as impressive as it is for films.

One other advantage this software has is that it optimizes the sound quality achieved by integrated loudspeakers. At certain frequencies, standard speakers in smartphones or tablets start to rattle or squeak. And smaller loudspeakers have particular trouble reproducing low-frequency sounds. By avoiding all this rattling, squeaking and roaring, Cingo makes the playback sound more natural. What the researchers did was examine all the varieties of loudspeakers





Any time, any place:  
cinema-quality sound  
makes for an impressive  
listening experience.  
© Fraunhofer IIS

that are integrated into tablets and smartphones and then tailor the software exactly to them. If manufacturers wish to pre-install Cingo on their devices, the scientists can provide them with an ideally suited version of the software.

The researchers have also managed to optimize the sound quality of headphones. Plogsties describes their approach: "We took a whole range of different sets of headphones and examined them all to determine a median value. Then we fine-tuned Cingo to this value, with the result that it improves sound quality for all of the headphones we studied." In the case of headphones that are supplied with a particular device, the sound quality can be exactly tailored just as it can be for the loudspeakers.

#### Nexus 7 and Nexus 10 – surround sound included

The first devices to feature surround sound recently came to market: Cingo is pre-installed

on Google's Nexus 7 and Nexus 10 tablets – and a number of other manufacturers' smartphones and tablet PCs are set to follow soon. Since manufacturers don't have to change the hardware in any way for the software to do its job, they can continue to use their standard loudspeakers and headphones.

Cingo is also an attractive proposition for app providers. If they integrate the software into their applications – say an app for downloading and watching films – then users will be able to enjoy videos on their mobile devices in surround sound. This works even if Cingo isn't pre-installed on their smartphone or tablet PC, because the audio software works as part of the app. South Korea's leading IPTV provider, SK Broadband, has already integrated this technology into its Btv mobile app, which gives subscribers access to the provider's entire range of content – from TV to movies – while they are on the move. "Our customers have come to expect the highest quality wherever they are.

We're certain that the intriguing sense of realism created will greatly increase customer satisfaction," says Han-Su Kim, Head of Media Business Group at SK Broadband.

#### Fast downloads with HE-AAC

Cingo makes it possible to enjoy perfect surround sound on mobile devices. But what is the best way to download the huge amount of data needed to tablets and smartphones? The answer is by using the High Efficiency AAC (HE-AAC) multi-channel audio codec. Co-developed by the IIS in the Moving Picture Experts Group (MPEG), this codec is already found in over six billion devices and supported by major operating systems such as Android, iOS and Windows. To complement its Nexus 7 and Nexus 10 devices, Google now offers films with the HE-AAC standard and with surround sound. "That's a perfect combination," says Plogsties, "as most users will choose to watch films with surround sound on their tablet or smartphone." ■

# More fun in the museum

At the Perot Museum of Nature and Science in Dallas, little folk and big folk are right in the middle of it all, not just spectators. They can feed dinosaurs, trigger an earthquake and participate in a trip through their very own bodies. A multimedia project makes all this possible. Brought to them in part by Fraunhofer.

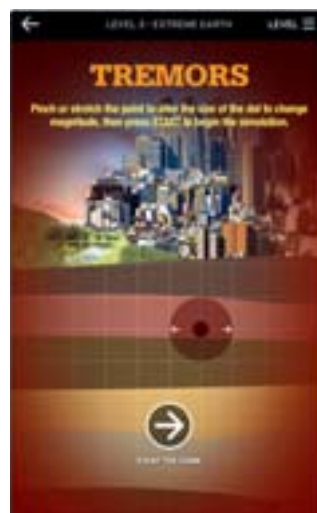
Text: Mandy Kühn

The touch of a finger is all it takes - and a storm is loosed. In the "Extreme Earth" exhibit at the Museum in Dallas, visitors can interactively provoke their own hurricane or make the earth shake – all done on a tablet computer screen. Childhood dreams come true in the Dino Department next door: a digital dinosaur comes to life with the click of a button and can even be fed virtual prey. Or you can take a trip in 3D through your own head and body. The Perot Museum hopes to awaken interest in the sciences among children and young people with a unique multimedia project. Visitors will get playful access to the world of the natural sciences through interaction and multimedia information.

In addition to Fraunhofer, the other participants in the project include Samsung and the Austrian knowledge management company NOUS. At the start of the museum tour, visitors receive a tablet PC. This enables them to learn right away about the museum and its extraordinary architecture. Their exact location is displayed on a three-dimensional floorplan to enable them to orient themselves within the extensive Museum. This is made possible through the 3D positioning technology called awiloc® from the Fraunhofer Institute for Integrated Circuits IIS in Erlangen. The software determines where the visitor is currently located in the museum within



The new multimedia guide opens playful access to the world of the natural sciences. © NOUS Wissensmanagement GmbH





a few meters' accuracy. The tablet delivers the corresponding knowledge to them using images, sound, and text, right at the exhibit. Visitors at the Perot Museum don't need to search for annoying exhibit numbers or fumble with buttons like with conventional electronic museum guides.

Karin Loidl from Fraunhofer IIS explains why the staff leading the project from the knowledge management company NOUS Wissensmanagement GmbH had decided in favor of the IIS solution: "Conventional positioning systems like GPS literally hit a brick wall in interior spaces. awiloc® works independently and is low-maintenance, thus highly suited to mobile museum guide systems. It requires neither a data communications channel nor a central server or networked WLAN system. It is sufficient to simply plug WLAN transmitters into the electrical wall outlets around in the building. The mobile end user devices measure the signal strengths of these transmitters to determine their own position." An additional advantage of the system: it conforms to data protection laws.

The tablet as museum guide

The 500 new-generation tablet PCs used by the Perot Museum come from Samsung. The Austrian company NOUS GmbH developed the

idea of the multilayer "In-House Guide" as well as an app that explains the current special exhibits of the Museum and makes available a complete floor plan of the building in 3D.

"The project is highly complex technologically," emphasizes Alexander Stickelberger, the founder of NOUS. "To keep the effort of the museum staff to a minimum, the guides contain a content management system that is user friendly and enables staff to update the contents easily. There is a security system integrated into the valuable tablets in addition to the awiloc® localization technology.

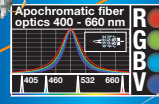
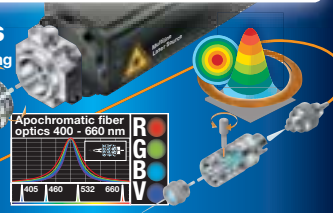
With the help of augmented reality functions on the mobile devices, visitors can undertake a special expedition through their own body. Or they can photograph their head – and their skull appears on the screen. The multimedia guide offers still other features, however. Visitors can select the correct fodder for the dinosaur from a menu and feed it, or trigger a virtual earthquake in the middle of New York City.

The museum's little visitors are especially enthusiastic about the multimedia guide. The science themes, founded in fact, graphic, and very entertaining, help make science an adventure and encourage repeat visits to the museum. ■

Fiber Optics, Components and Tools for Fundamental Research

Fiber Optics

polarization-maintaining for wavelengths 370 – 1700 nm

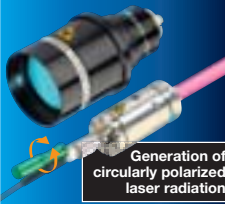


Fiber Port Clusters for Magneto-optical tags



- In global use:
- Austria
  - France
  - Spain
  - Germany
  - Russia
  - Italy
  - UK
  - USA
  - Switzerland
  - PR China
  - India
  - Japan
  - Republic of Korea

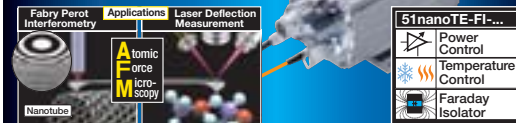
Fiber Collimator 60FC-Q-... with integrated Quarterwave Plate



Generation of circularly polarized laser radiation

Fiber-Coupled Laser Sources

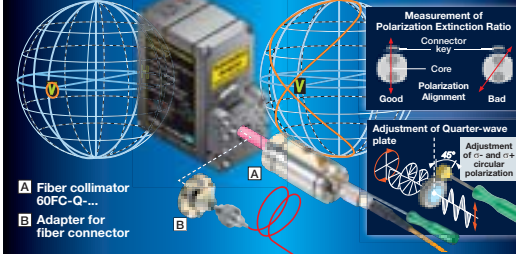
51nanoFI-... / 51nanoFCM-... with singlemode and polarization-maintaining fiber cables



- Applications:
- Fabry Perot Interferometry
  - Atomic Force Microscopy
  - Laser Deflection Measurement

- 51nanoTE-FI-... features:
- Power Control
  - Temperature Control
  - Faraday Isolator

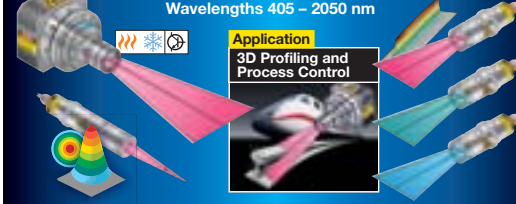
Polarization Analyzer Series SK010PA-... Interface: USB 2.0 • Multiple Wavelength Ranges 350 – 1600 nm



- Measurement System:
- Measurement of Polarization Extinction Ratio
  - Core Polarization Alignment
  - Adjustment of Quarter-wave plate
  - Adjustment of  $\sigma$ - and  $\pi$ -circular polarization

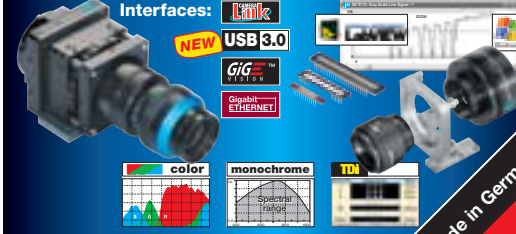
Lasers and Line Scan Cameras for Research and Machine Vision

Laser Line, Micro Focus and Laser Pattern Generators



- Wavelengths 405 – 2050 nm
- Application: 3D Profiling and Process Control

Line Scan Cameras



- Color, monochrome or TDI sensors from 512 to 12000 pixels
- Interfaces: CAN, NEW USB 3.0, GIG-E, Standard ETHERNET
- color, monochrome, TDI

Made in Germany



# The city of tomorrow

The world's metropolitan areas are growing, as are their problems. Researchers are investigating how cities can develop sustainably. Clever use of information and communications technology can help.

Text: Klaus Jacob

Today, already more than half of all people live in cities, with more every day. The proportion in Germany is already at 74 percent. Megacities like Tokyo and Mexico City have long since surpassed the 10-million mark. So any serious effort to build sustainable economies has to begin in the cities. There are certainly many approaches for this, but what is missing is a strategy connecting all of these individual efforts into an overall design. A zero-energy house here or a green recycling bin there won't be enough by themselves. Innovative solutions must be merged with new business models into an organic whole. Twelve Fraunhofer Institutes, selected leading-edge cities, and many well-known industrial firms, from Siemens to Volkswagen, intend to provide support for this approach through the project "Morgenstadt", City of Tomorrow. Lead institute is the Fraunhofer Institute for Industrial Engineering IAO in Stuttgart.

## Sustainable cities as examples

As a first step, scientists have selected six model metropolises from among around 300 cities world wide. These six are already some ways

ahead in practicing sustainability. Others can and should learn from their example. Copenhagen, for example, had already begun constructing a district-wide heating network decades ago. Since that time, 98 percent of all the buildings there are being heated with environmentally friendly energy. The city-state of Singapore purifies large quantities of waste water to solve its drinking water problem. Megapolis Tokyo is embroidered with a specialized logistics system. Trucks there do not head for every individual shop, but instead hand off their cargo to small logistics centers. This reduces traffic. And New York City is a good example of preparing for monster storms and the rising sea level. It therefore got off lightly when Hurricane Sandy swept over it in October 2012. Resilience is also increasingly important for cities in preparing for the future.

Two German cities have been selected for the project as well: Berlin and Freiburg. Freiburg, in southern Germany, has committed itself to renewable energy as its primary energy source. Berlin is known as a globally-oriented, multi-cultural city. With its energetic start-up scene and





ambitious politics, it has organized numerous exemplary innovation projects. As the capital of Germany, it is one of the pioneers in electromobility and car-sharing. Many government buildings also set a well-regarded example for private industry through their economical energy consumption. And through the “Efficiency House Plus” that was completed with the help of two Fraunhofer Institutes at the close of 2011: On top of providing energy for the occupants’ own use, it provides so much extra power that you can drive an electric vehicle about 60,000 kilometers (about 36,000 miles) with it.

### Berlin – a “smart” city

Berlin leads in IT and communications technology. The online platform “infrest” (infrastructure eStreet) went live on the Internet a year ago. Every company can now easily check where conduits for water, sewer, power, and telephone lines run in the city and where sections of streets are supposed to be excavated for repair work. The advantages are obvious: previously, it could happen that construction workers would dig a hole where their colleagues had just filled one

in. The unnecessary lack of coordination consumes resources and costs money. IAO expert Steffen Braun, who is responsible for the “Morgenstadt” project, provides a vivid example: “Fiber optic cable to be laid in Germany during the coming years will probably cost about 180 billion EUR. The cable itself costs only 20 billion EUR, while the largest portion of the funds will be eaten up by the construction costs – a case for infrest, the conduit information portal.”

 [www.ict-smart-cities-center.com](http://www.ict-smart-cities-center.com)

An additional IT and communications technology highlight of Germany’s capital city is called the “Open Data Platform”, which developed from an initiative of the Fraunhofer Institute for Open Communication Systems FOKUS in Berlin. Since Sept 2011, every resident of the city has been able to search for information that previously was only available to the city’s administration: from water quality in the city’s swimming lakes to Senate documents. In addition, local power company Vattenfall’s subsidiary “Stromnetz Berlin” is contributing data on independent

providers feeding power into the high-voltage transmission lines. The number of data records has jumped from initially 17 to 250 in June 2013 – and is continuing to grow. The transparency thereby achieved should assist in developing new business models and services.

There are also new ideas about how Berlin intends to use Tegel Airport once it is closed. The Urban Tech Republic TXL, an innovation park for urban technologies, is supposed to rise up on the airport site. This prototype part of town where people will be living in a few years is serving as a testbed for various renewable strategies. IAO has prepared feasibility studies for this. They involve new forms of energy production, energy conservation, mobility, waste water purification, recycling, and many others. Everything that you can hardly otherwise test under realistic conditions (for a multitude of reasons) is meant to be given a chance here. Few other cities have had access to comparable living laboratories up to now, though one example is Barcelona.

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

Researchers would like to jointly implement the insights worked out during the first part of the “Morgenstadt” project with additional cities and companies during the next phase in 2014-2015. This will involve not only developing new technologies, but also bringing larger-scale systemic innovations to market, explains Braun. This is the goal of the Fraunhofer initiative “Morgenstadt”, which involves a dozen of the 67 total Fraunhofer Institutes. “Because what good does the best energy design do if the market is not suited to it?” offers Braun. “Cities are both the cultural and technological substrates of our society. This means that we need to understand how the city as a whole system evolves toward sustainability, and what strategies and solutions are necessary for this evolution.” Cities such as Norderstedt, Düsseldorf, Ingolstadt, and Lörrach are already working successfully with Fraunhofer on strategies to develop this potential.

All of the stakeholders have to pull their weight for a city to be prepared for the future. “New alliances between city administrations, companies, researchers, and citizens are needed to effectively deal with the upcoming challenges,” says Braun. Living labs, open-access data and resident-oriented business models – project coordinators are convinced these are the right way for the future. ■

Berlin, capital of Germany, is making increasing use of information and communications technology for sustainable solutions.  
© plainpicture/  
Image Source



Renewable energy won't just be used to generate power. It will also power electric vehicles and heat buildings. © mauritius images/Tetra Images



# Protecting the climate pays off

Using a computer simulation, researchers have calculated how to achieve the German government's climate protection guidelines by 2050. They conclude that the plan not only benefits the environment but also saves money in the long run.

Text: Brigitte Röthlein

The German federal government has set itself the ambitious goal of reducing the country's greenhouse gas emissions by at least 80 percent compared with 1990 levels by the year 2050. But how can this task be achieved at reasonable cost? Which measures are necessary, and where will our energy supply come from in 2050? These are the questions that researchers at the Fraunhofer Institute for Solar Energy Systems ISE in Freiburg are asking. Since 2012, Professor Hans-Martin Henning, the institute's deputy director and head of the Thermal Systems and Energy Efficient Buildings business unit, together with his colleague Andreas Palzer, have been developing a computer simulation that depicts the German energy system, hour by hour.

Initially, they investigated what impact a supply of 100 percent renewable energy for electricity and heat would have in Germany. Now they have broadened the model to additionally include transportation and industry. "Our

simulation is uniquely comprehensive," Hans-Martin Henning says. "This in-house-funded research project tries to bring disparate worlds together. So far, there have been few initiatives to improve communication between the various actors in the energy sector, encompassing heat and power providers, building restoration and natural gas and fuel suppliers. But the issues affecting them are becoming increasingly interlocked."

In 1990, nearly 993 billion metric tons of carbon dioxide were emitted into the atmosphere as a result of human activities, the largest proportion of which came from generating electricity and heat. These 1990 figures represent the baseline for the 2050 targets, according to which CO<sub>2</sub> emissions are set to be reduced to a maximum of 198 million metric tons. It will only be possible to achieve this target by combining energy-saving measures with the more extensive use of renewable energy sources, which

according to the authors of the study means attributing a more central role to fluctuating energy sources such as sun and wind power. In a cost-optimized energy system that meets these climate goals for 2050, around 78 percent of electricity will be generated from these sources, 16 percent from combined heat and power plants, and the rest from fossil fuel plants. The resulting "green" energy will not only be used to operate low-power electrical appliances such as TVs and other equipment but also increasingly to recharge electric vehicles and for space heating by means of heat pumps. "Given that we're expecting a huge overproduction of renewably generated electricity in the future, we're assuming there will also be new opportunities to tap among all categories of consumers," stresses Andreas Palzer.

### Large-scale thermal storage

Researchers expect moderate expansion in heat distribution grids in combination with large-scale thermal storage and the implementation of predominantly electric combined heat and power plants for heating buildings in densely populated areas. By 2050, the largest market deliverer for the provision of heat will be heat pumps, at around 40 percent; solar thermal systems will deliver about 20 percent. Cogeneration plants and domestic boilers will each account for less than 17 percent.

The ambitious climate protection goal can only be reached whenever buildings require less energy for heating, which in turn depends on the availability of low-cost strategies for renovating buildings to make them more energy-efficient. "Possible solutions include making more extensive use of prefabricated building components, which will enable significant cost savings to be achieved in renovation projects, and also the use of novel inexpensive materials," explains Professor Henning.

Another point revealed by the simulation is that as soon as the amount of available fossil fuels falls into short supply, the need for synthetic fuels will grow. Hydrogen and methane are two such fuels, and both can be produced using electricity generated from renewable sources. The dividing point that tips the balance is determined on the one hand by the extent to which consumption levels can be reduced within the individual sectors, and on the other hand by the

success of efforts to persuade drivers to switch to electric vehicles or hydrogen fuel cell cars.

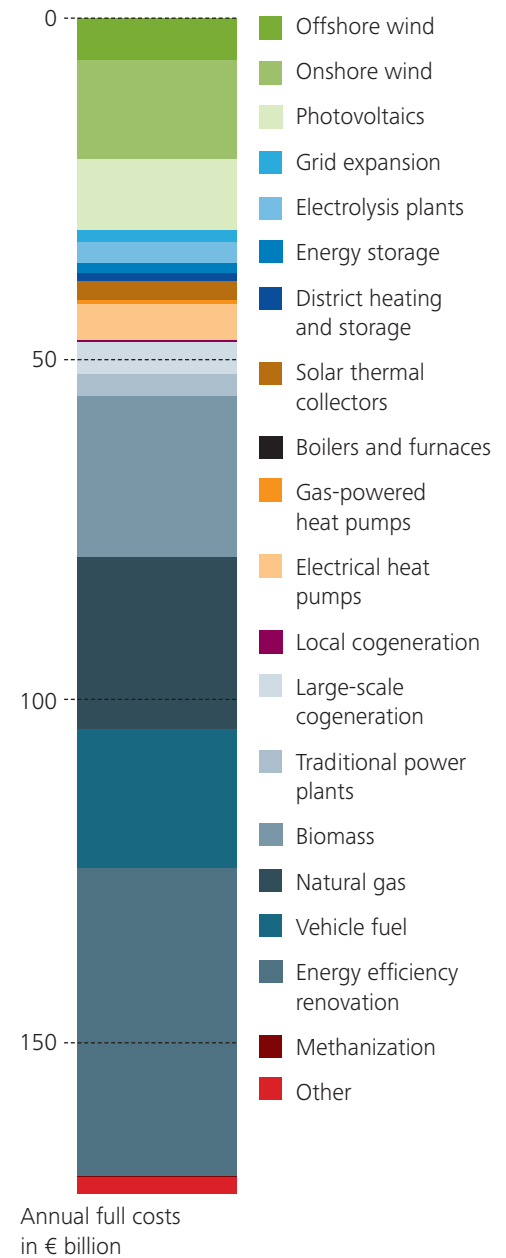
But what will it cost to reduce greenhouse gas emission levels? "Of course it will cost more in the beginning, but we'll reap the rewards later," says Hans-Martin Henning. "Once the transition has been accomplished in the electricity supply sector, the yearly total costs for the national economy will be comparable to what they are today. But if the power supply in 2050 continues in the same pattern as what we have today, expenditure will be noticeably higher, because global energy prices in the medium and long-term will continue to climb."

Not that forecasting future prices is an easy task. "In terms of technology, our evidence is pretty solidly substantiated," says Professor Henning. "But with costs, it's much more difficult to see into the future. For fuels, we're assuming a two percent per year increase in costs. How different technologies develop is more complicated; we just can't know what will happen with battery technology, for instance, or if the production of synthetic methane will continue to develop." This is why researchers have run various models to account for different amounts of fossil fuels, for varying distributions of photovoltaics and wind energy or deviations in the expected development of the mobility sector.

### Interest in the results

The simulation results have garnered a lot of attention in professional circles. "Companies are especially interested in finding out how they can adjust their portfolio to meet the changes," says the project manager. "This is just as relevant for companies in the automobile industry as it is for heating system manufacturers." Politicians are taking notice too. "We've received a lot of invitations to present papers at conferences since our first study was published in 2012," reports the researcher. "We've been invited to provide first-hand information at many events, ranging from workshops organized by the Ministry of the Environment to company board meetings."

Because so many companies are interested in not only the final result they are expected to achieve by 2050 but also how to get there, the ISE scientists want to expand their model to outline the transformative intermediate steps leading up to the desired climate target. ■



Total annual costs for operation and upkeep of the entire energy system average some € 173 bn. The largest single annual expenditure, with some € 45 bn: renovating buildings for energy efficiency.  
© Source: Fraunhofer ISI, Energiesystem Deutschland 2050 / Graphic: Vierthaler&Braun





# Adventures with snow algae and polar bears

An essay by Professor Günter Fuhr,  
director of the Fraunhofer Institute  
for Biomedical Engineering IBMT

Tell someone you're off on a polar expedition with a small group from the Fraunhofer Institute for Biomedical Engineering IBMT and it's likely you'll be met with a reaction somewhere between astonishment and admiration. They'll think they have an intrepid and seasoned athlete in front of them – an adventurer. They'll be thinking of Amundsen and Scott, the North and South Poles, bitter cold, frostbite and energy-sapping winters of raw polar nights. Today, polar expeditions such as those extreme tours made by the likes of Arved Fuchs and Reinhold Messner continue to attract considerably more attention than the many scientific excursions made each year to the Arctic and Antarctic. And this is reflected in the history books. These

regions have claimed more than their share of victims – now glorified as heroes – giving adventurism, research and extreme sport a somewhat tragic edge in the public consciousness. But this image doesn't fit in at all with our annual scientific polar expeditions. There is no struggle or hardship, and you don't have to be a top athlete or sports champion. Conducting considered, well-planned fieldwork is the order of the day. Nobody wants to know about the scientific subject matter that drives us to go on expeditions in the first place. And if they do, they are surprised to hear that Fraunhofer IBMT conducts fieldwork on Spitsbergen and has been doing so for the past thirteen years with great industrial success.

Distinctive red-yellow-green  
snow algae blooms on the  
Makarovbreen, a kilometer-  
sized glacier at the gateway  
to the Raudfjorden in the  
far north of Spitsbergen.  
© Fraunhofer IBMT





So what is it that lures Fraunhofer scientists to the Arctic wilderness? The answer is microscopic algae – snow algae that have adapted perfectly to the extreme climate and flourish on the wet landscapes of snow and glaciers. In some cases, they appear in vast quantities and in far greater variety than we have traditionally supposed. These days we can look to their genetics for some concrete answers. Although they manage to spread like wildfire in the late polar summer despite the low temperatures, turning entire snow ranges and glaciers red, orange and green, globally only very few strains of snow algae blooms have been stored in stable laboratory cultures. Research into the intricately complex parameters involved – the varying conditions of ice, snow, and meltwater, not to mention the effects of light levels, months of darkness, and the way different types of snow algae group together – has not come far enough to enable us to faithfully recreate the conditions of the Arctic wilderness in a laboratory. But this is what it will take if we want to use these algae in any practicable way. Finding industrial applications is no fantasy: among those performing research in the fields of biotechnology, cosmetics, pharmaceuticals and medicine, there is considerable interest in the special substances and genes that have formed as the algae have adapted, as well as in their growth optimum at temperatures just above zero. Snow algae could be used to bridge gaps in production at Central Europe's outdoor algae farms in the spring and fall; at present the choice is between the expense of additional heating and lighting, or closing down production for months on end. And that is just one argument for moving operations into the lab.

Some of these snow algae's special ingredients are already being used on an industrial scale – in the cosmetics sector, for example. And there is a lot more waiting to be discovered in these tiny organisms. New kinds of medication, perhaps? Nutritional supplements? Nobody knows better than the IBMT. Our "CCCrory" (<http://cccryo.fraunhofer.de>) has grown to become the world's largest collection of cryophilic algae. It comprises more than 370 strains of algae covering 75 genera and 125 species, many of which have never before been documented by science.

### Researchers have transferred algae strains to a stable mass-culture

Dr. Thomas Leya heads up the Working Group on Extremophile Research & Biobank CCCryo at Fraunhofer IBMT. Following several research expeditions, Dr. Leya and his team have succeeded in transferring algae strains to a stable mass-culture, thereby paving the way for industrial applications. In addition, all samples are cryopreserved long-term in the cryobiobank that has become a hallmark of our institute. We offer strains of algae with special characteristics, such as antifreeze proteins and others that produce bioreagents (long-chained carotenoids, antioxidants, pigments), or excrete particular gels. With interest in the collection growing year on year, we must continuously expand the Fraunhofer

algae collection. And that explains why we visit the polar regions, the habitat of cryophiles, from time to time.

Could these algae also have medical applications? Dr. Leya and his colleagues are putting a lot of effort into exploring this issue. They are particularly interested in ice structuring proteins (ISPs), which specifically bind to the expanding ice crystals and are thus capable of altering the crystals' morphology. Some of the snow algae in the CCCryo collection produce ISPs, which means we can already produce and isolate them on the customer's request. Potential applications for ISPs include cryoconservation. But it is likely that they also have other functions entirely different from what was previously thought. Results from recent sequencing have shown that a portion of the ISP gene evolved from genes that produce antifungal proteins. This suggests a connection between fungal antigens and isolated ISPs with their special effect on ice growth. Any natural substance with an antibiotic effect is bound to be of interest to the medical profession.

Another molecular group with potential are the unsaturated omega-3 fatty acids. With a positive effect on human metabolism, these have long since entered industrial-scale production and are marketed as a nutritional supplement. Although omega-3 fatty acids are present in saltwater fish, these are less than ideal as a source. The fish don't produce the fatty acids themselves, but absorb them through their diet of crustaceans and marine algae. It is far more efficient then to source these substances directly at the beginning of the food chain. Incidentally, since a whole host of beneficial substances come from algae, it may prove much faster and technologically convenient to use sunlight to help produce the desired material from green unicellular organisms.

But many questions remain unanswered. Our latest expedition was a collaboration involving IBMT researchers, the Helmholtz Association and industry partners aboard a small Norwegian coaster. As well as collecting more algae strains, the exhibition team focused on researching how algae propagate. Why is it that we see vast fields of red snow algae in some areas, but not in others – despite ample snow and apparently ideal conditions? A seemingly straightforward question, but one of fundamental importance for stably growing algae in the lab – all the more so when considering applications on an industrial scale.

Over the past few years, the Working Group on Extremophile Research & Biobank CCCryo has already examined several factors including nutrient content, direction of exposure, the proximity to bird colonies that provide a source of nutrients, as well as the pH value of meltwater. But a clear understanding of how these factors relate to snow algae bloom patterns had yet to be established.

For our latest expedition, the plan was an ambitious one. Weather permitting, the group intended to sail around and past Spitsbergen and then on to the islands that lie to the

east. The goal was to gain insight into geological relationships and places with more widespread algal blooms, which is why the group had a geochemist on board. We hoped to find answers on the significantly colder east side of Spitsbergen that is shielded from the Gulf Stream. As the researchers now know, this was the right tack to take. What was unmistakable was the acidic pH values found throughout the fields of snow algae. It seems algae prefer areas with bedrock that reacts to acidity such as slate or gneiss. It is this that affects the properties of the meltwater; the kinds of nutrients, whether organic or inorganic, play little role. It was Dr. Jens Klump, a geochemist from the GFZ German Research Center for Geosciences at the Helmholtz Center Potsdam near Berlin, who made this discovery. The “red snow” phenomenon mainly occurs on the west coast, which for Spitsbergen and the other islands making up the Svalbard group is the side most exposed to the elements. It is also seen high up on the glacier peaks. It seems that algae need to be exposed to sufficient precipitation over the course of the year in order to bloom.

### A high-tech journey

When Fraunhofer scientists travel, they’re always sure to pack plenty of high-tech equipment. On the lower deck of the expedition ship they installed a full biological lab complete with microscope, a station for measuring chemical parameters, and a range of analysis devices. In order to allow genome sequencing and produce more cultures back at the IBMT, the collected algae samples must survive the European summer on the trip to Germany. Here the challenge is that the cells die if they thaw out. The group’s solution was to use specially designed cooling containers. Also stowed on board was a radio-controlled helicopter equipped with a camera. This is how the group obtained images that gave an overview of the snow fields and even allowed us to explore glacier areas inaccessible by foot. What is more, from the air we can see certain details and algae distribution patterns that we would not appreciate when standing in the vast expanses of the snow fields. This was an essential approach for testing one of the expedition’s hypotheses: we contended that topography and hydrochemistry, which is influenced by the surrounding bedrock, are key factors at work in the phenomenon of snow algae bloom.

While this might all sound quite exotic, it’s also a little bit like Arctic tourism – and it certainly doesn’t compare to the pioneering polar expeditions mentioned earlier, which were full of danger, suffering and surprises. That is as it should be, and indeed a prerequisite for any endeavor undertaken by a publically funded institution. But field work is not always as safe as it might seem. Unlike the Antarctic, which is devoid of any danger from land-based predators, the Arctic is the realm of the polar bear. And that includes Svalbard, which is home to some 3400 members of these kings of the Arctic. It must be kept in mind that these creatures are protected all year round and setting foot on their territory can be dangerous –



Mass cultures of snow algae in a linked-column photobioreactor system at Fraunhofer IBMT. Green snow algae in the active growth phase can be seen here on the left; on the right in the red, carotenoid-producing stress phase.  
© Tobias Marschner

especially so far from civilization. As Julius von Payer wrote in the account of his 1870-71 expedition: “Polar bears are bold hunters, ... just like the tiger, they strike their prey silently and without warning. Magnificently adapted to their polar habitat, they commanded our every admiration.” As attacks on humans are not unheard of, it is essential to have a firearm and a flare gun with you in case you have to defend yourself against a surprise attack. But shooting is absolutely the last resort as a way to protect yourself against polar bears. What is required is constant vigilance so you can retreat quickly and neither disturb nor provoke them. Over the years, none of the IBMT groups had come face to face with a single polar bear. That all changed on our latest expedition – the team encountered no fewer than 18 bears! But thanks to cautious and well-practiced behavior, these meetings passed without incident.

After completing four weeks of intensive fieldwork, the team of five returned safe and sound to Potsdam-Golm with a wealth of samples and new experiences. And although the “blood snow” that struck fear into the hearts of medieval seafarers is yet to reveal all its secrets, our scientists have made a great deal of progress. It will take at least two years to complete the extensive work of cloning and characterizing the almost innumerable samples of algae. At Fraunhofer IBMT, the various isolates are first cleaned to remove any contaminants before being characterized according to their growth requirements and constituent substances. Once mass reproduction has been achieved in large glass-pipe fermenters – another technology focus at the IBMT – the next step will be to find potential industrial applications. A further 50 strains of algae collected over one Arctic summer on our planet’s fields of eternal snow are about to join those already in the refrigerators and cold chambers in Golm. A large, frozen treasure trove for applied research. ■

# Prize-winning solar research



For more than three decades, scientists at the Fraunhofer Institute for Solar Energy Systems ISE in Freiburg have been developing solutions for renewable energy use, especially solar energy. Now the institute has been awarded the Zayed Future Energy Prize 2014 for its long-standing commitment. The prize is endowed with 1.5 million U.S. dollars.

Text: Birgit Niesing

Decisive assessment criteria for the prize include the organization's long-term vision and innovation potential.  
© Fraunhofer ISE

"We are absolutely delighted that the Zayed Future Energy Prize committee has decided to honor Fraunhofer ISE's more than 30 years of work on sustainable energy systems in this way," says Prof. Eicke R. Weber, director of Fraunhofer ISE. The ISE has laid important groundwork for renewable energy solutions in the last thirty years, including the design of the first energy self-sufficient solar house in Germany. Its researchers have also steadily increased the efficiency of solar cells. New concepts, like the multi-junction solar cells used in concentrator photovoltaics, recently set a world efficiency record at more than 44 percent. The institute is also a leader in energy-efficient inverters, a central component of solar power systems.

Other milestones include the first autonomous solar air conditioning system in Germany and the development of wall plaster with integrated micro-encapsulated paraffin wax; this can then be used as a heat-storing building material. A more recent highlight is the first solar-powered

hydrogen fueling station in Germany. "This generous prize will enable us to apply our research to assist those countries that have not yet started the energy transition. For example, by further developing our energy system analysis and supply models, we will be able to adapt them to other regions in the world. Thus, we can provide support in effecting a smooth and cost-effective transition toward a sustainable energy system, and establish a basis for technological collaboration," reports solar expert Weber. A portion of the prize money will be invested in training programs as well.

## Important for the Middle East

Renewable energy is a hugely important topic for the Emirate of Abu Dhabi, one of the world's biggest energy producers. As a mark of how seriously it takes its sense of responsibility in this field, each year the Emirate awards the Zayed Future Energy Prize in memory of Sheikh Zayed bin Sultan Al Nahyan, the first president

of the United Arab Emirates and Emir of Abu Dhabi. There are prizes for companies, NGOs and educational establishments, as well as for an individual's lifetime achievement. The award recognizes the best solutions in the world of renewable energy and sustainability, and was first bestowed in 2008. Prizewinners are selected on the basis of the degree to which they bring about a tangible change in industry, society and the environment, their impact as a leader and role model, and the viability and innovative potential of their organization.

His Highness General Sheikh Mohammed bin Zayed Al Nahyan, Crown Prince of Abu Dhabi, presented the prize to Prof. Weber at the World Future Energy Summit in Abu Dhabi. Fraunhofer ISE, now Europe's biggest solar research institute, was one of three finalists in the NGO (non-governmental organization) category. It won out against the UK-based organization Practical Action and the US-based World Resources Institute (WRI). ■





TIETeK, a diving robot developed by Fraunhofer scientists, is able to carry out the dangerous aspects of offshore wind park inspections. © Fraunhofer IOSB

# Deep-sea Volkswagen Kombi

Oceanographers and the offshore oil industry rely heavily on underwater robots. Despite the huge number of autonomous underwater vehicles, AUVs, in existence, each one is made as an expensive one-off. With the boom in the offshore wind power industry meaning demand for AUVs is set to rise, Fraunhofer researchers have developed a sturdy and reliable standardized robot that is suitable for mass production and that can be adapted to perform different functions.

Text: Tim Schröder





Using robotic diving equipment to uncover the secrets of the deep has always been an alluring prospect, and even nowadays there is still something exotic about it that evokes Jules Verne's "Twenty Thousand Leagues Under the Sea." But working underwater has been a normal part of everyday business for quite some time now. Dozens of offshore wind turbines have been erected in the North Sea in recent years, especially off the coast of Great Britain, with many hundreds more set to be built by the end of the decade. In future it will be AUVs that carry out the maintenance of these wind farms. Modern oil companies – who these days can drill for offshore oil at water depths of around 3000 meters – would be all at sea without autonomous underwater vehicles, short AUVs, while geologists use robotic diving equipment as a matter of course when sounding the bottom of the sea in search of natural resources.

Given that using underwater robots is now a matter of routine, it seems all the more astonishing that manufacturing them is anything but. Even though demand for them is so high, most AUVs are tailor made to operate at specific depths and for set purposes. The situation calls for a robust yet multi-purpose device that can be produced in large quantities – a bit like the Volkswagen "Kombi" that also turns into a campervan, family car or transporter as required.

Now this deep-sea VW bus could soon become a reality. Experts at the Advanced System Technology AST branch of the Fraunhofer Institute for Optronics, System Technologies and Image Exploitation IOSB in Ilmenau have developed two such multi-functional diving robots in the past five years: one is a remote-controlled, torpedo-shaped submersible called TIETeK that will operate as far as 6000 meters down in future; the other is C-Watch, a rather boxy aluminum frame construction designed as an everyday workhorse for use in freshwater locations and coastal waters. C-Watch was developed in house at Fraunhofer IOSB, whereas TIETeK was developed and prototyped in a joint project involving four other Fraunhofer Institutes.

Two C-Watch robots were sold to China in May 2013, where they will be used on the one hand to carry out underwater observation at aquaculture facilities, monitoring the behavior of farmed fish and determining their health, and on the other to investigate water quality in canals and along the coast.

Both systems are very flexible. "We designed C-Watch and TIETeK to accept various different sensors and above all to make switching sensors a very quick process. The robots are also fitted with high-performance batteries, which means they can remain operational for many hours at a time," explains Prof. Dr. Thomas Rauschenbach, Director of the AST in Ilmenau. Another advantage of the new design is its low weight, which is under half that of standard diving robots. The latter are so heavy that they usually have to be lifted into the water from large research vessels with strong cranes – whereas the new, lighter systems can be transported in small boats.

### Versatile all-rounder

Work is not stopping there. Experts involved in Fraunhofer-Gesellschaft's self-financed TIETeK project are now looking to develop their prototype further by turning the underwater vehicle into a commercial product in a follow-up project. To make sure the development sets off on the right course, Fraunhofer IOSB invited oceanographers, specialists from the offshore wind industry and deep-sea marine biologists to come and visit them. "We wanted to hear straight from the horse's mouth what users want from their diving robots," Rauschenbach explains. It turns out that the main requirement is reliability, since unlike automotive vehicles, AUVs are still very prone to defects – particularly where their hardware is concerned. So the challenge is to create a system that is both reliable and energy-efficient enough to allow the robot to safely travel over long periods.

Increasing operating time is one of the main priorities in any case. Expeditions by boat are expensive, so ideally robots should be able to remain underwater collecting scientific data or performing other tasks for as long as possible. The problem with conventional systems is that they have to be hauled aboard frequently for battery changes or to extract data from their memory. IOSB scientists have tackled this issue by basing their designs on high-performance rechargeable batteries that will enable AUVs to travel for up to 23 hours at a time in future. "We're also working on a battery pack that users can replace in just a few simple steps," says Torsten Pfützenreuter, who heads up the Maritime Systems working group at AST. Scientists also plan to eliminate the time-consuming data transfer process by fitting the submersible with removable memory. Both

steps will help to greatly reduce the amount of time the robot has to spend on the boat.

But what truly makes an underwater robot multifunctional is its flexibility: users must be able to fit different sensors to it quickly and easily. Modern sensing equipment ranges from simple thermometers and salinity sensors to sophisticated depth-sounding antennas and acoustics systems of the kind used to search geological strata for minerals and crude oil. Some of these sensors are half a meter wide, and are usually attached to the robots by being painstakingly screwed to the sides. The Fraunhofer scientists plan to resolve this problem by making their AUV bigger, with cargo space roughly equivalent to the volume of a small refrigerator.

Pfützenreuter and Rauschenbach envisage a modular vehicle that customers can quickly and easily modify to suit their own requirements. "AUVs working in and around the base of wind turbine masts in offshore wind parks need strong motors and excellent control systems," says Pfützenreuter. "But when they're working in deeper waters, AUVs move much more slowly and require endurance more than anything else. We'll be able to kit our underwater robots out according to our customers' wishes."

In future, the scientists intend for both TIETeK and C-Watch to be manufactured under license. "We expect to see AUVs being produced in large quantities, as global demand for underwater robots has grown considerably in recent years," says Rauschenbach. Improving safety is another issue that the wind energy industry takes very seriously. To date the majority of underwater work and inspections carried out on offshore wind turbines has been done by divers, and occasionally this comes at the cost of human life. The most recent fatality was in the German North Sea in summer 2013. Versatile, lightweight underwater robots could do some of this work, and their low weight would mean smaller supply vessels could deploy them directly where they were needed in the wind parks.

"What also makes a good robot is the ease with which it can be lifted in and out of the water – ideally it shouldn't take more than a few people to launch and retrieve it quickly," Pfützenreuter adds. Having to first launch a dinghy costs time, and can even put the crew at risk in certain situations. ■

# New drugs to combat asthma and the like

Science and industry are collaborating to develop future pharmaceuticals for treating chronic inflammatory diseases.

Text: Monika Offenberger

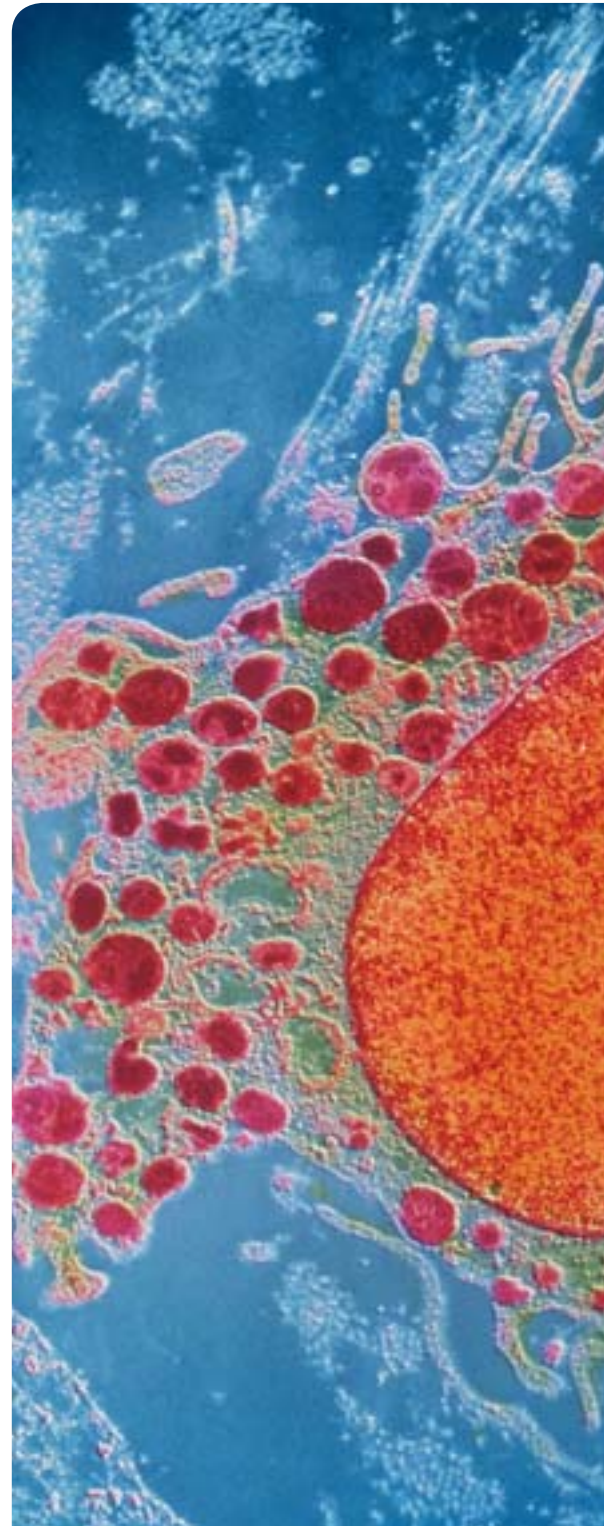
Statistics indicate that there are 300 million asthma sufferers worldwide, a further 600 million people living with chronic pneumonia and up to 30% of the global population contending with allergic rhinitis (allergic inflammation of the nasal airways). Chronic inflammatory diseases can also affect other organs and parts of the body beyond the respiratory system; they can occur in the intestine (in the form of inflammatory bowel diseases such as colitis ulcerosa), the joints (rheumatoid arthritis), the skin (scleroderma), or the heart and blood vessels (arteriosclerosis), to name a few. Symptoms vary considerably depending on the type of illness, but what each form of inflammatory disease has in common is that it stems from centers of inflammation in the body that are prevented from healing by immunological processes that have gone wrong.

This weak spot is where a new product made by the Canadian company Nuvo Research Inc., headquartered in Ontario, comes in. It is already approved for use in numerous countries around the world as a drug to assist local wound healing, and in Thailand is already sanctioned as a means to treat a variety of chronic diseases. Scientists at the Fraunhofer Institute for Cell Therapy and Immunology IZI are now working with a German subsidiary of the company, Nuvo Research GmbH, and the Translational Centre for Regenerative Medicine TRM at Leipzig University to develop a platform that will enable them to better understand the way the sub-

stance works. Their objective is to optimize the drug to make it more convenient to administer and better tolerated. Above all, the scientists are keen to develop derivatives of the drug with which it might be possible to alleviate an even broader range of chronic illnesses, and to prepare these drugs for approval on the European and Canadian markets. The cooperation project is set to run for two years, and is sponsored to the tune of 4.4 million euros by the European Regional Development Fund ERDF and Germany's Land of Saxony. The project is due to be completed in June 2014.

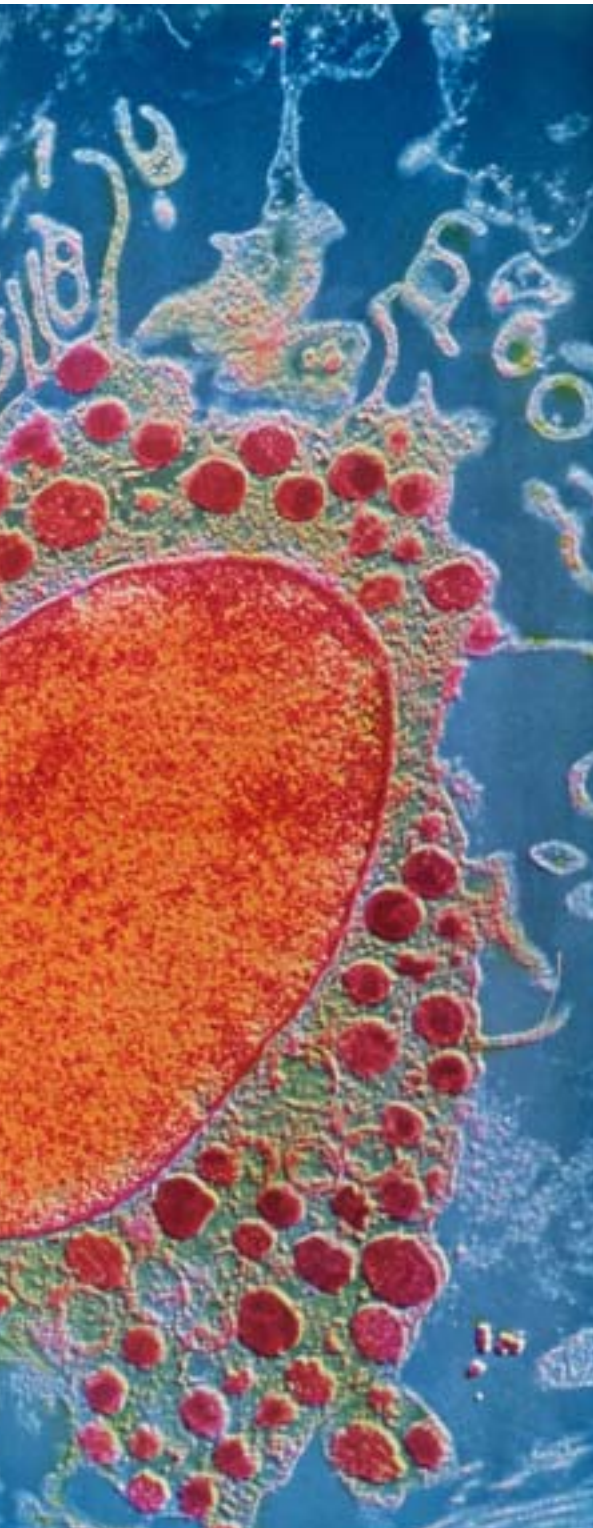
"Inflammation is the body's emergency response. It uses inflammation to try and defeat bacteria and other pathogens, as a response to injury and as a means to balance out insufficient supplies of nutrients," explains Professor Jürgen Arnhold, who is based at Leipzig University's Faculty of Medicine and also conducts research at the TRM. Inflammation normally begins to abate the moment it starts, Professor Arnhold continues. "In order for the organism to calm back down and stabilize, and to prevent any further tissue damage, the immune system is temporarily suppressed. The body suppresses its defense mechanisms until the inflamed tissue has managed to regain its normal functions. It seems that this regenerative process is disrupted in the case of chronic inflammation."

The precise details of this dysfunction are still poorly understood. All scientists are certain of





Mast cells are cells produced by the body's immune system. Allergies are one area in which they play an important role.  
© SCIENCE PHOTO LIBRARY



is that it upsets the entire immune system, with disastrous consequences. If immunosuppression is too severe or goes on for too long, it can lead to all manner of complications, such as bacterial or fungal infections and disruptions to the wound healing process. If such complications develop beyond a certain threshold, the immune system will suddenly leap back into action very violently. "We want to better understand the interplay between immunosuppression and this immunological overreaction. There is clearly a class of enzymes at work here that would normally be activated by immune cells within a very specific time window. If this activation occurs in an uncontrolled manner, the last phase of the inflammatory process is disrupted and becomes chronic," supposes Professor Arnhold. This is where the particularly small, low-molecular substance developed by Nuvo comes in: "Studies we conducted on isolated immune cells indicate that it should be possible to change the function of some of the enzymes involved," is Professor Arnhold's interim assessment.

Where scientists at the TRM are investigating the way selected immune cells react to the Canadian drug, researchers at the IZI are interested in looking at its effect on the organism as a whole. The reason for these investigations is that in order for the drug to be approved in Europe and North America, authorities demand that complex and time-consuming studies be conducted into its safety, tolerability and effectiveness. "We test the medication on mice that display the same sorts of symptoms of illness as patients with chronic inflammatory diseases," explains Dr. Franziska Lange, head of the Inflammation Models and Immunodiagnostics Unit at the IZI. "My working group focuses on three conditions: asthma, smoker's lung and scleroderma, all of them autoimmune connective tissue diseases. We established a total of 20 different model systems with which we are able to simulate different aspects of inflammatory diseases. This enables us to record the effects and side-effects of different doses of the drug on mice. We see ourselves as a service unit and offer many different ways to carry out preclinical tests on potential pharmaceuticals," she goes on to explain.

A further three IZI working groups are testing the drug on mice who have suffered a stroke or who have colitis to see whether the animals' symptoms improve. They are also investigating whether the drug might be useful in treating breast cancer. The reason certain cancer cells are able to survive so well in the human body is that they release substances to suppress the immune system. This enables them to outsmart the body's defense mechanisms and become more difficult to attack. Scientists hope that the active ingredients in the drug might also cancel out the immunosuppression triggered by the tumor and have a positive effect on the progression of the disease.

Fraunhofer IZI, Nuvo Research GmbH and Leipzig University have been working together since 2008. That the Canadian company chose to establish a subsidiary in Leipzig is no coincidence. "The company chose this location deliberately as a base from which to work on getting the drug approved. Both the Fraunhofer Institute and the university are renowned for their excellent medical research expertise and facilities," Lange explains. "On top of which, the collaboration between the IZI and the TRM goes back a long way, so we complement one another perfectly." The trio has already conducted two studies, and both of them proved the effectiveness and safety of the basic active ingredient. Currently the three partners are hoping to set up another cooperative project and have applied to the German Federal Ministry of Education and Research (BMBF) for funding. "This project is concerned with improving the method of application of the drug. In Thailand it is currently administered as an infusion, which means patients have to visit the clinic five days in a row for several hours at a time. We're working on preparing the drug in such a way that it can also be injected by family doctors," says Professor Arnhold. He is experimenting with liposomes, which are miniscule spheres made of biomembranes. His long-term objective is to find a way to gradually release the active ingredient from within liposomes rather than administering it all at once. This would potentially enable medical scientists to modulate the drug's pharmacological profile in a targeted way, and might also make the drug easier to administer to patients. ■



## Safeguarding infrastructure

Infrastructure disruptions can leave modern, industrialized societies vulnerable. Breakdowns in rail or air traffic, interruptions to data transmissions or outages in the power grid can result in huge costs, or worse, endanger people's lives. In order to safeguard various kinds of critical infrastructure – and to ensure communities are in a position to get things back up and running quickly in the event of a catastrophe – experts from six European research institutes are now working together in the EU-co-funded Critical Infrastructure Preparedness and Resilience Research Network (CIPRNet). With Fraunhofer, four universities, the International Union of Railways, and a Swiss IT security company as members, CIPRNet will set up a competence center for simulating and analyzing critical infrastructures.

The aim is to develop methods that help transportation, telecommunications and rail network operators react quickly in emergency situations. "To ensure and maintain the best possible response times, both the technology and the players have to be capable of adjusting quickly to continuous fluctuations in critical infrastructures," says Dr. Erich Rome, project coordinator at the Fraunhofer Institute for Intelligent Analysis and Information Systems IAIS in Sankt Augustin. "CIPRNet will pioneer modeling, simulation and analysis techniques that we hope will serve to support decision making in emergency and disaster management throughout Europe."



## Model port

A major transport hub for international goods, Singapore's container port is already the world's second largest; a planned new container terminal with a six-kilometer-long dock will soon make it even bigger. In an effort to avoid unnecessary chaos during the unloading and onward transportation of cargo, the Singapore Maritime Institute launched a competition calling on scientists worldwide to submit their ideas.

Together with partners from Germany, Finland and Singapore, researchers from the Fraunhofer Center for Maritime Logistics and Services CML simulated the operations required in future and came up with a concept to handle the unloading and transportation of millions of containers each year. "Our task in this project was to simulate and analyze processes at the central yard, the container stack, and the hinterland connection," explains Prof. Carlos Jahn, head of the CML. The team came in fourth out of 56 participating teams in the "Next Generation Container Port Challenge."



## Waterway transport

Europe's highways are often overloaded – especially thanks to heavy truck traffic, which results in traffic jams that can last hours. Theoretically, some of the freight could just as easily be transported on Europe's waterways.

Now an international research team is examining how this might work in practice. With funding from the EU's Seventh Framework Programme, the NEWS project (Development of a Next Generation European Inland Waterway Ship and Logistics System) is developing a novel hull type that drastically increases transportation capacity and is designed for use in conjunction with a logistics system. Experts are also examining how to use European waterways, particularly the Danube and its adjoining rivers and canals, in the most efficient way to transport containers.

Experts from Fraunhofer Austria are providing socio-economic analysis; they are investigating how automotive manufacturers and suppliers in particular would benefit by switching to European waterways for freight transportation.



## How ideas are born

Where do new ideas come from? How do ideas turn into innovations, and what impact might these have on society? In cooperation with the Institute of Policy and Management (IPM) at the Chinese Academy of Sciences (CAS), the Fraunhofer Institute for Systems and Innovation Research ISI has set up the "Joint Center for Innovation Research" in Beijing, so that German and Chinese researchers can work together to find answers to these and other questions. The goal is to improve collaboration and provide advice to German and other European companies looking to enter the Chinese market.

"It's crucial that we understand how innovation works in China," explains Marion A. Weissenberger-Eibl, head of the ISI. "Our activities give us an insight into the country's economic and political system – and that will allow us to give better advice."

Researchers at the new Joint Center for Innovation Research will be addressing a wide spectrum of topics, such as energy efficiency, renewables, urban transport systems and water infrastructure. Other areas of interest include how scientists and researchers collaborate in China, how intellectual property laws are structured, and the impact innovation is having on culture.





## Virtual exploration

How do people find their way around shopping malls, airports and railway stations? And how can we prevent them from getting lost and missing their connection? Researchers from Fraunhofer Austria in Graz have teamed up with the TU Graz to develop a virtual environment that helps to address these sorts of questions – before construction on new buildings and transport hubs has even begun.

All-round 3D projection allows users to take a virtual tour of places that don't yet exist. Researchers have used DAVE – short for Definitely Affordable Virtual Environment – to send 120 test subjects around Vienna's planned central station, observing how they find their way.

"The experiment shows if pedestrians really do find the shortest route, identifies any weak points or gaps in the signage and determines whether mobile navigation aids tally with the posted signs," explains Eva Eggeling, head of the Visual Computing business area at Fraunhofer in Graz.



## New medicines

German and Canadian researchers will now be working side by side to develop new treatments and diagnostic tools – as well as the processes needed for their automated production.

The Fraunhofer Institute for Cell Therapy and Immunology IZI and McMaster University in Hamilton, Canada, have recently signed a cooperation agreement and are planning to set up a joint "Bioengineering and Advanced Therapies" project center in Hamilton.

Researchers are already working together on a number of pilot projects. For instance, German-Canadian research teams are currently working on more efficient techniques for diagnosing viral and bacterial infections.

Further collaborations will be focusing on the optimization of cell-based therapies designed to treat cancer as well as research into the genetic origins of dyslexia.

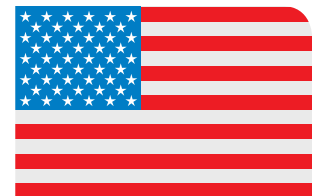


## Making use of waste heat

Industrial processes are never a hundred percent efficient. In fact, the losses involved are enormous – and up to two thirds of the world's energy gets lost as heat.

Getting this energy back and putting it to use – even tapping the energy of smaller-scale systems such as the heat of the human body – is at the heart of the EU "Nano-carbons for versatile power supply modules" project, coordinated by the Fraunhofer Institute for Material and Beam Technology IWS. Over the next four years, five companies, four universities and three research institutions from five European countries will be working together to develop nanostructured carbon materials for use in innovative thermoelectric generators and energy storage systems.

Researchers intend to draw on the Seebeck effect, which produces an electric voltage in certain materials when there is a difference in temperature. Nanostructured materials and nano-carbon materials such as nanotubes and graphene are particularly suited to generating electrical energy in this way. Researchers within the EU project want to modify nano-carbons so that they can convert waste heat into usable electrical energy. When incorporated into innovative, thermoelectric generators, they could then serve as energy storage devices – offering a resource-efficient alternative to the conventional battery.



## Reaching for the sun

By 2020, solar energy is set to compete on a level with fossil energy sources, even in the United States. Three years ago the US Department of Energy founded the SunShot initiative to make sure that is the case. SunShot supports universities and research centers in developing innovative ideas that will help reduce the cost of solar energy to six US cents per kilowatt hour.

The Fraunhofer Institute for Solar Energy Systems ISE in Freiburg is one of only three non-US research partners. Alongside the National Renewable Energy Laboratory NREL and project leader Georgia Institute of Technology, the Fraunhofer experts will be working on improving the efficiency of silicon solar cells still further.

"Photovoltaics have a key role to play in the vital global shift toward renewables – and a lot of room for development, which we must exploit through coordinated international research efforts," explains Prof. Eicke Weber, head of the ISE in Freiburg.

# Rescuing ruins

Pompeii is one of the most visited archeological sites in the world, but exposure to wind and weather is causing more and more irreparable damage to the ruins of the ancient city. Researchers are working to combat this ongoing degradation process.


Text: Klaus Jacob

According to contemporary witnesses, tremors shook the city of Pompeii on the morning of August 24 in the year 79 AD, causing buildings to collapse. Then the peak of Mount Vesuvius exploded and an enormous black cloud shot out of its crater. Ash rained down on the city and lava flowed down toward the valley. While the city of Herculaneum, which was located directly beneath the volcano, was immediately buried under mud, lava, and water, most of the victims in Pompeii were killed by lethal phosphorous gases or were crushed by boulders. By nightfall, Pompeii was completely covered by a layer of ash and pumice six to seven meters thick. And there the city lay for some 1500 years, undisturbed by the weather and the onward march of history. Its protective covering of lava and pumice meant that this ancient city in the Gulf of Naples was fully preserved – temple, laundry, brothel, the lot. It wasn't until around 1600 that the buried city was accidentally discovered during drainage work. Archaeologists started exploring Pompeii in earnest at the end of the 18th century, and continuous excavations that extended right into the 1970s uncovered a good two-thirds of the ancient city.

But Pompeii's ruins are sadly in danger; its re-discovery has set in train its second downfall. Frescoes and mosaics are exposed to adverse environmental and weather conditions, and painstakingly uncovered buildings are already collapsing in some cases. The huge number of tourists, over two-and-a-half million every year, also leave their mark. "That breaks our hearts. Despite the constant restoration work that goes on in Pompeii, the sheer size of the city means

that new efforts are needed all the time if we are to successfully carry out long-term, sustainable conservation work across the entire area," explains restorer Dr. Ralf Kilian, head of the Preventive Conservation and Preservation of Monuments group at the Fraunhofer Institute for Building Physics IBP.

He and archeologist Dr. Albrecht Matthaei visited Pompeii back in 1999. They were both students at the time, and both resolved to do something for the ancient city. This ambition was finally realized in 2012, when they laid the foundation for the Pompeii Sustainable Preservation Project.

 [www.pompeii-sustainable-preservation-project.org](http://www.pompeii-sustainable-preservation-project.org)

Together with international research partners and the responsible local authorities, the scientists are seeking a sustainable solution for the UNESCO World Heritage Site. In the project, it will not just be archeologists and restorers who set the agenda – as has been common practice up to now – but also scientists and engineers. And there's another new aspect to the approach taken by the Fraunhofer experts: "We want to use a targeted fundraising strategy to gain project sponsors who share our passion for preserving this irreplaceable testament to western culture," explains Fraunhofer IBP's campaign manager Nina Martens. "The project is ready to go and the Executive Board of the Fraunhofer-Gesellschaft has given us start-up funding. Now we are looking for investors to donate the ten million euros we require to implement our proj-







The ancient city of Pompeii is located at the base of the Mount Vesuvius, an active volcano in the Italian region of Campania in the Gulf of Naples. The ruins of Pompeii are an important site for learning about ancient culture and history. © Fraunhofer IBP

ect.” This is a completely new approach, as the cooperation between different institutions at international level and the capital required for such a project are very difficult or even impossible to realize by the conventional means of publicly funded research.

“Support from sponsors is a fast, unbureaucratic way of raising funds for this ambitious and comprehensive project,” says Martens. The Herculaneum Conservation Project serves as an example of best practice for this kind of funding. For the past ten years, the American David Woodley Packard has been investing in an extremely successful restoration project in the city of Herculaneum, which lies 20 kilometers from Pompeii.

### Developing new conservation methods

The project work is intended not only to conserve the World Heritage Site of Pompeii, but also to supply innovative methods and strategies to prevent further deterioration. The new technologies could then be used at other ancient sites as well. Researchers will be able to draw on a vast wealth of experience in realizing these goals. Sharing overall management of the Pompeii Sustainable Preservation Project are Fraunhofer IBP and the Chair of Restoration, Art Technology and Conservation Science at Technische Universität München. Also participating in the project are the UNESCO-affiliated International Centre for the Study of the Preservation and Restoration of Cultural Property, the universities of Pisa and Oxford, the German Archaeological Institute in Rome, and of course the responsible local authorities and in particular the Soprintendenza Speciale per i Beni Archeologici di Napoli e Pompei as the institution with direct responsibility. “Through interdisciplinary cooperation at international level, we want to get a project off the ground that involves restoring building structures, researching new restoration methods, and training a new generation of scientists all at the same time,” says Kilian, summarizing the project’s ambitious goals.



Initial excavations at the end of the 18th century unearthed the well-preserved remains of the city and gave science valuable insights into life in ancient times. © Fraunhofer IBP

Instead of concentrating on specific sections such as individual murals or houses with elaborately designed rooms, the partners in the Pompeii Sustainable Preservation Project are pursuing a holistic approach. The fundamental structural unit of the city of Pompeii is the “insula”, a kind of apartment building surround-



The layer of lava that covered the city and its inhabitants had the effect of preserving the tragedy of Pompeii throughout the centuries that followed. © Fraunhofer IBP



Pompeii's remains are now largely unprotected against adverse environmental and weather conditions. Researchers are working on a sustainable solution for conserving the World Heritage Site. © Fraunhofer IBP

ed by streets on four sides. Historically correct restoration that respects the city's nature must be based around this unit and secure everything that has survived there. A possible starting point for the project could be the insula known as the House of the Cryptoporticus (a "cryptoporticus" is a subterranean passageway), which with an area of just under 600 square meters is almost like a city within the city. With its six residences decorated to different degrees of elaboration, its five workshops and shops, and the largest surviving tannery in Pompeii, the insula combines precisely those architectural and socio-historical features that make the city so uniquely valuable as an historical source. Matthaei describes the planned approach as follows: "The first task will be to document the current building stock. We can then carry out initial emergency work to secure structures on this basis, before going on in further steps to restore the entire insula piece by piece using state-of-the-art methods."

### Training new talent

The year-round work of the scientists and other professionals will be supplemented by a summer academy, which is intended both for outstanding conservation and restoration students and

for restorers with no prior experience of working on ancient Roman sites. Expert tutors will impart knowledge about working methods, and students will later be able to use this in their own projects. In addition, Pompeii courses for schools from the Vesuvius region and international partner schools will awaken the fascination of future generations for the World Heritage Site along with a sense of responsibility for its preservation.

"However, it's the documentation and restoration of the insula that is the backbone of the project," says Killian. This work will be accompanied by research projects conducted by scientists and classicists. Architects will document the walls that are still standing and write the construction history of the buildings on this basis. Residents of ancient homes were as keen on renovations as we are today, and the traces left behind by this frequent construction work give us glimpses into how they lived. Archaeologists will carry out smaller excavations to search for earlier settlements in the interior of the homes and to find out what happened on the site of the insula before it was erected. Social historians will study the objects and inscriptions found in the buildings to show how the living space was divided up between rich and poor,

men and women, and free citizens, tradesmen, and slaves. At the same time, restorers will document the work being carried out on the building in order to verify how successful the individual restoration measures have been during excavations. While this work is going on, research will also be carried out that will contribute to developing new technologies and improving conservation methods and the preservation of monuments.

### Interdisciplinary collaboration

However, this project is not limited to technical issues and developments. Biologists will also be involved, carrying out work such as researching the best way of planting the area to prevent structures becoming overgrown with creepers. That would mean there would be almost no need for the herbicides that have been used in Pompeii until now – very good news, because they damage the buildings.

All partners in the Pompeii Sustainable Preservation Project want to work together to ensure that in future the ruins of Pompeii once again play a central role in the international debate over preservation of and access to cultural monuments. ■





# Fighting disease together

Sanofi and Fraunhofer create a Center of Excellence for Natural Products Research. In this new Center of Excellence, researchers will identify and optimize novel naturally-occurring chemical and biological compounds to fight infectious diseases.

Microbes such as Mycobacterium tuberculosis cause millions of deaths.  
© DOWSETT, Public Health England/  
Science Photo Library

Infectious diseases are dangerous. Microbes such as viruses, bacteria, fungi and parasites caused over 10 million deaths in 2011. Despite global efforts to prevent or delay the spread of antimicrobial resistance, bacteria are becoming ever less susceptible to antimicrobial drugs, while the pace of new discoveries in antibiotic research is declining. Multidrug-resistant bacteria have emerged as a severe threat to public health, making it increasingly difficult to manage the 17 million severe bacterial infections treated annually in the hospitals of industrialized countries, and the 9 million tuberculosis cases annually in the developing world. New antimicrobial strategies must be identified urgently in an effort to combat infectious diseases.

Based on a contractual agreement established in January 2014, Sanofi and the Fraunhofer Institute for Molecular Biology and Applied Ecology IME are aiming to identify and optimize novel, naturally-occurring chemical and biological compounds that fight the organisms that cause selected infectious diseases. Penicillin is one of a number of antibiotics derived from natural products, and this new collaborative venture will strive to identify novel compounds that are equally effective. The approach may also be extended to include other indications such as diabetes, pain and rare diseases, where natural products have already played an important role in the prevention and treatment of disease. Sanofi will share with Fraunhofer its microbial strain collection, one of the largest in the world, comprising more than 100,000 different microorganisms, and will also contribute its extensive knowhow in anti-infective research to the collaboration.

"There is a great medical need in the global fight against infectious diseases," says Elias Zerhouni, President, Sanofi Global

R&D. "This is critical given the spread of antibiotic resistance worldwide, especially in the hospital setting, resulting in serious, often life-threatening infections, where few advances have been made in the recent years. This cooperation with Fraunhofer is unique because internal and external scientists will work together as one team on common projects, in shared labs, to acquire new knowledge, aiming to develop novel medicines for patients suffering from infectious diseases." Prof. Dr. Rainer Fischer, Senior Executive Director of the Fraunhofer IME, stresses: "This pioneering Fraunhofer Center of Excellence for Natural Products is not only a win-win project for both partners, but goes far beyond drug discovery, because the access to Sanofi's natural product collection will create value also for other industries with significant economic opportunities."

The new Center of Excellence for Natural Products Research will be part of the newly established Loewe Centre for Insect Biotechnology and Bioresources in Giessen, led by Prof. Dr. Andreas Vilcinskas of Justus-Liebig-Universität Giessen, and has been funded by the Hessian ministry of science and arts (HMWK) for the next six years. The joint team of scientists will be led by Prof. Dr. Peter Hammann, Sanofi R&D, head of External Innovation of the Infectious Diseases Unit, and Prof. Dr. Andreas Vilcinskas, Division Director of the Fraunhofer IME, Giessen. The team will jointly analyze the genetic make-up of the strains, cultivating them under various conditions, stimulating them to produce active substances and investigating their biological effects. The hope is that extensive understanding is gained through this partnership, leading to the discovery and further development of new antibiotics for the treatment of serious infectious diseases, thus contributing to overcoming one of the greatest challenges of our times. ■

# Implanted infection protection

Hospital germs can be deadly because they are resistant to antibiotics. Alternative methods for fighting bacteria are needed. A German-French research team has succeeded in developing bone implants that hold pathogens at bay.

Text: Monika Weiner

The numbers are alarming: Each year, hundreds of thousands of patients in German hospitals become infected with germs resistant to all common antibiotics. As a result recovery takes longer, wounds fail to heal, and infections spread – weakening the patient’s body and sometimes even leading to death. The Robert Koch Institute estimates that at least four people die every day from hospital-acquired infections in Germany, and that this figure is on the rise.

It’s a problem that can barely be tackled with pharmaceuticals either, since the development of new antibiotics is expensive, complicated and time-consuming – and once a product does finally reach the market, it doesn’t take long for germs to mutate and become resistant to it, too. Much like the race between the tortoise and the hare, researchers just can’t win.

One opportunity for germs to enter the body is when surgeons implant a bone substitute material. Infections in the bone are particularly problematic because they are so difficult to treat; antibiotics transported by blood through the body reach the implants only in very weak concentrations. “It would be better to avoid infections from the very beginning by providing the implant with an antimicrobial shield,” explains Dr. Iris Trick, microbiologist at the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB. Along with materials scientists at the Carnot CIRIMAT Institute in Toulouse, France, the Fraunhofer team has developed a bone substitute with integrated protection against infection.

## Where bacteria have no chance

At first glance, the fine-grained implant material looks like flour. Only under the microscope does its true nature become clear: The individual

granules are formed of apatite crystals. These are comparable in composition and structure to apatite of natural bone and are formed from the same chemical elements, calcium and phosphorous. Surgeons have been using apatite granules for years, for instance to reconstruct a patient’s bone matter or accelerate healing after an accident.

In fact, the human body recognizes apatite as a building material and incorporates it into new bone matter formed after a break. This makes the granules ideal for use in implants. Some manufacturers coat their bone substitute with antibiotics in an attempt to prevent complications, but of course this cannot guarantee full protection because resistant bacteria can still spread.

“We wanted to take a different approach,” reports Dr. Michaela Müller, the IGB interdisciplinary research team’s chemist. “Our goal was to use naturally occurring substances to reduce, suppress or kill bacteria on the calcium phosphate crystals.” In the “Biocapabili” project – the name is short for Biomimetic Calcium Phosphate Anti-bacterial Bone Implants for Local-infection Inhibition – the international team experimented with various substances and compounds, including silver, copper and zinc ions but also enzymes and peptides that decompose bacteria. The French researchers successfully incorporated metal ions into the apatite crystals.

Proof that the resulting powder actually protects against infection was provided by the biologists in the IGB’s laboratory in Stuttgart. Here, Iris Trick took samples of the powder on microtiter plates, infected them with different species of bacteria – including various strains of staphylococcus, which are among the most common hospital pathogens – and subsequently

incubated them for several days. The result was that in the immediate vicinity of the apatite, the number of bacteria was reduced by as much as 90 percent.

A protein coating developed by the Fraunhofer team turned out to be just as effective. “We can use peptides to protect granules and pellets of apatite against bacteria.” These peptides are also produced by the human body to fight infection. The new coating likewise passed the microbiological test with flying colors, since the dangerous bacteria were unable to reproduce on the surface of the pellets. This proved that the peptide coating makes it possible to produce antibacterial bone implants.

## The dose makes the poison

“Unfortunately, antibacterial effectiveness on its own isn’t enough in medicine,” explains Dr. Anke Burger-Kentscher, group manager for molecular cell technology at Fraunhofer IGB in Stuttgart. “Before a product can be used in practice, there must be proof that it won’t harm the patient.” Researchers have already taken the first step, exposing cultures of human cells to the implant samples on microtiter plates. “With the help of these cytotoxicity tests, we can determine the quantity of metal ions, enzymes or peptides in the granulate cells can handle,” summarizes Burger-Kentscher.

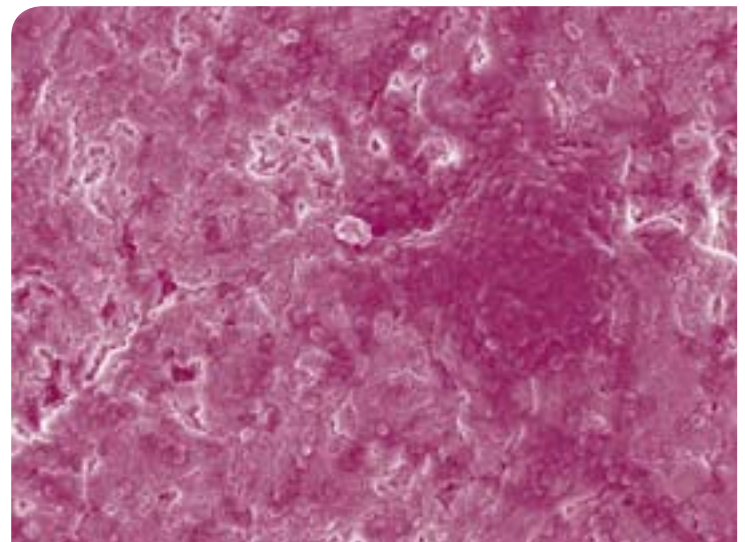
The next step, the clinical tests, will be carried out by the Franco-German team in collaboration with industry. Interested parties have already made contact – and that’s no surprise in Iris Trick’s opinion: “The number of multi-resistant germs will continue to grow in the future, so a product that not only prevents infection but also speeds up the recovery process is bound to do very well on the market.” ■



Researchers study whether and to what degree substances have an antimicrobial effect by way of a screening in which the bone substitute material is infected with different species of bacteria.  
© Fraunhofer IGB

### 60 Years of the IGB

Interfaces are very special places. They are contact points where something happens or where we meet, but also where something new can come into being. To find out more about these often atom-thin transitional spaces, in 1953 a small research laboratory was founded in Kirchheimbolanden in Germany's Palatinate region to study the physics and chemistry of interfaces. In 1962, the laboratory joined the still-young Fraunhofer-Gesellschaft and took the name "Fraunhofer Institute for Physics and Chemistry of Interfaces." Seven years later, the research team moved to the Stuttgart university campus and became increasingly involved in process engineering, which also gave rise to the institute's current name: Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB. In 1981, Fraunhofer IGB joined the Fraunhofer campus in Stuttgart Vaihingen. Today it is home to an interdisciplinary research team working on topics in the fields of medicine, pharmacy, chemistry, environmental technology and energy.



Dangerous staphylococcus bacteria grow on the surface of a calcium phosphate apatite crystal that was not modified with an antimicrobial substance.  
© Fraunhofer IGB





## Reliable bin picking

A new system for picking and placing steering wheel frames out of the crate saves time and cuts costs.  
© Takata AG

As things stand, most bulk goods delivered in crates today are unloaded by hand. Now scientists have developed software that enables robots to pick even the most chaotically arranged workpieces out of crates. The new software allows system integrators to offer their customers an all-in-one solution consisting of software and robotic system that is fit for industrial application.

Text: Isolde Rötzer

24 hours a day, seven days a week – the gripping system at Takata AG (formerly Takata-Petri) never stops. It removes steering wheel frames from crates and places them on a conveyor belt, achieving 98 percent availability in three-shift operation. 3D object recognition software ensures not only that the system is able to locate and remove a steering wheel frame every time it reaches into the crate, but also that it selects the frame that is most convenient to grab. “This fast and reliable gripper system went on line in 2011,” says Felix Spenrath of the Fraunhofer Institute for Manufacturing Engineering and Automation IPA in Stuttgart.

### Flexible and user-friendly

At the heart of the robotic system lies software developed at the IPA. Called bp3™, this software uses a robot-controlled 3D sensor to examine the situation in the crate and locate the workpieces contained within it. It then works out which unit the gripping system can remove without coming into contact with either the sides of the crate or other steering wheel frames. Another advantage of this system is how easy it is to use: operators have no difficulty working with it after just a

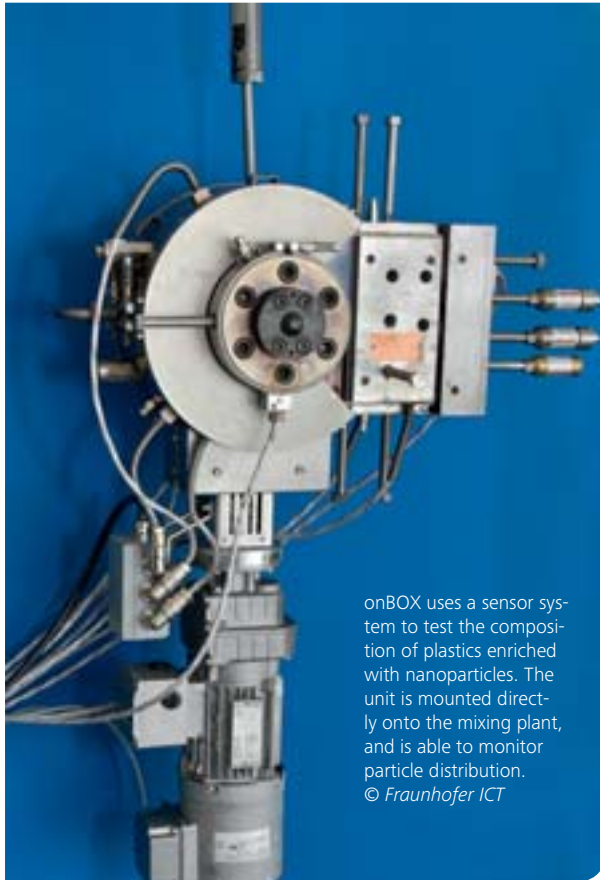
short training session, while learning how to handle different workpieces takes almost no time at all.

Many companies still transport workpieces to individual processing stations in crates or pallet cages where staff then unpack them by hand. But this kind of manual work puts a physical strain on employees that can lead to health problems further down the road. Robots and gripping systems not only relieve this burden, they also help to reduce costs. “Automation is especially important for companies in countries such as Germany as it supports domestic manufacturing,” explains Alexander Spiller, Spenrath’s colleague.

The bp3™ software was developed as part of a European research project called SMErobot (The European Robot Initiative for Strengthening the Competitiveness of SMEs in Manufacturing). Fraunhofer IPA researchers were involved from 2004 onwards and contributed to various developments in the project. “One of the things we worked on was bin picking,” remembers Spiller. A demonstrator on display at the Automatica 2010 trade fair caught the eye of automotive supplier Takata AG, then Takata-Petri.

A joint project ensued in which a complete solution comprising software and robotics was scaled up to manufacturing standards – and the resulting system is still running smoothly at Takata’s Aschaffenburg factory today.

Experts from the IPA’s Robot and Assistive Systems department have been cooperating since spring 2011 with Liebherr-Verzahntechnik GmbH, a CNC gear-cutting machine manufacturer and automation systems specialist. They are working together to turn the system into a complete package and to develop solutions fit for industrial application. “We’ve managed to bring research and practical application together in a way that works successfully,” says Thomas Mattern, head of automation system development at Liebherr. “We purchase the software license from Fraunhofer and offer our customers an all-in-one solution comprising robot and gripper, additional axes, and important strategies for parts recognition and the part picking process.” The Kempten-based specialists also provide employee training and any maintenance that is required. Liebherr and the IPA have since worked together to supply and install several systems for an American construction machinery manufacturer. ■



onBOX uses a sensor system to test the composition of plastics enriched with nanoparticles. The unit is mounted directly onto the mixing plant, and is able to monitor particle distribution.  
© Fraunhofer ICT

# Testing smart plastics in real time

Nano additives can make plastics scratch and flame proof, or give them antibacterial properties. A new device is now able to test the distribution within the plastic compound in real time.

Text: Tobias Steinhäuber

We encounter functional plastics parts whenever we open the refrigerator door. Besides being easy to clean and ergonomically shaped, the material built into a refrigerator also has antibacterial properties, thanks to nano-sized additives mixed in with pellets of plastic during the manufacturing process.

Parts like these can be modified to have all sorts of different properties, which vary according to the type and shape of the additive particles and their distribution within the polymer compound. Even though these particles are less than 100 nanometers across, it takes just a tiny quantity to make the plastic antibacterial, scratch proof and flame retardant, electrically or thermally conductive, or to give it greater mechanical rigidity. For these properties to function as intended, the ratio of pellets to additives and the overall particle distribution have to be exactly right.

Until now, checking this has always been a very complicated and time-consuming process that had to be carried out after the material is made. Manufacturers are often only able to achieve the desired plastic formula after mixing several trial batches, which slows down the production process and wastes material.

For three years the Fraunhofer Institute for Chemical Technology ICT in Pfinztal near Karlsruhe has been working in the EU-funded NanoOnSpect project to develop a tool for characterizing polymer nanocomposites during the ongoing production process. "This is not only more cost-effective in terms of material and time, it also helps us to improve the quality of the properties that the added nanoparticles bring to the polymer," says Irma Mikonsaari of the ICT.

## On-the-spot analysis

The onBOX device is simply mounted to the exit nozzle of the conveyor, where its sensors analyze and characterize the polymer compound while it is still in the mixing plant. The sensors use a combination of technologies including spectroscopy, ultrasound and microwaves to test the composition of the polymer-nanoparticle compound. They measure its viscosity, pressure and particle distribution, including any possible fluctuations in concentration, while simultaneously measuring the compound's temperature and its thermal and electrical conductivity. A computer then compares this data to the system's command variables and processes it inside an artificial neural network. The computer

determines the precise mixing ratios needed to achieve the intended effect as well as the manufacturing process this requires, and feeds this information directly to the machine's control system. "The result is that the network of nanoparticles develops just as we want it to," says Mikonsaari, "with optimal distribution of the individual particles." She adds: "We are able to characterize the state of the polymer melt as it is being discharged through the nozzle."

 [www.nanoonspect.eu](http://www.nanoonspect.eu)

The project NanoOnSpect was launched in 2011 and will run for a total of four years. A consortium of scientists and industrial partners are optimizing manufacturing processes for smart plastics that feature nanoparticle additives. They are developing technologies that help to improve characterization of the size, structure and distribution of the nanoparticle additives as well as the properties of the polymer compounds. In addition they are designing a new mixing procedure that combines the advantages of existing processes. "The onBOX is a very tangible product of our research from which industry stands to benefit immediately," says Mikonsaari, pointing out the relevance of the new tool and its scope for practical application. ■

# Laser technology is making air travel safer

Contaminated air in an aircraft's cabin can endanger both passengers and crew. As part of an EU project, researchers are developing optical sensors capable not only of detecting traces of hazardous materials, but also of recognizing explosives.

Text: Monika Weiner

May 12, 2013: A flight operated by Germanwings is forced to make an emergency landing in Geneva because of a pungent smell emanating from the cockpit. Just a few weeks previously, passengers on a Condor flight from Hamburg to La Palma had narrowly escaped disaster. One of the passengers reported: "There was a smell like burning plastic or oil vapors – definitely something chemical." He added that he had to hold a T-shirt over his nose and mouth and occasionally felt as though he couldn't breathe. Once the passengers had deplaned in La Palma, the flight crew fired up the engines again in an attempt to localize the problem, which caused the nasty smell to return immediately. Two members of the cabin crew lost consciousness and collapsed, and had to be taken to hospital.

Fear of such "fume events" occurring during air travel has been around since December 2010, when a plane came within an inch of crash landing in Cologne because the pilot's reactions had been severely dulled by having inhaled poisonous fumes. One source of such fumes is when lubricants and oil residues burn in the engines. Since fresh air for the cabin is drawn directly from the compressor section of jet engines, these combustion residues can get into the cabin and cause everyone on board to experience dizziness, nausea or even paralysis.

In the EU's MIRIFISENS project, an international team of researchers and operators are now working on a measurement device capable of raising the alarm long before the human nose gets wind of anything. "With the right sensors we can detect extremely low concentrations of organic compounds," explains Dr. Ralf Ostendorf from the Fraunhofer Institute for Applied Solid State Physics IAF. MIRIFISENS stands for Mid In-



fraRed Innovative lasers For Improved SENSors of hazardous substances, and the centerpiece of the new sensor technology is a semiconductor laser measuring just a few millimeters that produces infrared light. "The mid infrared range is particularly suitable for detecting the presence of organic compounds because the molecules absorb precisely these wavelengths, filtering out part of the spectrum in the process. Since different chemicals absorb different frequencies, each one leaves its unique fingerprint on the spectrum. This gives us a fast way of analyzing gases," says Ostendorf.

## Light from the electronic waterfall

In theory, constructing such optoelectronic sniffer devices isn't all that complicated: simply feed the sample gas in to the measuring chamber, send in an infrared light beam and then analyze the light that comes out the other side. The pattern of absorption lines indicates which organic compounds the sample contains.





But developing such analysis devices for the aviation industry is nothing to sneeze at. Not only do they have to be fast acting, they must also be reliable and – since every gram counts in air travel – lightweight too. Ostendorf's team in Freiburg is currently working on the laser source. By precisely controlling the growth of layers that are just a few atoms thick, the team can produce a semiconductor that generates photons of a specific frequency as soon as it is connected to a power source. This quantum cascade laser resembles a multi-tiered "electronic" waterfall – as electrons topple down they emit photons each time they hit an energy step. This in turn produces a whole bundle of light waves of a particular wavelength range that is then filtered to leave beams of the desired wavelength. Engineers from the Fraunhofer Institute for Photonic Microsystems IPMS in Dresden have developed a small, lightweight optical diffraction grating. "Electrostatic forces cause this grating to sway back and forth. Depending on the angle reached, it selects one of the light wavelengths to then be emitted by the laser," explains Dr. Jan Grahmann.

Dizzying heights: An optical electronic analysis device can help in the early detection of airborne contaminants in airplanes.  
© Bernhart/dpa

In the EU's MIRIFISENS project, coordinated by III-V Lab in France, experts from 18 research institutions and companies from nine countries are currently working on a new metrology technique that will allow a wide range of hazardous materials to be detected automatically. A small computer will compare the absorption lines with the fingerprints of organic compounds stored in a database. As soon as any toxic molecules are detected, the system raises the alarm.

### Sniffing out explosives, poisons and fuel

Not only is the new technique ideal for analyzing gases, it can also be used to identify hazardous materials in their liquid or solid states – detecting traces of explosives at airports, for example. "There are basically two ways of measuring. We can shine laser light through the sample and determine its composition based on the absorption lines. Alternatively, we can shine the light on a solid object and analyze the reflected light. This also uncovers fingerprints left by organic compounds," explains Ostendorf, who is convinced that there is a market for each analysis technique.

Prototypes are eagerly awaited by the MIRIFISENS project's industry partners. They plan to use the gas analysis technique to monitor the air inside airplanes. In addition the MORPHO company is currently testing the technique's suitability for the contactless inspection of passengers as they go through airport security: any potentially hazardous substances could be gathered up by an air current that is then guided through an analysis device. And yet other project partners plan to introduce the technique to sniff out any items of luggage bearing traces of explosives at distances of up to a hundred meters.

Monitoring the quality of kerosene – used as jet engine fuel – is another job for quantum cascade lasers. Infrared spectroscopy can detect even the slightest trace of organic contaminants that get mixed in with the kerosene – for instance when a fuel tanker that had previously been used to transport biofuel has not been properly cleaned. This kind of contamination can have disastrous consequences since the low temperatures encountered at 10,000 meters cause these contaminants to crystalize, which can block the flow of kerosene entirely.

Researchers are hoping to have prototypes ready and tested for all the planned applications by the time the project comes to an end in 2016. ■



[www.fraunhofer.de/en/press/audio.html](http://www.fraunhofer.de/en/press/audio.html)

# Crewless cargo ships

Fraunhofer researchers develop the concept of autonomous ships.

Text: Frank Grotelüschen

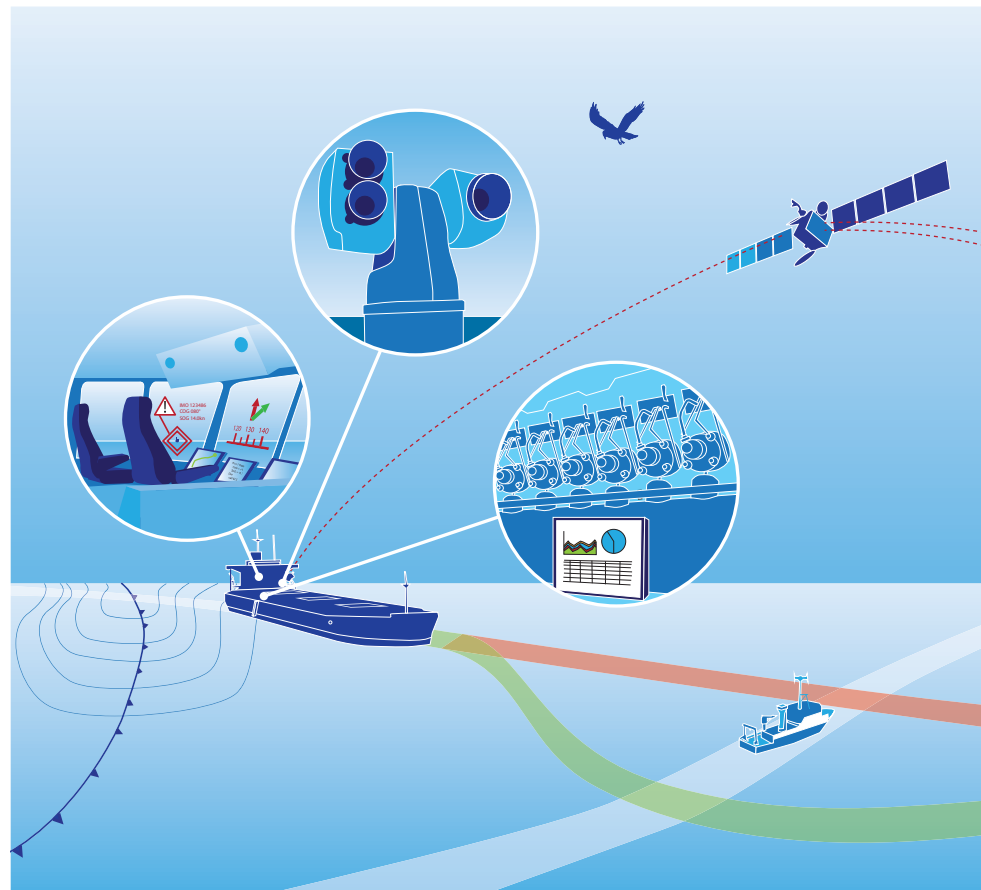
Hans-Christoph Burmeister casts his eye over the instrument panel, taking in the electronic nautical chart, the depth-sounding screen and the radar monitor beside it. Then he grabs the helm and steers his 220 meter long bulk carrier in a new direction. "We're now headed on a course of 290°, at a speed of twelve knots," he explains.

If you didn't know better, you'd think Burmeister was stood on the bridge of a real ship. But in actual fact he is at the Fraunhofer Center for Maritime Logistics and Services CML in Hamburg, standing in the middle of a room that houses a ship-handling simulator. The steering controls and instrument gauges may be just like those on a real cargo ship, but the view of the horizon out the window is just an image displayed on three screens, showing a seascape complete with white-caps, simulated twilight and the silhouettes of other ships.

The simulator is helping to progress an ambitious undertaking: the development of an autonomous ship – in other words, a bulk carrier able to navigate the world's oceans without a crew (see box). Fraunhofer scientists are working on the idea together with partners from five countries as part of the EU-sponsored MUNIN project. Burmeister, who coordinates the project, explains: "Like most industries, European shipping also has to cope with the demographic challenge in the near future. The exotic charm that the maritime industry had fifty years ago, is faded away in the networked world characterized by strict timetables." Going to sea often means being away for months at a time, which puts strain on family life. On top of that, the journeys from continent to continent tend to be fairly uneventful and instead administrative burdens characterize the work of the navigators onboard.

Some of the technology required to operate an autonomous ship is already available and in use on the bridges of modern ships. Captains today are assisted by autopilots that use GPS to follow a predetermined course, and cruise-control systems able to maintain a constant speed. Modern ships also feature radar devices and ship identification systems that scan the surrounding environment and automatically raise the alarm when the vessel is in danger. In addition to these technologies, autonomous ships would be fitted with extra sensor devices such as optical and infrared cameras to monitor the surface of the ocean and spot other vessels, flotsam or shipwreck victims.

Unmanned cargo ships are designed around a central software system. An autonomous control module evaluates all the data collected from the sensors and makes decisions such as



whether the ship should change course to avoid colliding with a container floating free in the water. Nevertheless, a crewless ship would never sail completely unsupervised. An operator would oversee everything that happens via satellite, and intervene if necessary by taking remote action. "It's conceivable that some situations might arise that go beyond what the autonomous onboard systems are able to cope with," Burmeister explains, "such as when several ships are on a simultaneous collision course or when technical failures occur." In such cases, a land-based station ready to intervene via satellite communication is able to step in and steer the ship remotely.

Burmeister fires up his simulator to show us what this intervention looks like in practice. On the screen we watch as a container vessel approaches on the port side. Despite Burmeister's freighter having right of way, the other ship seems determined not to take evasive action. To prevent a colli-

Many of the processes on the bridges of modern ships are already automated. Even the crewless ships of tomorrow will not sail completely unsupervised. © MUNIN



### Ship without a crew

The MUNIN (Maritime Unmanned Navigation through Intelligence and Networks) EU project was launched in September 2012 and will run for three years. Eight institutions from Germany, Norway, Sweden, Iceland and Ireland are involved in the project, among them the Fraunhofer Center for Maritime Logistics and Services CML in Hamburg. The total budget is 3.8 million euros, of which 2.9 million euros is provided by the European Union.

sion, the engineer takes over the control of the autonomous ship: "I deactivate the autopilot, set a change of course to starboard, drop our speed and wait until the other ship has passed." A few remote mouse clicks were all it took to avert the danger.

Control of the vessel will also be in human hands when ships dock and undock. Ships will have a crew onboard when leaving port and will remain crewed until the freighter reaches open seas, at which point the crew will disembark in pilot boats or by helicopter and leave the automated systems to take over. When a ship reaches its destination, the same thing happens in reverse: a crew will join the ship before it reaches the harbor entrance to steer it safely into port.

The MUNIN project started in fall 2012. Designing an autonomous ship means accommodating a range of incredi-

bly diverse requirements, so the experts have been puzzling over all sorts of different details. One of these is how to ensure the ship's engine can continue to run reliably for weeks at a time without an engineer checking it. As it stands, current machines are designed to function for 24 hours without supervision. "For journeys lasting two to three weeks, we would need to take extra steps to ensure the engine doesn't cut out in the middle of the Pacific," Burmeister explains. "It would make sense to include more than one of each of the most important components."

Sprinkler systems would have to come on automatically in the event of a fire on board, perhaps caused by a short circuit. Critical areas could be flooded with CO<sub>2</sub> as a preventive measure that would make it impossible for a fire to start there in the first place. In heavy seas, the autopilot would need to turn the hull to minimize the effect of the waves, and as a general rule the ship should try to avoid sailing into severe weather systems in the first place by circumnavigating them as the storms draw near. In theory an uncrewed vessel could even recognize people floating in the water. Burmeister believes that an automatic radar and camera surveillance system might even be better at spotting people than the crew on the bridge, who are often distracted by other duties and so are less reliable. Rescue boats could then be automatically launched to assist the person in the water – but this is an idea that goes beyond the scope of the MUNIN project.

### Circumnavigate potential danger with a few clicks of the mouse

But these vessels could well get into legal hot water. Without a captain on board, who takes responsibility in the event of an accident? "A project partner in Ireland is dealing with issues of this sort and drafting a legal framework for unmanned ships," says Burmeister. "It looks as though several existing regulations might have to be changed."

Due to be completed in fall 2015, the aim of the EU project is to create a computer simulation that experts can use to put their ideas to the test in a virtual environment. After that, they would be ready to fit out a real ship for full automation. "We're still a long way from autonomous freighters," says Burmeister. "But our results could benefit the crewed shipping industry long before then." Some of the components the MUNIN experts are working on would be an enormous help on the bridge of any modern ship: automatic look-out systems would help relieve the crew, while improved warning systems would help prevent collisions. ■



# Boundless broadband



The WiBACK network transmitting into the valleys from the peak of the Kronplatz. © mauritius images/Alamy

## A new data transfer technique connects even remote alpine farms to the internet.

Text: Monika Weiner

Blue skies, sunshine, well-groomed ski runs, lodges with atmosphere, all backed by the snow-crowned peaks of the Dolomites. The quilt of grazing meadows and fields in the valley are showing signs of spring. Just like out of a glossy travel brochure for South Tyrol. Perfect for skiing or simply just relaxing. The cable-drawn funicular railway is already bringing thousands of skiers and visitors up to the top of Kronplatz in early morning. Including Eric Schütz from the Fraunhofer Institute for Open Communication Systems FOKUS. He is not there for the scenery, however. Schütz is visiting a client.

The researcher, along with Florian Niederbacher from the Bruneck municipal works, steps out. His destination: the nearby transmission tower, a steel monster over 260 feet high that was erected in its time to send out the broadcast signals from television stations. The men carefully climb up the stairs in their heavy boots. A breathtaking panorama greets them from the first platform at this rarefied elevation. At the foot of the Kronplatz lies Bruneck, the center of a broad network of roads that snake through the valleys. "Many secluded farmyards and companies lie miles from Bruneck. Linking to a network that makes a fast Internet connection possible is therefore often involved and expensive," explains Schütz, a commercial communications engineer. "Installation of fiber optic cable is too expensive, the distances are too great for copper cable, and cell phone networks are too expensive and do not have sufficient transmission capacity."

### Just don't drop the connection

It's got to be broadband. Without a fast Internet connection, companies today are no longer able to compete effectively. If the infrastructure needed is not provided, companies move away, and the region's connection to the outside drops in both meanings of the word. Florian Niederbacher and his colleagues therefore decided to do something to ensure the future of the South Tyrol municipal district. In conjunc-

tion with Fraunhofer researchers from Berlin, they started a pilot project they named WiBACK. The abbreviation stands for Wireless Backhaul, a transmission system based on radio relay links. "Using a radio relay system between various nodes that can be separated from one another by up to 12 miles, you can bridge great distances simply and cost-effectively and service entire regions," explains Schütz. The advantage of the WiBack technology is its user-friendliness: "The installation of a network is normally quite involved, requiring trained technical personnel. In contrast, our system installs itself. It is so simple and easy that communities do it independently and can thus operate their own network."

The essence of the WiBACK technology is the radio relay nodes, white cabinets each not much larger than a shoebox. Four of them are attached to the tower on the peak of the Kronplatz. They are connected via a fiber optic cable with the electronic controller in Bruneck that manages the transmitting and receiving of the radio signals and data. The wireless transmission takes place from node to node: each box is equipped with a directional antenna that focuses the signals and sends them right to the next node. There, they are received and transformed by a router into WLAN that can be used by cell phones, tablets, or desktop computer users.

Because the system can operate at the same frequencies as traditional WLAN, there is no need to have a transmitting license. And the system is also secure: the data are encrypted along their journey from node to node.

### Boxes manage themselves

In addition, installation and operation are cost-effective. "The boxes are able to manage themselves. You only have to set them up so that the antennas are in each other's line-of-sight and the radio link works – the network then installs itself autonomously. If a new node is added, it

is integrated within a few minutes. So it means little effort, high reliability, and secure data," Schütz summarizes.

That all worked out smoothly in Bruneck: "WiBACK is simple to install and maintain, and allows high data transmission rates with very little latency," Niederbacher confirms. A single radio link can carry 100 Megabit/s – a luxury for the district of Bruneck. It was even free up to now, because users were not obliged to pay any fees during the pilot project. In future, the broadband connection will without doubt not be free because the municipal works now operates WiBACK commercially. However, pricing is expected to be significantly below what other telecommunications providers charge for comparable services elsewhere. The numerous requests from neighboring communities for a WiBACK connection demonstrate that the new technology is more than competitive.

The system can be expanded without difficulty: every box that is connected via radio link to a node can service households and companies within a radius of over 500 yards. And a connection can be made from any node to additional stations – as long as they are no further than 20 kilometers (12 miles) away and in line-of-sight. This way, the network can continually grow.

### Greetings from Facebook

Not only alpine farmers, residents, and companies in remote regions will benefit in future from the new technology, but tourists as well: the Bruneck municipal works have now installed a WiBACK node at the earthen pyramids near Oberwielenbach that draw thousands of visitors each year on account of their bizarre shapes and their impressive colors. The box is powered using solar cells and provides WLAN for visitors to use free of charge. It is perfect for people who want to immediately share their photos taken beside the pyramids with their friends or upload photos to social networks. ■





# A new rubber recipe

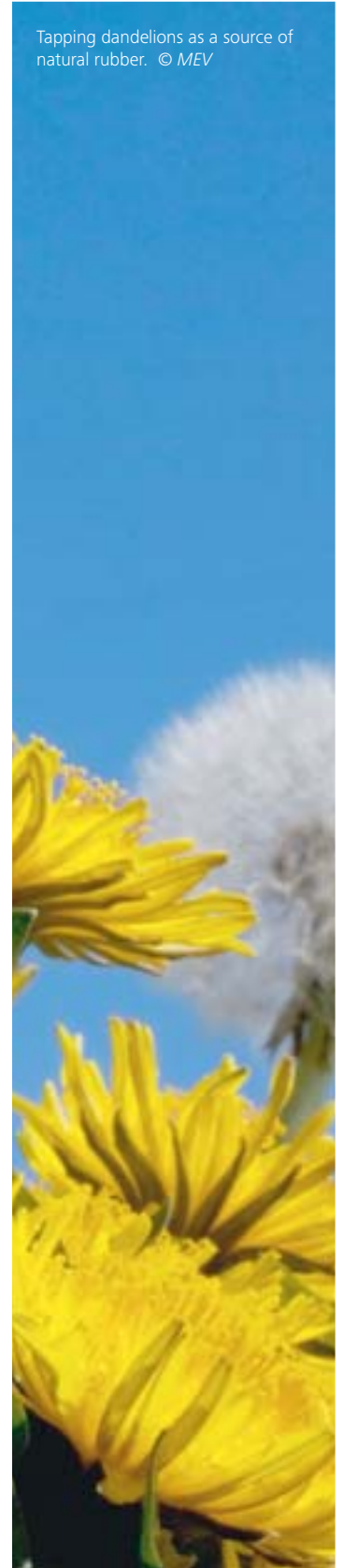
Fraunhofer scientists have succeeded in breeding dandelions with roots that yield particularly high volumes of natural rubber. In cooperation with Continental to turn their findings into an industrial-scale production process and just recently won “GreenTec Award”, Europe’s largest environmental and business prize.

Text: Tobias Steinhäuser

In the manufacture of vehicle tires, getting the compound right takes a good feel for ingredients – and rubber is essential. It is what lends a tire its elasticity and the necessary braking performance, while also ensuring it stands up to variations in weather and road surface. Up to 45 percent of a tire can be made up of natural and synthetic rubber. The coveted ingredient of natural rubber comes mainly from the milky sap of the rubber tree; natural rubber is also known as caoutchouc, an Amazonian Indian word meaning “tree of tears” (cao = tree; ochu = tears). By scoring the bark of the tree, growers can tap the “latex tears” and collect them in containers hung below.

But it’s not all that easy for tire manufacturers to get their hands on this sought-after sap. Rubber trees grow in tropical regions, are particularly

Tapping dandelions as a source of natural rubber. © MEV





Scientists have tamed the wild dandelion to produce a crop that delivers large amounts of natural rubber.  
© Fraunhofer IME

susceptible to pests and have exceedingly long vegetation periods. Chemist Dr. Carla Recker from Continental describes the current challenges: “At the moment, we have to import this raw material from far away and must contend with price fluctuations on the international market for natural rubber.” Recker, who heads up the Material Chemistry expert field within Continental’s Tire division, knows a thing or two about what goes into tires – one of her main jobs is to oversee the development of new raw materials and rubber compounds.

### High-yield Russian variety fits the bill

Ever since she met Dr. Dirk Prüfer from the Fraunhofer Institute for Molecular Biology and Applied Ecology IME, Recker just can’t get one particular ingredient out of her head: liquid latex from dandelions. Native to Europe and Asia, the dandelion – or more specifically, the Russian variety of the plant – is extremely hardy and delivers flawless raw materials for tires. What is more, it can be grown in many countries, including Germany – even on land that is generally unsuitable for growing other crops.

Although dandelion roots have been a known source of rubber since the mid-twentieth century, an industrial application was unthinkable until just a few years ago. Hardly anything was known about individual varieties of the plant and how much rubber each could provide – not to mention the biological mechanisms behind rubber production. “Wild varieties simply didn’t deliver high enough yields and were extremely reluctant candidates for cultivation,” explains Prüfer. Working together with partners from science and industry, the molecular biologist and his team made the decisive breakthrough: they managed to breed plants that offer a particularly high latex yield and to design a laboratory-scale pilot facility for obtaining natural rubber from dandelion roots.

### Faster, more targeted breeding

So after over fifty years of stagnation, why is so much happening now? Surrounded by his dandelion crop in a greenhouse at the IME’s



Münster site, Prüfer picks up one of the potted seedlings: “The answer lies in modern molecular biology. Thanks to the latest analysis techniques, we’re now able to breed plants for more specific purposes and faster than ever before.” Previous generations of breeders had to let each vegetation period run its course before finding out whether their hybrids were a success. This was an arduous and long-drawn-out process; sugar beet, for example, took more than 200 years to evolve from its initial cultivated form to the crop we know today. Such methods have now been eclipsed by genetic analysis. “Today we can analyze a plant’s genes in great detail almost immediately after the seeds are sown. This allows us to quickly determine which genetic predispositions encourage and which hinder the production of rubber in dandelion roots,” says Prüfer. IME scientists even managed to deactivate the gene that makes latex clot quickly. In a pilot mill facility, they succeeded in extracting several kilograms of rubber from dandelion roots – achieving a product of the same quality as that extracted from the species of rubber tree found in tropical countries and then exported.

Just how heavy vehicle tires are is relative to their size. Common car tires weigh between 7 and 15 kilograms, while those found on trucks can weigh anything from 50 to 80 kilograms. “Some tire models contain more than 20 kilos of natural rubber,” says Recker. In order to satisfy this level of demand, facilities need to be capable of producing ton upon ton of natural rubber. A facility on that scale using dandelions has never existed – and that is what Recker and Prüfer plan to change. Fraunhofer and Continental began their collaboration in October 2013. Their goal for the next five years is to build a production site for the manufacture of

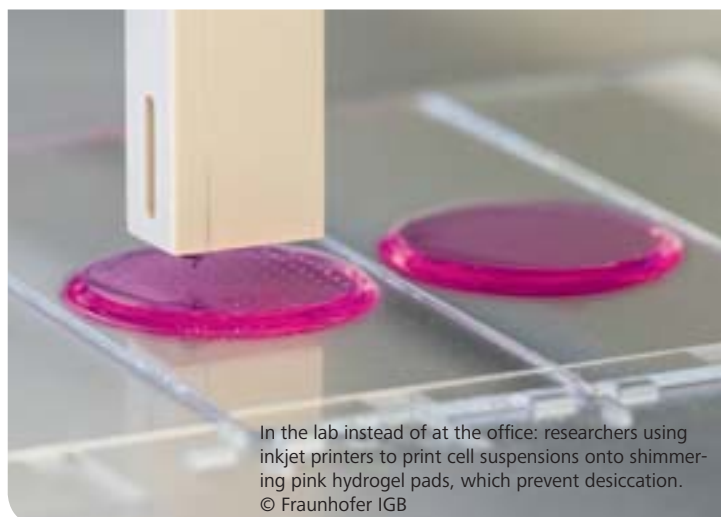
vehicle tires. Over the coming years, they plan to take to the streets to put the first tires made from rubber compounds containing dandelion rubber through their paces.

### Industrial pilot facility in Münster

Construction of the pilot facility is currently underway at the IME’s Münster site. At the same time, the partners are raising several hectares of high-rubber-content dandelions in fields in Bavaria and Saxony-Anhalt. And in order to optimize both the raw material yield and the plants’ blossom properties, the scientists are also cultivating new plants that offer an even higher proportion of latex and higher biomass yield. “We’re aiming to create a new variety characterized by consistently high rubber content. To achieve this, we plan to spend the next five years both extending our knowledge of molecular biological processes and expanding our plant-raising efforts,” says Prüfer.

Up to now, dandelions were seen merely as a wild-growing herb that peppered fields, gardens and the edges of paths. Most of us only really notice them at all when we see their gray-white seeds caught in our hair or clothes, or when we take a seed head and blow the seeds around in fun. Children feed green dandelion leaves to their rabbits and guinea pigs. A few of us use the plant’s healing properties to treat indigestion and bloating, or harvest the yellow blossoms to make tasty salads and honey-like spreads. Thanks to Fraunhofer and Continental’s dandelion-rubber project, the Russian variety could soon appeal to the automotive industry, too – as a cost-effective and eco-friendly ingredient for vehicle tire compounds. ■

# Need different types of tissue? Just print them!



In the lab instead of at the office: researchers using inkjet printers to print cell suspensions onto shimmering pink hydrogel pads, which prevent desiccation.  
© Fraunhofer IGB

What sounds like a dream of the future has already been the subject of research for a few years. Now scientists are able to produce various tissue types.

Text: Tobias Steinhäuber

The recent organ transplant scandals have only made the problem worse. According to the German Organ Transplantation Foundation (DSO), the number of organ donors in the first half of 2013 has declined more than 18 percent in comparison to the same period the previous year. At the same time, one can assume that the demand in the next years will continuously rise, because we continue to age and the field of transplantation medicine is continuously advancing. Many critical illnesses can already be successfully treated today by replacing cells, tissue, or organs. Government, industry, and research institutions have therefore been working hard for some time to improve methods and procedures for artificially producing tissue. This is how the gap in supply is supposed to be closed.

## Bio-ink made from living cells

One technology might assume a decisive role in this effort, one that we are all familiar with from the office, and that most of us would certainly not immediately connect with the production of artificial tissue: the inkjet printer. Scientists at the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB in Stuttgart have succeeded in developing suitable bio-inks for this

printing technology. The transparent liquids consist of components from the natural tissue matrix and living cells. The substance is based on a well known biological material: gelatin. Gelatin is derived from collagen, the main constituent of native tissue. The researchers have chemically modified the gelling behavior of the gelatin to adapt the biological molecules for printing. Instead of gelling like unmodified gelatin, the bio-inks remain fluid during printing. Only after they are irradiated with UV light, they crosslink and cure to form hydrogels. These are polymers containing a huge amount of water (just like native tissue), but which are stable in aqueous environments and when being warmed up to physiological 37°C. The researchers can control the chemical modification of the biological molecules so that the resulting gels have differing strengths and swelling characteristics. The properties of natural tissue can therefore be imitated – from solid cartilage to soft adipose tissue.

In Stuttgart synthetic raw materials are printed as well that can serve as substitutes for the extracellular matrix. For example a system that cures to a hydrogel devoid of by-products, and can be immediately populated with genuine cells. “We are concentrating at the moment on the ‘natural’ variant. That way we remain very close to the original material. Even if the potential for synthetic hydrogels is big, we still need to learn a fair amount about the interactions between the artificial substances and cells or natural tissue. Our biomolecule-based variants provide the cells with a natural environment instead, and therefore can promote the self-organizing behavior of the printed cells to form

a functional tissue model,” explains Dr. Kirsten Borchers in describing the approach at IGB.

The printers at the labs in Stuttgart have a lot in common with conventional office printers: the ink reservoirs and jets are all the same. The differences are discovered only under close inspection. For example, the heater on the ink container with which the right temperature of the bio-inks is set. The number of jets and tanks is smaller than in the office counterpart as well. “We would like to increase the number of these in cooperation with industry and other Fraunhofer Institutes in order to simultaneously print using various inks with different cells and matrices. This way we can come closer to replicating complex structures and different types of tissue,” says Borchers.

## The big challenge

The big challenge at the moment is to produce vascularized tissue. This means tissue that has its own system of blood vessels through which the tissue can be provided with nutrients. IGB is working on this jointly with other partners under Project ArtiVasc 3D, supported by the European Union. The core of this project is a technology platform to generate fine blood vessels from synthetic materials and thereby create for the first time artificial skin with its subcutaneous adipose tissue. “This step is very important for printing tissue or entire organs in the future. Only once we are successful in producing tissue that can be nourished through a system of blood vessels can printing larger tissue structures become feasible,” says Borchers. ■

## Traditional wines

Contact: Cecilia Díaz, [cecilia.diaz@ime.fraunhofer.de](mailto:cecilia.diaz@ime.fraunhofer.de)

Modern vintners are testing an ancient method. Instead of aging wine in wooden barrels, they are using qvevris, the amphorae or earthenware vessels typically used in the southern Caucasus. Two thousand years ago, this form of wine making was also widespread throughout the ancient Mediterranean world. But from the first century BC onwards the amphorae here were largely displaced by wooden barrels because of a serious drawback with the old production method: the quality of the future wine can't be predicted. For most vintners, this is just too risky. Now a researcher at the Fraunhofer Institute for Molecular Bi-

ology and Applied Ecology IME has worked with Weinkellerei Albert Mathier & Söhne, vintners based in the Swiss canton of Valais, to develop a yeast-detecting biochip. The detector is based on antibodies that can distinguish between different species of wild yeast. This allows wine-makers to determine if the selected grapes are suitable for fermentation and whether they will result in the desired taste.

This is the first time that the dynamic behavior of different yeasts has been investigated in real time and that different qvevri wines from all over Europe have been chemically analyzed.

Although the quality of the wine can't be predicted, aging wine in earthenware amphorae is growing in popularity. © shutterstock



Not every clinic makes use of embolization particles, in particular because until now both the particles' properties and their availability in hospitals have been unsatisfactory. © Fraunhofer IPA

## Starving cancer cells

Contact: Axel Storz, [axel.storz@ipa.fraunhofer.de](mailto:axel.storz@ipa.fraunhofer.de)

To survive, each individual cell in the body requires a sufficient supply of nutrients. Cancer cells in particular grow quickly and need a lot of sustenance. But that can be blocked by biocompatible polymer micro-particles that cut off the flow of nutrients by deliberately seizing the network of small blood vessels. Using a micro catheter, doctors can deliver these particles in a liquid solution directly to where they are needed. Together with physicians from the Mannheim Institute for Clinical Radiology and Nuclear Medicine (IKRN), researchers from the Project Group for Automation in Medicine and Biotechnology PAMB at Fraunhofer IPA in Mannheim have developed a new method to visualize the micro-particles with X-rays and in Magnetic Resonance Imaging (MRI).

## First aid for companies

Contact: Marc Rüger, [marc.rueger@iao.fraunhofer.de](mailto:marc.rueger@iao.fraunhofer.de)

With the lifecycle of business models shortening by the day, companies need to keep up with a rapidly changing business environment - as KPMG's "Survival of the smartest" study testifies. Some companies cannot cope with this challenge alone. To come to their assistance, the Fraunhofer Institute for Industrial Engineering IAO and the accounting company KPMG AG founded the Center of Business Model Engineering (CBME).

The goal of the CBME is to support companies as they redefine their business models and provide assistance over a longer period of time as necessary. CBME is avoiding companies from being left behind in the rapidly changing market.





# Sound of silence

Researchers are developing the speaker of the future in a room from which no sound escapes to the outside world.

Text: Monika Weiner



The massive door seals shut, the lock clicks, then everything is still. Frighteningly still. Thick wedges of mineral wool project like thorns into the room and swallow up every sound. The Acoustics Lab has massive walls of concrete and an independent foundation resting on a layer of rubber. Not a peep can interrupt the investigations here.

Wait – there is something. A quiet muttering? Or is someone singing? The hardly perceptible noise comes from a row of eight small loudspeakers mounted on a tripod in the middle of the room. And that is supposed to be the audio technology of the future? Curious, I follow Dr. Daniel Beer as he goes directly over to the strip of loudspeakers. The quiet muttering does not grow any louder, despite our coming so close. Or at least, not when you remain in the center. Now Beer takes a step to the right and waves me over. I walk over to him and suddenly hear music loud and clear: Marla Glen's "Cost of Freedom". As I take a step back toward the center, the music becomes softer and finally fades away completely. Astonishing! And if you step a little to the left, the voices grow louder: here you can listen to an audio book playing.

Researchers at the Fraunhofer Institute for Digital Media Technology IDMT in Ilmenau, Germany,

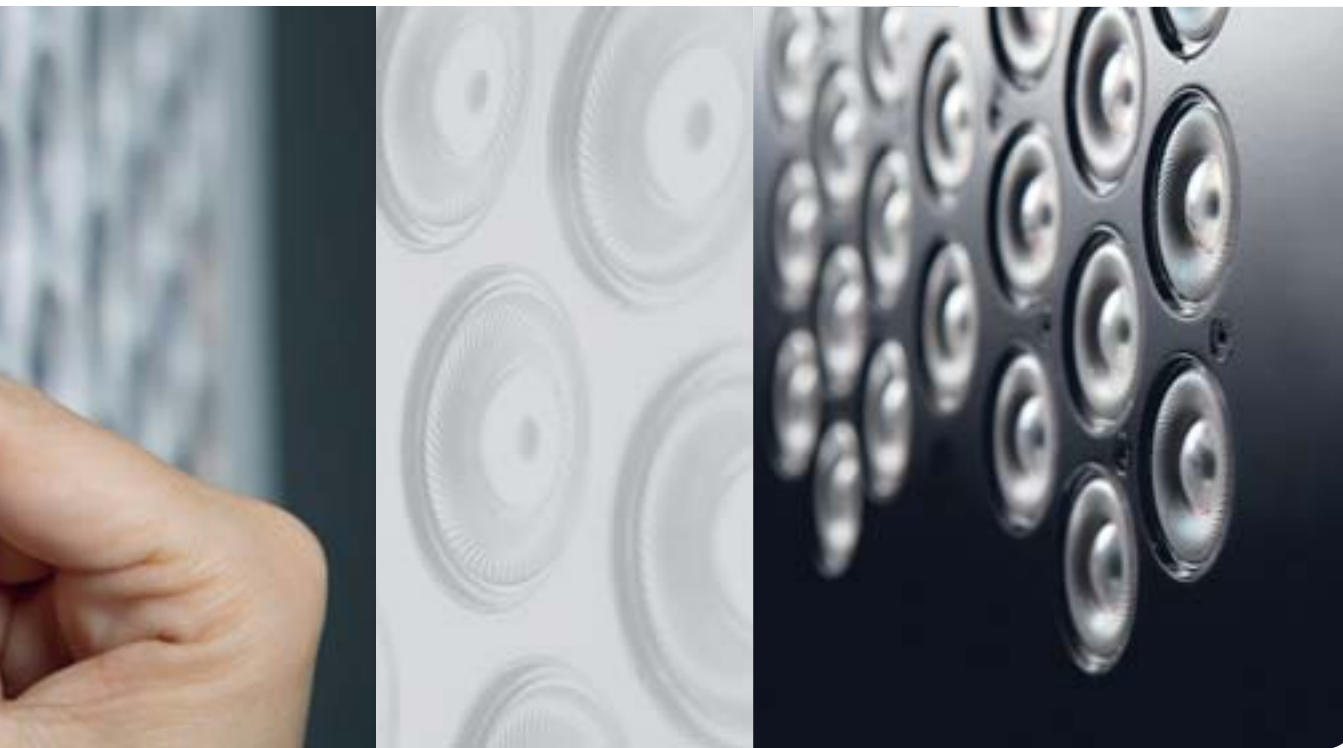
have recently applied for a patent covering the technology that creates differing "Sound Zones". The trick: "All the speakers radiate the same program material – the audio book and the song," explains Dr. Daniel Beer, head of the Electroacoustics Group at IDMT. "Control of the loudspeakers assures that the sound waves are superposed and thereby either amplified or cancelled." This way, beams of high-quality sound are formed that can be precisely directed. Such as in a vehicle, for example. Located in the automobile headliner, the loudspeakers would provide acoustic autonomy for all of the occupants. Parents could relax during a trip listening to music without being disturbed by children's audio books entertaining youngsters in the backseat. Theoretically, an independent sound field can be created for each one of the seats. No wonder the automobile manufacturers have shown great interest in the new Personal Sound Zone technology.

However, the loudspeakers are still too bulky. The speaker enclosures that the demonstrator is constructed from in the Acoustics Lab of IDMT each require a volume of two centiliters – the size of a shot glass. The entire loudspeaker array is 34 centimeters long and four centimeters thick – an arrangement that has not been suitable for

incorporation into the roofs of automobiles so far. The speakers therefore have to shrink: "One of the obstacles in miniaturizing the setup is the enclosure," explains Beer. His left hand forms an imaginary space which his right hand approaches closer and closer. "If we make the enclosure too small, the air in the interior acts like an attenuator that restricts the vibration of the membrane. You can imagine it like an air pump that is closed off: the air in the pump cannot escape and the piston that has to move to pump air is stuck. The same thing would happen to the membrane in too small a loudspeaker."

Couldn't you just do without the enclosure? "Theoretically yes," answers the engineer. "Without the enclosure, however, the sound produced by the transducer that transforms the electrical signals into acoustical ones would go in all directions." This would lead to a large loss of sound quality, because the interference of the sound emanating from the front side of the membrane and the rear side would delete a good part of the low frequency sound waves. In short: the enclosure is necessary. It is a pivotal element of good sound.

How far can it be reduced in size, though? To find that out, Beers' team set up a measure-



The loudspeaker panels of the future are thinner than a nickel or a quid, as powerful as a floor speaker and can be mounted directly on the wall. The arrays consist of an arrangement of small transducers that convert the electrical signals into acoustic ones (left images).

Close-up of the transducer arrays (images center and right). © Fraunhofer IDMT

ment station in the basement of the Institute to determine the minimum enclosure volume for each transducer. There is a new design on the test pedestal today – especially flat, especially small. Although only 11 mm thick, it contains all of the components needed by a transducer: the membrane with a coil on its rear surface, and the permanent magnets.

Beer rolls up the sleeves of his hoody and powers up the transducer. Because an electromagnetic field now develops around the coil, which is magnetically attracted or repelled by the permanent magnets, the membrane begins to vibrate. "Because the signal current in the coil is moving through the magnetic field of the permanent magnets, the current carrier – the wire of the coil – feels a perpendicular force proportional to the signal current and moves the coil as well as the membrane attached to it."

Software calculates the necessary volume of the enclosure from the vibration behavior. The new transducer requires a volume of one centiliter – about half a shot glass. It has therefore been reduced by half compared to the demonstrator. The volume can even be reduced further using technical tricks: "By using stronger drive that overcomes attenuation by the air, we can save an

additional third," explains Beer. The enclosure for the midget transducer is precisely constructed in the Institute's own workshop. Does the miniaturized loudspeaker still deliver the desired performance?

For the acid test, we return to the Acoustics Lab. And again encounter this eerie silence. Beer's voice sounds muted: "Admittedly, it's something you have to get accustomed to. But I like being here. It is the ideal place to test loudspeakers because there are no reflections to disrupt the measurements." The room is almost acoustically dead. Almost, because reflections can never be eliminated 100%, despite the thick wedges of mineral wool. So the researchers refer to their lab as "poorly reflecting."

#### Acid test in the Acoustics Lab

Beer has mounted the loudspeaker on a pedestal that rotates, and he now closes the door – from the outside, because no one may remain inside during testing: sound waves reflecting from a human body could taint the results. He starts the standardized test remotely from the control room next door. He can observe what happens via a camera. The new loudspeaker rotates around its own axis on the stand one degree at a time, then

turns facing upward and rotates again until all the directions in the room have been covered. He generates identical tones at every measurement point that sound like the squeal of a guinea pig. A microphone captures this sine-wave sweep tone and sends the signals to a computational unit. Now curves appear on the monitor screen. Beer nods in satisfaction: the radiation pattern is good. "If we improve the little loudspeaker a bit more, it should be powerful enough and loud enough to overcome the road noise." Eight of them located beside one another could then make individualized listening pleasure possible for the occupants of a vehicle, thanks to the Personal Sound Zone technology.

The new mini-speakers are not just suited to mobile sound applications, though. Flat speaker arrays containing dozens of the small sound sources connected can create optimum sound in living and conference rooms. "The sound quality is comparable to high-quality stereo loudspeakers," Beer emphasizes. And thanks to the tiny integrated enclosure, these kinds of flat speakers can be mounted directly on the wall, which opens up completely new applications. You can integrate them into a decorative picture, a flat-screen monitor, or a cabinet door. The sound of the future will no longer distract the eye. ■

## Fraunhofer technology used by Google

Now Android users can enjoy Google Play movies in cinema-quality surround sound. Google and the Fraunhofer Institute for Integrated Circuits IIS deliver the first movies with a true 5.1 channel surround sound experience. The immersive sound quality consumers have come to expect from TV, Blu-ray disc or DVD is now available with movies streamed or downloaded from Google Play directly to their Android devices running 4.1 or later.

Google chose HE-AAC Multichannel as Android's only surround sound codec due to its open-standard nature and excellent bit-rate efficiency.

When connected to a surround sound system and TV with an HDMI cable, Android users will be able to play high quality audio and video from their smartphones and tablets in surround.

## European Innovation Prize for Fraunhofer

Technology can assist in compiling history. For software that reconstructs files of the East German state security service Fraunhofer researchers received the European Innovation Prize from the European Association of Research and Technology Organisations EARTO recently.

Shortly before the fall of the Berlin Wall in autumn 1989 employees of the former East German state security service (Stasi) shredded about 40 million pages of documents by hand. The result: about 600 million paper fragments that contain the information about Stasi employees, human assets, and victims. Hand-assembling the pages, which were torn into as many as several dozen pieces each, is only possible to a limited extent and would take centuries. Comprehensive and considerably faster reconstruction

will be possible using the ePuzzler, developed by the researchers at the Fraunhofer Institute for Production Systems and Design Technology IPK in Berlin. The software evaluates the previously digitized snippets with the help of complex algorithms. Images of matching pieces are sought based on features such as shape, color, texture, lines, and lettering, then joined virtually together. "We immediately reduce the search space of the immense quantity of pieces this way and thereby accelerate the actual puzzle-solving process considerably," explains Jan Schneider, head of the IPK project.

The ePuzzler's technology is not only useful just for reconstructing the Stasi files. It is also interesting for reconstruction as well as preservation of culturally and socially significant documents and objects.

## Lasers for new markets

Small and medium-sized enterprises are often confronted with the challenge of how to take new manufacturing processes, designed to facilitate efficient production, and make them accessible to users in industry. This is an area where laser-based manufacturing processes have long led the way. Yet making these developments usable in industry, and opening up new markets, calls for a precise definition of the technical requirements, as well as in-depth knowledge of the market, combined with networking between users, suppliers and research institutes. Now the LASHARE project, co-funded by the EU, has been launched to give more than 30 SMEs a helping hand, bringing together six of the most renowned European research institutes under the leadership of the Fraunhofer Institute for Laser Technology ILT. The ambitious aim of the project is to enhance the competitiveness of the European laser industry by accelerating technology transfer.



Shortly before the fall of the Berlin Wall employees of the former secret police shredded about 40 million pages of documents by hand. © Fraunhofer IPK



## EMMY award



Thomas Schierl receives the Emmy Award in the Technology & Engineering category. © Fraunhofer HHI

Established in 1948 by the National Academy of Television Arts & Sciences, the Technology Emmy Award honors outstanding developments and innovations in the field of broadcasting. This year an Emmy Award in the Technology & Engineering category has been given to the Motion Picture Experts Group – MPEG – for the development of the MPEG-2 Transport Stream standard. As part of MPEG, Fraunhofer Heinrich Hertz Institute HHI played a leading role in the evolution of the MPEG-2 Transport Stream standard, particularly in integration of new video coding formats like MVC and HEVC.

MPEG-2 first came into use as a video and transport standard for digital TV in the 1990s. Today most of the world's digital receivers – from televisions and Blu-ray players to smartphones and tablets – are equipped with the MPEG-2 Transport Stream format for video reception. The numerous contributions made by Fraunhofer to the standardization of the format have enabled the standard to keep pace with the fast growing market for digital end devices.

## European cloud security

Fraunhofer Institute for Open Communication Systems FOKUS and Budapest University for Technology and Economy will collaborate in the development of strategies for secure Cloud Computing within European research projects.

The cooperation started recently with the signing of a Memorandum of Understanding during the Hungarian Innovation Forum. The Fraunhofer Innovation Cluster "Next Generation ID" contributes to the projects by creating solutions for secure identification of people, objects and services.

Bundesdruckerei GmbH and the Hungarian Central Office for Administrative and Electronic Public Services are official partners of the project. Fraunhofer FOKUS and the Technical University Budapest aim to secure the use of cloud technologies by protecting data and identities.

### Editorial notes

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