

# Fraunhofer 1/19 special issue magazine

LEARNING SYSTEMS AND SMART MACHINES – HOW DO WE TAP THEIR POWERS WITHOUT RELINQUISHING CONTROL OVER OUR DATA? QUANTUM EFFECTS – **HOW** CAN THEY HELP US COMMUNICATE MORE SECURELY AND MEASURE MORE ACCURATELY? KEEPING LIFE AND LIMB OUT OF HARM'S WAY – HOW **DO** WE LIVE UP TO THE RESPONSIBILITY OF MAKING EVERYONE FEEL SAFE? NEW MATERIALS – HOW DO **WE DEVELOP** SUBSTANCES WITH CUSTOMIZABLE PROPERTIES FOR MASS MANUFACTURING? SUSTAINABLE DEVELOPMENT AND PROCESSES – HOW DO WE TAKE CUES FROM NATURE'S INGENUITY TO BUILD BETTER TECH? MEDICINES – HOW DO WE MANUFACTURE **THE** DRUGS THAT PROVIDE FASTER, MORE AFFORDABLE RELIEF TO PATIENTS? MOBILITY – HOW DO WE SAVE **FUTURE** JOBS WHEN VEHICLES RUN ON ELECTRICAL POWER? AND HOW DO WE KNOW WHICH IDEA IS THE RIGHT ONE? LOOKING BACK TO YESTERDAY'S ACCOMPLISHMENTS AND AT TODAY'S POSSIBILITIES, WE KEEP ASKING: WHAT'S NEXT?

70 YEARS OF  
FRAUNHOFER  
**70 YEARS  
OF FUTURE**  
*#WHATSNEXT*

# WHAT'S THE IQ OF AI?

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**70 YEARS  
OF FUTURE**  
#WHATSNEXT

# 70 years of Fraunhofer – a dynamic success story



Prof. Reimund Neugebauer  
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The future has always been the force that drives the Fraunhofer-Gesellschaft. Our researchers ask the right questions, finding the answers that need to be found, the solutions that deliver immediate benefits to industry and society. How do we build smart, universally trusted machines? How do we manufacture drugs that provide faster, more affordable relief to patients? How do we live up to the responsibility of making everyone feel safe? And how do we know which idea is the right one? As researchers, entrepreneurs and visionaries, we see ourselves as pacesetters, an engine of progress that propels the advance of science and society. Our innovative powers, our partners and workforce, our 70-year history – these are the outward signs of our success.

Founded in Munich in spring of 1949, the Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V. was born to help rebuild Germany's de-industrialized post-war economy. On March 26, 1949, State Secretary Hugo Geiger invited 210 scientists, businesspeople and politicians to the Bavarian Ministry of Economic Affairs. While children played amid the rubble, and the Wirtschaftswunder – Germany's postwar economic miracle – was still a distant prospect, three people gathered in a Munich office to begin exploring ways of advancing the cause of applied research in Germany. Today, the Fraunhofer-Gesellschaft is Europe's largest organization in this field of endeavor.

Fraunhofer-Gesellschaft elected Hermann von Siemens president in late 1954 and founded the first of its institutes, taking it closer to its goal of becoming a mainstay of research in Germany. By 1969, it had grown to 19 institutes and research units with 1200 employees. Restructuring and a redoubled focus on contract research in the early 1970s set off another surge of growth. The Fraunhofer model of performance-based funding triggered the dynamic success that shows no signs of slowing. It rewards stellar performance, thereby providing the spark that ignites excellence.

Contract research accounts for more than two-thirds of the Fraunhofer-Gesellschaft's budget; funding from federal and state governments for roughly a third. With this business model and its laser-like focus on new technologies and markets, the Fraunhofer-Gesellschaft has become the domestic economy's innovation engine. Its inventions range from airbags, mp3 technology and white LEDs to dandelion rubber. Electric mobility, cognitive systems, programmable materials, quantum technology, translational medicine, public safety – these are but a few of the many fields explored by its researchers.

It is essential to not only conduct research with excellence and efficiency, but also to identify new topics at an early stage and set things in motion for the future. This enables us to respond that much faster to market demands. Our employees are the bedrock of our success. Like our eponymous founder, they strike the right balance between research and entrepreneurship, take responsibility for the future, develop solutions for tomorrow's challenges and keep asking: What's next?

I hope you enjoy reading our first edition of the *Fraunhofer magazine* in its anniversary year!

Yours sincerely,

Reimund Neugebauer  
President of the Fraunhofer-Gesellschaft

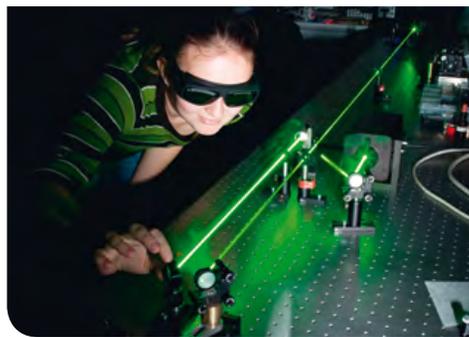
LEARNING SYSTEMS AND SMART MACHINES – HOW DO WE TAP THEIR POWERS WITHOUT RELINQUISHING CONTROL OVER OUR DATA? QUANTUM EFFECTS – **HOW** CAN THEY HELP US COMMUNICATE MORE SECURELY AND MEASURE MORE ACCURATELY? KEEPING LIFE AND LIMB OUT OF HARM’S WAY – HOW **DO** WE LIVE UP TO THE RESPONSIBILITY OF MAKING EVERYONE FEEL SAFE? NEW MATERIALS – HOW DO **WE DEVELOP** SUBSTANCES WITH CUSTOMIZABLE PROPERTIES FOR MASS MANUFACTURING? SUSTAINABLE DEVELOPMENT AND PROCESSES – HOW DO WE TAKE CUES FROM NATURE’S INGENUITY TO BUILD BETTER TECH? MEDICINES – HOW DO WE MANUFACTURE **THE** DRUGS THAT PROVIDE FASTER, MORE AFFORDABLE RELIEF TO PATIENTS? MOBILITY – HOW DO WE SAVE **FUTURE** JOBS WHEN VEHICLES RUN ON ELECTRICAL POWER? AND HOW DO WE KNOW WHICH IDEA IS THE RIGHT ONE? LOOKING BACK TO YESTERDAY’S ACCOMPLISHMENTS AND AT TODAY’S POSSIBILITIES, WE KEEP ASKING: WHAT’S NEXT?

**70 YEARS OF FRAUNHOFER  
70 YEARS OF FUTURE  
#WHATSNEXT**

**06**

**70 years of Fraunhofer**

This edition looks back to what we have achieved and, more importantly, ahead to the future. For this is how we go about our business, every day facing up to tomorrow’s questions boldly and with curiosity.



**24**

**An enlightening education**

Working with lasers – that is sure to be a top priority on the program at the Max Planck School of Photonics.



**44**

**State-of-the-art VR in the Elbedome**

The Elbedome affords companies the opportunity to bring models of machines, plants, factories and even entire cities to life.



**54**

**Living cells as sensors**

Cell-based sensors – an amalgam of biological and physical components.



**60**

**Signposts to the future**

Futures studies have recently started drawing on citizen participation and big data analyses.



**66**

**Fraunhofer research: the Swedish connection**

Sweden, a key partner country for applied research.

# Content

## 47 International

## 70 Events in the anniversary year

## 71 Editorial notes

## 70 years of Fraunhofer

**06 The dynamics of success – a chronicle**  
Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V. was born in spring of 1949

**12 “An elementary driver of innovation for the economy and society”**  
An interview with Prof. Reimund Neugebauer

## Solutions for tomorrow

**15 Go Beyond 4.0: Industrie 4.0 and then some**  
Finding a way to customize mass manufactured products

**18 Seven initiatives for the business hub Germany**  
End-to-end business-enabling solutions by Fraunhofer

**20 A thinking Internet**  
Cognitive Internet Technologies – a Fraunhofer Cluster of Excellence

**22 From square one to pilot production**  
The full package from the Research Fab Microelectronics

**24 An enlightening education**  
The Max Planck School of Photonics

**28 “I see myself as a clinician-scientist”**  
An interview with Prof. Antje Prasse

## Spin-offs

**30 Specialist for dental CAD: exocad**  
Fraunhofer Venture support spurs spin-off to success

**32 Multiphoton Optics: a spin-off from Würzburg**  
Seizing a slice of the market with ultra-precise 3D printing

## Information and communication

**34 Authentic holograms with new 3D video technology**  
Bringing a sci-fi experience to life

**36 “We need an education campaign in digital technology”**  
An interview with Prof. Ina Schieferdecker

## 38 Data science: learning from the experts

Coping with mountains of data courtesy of certified courses from the Fraunhofer Big Data AI alliance

## 40 The data detectives

The “sexiest job of the decade” – Dr. Dirk Hecker explains why data scientist is a hot job these days

## 42 Photon-based data encryption

Secure communication in the quantum age

## 44 State-of-the-art VR in the Elbedome

Europe’s biggest 3D mixed reality lab

## Energy

## 48 The transition to renewables – not a done deal

An interview with Prof. Kurt Rohrig and Prof. Hans-Martin Henning

## Biological transformation

## 52 When plastics become biologically active

Antimicrobial peptides: goodbye germs, hello squeaky-clean surfaces

## 54 Living cells as sensors

How do pharmaceuticals or environmental toxins work? Cell cultures have the answers

## 58 Lessons from the rain forest

Don’t grow, network

## #WHATSNEXT

## 60 Signposts to the future

Citizens opt in to futures study

## 64 Encouraging patients to research their own condition

Cystic fibrosis patients collaborate with scientists

## International activities

## 66 Fraunhofer research: the Swedish connection

Fraunhofer-Gesellschaft set up its first European research center outside Germany in Gothenburg 18 years ago

# March 26 Foundation of the Fraunhofer- Gesellschaft

Hugo Geiger  
Chairman of the senate



Joseph von Fraunhofer,  
namesake of the  
organization  
© Deutsches Museum

Prof. Walther Gerlach is appointed  
Fraunhofer's first president



Prof. Walter Gerlach  
© Fraunhofer

Dr. Wilhelm Roelen is appointed  
Fraunhofer's second president



Dr. Wilhelm Roelen  
© Fraunhofer

Prof. Emil Sörensen  
Chairman of the senate

Dr. Hermann von Siemens  
is appointed Fraunhofer's  
third president



Dr. Hermann von Siemens  
© Fraunhofer

Funding is extended to  
researchers throughout  
the federal republic

# 1949

# 1951

# 1953

# 1955

# 1950

# 1952

# 1954

# 1956

Funding for selected  
researchers, primarily  
in Bavaria

Start of  
cooperation  
with the Federal  
Defence Ministry



Romanstraße, Munich, original premises of the  
Fraunhofer-Gesellschaft © Fraunhofer

## The Marshall Plan

Initial funding comes from the European Recovery Program,  
better known as the Marshall Plan

Hans Luther, chairman of the senate and former German  
Reich chancellor



© Fraunhofer

## June 1 Establishment of the first Institute

for Applied Microscopy,  
Photography and Cinematography  
in Mannheim



Grinding and polishing benches from Joseph von Fraunhofer's workshop  
© Fraunhofer



The original glassworks, with the towers of Benediktbeuern Abbey behind

Inauguration of Fraunhofer's first institute building in Freiburg

Celebrations to mark the tenth anniversary

- Nine institutes
- 135 employees
- Business volume of 3.6 million deutschmarks

1959

Federal Research Minister Hans Lenz raises the prospect of base funding

The Fraunhofer glassworks in Benediktbeuern is restored to its original state and opened to the public

1963

The German Council of Science and Humanities recommends transforming the Fraunhofer-Gesellschaft into an umbrella organization for applied research

August Epp is appointed secretary general

1965

Twenty years after its founding, the Fraunhofer-Gesellschaft now comprises 19 institutes with 1200 employees and a budget of 33 million deutschmarks

1969

1962

Establishment of the Federal Ministry for Scientific Research

1964



Prof. Franz Kollmann © Fraunhofer

**Prof. Franz Kollmann is appointed Fraunhofer's fourth president**

The presidency is still an honorary position. Kollmann remains professor of wood research at the Technical University of Munich

1968



Prof. Otto Mohr © Fraunhofer

**Prof. Otto Mohr is appointed Fraunhofer's fifth president**

For the first time, the Federal Ministry of Research provides a grant of two million deutschmarks and sets up a commission to promote the expansion of the Fraunhofer-Gesellschaft

1970

The commission presents its recommendations to the federal research minister



Fraunhofer LBF, Darmstadt  
© Fraunhofer

A joint commission, chaired by the senior civil servant Max Scheidwimmer, is charged with restructuring the Fraunhofer-Gesellschaft. The commission comprises eight members: four from Fraunhofer and four from the relevant government ministries

The revised constitution enters into force with a new executive board: Otto Mohr, president; Max Scheidwimmer, executive board member for legal affairs and human resources; and August Epp, executive board member for financial affairs

A cabinet decision approves transforming the Fraunhofer-Gesellschaft into an umbrella organization for institutes working in applied research

Formerly spread across six buildings in Munich, the new and enlarged Fraunhofer headquarters relocates to larger premises on the Leonrodstrasse

1971

1973



Dr. Hans-Ulrich Wiese  
© Fraunhofer

A new framework agreement on research funding enters into force. Contract research in nonmilitary areas is supported by federal and regional governments at a ratio of 9:1

Dr. Hans-Ulrich Wiese is appointed executive board member for financial affairs

1977



Prof. Max Syrbe  
© Fraunhofer

**Prof. Max Syrbe is appointed Fraunhofer's seventh president**

1983

1972

The Fraunhofer model of performance-related base funding is being developed

1974

Twenty-five years after establishment, the Fraunhofer-Gesellschaft now has 1700 employees and, for the first time ever, a total business volume of more than 100 million deutschmarks. It is the start of a new era at the Fraunhofer-Gesellschaft

**Dr. Heinz Keller is appointed Fraunhofer's sixth president**

Dr. Eberhard Schlephorst is appointed executive board member for legal affairs and human resources

Dr. Heinz Keller  
© Fraunhofer



1976

Launch of the Fraunhofer program to promote contract research for small and medium-sized enterprises

1978

All institutes are given the uniform title "Fraunhofer Institute for..."

The Joseph von Fraunhofer Prize is inaugurated

The Joseph von Fraunhofer Prize is presented for the first time © Fraunhofer



Establishment of the European Association of Contract Research Organisations (EACRO)

Establishment of Fraunhofer-Management-Gesellschaft, which provides services to external institutes

Institutes involved in military research switch in part to civil research

Dr. Dirk-Meints Polter is appointed executive board member for human resources and legal affairs

1989



Prof. Hans-Jürgen Warnecke  
© Fraunhofer

**Prof. Hans-Jürgen Warnecke is appointed Fraunhofer's eighth president**

The Fraunhofer-Gesellschaft adopts a new set of guiding principles, known as "Leitbild 2000"

Total business volume exceeds one billion deutschmarks for the first time

Introduction of a unified Fraunhofer corporate image for all institutes

Establishment of the Fraunhofer Group for Materials and Components and the Fraunhofer Group for Manufacturing Engineering

The German Council of Science and Humanities approves Fraunhofer's proposal to establish organizations in the states of the former East Germany

1991

1993

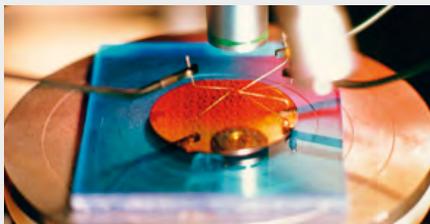
1995

1997

1984

Establishment of the Fraunhofer Group for Microelectronics

Microelectronics: testing a new chip © Fraunhofer IIS



1992

In the states of the former East Germany, a total of eight institutes, one branch and 12 branch labs are officially opened on January 1, 1992

1994

Establishment of Fraunhofer USA

1996

Fraunhofer expands its presence abroad

1998

Successful system evaluation of the Fraunhofer-Gesellschaft

Establishment of the Fraunhofer Group for Light & Surfaces

Establishment of Fraunhofer Sweden

Establishment of the Fraunhofer Group for Life Sciences

Prof. Dennis Tschritzis is appointed to the executive board as a fourth member

Creation of the Fraunhofer Information and Communication Technology Group from eight former GMD institutes and seven Fraunhofer institutes

2001



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Relocation to new premises: the Fraunhofer-Haus, on Hansastrasse in Munich

Focusing on strategy: presentation of 12 leading innovations

2003

Presentation of 12 signposts to tomorrow's markets

Foundation of the Fraunhofer Technology Academy

Establishment of the first innovation clusters

The Leibniz Prize to Prof. Andreas Tünnermann, director of Fraunhofer IOF

The German Environmental Award to Prof. Joachim Luther, director of Fraunhofer ISE

2005



Dr. Andreas Bräuer, Dr. Stefan Illek, Dr. Klaus Streubel © Deutscher Zukunftspreis

The German Future Prize to OSRAM and Fraunhofer IOF for "Light from Crystals"

The Leibniz Prize to Prof. Peter Gumbsch, director of Fraunhofer IWM

The Fraunhofer Information and Communication Technology Group is renamed Fraunhofer ICT Group

2007

Fraunhofer marks its 60th anniversary with the launch of a fresh corporate identity and the Fraunhofer brand

Establishment of Fraunhofer Austria

Establishment of Fraunhofer Italy

Incorporation of three FGAN institutes

2009

2000

The German Future Prize to Fraunhofer IIS for mp3

Establishment of a Brussels office

Incorporation of GMD-Forschungszentrum Informationstechnik

Dr. Bernhard Grill, Prof. Karlheinz Brandenburg, Harald Popp © Deutscher Zukunftspreis



2002

Dr. Alfred Gossner replaces Dr. Hans-Ulrich Wiese as executive board member for financial affairs

**Prof. Hans-Jörg Bullinger is appointed Fraunhofer's ninth president**



Prof. Hans-Jörg Bullinger © Fraunhofer

Establishment of the Fraunhofer Group for Defense and Security VVS

2004

Launch of the Partners for Innovation initiative

The German Future Prize to Siemens and Fraunhofer ISIT for a lab-on-a-chip system

2006

Prof. Ulrich Buller is appointed executive board member for research planning

Prof. Ulrich Buller © Fraunhofer



Prof. Hans-Jörg Bullinger and Dr. Arendt Oetker from the Stifterverband are chosen to head the Industry/Science Research Union, an advisory board to federal government

2008

The Leibniz Prize to Prof. Holger Boche from Fraunhofer HHI

Presentation of 12 Fraunhofer frontline themes

Prof. Marion Schick is appointed executive board member for human resources and legal affairs

The Fraunhofer Forum opens in Berlin

Establishment of the Fraunhofer Future Foundation

Establishment of Fraunhofer Portugal

Prof. Marion Schick © Fraunhofer





Prof. Neugebauer and Prof. Andreas Barner from the Stifterverband head the High-tech Forum, an advisory board to federal government on the implementation of high-tech strategy



Dr. Alexander Kurz is appointed executive board member for human resources and legal affairs © *Fraunhofer*

The German Future Prize to Prof. Karl Leo from Fraunhofer FEP for work on organic electronics

Establishment of Fraunhofer Chile

2011

Dr. Jens König, Prof. Stefan Nolte and Dr. Dirk Sutter © *Ansgar Prudenz/ Deutscher Zukunftspreis*

The German Future Prize to Bosch, Trumpf and Fraunhofer IOF for work on ultra-short pulse lasers

Fraunhofer formulates ten recommendations for federal government science policy

Presentation of Fraunhofer's international strategy

2013

Establishment of three high performance centers:

- Sustainability, in Freiburg
- Electronic Systems, in Erlangen
- Micro-/Nanoelectronics, in Dresden and Chemnitz

Fraunhofer opens a project center in Wolfsburg

Launch of a Fraunhofer initiative for secure data space

Establishment of the inaugural Young Research Class as a cross-institute research and career development program

2015

Base funding is increased to 60 million euros

Launch of research clusters as a new instrument for developing a distinctive scientific profile

Establishment of the Fraunhofer Group for Innovation Research

Launch of Research Fab Microelectronics Germany, involving 11 Fraunhofer institutes

2017

2010

The German Future Prize to Festo and Fraunhofer IPA for a robotic arm modeled on an elephant's trunk

© *Ansgar Prudenz/ Deutscher Zukunftspreis*



2012

Establishment of Fraunhofer UK

**Prof. Reimund Neugebauer is appointed Fraunhofer's tenth president**



Prof. Reimund Neugebauer © *Fraunhofer*

2014

Fraunhofer publishes a policy paper on cyber security

Prof. Alexander Verl is appointed executive board member for technology marketing and business models

Publication of the first ever Fraunhofer sustainability report

The German Future Prize to Fraunhofer IVV for work with lupine proteins

German Future Prize, Dr. Stephanie Mittermaier (spokesperson) Dr. Peter Eisner, Katrin Petersen © *Fraunhofer*



2016

Establishment of Industrial Data Space e.V.

Prof. Georg Rosenfeld is appointed new executive board member for technology marketing and business models



Prof. Georg Rosenfeld © *Fraunhofer*

2018

Launch of Agenda 2022, a new strategy program to increase the impact of research on business and society

Andreas Meuer replaces Prof. Alfred Gossner as executive board member for financial affairs

Andreas Meuer © *Fraunhofer*



# “An elementary driver of innovation for the economy and society”

In this interview, Fraunhofer President Prof. Reimund Neugebauer ushers in the 70th anniversary year with his thoughts about success and innovation, adjustments and solutions, retrospects and prospects, and the namesake of the Fraunhofer-Gesellschaft.

Interview: Franz Miller

It was not until the performance-based funding model was invented that the Fraunhofer-Gesellschaft's 70-year history really picked up steam. Was it an innovation that set the wheels in motion?

Performance-based funding is indeed an innovation. It was not until later, however, when we used the previous year's business income to calculate our internal allocation of funds, that it was effectively put into practice. Unfortunately, we still do not receive success-based funding from the federal government, but our internal allocation is based on success. No other research organization does this. This means that sustainable science has a much higher priority for our leaders. Our success proves us right; we keep growing and growing.

What prompted you to join the Fraunhofer family with your Chemnitz Institute in 1991?

At the time, I had the choice of pursuing a normal university career, going into business or getting into applied research at Fraunhofer in conjunction with a professorship at Chemnitz University. I then looked at the Fraunhofer Institutes in Berlin and Aachen, which made the decision very easy for me. I wanted to build something like this in my native central Germany and make a creative contribution in service of progress for this part of the country.

It takes a balancing act to straddle the demands of science and business – how has that changed today?

This balancing act between science and business has not changed all that dramatically, but industries are developing at different speeds. Take, for example, automotive engineering, the source of many innovations, some of which Fraunhofer is party to: The entire industry has suffered a severe setback as a result of the diesel scandal. However, this kind of thing usually results in demand for new innovations that change the situation for the better. Fraunhofer has also been part of a lot of new developments in the IT sector, microelectronics and medicine. What has fundamentally changed is that projects have become so complex. Conventional mechanical engineering, for instance, is now entwined with new materials technology such as programmable materials, IT solutions and control engineering. Projects are no longer about propelling just one company forward with a thrust of innovation; they are about making entire industries more competitive. Our institutes have joined in strategic project alliances. We have developed new formats to this end, including the lead projects and the Fraunhofer Clusters of Excellence.

The government often finds it hard to keep up with the Fraunhofer-Gesellschaft's success. You were recently able to close a growing funding gap. What is the next move here?

We were fortunate to have had a hike in our government funding – an additional 15 percent is significant. This will finally bring us back close to the 30 percent funding that is urgently needed to conduct the necessary pre-competitive

“Making entire industries more competitive”



Prof. Reimund Neugebauer  
© Fraunhofer/  
Bernhard Huber

research. This hike served to fund new strategic, interdisciplinary and system-relevant research formats. Looking to the future, we are holding talks with the federal government to establish national research centers, for example, for cyber security. We are also setting up a research factory for battery cell production. These are huge investments we are talking about here; orders of magnitude beyond anything Fraunhofer has seen in the past. I also have to praise the policymakers, who are responding with such a concerted effort to the major challenges facing the German economy.

“We want to further increase our impact on the economy.”

The effort to steadily improve research planning and strategy development is an important success factor. You have your sights fixed firmly on the future with the Agenda Fraunhofer 2022. How is the Fraunhofer-Gesellschaft going to safeguard the qualities that set it apart?

Fraunhofer is a rigorously mission-oriented research organization, and therefore has its fixed place in the science system. The Fraunhofer-Gesellschaft will continue to be an elementary innovation driver for the economy and society. In the future, we want to further increase our impact on the economy. We had this calculated back in 2014. The monetary effects on gross domestic product triggered by

Fraunhofer exceeded our own project-based revenue by a factor of 18. For every euro the public sector spends on the Fraunhofer-Gesellschaft, the federal government, states and municipalities get four euros in return in the form of higher tax revenues. This figure has since increased significantly as the impact of major strategic projects is gradually taking effect. And we are committed to creating value with values in mind: We want to produce more for a growing world population, while consuming fewer resources and protecting the climate and environment. After all, everything we do revolves around humankind and meaningful employment for people.

**By the Key Strategic Initiatives and your foresight processes, you want to set the agenda for key areas of research and aim to be the technology leader in these areas. What exactly are they?**

IT security is a very important topic. Hacking and cyber attacks are a big problem these days. In quantum physics, we have the photon entanglement effect. We can take advantage of this effect to enable hack-proof data communication. Our institutes are the global leaders in this field. We are also a leading player in programmable materials. Their internal structure is designed and manufactured for complex and locally variable functions to be programmed in specific ways. These materials hold the unique potential for new system-based solutions where the material itself provides key aspects of a function. Another area in which I see us at the forefront is research into RNA biomarkers. And, last but not least, there is 5G. Our institutes are working hard on preparations to put this high-speed Internet into practice. Research is not an issue for the 5G network; it is all a matter of implementation and funding. I could add more artificial intelligence and machine learning topics to the list.

“I am undaunted, for I believe rationality will prevail.”

**Disruptive innovations can topple entire industries, which is why they are a decisive driver of structural change. In what areas do you expect to see these breakthrough innovations?**

Breakthrough innovations cannot be predicted, but I can cite areas where they will emerge – certainly in photonics, beam sources and, by extension, in quantum communication. This is where we can expect to see innovations that will revolutionize entire industries. The energy sector is another area. The climate summit at Krakow showed that we still have a long way to go and bigger strides to take toward decarbonization in Germany. We will have to establish a hydrogen economy in Germany and Europe. New high-temperature electrolysis processes produce hydrogen with greater efficiency. A whole new industry will emerge here. This is of great importance to the Federal Republic of Germany. I also expect to see major advances in the field of artificial intelligence, which is disruptive. If we combine machine learning with neuroscience, we can develop algorithms that not only analyze upstream processes and find correlations, but also recognize causal relationships. This will have a major impact on a whole range of control technologies.

**If we look ahead 70 years into the future, what role will AI play in our lives?**

If I knew the answer to that, I would turn it into a business model and sell it! I suspect that in a few decades artificial intelligence will be a methodological tool that many industries and scientists will use as a very smart assistant. It will become somewhat routine to use methods involving artificial intelligence. Of course, we have a duty to implement this technology carefully and responsibly so that things do not – literally – get out of hand, which brings us to the subject of ethics. The same goes for genetic engineering. But humankind would not have made it this far had we not kept asking ourselves the right questions about fundamental ethics. I am undaunted, for I believe rationality will prevail.

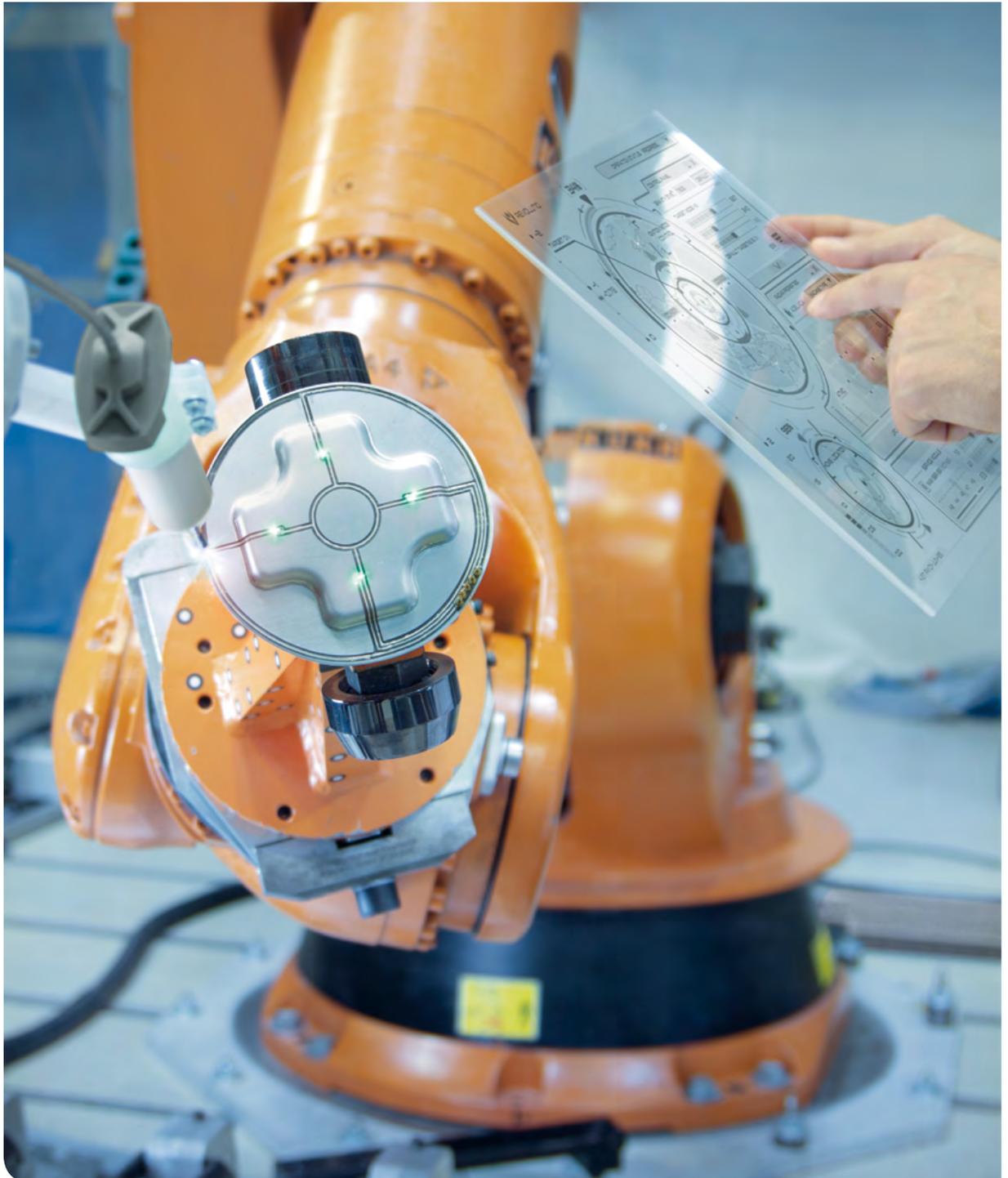
**If you could meet Joseph von Fraunhofer today, what would you like to talk to him about?**

The notion of combining scientific curiosity and entrepreneurship is what drove him in his time. Was it an altruistic wish to make the world a better place, or was it the desire to make money as an entrepreneur? Both are valid, but of course the former is particularly honorable. ■



# Go Beyond 4.0: Industrie 4.0 and then some

One of the main goals of the Go Beyond 4.0 lighthouse project is to transfer digital manufacturing processes from the lab to robot-assisted production lines. © Steve Leisner/Fraunhofer IWU





Components like these are used in the additive inkjet printing process, for example, for lab-on-a-chip systems.  
© Fraunhofer IOF

associated with industrial-scale manufacturing – the first using digital inkjet, dispensing and aerosol jet printing techniques, and the second by means of laser sintering. Fraunhofer researchers want to harness the powers of these technologies to add functions to any component during production. This initiative was sparked by an idea that Prof. Reinhard Baumann and Dr. Ralf Zichner had at the Fraunhofer Institute for Electronic Nano Systems ENAS in 2014. Now they are pursuing that notion with their research in the eponymous lighthouse project.

“The idea behind a lighthouse project is to support and finance readily applicable fundamental research in areas that have yet to be

funded by political bodies such as the EU or federal ministries. A lighthouse project addresses current industry challenges. The financial resources are provided exclusively by the Fraunhofer-Gesellschaft,” says Prof. Baumann by way of explanation. Fraunhofer is investing eight million euros in the project over a period of three years.

Prof. Thomas Otto, acting director of Fraunhofer ENAS, heads up the Go Beyond 4.0 lighthouse project. It is a joint effort of six institutes, the Fraunhofer Institutes for Laser Technology ILT, for Applied Optics and Precision Engineering IOF, for Silicate Research ISC, for Machine Tools and Forming Technology IWU, and for Manufacturing Technology and Applied Materials Research IFAM.

### Subprojects in aviation, automotive engineering and lighting

The researchers opted to go with three marketable applications. The Smart Wing subproject targets the aviation industry, Smart Luminaire the lighting technology sector, and Smart Door the automotive industry. The object of the latter, a car door, vividly illustrates how the people in the Go Beyond 4.0 project are putting digital printing technology to work. Andre Bucht, head of Adaptronics at the Institute for Machine Tools and Forming Technology IWU, says, “Car doors have many electronic modules and mechatronic functions built in. Fraunhofer printing technology can be used to add components such as sensors, switches, LEDs and conductor pathways.”

To install a conductor track, engineers first print an insulation layer made of polymers onto the component, followed by the conductive silver paste and then another insulation layer. A printer applies all these layers that a laser then cures with high spatial resolution. Robot arms guide a dispenser or an inkjet system and a laser over the component. On a conventional assembly line, workers have to crawl into the car and install cable harnesses by hand.

### Smart Luminaire – it’s all about light

Exciting innovations also figure prominently in the Smart Luminaire subproject. Dr. Erik Beckert, project manager at the Fraunhofer Institute for Applied Optics and Precision Engineering IOF in Jena, says, “I had had the basic idea of

While many companies are busy putting Industrie 4.0 concepts into practice in their factories, new challenges are already knocking at the door. For example, demand for customized products is on the rise. Fraunhofer researchers have set out to develop technologies to meet these emerging requirements and take Industrie 4.0 to the next level in a lighthouse project called Go Beyond 4.0.

Text: Mehmet Toprak

The basics of customized mass production are easily explained with a visit to the pizzeria around the corner. It is nothing unusual for a diner to order a Pizza Napoli base and then pile on the special requests – hold the olives, add some mushrooms, how about some extra capers. Ten minutes later, a steaming hot pizza pie replete with the diner’s favorite toppings arrives on a plate.

What has long been the norm in catering – a standard product tailored to the buyer’s taste – is now sweeping the manufacturing industry. The challenge for manufacturers is to find a way of customizing on the fly in highly flexible, connected Industrie 4.0 factories. This is akin to asking for bespoke products off the rack, delivered with assembly-line speed and reliability.

### Digital printing and laser sintering for Industrie 4.0 plants

The Go Beyond 4.0 initiative aims to make that happen with two technologies not normally

### The latest Fraunhofer lighthouse projects

**Quantum Methods for Advanced Imaging Solutions (QUILT):** The QUILT project’s objective is to develop new quantum imaging and detection techniques.

**Rare earths:** The Criticality of Rare Earths project aims to ensure industry has access to urgently needed raw materials, especially rare earths.

**eHarsh:** In this lighthouse project, researchers are seeking to build a technology platform to facilitate the development of sensor systems for deployment in extremely harsh environments.

**Electricity as a Raw Material:** Developing and optimizing processes that use low-carbon electrical power to synthesize key base chemicals – that’s what this lighthouse project is all about.

**Theranostic Implants:** Fraunhofer researchers are working on smart implants that combine diagnostics and therapy in a single medical device.

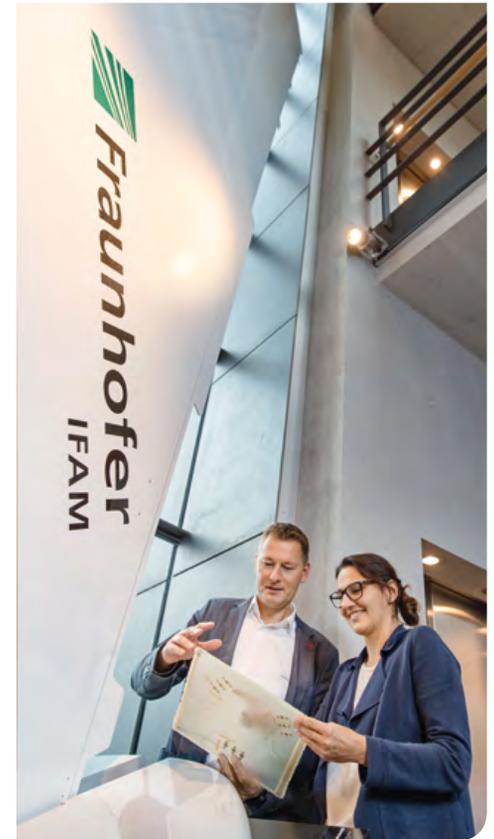


[s.fhg.de/lighthouse-projects](https://www.s.fhg.de/lighthouse-projects)

Structures printed on glass fiber fabric serve to integrate heating into the fiber composite. © Kay Michalak/Fotoetage



Various functions can be integrated into the process chain for aircraft components made of fiber-reinforced composites. © Kay Michalak/Fotoetage



methods. The equation is simple: assembly line plus robot plus printer equals fast, effective customizing.

### The team is the star

The management team's constructive collaboration has helped steer the Go Beyond 4.0 project to success. Emphasizing this point, Deputy Project Coordinator Ralf Zichner says, "This was never about one institute striving for a certain result. Instead, the participating institutes are interacting as equals, which is the key to success." All stakeholders are confident that the objectives will be achieved by the time the project wraps up in November 2019. Baumann expects that the technologies "will be established in German companies in three to five years at the latest." Consumers are sure to be delighted with the outcome – mass-manufactured products that are personalized to suit their tastes, just like that pie at the pizzeria round the corner. ■

producing optical components using inkjet processes back at the IOF." The Go Beyond 4.0 lighthouse project provided the perfect opportunity to explore it further. This subproject aims to make polymer optical components in an additive process. Inkjet printers serve to customize and add functions to existing optical components such as plastic lenses. For their ink, Beckert and his team are using ORMOCER®, an optical hybrid polymer developed by the ISC at Würzburg. The optical properties of this material come very close to those of good optical glass and can be adapted to the given application.

### Smart Wing: Wired for warmth

A truck with a big tank arriving to spray de-icing fluid over the wings is a familiar wintertime sight for passengers looking out the window of an airplane, longing for it to taxi out for take-off. Dr. Volker Zöllmer and his team expect that that truck could be soon be obsolete if the Smart Wing subproject gets off the ground and soars. Dr. Zöllmer heads up the Smart Systems department at the Fraunhofer Institute for Manufacturing Technology and Applied Materials Research IFAM. Its researchers have succeeded in integrating heating lines to defrost wings from the inside out. This handy capability also comes courtesy of printers. They apply silver paste to print current-carrying conductor tracks into the wing's fiber composite material.



Fraunhofer IFAM integrates printed functionalizations into fiber-reinforced plastics. © Kay Michalak/Fotoetage

This built-in defroster is just one of the applications on the team's R&D agenda. The Smart Wing can be also equipped with sensors to measure temperature or pressure in the wing or fuselage of an aircraft. These functions are deeply embedded in the composite material, which in aircraft construction typically consists of plastics reinforced with glass or carbon fiber. Sensors could also detect damage to the aircraft fuselage caused by bird strikes.

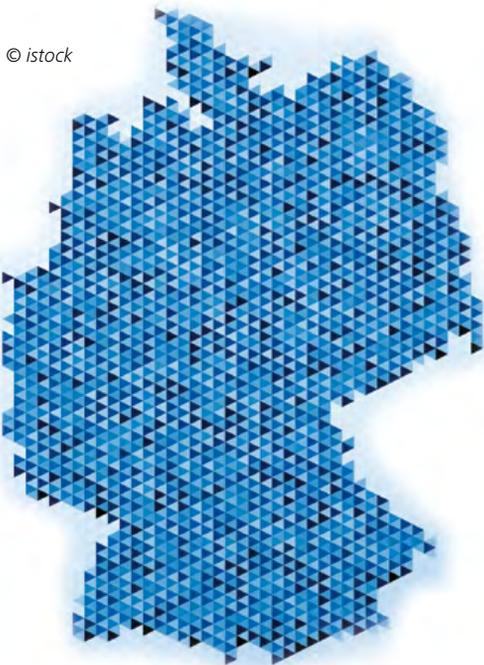
### The ties that bind

Although these applications are quite diverse, the three subprojects have much in common. The object of each is not just to make products; they all go to demonstrate the possibilities of

technology. The ability to print conductor pathways into car doors may be put to good use elsewhere – in the interior or on the dashboard, to stick with the automotive example. Much the same holds true for the Smart Wing. The techniques outlined above would also work for civilian drones, wind turbines, and automotive and mechanical engineering applications.

Zöllmer is quick to point out another aspect: "For the Go Beyond 4.0 project, we also set ourselves the goal of developing manufacturing process chains further so they can then be executed at a much faster rate and more efficiently, even for highly customized products." The key enabler here is the pairing of conventional manufacturing processes with digitally controlled manufacturing

© istock



# Seven initiatives for

When the Fraunhofer-Gesellschaft set out the Agenda 2022, it charted a roadmap for its research activities. One of the priorities on this agenda is to develop end-to-end solutions to provide the systems Germany needs to remain a hub of business. The organization launched a set of Key Strategic Initiatives (KSIs) centered on seven priority research topics to make that happen. One of these initiatives is all about cognitive systems, artificial intelligence and data sovereignty.

Text: Christine Bröll

More and more Fraunhofer institutes are turning their attention to artificial intelligence and learning machines. They put these technologies to good use in a wide range of applications from underwater robots to data analysis tools that screen medical images. Now they aim to pool their skills in these areas and develop them further as part of this KSI.

## Cognitive systems

Fraunhofer develops smart robots to serve many purposes. Service robots, for example, talk to customers and even detect the mood of the humans they interact with. Cognitive assistance robots in industrial manufacturing enable humans and machines to work together in close quarters. An underwater robot developed by Fraunhofer operates fully autonomously in the depths of the sea.

Researchers schooled these cognitive systems with machine learning techniques, so they really are able to learn. This training, paired with powerful algorithms, enables IT systems to recognize patterns and rules, and then solve problems. In other words, they are able to apply knowledge gleaned from data to new situations. Machine learning also provides the foundation for creating artificial intelligence.

## Artificial intelligence

Fraunhofer researchers are putting artificial intelligence (AI) to work in medicine. For example, they develop self-learning computer algorithms to screen medical images for potentially harmful mutations. Scientists are developing personal AI assistants for the elderly. Brain-computer interfaces that forge a direct link between brain waves and smart software are also in the works. They will enable people with severe physical disabilities to operate electronic devices. Many other AI projects in robotics, imaging, speech processing and process optimization are under way. These are all stepping stones on Fraunhofer's way to taking the lead in this key technology.

## Data sovereignty

This part of the KSI addresses a third topic, data sovereignty. Ever the pioneer, Fraunhofer broke new ground in this field by coming up with the concept of Industrial Data Space. As the name suggests, IDS creates a secure data space that enables companies of all sizes and from a variety of industries to cultivate and capitalize on their data while retaining control over it. A Fraunhofer Cluster of Excellence is also developing cognitive technologies for the industrial Internet (see pages 20–21 for more on this). ■

Artificial intelligence helps physicians assess images.  
© Fraunhofer IIS/Kurt Fuchs



# the business hub Germany

# 2022



Cognitive systems are taking on more and more tasks in industrial manufacturing. © zapp2photo/Adobe Stock



## Key Strategic Initiatives

The Fraunhofer-Gesellschaft is pooling the expertise of its 72 institutes in the Key Strategic Initiatives. The purpose of these KSIs is to develop end-to-end system solutions for strategically important issues, all of which are highly relevant to the German economy and society. The initiatives' objectives vary. Some aim to take the lead in science, others to generate significant business returns, and still others to raise public awareness for the given topic. The KSI addressing cognitive systems, artificial intelligence and data sovereignty is but one of seven. Six others are also ongoing:

### Battery cell production

Asia is the market leader in battery development and manufacturing, but Europe wants to catch up – or perhaps more accurately, it must close the gap. Fraunhofer has already accumulated a great deal of expertise in the Fraunhofer Batteries Alliance, a coalition of 19 institutes. This KSI goes to step up research into the various battery manufacturing methods.

### Programmable materials

This KSI's objective is to investigate ways of augmenting conventional materials with new capabilities. The idea is to modify their internal structure rather than change the material itself. A 3D nano-printer, for example, can accomplish this by printing a precisely calculated grid structure made of a plastic material. The structure's shape then serves to modify – or program, if you will – the material's properties in very specific ways.

### Quantum technology

Quantum physics sparked many technical advances in the past, such as transistors and lasers. Lately, though, quantum researchers have been achieving such spectacular breakthroughs that some have seen fit to call this new wave of innovation a second quantum revolution. This KSI aims to usher fundamental research out of the lab and into real-world applications as quickly as possible in areas such as quantum imaging and quantum communication.

### Translational medicine

No less than 40 of the 72 Fraunhofer institutes address four major areas of medical science – drugs, diagnostics, devices and data, or 4D for short. Many innovations are born at the crossroads where disciplines intersect, which is why this KSI encourages collaboration among physicians, scientists, computer specialists and engineers. This alliance of 4D experts is able to put new, cost-efficient ideas into practice that much faster.

### Public security

Fraunhofer is redoubling its efforts to develop innovative public safety technologies jointly with the police force and security agencies. New solutions have to effectively avert harm yet safeguard the rights of the individual and protect data. The institutes' expertise in this area encompasses civil security, public IT and cyber security.

### Biological transformation

The Fraunhofer-Gesellschaft is striving to advance the digital transformation with a little help from our friend biology. To this end, its researchers are looking into the concept of biological transformation – that is, ways of borrowing Mother Nature's materials, structures and principles to benefit technology. These scientists aim to create enduring added value with the benefit of bionics, biotechnology and bio-economics.





## Fraunhofer Clusters of Excellence

Cognitive Internet Technologies CCIT is a Fraunhofer Cluster of Excellence with the remit to research cognitive technologies for the industrial Internet. The aim is for cognitive solutions and products to underpin German companies' competitive stance, redouble their innovative powers and secure their digital sovereignty. With the benefit of its domain-centered expertise, CCIT is able to offer cognitive solutions tailored to every phase of the transformation process. It helps master complexity at every turn, from analyzing the given situation to planning a sustainable corporate strategy, developing agile technology and conducting trials in CCIT's many innovation and application centers.



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



Prof. Claudia Eckert, director of the Cognitive Internet Technologies CCIT cluster and head of the Fraunhofer Institute for Applied and Integrated Security AISEC.  
© Andreas Heddergott

critical the local situation happens to be. To this end, the sensor has to interact with other sensors in the vicinity. Then they need to merge their data to provide a bigger-picture view of the local situation in order to compute recommended actions, in real time and with exacting precision. What we need to accomplish this are new methods of generating knowledge based on machine learning. These methods have to deliver precise analysis results even when very little data is available, or when data is distributed across different components. This may be the case if not enough memory capacity is available to accommodate a great deal of data or when data have to be processed locally for security reasons.

### Where will these solutions be used?

The application scenarios are quite diverse, ranging from logistics to industrial manufacturing to autonomous driving. We are not merely interested in pursuing standalone solutions however; we want to combine key technologies. To do that, we need to cover all the domains, including IT security and data protection.

For example, a self-organizing production line has to be able to unequivocally identify and locate components, machine parts and tools. Data processed by way of cognitive computing has to be trustworthy. And these processes have to be executed in trustworthy, hack-proof environments.

Otherwise the outcome will be inaccurate forecasts and wrong decisions.

For applications such as autonomous driving, it is imperative that solutions based on ultra-precise cognitive models are able to detect traffic situations in real time and trigger an appropriate response. This requires new solutions that provide these cognitive abilities deep down at the local level of sensors and components in vehicles and infrastructure components. That way, these solutions will be able to respond very quickly to the given situation, plan proactively and take actions that are coordinated with the components in the immediate surroundings.

The cluster's work is up, working and has already presented its first solutions.  
What's next?

One aspect is very important to us – systematic interdisciplinary collaboration with a long-term outlook. We want to reimagine technological advances and put them into practice jointly with industry partners. The goal for the long term is to provide the industry with a technological infrastructure that helps companies improve their products, processes and services, and develop new business models that hone their competitive edge, enhance their powers of innovation and secure their digital sovereignty. ■

# From square one to pilot production



Jörg Amelung  
© Fraunhofer Group  
for Microelectronics

The Research Fab Microelectronics Germany (FMD) is an alliance of more than a dozen institutes across the country. In this interview, Jörg Amelung, head of central office of FMD, explains why a network as extensive as this has the clout to advance the cause of research.

Interview: Tim Schröder

Mr. Amelung, more than 2000 scientists are collaborating closely in the Research Fab Microelectronics Germany. What benefits do you expect to reap from this?

Close collaboration with the industry is a hallmark of the Fraunhofer institutes' work. In many cases, alliances with small or medium-sized companies emerge from personal connections or from companies asking if an institute can take on a task. In my experience, the lone institute does not always have the necessary skills at hand. Either you decline the job, or you set out on a tedious quest for help from other institutes, a search that may not always succeed. We are taking a much more fundamental, strategic path with the Research Fab. First, we inventoried and compared the expertise of the various institutes. Who has these technologies;

who has those competencies? In future, companies will no longer have to ask if an institute can carry out a given task. As a united front, we will be able to say, "Show us your problem, we'll find the solution." The Research Fab is bringing together many experts from the Fraunhofer institutes and the two Leibniz institutes. They are getting to know each other, which greatly facilitates collaboration. Strategy aside, this human element is a powerful force that is not to be underestimated.

Surely this is not going to work without close coordination among the institutes. How are we to picture this collaboration?

Take, for example, clean rooms. We have a total of 13 of them across all locations, each equipped for specific tasks. One of our major

industrial partners is GLOBALFOUNDERIES, which has a production facility geared for 300 mm wafers in Dresden. The various clean rooms can process these wafers further for diverse applications. A lone institute could not offer that kind of diversity. We are setting up a production management system of our own for the Research Fab; it will connect the flow of products and goods across all institutes, to include the clean rooms. This is akin to being in a big company with distributed locations.

And what exactly will you be able to offer your customers in future?

Everything up to pilot production. This means that we will not just develop the technology, we are also going to cover the entire chain up to manufacturing. One of the motivations

for setting up the Research Fab is not only to retain the R&D know-how, we also want to keep microsystems manufacturing technology in Germany so it does not migrate to other regions. We will be able to build a technology from the ground up to pilot production. This will enable us to provide components of microsystems technology to customers until they build production lines of their own. In fact, we will be able to set up production processes in our labs – for example, at our partner X-FAB's facility in Dresden – very much like those that manufacturers will later need. This will expedite the transition from the pilot production line to the company's factory.

The focus is on very different areas of technology here; for example, on More-than-Moore technologies, a term stemming from Moore's law, which states that the performance of chips doubles at regular intervals.

That's right. More-than-Moore is all about transcending the limits of this redoubled performance with new technologies – limits that are already within sight. But the Research Fab is not centered on conventional computer chips. We are focusing far more on industrial applications; on smart components for the Internet of Things or the automotive industry. The second major focal point of the Research Fab is microsystems technology. For example, we are working on high-performance sensors and actuators. The third of our research priorities goes by the heading of More-than-Moore. This involves building unprecedented high-performance components using conventional silicon technology alongside other semiconductors; that is, compound semiconductors such as silicon carbide or gallium nitride. We aim to develop and manufacture power electronics components for tomorrow's power grid, optoelectronic components for fast data transmission, and high-performance electronics products for fast mobile communications beyond 5G.

Southeast Asia rules the roost in microelectronics development and manufacturing. Its dominance

in mass manufactured smartphones – replete with the full sensor array – attests to that fact. How does the Research Fab intend to redress this imbalance?

It is true that mass manufacturing is taking place elsewhere today. The problem for many high-tech companies in Germany is that they need microelectronic components with very specific capabilities and properties for their products. One such example is surround sensors that monitor robot workstations where humans and machines work together. This sensor technology and the data communication have to be exceedingly reliable. Conventional smartphone technology fails to meet these requirements. As a rule, large corporations do not offer the tailored components needed by the individual customer. This is where we step in to offer the full range of services, from developing a tailor-made component to pilot production.

It is not just Germany – all of Europe is seeking to prevent the microelectronics market from decamping to other regions of the world. That is why the European Commission set up the Strategic Forum for Important Projects of Common European Interest, which also aims to address microelectronics. What's next? Is the Research Fab looking to forge long-term alliances?

We have indeed struck up talks with two renowned research institutes in Belgium and France, Imec in Leuven and Leti in Grenoble. We want to collaborate in emerging technologies such as artificial intelligence and quantum technology in the years ahead. But Europe comes later. First, we must put the Research Fab in Germany on a firm footing. This is a tall order to fill. I had worked for Fraunhofer in the past and later in industry, where I founded a company specializing in organic electronics. I was happy to return to the Fraunhofer-Gesellschaft to set up the Research Fab. It is a once-in-a-lifetime opportunity. Our goal is to create an institution that will endure. ■

### Promoting microelectronics in Germany

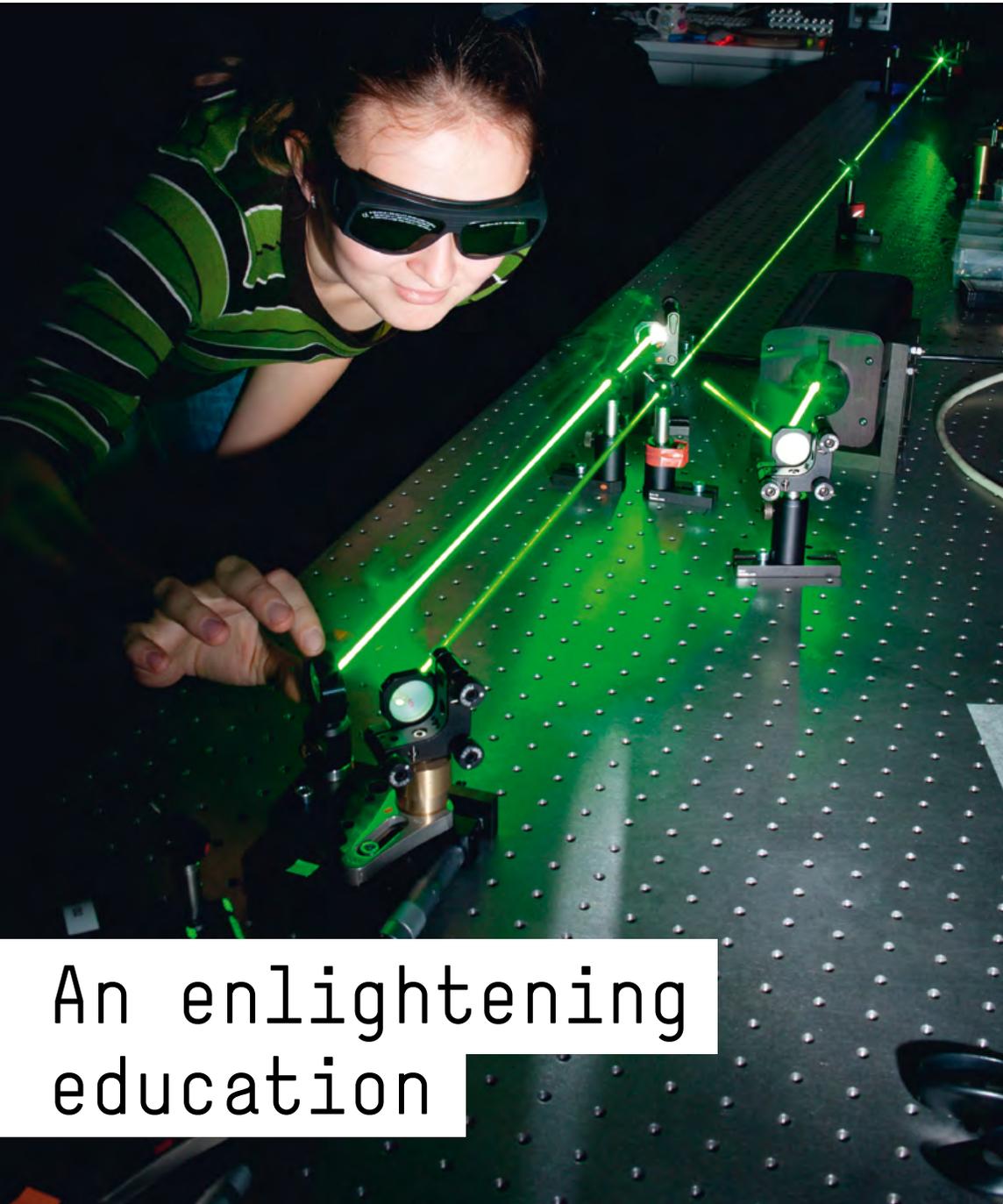
The Fraunhofer-Gesellschaft and the Leibniz Association joined forces to establish the Research Fab Microelectronics Germany (FMD). More than 2000 researchers from eleven Fraunhofer institutes and two Leibniz institutes are to collaborate across locations in pursuit of a common goal. Their mission is to champion the development, manufacture and marketing of microelectronic products and smart systems in Germany. This goes to promote brain gain and prevent brain drain, thereby keeping competencies close to home. FMD's efforts target four fields – silicon-based technologies, compound semiconductors, hetero-integration, and designing, testing and reliability. The products developed at FMD serve many purposes in sensor applications, information processing, energy, communications and the Internet of Things. One example is LiDAR; that is, new light detection and ranging solutions for the automotive sector and industrial applications. Scientists are now developing powerful components for vehicle sensors such as radar and camera technologies.

They are also working on new sensor functions and ways to assess and use data from various vehicle sensors. The German Federal Ministry of Education and Research (BMBF) is funding the effort to build FMD's research infrastructure with around 350 million euros.

 [www.forschungsfabrik-mikroelektronik.de/en.html](http://www.forschungsfabrik-mikroelektronik.de/en.html)

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Working with lasers – that is sure to play a major role on the program at the Max Planck School of Photonics. © Adobe Stock

## An enlightening education

Pooling scientific excellence in Germany and offering integrated Master's degree programs according to international practices – these are the aims of the Max Planck Schools when the first students enroll in 2019.

Prof. Andreas Tünnermann is spokesman of the Max Planck School of Photonics, director of the Fraunhofer Institute for Applied Optics and Precision Engineering IOF and director of the Institute for Applied Physics at the University of Jena. In this interview, he spells out what makes this program so special and how he aims to attract the best of the best.

Interview: Christine Broll



© Anne Günther,  
FSU-Fotozentrum

## Prof. Andreas Tünnermann

Prof. Andreas Tünnermann, spokesman of the Max Planck School of Photonics, heads up the Fraunhofer Institute for Applied Optics and Precision Engineering IOF in Jena and chairs the Fraunhofer-Gesellschaft's Scientific-Technical Council WTR. He is also director of the Institute for Applied Physics at Jena's Friedrich Schiller University and a member of the Helmholtz Institute's board of directors. In 2005, the German Research Foundation acknowledged his research work in the field of fiber lasers with the Leibniz Prize. In 2011, he received the Order of Merit of the Free State of Thuringia.

How does the head of a Fraunhofer institute become a Max Planck School spokesman?

Max Planck Schools are not about representing specific institutions. These schools are an alliance of outstanding scientists in a particular field. Prof. Gerd Leuchs of the Max Planck Institute for the Science of Light and I took the initiative to establish the Max Planck School of Photonics. We were able to recruit colleagues who figure prominently in their fields, including renowned experts from the Fraunhofer Institute for Applied Optics and Precision Engineering IOF at Jena and the Fraunhofer Institute for Laser Technology ILT in Aachen. This network also includes several Leibniz Prize winners and one Nobel Prize winner, Prof. Stefan Hell from Göttingen. He was awarded the Nobel Prize for Chemistry in 2014 for his work in ultra-high resolution fluorescence microscopy.

Why was photonics chosen as the agenda for one of the three Max Planck Schools?

The Max Planck Schools' program also addresses students who are just in their fourth or fifth semester, so it needs to include subjects that interest young people; topics they have come across before during their studies. Photonics is a key technology for both science and industry, which means it has great appeal. What's more, seven Nobel Prizes have been awarded in the field of photonics in recent years.

What are the potential research projects?

The main subject is controlling light on all scales. We control light with diverse wavelengths ranging from X-rays to

microwaves. We work with extremely short pulses and very high light intensities. With our optical research methods, we can study electrons in atoms as well as the universe.

How is studying at the Max Planck School of Photonics different from a classic university program?

This is an integrated master's doctoral program based on the US model, which is now being established for the first time in Germany. In a pilot phase at the Max Planck Schools, we want to see how successful we can be at attracting excellent international and German post-graduates with this integral system. In many countries such as the USA, students reorient themselves after graduating with a bachelor's degree and set out in search of a place to study for a master's degree or proceed directly to a PhD program. We want to reach these students.

We expect over a thousand applications for the 20 slots available at the Max Planck School of Photonics in 2019. Then we will select the best of the best in a process that runs through multiple stages. Students come to Jena, Erlangen or Karlsruhe, where international photonics courses are already in place, for the two-year master's program. Tutors closely mentor students who attend additional lectures and seminars that go beyond standard curricula. There are also research stays of varying lengths available within the network. After earning a master's degree, candidates can apply for PhD candidate positions with participating scientists throughout Germany. It is also possible to enter directly into the PhD program, which runs for three years.

You compete with top universities all over the world for the best students. Why should a student from Hong Kong come to Jena, of all places?

Our network has members with great reputations for science, highly respected abroad. German scientists are a decisive force in photonics. All this makes the degree program very attractive. And German companies are world market leaders in laser technology with their innovative products.

What competencies does the Fraunhofer IOF bring to the graduate school?

One of the focus areas of our research is developing complex optical systems for image acquisition and rendering. We share these systems with third parties that use them for fundamental research. A good example of a joint project is the infrared spectrometer MERTIS, currently on its way to Mercury with the BepiColombo space probe to characterize mineral deposits. We also have projects initiated by the industry, where we develop and deliver high-power laser systems, among other things.

How can the Max Planck School inspire research in photonics?

Our aim is to intensify the collaboration among colleagues across locations, institutes and institutions. This means that we supervise thesis candidates and jointly determine the subjects. We want to bring the community even closer together and establish a virtual campus.

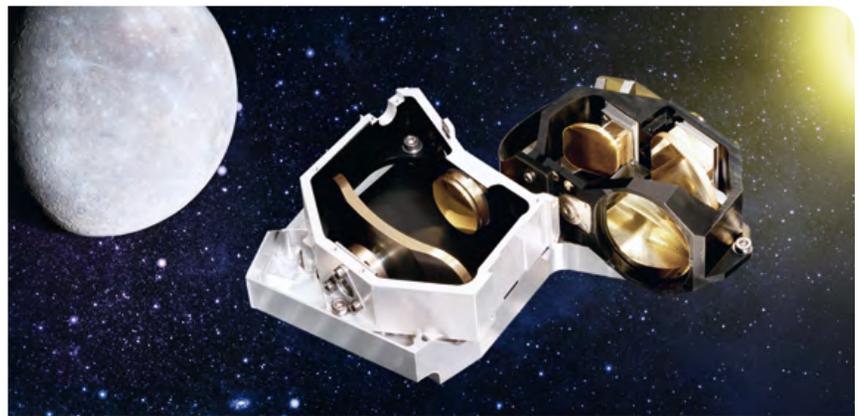
You head up a Fraunhofer institute and a university institute, you are a member of the board of directors of a Helmholtz institute and you chair the Scientific and Technical Council of the Fraunhofer-Gesellschaft, to name but a few of your functions. How do you manage to juggle your many tasks?

That's what I always ask myself (laughs). It's important to have fun with what you're doing. The decisive point, however, is to try to master these challenges in a collaborative effort with others. I have excellent teams at both the Fraunhofer institute and my department at the university, who are pulling together to achieve great things

The motto for Fraunhofer's anniversary year is #WHATSNEXT. On that note, what technology do you think will change society more than any other?

The greatest challenge in the years ahead will be human-machine interaction. We can make an important contribution here with photonics. Man is a visual creature. Human beings communicate 80 percent by way of gestures, facial expressions and body language. In the years to come, photonics will face the great challenge of getting machines not only to see situations, but also to understand and interpret them. Only then will we really be able to raise human-machine interaction to an unprecedented level of quality. ■

Applied photonics en route to Mercury: Fraunhofer IOF had a formative hand in developing the MERTIS spectrometer, now on a mission to characterize mineral deposits on the planet closest to our sun.  
© Fraunhofer IOF



### Max Planck Schools – graduate schools with international appeal

Research excellence in the UK and USA is clustered at renowned universities such as Oxford or Harvard. In Germany, top researchers in a specific field often work at different universities or non-university research institutions. The Max Planck Schools bring together excellence in innovative research fields and create a virtual campus aimed at attracting outstanding young scientists from Germany and abroad.

Max Planck Schools are a joint initiative of the Max Planck Society, German universities and non-university research organizations. Three pilot schools will launch in 2019 – the Max Planck School of Cognition, the Max Planck School Matter to Life and the Max Planck School of Photonics. These three pilot programs will receive initial funding for five years to the tune of nine million euros annually from the Federal Ministry of Education and Research.

The schools began accepting applications from candidates in 2018, with the cutoff date for each year coming in mid-December. The master's program starts in the following fall. The Max Planck School of Photonics will be admitting 20 students per year to the master's program during this startup phase. Eventually, it will accommodate around 40 master's candidates and around 120 PhD candidates.



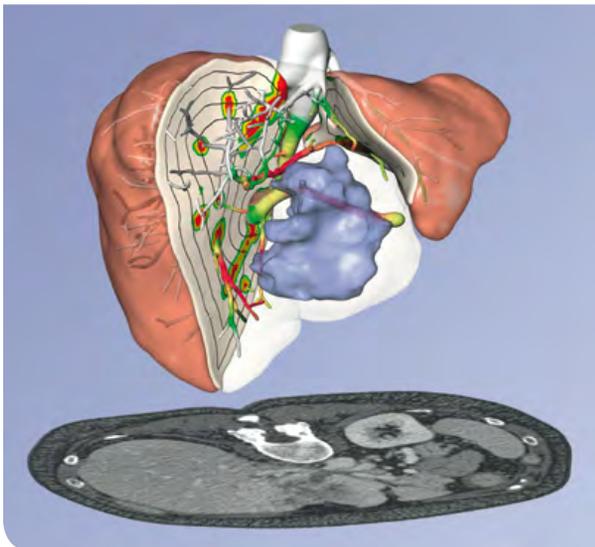
[www.maxplanckschools.de/en/photonics](http://www.maxplanckschools.de/en/photonics)

## Algorithms for liver surgery – and safer procedures worldwide

Liver cancer is the world's second leading cause of cancer-related deaths. Unlike other cancers, the incidence rate continues to rise. Because the liver's vascular systems are so complex and tumors hard to reach, resection is often a daunting task for surgeons.

The Fraunhofer Institute for Digital Medicine MEVIS developed software that analyzes radiological data. Initially offered as a data service, an industry partner rolled it out in 2014; this medical product has since been available to hospitals. It enables surgeons to plan ahead for difficult procedures and mitigate the risk of postoperative liver failure. Hospitals around the world joined in to develop a standard known as MEVIS analysis in liver surgery, with MEVIS scientists earning a Joseph von Fraunhofer Prize in 2018 for their efforts.

Penetrating insight for planning and analyzing the risk of surgery to remove a deep-seated liver tumor. © Fraunhofer MEVIS



## Powerful fiber lasers

Fiber lasers are powerful radiation sources for applications in science and industry.

Advanced fiber lasers are eagerly awaited by manufacturers with lasers in their production lines, and demand from other industries is no less keen. Particularly the aerospace and medical sectors stand to benefit from powerful, efficient and robust lasers with high-quality beams. Heeding their call, researchers at the Fraunhofer Institute for Optics and Precision Engineering IOF in Jena developed a new generation of laser systems with improved parameters. These fiber laser systems serve up several kilowatts of power with nearly diffraction-limited beam quality.

In 2013, a team from the IOF and Jena's Friedrich Schiller University was honored with the Federal President's Deutscher Zukunftspreis for its research on ultra-short pulse lasers for industrial mass manufacturing. The team developed laser-based tools that emit light in ultra-short high-energy pulses. Though remarkable, this accomplishment is hardly surprising: The IOF has been conducting cutting-edge research on high-power fiber lasers for some 20 years now.

The Fraunhofer IOF short-pulse fiber laser has already proven its merits in space. © Fraunhofer IOF



# “I see myself as a clinician-scientist”

The life expectancy of patients with untreated pulmonary fibrosis is three years. Drugs can slow, but not stop, the disease's progress. Prof. Antje Prasse and her Fraunhofer Attract research group want to change that.

Interview: Dr. Sonja Endres

It is hardly surprising that Antje Prasse ended up at Fraunhofer. Her parents worked at the Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut EMI in Freiburg, which is where they met and fell in love. The apple doesn't fall far from the tree – Prasse's talent for science surfaced at an early age. Unlike her parents, though, she was infatuated with medicine rather than physics. She studied at Freiburg, earned a doctorate in 1996 and attained her habilitation – that is, the qualification to teach at universities – in 2008 at Freiburg University Hospital with a thesis on interstitial lung diseases.

Pulmonary fibrosis is a complex disease with mechanisms that remain largely unexplored. What is certain is that the connective tissue surrounding the alveoli runs rampant with cells multiplying and hardening. As a result, blood is not properly oxygenated. Patients suffer from and eventually



Researching and interacting with patients – both are near and dear to Prof. Antje Prasse.  
© Fraunhofer ITEM

succumb to increasing shortness of breath. Of the many different types of pulmonary fibroses, the most common is idiopathic pulmonary fibrosis (IPF), but the cause of the disease remains a mystery.

Prasse has headed up an Attract research group at the Fraunhofer Institute for Toxicology and Experimental Medicine ITEM at Hannover for nearly five years. This group is developing new concepts for treating pulmonary fibrosis. The Fraunhofer Attract program's funding will run out in fall of 2019. *Fraunhofer magazine* spoke with Antje Prasse about her research findings, her plans and the future of fibrosis research.

## How did you hear about the Fraunhofer Attract program?

Prof. Norbert Krug, head of ITEM, and Prof. Jens Hohlfeld, head of Respiratory Research at ITEM, called my attention to it. We knew each other well from a joint research project. At the time, I was a senior physician at Freiburg University

### Fraunhofer Attract

The Fraunhofer Attract funding program affords outstanding external scientists the opportunity to pursue innovative ideas with a research group of their own. They do so in close collaboration with the industry, mindful of market demand and with an eye to real-world application. Researchers have a budget of up to 2.5 million euros at their disposal to set up and lead a group for five years. Learn more at:

 [s.fhg.de/attract-en](https://www.s.fhg.de/attract-en)

Hospital and had set up a team to measure cell biology in interstitial lung diseases. The pharmaceutical industry was interested in our work, and I had conducted many projects for it. I was on a several-month research stay at Yale University when Norbert Krug got in touch with me.

**What made Attract so attractive that you turned your back on Yale and heeded the call from Hannover?**

There were several reasons. The Attract budget of 2.5 million euros over five years afforded me a great deal of freedom that I would not otherwise have had. The Hannover location was also persuasive. With the ITEM, the Hannover Medical School (MHH), the Clinical Research Center Hannover and the German Center for Lung Research, it offers unique infrastructure for clinical research into lung diseases.

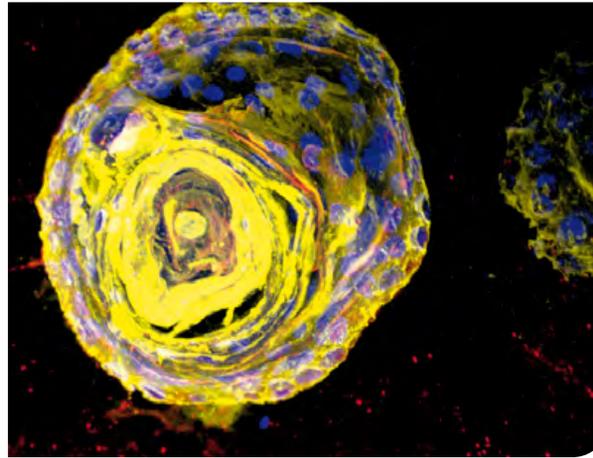
**Working for the ITEM is not your only job. You also treat fibrosis patients as a senior physician at the MHH Department of Respiratory Medicine. Isn't that a bit much for you?**

No. The ties to the clinical practice and the personal interaction with patients are very important to me. I see myself as a clinician-scientist who quickly translates scientific insights into applications. Fraunhofer ITEM and the Department of Respiratory Medicine of the MHH are closely linked, both in terms of personnel and via the Centre for Lung Research. Being able to work for both institutions is ideal for me.

**The Attract program's funding will soon come to an end. What were the most important findings in the past five years?**

We accomplished some outstanding things on the clinical side. We set up a pulmonary fibrosis center for patients from all over central and northern Germany. They know that they are in the best of hands here and are eager to take part in studies to finally find effective remedies against this disease. This enabled us to collect many samples, so we now have a deep well to draw on. Using our extensive biobank, we have developed several cell culture systems that pharmaceutical companies can use to test new agents. More and more companies are showing great interest in this. We have quite a few national and international cooperation partners, including Boehringer, Novartis, AstraZeneca, Indalo Therapeutics, and Nitto, a Japanese company.

**Why is the industry showing such great interest? Are there really that many pulmonary fibrosis patients?**



Fibrosis patients' lung stem cells form spheroids. These globular structures are probably responsible for the growth of honeycomb cysts in the lung tissue, which are typical for fibrosis. © Fraunhofer/Ralf Mohr

Some 500,000 people in Europe suffer from pulmonary fibrosis, and the patient count is rising. Pulmonary fibrosis is an age-related condition; patients are 68 years old on average. The incidence rate will increase as the demographics change. The catabiotic degenerative process plays an important role in the disease. It seems that the lungs are predisposed toward fibrosis, but other organs such as the liver, kidneys or eyes can also develop fibrosis, which leads to tissue destruction. We expect that if we succeed in treating pulmonary fibrosis, we can arrest the aging process – not only in the lungs, but also in other organs.

**So this is about the vision of immortality?**

In a sense, yes.

**When do you think pulmonary fibrosis will be curable?**

I doubt that we will be able to turn destroyed tissue back into healthy tissue anytime soon. We will not have arrived at this point in ten years' time. But we could be there in twenty years if the pace of development continues at the current rate. What we can already do is significantly slow the course of the disease, and soon we may even be able to stop it altogether.

**What's next for you personally?**

I am unconcerned about my future. There are no signs of the pharmaceutical industry's interest in my research waning; on the contrary. I am aiming for an academic chair, a W3 professorship, and I can well imagine continuing to work for both Fraunhofer ITEM and the MHH. It remains to be seen if the structures here are such that this will be possible. I would be delighted if that were the case. ■

# Specialist for dental CAD: exocad

Young startups are often exposed to substantial risks and struggle to survive, or that's the generally accepted view. Dental software specialist exocad, however, has enjoyed a smoother ride. In less than a decade, the Darmstadt company has established a thriving international business - thanks, not least, to expert support in the early years.

Text: Mehmet Toprak

When it comes to bolstering the German economy, high-tech startups and young spin-offs like the Darmstadt company exocad have an important role to play. Founded by Tillmann Steinbrecher and Maik Gerth in 2010, exocad produces CAD/CAM (computer-aided design/computer-aided manufacturing) software for dental clinicians and dental labs. Before becoming entrepreneurs, Steinbrecher and Gerth worked as research fellows at the Fraunhofer Institute for Computer Graphics Research IGD, also located in Darmstadt. Their company got off to a flying start and has grown at a remarkable rate ever since. Today, a mere eight years on, exocad has company offices in the USA, Hong Kong, the UK and Luxembourg.

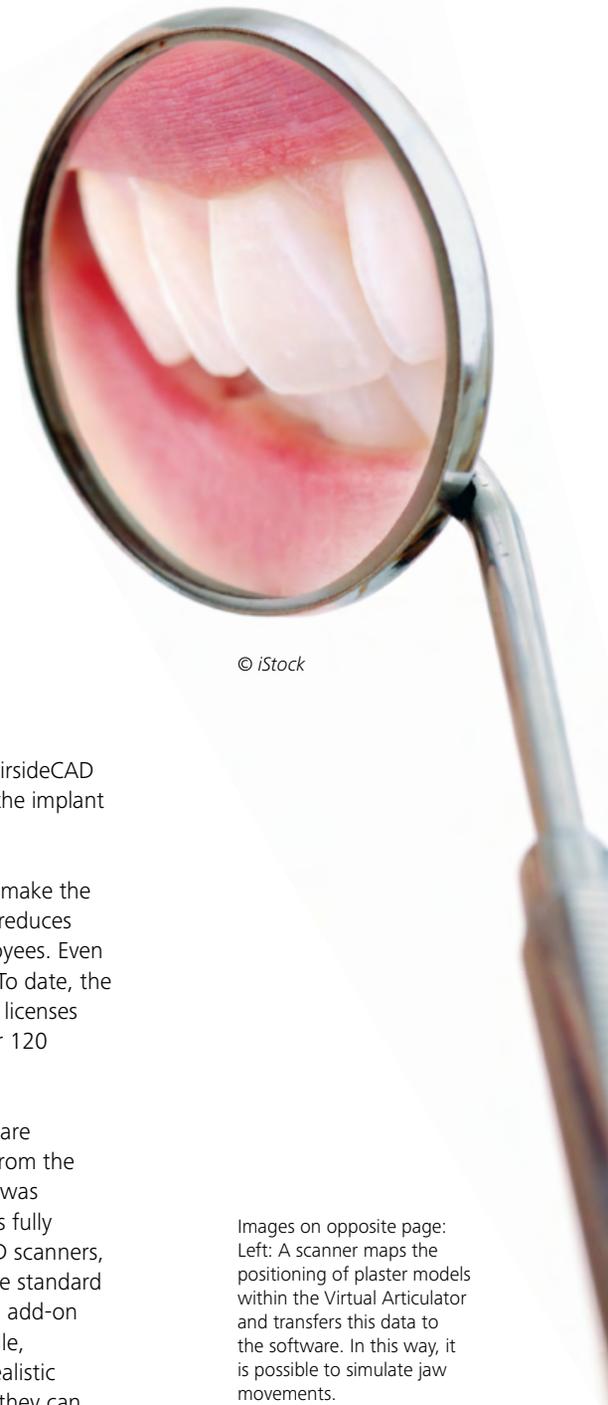
## Software for dental labs

The company's success is founded on CAD software that Steinbrecher and his team developed at Fraunhofer IGD. Its DentalCAD software helps with planning and design in almost every area of dental prosthetics - crowns, bridges, inlays, full and partial dentures, and complex implants. Prosthetics is a very individual process. "Designing a prosthesis is highly specific; after all, each crown or bridge for a specific patient is only ever made once," Steinbrecher explains. Software from exocad ensures a perfect result every time. Alongside the now well-established lab software DentalCAD, the company has

expanded its portfolio to include ChairsideCAD - a CAD software for dentists - and the implant software exoplan.

A key concern for developers was to make the software quick and easy to use. This reduces the costs of training dental lab employees. Even newcomers soon get the hang of it. To date, the company has sold more than 32,000 licenses worldwide and has customers in over 120 countries.

In recent years, the company's software platform has continued to expand. From the word go, vendor-neutral integration was a top priority, meaning that exocad is fully compatible with a whole range of 3D scanners, milling machines and 3D printers. The standard software package is upgradable with add-on modules and special features. TruSmile, for example, gives dentists a photorealistic display of proposed dental work, so they can then show patients chairside what a ceramic restoration looks like instead of a metal crown. And with ChairsideCAD, dentists can design and produce inlays, crowns or bridges on the spot, with guaranteed seamless integration in the workflow of the dental practice or dental lab. In the field of implantology, the company's exoplan software provides a virtual interface for dentists and dental technicians to precisely plan implants on the basis of the actual prosthesis.



© iStock

Images on opposite page:  
Left: A scanner maps the positioning of plaster models within the Virtual Articulator and transfers this data to the software. In this way, it is possible to simulate jaw movements.

Middle: The company's CAD software generates a detailed and realistic rendering of how crowns, bridges, inlays or implants will look in the mouth.

Right: The exocad Implant module makes the design of screw-retained crowns, copings or bridges easy and precise. All images © exocad

### Spin-off was the logical move

The technological bases for exocad were already well in place before the company was founded in 2010. Gerth, now CTO at exocad, recalls: "We were just about ready to go to market while we were still at Fraunhofer IGD. There was great demand for the product, and we also had potential customers lined up. It was therefore the logical move to set up our own company."

Fraunhofer Venture was on hand to provide specialist advice and help Steinbrecher and Gerth prepare for the launch of their new spin-off. In parallel, the Fraunhofer-Gesellschaft came on board as a founding partner. "That was a big help in the beginning," Steinbrecher says. "When I went to trade events like the International Dental Show in Cologne, Fraunhofer's good name meant that people took us seriously. So it wasn't long before we were able to find top-quality partners."

### Buyout by an international investment company

At the time it was founded, back in 2010, exocad had three employees. Today, there are over 80, and the company is more than

capable of standing on its own two feet. The Fraunhofer-Gesellschaft therefore divested its stake in September 2016. In parallel, the Carlyle Group, an international investment company, acquired a majority holding. With a powerful new investor on board, Steinbrecher and Gerth expect the pace of global expansion to intensify.

What makes this success story even more special is that, back in 2010, the funding and the support on offer from Fraunhofer were by no means as extensive as they are today. As investment manager Markus Weitzel from Fraunhofer Venture explains, there's now much more assistance available for spin-offs: "Over the years, Fraunhofer has acquired a great deal of experience in identifying exciting research topics and developing them into products and solutions that are close to the marketability stage. In addition, we often bring together all the various partners and stakeholders who are involved in setting up a new spin-off. It's an area where Fraunhofer excels compared to all the other research establishments worldwide."

In other words, there's never been a better time for Fraunhofer researchers with an innovative development and a sharp business idea who are looking to launch their own startup venture. ■

### Facts and figures: Fraunhofer Venture

**Established:** 2001

**Object:** setting up spin-offs to further the practical and commercial exploitation of innovative technology

**Employee numbers:** 28

**Number of spin-offs to date:** 400

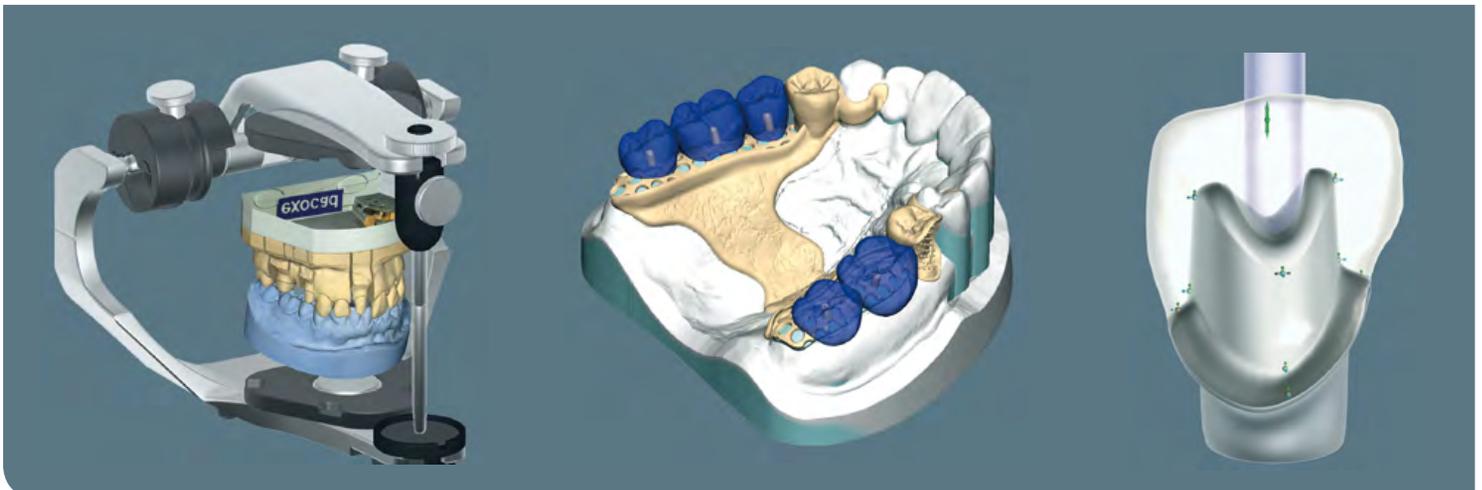
**Success rate:** 97 percent of Fraunhofer spin-offs are still in existence 36 months after establishment – compared to 69 percent of all high-tech startups in Germany (source: KfW Start-up Monitor 2018)

**Venture capital:** active FhG holdings founded in the period 2008–2017 attracted venture capital investment of around 19 million euros in 2017

**Combined revenue:** active FhG spin-offs founded in the period 2008–2017 generated a combined revenue in 2016 of around 170 million euros

**Jobs created:** active FhG spin-offs founded in the period 2008–2017 created 1798 jobs

 [www.fraunhoferventure.de/en.html](http://www.fraunhoferventure.de/en.html)



# Multiphoton Optics: a spin-off from Würzburg

Multiphoton Optics is taking the market for high-precision 3D printing by storm. The technology is based on ultra-short laser pulses and can produce structures with a surface quality on the nanometer scale. The startup grew out of a spin-off from the Fraunhofer Institute for Silicate Research ISC. Fraunhofer Venture helped launch the new company.

Text: Mehmet Toprak

Take your pick: integrated manufacture in one, two or three steps for low-cost production of lenses.  
© MPO



Best of Industry Award for MPO: Dr. Alexander Krupp, Dr. Benedikt Stender, Dr. Ruth Houbertz and Felix Kiesel (left to right). © MPO



Above: Dr. Alexander Krupp, applications engineer at Multiphoton Optics, pictured at the handover to Heidelberger Druckmaschinen of a LithoProf3D® printer in the new, fully integrated design.



Far left: A scanning electron microscope image of a component produced by a LithoProf3D® printer. The image to the right shows a software-based simulation of the same part. © MPO

It's been quite a journey for Ruth Houbertz: from head of department at Fraunhofer ISC to founder and managing director of her very own company, Multiphoton Optics. Launched in 2013, the Würzburg startup is one of today's leading players in high-precision 3D printing. Using a technique known as two-photon polymerization, the company's 3D printer can create minuscule structures ranging from the nanometer to the centimeter scale.

This success story also involved substantial input from Fraunhofer Venture. This is the department at Fraunhofer-Gesellschaft responsible for launching spin-offs, thereby ensuring that promising Fraunhofer technologies find their way to market.

### How Fraunhofer supports spin-offs

The Fraunhofer-Gesellschaft is a founding partner of Multiphoton Optics. At the practical level, its department Fraunhofer Venture provides budding Fraunhofer entrepreneurs with a wide variety of support at every stage of the commercialization process – from formulation of the initial business idea to managing the tech transfer and on to the actual founding of the new startup. As Maximilian Frank from Fraunhofer Venture explains: "We act as a guide and mentor for Fraunhofer spin-offs during the preparation for launch; and, once the company is up and running, we continue to advise the partners and executive management on business and legal matters."

In addition to providing such expertise, Fraunhofer Venture also ensured Multiphoton Optics received funding from the Fraunhofer-Gesellschaft. "What's more, we were also able to secure capital from the state of Bavaria's very own high-tech startup fund, Bayern Kapital, and from a variety of business angels," Frank says.

### Two-photon polymerization

Multiphoton Optics uses a special technology known as two-photon or multiphoton polymerization. This involves bombarding a material with ultra-short laser pulses, which results in a chemical reaction. This in turn triggers a process of polymerization, in the course of which groups

of photochemically reactive polymers are joined together. In this way, it is possible to "print" 3D structures in a process commonly known as additive manufacturing. The process is so precise that it can be used to fabricate structures down to less than 100 nanometers. At the same time, it is highly scalable. As Houbertz explains: "We are the first company worldwide to have demonstrated that the technology also functions on six-inch silicon wafers."

There are potential applications in many areas, including sensor systems, augmented and virtual reality, imaging, illumination and medical technology. For example, the process can be used to manufacture tiny lenses. Here, the ultra-short laser pulses for the fabrication process are controlled by the LithoStream3D software, which in turn is fed with G-code generated by the LithoSoft3D software package. Both the LithoProf3D® printer and the corresponding software package were developed by Houbertz and her team in a project that has its roots in work undertaken at Fraunhofer ISC.

The process is also incredibly flexible, much to the delight of customers from industry. For example, the 3D printer can be used on glass, silicon, photonic integrated circuits (PIC), metals, paper, plastics, modules and preassembled components such as lasers or LEDs. And the process is highly scalable in terms of both size and surface quality. In an automated process involving just a few steps, it is possible to produce functional structures. Here, too, industry customers benefit, since the process significantly reduces costs and also protects the environment.

Given the extreme flexibility and precision of its 3D printer, the company is also receiving inquiries from research establishments and universities. In other words, technology transfer has come full circle: from the laboratory to industry and back again.

### From the original idea to the startup

Two-photon polymerization has been a pet project of Houbertz' for a long time: "All in all,

I've spent 18 years of my life on this topic; 13 of those were at Fraunhofer ISC, where I was also director of the Optics and Electronics unit." Her aim had always been to develop some kind of industrial application. But she was unable to find a manufacturer willing to build the right kind of machine. So she ended up founding her own company. "There was no choice but to get stuck in and do it ourselves. That's how Multiphoton Optics came about," she says. The company currently has ten employees and, on the strength of continued growth, should have five or six more by the end of 2019.

Fraunhofer's excellent reputation has certainly played a role in the company's rapid success. "If a startup comes along with an innovation from Fraunhofer, then that gives investors and customers from industry the confidence that the underlying technology is sound," explains Frank from Fraunhofer Venture.

One of the company's secrets of success is its pragmatic approach. When dealing with obstacles or setbacks, the response of Houbertz and her team is to set about solving the difficulty as quickly as possible – or simply to find a workaround.

Yet not every problem can be tackled with pragmatism alone. Houbertz would like to see more women at her company, for example, but there are simply too few female applicants. She points to scientific studies that show that mixed teams produce better results. "We should stop going on about the supposed differences between men and women. In research and in the world of work, everyone reaches a result by their own means, irrespective of whether they are a man or a woman."

And there's something else bothering Houbertz: "I wish Germany were friendlier to innovation. But everything takes an age here! It's high time we started getting rid of the various barriers – approval procedures, for example, and other bureaucracy." With her own startup, Houbertz has offered a fine example of what that might achieve. ■

# Authentic holograms with new 3D video technology

Known as 3D human body reconstruction, the software is already in use at Studio Babelsberg in Potsdam.  
© Stefan Kny

This innovative technology enables new forms of interactive experience with exciting entertainment and educational applications.  
© Fraunhofer HHI

A total of 32 cameras are installed in the circular studio. © BlacPic



Equipped with a VR headset, spectators can immerse themselves in a virtual world featuring incredibly lifelike 3D images of real people. Thanks to the work of a Fraunhofer research group, this vision is now a reality.

Text: Anika Abfalg

Imagine a hologram of your favorite film star in your very own living room. And imagine you could walk around that image and look at it from all sides. Back in the year 2000, Oliver Schreer was gently mocked for this vision. Back then, the idea of 360-degree, volumetric video representation of a real object was merely that – an idea, nothing more. However, a research group by the name of Immersive Media & Communication, headed by Schreer and Ingo Feldmann at the Berliner Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institut HHI was already following up precisely that vision – namely, to produce extremely lifelike 3D video images that you can inspect from all angles.

Using stereoscopic image-processing software, Schreer and his team first described the geometric relations between two camera images – a key step in generating 3D images. More and more cameras were added; at present, the system employs a total of 32. Using software

known as 3D human body reconstruction, which was developed at Fraunhofer HHI, the images from these cameras are combined to form a 3D representation. The technology has been on the open market since June 2018 – at the volumetric studio of the Potsdam company Volucap. “I never thought for a minute it would be such a success – that we would open a commercial studio and suddenly be competing with companies like Microsoft,” says Schreer.

The 32 high-resolution cameras are paired in 16 stereoscopic systems. Unlike computer-animated graphics, the images produced are extremely lifelike and authentic, capturing facial expressions and even slight movements of clothing. A huge volume of data is involved: each camera has a resolution of 20 megapixels, ten times more than conventional full HD video. This generates a total data volume of 1.6 terabytes every minute – too much to be used directly. “You need a system working in the background that can handle this amount of data and extract the really necessary information,” Schreer explains.

At the heart of this system is software that processes video images from 32 perspectives and combines them into a discrete 3D point cloud that is then mapped onto a wireframe model. In this way, it is possible to produce an extremely lifelike and dynamic representation of a person and their movements in top quality and with great geometrical and textural detail. The resulting 3D model is stripped of

superfluous data. After further processing, it can be fed into any standard 3D graphics software for incorporation in a virtual environment.

## A new level of authenticity

Thanks to this new technology, virtual reality and augmented reality now become even more authentic. For example, 3D video images produced in a volumetric studio can add a whole new interactive dimension to viewers’ experiences of narrative in a VR setting.

For Schreer, however, there are many other applications beyond the realm of pure entertainment. For example, volumetric representations might be used to present past worlds and historical figures, thereby making them accessible to a large audience and helping to preserve their memory. This might include UNESCO world heritage sites – a virtual reconstruction of the ancient city of Palmyra, say, or the Inca citadel Machu Picchu – or the worlds inhabited by famous people from the past.

Schreer’s vision also covers live 3D video. Indeed, with a system comprising eight cameras at low resolution, his company can already record and transmit live 3D video images. In the future, therefore, it may well be possible to hold business meetings in a virtual boardroom in which participants talk and interact with one another, while in reality they are at completely different locations and equipped merely with a VR headset. ■

## Fraunhofer innovations

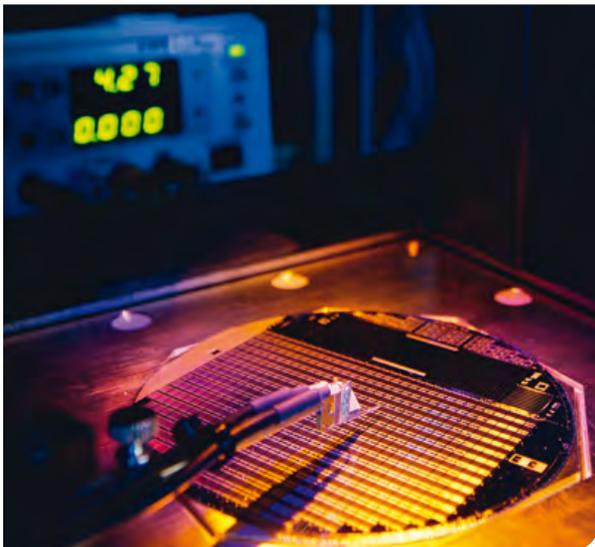
**70 YEARS  
OF FUTURE**  
#WHATSNEXT

### *World record-setters at converting sun- light into electrical energy*

Projected scenarios for future energy systems have one thing in common – our energy supply will have two legs to stand on, solar and wind power. With technological progress, economies of scale, and lessons learned driving down prices, the cost of solar power has plummeted 75 percent since 2006. Photovoltaic power plants in Germany today are able to provide energy at a competitive four to five euro cents per kilowatt hour. Europe's largest solar research institute, the Fraunhofer Institute for Solar Energy Systems ISE, has been helping this progress along for many years now.

Since it was founded in 1981, the institute has been setting efficiency records for solar cells and egging on the global success of photovoltaics. It has held the world efficiency record of 22.3 percent for multicrystalline silicon solar cells since 2017. The same goes for the absolute world record for converting sunlight into electrical energy, which stands at 46.1 percent. ISE experts achieved this feat with a multi-junction solar cell based on III-V semiconductors under concentrated sunlight.

A multiple solar cell based on III-V semiconductors with 46.1 percent efficiency set the world record for converting sunlight into electrical energy. © Fraunhofer ISE



### *The white LED, the tiny emitter that sparked an industry revolution*

When Prof. Jürgen Schneider from the Fraunhofer Institute for Applied Solid State Physics IAF presented one of his first white light LEDs to a customer, that gentleman mistook it for an "odd paper clip" and promptly binned it. As irony would have it, this invention paved the way for the cost-effective, energy-efficient and long-lasting white light LEDs that are now indispensable in the automotive industry, streetlamps and interior lighting.

Back in 1995, the late Prof. Schneider and his team at Fraunhofer IAF succeeded in producing white light with just one light-emitting diode chip. Until that breakthrough moment, this could only be done by mixing three monochrome light-emitting diodes using a complicated regulator.

Fraunhofer IAF's research into efficient and reliable LED lighting continues. A case in point: Its scientists are busy developing adaptive LED modules that adjust to human biorhythms.

LEDs are now available in all colors. They consume but little energy, yet last and last – lighting the way for cars, and illuminating roads and rooms. © Fraunhofer IAF



# “We need an education campaign in digital technology”

Little by little, digital transformation is changing the very fabric of our society. Yet there is still little serious discussion of just what form this process should take. Together with an interdisciplinary research team at the Weizenbaum Institute for the Networked Society – known also as the German Internet Institute – Prof. Ina Schieferdecker is going to be exploring this issue in more detail.

Interview: Dr. Sonja Endres



Prof. Ina Schieferdecker  
© Fraunhofer Fokus

The mathematician and computer scientist Prof. Ina Schieferdecker is a woman of great energy and considerable talents. Together with Prof. Manfred Hauswirth, she heads the Fraunhofer Institute for Open Communication Systems FOKUS. In parallel, she holds the chair in Quality Engineering of Open Distributed Systems at the Technische Universität Berlin and is a member of the German Advisory Council on Global Change, a federal government body. She is one of the three founding directors of the Weizenbaum Institute for the Networked Society, which was established in September 2017, thanks in no small part to her efforts. The Weizenbaum Institute is at present a consortium, although,

as its name intimates, it hopes very much to become a permanent institution. This consortium brings together a total of 120 researchers from the fields of computer science, the humanities, the social sciences, economics and law. These researchers are now busy investigating the impact of advancing digitalization on society.

*Fraunhofer magazine* spoke with Prof. Schieferdecker about the key challenges of digital transformation, the widespread fears it provokes, and the need for a campaign of education in digital technology.

### Prof. Schieferdecker, why does Germany need an Internet Institute?

Because here, in Germany, there is still a lack of proper critical reflection on the social implications of digitalization. That's why we've focused on the social sciences and named the institute after the Internet pioneer Joseph Weizenbaum. He was one of the very first people to remind scientists very emphatically of their responsibilities when developing new technologies and of the need to consider their possible social implications.

### Which burning social questions will the 20 interdisciplinary research groups at the institute focus on?

The groups are divided into six research areas: labor, innovation and value creation; contracts and responsibility in digital markets; governance and norm setting; technological change; and knowledge, education and social inequality; democracy, participation and the public sphere. Researchers are exploring such issues as the current practice of selling private data and asking whether this should be accepted, promoted or prevented. They are also looking at how social bots and fake news are changing the media. And another research group is investigating what digitalization of the workplace will mean for people working in industry, logistics and the service sector.

### A question that concerns a lot of people stems from the fear that they will soon be superfluous to requirements, because machines will take over a lot of their work. Is that fear justified?

Yes and no. I think that a lot of jobs are going to change dramatically, even in the sciences. Some occupations are going to disappear completely. But it won't be the first time that's happened. There's been a process of upheaval ever since the Industrial Revolution. Today, automation continues to increase, and digitalization is merely another, exceptionally powerful manifestation of this process. But it will not only make some jobs superfluous, it will also create new ones. Besides, the social partners are aware of this problem and are working to ensure that the principle of solidarity continues to apply in a digitally networked society.

### Beyond the world of work, where do the biggest challenges of digital transformation lie?

In the area of sustainability. First of all, we have to secure the future of the planet, as it were, and then we can tackle the other problems. We need to use digitalization to help achieve sustainability targets.

### Your research explores the security of digital systems and ways of making it more resilient to malfunctions, outages or attacks. How can we obtain advance warning of these risks?

That's difficult. All technology involves risks. The problem is that the risks connected to information and communications technology are often swept under the carpet. We need to be completely open about any digital incidents and failures. By sharing this information, we can help make it easier to develop reliable digital systems. I would therefore argue in favor of expanding the reporting regulations as specified in the IT Security Act. At present, any system attacks must be reported, but not attacks on system safety. It's bad enough when a system fails, but the important thing is to learn from that quickly and comprehensively.

### How can risks be limited?

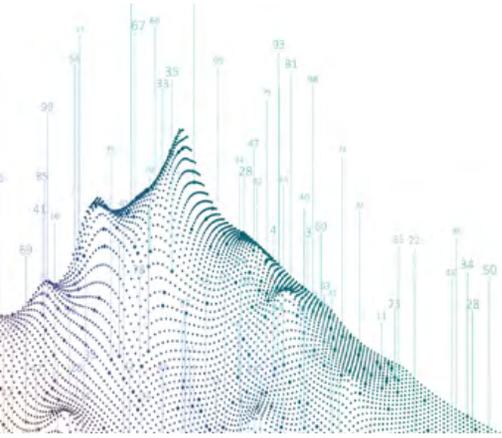
Society needs to recognize that digitalization requires safety mechanisms and that these safety mechanisms cost money. You can't have a system that is secure, reliable and compliant with data-protection regulations, and then still expect it to cost nothing! If we've got minimal solutions that have been cobbled together and released without being properly tested, so that the user becomes the tester, then we've got a problem. And if that happens in a context with security or safety implications, we're simply being irresponsible. An aircraft, for example, can't take off without the appropriate technical, administrative and safety paperwork. The fact of increasing connectivity means that critical infrastructure can now end up being accessible via what are still noncritical, unsecured areas. Society should be prepared to pay for – and demand – an appropriate level of security.

### When citizens call for regulation and are expected to make informed decisions, they should have a sound basic knowledge of digitalization. Do we need a campaign of education in digital technology?

Yes, we do need that, absolutely. It's not enough to know how to use Word or Excel. People have to know what kind of options they have when using automated decision-making tools. We are committed to teaching people not only about the basic principles of digitalization but also how they are applied and what their social implications are.

### Which types of technology are going to have the greatest impact on the world?

Apart from digital technology – biotechnology and materials technology, because together they will soon be the basis of every innovation. ■



# Data science: learning from the experts

Special skills are required to handle huge volumes of data and extract valuable information from them. Certified courses offered by Fraunhofer BIG DATA AI provide the necessary know-how.

Text: Janine van Ackeren

In today's world of business, data is the new commodity. Every time you proffer a customer loyalty card at the drugstore checkout, make an online purchase or simply surf the net, you leave behind a trail of data that companies can then exploit. This might be a music provider that will then recommend listening choices tailored to your own personal taste. Or it might be one of the data giants, like Google, which can glean huge volumes of data in order to harvest useful information for purposes such as route

Alliance. Known as Fraunhofer BIG DATA AI, this alliance involves more than Fraunhofer institutes. Some courses conclude with a certification exam. The introductory gateway course is Certified Data Scientist Basic Level. At a higher level, intermediate courses such as Certified Data Scientist Specialized in Data Analytics/Scientific Data Management/Machine Learning teach how to use various methods in one or other specialist area, while also offering an insight into the theory and mathematical foundations of data science.



Fraunhofer is offering a range of courses designed to help budding data scientists learn all about data analytics and data processing. © Fraunhofer IAIS/Maximilian Waidhass

planning. Other sectors of the economy are only now waking up to the importance of data analytics. In industry, for example, analyzing data from sensors monitoring the manufacturing process gives companies advance warning of production problems and helps them avoid costly downtime. So, the key question is, how can employees make the leap from merely using data processing software to becoming genuine specialists in data analytics?

## Certified courses for budding data scientists

One concrete option here is to sign up for the training courses for data scientists offered by the Fraunhofer Big Data and Artificial Intelligence

Finally, those looking to delve even deeper into the subject – and who already have project experience in the field of data analytics – can sign up for an advanced or senior level course.

The Fraunhofer campus at Schloss Birlinghoven near Bonn is currently staging the intermediate course for data scientists specializing in data analytics. Directed at professionals with basic statistics and programming skills, the course is designed to teach the essential foundations of modern data analytics. Practical work is based on the open source software KNIME, and participants also gain experience of the programming language Python. After the course, participants will be able to produce their own data analyses and evaluate the benefits of machine learning.

In the seminar room at Schloss Birlinghoven, a bulky folder awaits each of the 15 students. Birgit Kirsch, one of the course leaders, is a research fellow and doctoral student at the Fraunhofer Institute for Intelligent Analysis and Information Systems IAIS. She will focus on the question of what comprises a text and how to extract specific information from it. Her colleague Daniel Trabold is a member of the Fraunhofer Expert Committee on Data Science and also a doctoral student at Fraunhofer IAIS – he reveals with a smile that he has almost completed his thesis on the analysis of data streams. Trabold begins by explaining to participants what exactly a data scientist does. Data scientists, he tells the group, are needed in almost every sector of the economy: in agriculture, for example, where they help the farmer to spread fertilizer only on ground where

manager for stocks and shares. I'm now seeing more and more data scientists looking for jobs in my field. I'm hoping that the course will teach me how to use data science. I'd like to know what it can do for me in my field of work." Two risk managers from the insurance business are here for similar reasons and hope to gain an insight into the methods and applications of data analytics. A business informatics specialist, various consultants and several employees from automotive manufacturers make up the rest of the group.

### Why data analytics? Two prominent examples

Kirsch begins with a short review of the history of data analytics. "Back in the 1990's, companies such as Yahoo tried to put together something like a yellow pages for the Internet. Their method

2007. From the early days, however, it carefully gathered data about which users favored which type of film or series. On the basis of this rich dataset – Netflix now has well over 100 million customers – the company began producing its own content, resulting in, for example, the highly successful series House of Cards.

Trabold then explains that the idea of analyzing data in order to discover patterns and interconnections is by no means new. As early as the 1950's, the ENIAC computer was employed to generate weather forecasts. However, a lack of adequate computing power meant that many of the methods developed in the 60's and 70's remained impracticable. Indeed, it was only decades later, with the development of artificial neural networks, that data analytics had its real breakthrough.



it is actually needed; or in the engineering industry, to determine when machine tools will become blunt and require replacing.

### What participants hope to gain from the course

The budding data analytics experts are gathered around a large seminar table and exchange furtive glances. Who else has signed up to become a certified data scientist? One participant works for a major supermarket chain. He introduces himself to the rest of the group: "I'm responsible for monitoring the supply chain and hope to find out something about the tools used in data analytics." Then it's his neighbor's turn: "For the last 22 years I've been a portfolio

was to mark individual pages with keywords," she explains. "But two doctoral students from the University of Stanford had a better idea. They analyzed the hyperlinks between pages and developed an algorithm – the so-called PageRank algorithm – to count the number of links to a specific page from other pages and also the number of links from that specific page to other pages. Their development changed the world." This is because the PageRank algorithm would form the basis of the Google search engine.

Another company that made a clever business decision based on data analytics is the streaming service Netflix. As Kirsch explains, the company began life in 1997 as an online video library and only went into the streaming business in

### Data science is based on teamwork

In the meantime, the methods used in data analytics have come on in leaps and bounds. At the same time, there are now very few areas in which data analytics doesn't already play a role. So what key skills must a budding data scientist have? "You need to be able to program and have some know-how in the areas of math and statistics, and, of course, you need some specialist knowledge of data analytics," Kirsch says. The group looks worried, but she quickly reassures them: "No one has enough know-how to cover all three areas, which is why data science is always based on teamwork!" ■

# The data detectives

As an expert in big data analytics, predictive analytics, deep learning and mobility mining, Dr. Dirk Hecker is the right person to consult on the topics of data analytics and machine learning. As manager of the Fraunhofer Big Data and Artificial Intelligence Alliance BIG DATA AI and deputy director of the Fraunhofer Institute for Intelligent Analysis and Information Systems IAIS, he is also ideally placed to talk about the Alliance's new program of continuing education for prospective data scientists.

Interview: Janine van Ackeren

Dr. Dirk Hecker, manager of Fraunhofer BIG DATA AI, is well aware of the lack of data scientists in Germany. He is therefore committed to improving study and training opportunities in this field. © Fraunhofer IAIS



Mr. Hecker, most people won't be familiar with the profession of data scientist. What does this job involve?

If you went to a concert ten years ago, most people would have been dancing. Today, lots are simply holding up a cell phone to record the whole thing. It's a process of creeping digitalization that we're seeing throughout society. In the period since 2003, the volume of digital data has outstripped that of analog data. What's more, it's also rising at an exponential rate: the amount of data is doubling or trebling every year. To cope with this flood of data, we need data scientists – that means specialists who know how to handle data analytics. Unfortunately, their number is not growing anything like fast enough to keep pace with the increase in data. Major German companies, for example, are looking to hire literally hundreds of data scientists.

What exactly is it that data scientists do?

You could say that data scientists are like data detectives: they search through data for completely new patterns and relations. The typical job profile for a data scientist sounds like the proverbial jack-of-all-trades: you need to have good analytical skills, possess a good knowledge of math and be well versed in programming languages such as Python and R. What data scientists do, for example, is help business developers and people with large amounts of data on their hands to decide what kind of questions they can answer with that data. They are data managers, and they're responsible for data quality and enriching data with supplementary information. They're also data analysts and develop statistical prediction models based on that data. And they're system architects, responsible for creating a scalable computer architecture – because to process a lot of data quickly, that data has to be spread over a lot of computers. In short, data scientists are expected to have an enormous range of skills. It's impossible for one person to have all of them; that's why data science is always based on teamwork.

What kind of thing can data scientists find out from a mountain of data?

Well, take cars, for example: today's cars are like cell phones on wheels. They're equipped with sensors, GPS and a UMTS card. Their positional data are used to generate real-time forecasts of traffic congestion. Or items of agricultural machinery: they're also equipped with sensors which monitor every square meter of land under cultivation. This enables seed manufacturers to provide the farmer, at the time of purchase, with a guaranteed yield for the harvest based on weather and soil data. That's a key competitive advantage. Or voice recognition systems: they have become so good at understanding each of us because they've learned from the voice data of lots and lots of users. And self-driving cars: they're able to navigate the traffic because they have learned on the basis of image and sensor data gathered by large fleets of vehicles.

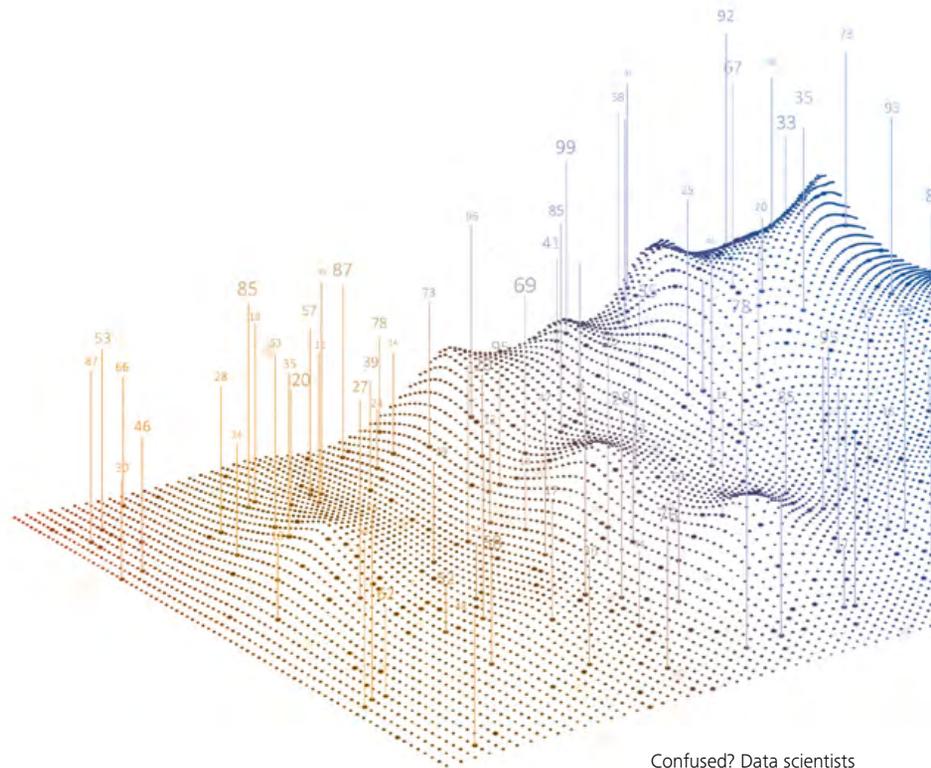
## Why is it so important to train data scientists?

Germany makes the best sensors and the best machinery. But so far, we've paid far too little attention to ways of analyzing and using the data they produce. In today's world, it's the person with the most data who goes on to develop smarter devices and better services. That's why people now compare data to oil, as the world's most precious resource. Data scientists are the new engineers. Look at automobile manufacturing. Nobody laughs at Chinese cars anymore. The key factor now, when buying a new car, is the quality of service. At present, that applies to navigation devices, but soon it will mean driverless vehicles. Here, in Germany, we've neglected to collect and use the data that is needed for this. If we want to avoid being left behind in the wake of China and the USA, we urgently need to build up our store of data along with the relevant analytic skills and other services. If not, we're going to find ourselves surrounded by a foreign digital infrastructure.

And we also need to regain control over our own data. It's only if we program the systems ourselves that we can incorporate our own social and ethical attitudes and beliefs – German, European attitudes and beliefs. If we want to see them reflected in the speech and image processors used in smart assistants or robots, then we need to get busy now and start developing alternatives. Time's running out: China has said it wants to be the world market leader in artificial intelligence by 2030. That's worrying. Data are the bedrock of artificial intelligence, and you need data scientists to use those data.

Tell us about how Fraunhofer BIG DATA AI came to be offering various certificate courses in data science. And what's special about these courses?

There's a huge demand for data scientists right now, which the universities and other institutions of higher education are unable to meet. What's more, the people who do their courses don't gain any industry-specific knowledge. Back in 2013, Fraunhofer BIG DATA AI therefore decided to launch an extensive program of courses for prospective data scientists. By now, it's the biggest study program on offer at the Fraunhofer Academy. We have around 800 enrollments a year, and numbers are rising. People frequently opt to start with the gateway course, Certified Data Scientist Basic Level. This gives them a general grounding in the field and establishes a common language for data managers, system architects and data analysts. Those opting for the Data Scientist Advanced Level course can choose between different areas of specialization. The latest addition here is a course



Confused? Data scientists specialize in eliciting valuable information, patterns and relations from huge datasets. © Fotolia

focusing on current methods in machine learning and their application in the areas of machine vision, machine reading and robotics. To gain the certificate, students have to pass a final exam and demonstrate some professional experience in the field. The senior level course is one step higher. Here, they need to submit a course assignment.

## What kind of qualifications do participants need?

It's a good thing to have a science degree. They shouldn't be frightened of programming or mathematical formulas. And they should enjoy analyzing data. It's very worthwhile. In the 1970's, the sexiest job of the decade was that of a pilot; in the 1990's, it was a cosmetic surgeon; and today, it's a data scientist. ■

### The Fraunhofer Academy

The Fraunhofer Academy is the Fraunhofer-Gesellschaft's specialist provider of continuing education for people in employment. It offers part-time courses of study, certificate courses and seminars based on the research activities of the Fraunhofer institutes. The study program covers five areas: energy and sustainability, logistics and production, information and communication, manufacturing and testing technology, and technology and innovation.

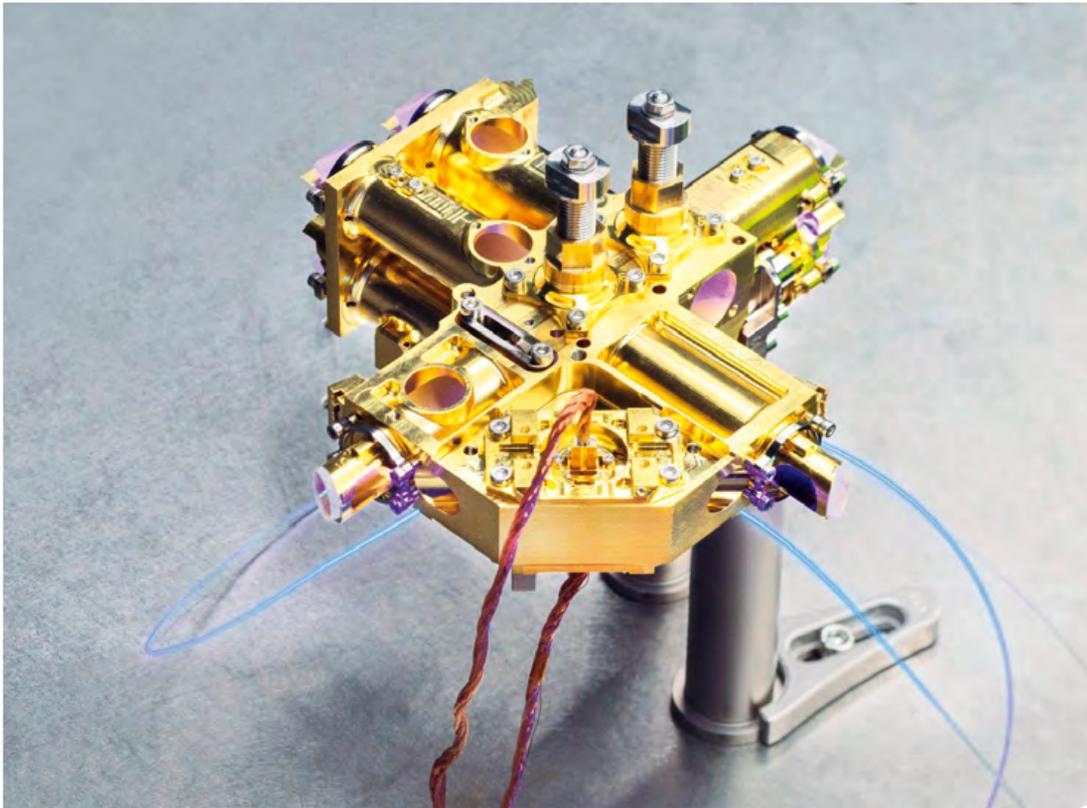


[www.academy.fraunhofer.de/en](http://www.academy.fraunhofer.de/en)



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

# Photon-based data encryption



The quantum source at Fraunhofer IOF generates entangled photons and transmits them from a satellite back to Earth, where they are used to share secure keys for data encryption.  
© Fraunhofer IOF

By installing miniaturized components on a micro-optical bench, researchers at Fraunhofer HHI can combine the advantages of free-space and integrated optics.  
© Fraunhofer HHI

The advent of quantum computers will make it easy to crack conventional encryption methods. A completely new approach to matters of security is therefore required. Happily, new developments in quantum technology promise to keep our data safe.

Text: Mandy Bartel



Quantum technology will generate all kinds of new opportunities in the digital society. Yet there are risks, too. For example, quantum computers will make it easy to crack conventional methods of mathematical encryption. However, quantum communication promises to give us back control of our data. The Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institut HHI in Berlin and the Fraunhofer Institute for Applied Optics and Precision Engineering IOF in Jena are now exploring two different ways of using quantum technology to protect sensitive communications. Both are based on the same principle and complement each other in their respective area of application.

### The basic principle behind quantum communication

In a quantum source, a laser beam is fired at a nonlinear crystal. This generates countless pairs of photons. In each pair, the two photons are entangled with one another. This means that irrespective of how far one paired photon is apart from its twin, each has the same electromagnetic polarization. In other words, if you measure the polarization of one of the photons, you automatically know the polarization of the other. Einstein called this phenomenon "spooky action at a distance." It can be used to generate and to share an encryption key that will tell both the sender and the receiver of a communication when someone is trying to eavesdrop. As soon as someone tries to intercept the communication, the two photons become disentangled, thereby revealing that a hacking attempt is underway.

### Quantum communication for everyone

Moritz Kleinert heads a team of researchers at Fraunhofer HHI. Their objective is to make quantum communication affordable for the mass market: "We're developing miniaturized components for quantum communication that can be easily installed in a standard router," Kleinert explains. "For this, we're using our PolyBoard integration platform." The aim is to develop components that are as small and as robust as possible. For example, the nonlinear crystals required to generate the entangled photons are connected by means of integrated optical chips only a few millimeters in size. Tiny

lenses installed on a micro-optical bench create free-space sections. "This approach enables us to combine the benefits of free-space and integrated optics," Kleinert says. In addition, the chips are designed in such a way as to minimize the loss of photon pairs.

Miniaturization means that more chips can be fitted onto each wafer. In turn, this means that fewer wafers are required, which therefore reduces the costs of production. At the same time, costs can be further cut by the use of automated integrated circuit packaging technology. For, as Kleinert explains, assembly is one of the major cost factors in photonics.

### Different perspectives open up new horizons

This ambitious project is part of two European programs: the Horizon 2020 program UNIQORN – Affordable Quantum Communication for Everyone: Revolutionizing the Quantum Ecosystem from Fabrication to Application; and the EU's Quantum Flagship initiative. The aim of the UNIQORN program is to miniaturize complex photonic systems, which currently require optical components of several meters, so that these systems can be installed on chips just a few millimeters in size. This will not only reduce dimensions and costs but also make the systems more robust and easier to reproduce.

The UNIQORN consortium comprises 17 partners from throughout Europe. These partners are working on a multidisciplinary research program over a period of three years. According to Kleinert, this brings together quantum researchers with photonics experts and potential users: "And that means there's a cross-pollination between all the various perspectives, which opens up completely new horizons."

### Two transmission methods for different distances

In the encryption solution from Fraunhofer HHI, the photon pairs are transmitted to each communication partner via fiber optic cable – using, for example, the existing telephone network. The drawback with this method is that it is only suitable for distances of up to 20 kilometers. Anything above this, and the photon transmission rate decreases too much as a result

of losses in the cable, so that the photon pairs are no longer distinguishable from noise signals. Researchers at Fraunhofer IOF are therefore working on alternative methods.

Their idea is to use a satellite to launch a quantum source into space. From a low Earth orbit at an altitude of around 400 kilometers, this source will then transmit a clean supply of entangled photon pairs back to Earth. "The big challenge here is to ensure that the quantum source is sufficiently robust and powerful," says Dr. Oliver de Vries, project leader at Fraunhofer IOF. "Remember, it must be able to withstand a rocket launch and still be able to provide a reliable supply of photon pairs."

The project team at Fraunhofer IOF has now succeeded in developing a highly stable and very powerful quantum source capable of producing 300,000 entangled photon pairs every second. "We've made the quantum source more stable by using a clever design, effective inorganic bonding techniques and resilient materials that do not expand much when exposed to changing temperatures," de Vries explains. This will ensure that the quantum source is able to handle the satellite launch and the conditions in space.

### Via telescope or router

Before satellite-based quantum encryption becomes a reality, however, the infrastructure needed to share keys must first be established. This will take another three to five years. One option will then be to receive the photons via a telescope that is connected to an IT system. But this will only be practicable for large organizations or government bodies that require ultra-secure communications.

Ultimately, the most practical solution may well be to combine the two different approaches. When large distances are involved, satellite-based quantum encryption will be the natural choice. Back on earth, however, the entangled photon pairs could then be rapidly transmitted over short distances via fiber optic cable to a router. "Five years from now, in sectors such as banking or government, where security is vital, quantum communication will be standard," Kleinert prophesies. "And within ten years, normal end users will also be using this technology." ■

# State-of-the-art VR in the Elbedome

The biggest 3D mixed reality laboratory in Europe is located in Magdeburg. Four meters high and sixteen meters in diameter, the Fraunhofer Institute for Factory Operation and Automation IFF's Elbedome resembles a hemisphere. Companies can bring machines, plants, factories and even entire cities spectacularly to life at a scale of 1:1.

Text: Britta Widmann

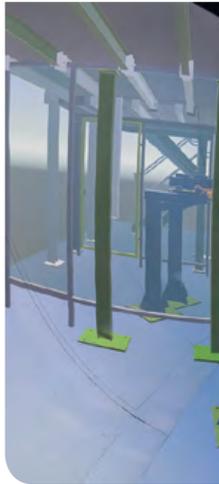
Employees can be trained effectively and experts can share their experience in the Elbedome's virtual training environment.



In the Elbedome, virtual contents are presented as high-definition holograms on a 360-degree panoramic and floor projection surface covering more than 450 square meters. These imposing dimensions make the system ideal for presenting large objects in life size. As many as thirty people in a group can explore virtual worlds simultaneously.



Elbedome manager Steffen Masik about the lab's distinctive features.





The Elbedome is a discovery, learning and creative space all in one and can enhance the effectiveness of client communication.



Manufacturers use such large-scale visualization to assess designs in progress and to expedite decision-making.

The Elbedome's panoramic and floor projection surface of more than 450 square meters makes it ideal for visualizing large objects such as machinery, plants, factories or even entire cities.  
All images © Fraunhofer IFF

# Fraunhofer innovations

**70 YEARS  
OF FUTURE**  
#WHATSNEXT

## *E<sup>3</sup> - industrial manu- facturing re-imagined*

How do we maximize valued added while minimizing resource consumption? Thirteen Fraunhofer institutes answered this question with E3, a holistic take on manufacturing. The three Es stand for efficient processes and products, efficient factories and efficient working environments. In an effort coordinated by the Fraunhofer Institute for Machine Tools and Forming Technology IWU, scientists worked from 2013 to 2016 to develop holistic manufacturing solutions for large-scale deployment. These solutions encompass renewable power in manufacturing, smart assistance systems to reinforce manufacturing personnel's cognitive and physical abilities, and manufacturing processes efficient in both material and energy.

Many of the E3 lighthouse project's accomplishments have set standards and been incorporated in follow-up projects such as SynErgie, which is part of the Kopernikus initiative, Germany's biggest research effort toward the transition from fossil fuels to renewables. With this campaign, the Federal Ministry of Education and Research is encouraging science, industry and private users to put fundamental research into practice.

Holistic concepts enable efficient planning.  
© Art-Kon-Tor / Fraunhofer IWU



## *Taraxagum™ - dandelion rubber hits the road*

The Taraxagum™ project is all about an unassuming plant that goes by various names, Russian dandelion being the most common. But this plant has one property that sets it apart – latex that contains lots of rubber. This story starts with Dirk Prüfer, professor at the Westfälische Wilhelms-Universität Münster and department head at the Fraunhofer Institute for Molecular Biology and Applied Ecology IME, and his team. They joined forces with plant breeder ESKUSA, Continental Reifen Deutschland GmbH and the Julius Kühn Institute to turn a wild plant into a serviceable crop. It took a few years of development effort and constant scrutiny, but the Russian dandelion proved its merits as an alternative source of rubber.

Car, truck and bicycle tires made with this rubber passed muster. The success story continued with Continental inaugurating the Taraxagum Lab Anklam, a research and testing facility, in late 2018. Locally extracted natural rubber slashes shipping miles and shrinks the carbon footprint.

An incision at the roots reveals the Russian dandelion's latex.  
© Fraunhofer IME



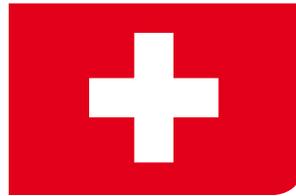


## Joint research

Fraunhofer joined forces with the prestigious Hebrew University to establish two new project centers in Jerusalem.

Now the Fraunhofer Project Center for Drug Discovery and Delivery is laying the groundwork for a new generation of drugs to combat infectious and inflammatory disease. One aim is to prevent pathogens from proliferating while the latent infection has yet to exhibit any outward signs. Researchers from the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB are collaborating with scientists of the Institute for Drug Research at the Hebrew University Faculty of Medicine's School of Pharmacy.

A joint German/Israeli research team at the Fraunhofer Project Center for Cybersecurity is developing new strategies to protect data, IT systems and critical infrastructures from unauthorized access. Its efforts focus on security, cryptography, secure network protocols, robust distributed systems, system recovery and machine learning to detect threats. Specialists from the Fraunhofer Institute for Secure Information Technology SIT are working with the Hebrew University School of Computer Science and Engineering to these ends.



## Batteries made in Europe

Automakers around the world are manufacturing hundreds of thousands of electric cars these days. Most are equipped with lithium-ion batteries made in Asia. But this technology has its drawbacks. Battery size is finite, so the vehicle's range is limited. Charging takes relatively long. And the liquid electrolyte can ignite when subjected to high temperatures.

Researchers from the Fraunhofer Institute for Silicate Research ISC have teamed up with experts from Empa, the Swiss Federal Laboratories for Materials Science and Technology, in an International Cooperation and Networking Project. Called ICON for short, this endeavor goes to usher in a new generation of batteries.

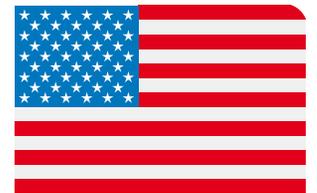
These solid-state batteries contain no liquids. Although the conductive medium between the anode and cathode is a solid, this substance is permeable to ions. This solid medium makes them not only safer than lithium-ion batteries, their energy density is also greater. Each side brings its specialty skill set to the development effort. The ISC team has a great deal of experience with inorganic and hybrid polymer materials; the experts in Switzerland specialize in innovative coating processes. Together, the researchers aim to kick-start a new generation of batteries to be made in Europe.



## Collaboration in lightweight design

German and Polish companies and research institutions have certainly stepped up their collaborative efforts since Poland joined the EU in 2004. In more recent news, the Fraunhofer-Gesellschaft opened a project center in Poland. Researchers from the Fraunhofer Institute for Machine Tools and Forming Technology IWU are pooling resources with teams from the Technical University of Opole in the Fraunhofer Project Center for Advanced Lightweight Technologies ALight. "The Fraunhofer IWU has wide-ranging expertise in lightweight construction and will also contribute its know-how in handling the latest materials." The researchers at the Opole University of Technology will contribute their specific areas of expertise, for example in simulations of processes and process engineering. Together we can add value, intensify knowledge transfer and make the companies involved more innovative," says Fraunhofer President Prof. Reimund Neugebauer.

With this joint effort, the two research partners are seeking to develop production processes, new design ideas and pricing strategies for the manufacture of lightweight hybrid components. These advances are sure to interest the automotive industry. Electric motors and hybrid engines add weight to vehicles, so manufacturers need lightweight components to offset the weight gain. This German/Polish research alliance is keen to produce lightweight structures for future mobile applications in a more cost-effective, energy-efficient and environmentally friendly way.



## Industrie 4.0 in Chicago

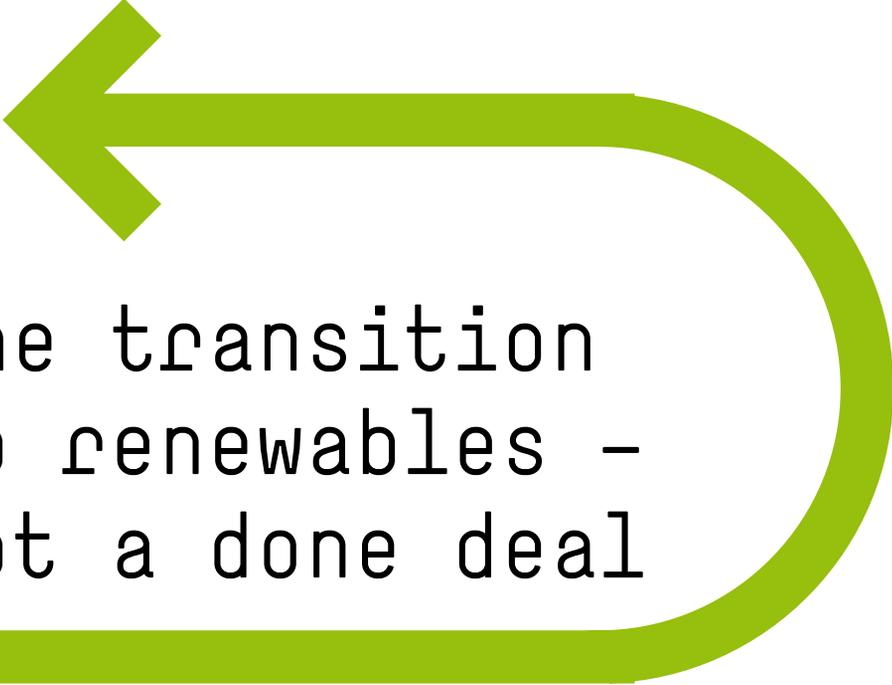
Tomorrow's production lines will be unconfined by conventional constrictions. In the age of Industrie 4.0, machines, processes and locations will be digitally connected. Researchers from 13 German Fraunhofer units and four Fraunhofer USA centers presented connected manufacturing technologies at the International Manufacturing Technology Show IMTS in Chicago, one of the world's leading industrial trade fairs. This was the first joint showcase for the parent company and the independent subsidiary. The 2018 fair in Chicago was also the first IMTS to be staged in cooperation with Hannover Messe USA.

Virtual reality solutions, new additive manufacturing techniques, mass-manufactured small-batch and custom products, smart maintenance, new assistance systems, machine learning methods and digital networks to connect machines, products and suppliers featured prominently at the Fraunhofer teams' IMTS showcase.

Prof. Kurt Rohrig: deputy director of the Fraunhofer Institute for Energy Economics and Energy System Technology IEE in Kassel, scientific program director and ombudsperson for Good Scientific Practice.  
© Fraunhofer/Valeria Mitelman



Prof. Hans-Martin Henning: head of the Fraunhofer Institute for Solar Energy Systems ISE in Freiburg, professor of solar energy systems at the Institute of Sustainable Systems Engineering in the Faculty of Engineering, University of Freiburg and spokesperson of the Fraunhofer Energy Alliance.  
© Fraunhofer/Valeria Mitelman

A large, thick green arrow that starts from the right side of the page, curves downwards and then points to the left, framing the text below it.

## The transition to renewables - not a done deal

The German government's political agenda calls for an exit from fossil fuels and nuclear power. This transition to renewables is underway, but is it making any progress? What has to be done to mitigate climate change and what can Fraunhofer researchers do to help? Two experts speak their minds in this interview.

Interview: Chris Löwer

## How far along is Germany's exit from fossil fuels?

**Prof. Kurt Rohrig:** The transition to renewables is making strides, but the gap between the goals of the Paris Agreement on climate action and current events is widening. We are no longer on course to reduce greenhouse gas emissions by the minimum 80 percent target for 2050, at least not without a major effort. Then again, we have seen some initial success. For example, renewable energy sources provided 35 percent of the electrical power consumed in the first half of 2018. That is a bigger share than from lignite and hard coal combined. On the downside, carbon emissions are on the rise, which is mostly due to increasing traffic.

**Prof. Hans-Martin Henning:** We have to keep reminding ourselves that this is a huge societal project. A part of our core infrastructure is being rebuilt. My impression is that many policymakers still stand behind these ambitious goals. It is now dawning on us that this will take a great deal of patience, and that change has many implications for society and also for the landscape. This is why we need to take an unequivocal stand and press ahead with the exit from fossil fuels and nuclear power. To date, this transition has been very much focused on electrical power. The progress made in transportation and heating is sluggish by comparison.

## What needs to be done to nudge the transition to renewables to the tipping point?

**Henning:** The costs of solar and wind power plummeted in the first phase of the transition to renewables. Production costs are now competitive. We achieved this without having to make any major changes to the power supply system. The next big step is to bring the other sectors on board, for example to power heating and transportation with renewables. Of course, we will have to drastically expand renewable production capacity to do this. What's more, electricity consumption is sure to rise. We are facing the challenge of integrating and stabilizing energy sources that fluctuate with the wind and weather. This is why the power supply paradigm is changing, shifting away from big regulated power plants that merely respond to demand. That is not going to work in the future. The give and take of volatile energy production and consumption is just too complex.

## How so?

**Henning:** Heat pumps provide an efficient way of heating buildings with renewable electricity, and especially so for low-temperature heating systems. These are usually installed in buildings that have been renovated with energy

## An alliance for the transition to renewables

The Fraunhofer Energy Alliance is one of the biggest energy research organizations in Europe. Some 2000 people are researching renewables, energy-efficient technologies, smart power grids, digitalization in the energy industry, energy storage, buildings and components. They are on a mission to provide competitive products at the system level; products that are sound investments and future-proof. This alliance's efforts go to afford small and medium-sized enterprises, industrial enterprises and the energy sector access to a wide range of research and development offerings geared to help them achieve success with innovative products and win new markets. Serving in an advisory capacity, the Fraunhofer Energy Alliance also shares its collective know-how with political and societal actors and institutions. All its efforts center on one goal – a power supply system that is sustainable, secure, economically feasible and fair for all of society.



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

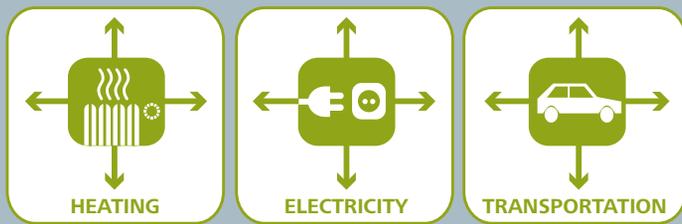
efficiency in mind. This means we have to overhaul more buildings to make wide-scale use of this technology. Today, these upgrades are confined mostly to detached and semi-detached houses. Apartment buildings and commercial properties are very rarely equipped with heat pumps, partly because the specifications for hygienic water heating are more demanding for this use. This presents a challenge for heat-pump technology that Fraunhofer researchers are working to resolve. Heat pumps can also be used for cooling, which is why we will see a lot more of them in the future. When our summers get hotter, they offer the option of energy-conserving air conditioning.

## So heat pumps are a key link for sector coupling. What other areas do we need to address?

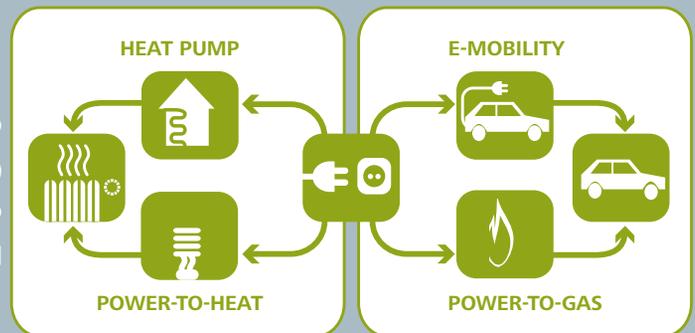
**Rohrig:** The various transportation sectors – from privately owned vehicles to air and marine traffic – have to be made carbon-free. An important part of this will be smart charging strategies; solutions where a car is charged with electricity when there is a lot of power in the grid or, in the event of unexpected bottlenecks, the vehicle's battery offloads electricity to the grid. It will take smarter charge management, both for individual charging stations and the greater grid, to do this. Fraunhofer is also working toward that objective. Information technology has to bridge the divide between the worlds of transportation and electrical power supply. We also

Wind and solar power generation fluctuates with the weather. It will take more total installed capacity to keep the electricity flowing; certainly far more than legacy power plants have today. The fluctuating production pattern of renewable energy sources can be countered with the right consumption dynamic. And that can be created by coupling diverse sectors – heating, cooling, transportation, and industrial and chemical processes. © Fraunhofer

T O D A Y



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need precise forecasts for electricity requirements based on time, weather, temperature and the like. This is yet another topic our researchers are pursuing. They are striving to simulate and model consumption patterns with such accuracy that these models can serve to develop better strategies for charging e-vehicles. One example of this is a joint research project with a car manufacturer and a grid operator where we are assessing data from fog and brightness sensors in an effort to make local solar irradiation more predictable for photovoltaic systems.

What role do storage systems and grids play? What actions could be taken to fast-track progress?

**Henning:** Storage is one of the big issues. We will need short- and long-term storage systems and flexible power usage models to help compensate for volatile electrical power sources. This would make wind and photovoltaic power plants easier to regulate so they would be more flexible in delivering electricity – that alone would justify these systems and models. Reserve capacities are also needed to back up the power supply during what we call 'dark doldrums'.

**Rohrig:** Smart grids are designed to keep energy sourced from distributed wind and solar power plants flowing smoothly and stably. We have to go further in converting legacy distribution grids into bi-directional electricity exchange infrastructures for the power flow to be managed in smart ways. It is important to identify overloads and

bottlenecks at an early stage. The grid infrastructure has to be modernized and digitalized step by step. We need the most flexible energy supply possible, and for that it is essential for transmission and distribution grid operators to step up their collaboration and support national and international expansion efforts. This is not going to happen in one fell swoop.

Alternative energy supplies sometimes devour valuable resources. Batteries are a case in point...

**Henning:** ... which is why it is important for us to address sustainability and resource efficiency at an early stage. This is going to be one of the key questions. We can already calculate how many photovoltaic systems will shut down in the next 20 years. We can't just scrap and bin these plants; every bit of them that can be recycled should be recycled. We need to be thinking in terms of closed loops when we start developing technologies from the battery to the wind turbine. Burning fossil fuels did not consume a lot of other resources, but this power supply system requires vast quantities of materials.

To what extent can digitalization drive the exit from fossil fuels?

**Rohrig:** Several smart components such as inverters and sensors are already communicating with one another. We are going to see a lot more of that. If the aim is to achieve predictive plant management, big data is also going to be

Wind and solar plants will provide the lion's share of energy for a renewables-based system that also powers heating and transportation.  
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a huge topic for the power industry. It will be crucial to use artificial intelligence to extract valuable information from the mass of data. For example, digital twins of systems can serve to simulate and predict when and where they will reach critical operating states.

How much is the transition to renewables going to cost?

**Henning:** First this begs the question of what costs really are. We are investing in an urgently needed system rebuild. In economic terms, investments are not costs. As to the added systemic costs, we expect expenditures of around one to two percent of today's gross domestic product on average over the next decades up to 2050. This is above and beyond what we would spend if we just carried on with what we are doing now, the outcome of which would be a spectacular failure to meet climate protection targets. This calculation does not even include the offset of added value newly created as we change over to renewables. This added value would certainly benefit GDP. Besides, the investment budget is manageable because the transition's objectives are so clearly defined. But, yes, we will have to spend money. In the end, though, our power supply will not be any costlier than it is today; actually, it will probably be cheaper. But, above all, it will be less susceptible to volatile fossil fuel markets, because we are talking about a system that feeds on inexhaustible sources such as the sun.

What are the biggest levers for achieving climate goals?

**Rohrig:** The short-term goal is it to take very many of the old lignite-fired power plants off the grid because of their high carbon emissions. It has been proven that the power supply can be guaranteed without these plants.

**Henning:** ... whereby wind and solar power plants should be rapidly expanded to compensate for the drop in coal-fired power.

Do you think there will ever be a power supply that is totally climate-neutral?

**Rohrig:** Many studies show that those last meters are the hardest, but I am confident that we can arrive at a totally climate-neutral power supply. Things will be looking up if we manage to optimize and couple all the sectors. We modeled and analyzed the transition to 100 percent renewables at Fraunhofer to get a picture of the situation. We found that this is achievable, and the costs are manageable. The big questions about the exit from fossil fuels have been answered. Now it is up to policymakers and society to walk the talk. Acceptance is the decisive factor.

**Henning:** Indeed, there is no showstopper to be seen anywhere, but we do have to say that there is room for us to improve a number of technologies. For example, the cost of batteries, hydrogen drives and power electronics has to come down just like it did for photovoltaic and wind power plants. And there is still plenty of room for improvement, even for these established technologies. We have a long way to go yet before we run out of road. ■

# When plastics become biologically active

Antimicrobial peptides found in tears are known to protect the eyes from infection. In future, these very same peptides could help hygienically protect the surface of operating tables or doorknobs – by incorporating them in a biofunctional plastic belonging to a new category of innovative materials.

Text: Christine Broll

Dr. Ruben R. Rosencrantz embeds macromolecules containing sugar in a resin used to coat various surfaces.  
© Fraunhofer IAP



Prof. Alexander Böker is convinced that a new era has begun in the development of plastics – a term that is used to describe a wide variety of long-chain polymers with different characteristics and uses. “Today, plastics are characterized by their chemical and physical properties, such as strength, elasticity and rigidity,” explains the director of the Fraunhofer Institute for Applied Polymer Research IAP. “We are currently expanding this spectrum to include biological properties as well.” This is done by directly incorporating biomolecules such as proteins, peptides and sugars into plastic materials.

There are plenty of biomolecules that work well here. Over the course of evolution, nature has given rise to highly specialized active substances that boast a whole host of functions. Take defensin, for example, which is found not only in human tears but also in many plants and animals. Defensins are small protein molecules (peptides) that are capable of penetrating – and thereby killing – bacteria, resulting in a strong antimicrobial effect.

## Sterile surfaces

As a functional group, antimicrobial peptides are generally easy to produce and are relatively

stable, so they lend themselves well to being embedded in a polymer matrix. This is one of the aims of the Biofunctionalization/Biologization of Polymer Materials BioPol Project Group. Set up in July 2018, it sees researchers from Fraunhofer IAP and Brandenburg University of Technology Cottbus-Senftenberg working closely together. In a joint effort, antimicrobial peptides are being incorporated into a resin that can be used to coat all kinds of surfaces – from operating tables to doorknobs. This resin coating will keep surfaces germ-free because the antimicrobial peptides prevent bacteria from surviving.

Antimicrobial peptides certainly have the edge over traditional antibiotics in this respect, as studies have shown that they do not generate any kind of resistance in bacteria. That makes them strong candidates for use in a wide variety of applications, especially those involving a large surface area. Research is currently underway to determine whether functionalized plastics of this kind would be viable for use in train interiors, for example in the restrooms.

In order to produce hygienic surfaces, the researchers at Fraunhofer IAP are also drawing

on a second group of biological substances, called mucins. These macromolecules have a high sugar content and are produced by the body’s mucosa to protect against chemical and mechanical influences. Mucins are found in saliva, gastric acid and the bronchi, for instance, and exhibit an extremely low coefficient of friction, making them slippery.

Just like antimicrobial peptides, mucins are also being embedded in a resin that can then be applied to surfaces. This coating is expected to be so smooth that bacteria will not be able to settle on its surface. As a result, a simple jet of water will do to keep everything germ-free.

These biofunctionalized plastics are not yet available on the market, though, and are often met with skepticism, reports Alexander Böker. “Many customers believe the biological components are alive and will therefore soon die off. This leads them to the false conclusion that the material is not durable.” His response is that while the biological molecules used in the plastics may well be active, they are nonviable, which logically means they cannot die. He also emphasizes that the materials are highly



The Schwaneberg group at RWTH Aachen University is fermenting *E. coli* bacteria that produce special channel-shaped proteins. In the years ahead, these proteins will be incorporated in special filters for pharmaceutical production. © Chair of Biotechnology, RWTH Aachen University

durable, so “we simply need to work even harder at persuading them.”

### Special filters for pharmaceutical production

Biological components harnessed by the scientists might also be of an extremely complex nature – for example, the channel-shaped proteins in the cell membrane of *E. coli* bacteria that facilitate the passage of compounds containing iron. Fraunhofer IAP has managed to integrate the channel proteins produced in *E. coli* into an artificial membrane. Bacteria were fermented and proteins isolated in cooperation with the Schwaneberg group at RWTH Aachen University.

This was just the first step in an ambitious project, followed by a second step that genetically modified the channels to serve as highly specialized filters in pharmaceutical production. Redesigned in this way, the channels are able to separate chemical substances based on their chirality, which plays a significant role in chemistry. The most widely known example of chirality, and its potentially devastating effects,

is the agent thalidomide, contained in the drug Contergan. Thalidomide comes in two different mirror-image forms that interact much like the right and left hand: they may be identical in form, but they cannot be superimposed on one other. One of thalidomide’s mirror images induces sleep, while the other is genetically harmful. Use of the sleeping pill Contergan in the late 1950’s and early 1960’s was therefore responsible for many deformities observed in children born at the time.

Chiral compounds are still created during the production of medication today. They are extremely difficult to separate as they have the same chemical structure. If artificial membranes featuring genetically modified channel proteins could solve this problem, then that would be a big step forward.

### On the way to large-scale production

If biofunctional groups can be successfully embedded in thermoplastic materials such as polyester or polyethylene, a huge market is on the horizon. But manufacturing on an

industrial scale is no easy feat. Thermoplastics are processed at temperatures ranging from 100 to 250 degrees centigrade, whereas biological molecules are highly sensitive to heat. For example, many enzymes denature at just 40 degrees; peptides and sugars, however, are more robust.

Finding practical solutions that address this challenge is another key objective of Fraunhofer’s BioPol Project Group, whose work is carried out largely at the Processing Pilot Plant for Biopolymers. Run by Fraunhofer IAP on the BASF site in Schwarzheide, the plant is situated right next to the Senftenberg campus. The Brandenburg Ministry of Science is providing a total of 2.5 million euros in funding toward the project.

Alexander Böker is convinced that there are ways to produce all kinds of biofunctional materials on an industrial scale. “As plastics designers, we are now able to develop materials that benefit from and specifically interact with nature,” says the institute director. “This marks the next stage in the evolution of polymer materials.” ■

# Living cells as sensors



Cell-based sensors are made up of biological and physical components. Grown in sterile culture bottles, living cells are then used to coat an electrode layout. © Fraunhofer EMFT/Bernd Müller

Test systems based on cell cultures are widely used to assess the biological effects of poisons and medications. Now a group of Fraunhofer researchers in Regensburg is breaking new ground by developing hybrid sensors from living cells and physical signal converters.

Text: Monika Offenberger

What dosage of toxins or radiation is deadly? How do nanoparticles behave in tissue? Could a new tumor medication damage the heart? Cell cultures are commonly used to test the biological effects of substances. So-called cell-based assays aid not only in the analysis and evaluation of environmental pollutants or microorganisms, but also in pharmaceutical drug screening and the approval of cosmetics, dyes or detergents. Researchers explore how the test substance influences the particular metabolites, genetic elements or cell components. Yet, as Prof. Joachim Wegener points out, "unexpected cell reactions might go undetected in this type of assay." He goes on to list other shortcomings: "In many conventional methods, the cells have to be killed off at a predetermined time in order to quantify the specific biomolecules. The same cells can no longer be used after that. So if you want to take measurements at different points in time and observe the course of a reaction, you have to set up a corresponding number of parallel experiments."

To overcome these major drawbacks, Prof. Joachim Wegener at the Fraunhofer Research Institution for Microsystems and Solid State Technologies EMFT in Regensburg is developing a new class of test systems. The principle behind it is as clever as it is simple: Established cell cultures are grown on the surface of physical sensors that convert the behavior of the cells directly into measurable signals. These physical signal converters continuously record if and how quickly the cells clinging to them are growing, if they are dividing, moving or dying and if their shape or central energy metabolism is changing. To this end, the cells are subjected to very small but non-invasive disturbance variables such as current, voltage, light or pressure. If they are then brought into contact with particular substances or other stimulants, their reaction

is demonstrated by their response to these disturbance variables and not, as in conventional testing methods, by the concentration of previously selected biomarkers.

### An approach with many advantages

This approach offers many advantages. "We do not have to mark the cells with dyes, antibodies or radionuclides, but instead look only at our disturbance variables. We can measure them continuously, as often and as long as we want and at intervals from milliseconds up to hours or days, and this allows us to draw conclusions about the state of the cultures," explains Wegener. Which disturbance variables are employed depends upon the type of signal converter. In electric cell-substrate impedance sensing, or ECIS, the cell behavior can be observed on the basis of the alternating current resistance, the impedance. For this purpose, the base of a multiwell plate is coated with a thin gold film and structured so that the precious metal forms two electrodes. The cells are seeded on it and kept alive with a nutrient solution that, due to its salinity, also serves as a conductive medium. If a weak alternating current is then applied, it can initially flow unobstructed between the two electrodes. However, as soon as cells settle on the electrodes and obstruct the flow of current with their non-conductive cell bodies, the resistance increases – rising more significantly the more the cell culture spreads.

This correlation is harnessed for toxicological measurements: If a cell is poisoned, it changes shape, swells or shrinks – and thereby influences the impedance. The shape changes in living cells can equally be measured and can provide insight into the biological effect of a test substance. Take cardiac muscle cells, for instance: In the body, they cause the heart to

beat approximately one time per second. They contract and relax in the same rhythm under the artificial conditions of a cell culture as well. In so doing, their shapes regularly change – and hence so does the resistance with which they can oppose the electrical current. "In places where the electrode is overgrown, the current is forced to flow around the cells and can penetrate only at the cell boundaries. The current paths then also change with the shape of the cell because the intercellular spaces become larger or smaller. In this way, the heartbeat rhythm of the cardiac muscles can be measured precisely," describes Wegener.

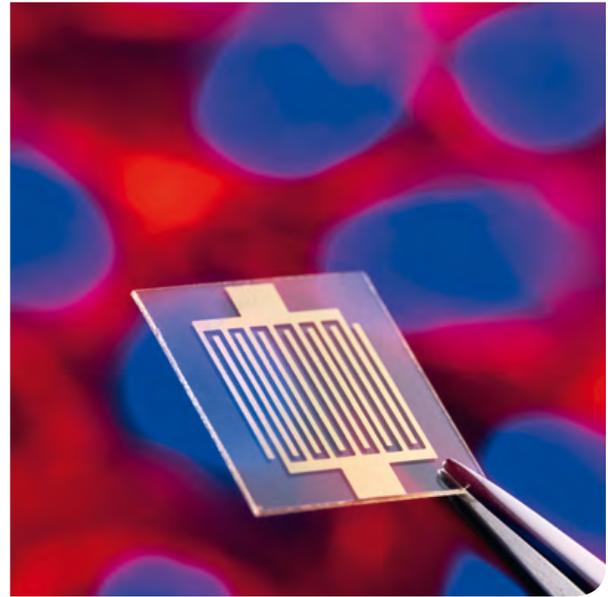
### Numerous applications

The market for this ECIS application is huge. Every newly developed medication must be tested for cardiac safety before its approval in order to ensure that it will not cause arrhythmia in the heart muscle. Currently established tests, however, only record the electrical potentials of cultivated cardiac muscle cells. "The impedance technique, by contrast, directly measures the contraction of the cell body – in other words, the ultimate function of the heart muscle. ECIS is therefore superior to conventional methods," says Wegener. The chemist sees further areas of application in the largely still unexplored effects of nanomaterials. "Many conventional assays fail there because they operate with fluorescent dyes. Nanomaterials can reflect or absorb light, though, and interfere with the measurement as a result. This problem does not occur with ECIS."

Wegener's team pioneered in developing ECIS, and today it has become one of the leading working groups internationally. For several years, Fraunhofer EMFT has been cooperating with the Institute of Analytical Chemistry, Chemo- & Biosensors at the University of Regensburg. In a first joint study in 2011, the toxicity of nanosensors was investigated using ECIS. "This study is one of the many preliminary works that drew Fraunhofer's attention to our field of research," says Wegener. Along with his longtime colleague, the chemist Dr. Stefanie Michaelis, the scientist has been establishing the cell-based sensor technology as an innovative field of research at Fraunhofer EMFT since early 2017. In addition to ECIS, they are developing multiple other hybrid test systems to measure the behavior of cells with electrodes, acoustic resonators or

optical waveguides. Particularly well advanced is the quartz crystal microbalance, or QCM, which uses a piezoelectric crystal as a signal converter. "As soon as we apply an alternating voltage, the crystal begins to oscillate. If it has cells growing on it, its resonance behavior changes. The oscillations are damped, and the more they are damped, the more rigid the cell. This

Two different signal converters in front of greatly magnified cells: oscillating quartz for examining cell mechanics (image below) and interdigital electrodes for impedance-based monitoring of animal cells (image to the right). © Fraunhofer EMFT/Bernd Müller



provides information about the cytoskeleton of the cell, whether it is intact or degenerated," the Regensburg researcher explains. Many cancer drugs do actually aim to weaken cytoskeletons in order to prevent the tumor cells from dividing and multiplying. QCM can be used to precisely measure this effect. This also works with small numbers of cells such as are found in biopsies – which could be another area of application for the hybrid sensors.

### Next door on the university campus

Market-oriented research in all fundamental and applied biomedical areas is in fact the stated objective of the Fraunhofer research institution at Regensburg, and the campus at the university provides the ideal conditions. This is where the scientific expertise of Wegener's twelve-person university research group meets the technical facilities of Fraunhofer EMFT, bridging the gap from cell-based bioanalysis to microelectronics and microsystems technology. Indeed, Fraunhofer EMFT is already working with industry partners from several federal states to develop cell-based assays that are tailor-made for them. In addition to feasibility studies, the range of services on offer includes consulting on assay formats and data analysis. Wegener also believes that the potential for hybrid test systems is far from exhausted: "We are currently working to place several different signal converters in a



Cell and tissue samples are cultivated under sterile conditions at 37 °C in an incubator. The red dye in the nutrient medium aids in monitoring the pH value. © Fraunhofer EMFT/Bernd Müller

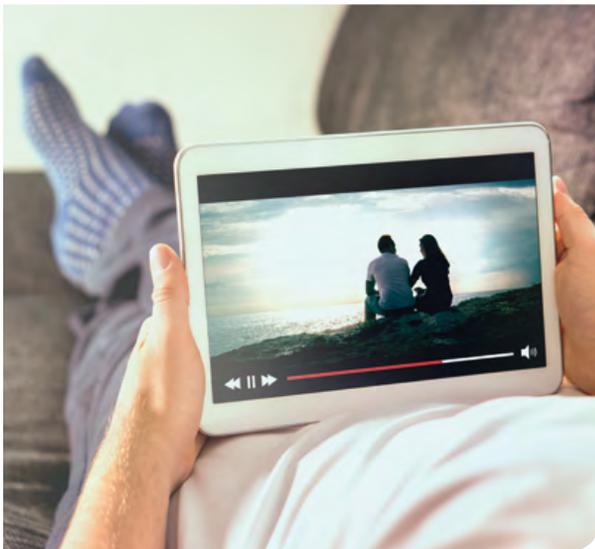
single cell population. We can already combine QCM and ECIS. If we are successful in uniting even more technology in one test system, we will be able to maximize the amount of information we can obtain about the most fundamental unit of life." The fact that the young Fraunhofer team has already filed five patents shows how fast this area of research is moving. ■

## High Efficiency Video Coding (HEVC)

Compressed video is flourishing more rapidly than ever. These data already account for the biggest slice of the bit pie on the Internet and in mobile data traffic. What's more, the latest in ultra-high resolution TVs also feature 4K full HD. The surge toward higher-quality, higher-definition images and videos brings a steadily rising deluge of data in its wake. It will take ever better compression to shuttle all those bits and bytes back and forth in an efficient way. The H.265/High Efficiency Video Coding (HEVC) standard offers precisely the sort of ultra-compression that can move mountains – of data, that is. Co-developed by the Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute HHI and big-name mobile communications and consumer electronics manufacturers, it won a Primetime Engineering Emmy Award in 2017.

Engineers are now looking to standardize HEVC's successor, Versatile Video Coding (VVC). Fraunhofer HHI is again a big part of this push. VVC will squeeze data into ever smaller packages with experts expecting it to slash 50 percent off HEVC bit numbers by 2020.

Mobile TV – we have ultra-efficient compression to thank for entertainment to go. © iStock

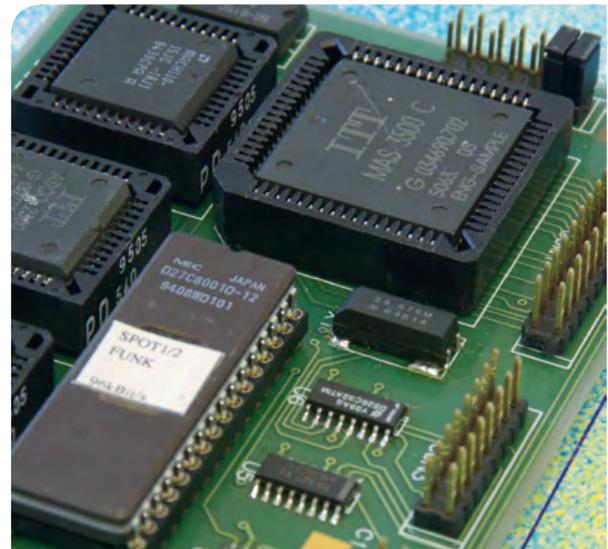


## Compressed music, mp3 style

With the benefit of hindsight, it can be said that mp3 was the inceptive generation for several audio coding techniques developed at the Fraunhofer Institute for Integrated Circuits IIS. Audio codecs store audio signals in smarter ways than, say, a CD to shrink the data footprint. The original mp3 format was a global blockbuster, and the second and third generations emulated its business success.

Today, these technologies feature in all consumer electronics devices. The fourth generation was just launched, making a big splash and looking to be yet another chart-topping hit. This long success story is rooted in the scientific excellence of Fraunhofer IIS, which over the past 30 years has won all technical audio standardization competitions against rivals that included global giants in this arena. And more than ten billion licensed devices says a lot about the marketers' ability to bring this technology to the masses.

Inaugurated in 1994, this is the first prototype of an mp3 player without moving parts. © Fraunhofer IIS



# Lessons from the rain forest

Population growth, dwindling resources, a lack of sustainability – to get a handle on problems like these, the human race could do worse than turn to nature and its ecosystems. Take the tropical rain forest, for example...

Text: Janine van Ackeren

There's a rustling and a scurrying deep in the undergrowth of the shady forest floor. High above, monkeys swing through the treetops, while dazzling tropical birds hover beneath the leafy canopy. The air is alive with the hum of buzzing insects. Here in the rain forest, different species cohabit more closely than in almost any other habitat. And they do so without destroying their living environment. "That's because there's a closed-loop economy with an almost optimal utilization of resources – any nutrients released are promptly reused," explains Prof. Christoph Schäfers, acting director of the Fraunhofer Institute for Molecular Biology and Applied Ecology IME. "There's been a sustained habitat here for a long time, and resources are stable. The various species have been able to adapt, specialize and then occupy highly diverse ecological niches. This has led to the establishment of a so-called climax community or ecosystem." For this to happen, it requires a smart system that generates value by capitalizing on diversity in an environment in which all the available niches are occupied.

## From climax ecosystem to climax economy

That's all well and good – but what does it have to do with the problems facing the human race? "Quite a lot," says Schäfers. In many ways, nature can serve as a role model or source of ideas. And it can do so not merely in terms of suggesting concrete technologies, but also by helping us to answer the question of how we can ensure that limited resources remain

available for coming generations – the question, in other words, of how we can sustainably manage our habitat here on Earth.

What is urgently required is a change in mindset. "If we continue to focus on growth and try to squeeze out every last drop, we are going to destabilize the planet," says Schäfers. "Resources flow into the industrialized countries, yet all the population growth is taking place in the developing and emerging nations. What are now described as migration flows are in fact a mere trickle, compared to what is going to happen long term if we don't do some rethinking. At that point, the idea of a climax ecosystem will become meaningless, because there will no longer be any stability. Our goal must therefore be to optimize recycling and interconnectedness. By analogy with a climax ecosystem, we could describe this as a climax economy."

## No blanket solution

What this might look like in concrete terms is best illustrated by examples from areas such as transport. In our cities, transport infrastructure is hard pressed to cope with the growing volume of traffic. In particular, there is often the problem of the last mile: passengers can get close to their destination using public transport, but not all the way. The result is they take the car. "Following the model of a climax ecosystem, this is exactly where smaller players can make a valuable contribution to solving this problem," says Dr. Florian Herrmann, division director at the Fraunhofer Institute for Industrial Engineering IAO. "By using digital platforms to provide a suitable transport solution – for example, electric scooters as part of a smart sharing concept – they can occupy a niche that has hitherto been neglected."

When it comes to a climax ecosystem, the key word is diversity. "There is no one blanket solution to be applied to all of the problems," Schäfers explains. "Instead, we need a whole range of approaches, just like in the rain forest." And this is exactly what we see in the area of

transport. For a long time, people looked upon the car as a universal solution. With the threat of vehicle bans, however, people are starting to rethink their transport choices.

ARENA2036, a research program involving Fraunhofer IAO, is showing how cooperation between startups and other companies can be encouraged and strengthened. In effect, it has created an open ecosystem in which various industrial companies, startups and research organizations can work together.

## Energy: smart grids for efficient energy supply

In the field of energy, too, Schäfers is convinced that diversity is the way forward: "Building larger and larger centralized power-generation facilities is an idea that belongs to the last century. And wind energy can't provide the sole solution. Instead, what we really need is an interconnected system that enables us to balance power generation and power consumption." Herrmann agrees. To this end, his colleagues are currently working on micro smart grids. These grids link different components of the energy infrastructure, such as buffer batteries, photovoltaic systems and hydrogen storage solutions, so that the energy required to supply a small local area – e.g., a housing development – can be generated, stored, utilized or released in the most efficient way.

## Agriculture: robotics enables small-scale farming

Drive through the countryside, and it's plain to see: fields are getting larger, monocultures are on the rise and diversity is disappearing. "This is clearly the wrong path to take," says Schäfers. "We're way past the stage where we can maximize yields in this way." The aim, he says, should be to move in the opposite direction and diversify production. Until recently, small-scale farming wasn't an option. It was simply too time-consuming and costly. Sooner or later, however, robotics should make this kind of agricultural diversification profitable.

In the tropical rain forest, the diverse species have specialized and occupy highly varied ecological niches. This climax ecosystem can help us solve some of the problems facing society. © 123rf

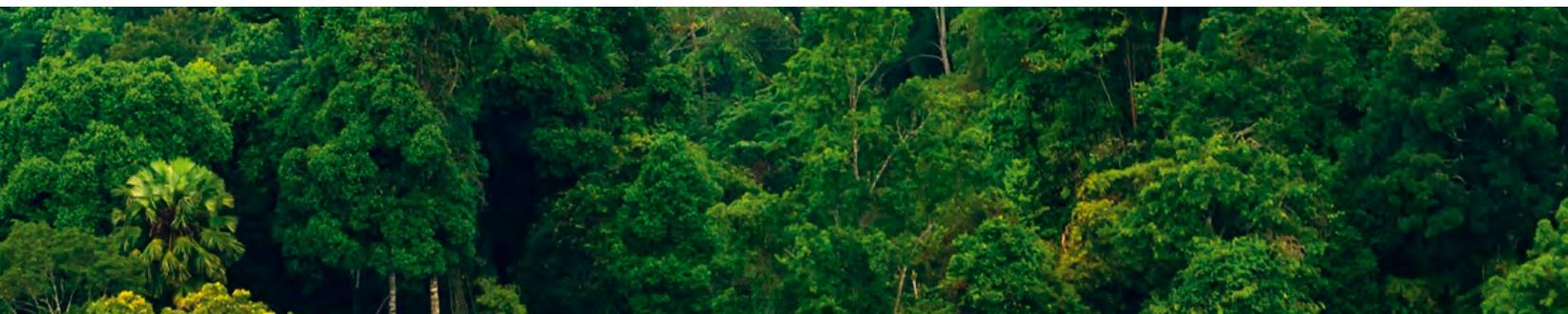


### Maintaining rather than simply renewing

In many respects, a climax ecosystem comes about when its structures are conserved and maintained rather than simply renewed. The same can be said of the economy. Germany has a lot of small and medium-sized enterprises. In other words, there's a lot of diversity in the

economy. But how can this best be maintained? "Fraunhofer has a big responsibility here – and a great deal of influence," says Herrmann. "If we strengthen this sector, we can make ourselves more resilient." This includes ensuring that SMEs are up to speed with respect to Industrie 4.0 and digitalization. With this in mind, researchers at Fraunhofer IAO are involved in a major project known as the Business Innovation

Engineering Center (BIEC), which is funded by the state of Baden-Württemberg. In particular, they are working on various digital solutions specifically oriented to the challenges facing small and medium-sized enterprises. In other words, there are many ways in which the lessons of the rain forest can be applied to society. ■



# Signposts to the future

How can we meet the challenges of the future? Which topics should researchers have at the top of their agenda? And how can businesses help? Future studies offer answers to these questions – and now researchers are expanding them to include citizen participation and big data analyses.

Text: Christine Broll

The conference room gradually falls silent. The workshop participants close their eyes as the facilitator starts to speak: “Imagine 30 years have passed and you are stepping through a door into a new world. What can you see and hear around you? Who do you meet?” Everyone is absorbed in their own thoughts of what the future might hold. After the exercise, they break into small groups to write down their visions, hopes and fears and discuss the results.

This imaginary journey into the future took place at the Fraunhofer Institute for Systems and Innovation Research ISI in Karlsruhe, and the 40-plus participants were ordinary citizens who came from all over Germany to take part in a consultation study as part of the CIMULACT project. Using a workshop format, citizens from 30 European countries were asked to describe their visions of a desirable future. The CIMULACT team then used this input to derive recommendations on how to shape the European research and innovation agenda.

The EU’s current framework program for research and innovation, Horizon 2020, comes to an end next year. The European Commission is already working on a follow-up program called Horizon Europe, which will help set the agenda for European research from 2021 through 2027. CIMULACT marks the first time that the European Commission has

commissioned a study with public participation as a basis for drawing up the European research agenda.

## Life in harmony with nature

Dr. Philine Warnke from Fraunhofer ISI played a key role in designing and conducting the consultation study. She reveals that “the citizens’ top priority was living in harmony with nature,” a goal that would require efforts to encourage more people to adopt ecological or “green” lifestyles. In second place was the desire for fair and comprehensive healthcare coverage for all citizens. The study participants also rated good, healthy food as important and called for more innovative research and an increase in public knowledge on food sustainability issues. The citizens’ top five priorities also included new methods of energy efficiency and personalized medicine.

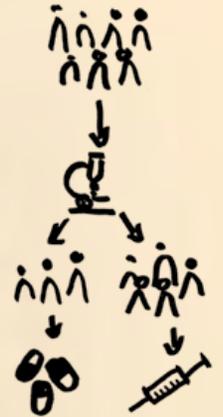
 [www.cimulact.eu](http://www.cimulact.eu)

In an accompanying report, the CIMULACT team compared the results of the citizen-based consultation with 16 expert-based future studies. “The topics themselves are fairly similar, but the citizens took a completely different approach,” says Philine Warnke, summing up their findings. “Citizens look at big topics from their own everyday angle and bring a holistic perspective into the discussion.” That does, however,

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## Results of the CIMULACT study: Citizens’ wishes for the future

1. Life in harmony with nature
2. Fair and comprehensive healthcare coverage for all citizens
3. Good, healthy food
4. New technologies to reduce energy use
5. Personalized medicine





© Photocase



Inspired by photos of the past and present, citizens came up with visions of the future at the CIMULACT workshop. © Fraunhofer ISI/Petra Sandker

make it difficult to channel the CIMULACT recommendations directly into the framework research program because there is no one specific department that could promote "life in harmony with nature." Instead, topics such as water, agriculture and energy are tackled by a number of separate research groups working independently.

"The best thing about this study is how it has paved the way for greater public participation in planning research," says Philine Warnke. The OECD chose the CIMULACT project as a best practice case and has recommended that the governments of EU member countries should follow its example. The German federal government's current High-Tech Strategy 2025 also drew inspiration from the CIMULACT model, stating that it intends to incorporate more citizen engagement in research and innovation. The aim is to expand dialog using new, participative formats ranging from public involvement in setting research agendas right through to citizens running their own research activities.

#### Survey of international experts

In parallel with the CIMULACT study at Fraunhofer ISI, researchers were also busy gathering

data for a second study in support of Horizon Europe: the BOHEMIA strategic foresight study. "The idea behind BOHEMIA was to analyze future global challenges through 2040 and highlight how research and development could contribute to solutions and transformations," says Dr. Kerstin Cuhls from Fraunhofer ISI, who was heavily involved in the project.



**Bohemia:**  
<http://s.fhg.de/bohemia-eu>

At the heart of this study was a Delphi survey, a future studies technique named after the Oracle of Delphi that channels information into a format that can be used to shape policy. A modern version known as the Argument Delphi presents experts with statements of a hypothetical future reality; for example: "Fifty percent of food sold in the EU comes from organic farming." The experts are asked to evaluate when this hypothesis might come true and how important it is while simultaneously providing reasons for their judgements. In the second round, they are presented with the same statements once again but this time in combination with the anonymized evaluations by the other experts. This allows them to incorporate other people's arguments in their considerations

and assess them, or to develop new arguments and adapt their judgement accordingly.

#### Achieving sustainability targets

The BOHEMIA study team asked more than 700 international experts to evaluate a total of 147 statements about the future of research and technology and developments in society. The most important topics were then fleshed out by the project team and condensed into 19 scenarios. "Digital connectivity and health came out on top, as well as issues connected to ageing societies," says Kerstin Cuhls. One of the recommendations from BOHEMIA is therefore to make life easier for the sick and elderly in their own homes by employing strategies such as robot assistants, telemedicine and new services. The 19 priority research areas also included the development of new circular bio-economic processes as well as concepts for energy efficiency, innovative methods of energy storage, cyberwar, artificial organs and precision medicine.

Perhaps the most important result of the study is the project team's framing of overarching goals in the form of recommendations to the research program developers: "We need a new pact



### Ancient predictions of the future

The Pythia priestess, keeper of Apollo's oracle at Delphi, made divine predictions of the future 2,000 years ago.

### Modern predictions of the future

Today's future studies are based on the opinions of experts and citizens. © Adobe Stock / Antikensammlung Berlin

between science, society and policymakers," they argue in their conclusions and policy recommendations. "Research and innovation should contribute to tackling the major challenges facing society," they add, noting that the EU's research policy could become the engine of transition and lay the foundations for meeting the UN Sustainable Development Goals.

### Big data analyses

When companies focus on the future, they typically ask themselves concrete questions about how their markets and industry sectors will develop. The more tangible the scenarios they come up with, the easier it is to plan their strategy and associated investments. A particularly striking example of this approach involves a network of 50 companies from the Nuremberg metropolitan region. Together, they are developing scenarios to help them achieve the region's 2030 climate change targets.

By examining key indicators, they hope to predict how the future might play out. For example, might changes in citizens' attitudes cause the expansion of wind power to accelerate in the region? And which methods of energy storage are currently completing their

transition from experimental pilots to full-scale commercial availability? A recently formed research group called "Future Engineering" is currently investigating how to derive answers to these questions from a multitude of fragments of publicly available information. The group is a collaborative initiative involving Nuremberg Tech – Technische Hochschule Nürnberg and the Fraunhofer Center for Applied Research on Supply Chain Services SCS at the Fraunhofer Institute for Integrated Circuits IIS.

 **Future Engineering:**  
<http://s.fhg.de/iofo>

The research group develops its future studies by systematically analyzing a broad range of data sources. "We have identified over a thousand subject-specific sources at both a national and international level that provide us with useful information. They include websites published by businesses, associations and media companies," says Prof. Ralph Blum, who heads up the Future Engineering research group.

All the news and feeds from the selected websites – sometimes as many as several thousand a week – are automatically retrieved and stored

in a huge database. Such huge quantities of data involving different formats and content can no longer be browsed efficiently by the human eye, so the research group employs innovative methods of natural language processing and semantic web analysis to extract the information relevant to them. For example, press releases about the allocation of municipal land for wind power can be one useful measure of how much wind power capacity is likely to be installed over the medium term. The advantage of this method is that it channels various types of press releases into a format that can be used to forecast future trends.

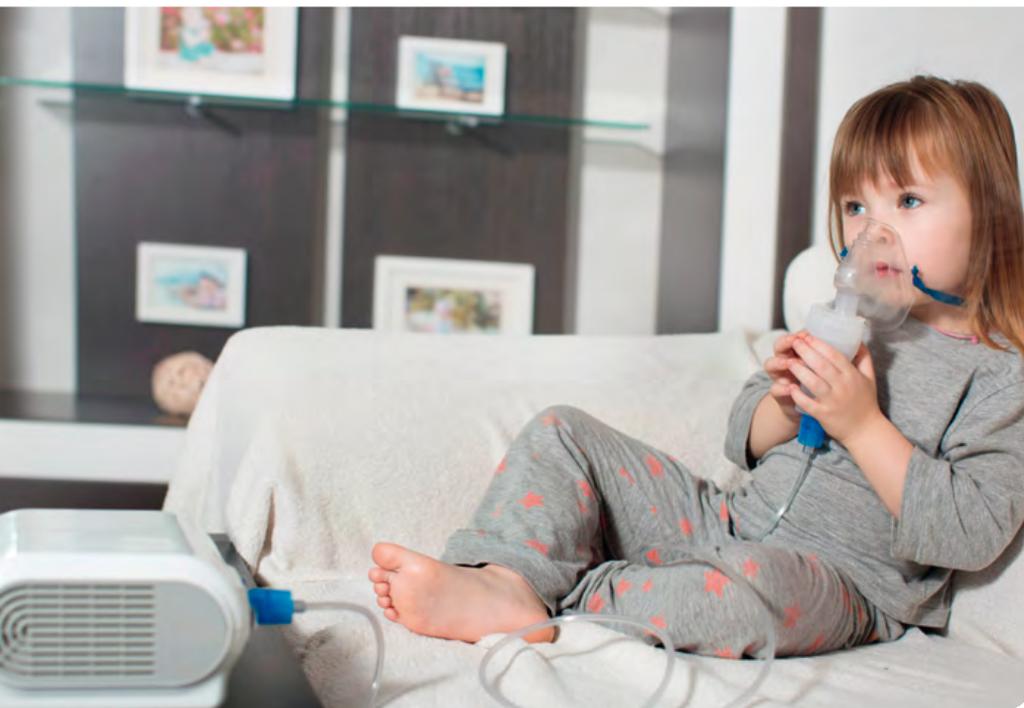
The research group then combines this data analysis with traditional methods of future studies such as the Delphi technique. As before, a group of experts ultimately decides whether these future scenarios are realistic or not.

Meanwhile, Ralph Blum is already thinking one step ahead. "We could also post the results on social networks and blogs and get them rated by the crowd." That would pave the way for using both big data analyses and citizens' opinions as a basis for future studies. "But the day we can bring that kind of idea to fruition is still firmly in the future!" says the futurist. ■

# Encouraging patients to research their own condition

What better person to research a disease than someone who is actually living with it? That's the idea behind the Patient Science project, in which people living with cystic fibrosis are working hand in hand with researchers. Together, they are studying how people cope with the condition - and how their daily lives could be improved.

Text: Christine Broll



Regular inhalation to loosen thick mucus in the bronchi is part of the treatment for people living with cystic fibrosis.  
© Shutterstock

sector in which patients are actively involved as equal partners. Clinical studies generally only assign them a passive role," says Nils Heyen. The main project partner is the cystic fibrosis outpatient clinic at Frankfurt University Hospital. It was this clinic that recruited the 11 people who are now working as patient researchers, including adults who have cystic fibrosis themselves and the parents of children with the condition. The project is funded by the German Federal Ministry of Education and Research as part of an initiative to promote citizen science (see box).

## A better understanding of patients' everyday problems

The first two workshops were held in April 2018. They were attended by patient researchers, specialists from the university hospital, the head of the German federal association for cystic fibrosis and a number of scientists and researchers. Together, they came up with a research concept that aims to help improve patients' lives. The first step is to conduct an online survey of patients and family members with the assistance of the association for cystic fibrosis. The team is hoping to reach as many as possible of the approximately 8,000 people in Germany who have cystic fibrosis.

Professionals are currently working with patients to draw up the questionnaire. "The patients

Katja Wecke is a cystic fibrosis patient who is collaborating on the project as a "patient researcher." The 39-year-old has a degree in public administration and has had cystic fibrosis since she was born. One of the symptoms of this inherited metabolic disorder is the production of a viscous mucus that leads to serious health problems in many organs, particularly the intestines and bronchi. In the past, people with cystic fibrosis were only expected to live for 20 to 30 years. Today, some even reach retirement age - though only by showing tremendous discipline in following the time-consuming treatment plan.

"I have to spend 45 minutes inhaling to loosen the mucus every morning and evening," says Katja Wecke. This is in addition to the drugs she takes to keep the disease under control. Despite the therapy and her full-time job, she decided to participate in the Patient Science project: "I want to document my experience of living with cystic fibrosis and pass that on to other people with the condition." The head of the Patient Science project is Dr. Nils Heyen from the Fraunhofer Institute for Systems and Innovation Research ISI in Karlsruhe, and he emphasizes that the project is breaking new ground: "There are currently no other studies in the health



Patients are very susceptible to infections, so traveling by public transport poses a significant risk. © Shutterstock

explain to us which questions are important. As professional researchers, we can then show them how to phrase the questions in a way that will provide robust and meaningful data," says Nils Heyen, pointing to this constructive collaborative effort. The idea behind the questionnaire is to find out what problems patients face in their daily lives and how they overcome them.

### High risk of infection

Many of the everyday problems faced by people with cystic fibrosis stem from their increased susceptibility to infections. A simple cold can have serious consequences for them because the thick mucus in their bronchi and lungs is such a perfect breeding ground for bacteria. To

prevent infections, many patients avoid contact with other people, but that makes activities such as meeting friends and traveling by public transport extremely challenging. Daily inhalation is also very stressful, especially for parents who have to motivate their children to do it every day.

The data obtained from this comprehensive survey will be analyzed in a joint effort by the patient researchers and team of scientists. One of the goals is to use the results to produce a self-help guide. Patient researcher Katja Wecke argues that this would be a major achievement because the inclusion of her own experiences in the project will ultimately benefit other people with the same condition. ■

## Citizen science

Enthusiasm for research is spreading, with more and more people getting involved in projects at a variety of institutions. When the German Federal Ministry of Education and Research first announced funding for citizen science projects, there was a huge response, with more than 300 projects put forward. A total of 13 projects were selected by an expert jury and have been receiving funding since July 2017. Fraunhofer institutes are involved in five of these citizen science projects. In addition to Patient Science at Fraunhofer ISI, the other four projects are:



### **CitizenSensor – Environmental Analytics For All, Fraunhofer EMFT**

Scientists measure the nutrient content of soil by analyzing soil samples in the lab. This is an expensive and time-consuming process. The Fraunhofer Research Institution for Microsystems and Solid State Technologies EMFT is collaborating with an "open to all" citizens' workshop to develop a new measuring device that would give keen amateur gardeners a quick and easy way to calculate how much fertilizer they need to add to their beds. The new technique is based on electrochemical sensors developed by Fraunhofer EMFT. The project also aims to develop guidelines on collaboration between institution-based research and maker culture.

### **Hear how you like to hear – self-determined hearing for people with and without hearing impairments, Fraunhofer IDMT**

More than half of people aged 65 or over have a hearing impairment, yet only a quarter of them choose to use a hearing aid. The Fraunhofer Institute for Digital Media Technology IDMT is relying on citizens' creativity to give new impetus to the development of next-generation hearing aids. Participants attend workshops where they use simple technical equipment to try out personalized solutions for everyday life and develop innovative design concepts. Their goal is to focus on the well-being of hearing-impaired people.

### **Urban agriculture – sustainable integration and networking of small-scale food production, Fraunhofer UMSICHT**

Many people in cities and towns already produce their own food, either on their balconies or in community gardens. The Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT and the Bonn Science Shop are aiming to work together with citizens to develop new ideas for better food production in urban areas. One of their strategies is to develop specially tailored technologies. The team is working in Oberhausen and Bonn to compile research questions, test them out on two consecutive harvests and assess them against sustainability criteria.

### **OpenLabNet – Make Science! (Joint research project), Fraunhofer IMWS**

OpenLabNet – Make Science! brings together multiple citizen science projects on a range of topics including particulate matter measurements, green blogging, sustainable lifestyles and self-sufficient living in old age. The "Surveying the World 2.0" project run by the Fraunhofer Institute for Microstructure of Materials and Systems IMWS was set up to measure fine particulate levels in the German city of Halle. The "Make Science! Open" competition encourages citizens to submit their own research topics and win prize money to fund their project.

# Fraunhofer research: the Swedish connection



Eighteen years have passed since the Fraunhofer-Gesellschaft founded its first European research center outside Germany in Gothenburg. Since then, Sweden has become an important partner country for applied research, with Fraunhofer teams working in two locations to develop practical solutions for Swedish and German companies – including leading manufacturers of passenger cars and commercial vehicles.

Text: Monika Weiner

Strolling around the port, grabbing a coffee in the old town and visiting the Viking windjammer are just some of the must-do highlights of a visit to Gothenburg. “They are on my list every time I go there,” says Prof. Dieter Prätzel-Wolters. “But each time I end up going straight from the airport to Chalmers University campus and back again. There’s simply never enough time!” The director of the Fraunhofer Institute for Industrial Mathematics ITWM flies to the Swedish port city at least three times a year to

visit the Fraunhofer-Chalmers Research Centre for Industrial Mathematics FCC on the Chalmers University campus. The FCC was founded in 2001 as Fraunhofer’s first European subsidiary outside Germany. Since then, ITWM’s director and many of its staff have taken regular trips to Gothenburg for project meetings and research placements, and their Swedish colleagues have often made visits to Kaiserslautern in return. Whenever the researchers meet, their main topic of discussion is how to improve industrial

products, processes and workflows using mathematical methods – a challenge that cannot be addressed with a one-size-fits-all solution. Customers from different sectors – say paper-making and agricultural machinery, for example – will inevitably require different approaches. “Fortunately, the tremendously wide range of expertise in our German and Swedish teams allows us to develop tailored solutions for all the 200 or so customers we now work with,” says Johan Carlson PhD, director of the FCC.

Fraunhofer researchers often travel to Gothenburg to meet up with their long-term cooperation partners. © 123rf

## 18 years of joint research

The Fraunhofer-Chalmers Research Centre for Industrial Mathematics FCC is a genuine success story – and it all began with a meeting between two mathematicians: Prof. Helmut Neunzert, former director of ITWM, and Dr. Uno Nävert, then head of the Swedish Institute of Applied Mathematics ITM. The two researchers were keen to channel the expertise of their respective institutes into joint research projects in order to acquire research contracts in both the Swedish and German markets. One of the challenges they faced was that many research contracts in Germany are awarded by small and medium-sized companies, while research commissions in Sweden are dominated by big companies such as Volvo, ABB and Tetra Pack.

Their plan finally came to fruition in 2001 when the Fraunhofer-Chalmers Research Centre was founded in Gothenburg with the support of Chalmers University of Technology. Right from the start, core funding for the FCC came from a foundation in which Fraunhofer and Chalmers are equal partners. The FCC started out with just four employees, one of whom was Johan Carlson, now the FCC's director. It now employs 70 people and has a budget of six million euros, 40 percent of which come from industrial contracts.

The mathematicians in Gothenburg specialize in multiphysics simulations, geometry, biological system modeling, data mining and software development, while the ITWM researchers offer decades of experience in material design, high-performance computing, vehicle and flow simulation and the optimization of products and processes.

And it's not only Fraunhofer mathematicians who are keen to collaborate with Swedish counterparts. Over the past two years, the Fraunhofer Institute for Machine Tools and Forming Technology IWU in Chemnitz and the Fraunhofer Institute for Production Technology IPT in Aachen have been working closely with Swedish scientists from the KTH Royal Institute of Technology and the RISE research organization. Together, the teams established the Powertrain Manufacturing for Heavy Vehicles Application Lab, or PMH, in Stockholm.



The Fraunhofer-Chalmers Research Centre for Industrial Mathematics FCC was founded in Gothenburg in 2001. © alamy



"The idea of working with Fraunhofer to open an applied research and development lab for manufacturing technologies came from the commercial vehicle manufacturers Scania and Volvo and the machine tool systems manufacturer Sandvik," says Prof. Thomas Berg from Fraunhofer IPT. It didn't take long to find the perfect location: "The KTH campus in Stockholm offers all the technical equipment we need and plenty of highly motivated young researchers – and it's very close to our industry customers," enthuses Dr. Jannik Henser, who set up and now runs the PMH.

### Shared interests

In fact, both the Swedish capital Stockholm and the country's second-largest city Gothenburg are popular locations for applied research. This part of Scandinavia has built up a reputation for car and commercial vehicle manufacturing

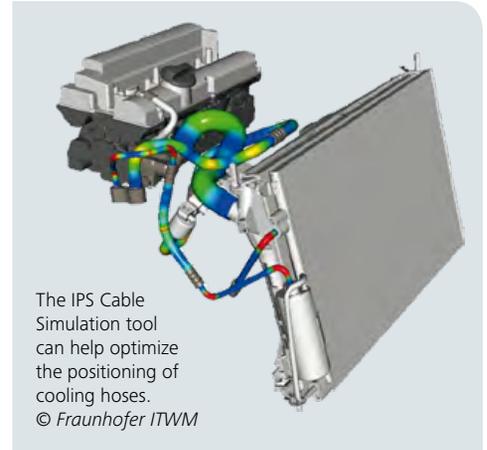
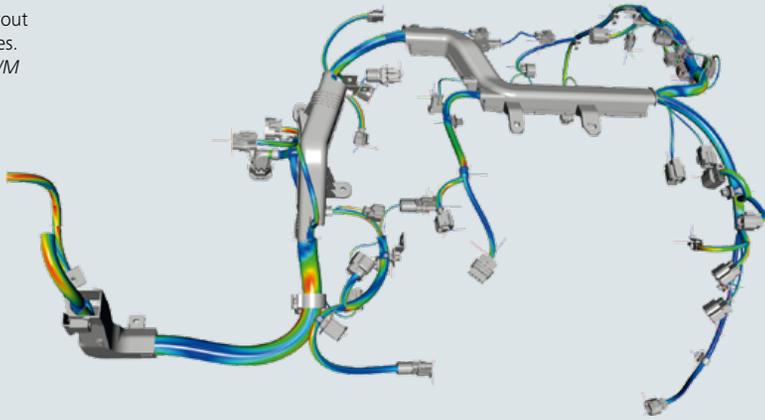
Swedish and German teams are working together in Stockholm to develop expertise in automotive Industrie 4.0. © iStock

as well as wood and paper processing, and these two cities are where the big players are based. Key advantages for the Fraunhofer teams include close proximity to the customer and a plethora of potential cooperative ventures, and the main focus of their research is on automotive engineering. This is one of the most important industry sectors not just in Sweden, but also in Germany, so both countries benefit from joint projects.

### Reliable design and intelligent wiring layouts

Researchers at the Fraunhofer-Chalmers Research Centre have already developed a manual for robust and reliable vehicle design in

Simulating the layout of wiring harnesses.  
© Fraunhofer ITWM



The IPS Cable Simulation tool can help optimize the positioning of cooling hoses.  
© Fraunhofer ITWM

collaboration with the ITWM and six European truck manufacturers: DAF, Daimler, IVECO, MAN, Scania and Volvo. The “Guide to Load Analysis for Durability in Vehicle Engineering” was published in 2013 and forms the basis for developing new commercial vehicles.

Teams of mathematicians in Gothenburg and Kaiserslautern have also jointly developed a simulation program for the design and virtual validation of cables, hoses and wiring harnesses, which aims to help automakers save time and money. The IPS Cable Simulation software tool helps engineers determine at the design phase whether the materials they intend to use are fit for purpose. With a typical passenger car containing up to three kilometers of wiring – or even a few kilometers more in the case of hybrid vehicles – this is no easy task. “During the vehicle’s lifetime, these cables not only have to withstand heat, cold and vibrations, but also mechanical stresses and strains. The software can simulate all these factors and display them in real time,” says FCC director Carlson. “So users immediately see the results of their input on the screen.” A total of 80 companies in Europe, Asia and the US are already using the program. The IPS Cable Simulation tool is marketed by a spin-off of the Gothenburg-based FCC called IPS Industrial Path Solutions Sweden AB, which was founded in 2012, as well as by the company fleXstructures GmbH in Kaiserslautern, a spin-off of ITWM. The company fleXstructures received the Robotics Award at Hannover Messe 2017 and the Pfalz Future Prize soon after.

### Smart painting robots

The Fraunhofer team in Gothenburg is currently working on a fully automated paint booth. “The

idea behind the SelfPaint project is to speed up the vehicle manufacturing process,” says Carlson. Currently, factories typically encounter delays when the time comes to switch a paint booth to a new model with new geometries. Together with researchers from ITWM and the Fraunhofer Institute for Manufacturing Engineering and Automation IPA, the Swedish mathematicians have now developed the prototype of a fast and flexible painting booth. This employs simulation software to calculate the entire painting process in advance and 3D scanners to precisely measure each part that comes off the production line before it is painted.

Using this data, the robots can be programmed to apply an even coating of paint with the required thickness. During the painting process, terahertz waves are used as a non-contact quality assurance method, with intelligent algorithms making adjustments as necessary in the event of deviations. Together with experts from other Fraunhofer institutes, Carlson and his team are hoping to tailor the concept of fully automated painting to the needs of small and medium-sized companies that produce individual parts.

### Connected machines

In the future, digital technologies will help to make production faster and more flexible. At the “Powertrain Manufacturing for Heavy Vehicles Application Lab” in Stockholm, a Swedish-German team is now developing expertise in automotive Industrie 4.0. “The primary goal is to increase flexibility on the shop floor and boost machine utilization,” says Berg. To discover how to achieve this in practice, the Stockholm-based

researchers created a unique experimental environment: the “Swedish-German Testbed for Smart Production” covers the three locations of Stockholm, Aachen and Chemnitz, each of which has production facilities that are connected and able to communicate with each other. Current projects include the production of gear wheels for truck transmissions. During the manufacturing process, the machines exchange data and learn from each other, gradually building up information about which machining technology works best, how often tools need to be replaced, and how the capacity utilization of the various machines can be improved. The machines use a specially developed messaging service – a kind of Twitter for machines – to transmit the data wirelessly and in real time, with Swedish company Ericsson providing the required 5G cellular technology.

### Digital twins

Even more complex is an Industrie 4.0 research project in which various engine and transmission components for the powertrain are manufactured at the two German locations and then further processed in Stockholm. All the information gathered during production concerning the type of machining and the parts’ strength, geometry and durability is collected in a database. This creates a “digital twin” in tandem with the actual workpiece. “This twin makes the data available along the entire delivery and production chain and across multiple locations, so it can be used to optimize the part processing operations,” says Berg. The researchers will be presenting their first applications at Hannover Messe 2019, the year in which Sweden is participating as the official partner country. ■

Modeling can help reduce the physical strain experienced by workers. This simulation was generated by the IPS IMMA software. © Industrial Path Solutions Sweden AB

**Applied mathematics at the Fraunhofer-Chalmers Research Centre**

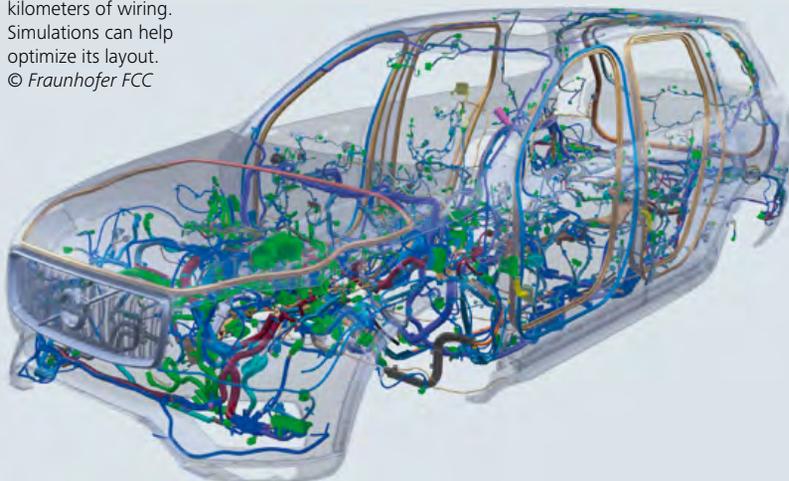
Mathematical models can make life easier: researchers in Gothenburg collaborated with experts from five different Fraunhofer institutes to develop a digital human model designed to improve working conditions in automotive and commercial vehicle manufacturing. The model can be used to simulate the movements workers carry out when they operate the machines. This makes it easier to plan production facilities in a way that reduces people's exposure to harmful stresses and strain in the workplace.

Simulations can also be used to optimize packaging. Researchers developed a computer model for the Swedish paper industry that shows how the choice of pulp and manufacturing method affects the quality of packaging used for liquids. The software reveals the paper's microstructure and allows users to model mechanical properties such as thickness, hardness and foldability.

The construction industry can also benefit from mathematics. In collaboration with the construction and property development group NCC AB, researchers working on the DigiRoad project "Simulation and visualization of road construction" developed a computer model that can be used, for example, to predict the stability of aggregate base courses. The simulation takes into account the size of the stones as well as their distribution and degree of compaction. This offers a cost-effective means of achieving high quality road construction while simultaneously reducing the need for subsequent maintenance.



An average passenger car contains several kilometers of wiring. Simulations can help optimize its layout. © Fraunhofer FCC



The PMH Application Lab in Stockholm develops manufacturing technologies for commercial vehicle powertrains. © Volvo Trucks Corporation



# Events in the anniversary year

70 YEARS OF  
FRAUNHOFER  
**70 YEARS  
OF FUTURE**  
#WHATSNEXT

## March 26 in Munich

Ceremony, Bavarian State  
Reception, Gala Dinner

The Fraunhofer-Gesellschaft's story began on March 26, 1949, in the Bavarian Ministry of Economic Affairs. Renowned politicians, scientists and captains of industry will gather for a ceremony at the association's birthplace to delve into the idea of "Research for Europe." Later in the evening, the Bavarian State Government will host a reception in the Munich Residence, followed by a gala dinner under the heading of "Fraunhofer Talents" to close out the anniversary celebration on a high note.



## April 1 through 5 in Hannover

Hannover Messe

Over the course of five days, close to 40 Fraunhofer institutes and facilities will present solutions and ideas for projects to our industry customers at one of the world's leading industrial trade shows. In this, its anniversary year, Fraunhofer is redoubling its focus on cognitive systems for Industrie 4.0 technologies.



## Fraunhofer at trade fairs

### April, May

April 1–5  
Hannover Messe, Hannover, Germany  
Industrial manufacturing

May 7–10  
Control, Stuttgart, Germany  
Optics, metrology, test systems

### June

June 3–6  
BIO, Philadelphia, USA  
Biotechnology

June 4–7  
Transport und Logistik, Munich, Germany  
Logistics, mobility, IT and  
supply chain management

### June

June 17–23  
SIAE, Le Bourget, France  
Aerospace technologies

June 24–27  
Laser, Munich, Germany  
Lasers in manufacturing, optical technology

June 25–27  
SENSOR+TEST, Nuremberg, Germany  
Measurement and sensor technology

To learn more about all trade fairs,  
visit or contact  
<https://www.fraunhofer.de/en/events.html>

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May 8 and 9 in Munich

### Annual Conference

Tomorrow's research trends will figure prominently at the Annual Conference's in-house and public events, where priority strategic initiatives and select Foresight-related topics take top spots on the agenda. The awards ceremony for the Joseph von Fraunhofer and Fraunhofer Human-Centered Technology Prizes is sure to be a festive highlight.



November 20 in Berlin

### Alumni Summit

There is no better calling card than success, which is why the Fraunhofer-Gesellschaft takes such great pride in our alumni. Every year, we bring together the brightest minds in business, government and industry for an always entertaining event replete with unexpected moments. Artificial intelligence will be the hot topic at the FUTURAS IN RES kick-off event.



November 21 and 22 in Berlin

### FUTURAS IN RES

"What's the IQ of AI" – seeking answers to this question, eminent researchers, businesspeople and policymakers will discuss the potential and limits of artificial intelligence with an international audience. Science excellence, an international web of connected experts and industrial value creation are the hallmarks of this conference.

## WHAT'S THE IQ OF AI? FUTURAS IN RES

### Editorial notes

#### Fraunhofer magazine

All about research, technology and innovation.

ISSN 1868-3428 (printed edition)

ISSN 1868-3436 (online edition)

#### Publisher:

Fraunhofer-Gesellschaft  
Hansastraße 27c, 80686 Munich, Germany  
Editors same address as above  
Phone +49 89 1205 1301  
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<http://s.fhg.de/magazines>

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**Graphic design:** BUTTER. Düsseldorf

**Layout & lithography:** Vierthaler & Braun, Munich

**Cover image:** Fraunhofer

**Printed by:** H. HEENEMANN GmbH, Berlin

**Translation:** Burton, Van Iersel & Whitney, Munich



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