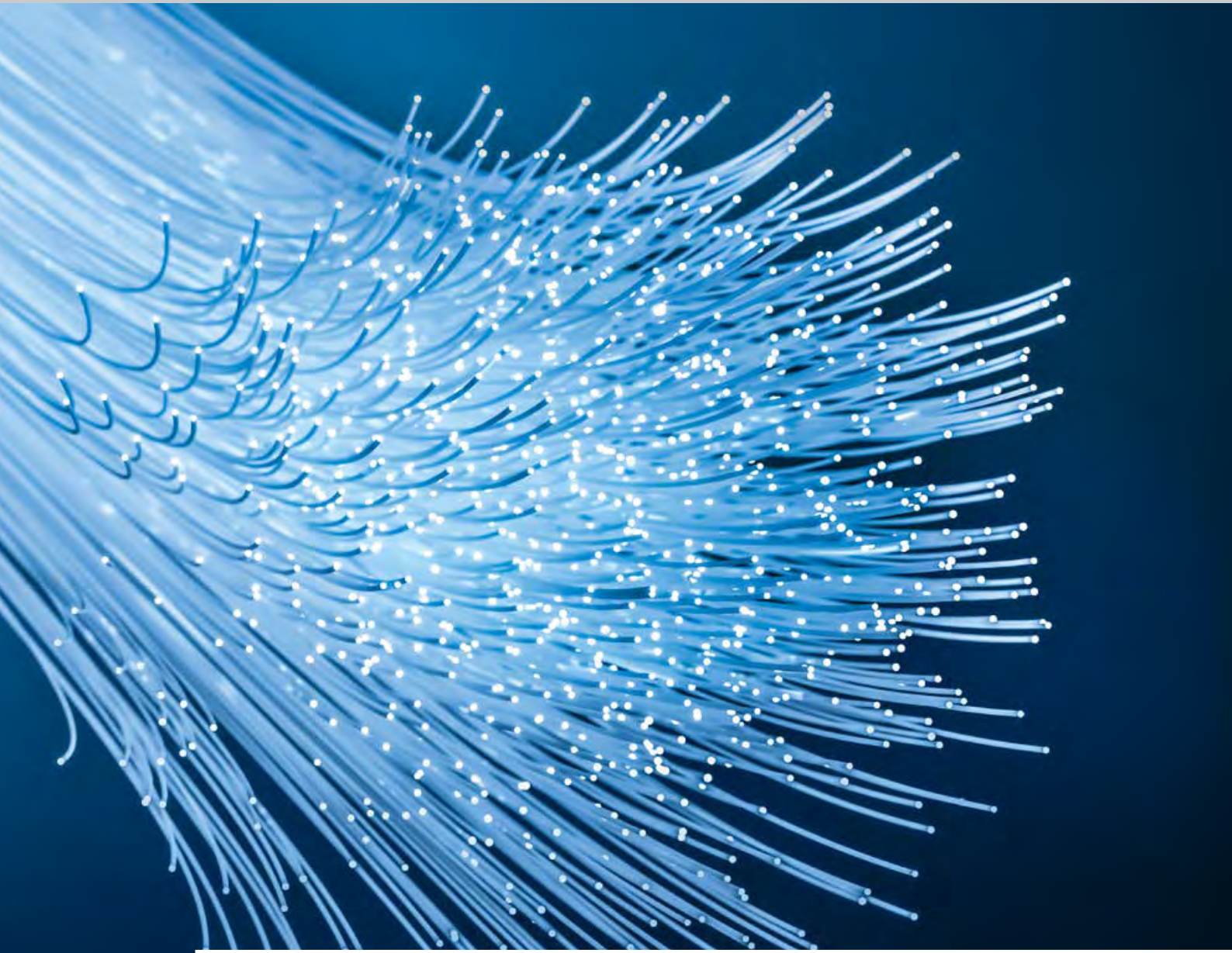
Fraunhofer



ANNUAL REPORT 2016

EMBRACING DIGITALIZATION

Fraunhofer-Gesellschaft

Research of practical utility lies at the heart of all activities pursued by the Fraunhofer-Gesellschaft. Founded in 1949, the research organization undertakes applied research that drives economic development and serves the wider benefits of society. Its services are solicited by customers and contractual partners in industry, the service sector and public administration.

At present, the Fraunhofer-Gesellschaft operates 69 institutes and research institutions in Germany. The majority of the 24,500 staff are qualified scientists and engineers, who work with an annual research budget of 2.1 billion euros. Of this sum, 1.9 billion euros is generated through contract research. More than 70 percent of the Fraunhofer-Gesellschaft's contract research revenue is derived from contracts with industry and from publicly financed research projects. Almost 30 percent is contributed by the German federal and state governments in the form of base funding, enabling the institutes to work ahead on solutions to problems that will not become relevant to industry and society until five or ten years from now.

International collaborations with excellent research partners and innovative companies around the world ensure direct access to regions of the greatest importance to present and future scientific progress and economic development.

With its clearly defined mission of application-oriented research and its focus on key technologies of relevance to the future, the Fraunhofer-Gesellschaft plays a prominent role in the German and European innovation processes. Applied research has a knock-on effect that extends beyond the direct benefits perceived by the customer: through their research and development work, the Fraunhofer Institutes help reinforce the competitive strength of the economy in their local region, and throughout Germany and Europe. They do so by promoting innovation and the acceptance of new technologies, and by helping to train the urgently needed future generation of scientists and engineers.

As an employer, the Fraunhofer-Gesellschaft offers its staff the opportunity to develop the professional and personal skills that will allow them to take up positions of responsibility within their institute, at universities, in industry and in society. Students who choose to work on projects at the Fraunhofer Institutes have excellent prospects of starting and developing a career in industry by virtue of the practical training and experience they have acquired.

The Fraunhofer-Gesellschaft is a recognized non-profit organization that takes its name from Joseph von Fraunhofer (1787–1826), the illustrious Munich researcher, inventor and entrepreneur.

Figures as at January 2017
www.fraunhofer.de

ANNUAL REPORT 2016
EMBRACING DIGITALIZATION

Ladies and gentlemen,

Fraunhofer is making sure and steady progress. The Executive Board and the Presidential Council spearheaded various changes in 2016 to optimize the organization's performance, including giving more responsibility to the Fraunhofer Groups and introducing measures to limit the risk exposure of individual institutes. This enabled the institutes to improve their business results and thereby contribute to the growth of the Fraunhofer-Gesellschaft. We also expanded our role as one of industry's leading technology partners. With an annual research budget of well over €2 billion euros, we are a respected global player in the applied research market.

In 2016 we scored an important success with respect to the organization's base funding with an increase in federal and state funding of €67 million, restoring the 70:30 balance prescribed by the Fraunhofer model. These funds are used to finance pre-competitive research with the aim of developing new technologies to the point of commercial maturity. We take a vigilant approach when planning the distribution of our resources, including those designated for specific purposes, such as the €280 million used to create the Research Fab Microelectronics Germany (FMD), an initiative of the Fraunhofer Group for Microelectronics.

Digitalization is a phenomenon that affects wide areas of business and society, and hence a subject to which we accord increasing attention. The Industrial Data Space concept is our response to industry's need for data protection, secure data

exchange and sovereignty over proprietary data that represents the economic lifeblood of many companies. As part of this initiative, we created Industrial Data Space e.V. in early 2016, a non-profit association with meanwhile more than 42 members in many countries. We have since expanded the original concept to include more specialized areas such as a Materials Data Space and a Medical Data Space, thus placing the initiative on a broader basis that will allow the platform to support the digitalization of many more business processes.

To adapt to these new demands, Fraunhofer launched a wide-scale participatory process in 2016 to formulate and obtain consensus on a new set of Guiding Principles. In this document, we define our mission (how we identify ourselves), our vision (where we want to go), and the six main principles that guide our work.

We will continue to pursue our overriding objective of generating positive operating results while advancing science and technology through an approach that combines original thinking, disruptive innovation and strategically relevant project management. In this way, we will be able to meet the steeply rising demand for Fraunhofer's services from industrial clients, which partly stems from the German economy's reorientation toward digitalization and biologization. Fraunhofer's contribution to the sustainable development of the research infrastructure includes the creation of 17 High Performance Centers, with the aim of optimizing the transfer of research findings to all sectors of industry and creating a national technology-transfer infrastructure for Germany.

Applied research takes place in a rapidly changing environment in which political factors, market trends, and technologies are in constant evolution. Our response is to create flexible structures with an inherent capacity for change. Through the Fraunhofer 2022 Agenda, we intend to sustain this dynamic process and develop it into a master roadmap.

Fraunhofer's success can be largely attributed to the dedication of its employees. I would like to extend my sincerest thanks to them on behalf of the entire Executive Board. I also wish to thank the members of the institutes' advisory boards and the Fraunhofer Senate for their enduring trust and outstanding commitment.

Sincerely,

Reimund Neugebauer
President of the Fraunhofer-Gesellschaft

REPORT OF THE EXECUTIVE BOARD

8 The Executive Board
12 Management Report 2016
50 Report of the Senate on the financial year 2016
52 Inside the Fraunhofer Senate

REVIEW OF FRAUNHOFER RESEARCH

58 Smart Data – the stuff innovations are made of
68 Projects and results 2016
86 New initiatives and High Performance Centers
92 Awards 2016
94 People in research
106 Fraunhofer Institute spin-offs

FINANCIAL REPORT

112 Balance sheet at December 31, 2016
114 Income statement for the financial year 2016
116 Reconciliation between income statement and performance statement (cash-basis accounting)
118 Performance statement for individual Fraunhofer entities
124 Excerpts from the notes to the financial statements
127 Independent auditor's report

SERVICE

130 Structure of the Fraunhofer-Gesellschaft
132 Members, constituent bodies, committees
134 Fraunhofer Groups
135 Fraunhofer Alliances
136 Addresses in Germany
138 International addresses
140 Editorial notes

REPORT OF THE EXECUTIVE BOARD

THE EXECUTIVE BOARD

MANAGEMENT REPORT 2016

REPORT OF THE SENATE
ON THE FINANCIAL YEAR 2016

INSIDE THE FRAUNHOFER SENATE

THE EXECUTIVE BOARD

Reimund Neugebauer is Professor of Machine Tools and Forming Technology at Technische Universität Chemnitz (TU Chemnitz). After leadership roles in the mechanical engineering industry, he set up the Fraunhofer Institute for Machine Tools and Forming Technology IWU in 1991, which grew to become an international center for manufacturing engineering in his 21 years of service as its director. He has been President of the Fraunhofer-Gesellschaft since 2012.

Prof. Dr.-Ing. habil. Prof. E. h. Dr.-Ing. E. h. mult. Dr. h. c. mult.
Reimund Neugebauer
President, Corporate Policy and Research Management

Georg Rosenfeld trained as a physicist and then worked as a research scientist at Forschungszentrum Jülich and at the University of Twente in the Netherlands before joining the Fraunhofer-Gesellschaft as Division Director Corporate Development and then as Division Director Research. The Senate appointed him to the Executive Board in 2016.

Prof. Dr. rer. nat.
Georg Rosenfeld
Executive Vice President Technology Marketing and Business Models

After studying to become a lawyer, Alexander Kurz worked as a manager and board member for major research organizations such as CERN in Geneva and the Karlsruhe Institute of Technology (KIT). He has been a member of the Executive Board of the Fraunhofer-Gesellschaft since 2011.

Prof. Dr. rer. publ. ass. iur.
Alexander Kurz
Executive Vice President Human Resources, Legal Affairs and IP Management

Alfred Gossner initially pursued a career with the Allianz Group, including various international postings. Before joining the Fraunhofer-Gesellschaft in 2002, he served as a member of the board of management of Allianz Versicherungs-AG.

Prof. (Univ. Stellenbosch) Dr. rer. pol.
Alfred Gossner
Executive Vice President Finance, Controlling and Information Systems

MANAGEMENT REPORT 2016

13 Summary of the Fraunhofer-Gesellschaft's business development in 2016

14 Strategic development
Profile of the Fraunhofer-Gesellschaft
Objectives and strategic initiatives
Structural growth
Sustainability
Science policy framework

21 Business report
Economic environment
Total business volume
Contract research
Defense research
Major infrastructure capital expenditure
Fraunhofer Groups
Financial situation
Net asset position
Equity investments, subsidiaries and spin-offs
International activities of the German Fraunhofer Institutes
Intellectual property activities

41 Employees
Overview
Equal career opportunities for men and women
International orientation

46 Risk situation and outlook
Risk management and identified risks
Outlook

Summary of the Fraunhofer-Gesellschaft's business development in 2016

	2015	2016	Change	
Business volume in € million	2115	2081	–34	–2%
Contract research	1835	1879	+44	+2%
Defense research	127	114	–13	–10%
Major infrastructure capital expenditure	153	88	–65	–42%
Breakdown of expenditure in %				
Personnel expense ratio	55	59	+4	
Non-personnel expense ratio	29	30	+1	
Capital expenditure ratio	16	11	–5	
Contract research funding in € million				
Project revenue	1305	1386	+81	+6%
Industrial revenue	641	682	+41	+6%
Public-sector revenue [1]	664	704	+40	+6%
Funding requirements	530	493	–37	–7%
Sources of contract research funding in % [2]				
Projects	73	74	+1	
Industry	37	37	0	
Public sector [1]	36	37	+1	
International revenue in € million [3]	291	304	+13	+4%
Patent applications per year	506	608	+102	+20%
Active patent families at year end	6573	6762	+189	+3%
Employees at year end	24 084	24 458	+374	+2%

1 Public-sector funding includes Germany's federal and state governments, the European Commission and other sources (research grants, other R&D, non-R&D).

2 Funding sources for the operating budget including imputed depreciation of investments (excluding research institutions in the setup phase and change in reserves).

3 Revenue from work with international customers and partners (incl. income generated by international subsidiaries with third parties).

STRATEGIC DEVELOPMENT

Profile of the Fraunhofer-Gesellschaft

Research of practical utility lies at the heart of all activities pursued by the Fraunhofer-Gesellschaft. Founded in 1949 and based in Munich, this non-profit research organization undertakes **applied research and development** (R&D) in areas of the natural and engineering sciences of importance to the competitiveness of the German economy. It currently operates 69 Fraunhofer Institutes and Research Institutions across Germany. Their mission is to develop innovative solutions of direct benefit to industry and society as a whole. Fraunhofer's research portfolio covers a broad spectrum of topical issues, which also feature in the German government's High-Tech Strategy, including resource-efficient manufacturing, transportation and mobility, energy and housing, information and communication technologies (ICT), protection and security, as well as healthcare, nutrition and the environment.

The majority of the 24,500 people who work for Fraunhofer hold academic degrees in the natural or engineering sciences. Together they generate an annual business volume of nearly €2.1 billion. Of this sum, some €1.9 billion is generated through **contract research**. More than 70 percent of the Fraunhofer-Gesellschaft's contract research revenue derives from contracts with industry and from publicly financed research projects. Together with their customers and project partners, the Fraunhofer Institutes develop and optimize processes, products and systems to the point of industrial or commercial maturity. Base funding provided by the German Federal Ministry of Education and Research (BMBF) and the state governments in a ratio of 90:10 covers the remaining 30 percent of Fraunhofer's financing needs, and is used principally to finance pre-competitive research in areas of future importance to industry, society and government.

Fraunhofer aligns the composition of its broad research portfolio with the dynamically changing conditions of the research market by means of quality-assured planning processes. The organization plans its R&D strategy on three interconnected levels.

Each Fraunhofer Institute defines its own market orientation and core competences on the basis of its immediate market environment and its networking ties with the scientific community.

The seven **Fraunhofer Groups** provide a means of developing and coordinating a cross-institute research strategy by bringing together institutes with related areas of expertise:

- Information and Communication Technology
- Life Sciences
- Light & Surfaces
- Materials and Components – MATERIALS
- Microelectronics
- Production
  and
- Defense and Security VVS

Moreover, institutes with complementary areas of expertise can group together to form **Fraunhofer Alliances**, enabling them to jointly develop and market solutions for specific business sectors.

As part of its wider research strategy, Fraunhofer identifies innovative areas of business and trending technologies with significant market potential and high social impact. These are then taken up mainly in the form of in-house research programs led by a consortium of institutes chosen through a competitive selection process.

Seven Fraunhofer Institutes work on research topics of specific interest to the German Federal Ministry of Defence (BMVg). These activities, which are fully funded by the BMVg, are accounted for separately in the Fraunhofer-Gesellschaft's annual financial statements under **defense research**.

The Fraunhofer Institutes maintain close **ties with the world of academic research**, an arrangement that benefits both parties by forging links between teaching and evidence-based practice, leading on to technology transfer and contract research. Almost all directors of Fraunhofer Institutes hold parallel posts as the chair of a university department. In this way, Fraunhofer plays a prime role in educating the next generation of scientists and engineers.

Fraunhofer has **subsidiaries** in Europe, North America and South America and representative offices in Asia and the Middle East. These form a bridge to the world's main regions of current and future economic and scientific interest. Numerous strategic partnerships with organizations of excellence round off Fraunhofer's international portfolio.

Objectives and strategic initiatives

In keeping with the Fraunhofer-Gesellschaft's mission as an applied-research organization, we partner with companies to transform original ideas into innovations that benefit society and strengthen both the German and the European economy. Fraunhofer's vision, as formulated in the new **Guiding Principles** issued in 2016, is to be an innovation driver, leading strategic initiatives to master future challenges. Other points addressed in the Guiding Principles include optimizing collaboration with our customers, promoting interdisciplinary cooperation between institutes, and recognizing the important role played by our employees in assuring the Fraunhofer-Gesellschaft's success.

Fraunhofer has established new communication processes and networking instruments to drive forward its innovation initiatives on an organization-wide basis, with the support of a central moderation team. Such initiatives include the creation of **"Industrial Data Space e.V.,"** a non-profit association founded in 2016 in which Fraunhofer and meanwhile more than 42 members in eight countries have taken the first decisive step toward shaping tomorrow's digitally connected industry. The Industrial Data Space concept is Fraunhofer's response to industry's need for secure data exchange and sovereignty over proprietary data that represents an increasingly important economic resource. Fraunhofer has taken this concept another step further by launching two related initiatives based on the Industrial Data Space architecture. The Material Data Space helps assure digital sovereignty throughout the supply chain and over the entire product lifecycle. The Medical Data Space provides a secure environment linking medical research to clinical practice.

To promote scientific excellence, Fraunhofer introduced the use of **research performance indicators** in 2016. These indicators are specifically adapted to Fraunhofer's mission and the results are analyzed and discussed internally. Communication is also growing in importance as a value creation factor. In 2016, as a means of continuously improving the effectiveness and efficiency of the measures we implement as part of our communications strategy, we defined methods for measuring their success together with a set of **communication performance indicators** aligned to the pre-existing strategic objectives.

To ensure that Fraunhofer's heterogeneous and dynamically changing R&D portfolio keeps pace with future demand, the bottom-up approach whereby individual Fraunhofer Institutes define their own strategies must be complemented by organization-wide instruments and methods that enable **high-potential R&D topics** to be identified, evaluated and developed at an early stage. In 2016, this led to the adoption of new fields of research such as quantum technology, aquaculture, and programmable materials, each of which derives from a combination of key skills previously offered separately by various Fraunhofer Institutes. The aim is to systematically build up expertise in these fields and thereby carry Fraunhofer confidently into the future. In addition to these new research areas, Fraunhofer also follows major trends in industrial R&D such as digitalization and biologization. This is where Fraunhofer could benefit from a unique selling proposition (USP) by leveraging the synergy effect of combining disciplines in which the organization already excels, e.g. life sciences and materials science in the case of medical devices. New internal funding models are available to support this type of collaboration.

Strategic partnerships with key customers are another means of giving added stimulus to contract research activities, for example in the form of a matching process. This involves identifying a company's R&D needs and selecting the areas in which a collaborative approach would be most useful. As the outcome of this structured, coordinated process, a consortium of institutes can be created to work on the customer-specific R&D project. An added advantage for the research provider is that this approach enables successful business models to be identified and supported at corporate level. One example is the concept of the **"embedded scientist,"** in which a company seconds a member of its research staff to work at a Fraunhofer Institute on a joint project to analyze the company's R&D requirements.

The **Cyber Security Learning Lab** created in 2016 with BMBF support is a significant addition to Fraunhofer's **research-based training activities** in an area of technology of vital importance to the future of industry and society. It is operated by the Fraunhofer Academy in cooperation with selected universities of applied sciences, and offers managers and other professionals practice-oriented training in IT security based on the latest research findings. This support enables companies and public bodies to embrace the opportunities offered by digitalization without taking unnecessary risks. Training is provided in ultramodern laboratories equipped with the latest IT infrastructure, and comprises separate modules dealing with specific industries, security issues, and security functions.

Structural growth

The Fraunhofer-Gesellschaft's structural growth is based on the continuous expansion of the Fraunhofer Institutes, the integration of external research institutions and the creation of new project groups. As a rule, project groups are initially established for a duration of five years. At the end of this transitional period, their performance is evaluated to determine whether they are eligible for support according to the Fraunhofer funding model, which entitles them to base funding by the federal and state governments in a ratio of 90:10. A critical consideration in this evaluation is whether the entity's competency profile is a strategic fit with Fraunhofer's existing R&D portfolio. In addition, it must be ensured that adequate resources can be made available under the Fraunhofer model (including additional base funding) to cover the project group's medium-term funding requirements. Five new projects groups passed this evaluation test in 2016:

- The Fraunhofer Project Group for Personalized Tumor Therapy, at Fraunhofer ITEM in Regensburg
- The ATZ Development Center – energy, resources, materials, at Fraunhofer UMSICHT in Sulzbach-Rosenberg
- The Project Group for Processing Technologies in Lightweight Construction, at Fraunhofer IPA in Stuttgart
- Integration of the former German Plastics Institute (DKI) as a new branch of Fraunhofer LBF in Darmstadt
- The Project Group for Components and Systems Design of Electrical Energy Storage Systems, at Fraunhofer IFAM in Oldenburg

All five project groups are now eligible for base funding, split between the federal and state governments in a ratio of 90:10. Fraunhofer also established two new Fraunhofer Institutes and one new Fraunhofer Research Institution in 2016, all three of which were derived from positively evaluated project groups or institute departments.

The Fraunhofer Institute for Microstructure of Materials and Systems IMWS based in Halle (Saale) became an independent entity on January 1, 2016, due to the successful results of the Halle branch of the Fraunhofer Institute for Mechanics of Materials IWM. The creation of Fraunhofer IMWS gives added strength to the Fraunhofer Group for Materials and Components – MATERIALS and the new institute has already joined numerous Fraunhofer Alliances.

The Fraunhofer Research Institution for Casting, Composite and Processing Technology IGCV was established in July 2016, with twin sites in Augsburg and Garching. Fraunhofer IGCV was formed by merging the Functional Lightweight Design (FIL) branch of the Fraunhofer Institute for Chemical Technology ICT, the Project Group for Resource-efficient Mechatronic Processing Machines (RMV), formerly a part of the Fraunhofer Institute for Machine Tools and Forming Technology IWU, and the Working Group on Metal Forming and Casting at the Technical University of Munich (TUM).

The Fraunhofer Institute for Mechatronic Systems Design IEM in Paderborn, founded on January 1, 2017, is a perfect example of the emergence of an institute from a project group. It started out in 2011 as a project group at the Fraunhofer Institute for Production Technology IPT and five years later obtained the status of a Fraunhofer Research Institution. Now, another year later, it has been recognized as a full-fledged Fraunhofer Institute.

Sustainability

As a major player in the German and European research and education system, Fraunhofer is an active contributor to the social debate concerning the sustainability and competitiveness of industry in this geographical region. The focal points of this engagement include embracing new areas of innovation, for instance by supporting the Sustainable Development Goals set out by the United Nations, and by continuously improving Fraunhofer's social and **corporate responsibility** as an employer and research organization.

To honor its commitment to sustainable development, Fraunhofer places great value on scientific excellence and moral integrity, a proactive approach to knowledge and technology transfer, needs-oriented and problem-oriented research, strategic initiatives and partnerships, and value-oriented human resources management. The latest Fraunhofer **Sustainability Report**, published in 2016, presents the measures being taken by the Fraunhofer-Gesellschaft to reach its defined targets with respect to science, economic impact, employees, society and resources.

Fraunhofer also aims to set new standards for **sustainability management** within the German research community. As part of a BMBF-funded collaborative project, Fraunhofer experts in research practice and administration joined forces with colleagues from the Leibniz Association and the Helmholtz Association to develop sustainability guidelines tailored to the research context. The results of this project, which was concluded at the end of 2016, were presented in the presence of the German Minister for Education and Research, Prof. Dr. Johanna Wanka. After three years' work, the project partners have reached a common understanding of the essential requirements of a sustainability management process, which will allow them to affirm their social responsibility and take concrete steps to implement the necessary measures.

Following this strategy, the decision was taken in 2016 to enhance the visibility of **socioeconomic and sociotechnological research** at Fraunhofer and to promote closer interdisciplinary collaboration between the Fraunhofer Institutes concerned. One particularly relevant research topic is the process or processes that give rise to technological innovations, and how they spread. By improving our knowledge of the complex processes associated with the adoption of new technologies, it will be possible to actively manage their long-term consequences for industry and society on an economic, social, political and cultural level.

Despite the usefulness of technology impact assessments as such, and the measures that can be derived from them, the wider question is how to place them in a social context that will foster innovation in Germany and Europe. This calls for initiatives that allow all stakeholders to have their say in the innovation process – including the end users. Fraunhofer's position at the interface between science, industry and society is the ideal starting point for such common initiatives. In 2016, **participatory technology design** was the subject of an in-house project in which Fraunhofer analyzed the results of different methods of participatory design utilized in the past by various Fraunhofer Institutes. The findings of this project were presented in the form of recommended requirements for a systematic methodology that will help open up the innovation process and organize it in such a way that it brings benefits to all concerned. The participative approach is a particularly effective way of winning public approval for innovative solutions in the domain of integrated energy, mobility and urban systems.

Science policy framework

As a player in the German research and education system, the Fraunhofer-Gesellschaft is obliged to operate within a complex science policy framework.

In the course of 2016, the **High-Tech Forum** gave impetus to the implementation of the German federal government's current High-Tech Strategy while at the same time drawing up strategic guidelines and defining areas of priority for its future evolution. Fraunhofer and Stifterverband für die Deutsche Wissenschaft e. V. manage the High-Tech Forum's activities through a joint office. As a leading member of the High-Tech Forum, Fraunhofer has the opportunity to formulate recommendations for a concrete action plan, designate specific programs and projects, and suggest thematic areas for inclusion in the government's innovation policy. At the same time, by contributing its knowledge and methodological expertise, Fraunhofer can propose concrete measures to implement the High-Tech Strategy.

The **Innovation Dialog** is a twice-yearly event in which the German Chancellor and other representatives of the federal government meet with prominent members of the scientific community and representatives of business associations and social institutions. These meetings are scheduled to continue through 2017. The President of the Fraunhofer-Gesellschaft, Prof. Dr. Reimund Neugebauer, is a member of the steering committee. A frequent item on the agenda is the question of creating the right conditions to sustain research and innovation into the future. The main topics of the two dialog sessions in 2016 were modern forms of knowledge, technology and know-how transfer, and biotechnology's potential as an innovation driver. Possible instruments for promoting disruptive innovations will be discussed in greater depth at the steering committee's final meeting June 2017. With the President of the Fraunhofer-Gesellschaft on the steering committee, the organization is in a position to help shape the thematic focus and content of the Innovation Dialog.

The **Joint Initiative for Research and Innovation III** came into force at the beginning of 2016 and runs to the end of 2020. In this third period of the initiative, the German Chancellor and the prime ministers of the states agreed that the base funding granted to non-university research organizations would be increased at an annual rate of 3 percent, as opposed to 5 percent in the two preceding periods up to the end of 2015. In its declaration stating the measures it plans to take to achieve the research policy goals defined for the third period of the Joint Initiative for Research and Innovation, Fraunhofer formulated six key mission objectives. The full text of Fraunhofer's declaration can be found (in German only) on the Joint Science Conference (GWK) website (www.gwk-bonn.de).

One of the Joint Initiative's research policy goals is to "create dynamic and performance-enhancing networks in the science system." Fraunhofer intends to do so by **expanding networking and cooperation** with universities and non-university research organizations. At a joint event in the summer of 2016, the Fraunhofer-Gesellschaft and the Max Planck Society presented three collaborative research projects: "PowerQuant – Quantum effects in high-power lasers," "Pompeii – New conservation methods for world heritage sites" and "Aim Biotech – Application of insect-associated microbes in industrial biotechnology."

To strengthen its collaborative ties with universities and networking with local industry, above and beyond the commitment to the research policy goals mentioned earlier, Fraunhofer has continued to expand its network of national **High Performance Centers** to 17 at the present date. Until the end of the current pilot phase, their funding is assured by mutual agreement between the host states, industrial partners, and Fraunhofer. In the longer term, it is hoped that the federal government will grant additional funds.

Base funding enables the Fraunhofer Institutes to uphold Germany's innovative strength by conducting pre-competitive research. But in recent years the annual rate of increase in base funding has fallen below the more substantial increase in revenue from industrial and public-sector research contracts. Any further reduction would threaten the successful Fraunhofer funding model, which guarantees the diversity of the organization's research. At the end of 2016, the federal government therefore decided to **increase base funding** for Fraunhofer by €60 million, out of its own budget. The state governments have agreed to contribute to this increase in a ratio of 90:10.

The borrowing restrictions imposed as part of the initiative to consolidate public spending took effect in 2016 for the federal government and will apply to the state governments as of 2020. A shift in public funding priorities can also be expected. This could mean that urgently needed expenditure on the construction or renovation of public infrastructure and related equipment (e.g. in the budgets for public security, defense, and road and rail networks) could lead to cuts in public spending on research and development. For this reason, Fraunhofer expects that in the medium term the increase in its **project funding on the part of the federal and state governments** will tend to level off compared with the increases of the previous years.

At a European level, the EU's **Horizon 2020** framework programme for research and innovation is currently undergoing an interim evaluation that, among other things, will result in recommendations for the next framework programme. This will demand reflection on the application of the full-cost model, new funding instruments (e.g. the European Innovation Council), and the thematic orientation of the next EU Framework Programme for Research and Innovation, especially with regard to applications and technology transfer.

BUSINESS REPORT

Economic environment

- Sound German economy growing at a steady rate
- Germany has reached the EU's 3-percent target for research intensity
- Education and research remains high priority for federal government

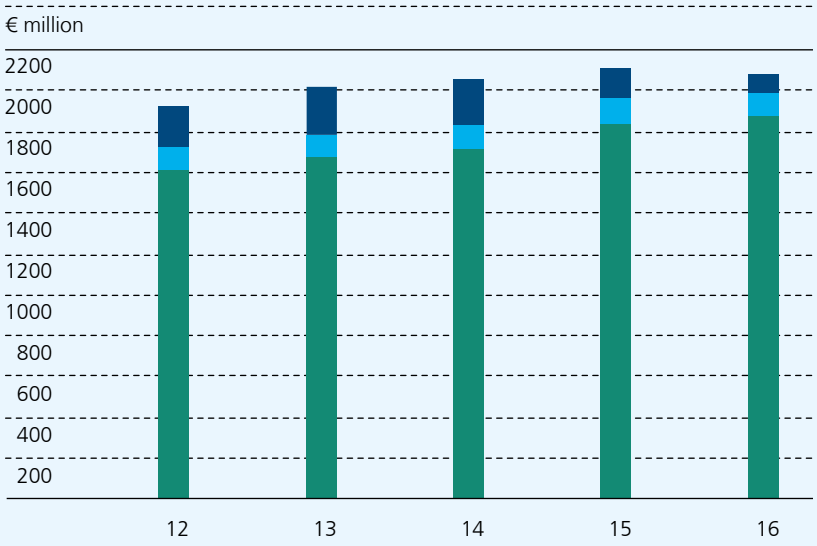
Germany's economic situation in 2016 was once again marked by solid, continuous growth. The country's **gross domestic product (GDP)** increased by 1.9 percent in real terms, which indicates that the economy is growing faster than in the two previous years (GDP up 1.7 percent in 2015, and up 1.6 percent in 2014). Economic growth thus remained above the ten-year average of 1.4 percent per annum. Governments successfully continued their efforts to rein in public spending in 2016. Altogether, federal, state and local governments and social security funds generated a budgetary surplus of €23.7 billion. This is the third year in succession that public accounts recorded a surplus.

Germany has just about reached the European Union's target of raising total expenditure on research and innovation to **3 percent of GDP** by 2020. The country's R&D intensity, i.e. R&D expenditure as a percentage of GDP, amounted to 2.99 percent in 2015, according to the R&D survey published by Stifterverband für die Deutsche Wissenschaft in December 2016. German industry was the driving force, with an increased R&D intensity of 2.1 percent, while public-sector R&D intensity remained at around the previous year's level of 0.9 percent. The number of people employed by industry in R&D also reached a new peak in 2015, growing by 12 percent compared with the previous year to 416,000 (full-time equivalent positions). Expenditure by private industry on in-house R&D amounted to €62.4 billion in 2015, according to the Stifterverband survey. This represents a year-on-year increase of 10 percent, and even 60 percent during the past ten years. Expenditure on external contract research almost doubled during the same ten-year period, rising to €17.4 billion. A large part of the growth registered in 2015 is attributable to the automotive industry, which boosted its expenditure both on in-house R&D and on external contract research by around 10 percent respectively. The upward trend in external contract research was even more marked in the case of the pharmaceutical industry, where its expenditure rose by 25 percent.

The federal government has also been instrumental in enabling Fraunhofer to reach its growth targets, by increasing R&D spending by more than 60 percent over the past ten years. The education budget has more than doubled over the same period. The annual budget allocated to the **Federal Ministry of Education and Research (BMBF)** for 2017 has been increased by nearly 8 percent to around €17.6 billion. This shows how much importance the German government accords to promoting research and innovation.

Industry and government alike remain aware of the vital importance of research and innovation to future competitiveness. On the whole, the **upward trend** in R&D expenditure can be expected to continue, thus supporting German industry's innovation efforts. According to the EU Industrial R&D Investment Scoreboard 2016, Germany holds third place behind the United States and Japan in terms of R&D investment.

The Fraunhofer-Gesellschaft's total business volume 2012–2016



	2012	2013	2014	2015	2016
Major infrastructure capital expenditure	199	235	226	153	88
Defense research	113	114	118	127	114
Contract research	1614	1661	1716	1835	1879
= Total business volume in € million	**1926**	**2010**	**2060**	**2115**	**2081**

Total business volume

- Total business volume slightly down on the previous year at €2081 million
- Contract research on continuing growth trend
- Capital expenditure on major infrastructure relatively low

The Fraunhofer-Gesellschaft generated a total business volume of €2081 million in 2016. This represents a slight decrease of €34 million compared with 2015, which is principally due to the relatively low capital expenditure on major infrastructure. The total business volume comprises on the one hand all personnel and non-personnel expenses incurred by the Fraunhofer-Gesellschaft, recognized in accordance with general accounting practice, and on the other hand all capital expenditure on fixed assets as measured at the date of acquisition. Consequently, the total business volume does not include depreciation or amortization charges.

Budgeted expenditure on contract research increased in 2016 by €44 million to a total of €1879 million, while budgeted expenditure in the defense sector decreased by €13 million to €114 million. Capital expenditure on institute buildings, including the initial cost of equipment for newly constructed buildings or extensions, is recognized as a separate accounting item, major infrastructure capital expenditure. This item amounted to €88 million in 2016, which is significantly lower than in 2015. In the following we report on expenditure and income items separately for each of the two segments, contract research and defense research.

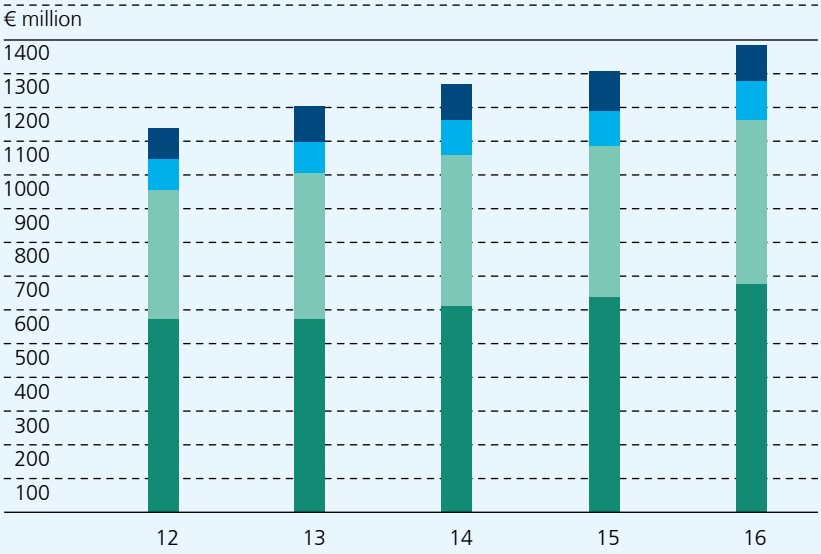
Contract research

- Annual research budget approaching €1.9 billion
- Industrial revenue up 6 percent
- Project funding by federal and state governments up 10 percent on the previous year

The contract research segment comprises three complementary areas of work: research conducted under contract to customers in industry and the service sector, publicly funded research projects, and pre-competitive research financed by means of the organization's base funding. Through their research for private-sector customers, the Fraunhofer Institutes help translate their research findings into real-life applications. In doing so, they play a central role in the innovation process that drives the German and European economies. The goal of many of Fraunhofer's publicly funded research projects is to improve existing infrastructure in essential areas such as energy, transportation and healthcare. Moreover, these projects make an important contribution toward the creation of networks linking different elements of the public science and education system, and promote innovation in the business world.

In 2016, budgeted expenditure for the contract research segment increased by 2 percent to a total of €1879 million. Personnel expenses rose by 5 percent to €1118 million. Non-personnel expenses increased by 2 percent to €591 million. Capital expenditure amounted to €129 million, which is significantly lower than in the previous years. One of the reasons for this decrease is that certain major investment programs financed by means of project revenues came to an end during this period. A further factor affecting this segment's budgeted expenditure in 2016 was an allocation of €41 million to the special reserve for license-fee revenue.

Revenue and expenditure in the contract research segment 2012–2016



	2012	2013	2014	2015	2016
Project revenue	**1137**	**1200**	**1272**	**1305**	**1386**
Other revenue	97	99	103	118	111
EU revenue (European Commission)	88	92	106	105	106
Public-sector revenue (German federal and state governments)	382	431	445	441	487
Industrial revenue	570	578	618	641	682
Funding requirements[1]	**477**	**461**	**444**	**530**	**493**
= **Total revenue in € million**	**1614**	**1661**	**1716**	**1835**	**1879**
Personnel expenses	868	945	1021	1066	1118
Non-personnel expenses	543	549	556	580	591
Change in special reserve for license-fee revenue and allocation to foundation capital	52	0	–15	29	41
Capital expenditure	151	167	154	160	129
= **Total expenditure in million**	**1614**	**1661**	**1716**	**1835**	**1879**

1 In 2012 and 2013, this item included the transfer of funds from Fraunhofer reserves.

Over two-thirds of Fraunhofer's budgeted expenditure for contract research is financed by means of project revenue, which in 2016 increased by 6 percent to a total of €1386 million. Project revenue comprises not only revenue from contracts with industry but also public funding granted by the German federal and state governments and the EU, and miscellaneous other sources. Industrial revenue grew by 6 percent to €682 million. Revenue from project funding granted by the German federal and state governments increased in 2016 by 10 percent to reach €487 million. Revenue from project funding granted by the European Commission, at €106 million, was slightly higher than in the previous year. Revenue from other sources decreased by 6 percent to €111 million. In 2016, an amount of around €493 million granted to Fraunhofer by the German federal and state governments in the form of base funding was utilized to finance contract research.

Defense research

- Annual research budget amounting to €114 million
- Project funding below the previous year's level
- Moderate increase in base funding

The defense research segment groups together the research activities of seven Fraunhofer Institutes in the field of defense and security, which are financed by the German Federal Ministry of Defence (BMVg). The purpose of this research is to develop solutions that provide the best possible protection against the entire spectrum of potential threats of a military or paramilitary nature so as to assure the security of people, infrastructure and the environment. Alongside their defense-related activities, these institutes also have contract research departments that work together with private industry and public-sector customers on the development of solutions for civilian applications. This aspect of their work is equally successful, thus supporting the concept of dual-use research and enabling security issues to be studied from a holistic perspective.

The defense research segment's budgeted expenditure decreased in 2016 by 10 percent to €114 million. This amount comprises €76 million in personnel expenses, €28 million in non-personnel expenses and €10 million in capital expenditure. The reason for this decrease is that project funding granted to Fraunhofer by the German Defence Ministry, at €49 million, was around 20 percent lower than in 2015. This in turn is because the Defence Ministry's respective research budget was cut from €300 million in 2015 to €250 million in 2016. On the other hand, the German Defence Ministry contributed €65 million in the form of base funding, which is slightly more than in 2015.

Major infrastructure capital expenditure

- Comparatively low expenditure on research infrastructure
- Many major construction projects still in the planning phase

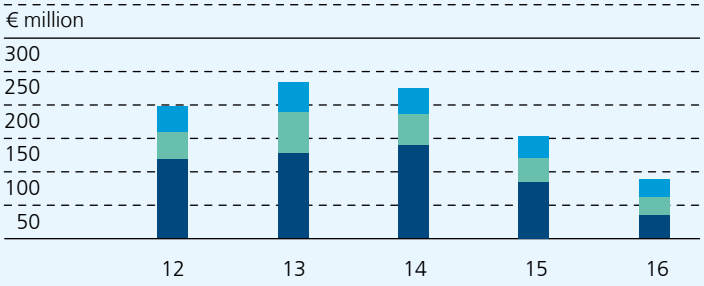
In Fraunhofer's financial statements, major infrastructure capital expenditure is an item that comprises all construction costs of Fraunhofer Institute buildings, together with the furnishings and scientific instruments needed to equip these newly constructed buildings. This item mainly comprises all major construction projects costing several million euros financed by means of special financing arrangements. This item also includes minor building projects that require an outlay of less than €1 million per project, and are financed using the base funding granted by the federal and state governments.

In 2016, Fraunhofer's major infrastructure capital expenditure totaled €88 million, which is significantly less than in previous years. The main reason for this decrease is that many major construction projects are still in the planning phase, and have only incurred planning costs so far. It is also a cyclical development due to the transition between ERDF (European Regional Development Fund) funding periods. Total expenditure on major construction projects amounted to €62 million, €36 million of which relates to building costs and the purchase of land, and €26 million to the initial equipment of new facilities. Expenditure on minor building projects totaled €26 million, which corresponds to just under one third of the organization's major infrastructure capital expenditure.

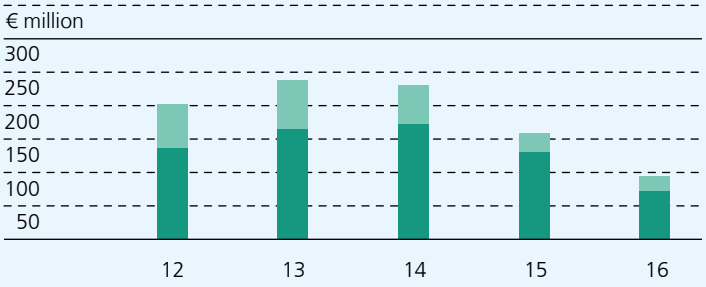
Major construction projects are financed on a 50:50 basis by the federal government and the state in which the facility is located. In many cases, the state obtains co-financing from the European Regional Development Fund (ERDF), reducing the share of costs borne by the federal and state governments. Minor building projects, on the other hand, are 90-percent funded by the federal government, with the state contributing the remaining 10 percent. Overall in 2016, the federal and state governments together provided around €73 million in funding for such projects. An additional amount of €15 million derived from the ERDF.

One major project for which the groundbreaking ceremony took place in 2016 is the construction of a new research building for the Fraunhofer Project Group Bioresources in Gießen. The costs amounting to €30 million are shared equally between the federal government and the state of Hesse. Of this sum, €6.5 million will be spent on initial laboratory equipment. Some 100 researchers from the Fraunhofer Institute for Molecular Biology and Applied Ecology IME will work here on the development of new active ingredients derived from insects, bacteria and fungi. The longer-term goal is to transform the project group into a full-fledged Fraunhofer Institute for Bioresources.

Major infrastructure capital expenditure and funding sources 2012–2016



	2012	2013	2014	2015	2016
Minor building projects [1]	38	45	38	32	26
Equipment of new facilities with scientific instruments and furniture	41	61	47	35	26
Purchase of land, construction of new buildings and extensions	120	129	141	86	36
= Total major infrastructure capital expenditure in € million	**199**	**235**	**226**	**153**	**88**

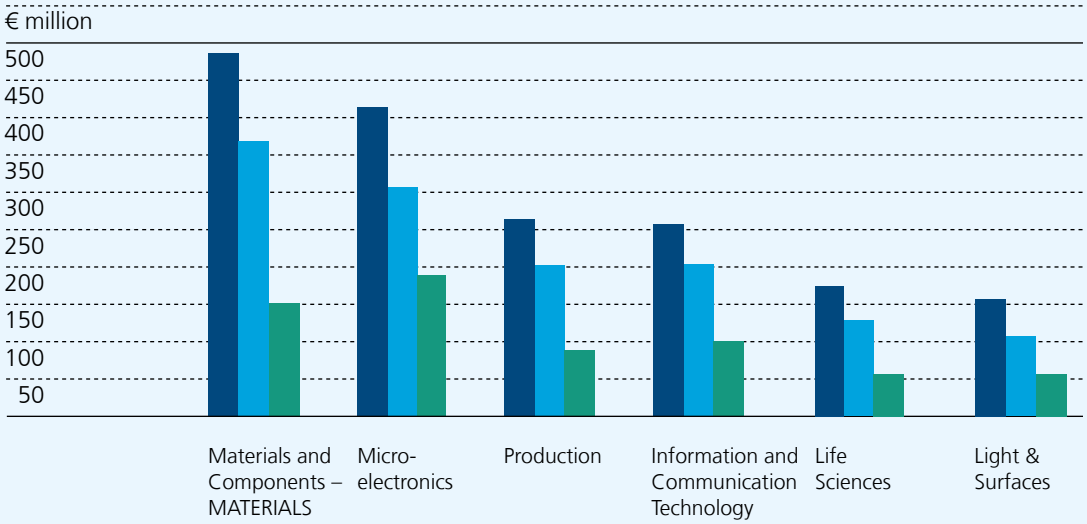


	2012	2013	2014	2015	2016
European Regional Development Fund (ERDF)	62	71	54	28	15
German federal and state governments [2]	137	164	172	125	73
= Funding of major infrastructure capital expenditure in € million	**199**	**235**	**226**	**153**	**88**

1 Small-scale construction, extension and renovation projects costing less than €1 million.

2 Incudes other sources of income, which in 2016 amounted to €1 million.

Expenditure and revenue of the Fraunhofer Groups in the contract research segment 2016



	Materials and Components – MATERIALS	Micro-electronics	Production	Information and Communication Technology	Life Sciences	Light & Surfaces
Budgeted expenditure in € million	**485**	**414**	**266**	**257**	**176**	**156**
Operating expenses	445	389	249	247	160	139
Capital expenditure	40	25	17	10	16	17
Project revenue in € million	**374**	**315**	**201**	**205**	**128**	**108**
Industrial revenue	152	191	91	101	56	57
Public-sector revenue [1]	222	124	110	104	72	51
Growth in %						
Budgeted expenditure	– 1	0	+5	+3	+4	+1
Project revenue	+3	+2	+12	+13	+5	+1
Industrial revenue	+6	– 1	+4	+21	+13	– 7
Public-sector revenue [1]	+1	+8	+19	+6	0	+11
Project funding ratio in % [2]						
All projects	84	81	81	83	80	78
Industrial funding	34	49	37	41	35	41
Public-sector funding	50	32	44	42	45	37

1 Public-sector revenue comprises funding granted by the German federal and state governments and the European Commission, and other revenue (research grants, other R&D, non-R&D).

2 Proportion of operating expenses covered by project revenue (excluding imputed depreciation of capital assets).

Fraunhofer Groups

Collaboration in groups based on related areas of expertise enables the Fraunhofer Institutes to develop cross-institutional research strategies and to coordinate the procurement and shared use of strategic items of equipment. It also enables the institutes to participate in Fraunhofer's overall policy-making processes through the intermediary of the group chairs, who hold seats on the Fraunhofer-Gesellschaft's Presidential Council. There are six Fraunhofer Groups comprising Fraunhofer Institutes and Research Institutions in the contract research segment, plus the Fraunhofer Group for Defense and Security VVS, in which the institutes funded by the German Federal Ministry of Defence (BMVg) have joined forces.

With budgeted expenditure of €485 million in 2016, the Fraunhofer Group for **Materials and Components – MATERIALS** is the largest group within the Fraunhofer-Gesellschaft in financial terms. It encompasses 15 institutes whose areas of expertise extend from developing new materials, improving the properties of existing materials, materials characterization and evaluating the behavior of materials under different conditions of use, to the development of production processes. This group's revenues increased by 3 percent in 2016 to €374 million, 84 percent of which were derived from external sources, thus propelling it into first place among the Fraunhofer Groups in terms of external funding ratio.

The Fraunhofer Group for **Microelectronics** consists of 11 member institutes that conduct cutting-edge research and develop application-oriented solutions in seven cross-institute technological core competences: design for smart systems, semiconductor-based technologies, sensors and sensor systems, power electronics and system technologies for energy supply, quality and reliability, system integration technologies, and RF and communication technologies. In 2016, this Fraunhofer Group's budgeted expenditure amounted to €414 million, close to the previous year's level. It is noteworthy that a major part, namely 49 percent, of the group's operating expenditure was covered by industrial revenue – the highest ratio of all the groups. Moreover, the group's public-sector revenue increased by 8 percent in 2016.

The Fraunhofer Group for **Production** combines the expertise of 9 Fraunhofer Institutes that specialize in the fields of product development, manufacturing technologies and systems, logistics, production processes and production workflow managment. Together they offer a range of services encompassing the entire product lifecycle and every link in the supply chain. Focal areas of the group's research include energy-saving and resource-conserving manufacturing technologies and efficient logistics design. In 2016, the group's budgeted expenditure increased by 5 percent to €266 million. This growth was supported by a rise of 19 percent in public-sector revenue, and of 4 percent in industrial revenue.

The Fraunhofer **ICT Group** combines the expertise of 17 Fraunhofer Institutes and Research Institutions that offer tailored IT solutions, professional technology consulting and pre-competitive research for new products and services in the business areas of digital media, e-commerce and e-government, information and communication technologies, energy and sustainability, medicine, production, security, financial services, and automotive manufacturing. Examples of the group's work include the development of imaging techniques for use in medicine and integrated software solutions for applications ranging from the interconnection of different media to the digitization of historic monuments. In 2016, the group's budgeted expenditure increased by 3 percent to €257 million. Its industrial revenue grew by 21 percent, the highest rate of all the groups. The industrial funding ratio reached a high 41 percent.

The Fraunhofer Group for **Life Sciences** pools the Fraunhofer-Gesellschaft's expertise in the biological sciences, biomedicine, pharmacology, toxicology, and food technology. The 7 member institutes of this group give their customers access to innovative

know-how in the fields of medical translational research, biomedical engineering, regenerative medicine, health-promoting foods, biotechnology, and safety issues pertaining to processes, chemicals and pesticides. In 2016, the group's budgeted expenditure increased by 4 percent to €176 million. Its industrial revenue grew by a substantial 13 percent, resulting in a funding ratio of 35 percent.

The 6 member institutes of the Fraunhofer Group for **Light & Surfaces** conduct research into the key enabling technologies of photonics and surface engineering. The group's core competencies include coating systems and functionalized surfaces, laser-based manufacturing processes, materials processing, optical measuring techniques, and the development of micro-optical and precision-engineered systems. Through this work, the group follows in the footsteps of the organization's founder, Joseph von Fraunhofer, who was the first scientist to measure the absorption lines in the solar spectrum, over 200 years ago. In 2016, the group's budgeted expenditure rose slightly to €156 million. Public-sector revenue grew by a substantial 11 percent to €51 million. Although industrial revenue was lower than in the previous year, it still represented a very high project funding ratio of 41 percent.

The Fraunhofer Group for **Defense and Security VVS** brings together the expertise of the 7 defense-related Fraunhofer Institutes and their respective civilian-sector contract research departments. Its research activities are mainly focused on the protection of people, enhancing the security of critical infrastructure, proactive crisis management, and monitoring risks to the civilian population and armed forces. In Germany, the group has established a strong reputation as a driver of innovation in all areas of defense and security research. The member institutes are also very active on a European level, and make use of their many networking contacts to carry out joint research activities. In 2016, the group's budgeted expenditure amounted to €223 million. Of this sum, €114 million relates to defense research and €109 million to contract research for civilian applications.

Financial position

- External sources of funding reach all-time high of over 74 percent
- Increased base funding stabilizes funding mix
- Wide variation in project funding by state governments

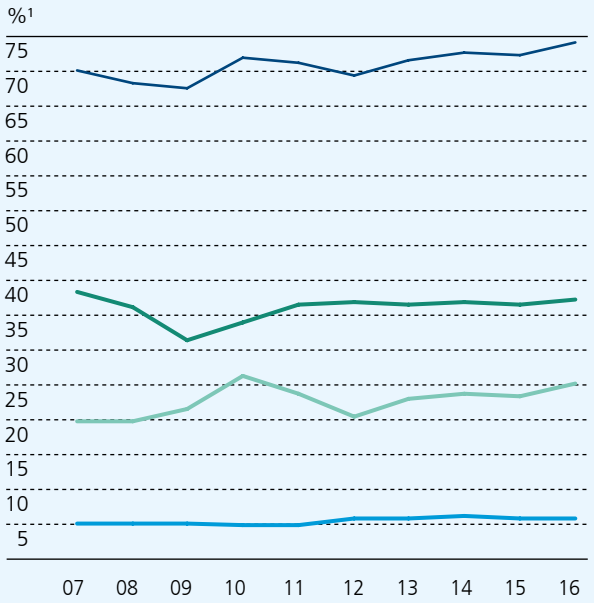
The Fraunhofer-Gesellschaft's funding rests on three pillars – base funding, revenue from contracts with industry, and revenue from public-sector project funding. According to the principles of the **Fraunhofer funding model**, each of these sources should account for roughly one third of total funding. The proportions of budgeted expenditure covered by industrial revenue and public-sector project funding respectively have grown significantly year on year, confirming that the Fraunhofer Institutes continue to play an important role in Germany's success as a driver of innovation.

At the reporting date for the financial year 2016, the proportion of project revenue from all sources relative to operating expenditure, including imputed depreciation of capital assets (excluding research institutions in the startup phase and change in reserves) amounted to an **all-time high** of 74.3 percent. Industrial revenue accounted for 37.4 percent of the funding required to cover Fraunhofer's operating expenditure. A further 25.1 percent was covered by project funding granted by the German federal and state governments. Project funding provided by the European Commission contributed an additional 5.8 percent, while the remaining 6.0 percent originated from diverse other sources.

However, these ratios also reflect a downward trend in the volume of research financed by means of the organization's base funding, which, despite the increases of recent years, has not grown at the same rate as project revenue. To correct this situation, at the end of 2016, the federal government decided to **increase base funding** for Fraunhofer by €60 million, out of its own budget. The state governments have agreed to contribute to this increase in a ratio of 90:10. This measure returns Fraunhofer's mix of funding sources to a stable footing.

Public-sector funding of research projects is subject to the German Federal Budgetary Regulations and equivalent regulations in the individual states. Additional regulations on the part of the European Union may also apply if EU funds are used for refinancing. The EU regulations make provision for the flat-rate reimbursement of costs in cases where the full-cost model is not applicable. As a publicly funded research organization, Fraunhofer's mandate includes the duty to utilize part of the funds it receives to develop new areas of strategic interest through pre-competitive research. Inadequate funding quotas, funding that only partially covers the costs incurred, and insufficiently high flat-rate reimbursement of personnel costs and overheads makes this difficult to achieve, because this ties up resources from base funding that could otherwise be used to finance pre-competitive research. In the case of projects funded by the German Federal Ministry of Education and Research (BMBF), there are binding rules for determining funding quotas. These generally provide for the application of the full-cost model when allocating project funding to Fraunhofer, thus making it unnecessary to appropriate a portion of the organization's base funding. In Fraunhofer's opinion this practice, which also applies to collaborative projects involving industrial partners, has proved to be expedient. In view of the limited availability of base funding and in keeping with the underlying principles of the Fraunhofer model, this practice urgently needs to be extended to research programs funded by other federal ministries that meet the relevant criteria.

External sources of funding in the contract research segment 2006 – 2016 [1]



- Project funding (total) [2]
  74.3% (2015: 72.5%)
- Industrial funding (contract research)
  37.4% (2015: 36.5%)
- Project funding granted
  by the German federal and state governments
  25.1% (2015: 23.4%)
- Project funding granted by the European Commission
  5.8% (2015: 5.9%)

1 As a percentage of the operating budget including imputed depreciation of capital assets (excluding research institutions in the setup phase and change in reserves).

2 Includes other sources, which account for 6.0 percent of total project funding (2015: 6.7 percent).

The allocation of project funding by the state governments is similarly disparate, due to the varying legal and financial conditions that apply in different states. These differences are particularly marked in cases where such funding is refinanced by the European Regional Development Fund (ERDF) or the European Social Fund (ESF). The provisions of state aid rules for the current ERDF funding period (2014–2020) range from flat-rate costing, which is insufficient to cover actual costs, to recognition of the full-cost model, which covers all or most of the costs incurred by Fraunhofer. As a result, actual funding quotas diverge substantially, and average well under 100 percent. In view of the present public-funding objectives and budgetary constraints, the framework for project funding by the state governments needs to be harmonized across the board to enable wider use of the full-cost model. The rules governing the use of structural funds already permit this approach in cases where EU funds are utilized for refinancing. It is imperative that base funding should be reserved exclusively for the financing of in-house pre-competitive research, so as to allow the Fraunhofer-Gesellschaft to continue enhancing its innovative strength and thereby help secure Germany's economic growth and prosperity.

Net asset position

- Total assets approaching €3 billion
- Structure of assets dominated by property, plant and equipment (64 percent)

The Fraunhofer-Gesellschaft's total assets at the reporting date of December 31, 2016 amounted to €2952 million, or 3 percent above the previous year's level. Fixed assets decreased by 3 percent to €1931 million. Of this sum, €1898 million related to property, plant and equipment, which represents 64 percent of total assets and was thus the predominant item on the assets side of the Fraunhofer-Gesellschaft's balance sheet. Intangible assets amounted to €11 million and financial assets to €22 million.

Current assets increased by 19 percent to €1006 million. This item includes inventories amounting to €31 million, net of advance payments received. The total amount of receivables and other assets was €592 million. The present value of future payments relating to the sale of patent rights, amounting to €78 million, was recognized in a special reserve.

Marketable securities increased by €68 million to €299 million. In 2016 as in previous years, the Fraunhofer Fund's available assets were invested in a widely diversified portfolio consisting of money-market instruments, bonds, multi-asset funds, stock-market shares, commodities, and shares of equity in renewable-energy companies. In view of the uncertain market situation, the Fraunhofer Fund applied a risk-adjusted model in its asset allocation policy, with the Fund steering and proactively containing its investment risks through dynamic and systematic management of the allocations to the individual segments and through risk overlay with threshold control. Cash and cash equivalents, including the balance available on the Fraunhofer-Gesellschaft's checking accounts, increased by

€31 million to €84 million. At the end of 2016, steps were taken to reorient the management of the Fraunhofer Fund toward a more passive investment strategy in which its assets were gradually reallocated to exchange-traded funds based on index-linked stocks and bonds and near-money-market funds. This passive investment strategy is seen as a temporary solution.

Prepaid expenses and deferred charges, which mainly relate to prepaid rent, maintenance contracts, and other services, amounted to €15 million.

Total equity rose slightly compared with the previous year and amounted to over €16 million at the reporting date. In addition to an amount of €15 million carried forward, the capital of the non-profit organization also includes €1 million recognized as a restricted reserve. The non-profit organization's capital is that portion of the Fraunhofer-Gesellschaft's assets that has not been acquired out of public funds.

For the purposes of asset management, equity is also deemed to include the special reserves for license-fee revenue and for grants relating to fixed assets in addition to the capital of the non-profit organization and the restricted reserve. The special reserve for license-fee revenue increased by €41 million in 2016 and amounted to €299 million at the reporting date. This net increase represents the difference between the amount of €8 million that was utilized and the amount of nearly €49 million that was transferred to this reserve. Funds received for the purpose of acquiring or constructing fixed assets are transferred to the special reserve for grants relating to fixed assets, which is reduced each year by an amount corresponding to the annual depreciation expense on the assets in question. The carrying amount of this special reserve decreased by €64 million to €1915 million in 2016.

The special reserve for funds used to finance current assets is used to account for income not yet received less expenses not yet paid at the reporting date. In 2016, this reconciliation item amounted to €236 million, which is on a level with prepaid expenses. The special reserve created to account for the present value of future payments from the sale of patent rights amounted to €78 million.

Provisions for pensions and similar obligations amounted to €9 million. The pension provisions are measured using the capitalized value of the pension obligations at the reporting date as calculated by the reinsurer. Other provisions increased by €6 million to €143 million. With the exception of provisions for compensated leave, the change in other provisions had no impact on the funding situation due to the simultaneous change in the special reserve for grants used to finance current assets. In the case of pension and compensated leave provisions, corresponding balancing amounts are entered on the assets side of the balance sheet.

In 2016, total current liabilities increased by €74 million to €251 million. This item included €155 million in unappropriated grants from the federal and state governments, €84 million in trade payables, and close to €12 million in other current liabilities.

Deferred income amounted to €4 million and relates primarily to lump-sum license-fee payments received for mp3 technology before the reporting date that are not yet recognized as revenue.

Equity investments, subsidiaries and spin-offs

- Shareholdings in a total of 84 companies
- Considerable activity in investment portfolio
- 41 new spin-off projects supported in 2016

At the reporting date, the Fraunhofer-Gesellschaft held equity investments in a total of 84 companies operating in a wide range of market sectors. Technology transfer to industry was the main reason for Fraunhofer's investment in 61 of these companies, while the remaining 23 were of a strategic nature. There was considerable activity in Fraunhofer's investment portfolio in 2016. Overall, some €1.6 million was used to acquire equity interests in private companies. The Fraunhofer-Gesellschaft added 7 companies to its investment portfolio and divested its shares in 8 companies. The **total carrying amount of all equity investments** at the reporting date was €9.7 million or almost unchanged compared with the previous year. The proceeds from the disposal of equity investments in 2016 amounted to €12.3 million.

Fraunhofer manages and operates its R&D activities outside Germany through the intermediary of four **international subsidiaries** as well as two foundations and one non-profit association, which in turn run their own research units.

Established in 1994, **Fraunhofer USA, Inc.** is a wholly owned, not-for-profit subsidiary of the Fraunhofer-Gesellschaft headquartered in Plymouth, Michigan. Under the auspices of Fraunhofer USA, seven Fraunhofer Centers conduct research on behalf of industrial clients, public-sector organizations and academic institutions. In addition, Fraunhofer USA hosts the American marketing activities of one Fraunhofer Institute. Based on provisional data, the budgeted expenditure of Fraunhofer USA in 2016 amounted to the equivalent of around €37 million, while its project revenues generated by contracts with third parties, translated into euros, totaled €19 million. With U.S.-dollar revenues equivalent to €5 million, the Center for Molecular Biotechnology CMB was once again the best-performing Fraunhofer Center in the United States.

Fraunhofer's Austrian subsidiary, **Fraunhofer Austria Research GmbH**, started operating from its headquarters in Vienna in 2009. The Fraunhofer-Gesellschaft is the sole owner of this not-for-profit, limited-liability company. The legal entity Fraunhofer Austria covers the activities of two Fraunhofer Institutes at two locations in Austria: the Production Management and Logistics unit in Vienna and the Visual Computing unit in Graz. Based on the available provisional data, Fraunhofer Austria's operating budget in 2016 amounted to €4 million and its project revenue from contracts with third parties totaled €2.5 million.

Together with the Trade Association of South Tyrol, Fraunhofer established the not-for-profit subsidiary **Fraunhofer Italia Research Konsortial-GmbH** with headquarters in Bolzano in 2009. The Fraunhofer-Gesellschaft holds 99 percent of the shares in this entity that represents the legal interests of present and future Fraunhofer Centers operating in Italy, such as the Fraunhofer Innovation Engineering Center IEC in Bolzano, which receives base funding from the Independent Province of Bolzano in South Tyrol. Under the terms of the province's current research funding program for the period from 2015 to 2018, the center can expect to receive a total of around €4.9 million in base funding from this source. According to the latest projections, Fraunhofer Italia had an operating budget of €1.2 million in 2016, of which approximately €0.5 million was covered by project revenue.

Fraunhofer UK Research Ltd., a wholly owned subsidiary of the Fraunhofer-Gesellschaft with headquarters in Glasgow, Scotland, was established in 2012. It jointly manages the Fraunhofer Centre for Applied Photonics CAP in a collaborative venture between the Fraunhofer Institute for Applied Solid State Physics IAF in Freiburg, Germany, and the University of Strathclyde in Glasgow. According to the preliminary data

for 2016, Fraunhofer UK's operating budget (translated from pounds sterling into euros) amounted to €2.7 million, of which €1.3 million was covered by project revenue from contracts with third parties.

Domiciled in Santiago de Chile, the **Fundación Fraunhofer Chile Research** was set up in 2010 with the legal status of a not-for-profit foundation, wholly owned by the Fraunhofer-Gesellschaft. The foundation currently operates two research centers. Based on provisional data and translated into euros, Fraunhofer Chile's operating expenditure in 2016 amounted to €5.0 million and revenue from its projects with third parties was just under €0.9 million. A restructuring process was launched in 2016 to redefine the focus of Fraunhofer Chile's research activities.

Associação Fraunhofer Portugal Research is based in Porto and was created in 2008 as a not-for-profit organization under Portuguese law as a collaborative venture between the German and Portuguese chambers of commerce. The Fraunhofer Portugal Research Center for Assistive Information and Communication Solutions AICOS currently operates under the umbrella of this association. According to its provisional financial statements, Fraunhofer Portugal generated project revenues with third parties of €1.4 million in 2016 and its budgeted expenditure amounted to €2.7 million.

In Sweden, **the Stiftelsen Fraunhofer Chalmers Centrum för Industrimatematik** was founded in 2001 as a not-for-profit foundation under Swedish law. The Fraunhofer-Gesellschaft and Chalmers University in Gothenburg have equal voting rights on the foundation's board of trustees. The foundation manages the activities of the Fraunhofer-Chalmers Research Centre for Industrial Mathematics FCC, which was established in collaboration with the Fraunhofer Institute for Industrial Mathematics ITWM in Kaiserslautern, Germany. According to the provisional financial data for 2016, translated from Swedish krona into euros, the subsidiary generated project revenues of €3.5 million from contracts with third parties, and its research budget amounted to €5.0 million.

Fraunhofer has only one subsidiary in Germany: **PIA gGmbH**. A new consumer protection law introduced at the beginning of 2017 requires insurance providers to inform clients of the risks associated with their pension plans in a standardized format that facilitates comparison with similar products. PIA was created in 2015 as a not-for-profit limited-liability company with the registered name "Produktinformationsstelle Altersvorsorge gemeinnützige GmbH", based in Kaiserslautern and wholly owned by the Fraunhofer-Gesellschaft. Its purpose is to serve as an independent evaluator of pension insurance products (risk-benefit analysis), working under contract to the German Federal Ministry of Finance (BMF). According to the provisional financial data, PIA generated revenues of €1.0 million in 2016.

In addition to its subsidiaries, the Fraunhofer-Gesellschaft's equity interests also include spin-offs created by former Fraunhofer employees, in which it frequently acquires a minority shareholding for numerous different reasons.

Spin-offs play a very important role as an avenue through which Fraunhofer can capitalize on its intellectual property rights. The Fraunhofer Venture department typically provides support to the founders of spin-off companies during the early stages of the creation process; in certain cases, Fraunhofer enters into a technology transfer agreement with the new company in return for a consideration in the form of a minority share in the company's equity. As well as generating returns from the transfer of technology, spin-offs also help promote entrepreneurial thinking and the establishment of cooperative networks with businesses operating in the same spheres as the Fraunhofer-Gesellschaft. Moreover, spin-offs are of great benefit to the national economy because they lead to the creation of new jobs and give industry a stronger competitive edge through product innovation. In 2016, Fraunhofer Venture

provided support to 41 new spin-off projects, and 22 new businesses were established as spin-offs from the Fraunhofer-Gesellschaft.

Under the framework of the "FFE – Fraunhofer Fosters Entrepreneurship" program, Fraunhofer granted funds totaling €0.5 million to ten spin-off projects in 2016. Under a parallel initiative, the "FFM – Fraunhofer Fosters Management" program, seven startups in which the Fraunhofer-Gesellschaft holds an equity interest received financial support totaling €0.3 million in 2016. The aim of this program is to enable the executives of these companies to improve their management skills.

Overall, the Fraunhofer-Gesellschaft expects the positive trend in its spin-off activities to continue in the medium term. A new proactive approach is offered by the latest program: "FDays", part of the "Fraunhofer Fosters Intrapreneurship" program. With its focus on business design and reducing critical uncertainties, this program aims to empower selected groups of Fraunhofer intrapreneurs by systematically breaking down preconceived ideas in order to accelerate startup activities. In 2015, an additional, financial, incentive was introduced in the form of a spin-off award for institutes that take the bold step of choosing this technology transfer route despite the uncertainties with which it is often associated. A second round of awards was offered in 2016.

International activities of the German Fraunhofer Institutes

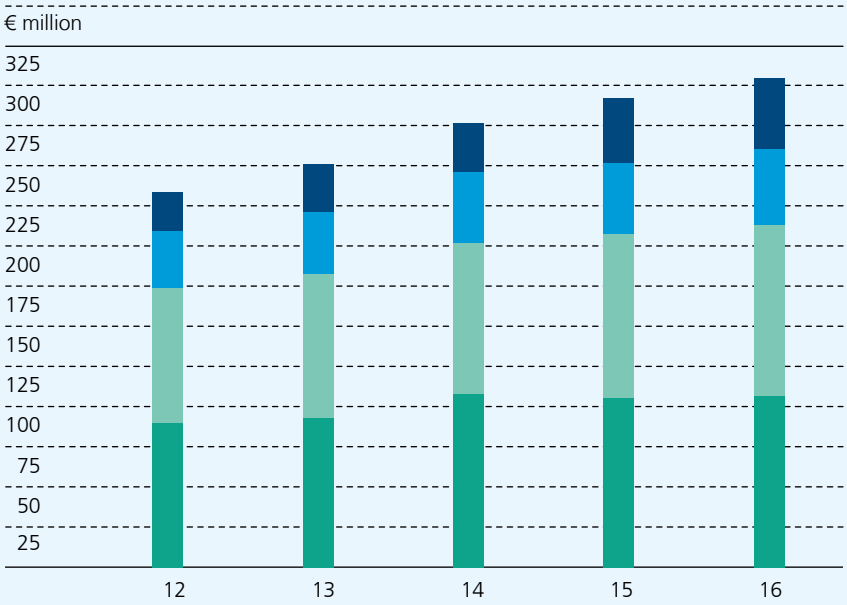
– International revenue continues to grow
– Creation of new strategic partnerships

Fraunhofer's internationalization strategy is based on the principle of creating scientific value for Fraunhofer while generating positive effects both for Germany and for the partner country concerned. Working in collaboration with the world's best in every field enables Fraunhofer to develop future-proof solutions and innovative responses to global challenges. In the past two decades, Fraunhofer has built up a strong reputation as a highly sought-after partner in the competitive international research marketplace.

In 2016, **revenue generated from projects with international partners** increased by 5 percent to a total of €304 million (excluding license-fee revenue). This sum includes €275 million in revenue generated by the Fraunhofer Institutes through contract research in the international market, plus €29 million generated by the organization's foreign subsidiaries through contracts with third parties.

International revenue generated in Europe increased in 2016 by 3 percent to a total of €212 million. The proportion of this revenue originating from **European customers** outside Germany amounted to €106 million, which represents an increase of 5 percent. Switzerland is the most important European market for Fraunhofer, contributing €22 million to Fraunhofer's revenues, followed by Austria with €16 million and France with €9 million. These industrial revenues are complemented by public-sector project funding, one of the major sources of which is the **European Commission**. In 2016, revenue from EU project funding amounted to €106 million, which is on a

Revenue from work with international customers and partners 2012–2016



	2012	2013	2014	2015	2016
Asia	24	29	30	40	44
North and South America	35	38	44	44	47
European countries	84	90	94	101	106
EU revenue (European Commission)	88	92	106	105	106
Other countries	2	1	2	1	1
= Total international revenue[1] in € million	**233**	**250**	**276**	**291**	**304**

1 Includes revenue generated by international subsidiaries with third parties, which amounted to €29 million in 2016.

par with the previous year's level. According to the European Research Ranking, which is based on statistics gathered by the European Commission, Fraunhofer has been the best-performing German organization every year since 2007 in the categories "Funding & Projects," "Networking" and "Diversity."

The Powertrain Manufacturing for Heavy Vehicles Application Lab opened in Stockholm in the fall of 2016, with the dual mandate of developing new powertrain manufacturing technologies for trucks and utility vehicles and providing engineering students and professional engineers with training opportunities leading to high-level qualifications. The founding members of the consortium formed to manage the new facility comprise three Fraunhofer Institutes, the Fraunhofer-Chalmers Research Centre for Industrial Mathematics FCC, Chalmers University of Technology in Gothenburg, the Royal Institute of Technology in Stockholm, two institutes belonging to the RISE (Research Institutes of Sweden) network, and three Swedish industrial companies.

At the end of 2016, the Fraunhofer Institute for Production Technology IPT and Dublin City University (DCU) entered into a long-term collaborative research agreement focusing on lab-on-a-chip technology and bioanalytical systems. A new R&D department will be established at the Irish university, named the Fraunhofer Project Centre for Embedded Bioanalytical Systems. By combining Fraunhofer's expertise in production technology with new, mobile bioanalytical methods, the two partners aim to address customers' needs by exploring new areas of application.

In 2016, Fraunhofer's revenue from projects in **North and South America** amounted to €47 million, which is 7 percent higher than in the previous year. The United States accounted for €41 million of this total, €19 million of which was generated by the organization's North American subsidiary Fraunhofer USA, Inc. Fraunhofer's most important market in South America is Brazil, which claimed second place with revenues of €2.0 million in 2016.

The Fraunhofer Institute for Chemical Technology ICT and the University of Western Ontario agreed in 2016 to continue operating the Fraunhofer Project Centre for Composites Research in Canada for an additional five years. This collaborative venture was launched in 2011, and has since grown into the most advanced research center for lightweight construction methods in North America. Its services are also solicited and appreciated by companies in Germany and other European countries.

Fraunhofer's revenues in **Asia** grew by 10 percent in 2016 to a total of €44 million. Japan and China were by far the strongest Asian markets, generating revenues of €16 million and €14 million respectively, followed by South Korea in third place with €4 million. Revenue from the countries of the Middle East totaled €4 million in 2016.

The Fraunhofer Project Center for Composites Research, based at the Ulsan National Institute of Science and Technology (UNIST) in South Korea, was established in 2016 by the Fraunhofer Institute for Chemical Technology ICT. The focal areas of the project center's research activities are machining processes for fiber-composite materials, new materials solutions, and the scaling-up of lightweight construction methods to high-volume industrial production. UNIST is a relatively young university, but it is already recognized as a leading light in the field of materials science. This collaborative venture in South Korea has enabled Fraunhofer ICT to gain access to a valuable source of innovation in the growing Asian automotive industry.

Intellectual property activities

- More than three invention disclosures per working day
- More than two patent applications every working day
- Fraunhofer again among the Top 100 Global Innovators

In 2016, Fraunhofer reaffirmed its **position as the top German research organization** in terms of number of inventions, patent applications, and ownership of industrial property rights. Even when compared with the performance of industrial research departments, Fraunhofer's output is outstanding. For ten successive years, Fraunhofer has ranked among the German Patent and Trade Mark Office's 10 to 20 most prolific patent applicants, and has consistently held positions ranging between 5th and 10th in the register of trade marks. Similar statistics compiled by the European Patent Office (EPO) have placed Fraunhofer among the most active patent applicants for many years: in 2016 Fraunhofer ranked 45th.

Fraunhofer employees submitted 798 invention disclosure reports in 2016 – more than in any previous year. Of these, **608 were filed with the relevant patent offices as patent applications claiming rights of priority**, which corresponds to a rate of more than two patents filed per working day. After a slight decrease in 2015, Fraunhofer's portfolio of active patents and utility models and pending patent applications rose again in 2016 to 6762 patent families. The total number of newly registered German patents granted to Fraunhofer increased to 3114. Fraunhofer signed 401 new licensing agreements in 2016, raising the total number of active licensing agreements to 3210. License-fee revenue increased by 4 percent compared with the previous year, to €143 million.

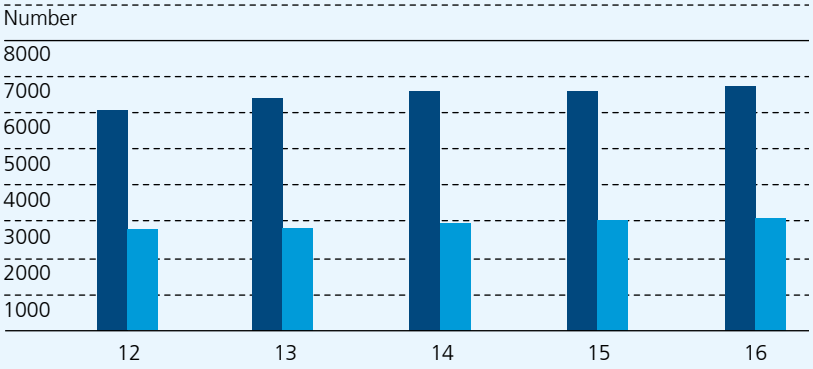
In 2016, as a result of this performance, Fraunhofer ranked among the **Top 100 Global Innovators** for the fourth successive year. This award is presented annually by the Thomson Reuters media group to companies and organizations on the basis of the number and quality of patented inventions. In 2016, apart from Fraunhofer, three German industrial companies featured among the Top 100. So far, Fraunhofer is the only German laureate to have won this award four times in succession.

To guarantee a continuous flow of revenue from the exploitation of intellectual property rights, patents owned by different institutes are increasingly being grouped together in application-specific portfolios to create offers for selected companies. This approach creates new opportunities for generating income from licensing agreements and R&D projects. In 2016, targeted **IP portfolios** were put together for thematic areas such as "glass," "bionics," "smart home" and "e-health," each comprising relevant patent families stemming from the work of multiple institutes. This was preceded by an evaluation of the earnings potential of the technologies concerned and the possible volume of contracts.

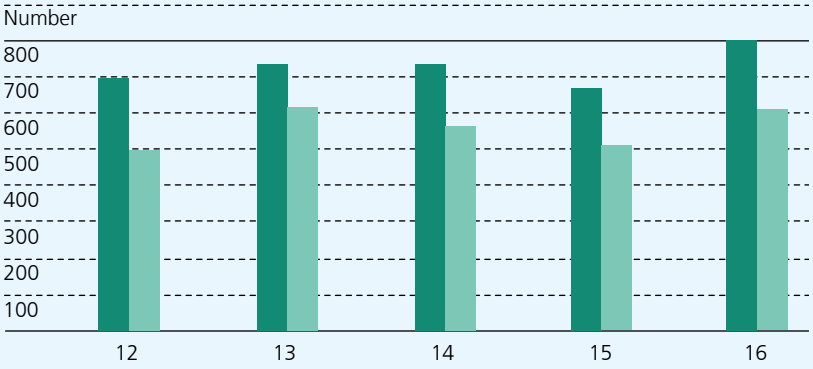
There is much to be said for an IP exploitation strategy extending beyond Europe, in selected areas of technology. Fraunhofer has already built up useful long-term relationships with **commercialization partners** in the U.S. and Asian markets. To cite a few examples, in 2016 such partnerships resulted in 2 patent sale agreements, 4 prosecutions for IP law infringements, and 5 active licensing agreements. In addition to the increased project income, such activities offer further benefits in the form of access to local networks, market intelligence, and a better understanding of national legal systems.

The Fraunhofer-Zukunftsstiftung (Fraunhofer Future Foundation) is another instrument that promotes the commercialization of Fraunhofer technologies, in this instance by providing funding for in-house research projects that it has identified as being crucial to future market demand. This creates a fast track to implementation of the research findings in commercial applications through licensing agreements with high-tech companies. In some cases, startups are formed specifically for this purpose.

Invention disclosures and patent applications by the Fraunhofer-Gesellschaft 2012–2016



	2012	2013	2014	2015	2016
Active invention disclosures[1]	6103	6407	6625	6573	6762
of which patents valid in Germany	2794	2847	2955	3001	3114



	2012	2013	2014	2015	2016
Invention disclosure reports per year	696	733	736	670	798
Patent applications per year	499	616	563	506	608

1 Portfolio of active patents and utility models and pending patent applications at year end.

EMPLOYEES

Overview

- Number of employees increased by nearly 400
- High employer attractiveness rating
- Wide-ranging support for future specialists in the STEM fields
- Excellent career prospects with Fraunhofer

At December 31, 2016, Fraunhofer had 24,458 employees, most of whom hold degrees in the natural sciences or an engineering discipline. This represents an increase of nearly 400 employees or 1.6 percent of the workforce compared with the previous year.

Employer branding surveys are an important source of feedback from the labor market. Fraunhofer's excellent ranking in surveys conducted by independent agencies testify to the research organization's positive image. For example, in the results of the Universum survey published in September 2016, Fraunhofer improved its ranking in many relevant fields of study. Most notably, Fraunhofer is consistently rated as one of the 3 most attractive employers in Germany for students of the natural sciences.

In addition to interesting research topics, a high degree of personal responsibility, and an excellent research infrastructure, an increasingly important factor in the evaluation of an employer's attractiveness is **work-life balance**. In the 2016 Glassdoor study, Fraunhofer was in the top three for work-life balance, ahead of major industrial players such as Bosch, BMW and SAP. The parenting magazine "Eltern" and the statistics platform "Statista" both rated Fraunhofer among the best family-oriented employers in 2016. In these surveys, Fraunhofer excelled in the category of "HR services, advice, local agencies, and science and engineering."

Fraunhofer's attractiveness as an employer was also confirmed in 2016 by the significantly higher number of people enrolled in its dual study and professional **training programs**.

At December 31, 2016, 472 trainees were receiving education at Fraunhofer, including more young women than ever before, namely 37 percent. Given that Fraunhofer's training programs are designed to cover the research organization's own needs, it is a positive point that candidates were found to occupy almost all training positions, despite there being fewer applicants in 2016. Another positive trend is that more and more trainees stay with the Fraunhofer Institute in which they trained after graduation. Even students who choose to prolong their education often remain attached to "their" institute by working there as an intern.

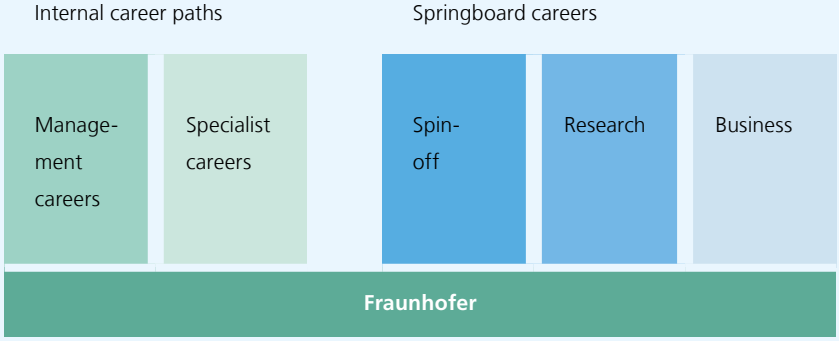
To encourage young people **to take an interest in the STEM fields** (science, technology, engineering and mathematics), Fraunhofer offers numerous programs adapted to the learning capacity of all different age groups – starting with "kids kreativ!" for pre-school children and extending to mentoring programs for university students. These programs continued to produce successful results in 2016. For example, nearly 2400 young people have attended Fraunhofer Talent School events since the program was inaugurated in 2006, and the "Talent Take Off" (TTO) study orientation program signed up its eight-hundredth participant in 2016. The latter is a joint Fraunhofer/ Femtec program consisting of three modules, "Getting started," "Getting going" and "Networking," which provide participants with support at different stages of higher education, from choosing a degree course and study orientation to research options. Fifty percent of the participants in this program are women.

These organization-wide programs are supplemented by initiatives and programs managed by individual Fraunhofer Institutes. One outstanding example is the **Roberta** – Learning with Robots initiative launched by the Fraunhofer Institute for Intelligent Analysis and Information Systems IAIS 14 years ago. In 2016, these activities were expanded to facilitate the access to "STEM coding" thanks to Google's support, which enabled the creation of the free, cloud-based platform "Open Roberta Lab." Through this new initiative, Fraunhofer IAIS intends to make its programming environment available to all German schools and other places of learning to help youngsters develop their digital skills.

Education in the STEM fields for all age groups, from kindergarten to university

Pre-school ▼	kids kreativ! competition		myTalent portal
Elementary school ▼	Explorer Campus online game Romy, Julian und der Superverstärker (Romy, Julian and the super amplifier) / book Forsche(r) Kids / teaching material		
Junior high school ▼	Junior Academy Junior Engineering Academy Girls' Day	Jugend forscht / national youth science competition BoGy / BoRs / career guidance	
Senior high school ▼	Fraunhofer Talent School Europäische Talent Academy	Jugend forscht / national youth science competition Fraunhofer MINT-EC program for STEM talent	
▼	Talent Take Off modules I–III		
University ▼	Science campus (national / international)		
	Hiwi Day for student assistants		

Careers with Fraunhofer



"Our employees shape the future – in ambitious positions at Fraunhofer or in other areas of science and business. Fraunhofer therefore places great importance on their professional and personal development."

As underlined by this extract from the re-edited 2016 version of the Guiding Principles of the Fraunhofer-Gesellschaft, time spent at Fraunhofer is often seen as a **springboard** to achieving personal career ambitions. Each year, some 10 percent of Fraunhofer employees leave the organization to pursue their career path in business, with another research organization or in a company spun off from one of the Fraunhofer Institutes. The career system at Fraunhofer was modified in 2016 to give employees who wish to advance their career with Fraunhofer the option of choosing between the traditional route leading to a purely management position and one that allows them to obtain an equivalent status as a specialist. This alternative career path has already been introduced by some Fraunhofer Institutes.

A motivated and healthy workforce is an important factor in Fraunhofer's success. Fraunhofer's concept of **health management** is that minimizing physical and mental stress liberates resources that improve both operational and individual performance. The four relevant action areas defined by Fraunhofer are:

- Corporate culture and management
- Workplace design
- Occupational health and protection
- Individual training and learning

In each of these areas, Fraunhofer aims to develop organization-wide measures and concepts to support the health of its employees. Fraunhofer has revised its leadership principles to include responsibility for employees' health and wellbeing. A supplementary set of guidelines devised by in-house and independent experts to evaluate stress-related health risks was distributed to the Fraunhofer Institutes in 2016.

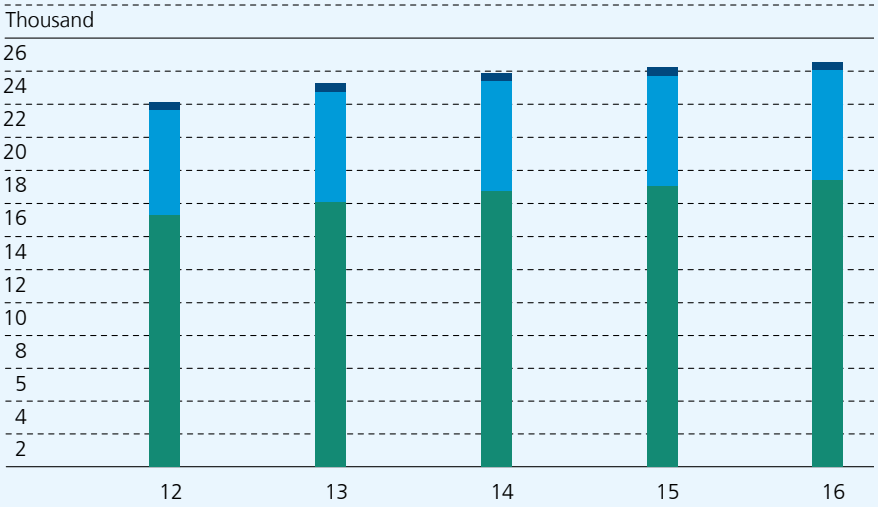
Equal career opportunities for men and women

- Gender equality is an important goal of Fraunhofer's diversity management strategy
- Focus on overcoming unconscious bias

Fraunhofer adheres to the important goal of encouraging more women to take up a career in applied research. The organization has set itself clearly defined targets to increase the proportion of women at all levels of the hierarchy, and even more so in management, in accordance with the principles of the so-called cascade model. The organization-wide **TALENTA career development program** helps the Fraunhofer Institutes to provide the necessary ongoing career support to women scientists.

The data collected during the 2015 Fraunhofer-wide employee survey were analyzed to find out how scientists perceive Fraunhofer's performance as an **equal opportunities** employer. The focus lay on perceived employer attractiveness and the factors that influence the employment experience while working for Fraunhofer. The results with respect to attracting and retaining female scientists suggest that most of the criteria used to judge perceived employer attractiveness are unrelated to gender or family situation. Men and women alike identified support with career planning and professional development as the most important areas for improvement.

Growth in the Fraunhofer-Gesellschaft's workforce 2012–2016



	2012	2013	2014	2015	2016
Trainees	470	494	480	452	472
Graduate, undergraduate and school students	6403	6694	6619	6554	6654
Scientific, technical and administrative personnel	15220	16048	16687	17078	17332
= Total number of employees	**22093**	**23236**	**23786**	**24084**	**24458**

Nonetheless, there are still areas in which cultural change can contribute to a more equitable experience with respect to career opportunities. Since 2016, Fraunhofer's diversity management strategy has given greater emphasis to the cultural and organizational effects of **"unconscious bias,"** which arise from ingrained thinking habits, distorted views of reality, and outdated role models. As well as developing gender-neutral guidelines for recruitment and employee assessment, Fraunhofer also applies gender-specific criteria in its evaluations to reveal possible inequalities in these areas and in the distribution of short-term contracts and bonus payments. Fraunhofer is currently developing an in-house training and awareness plan to deal with the question of unconscious bias. It includes setting up a dedicated information platform in the Fraunhofer intranet and designing new modules for incorporation in Fraunhofer's in-house management training program, such an online training application developed in collaboration with the "Chefsache" management responsibility initiative (initiative-chefsache.de).

International orientation

- Application pending for EU "HR Excellence in Research" logo award
- Internationally oriented HR strategy

Fraunhofer signed the **European Charter for Researchers and Code of Conduct for the Recruitment of Researchers** in 2013, thereby publicly endorsing this initiative. Fraunhofer has implemented the Charter's recommendations for many years.

In 2016, Fraunhofer was the one of the first non-university research institutions to apply for the European **HR Excellence in Research** Award and for the right to use the HRS4R logo, which constitutes public recognition of the quality of an organization's HR services on a European level. The award is based on a self-appraisal of the applicant's compliance with and implementation of the HR Strategy for Researchers. An independent evaluation is carried out by the European Commission four years at most after the award of the HRS4R logo.

Last but not least, the **international dimension** of Fraunhofer's activities serves as the ideal proving ground for scientists with high professional ambitions in the global market for research and related business services. The increasing number of bilateral and multilateral international projects, i.e. in collaboration with a single customer or in the context of EU funding programs, gives Fraunhofer employees the opportunity to gather in-depth experience of working together with partners in other countries and enhance their knowledge of international markets.

RISK SITUATION AND OUTLOOK

Risk management and identified risks

- Continuous monitoring of risk exposure
- No anomalies in the overall risk situation

In carrying out its applied research, Fraunhofer takes calculated risks in order to transform original ideas into innovations that benefit society and strengthen both the German and the European economy. Fraunhofer understands **"risk"** to mean all internal and external events and developments that might jeopardize the organization's success. These include both risks that can be given a monetary value and those of a qualitative nature.

The **risk management system** is designed to identify existing and potential risks at an early stage and to manage them in such a way that they either do not materialize at all or have no consequences that could jeopardize Fraunhofer's ability to fulfill its mission as defined in its statutes or prevent it from meeting its business objectives. The central departments inform the Executive Board of relevant risk-related developments – both routinely and on an ad-hoc basis – via the established reporting channels.

Once a year, Fraunhofer asks its **risk assessment experts** to carry out a systematic review of the risk situation. The results are summarized and prioritized in a separately prepared risk report. For the purposes of risk reporting in the context of this annual survey, individual risks are classified according to the four categories of most interest to Fraunhofer, namely business model, financing, resources, and business operations. The risk management structures and processes are set down in the Fraunhofer-Gesellschaft's risk management manual.

Business model risk encompasses those types of risk that represent a threat to the continuation and evolution of the Fraunhofer funding model. Such risks may arise from external sources or from internal differences in the way the Fraunhofer model is applied.

As a not-for-profit organization and beneficiary of public funds, Fraunhofer keeps a close eye on **changes in legislation and taxation** that might affect its access to financial support and continuously evaluates these changes with respect to their possible impact on the financing of its activities. Fraunhofer maintains an ongoing dialog with the funding agencies at federal, state and EU level and, if necessary, makes the appropriate amendments to its funding model to ensure that it remains in conformity with current funding legislation. The construction of a plastics manufacturing pilot plant in Bayreuth is a special case not covered by the usual funding rules, because a not insignificant part of the facility is leased out to an industrial customer. In consultation with the public funding agencies, agreement was reached in 2016 on a solution that allows the project to be implemented within the statutory framework for government grants and assistance.

Established strategy planning processes permit constant feedback from relevant market players in Germany, Europe and worldwide as well as assuring the continuous enhancement of Fraunhofer's diversified **research portfolio**.

Fraunhofer channels the results of its research – such as patents or copyright – into existing companies or its own start-ups. This generates returns for Fraunhofer in the form of additional research contracts or the proceeds of the subsequent disposal of shares in these businesses. The development of **equity investments** is monitored in close to real time by the financial controlling department.

Financial risks for the Fraunhofer-Gesellschaft may arise from contingent liabilities and operational risks in connection with its internationalsubsidiaries, to the extent that the parent organization has long-term contractual obligations toward the subsidiary in question. The American subsidiary Fraunhofer USA, Inc. is currently engaged in legal action against a company in the United States for the infringement of intellectual property rights. The legal proceedings are being monitored by Fraunhofer USA in consultation with the Fraunhofer-Gesellschaft.

The financial controlling department monitors the performance and liquidity of Fraunhofer entities outside Germany in close to real time. The controlling system for Fraunhofer's **international activities** is updated whenever necessary to take account of changes in the national and international operating environment.

A key issue in the context of **financial risks** is that of containing risks that might compromise Fraunhofer's access to research funding or the organization's solvency.

Base funding by the German federal and state governments is one of the three main pillars of the organization's financial security. To counter the risk of a possible decline in the proportion of base funding relative to total spending requirements, Fraunhofer applies a strategy of forward-looking growth management combined with lobbying to maintain its institutional funding at a level in keeping with its mission and in proportion to its performance.

Fraunhofer's access to **public-sector project funding** is affected by changes in the supported thematic areas of research and the available funding instruments, for instance in the case of the European Framework Programme. A loss of income can also result from changes in funding regulations or a disadvantageous interpretation of such regulations. By carrying out frequent audits and continuously improving its cost management processes, the Fraunhofer-Gesellschaft ensures that it meets the requirements for the reimbursement of incurred expenses, and negotiates with the relevant European and national bodies to obtain their approval of the costing models Fraunhofer applies.

Fraunhofer counters the risk of a possible decline in its project revenue from **industrial research contracts** by developing new areas of research and collaboration models geared to market requirements and through the strategic expansion of its customer acquisition and loyalty activities, especially at a cross-institute level.

Systematic checks by the central controlling department are used to keep track of the spending and earnings of individual institutes. Regular comparisons of each institute's results with respect to its annual targets permit the identification of downward trends, enabling the necessary countermeasures to be developed and implemented in good time.

Credit risk, which essentially relates to project pre-financing and unrecoverable payments, is minimized by near-real-time monitoring of payment schedules, coupled with effective dunning procedures and contractually agreed terms of payment.

Resource risk encompasses those types of risk that may affect the availability of material and immaterial resources needed to successfully carry out research activities.

The Fraunhofer-Gesellschaft preserves and expands its research expertise by recruiting highly qualified **scientists** and encouraging them to stay with Fraunhofer. To ward off the potential risk of being unable to recruit a sufficient number of qualified specialists, Fraunhofer maintains close ties with universities, which are one of its main sources of new employees, and operates a sustainable HR policy geared to its long-term staffing requirements.

Protecting and developing the organization's **intellectual property base** is a critical factor in Fraunhofer's success and is the prerequisite for the exploitation of research results. Fraunhofer constantly monitors initiatives stemming from the regulatory environment and assesses them for possible negative impact on the conditions governing the protection and exploitation of intellectual property rights.

Fraunhofer is exposed to capital market risk insofar as it invests part of its **capital and reserves** with a view to earning a return. These investments are concentrated in open-end funds within the meaning of the German Investment Act and in closed-end funds. The organization pursues a widely diversified investment

policy and, in view of the uncertainty prevailing in the money and capital markets, keeps a constant watch on the risk situation.

Operational business risk comprises those types of risk that may arise from processes used in research and administration, or from the execution of specific research projects.

Through its contract research projects for German and international customers, Fraunhofer is exposed to contingent **liabilities and performance risks** such as product liability and warranty commitments. It manages these risks through suitably formulated liability restriction clauses in its standard contracts and general business terms and conditions, as well as through a multilayer approval process based on the advice of competent lawyers.

The application of strict IT security measures is of elementary importance to the ongoing existence of a knowledge-based research organization. Fraunhofer takes targeted measures to mitigate potential **IT risks**. These measures are defined in a binding IT security manual.

By continuously optimizing its standard procedures and guidelines, Fraunhofer ensures that its **business processes** are designed and implemented in compliance with the increasingly stringent legal and regulatory requirements. A compliance management system is in place to ensure that all matters concerning rules and regulations are dealt with in a systematic manner. The organization's internal auditors carry out regular and ad-hoc audits to verify compliance with internal regulations and control mechanisms.

The current overall assessment of the Fraunhofer-Gesellschaft's risk situation reveals nothing that could endanger its existence in the long term.

Outlook

The Fraunhofer-Gesellschaft will continue to grow in 2017 on the back of a solid financial position. Its sources of income are evenly balanced between revenue from industrial contract research, public-sector project revenue, and base funding by the German federal and state governments. In the latter case, it was gratifying to see that the level of institutional funding was restored to its previous equilibrium, and in 2017 will once again account for more than 30 percent of the organization's budgeted expenditure, thanks to a top-up agreement with the federal and state governments that will increase the annual rate of increase above that foreseen in the Joint Initiative for Research and Innovation. This gives Fraunhofer more scope for investment in pre-competitive research and the development of system-based innovations. The contractual value of research projects scheduled for 2017 is higher than in previous years, enabling Fraunhofer to predict a moderate increase of around 4 percent in its contract research revenue.

Fraunhofer expects its major infrastructure capital expenditure to increase significantly in 2017. As well as investing a higher amount of its own financial resources in major building projects, work is due to start on the construction of premises for the **Research Fab Microelectronics Germany** (FMD), a multi-institute project for which the BMBF has granted funding totaling some €300 million over the coming years. In the long term, the FMD's state-of-the-art laboratory equipment will strengthen Germany's role in the key industrial sector of microelectronics research. The FMD will be managed jointly by 11 Fraunhofer Institutes and 2 institutes belonging to the Leibniz Association.

Fraunhofer is making concerted efforts to meet the 2020 targets defined in the German government's Joint Initiative for Research and Innovation. This includes developing a corporate culture that promotes cooperation among groups of Fraunhofer Institutes, strengthens research priority areas in the Fraunhofer portfolio, and systematically integrates aspects of social responsibility.

Building on the long-term vision of the organization's Guiding Principles, Fraunhofer is developing a **Fraunhofer 2022 Agenda** to further increase scientific excellence and cost efficiency in the medium term. Across all Executive Board functions, and with the support of the Presidential Council, a master plan is being drawn up to guide the development of the Fraunhofer-Gesellschaft. It describes all currently existing and planned strategic projects of major importance up to the year 2022. These projects include the future evolution of the Fraunhofer research portfolio, the organization's international strategy, and the acquisition of new sources of funding. The Presidential Council of the Fraunhofer-Gesellschaft will follow the progress of the Fraunhofer 2022 Agenda through continuous quality monitoring, adapting it to new requirements if necessary.

Fraunhofer employs a range of instruments to develop new thematic areas from the basic research stage (Technology Readiness Level TRL 2) to pilot applications (TRL 8). They extend from support for high-risk ideas to the exploitation of intellectual property rights and the creation of new lines of business spanning several institutes. In this context, **networking and cooperation among institutes** plays an increasingly vital role. Fraunhofer is planning to set up what it calls Fraunhofer Research Clusters, in which several Fraunhofer Institutes work together according to a shared roadmap on a technology with disruptive potential. The Fraunhofer Research Clusters will provide structured interfaces for interdisciplinary collaboration and release synergy effects enabling system-related innovations to be developed efficiently.

One of Fraunhofer's **HR management** goals is to help women scientists obtain the qualifications and credentials they need to be eligible for a professorship. At the same time, efforts are being made to increase the number of young women aspiring to a career in research. The Fraunhofer-Gesellschaft offers programs and activities specifically addressing this target group, starting while they are still at school or university.

Fraunhofer has a balanced, stable mix of funding sources and numerous effective instruments that enable its research portfolio to be continuously adapted to the changing requirements of the organization's operating environment. Moreover, Fraunhofer has strong networking ties with its stakeholders, including political decision-makers, industry, and society at large. Fraunhofer will thus continue to deliver excellent research and uphold its responsibilities to society, industry and government by serving as a reliable partner and driver of innovation.

Fraunhofer-Gesellschaft zur Förderung
der angewandten Forschung e. V.

The Executive Board
Prof. Dr.-Ing. Reimund Neugebauer
Prof. (Univ. Stellenbosch) Dr. rer. pol. Alfred Gossner
Prof. Dr. rer. publ. ass. iur. Alexander Kurz
Prof. Dr. rer. nat. Georg Rosenfeld

REPORT OF THE SENATE ON THE FINANCIAL YEAR 2016

In 2016, Fraunhofer implemented various forward-looking changes to its structure and business policy. The steps taken to give the Fraunhofer Groups greater responsibility and to limit the risks borne by individual institutes had a positive impact on the research portfolio and the organization's performance. Another important success was that of restoring the level of base funding granted by the German federal and state governments to the 30 percent of total budgeted expenditure originally prescribed by the Fraunhofer model.

The Fraunhofer-Gesellschaft's positive financial statements for 2016 again received an unqualified audit certificate from the independent auditors.

In 2016, the Senate fulfilled the tasks it is charged with under the Statute of the Fraunhofer-Gesellschaft. It convened twice in the course of the financial year: on May 10 at the Colosseum Theater in Essen and on October 11 at the Fraunhofer Forum in Berlin.

The main decisions taken in accordance with the Statute concerned the Fraunhofer-Gesellschaft's structure and the composition of the Executive Board:

– By resolution of the Senate, the Fraunhofer Research Institution for Casting, Composite and Processing Technology IGCV was established as an independent entity as of July 1, 2016. Its Augsburg location consists of two departments, "Functional Lightweight Design" and "Resource-efficient Mechatronic Processing Machines," both of which previously formed part of existing Fraunhofer Institutes; a third department, "Metal Forming and Casting," has been set up in Garching near Munich. The new research institution is led by Prof. Dr.-Ing. Gunther Reinhart, Prof. Dr.-Ing. Klaus Drechsler and Prof. Dr.-Ing. Wolfram Volk. It was created in response to industry's increased demand for research in the field of lightweight design – especially in the overlapping areas of metal casting, composite materials and smart automation.

– The Fraunhofer Research Institution for Large Structures in Production Engineering was established on January 1, 2017. The former application center of the Fraunhofer Institute for Manufacturing Engineering and Automation IPA now operates as an independent entity. It benefits from the unique selling proposition of focusing on a specific area of expertise that ideally complements the Fraunhofer research portfolio. In the past years, the application center had been very successful in growing its business, leading to a significant increase in the number of employees.

– Prof. Dr. rer. nat. Georg Rosenfeld was elected unanimously by the members of the Senate as the new Executive Vice President Technology Marketing and Business Models for a term of office extending from April 1, 2016 to March 31, 2021.

– The incumbent President of the Fraunhofer-Gesellschaft, Prof. Dr.-Ing. Reimund Neugebauer, was re-elected for a further term of office from October 1, 2017 to September 30, 2022. Similarly, Prof. (Univ. Stellenbosch) Dr. rer. pol. Alfred Gossner was re-appointed as Executive Vice President Finance, Controlling and Information Systems for the period September 1, 2017 to February 28, 2019.

The deputy chairman of the Fraunhofer Senate, Prof. Dr. phil. nat. Hermann Requardt, relinquished his post at the end of 2016, in accordance with the rules of the Statute. In recognition of his many years of dedicated service and as a sign of gratitude, he was presented with the Fraunhofer Medal at the Senate's meeting on October 11, 2016. His elected successors to the post of deputy chair are Prof. Dr. phil. Dr.-Ing. Birgit Spanner-Ulmer and Prof. Dr.-Ing. Hubert Waltl, who took up their new function as of January 1, 2017.

The Senate wishes to thank the Executive Board and all employees of the Fraunhofer-Gesellschaft for their commitment and successful work in the financial year 2016.

Prof. Dr.-Ing. Heinz Jörg Fuhrmann
Chairman of the Senate of the Fraunhofer-Gesellschaft

INSIDE THE FRAUNHOFER SENATE

At their annual assembly, the members of the Fraunhofer-Gesellschaft elect leading figures from the worlds of science, industry, business and public life to serve on the Fraunhofer Senate for a three-year term of office. Here we present profiles of two newly elected senators.

TANKRED SCHIPANSKI MDB

Tankred Schipanski, member of the German national parliament sitting in the CDU/CSU parliamentary group, was appointed to the Fraunhofer Senate at the beginning of 2017.

Schipanski studied jurisprudence at the universities of Bayreuth and Vienna, and obtained his Bachelor's degree in 2002. After further studies in administrative and business law, and a period of postgraduate legal training in Mainz, he passed his bar exam in 2005. Schipanski then worked as a research assistant in the legal studies department of Technische Universität Ilmenau, specializing in media law, and from 2006 onward as a legal attorney. Schipanski has been an elected member of the German national parliament since 2009. In addition to his work as a member of the parliamentary committee on education, research and technology impact assessment, he also holds seats on other committees such as those dealing with the digital agenda and national security investigations.

"Research is the key to maintaining a country's innovative strength and competitive edge, and provides answers to urgent issues affecting our future. With its practice-oriented approach and dedication to applied research, the Fraunhofer-Gesellschaft is a major contributor to the innovation process in Germany. Through my experience as a politician in the domains of research and the digital economy, I have come to appreciate the expertise of the Fraunhofer Institutes and Research Institutions, and look forward to working together with them during my time as a member of the Fraunhofer Senate."

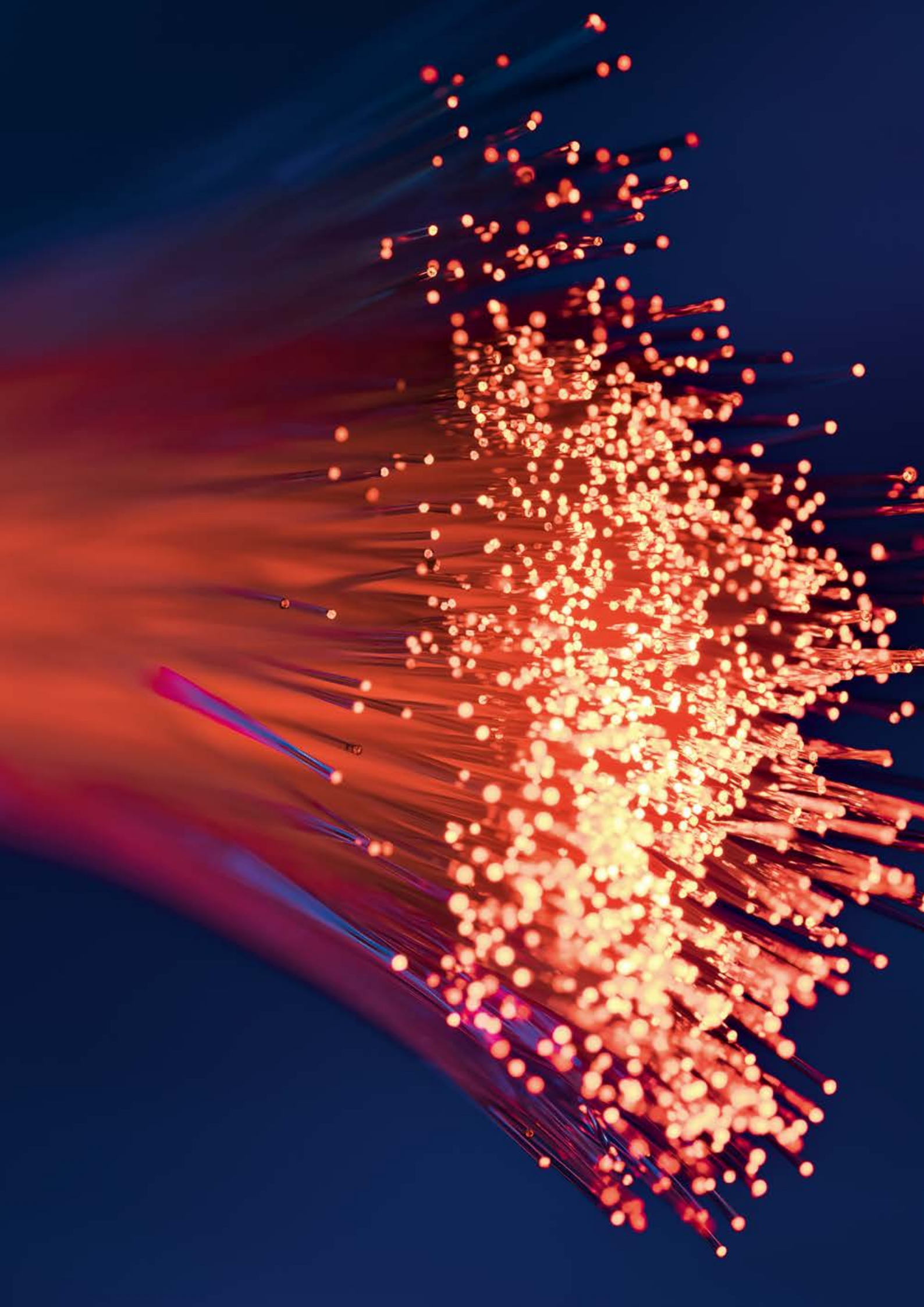
PROF. DR.-ING. SIEGFRIED RUSSWURM

Siegfried Russwurm became a member of the Fraunhofer Senate on January 1, 2017.

Until March 31, 2017, Russwurm was a member of the Managing Board of Siemens AG. After studying production engineering, he began his career at Siemens in 1992 as production planner and project head in the Medical Engineering Group. He subsequently occupied numerous key management posts in Germany and abroad, including head of the Motion Control Systems Division. In 2006, he was appointed to the Group Executive Management of Siemens Medical Solutions. Russwurm became a member of the Managing Board of Siemens AG in 2008, as Corporate Head of Human Resources and Labor Director, and was named CEO of the company's Industry Sector in 2010. In 2014, he took over the post of Chief Technology Officer and Head of Corporate Technology. His role on the Managing Board also included responsibility for the Middle East and Russia/CIS regions, and for the separate Healthcare business.

In 2009, Russwurm was awarded an Extraordinary Professorship in Mechatronics by the Friedrich-Alexander University of Erlangen-Nürnberg (FAU). He has also been a member of the Board of Governors of RWTH Aachen University since 2012.

"For decades, the Fraunhofer-Gesellschaft has successfully advocated for a bridge-building approach that places research in an industrial and social context. Through their purpose-driven research and focus on transforming scientific knowledge into practical applications, the Fraunhofer Institutes are the ideal counterpart to the – equally valuable and important – world of basic research. I look forward to supporting this effort as a member of the Fraunhofer Senate – to the benefit of German industry and society as a whole."



REVIEW OF FRAUNHOFER RESEARCH

SMART DATA – THE STUFF INNOVATIONS ARE MADE OF

PROJECTS AND RESULTS 2016

NEW INITIATIVES AND HIGH PERFORMANCE CENTERS

AWARDS 2016

PEOPLE IN RESEARCH

FRAUNHOFER INSTITUTE SPIN-OFFS

REVIEW OF FRAUNHOFER RESEARCH

SMART DATA – THE STUFF INNOVATIONS ARE MADE OF

Albert Heuberger, Boris Otto, Michael Waidner

Digital data play an essential role in the design, planning and control of industrial processes. As well as being needed as input, data are also generated and output in large quantities and can be utilized to develop new products, services, and business models. Fraunhofer collaborates with numerous companies in projects to develop concepts and methods that will enable the digital treasure trove to be utilized in a secure environment, thereby extracting more added value from industrial processes.

New business models

Björn Heinze is in a hurry as usual. He's been called to a last-minute meeting in Cologne that starts in two hours, which leaves him very little time to get there from his engineering studio in Bonn. Heinze doesn't own a car: he sold his last one a while ago, when parking became almost impossible in the downtown areas of the city. Instead he picks up his smartphone and books an autonomous electric vehicle via a car-sharing platform. In next to no time, his order has been processed and the car rolls up to his doorstep, guided there by the user profile he previously registered on the service provider's website. The journey would normally be a test of patience, because the roads to Cologne are frequently congested, but the self-driving vehicle's onboard navigation system quickly finds an alternative route that brings Heinze to his destination relaxed and on time.

Admittedly, this is a fictive scenario that doesn't quite work out like this at present, but the technology on which it is based is very real. Many of the processes involved already exist – scheduling the meeting, booking a vehicle and paying the rental fee, geolocation, finding alternative routes, locating a charging station in Cologne to recharge the vehicle's batteries for the homeward journey (because there might not be enough juice left to cover the whole distance), and invoicing the amount of electricity consumed. The protagonist in this story might not be aware of it, but huge amounts of data flow back and forth in the background, shuttling information between the car-sharing website, the parking facility operator, the utility company and its charging infrastructure, the traffic information service, the rental vehicle, and of course Björn Heinze himself.

The economy of data

The mobility revolution is in full swing. Auto manufacturers have woken up to the idea that the old business model of selling cars is becoming obsolete, and that they need to rebrand as mobility providers. People in the automotive industry are beginning to ask themselves whether the value they create by providing digital services might one day soon exceed the value they create by selling vehicles. Similar reflections are gaining ground in many other industries, for instance in medical and mechanical engineering, where the cost of devices and machines is falling steadily and an increasing share of value creation is accounted for by services such as predictive maintenance. The economy of things is gradually giving way to an economy of data – with far-reaching consequences. What these consequences are, and how industry can draw the greatest benefit from them, are questions currently being investigated by numerous Fraunhofer Institutes.

The rise of data-driven business models is forcing companies to completely rethink their corporate structures and the way they organize their internal and external supply chains. Whereas, in the past, systems were painstakingly configured by highly trained engineers, built-in sensors have now taken over their job – using systematically collected and recorded human know-how, which by rights ought to belong to the originator of that knowledge and, in many cases, would normally constitute an industrial secret. On the other side of the equation, online commerce has created a situation in which the open sharing and linking of data creates new assets. This is tantamount to a paradigm shift in the concept of data management:

- Data have become a commodity that can be freely mined and traded, but also be manipulated or stolen.
- Many market players share jointly generated data instead of keeping it to themselves.
- Data ownership and usage rights are often undetermined, and can only be clarified after long negotiations between the parties concerned.
- Platforms combine data from many different sources, and may include personal or other data that can be traced back to an individual person or group of persons.

Data are a valuable asset for companies because they increasingly serve as the basis for new business models, but at the same time represent a new and increasing cost factor due to the elevated consumption of resources, such as the energy required to supply the processing power for the high-performance servers and databases so essential in this age of big data. So what is the best way of attributing a monetary value to data? The Fraunhofer Institute for Software and Systems Engineering ISST in Dortmund has spent many years looking into this question.

Companies can measure the value of their data assets on the basis of:

- the cost of registering ownership rights and updating proprietary databases.
- the value in use of the data. Predictive maintenance is a pertinent example because it results in cost savings by detecting faults before they become acute and thereby avoiding downtime.
- market value. One way to determine this is by offering user data for sale and seeing how much buyers are willing to pay.

But what are the implications in the case of personal data, which are subject to strict privacy laws in Germany and other countries? How can a monetary value be placed on medical records held by hospitals and doctors' surgeries, when people's health is at stake? What special rules need to be applied in respect of official data gathered in the context of public administration processes? Can data concerning critical infrastructures such as the power grid or the Internet be treated as a saleable commodity without running the risk of triggering the collapse of entire market sectors or society as we know it? As the long list of questions shows, many different factors and legal issues can influence the value of data and the conditions under which data may or may not be exploited. It's also sometimes necessary to look at certain issues from an international point of view, because differing interests may need to be reconciled.

Digital treasure: Find it, keep it safe, exploit it

Since the advent of Industrie 4.0, many industrial companies have adopted a data lake strategy, i.e. digging up all the data they can find within the company, tipping it into a vast repository or "lake," and only afterward deciding what to do with it. But this type of strategy doesn't necessarily produce the desired results because it leaves the field open for outsiders to

step in and make money from data they didn't even produce themselves. It's easy to guess who these outsiders might be: first in line are the giant U.S.-based IT corporations, especially Google and Amazon. They are busily expanding into other sectors, backed by their expertise in the smart processing of large quantities of information. Google, for example, exploits freely available data and is avidly buying up companies that generate data. The best-known example is Nest, a manufacturer of smart heating control systems. Google's interest doesn't lie in the hardware but in gaining access to the data transmitted to and from the heating systems and the users' smartphones, and other smart-home applications in the future, in order to sell digital services. All that without having to pay for the data on which the services are based.

German industry has similar opportunities for exploiting the considerable amount of data generated in use, for example, by German-made machines and vehicles, as well as data derived from communication with customers. New Internet of Things (IoT) technologies represent an abundant source of data. One example is the MIOTY® wireless IoT platform based on low power wide area (LPWA) technology developed by the Fraunhofer Institute for Integrated Circuits IIS, which enables a single receiver to download millions of data items collected by environmental sensors, machine control sensors, or traffic and in-vehicle sensors within a range of several kilometers. It is a very energy- and cost-efficient system. The sensor and location data can then be made available for new IoT applications after being processed using advanced data analytics methods developed by Fraunhofer IIS, including machine learning.

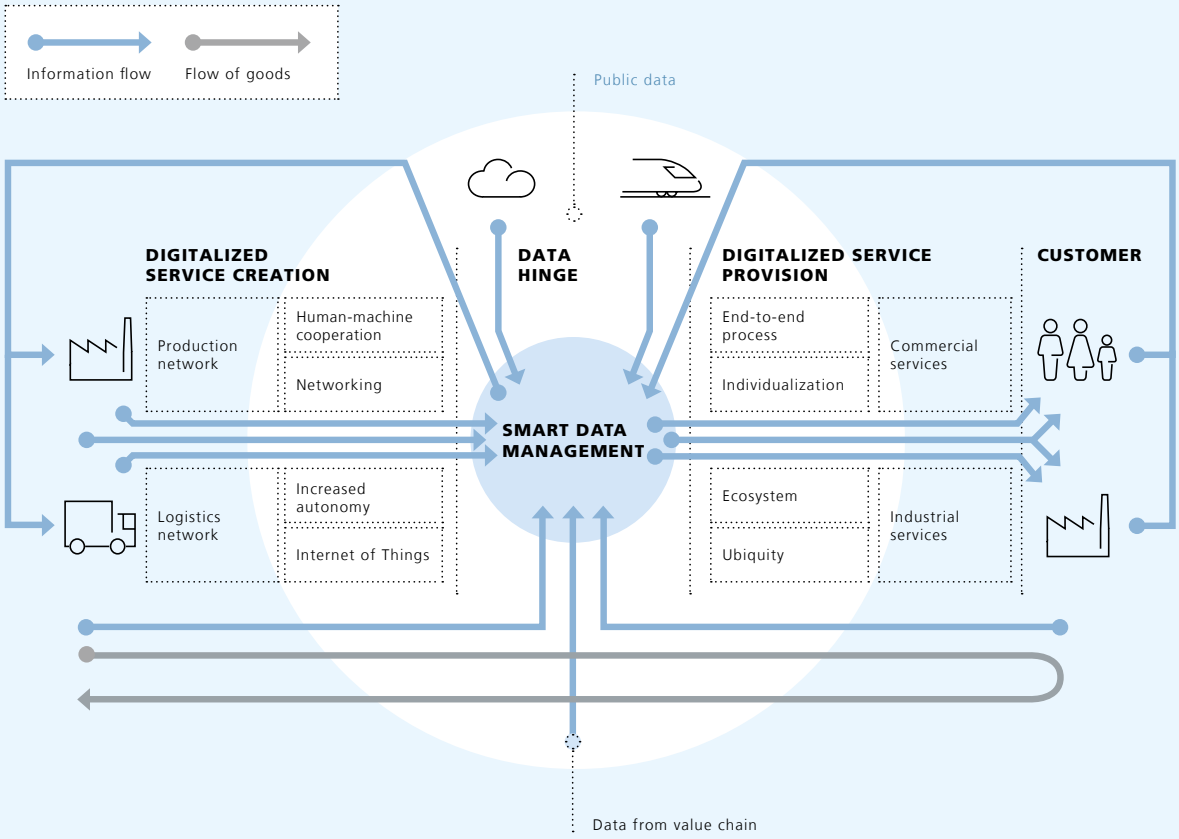
So far, companies have been slow to grasp these opportunities. Fraunhofer has made it its mission to help them get more out of their unexploited data assets. Many institutes follow a traditional approach focusing on the technical aspects, where there is undoubtedly still a lot to do. But companies are increasingly looking for support in other areas such as data analysis, data protection, and the design of digital business models.

This is where Fraunhofer IIS and the associated Fraunhofer Center for Applied Research on Supply Chain Services SCS in Nuremberg can offer their expertise in service development and business model design. The biggest problem for companies is not a lack of data but that of knowing how much of their existing data is genuinely useful and what additional data they need to collect to fill in the gaps in their knowledge. In this digital era, one possibility is to make use of microelectronic devices integrated into physical objects, such as the containers used in production-line parts delivery systems, to create cyber-physical systems (CPS). A CPS is a distributed network of uniquely identifiable, interconnected embedded systems capable of communicating in real time. Production processes can be configured to take a CPS's position into account. The CPS uses sensors to monitor the environmental parameters of physical processes. Each CPS processes its own data, enabling it to manage or regulate process parameters and exchange data with third parties. This results in a wealth of data that can be added to the company's existing databases and used in other contexts.

Adding value by means of new business models

The Fraunhofer Center for Applied Research on Supply Chain Services SCS has been developing data-based services and business models for companies for many years now. This not only requires an evaluation of the company's own requirements with respect to its internal processes but also means identifying the customer's needs so that they can be incorporated into new services and business models. In its many projects completed to date, the Fraunhofer Center has helped design end-to-end processes covering the collection, analysis and processing of relevant data and translated the results into business models enabling these data to be exploited in digital business models.

Data as the link between Industrie 4.0 and the world of smart services



Smart data management

To specifically address the diverse business management issues associated with the design and implementation of business models in the digital world, Fraunhofer IIS set up the Research Center for Business Models in the Digital World (www.geschaeftsmodelle.org) in 2014. It is operated on behalf of Fraunhofer IIS by the Fraunhofer SCS research group in cooperation with the University of Bamberg. This Research Center proposes a six-stage, structured transformation process as a means of providing support to companies wishing to develop digital business models. Top priority is given to the question of how to make the best use of data, starting with the definition of the company's own potential and followed by an analysis of the status quo, before finally arriving at a suitable scenario. Concrete use cases are studied with a view to creating the right transformation strategy for each company. These strategies can then be implemented and tested using Fraunhofer IIS's own infrastructure, for example in the L.I.N.K. Test and Application Center for positioning, identification, navigation and communication technologies. An alternative is to make use of the open lab facilities offered by the JOSEPHS® service manufactory, a bricks-and-mortar storefront located in the heart of downtown Nuremberg where companies can invite potential users of new products and services to participate directly in their development and testing. But whatever the chosen route, it is essential that the transformed, data-driven business model generates added value for the end user. That is why Fraunhofer SCS places great importance on structured risk analysis and management processes that support data-driven business models.

Another institute working on methods for developing digital business models is Fraunhofer ISST. Its Digital Business Engineering method provides a step-by-step approach, not unlike a food recipe, that has already been tested with success in a number of use cases. The next step envisioned by the researchers is to roll out this method in many more applications and to develop a toolbox that companies can use to produce their own digital business model according to a proven set of basic principles. There is a need for fundamental guidelines because much of this territory is relatively unexplored. Nonetheless it will be a while before major companies start to include data assets in their balance sheet alongside the more traditional items that form part of their net asset position. And maybe one day budding entrepreneurs will be able to go their bank and obtain a startup loan using their data assets as security. Anyone who tries that today has little chance of a sympathetic response on the part of the bank manager. But that's bound to change eventually.

The goal: Digital sovereignty

One important prerequisite for such scenarios is being able to prove who owns the data. This is fairly straightforward in the case of industrial applications such as predictive maintenance. The information generated by a machine in the course of its operation belongs to the user of that machine. But this doesn't prevent the company that manufactured the machine from using the same data to develop algorithms for predictive maintenance and improve future versions of the product. Sales contracts normally exclude any other forms of commercial utilization.

Such data management puzzles place data owners in a quandary. On the one hand, their data increase in value the more they are utilized and shared, but this also augments the need for protective measures. In essence, this means it would be better to keep proprietary data under lock and key. Finding a way out of this dilemma is one of the biggest challenges of digital business. What companies want is the freedom to distribute their data without ever losing control over this valuable resource. The term commonly used to describe this issue is digital sovereignty.

Here's an example: When online marketplaces for the procurement of parts and components first appeared at the end of the 1990s, suppliers willingly put their product catalogs online because they thought it would bring them more business. But when customers such as car manufacturers demanded that they should add customer-specific price information to the electronic data, the suppliers refused to do so. They didn't want this information to be stored on a platform operated by a third party – in other words, they didn't want to lose sovereignty over these particular data. Many other examples like this illustrate the point that some types of data are more sensitive than others and necessitate more protection.

Fraunhofer researchers are working on various solutions that allow data to be packaged, protected and enriched while also preserving sovereignty. Their ideas include:

- providing on-demand data sharing, which allows users to opt out of data lake strategies requiring all data to be stored in a central repository,
- developing connectors within the Industrial Data Space (see below) as a means of organizing conditional data sharing,
- tagging data with restriction notes that specify the (limited) conditions under which their use is authorized,
- using distributed database technologies like blockchain to record data transactions,
- using standard vocabularies to improve interoperability and portability between different cloud platforms,
- developing transparency functions that notify users of transactions involving their data, giving them self-determined control over these data.

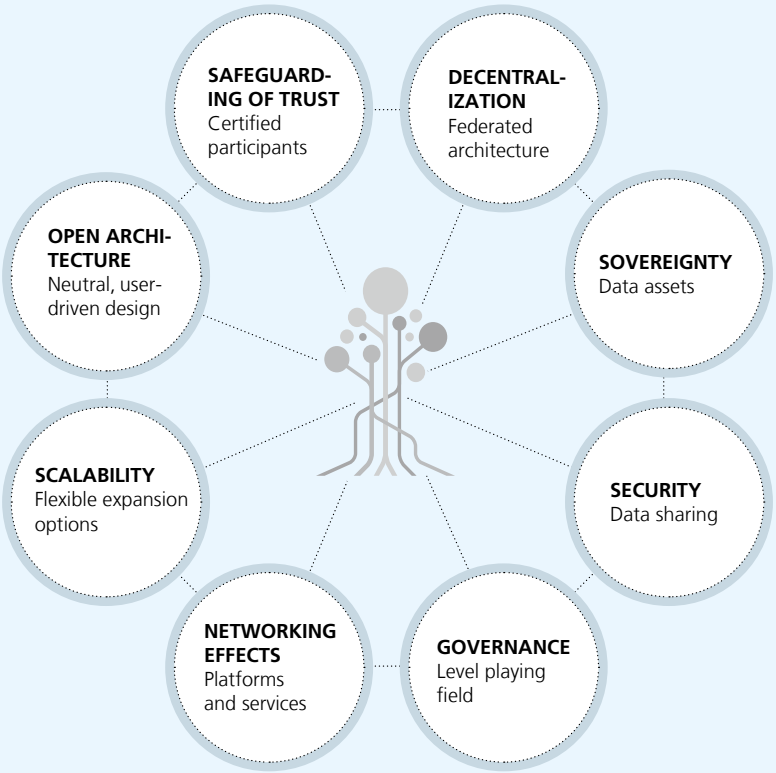
Digital sovereignty isn't a permanent state. Imagine it as a set of scales in which both sides need to be balanced. One pan contains the weight representing the data owner's interests, namely privacy and security, and the value attributed to the data. The other contains the counterweight representing the user's interests, which means the right to utilize, transfer, and share those data. Each case is different, but the common denominator of the proposed solutions is that the data owner has the last word in any conflicts of interest. This is one of the keys to success in the data economy.

The solution: The Industrial Data Space

Until now, the missing link in the digitalization process was the availability of a technology that enables companies to develop a business model that permits data sharing without loss of sovereignty. It is up to the owner to decide whether data come with a price tag or are distributed for free. Data owners need reassurance that their sovereign rights are inviolable and that nobody can gain access to these data under a false identity. In short, this technology serves as the custodian of digital sovereignty for all parties concerned, while still leaving scope for creative partnerships.

It was precisely this line of thought that led to the creation of the Industrial Data Space. No less than twelve Fraunhofer Institutes are involved in the development of this secure data platform for German industry (www.industrialdataspace.org). The collaborative research project was launched in October 2015 and is funded by the German Federal Ministry of Education and Research (BMBF). Its aim is to create a protected data space in which companies can share information using standardized, secure interfaces while at the same time retaining full sovereignty over their proprietary data. In parallel with the research project, a non-profit association was founded to represent the interests of Industrial Data Space users. It currently has 42 members from trade and industry, including thyssenkrupp, Bayer, Allianz and Rewe. Fraunhofer is also a member of this association. The association's work includes defining a reference architecture model and piloting it in use cases.

Overview of the Industrial Data Space



Key aspects of the Industrial Data Space

The reason why so many companies have joined the association so soon after its creation is because the Industrial Data Space concept gives them confidence that the issue of data sovereignty ranks high in its order of priorities. German companies don't want to run the risk of having their scope of action confined by dependency on big cloud service providers like Amazon and Google. Hence their insistence on the highest standards of control for essential services and data.

The software entities via which companies communicate with the Industrial Data Space are called connectors. They serve as an interface between the participating companies and support a wide range of protocols used to provide web services and connect with the Internet of Things. The connector correlates the company's data and distributes it within the Industrial Data Space at the company's request. In the opposite direction, the connector forwards inquiries from the Industrial Space to the company's own systems. Connectors can also run various apps to filter or transform data and provide input for business processes. The Fraunhofer researchers working on the project intend to develop prototype connectors and apps for the reference architecture and demonstrate their use in typical use cases.

The industrial group thyssenkrupp AG has implemented a logistics pilot project in which a connector is linked on the internal side to the company's freight entrance and loading dock management system. By consulting a chart, the controller can see immediately whether a particular truck carrying steel parts is running late or early, and adjust the schedule accordingly. The link to the real world of logistics is provided by the connector, which communicates via the Industrial Data Space either directly with the relevant apps on the truck driver's smartphone or with the transport management system operated by the logistics service provider. The objective of this project is to save time and costs by optimizing the time window for loading and unloading.

The challenge: Data security

Despite all the talk about the value of data, data security, and sovereign ownership of data, it should not be forgotten that digitalization continues to be a major technological challenge. Numerous Fraunhofer Institutes are working closely together with industry to develop new solutions. One of them is the Fraunhofer Institute for Secure Information Technology SIT, which specializes in cybersecurity, i.e. the protection of data against theft and hacking. The Industrial Data Space is a good example showing how technologies like this go hand in hand with business models.

A similar approach could also be applied in the automotive context. Fraunhofer SIT, for example, is developing suitable data protection measures that can be integrated into vehicle control systems as early as the design stage. Without such measures, hackers would be able to disable the braking or other safety-critical systems in an autonomous car-sharing vehicle, posing a risk to life and limb of the vehicle's occupants. Another type of risk arises from the analysis of vehicle data, which allows the owner's movements to be tracked on the basis of journey or driving behavior profiles. Sometimes seemingly insignificant data can have unexpected consequences. A few vehicle insurers already offer special tariffs that reward good driving behavior. This requires the use of an in-vehicle data recorder that generates a speed profile. However, the evaluated speed data can also be used to create a profile of the vehicle's movements and hence track the owner's whereabouts. Fraunhofer SIT is therefore working on more transparent solutions that provide greater data protection by enabling users to see what use is being made of "their" data by third parties and give them greater control over the attribution of data access rights.

A crucial aspect of cybersecurity is making sure that systems are free of vulnerabilities. Fraunhofer SIT operates a test laboratory for the security analysis of IT systems ranging from discrete embedded systems to more complex systems such as a vehicle's entire onboard network architecture, and even IT infrastructures and cloud services.

Smart innovations need 5G

Needs-based data collection requires a flexible transmission technology. The next-generation 5G wireless communication system will be one of the fundamental elements. The aim of 5G is to define a universal transmission standard for heterogeneous vertical markets such as Industrie 4.0, the automotive sector, the Internet of Things, and the smart grid. Key aspects of the 5G specifications include extremely low latency (less than one millisecond), high data rates, low power consumption, and the convergence of different network technologies. Researchers at the Fraunhofer Institutes for Integrated Circuits IIS, for Telecommunications, Heinrich-Hertz-Institut, HHI, and for Open Communication Systems FOKUS are working on appropriate solutions.

The new standard will be more than just another new generation of mobile technology. The aim is to create a universal wireless standard to serve as the basis for future-shaping topics such as the Internet of Things (IoT) and autonomous driving, and as a means of providing an advanced infrastructure for the development of telemedicine in the healthcare sector, smart living solutions for people with disabilities, and smart grid functions to support the energy transition.

This raises the question of where to store and process the data for these applications. In the cloud? That's fine for companies that want to collect as much data as possible in a "data lake" structure, but quite the opposite of what is needed for Industrie 4.0, which is based on the concept of decentralized, largely autonomous, cyber-physical systems. Edge computing, in which data are filtered and processed by smart terminals on the edge of the network, is a better option in this case. But this option has the drawback of requiring the synchronization of data from many different sources in order to produce exploitable knowledge. The real answer probably lies halfway between the two. The Fraunhofer Institutes are therefore looking into hybrid concepts that combine the best of both approaches.

Outlook

As the above examples show, digitalization is a complex subject that involves technological, organizational, economic and social changes. This new industrial revolution has the capacity to mark and change our lives like never before, and calls for the active participation of the business world. The Fraunhofer-Gesellschaft's holistic and application-oriented approach to research makes it the ideal partner in the quest to shape these developments to their best effect, and create benefits for industry, society and end users alike.

Prof. Dr.-Ing. Albert Heuberger is the director of the Fraunhofer Institute for Integrated Circuits IIS in Erlangen.

Prof. Dr. Boris Otto is the director of the Fraunhofer Institute for Software and Systems Engineering ISST in Dortmund.

Prof. Dr. Michael Waidner is the director of the Fraunhofer Institute for Secure Information Technology SIT in Darmstadt.

HEALTH AND ENVIRONMENT

Stifterverband Science Award

Personalized radiotherapy

Radiotherapy is one the three main forms of cancer treatment, alongside surgery and systemic therapy. It involves irradiating tissue at an energy level sufficient to kill cancer cells by disrupting their DNA. But working out the ideal treatment plan for a specific patient is never an easy task. A research group led by Prof. Karl-Heinz Küfer at the Fraunhofer Institute for Industrial Mathematics ITWM, consisting of Dr. Michael Bortz, Dr. Alexander Scherrer, Dr. Philipp Süss and Dr. Katrin Teichert, has developed a solution in collaboration with Prof. Thomas Bortfeld of the Massachusetts General Hospital, Prof. Jürgen Debus of the Heidelberg University Hospital, Prof. Wolfgang Schlegel of the German Cancer Research Center (DKFZ) in Heidelberg, and Dr. Christian Thieke of the University Hospital of Munich. Their user-friendly planning software enables any radiologist or oncologist to produce optimized treatment plans for individual patients much faster than before. A foresighted IP strategy guarantees Fraunhofer's commercial exploitation rights while allowing more than 60 percent of therapy stations worldwide to make use of this new technology. The members of the research team received the 2016 Stifterverband Science Award for their achievements.

Food preservation without heat 1

Consumers want to be able to buy food that retains its full nutritional value without the addition of synthetic preservatives, but still expect such products to have a long shelf life. The disadvantage of heat sterilization is that it often results in foodstuffs that are less flavorsome, nutritious, and visually attractive than untreated produce. Researchers at the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB have perfected an industrial application of

pressure change technology, also known as cold pasteurization, for treating liquids. This purely physical process destroys the cells of microorganisms without in any way affecting the nutritional function of proteins, vitamins and other vital food elements. It can be used to sterilize fruit and vegetable juices, alcoholic beverages, dairy produce, plant extracts, and suspensions of active ingredients.

Sport apparel with integrated sensors

Physical exercise is good for health. More and more people are using wearable technologies that display information about their vital signs while working out. A joint team of researchers from the Fraunhofer Institutes for Silicate Research ISC and for Silicon Technology ISIT is developing a shirt with integrated pressure, deformation, temperature and proximity sensors. Functional clothing equipped with such sensors may one day serve as a personal coach, providing feedback on the wearer's movements. Because the sensors are made of a transparent, flexible material, they allow textile designers free scope in their choice of colors and styling. Other conceivable applications of this technology include monitoring the body temperature and breathing rate of bedridden patients or young infants.

Transforming liquid effluent into gold

The amount of liquid effluent produced each year by pig, cattle and poultry farms in Europe is estimated at around 1.8 billion cubic meters. A large part of this agricultural waste stems from intensive livestock farming, in areas where there is not enough cultivated land in the vicinity to absorb it in an environmentally responsible manner. As a result, it is carried away in millions of tanker loads. But if liquid effluent can be broken down into specific components for use as a natural crop fertilizer, this unwanted farming byproduct can be transformed into a valuable resource. Proof of this concept has now been demonstrated using a process developed at the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB in a pilot plant designed as part of the EU-funded BioEcoSim project. The effluent is converted into three main products: ammonium sulfate, phosphate salts, and humus-building soil improvers. Their dry mass represents no more than 4 percent of the original liquid effluent, which simplifies transportation and handling. This approach also saves money by eliminating the need for energy-intensive synthetic fertilizer production.

Seaweed as a salt substitute

Salt is an essential part of our diet, and it also enhances the flavor of the food we eat. But consuming too much salt is bad for health. Industrially manufactured products such as bread, cheese, processed meat, and convenience foods account for around 7 percent of our daily salt intake. Researchers at the Fraunhofer Institute for Process Engineering and Packaging IVV are investigating possible substitutes. One of the promising candidates being studied is seaweed. The challenge for the process engineering experts is to find a way of eliminating the strong taste and smell of the algae, which many people find unpleasant, while retaining the salty component, and thus develop a product that can be used to reduce the salt content of foodstuffs. The result of this research at Fraunhofer IVV is a manufacturing process for a seaweed powder that can be used to replace part, although not all, of the salt added to food.

1

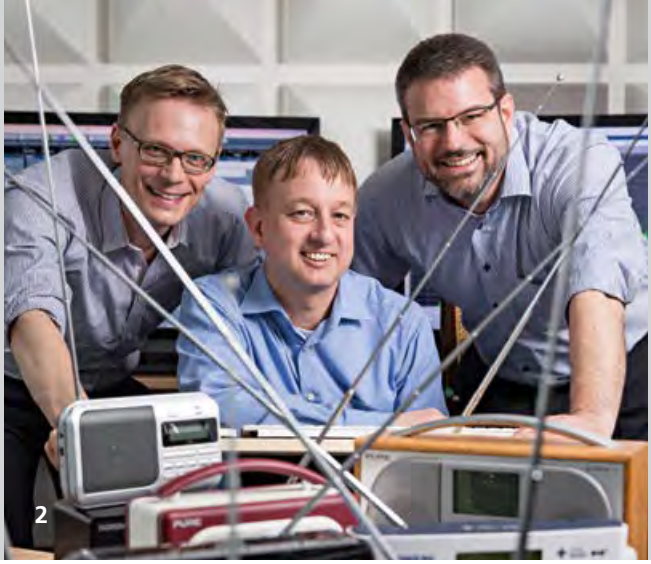
Detecting nanoparticles in environmental samples

Nanoparticles have chemical and physical properties that differ markedly from those of solid materials or larger particles. That is why they are used to enhance the characteristics of materials employed in products such as optical devices. But further research is needed in many areas to determine the impact of nanomaterials on organisms. Nanoparticles are extremely difficult to detect, because they are generally present in very low concentrations. The NanoUmwelt project, funded by the German Ministry of Education and Research (BMBF), aims to provide answers. Participants in this project include the Fraunhofer Institutes for Biomedical Engineering IBMT and for Molecular Biology and Applied Ecology IME. Their approach is based on a modified version of the field flow fractionation technique, which enables complex, heterogeneous mixtures of materials consisting of particles suspended in different liquid matrices to be broken down into separate fractions. The solid components can then be sorted by size and quantified, as a means of detecting the presence of nanoparticles in environmental and human samples.

Hugo Geiger Prize

Decision support based on data analysis 1

The volume of data generated worldwide is growing exponentially, and with it the need for meaningful ways of analyzing these data so that they can be used in decision support. In his dissertation paper, Dr.-Ing. Jürgen Bernard of the Fraunhofer Institute for Computer Graphics Research IGD focuses on time series data analysis. He demonstrates how developers of exploratory search systems can create powerful, application-oriented data analysis solutions by working together with domain experts in a user-centered design process. His main area of interest is applications in the field of medical research. Time-based patterns play an important role in disease prognosis, blood paneling, and therapy planning. In the domain of prostate cancer, the researcher was able to significantly enhance his data analysis method through collaboration with the Martini-Klinik in Hamburg. Other possible applications include analyzing existing and planned power grids with respect to the use of renewable energy sources, and predicting the probability of telecommunication network failures. Dr. Bernard was awarded the 2016 Hugo Geiger Prize for this work.



2

COMMUNICATION AND KNOWLEDGE

Joseph von Fraunhofer Prize
Worldwide digital radio 2

Digital radio has already achieved market breakthrough in many parts of the world, but it took a huge development effort to overcome the numerous, complex challenges associated with its technical implementation. The Fraunhofer Institute for Integrated Circuits IIS has spent many years developing the technological basis for standards such as DAB (Digital Audio Broadcasting) or DRM (Digital Radio Mondiale), which define the operating parameters, transmission modes and tuning frequencies of digital radio receivers. Alexander Zink MBA (left) and Martin Speitel (center) helped develop the transceiver technologies along with other members of the IIS team, and have accompanied the project from the system definition phase though to the introduction of the new digital radio standards. Max Neuendorf (right) was responsible for developing the xHE-AAC codec, which lies at the heart of the DRM digital radio system. The unified algorithm for encoding of voice and audio is a result of his team's work. The three researchers were awarded the 2016 Joseph von Fraunhofer Prize for their achievements.

Joseph von Fraunhofer Prize
High-performance, compact light projectors

Modern lighting and projection systems have very little in common with their predecessors, which were limited to simple lighting and presentation functions. Thanks to the increasing miniaturization of optical components coupled with the continuous improvement of their performance, many interesting new applications for such systems are beginning to emerge. Three physicists from the Fraunhofer Institute for Applied Optics and Precision Engineering IOF – Dr. Peter Schreiber, Marcel Sieler and Dr. Peter Dannberg – have been working since 2009 on the development of advanced LED modules

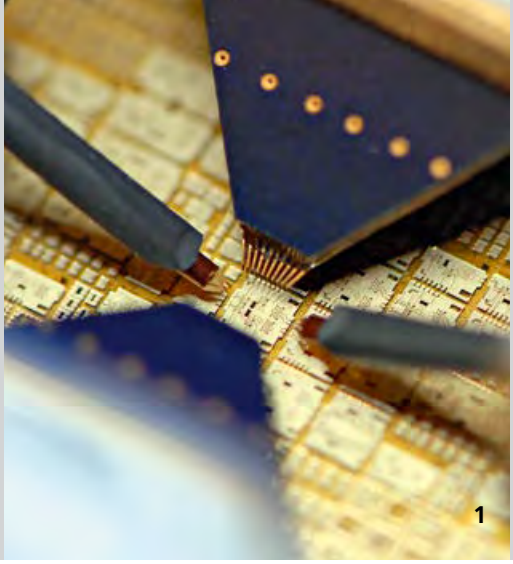
for a wide range of different applications. By opting for a novel design approach based on array projection, as opposed to the traditional method of single-channel projection, the researchers were able to do away with the until-now fixed ratio between physical size and light output, enabling tailored lighting solutions to be created using ultrathin projectors. Within no less than six years, the team has taken array projection from the original idea to industrial application. The innovative character and market appeal of such solutions is borne out by the use of this technology in the Welcome Light Carpet ambient light option in premium-selection BMW and other cars. The three researchers were awarded the 2016 Joseph von Fraunhofer Prize for this work.

Display and sensors for data goggles

OLED microdisplays are an essential component of many virtual or augmented reality goggles. A highly promising development is that of embedding image sensors in the display, enabling the user to control the action on the miniaturized screen by means of eye movements. This type of bidirectional OLED microdisplay has been created by the Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology FEP. Depending on its intended purpose, it can be designed to consume very little power and is ideally suited for augmented reality applications in which users need to keep their hands free instead of using them to operate the system. A possible application is as a communication and entertainment platform for patients suffering from amyotrophic lateral sclerosis (ALS). Alternatively, it could be used in industrial applications such as the testing of electronic components, a task where users also need to keep their hands free. The data goggles were developed as part of the FAIR project, which was funded by the German Federal Ministry of Education and Research (BMBF) and was successfully completed this year.

Virtual reality technology for videoconferencing and movies

Capturing images of people and storing them on digital media is a relatively simple affair these days. It is a more complicated matter if you want to record a three-dimensional model of a person from every side, including all body movements, typical gestures and facial expressions, and transfer this model to the digital world. Scientists at the Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institut, HHI in Berlin have developed a method that enables a lifelike digital representation of a person to be created from captured images using 3D Human Body Reconstruction technology. An original set of images is recorded by 20 stereoscopic cameras arranged in a semicircle, each one imitating a pair of human eyes. Complex algorithms are then used to compose an animated 3D model of the subject, which moves like a real person, from the depth-of-field information in the original 3D images. This might seem like a lot of work, but it opens the way to some very interesting applications in areas such as live 3D videoconferencing or movie production, where it will permit a smoother interaction between digital characters or virtual sets and real actors without the time-consuming effort involved in using full-body motion tracking sensors.



1

2

Achieving maximum speeds in heterogeneous networks 1

As of 2020, the 5G wireless communication standard will provide a new basis for high-speed, energy-efficient data transmission. This calls for new technologies to deal with the exponentially rising volume of data transmitted by the more than 8 billion web-enabled mobile devices (at the last count) in the hands of users around the world. 5G combines new mobile communication technologies with landline access networks in a virtual, software-based environment. Numerous Fraunhofer Institutes, including those for Telecommunications, Heinrich-Hertz-Institut, HHI, for Integrated Circuits IIS, for Applied Solid State Physics IAF, and for Open Communication Systems FOKUS, are contributing to the standardization process as well as developing overlapping, intermeshed technologies. Until now, wireless communication via the Internet meant person-to-person communication, but in the future these communication flows will also include vehicles, electronic devices and production machinery. At the same time, energy consumption per transmitted bit or byte needs to be significantly reduced, in the interests of cost efficiency and environmental compatibility. To meet these increasingly demanding requirements of mobile communication networks, the Fraunhofer Institute for Applied Solid State Physics IAF is developing new gallium-nitride high-frequency power amplifiers, because this semiconductor material is particularly well adapted to the extreme demands of future transmission technologies.

Shaping the future together

New technologies have little chance of being accepted unless they answer the needs and desires of the average user. Applied research is best served by listening to the needs and opinions of real people. But there is a lack of structured processes to support the dialog between ordinary citizens and researchers. The Center for Responsible Research and Innovation CeRRI, hosted by the Fraunhofer Institute for Industrial Engineering IAO, has developed a model process as part of the "Shaping Future" project to facilitate this type of exchange. It allows people to express their wishes and concerns regarding future technological developments, specify their requirements, and discuss them with Fraunhofer experts. The project is funded by the German Federal Ministry of Education and Research (BMBF). Many Fraunhofer Institutes have developed technology roadmaps derived from citizen input, and are using them as a kind of blueprint for new research projects and production innovations.

3D sound for the opera 2

In modern opera productions, the singers' voices and orchestra's music may be accompanied by sound effects produced using loudspeakers. But this can soon stretch conventional audio systems beyond their limits. The Fraunhofer Institute for Digital Media Technology IDMT has installed a new system in the Zurich Opera House that uses SpatialSound Wave technology to create a three-dimensional sound experience and simulate any kind of room acoustics without having to make physical alterations to the building. A sophisticated control system operates each loudspeaker individually. The virtual sound sources can be positioned anywhere in the auditorium, regardless of where the actual loudspeakers are located, creating a truly immersive listening experience. The acoustics can even be manipulated to make it seem as though the sound is coming from outside the auditorium. The control system also permits ad hoc adjustments during a live performance. This gives opera directors more scope for creativity in their productions.

1

PROTECTION AND SECURITY

Hugo Geiger Prize

More safety through gas-sensitive fire detectors 1

Current fire protection systems mostly rely on smoke detectors to trigger an alarm. But smoke doesn't usually arise until a fire has already taken hold, or there may be no smoke at all, as in the case of smoldering fires. The use of gas-sensitive fire detectors would make it easier to extinguish fires before they have time to spread. In her dissertation paper, Dr.-Ing. Carolin Pannek of the Fraunhofer Institute for Physical Measurement Techniques IPM sets out the basic working principles of a gasochromic sensor, which promises to be the first truly viable alternative to conventional gas sensors. The latter tend to lack the necessary sensitivity and durability, whereas the new sensor is better suited to use as a fire detector due to its low energy requirements and its greater sensitivity and selectivity. The waveguide-based sensing system also promises to be cheaper to manufacture and remain active for five years without needing a battery change. The researcher was awarded the 2016 Hugo Geiger Prize for her work.

2

Machines detect safety-critical worker alertness

People are prone to errors. The ideal machine would be one that assists operators by alerting them before they make a mistake. This calls for a system capable of detecting the physical and psychological warning signs indicative of stress overload, fatigue, poor concentration and motivation, or emotional instability. Researchers at the Fraunhofer Institute for Communication, Information Processing and Ergonomics FKIE have developed a real-time diagnostic interface that analyzes numerous measurable parameters to determine the point at which each contributing factor reaches a critical level, and forwards this information to the machine. This in turn enables automated systems to respond to changes in the operator's work capacity. This would be useful in any kind of highly automated work environment where worker alertness is a critical safety factor, for example when performing tasks that demand a high level of mental concentration or involve monotonous surveillance routines.

Fraunhofer-Zukunftsstiftung
(Fraunhofer Future Foundation)

Protection against allergies

Eating doesn't necessarily rhyme with pleasure; the incidence of food allergies has been growing for many years. At present, the only solution for allergy sufferers is to avoid products containing ingredients to which they are allergic. Specific reactions are triggered most frequently by peanuts, fish, milk, eggs, celery, seafood, tree nuts, mustard, sesame seeds, and soya proteins. Fraunhofer aims to offer relief through the FoodAllergen project, in which the Fraunhofer Institutes for Process Engineering and Packaging IVV, for Cell Therapy and Immunology IZI, and for Molecular Biology and Applied Ecology IME have joined forces to develop novel methods of analyzing food allergies, reliably characterizing allergens, assessing and reducing the allergenic potential of foodstuffs, and precisely detecting allergens.

Unexploded bombs on the seabed 2

In the coastal waters of the North and Baltic Seas, it's as if the two world wars had never ended. More than 1.6 million metric tons of munition still lurks on the seabed, dumped there after hostilities ceased. Today these unexploded bombs and grenades represent a serious danger, not least because many of them have been swept far away from the original dumping site by the current. To prevent accidents, for instance when offshore wind farms are being built, the Munitect network is researching solutions that will facilitate detection of these hazardous objects in the North and Baltic Seas. This network was created by a group of companies and research institutions with the aim of furthering the development and deployment of cost-efficient munitions detection systems for underwater use. Their overriding goal is to provide safe working conditions for the people who make a living from the resources of the North and Baltic Seas. The Fraunhofer Institute for Computer Graphics Research IGD is responsible for coordinating the network's activities.

1

Rapid pathogen testing

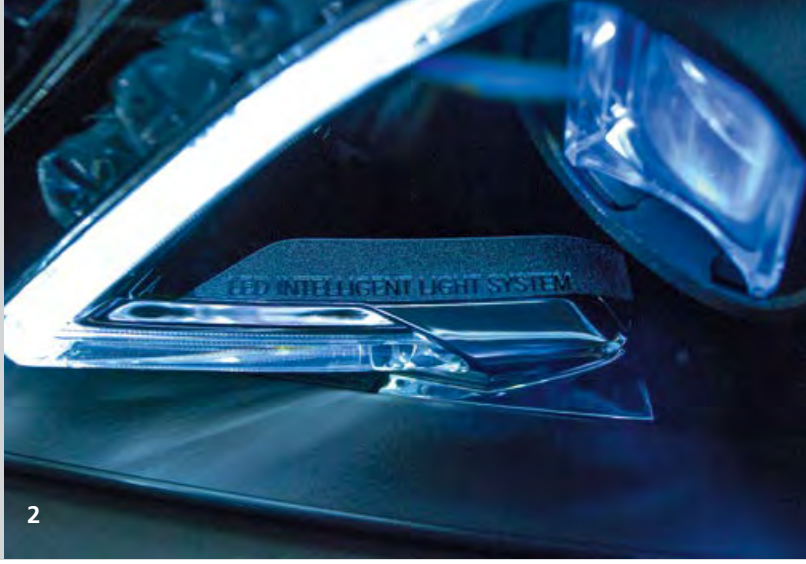
Detecting and clearly identifying bacterial, fungal or viral pathogens is normally a long-drawn-out process involving extensive laboratory tests or animal studies. To obtain more rapid results, researchers at the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB are developing a dipstick method similar to over-the-counter pregnancy tests. The project is supported by the Fraunhofer Discover Program, which provides one year's funding to demonstrate the feasibility of a new technology. Tests using the LPS bacterial pyrogen produced convincing results. Once the new method has been perfected, it will be possible to use it in applications requiring a rapid response in situations where strict hygiene is a primordial consideration, for example in the food and pharmaceutical industries and in intensive care units.

Biological pest control 1

South America is engaged in a running battle against the tiger mosquito, which is a vector for yellow fever, dengue fever and the zika virus. Meanwhile, wine and fruit growers in central Europe live in fear of crop losses caused by the cherry vinegar fly, or spotted wing drosophila. Existing methods of pest control are becoming increasingly ineffective, or are being abandoned because of the damage they cause to the environment. This situation prompted the bio-resources project group at the Fraunhofer Institute for Molecular Biology and Applied Ecology IME in Gießen to develop new pest control strategies that are species-specific and do not rely on environmentally toxic insecticides. One such strategy is based on the sterile insect technique (SIT). It involves rearing the target insect species and modifying the genetics of the males so that they become infertile. When released, they mate with wild females but do not produce any offspring. A special food supplement can be given to the reared insects to temporarily reverse the effect of sterilization, in order to maintain a breeding population in the lab.

Low-cost, reliable biotesting

The bioconcentration factor (BCF) is one of the main factors used to assess the bioaccumulation potential of chemicals in the context of environmental impact assessments. It indicates the likelihood that a substance will be taken up from the surrounding medium and concentrated in an organism. BCF values are usually determined by means of flow-through fish tests as specified in OECD Test Guideline 305. But these tests are costly and time-consuming, and require a large number of fish test subjects. Experimental studies carried out at the Fraunhofer Institute for Molecular Biology and Applied Ecology IME have demonstrated that the Mexican freshwater shrimp *(Hyalella azteca)* could replace fish in bioconcentration tests. Tests performed using this aquatic invertebrate produce comparable results while substantially reducing costs, time and resources. Moreover, because tests using *Hyalella azteca* require a smaller amount of the test substance, they can be carried out at an earlier stage in the chemical development process.



2

MOBILITY AND TRANSPORTATION

Hugo Geiger Prize

Telemetry for the Internet of Things

Telemetry is basically the transmission of sensor measurements to a remote location, which nowadays implies the use of wireless connections. It is a fundamental enabling technology for the Internet of Things. But until now the functionality and range of such systems has been limited mainly by the available transmission power. As part of his doctoral dissertation project at the Fraunhofer Institute for Integrated Circuits IIS, Dr.-Ing. Gerd Kilian developed a new concept that promises to significantly improve the efficiency of wireless telemetry systems. By fragmenting the individual telegrams into smaller packets and transmitting them in a time-division-multiplexed data stream, it becomes possible to substantially increase both the transmission range and reliability of the telemetry system. This approach could also be used to optimize the performance of other packet-mode data transmission systems. Several German and international patent applications have been filed for new inventions based on this research. Gerd Kilian was awarded the 2016 Hugo Geiger Prize for this work.

Night driving without glare: Pixel headlamps 2

The quality of a vehicle's lighting systems determines whether night driving is a relaxed affair or a stressful and even dangerous experience. Headlamps need to be sufficiently bright to allow the driver to see clearly in the dark, but without causing glare that could blind oncoming traffic. A group of German researchers has developed a concept for smart, high-resolution LED headlamps that takes adaptive headlamp control into a new dimension. In collaboration with Infineon, Osram, Hella and Daimler, the Fraunhofer Institute for Reliability and Microintegration IZM has developed an adaptive front headlight system capable of controlling the distribution of light down

1

to the very last detail. As part of the same project, which is funded by the German Federal Ministry of Education and Research (BMBF), the Fraunhofer Institute for Applied Solid State Physics IAF in Freiburg has developed a new technology that allows defective LEDs to be repaired during the manufacturing process, leading to a significant increase in the operational life of the lighting units.

Better cabin air quality

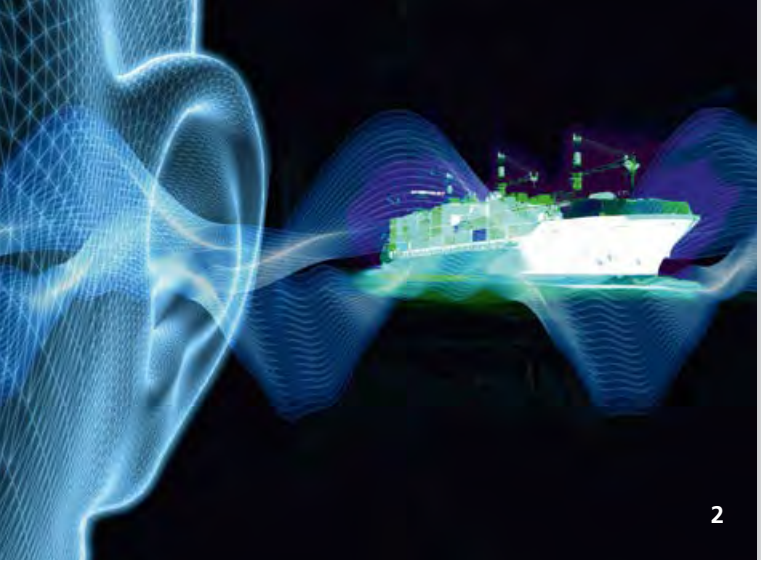
The air in aircraft cabins is deliberately kept dry, typically at a relative humidity of around 20 percent, to prevent the formation of condensation on the inner surface of the fuselage. But this causes discomfort to passengers because the extremely dry air dehydrates the mucous membranes of the nose and mouth. The Fraunhofer Institute for Building Physics IBP has developed a new technology that promises to solve this problem. It consists of a vortex ring generator built into the rear of each backrest, which delivers humidified air at the face level of the passenger seated in the row behind. This solution improves passenger comfort without any significant increase in overall cabin humidity. And better air quality has a positive impact on the passengers' feeling of wellbeing.

Mass-produced mini-submarine

Research and industry are taking a growing interest in the ocean floor. Deep-sea activities include prospecting for oil and gas and other resources and geological profiling in preparation for laying underwater cables or installing anchoring systems for floating structures such as offshore drilling platforms and wind turbines. To help with this work, researchers at the Fraunhofer Institute for Optronics, System Technologies and Image Exploitation IOSB have designed a robust, lightweight and powerful autonomous underwater vehicle (AUV) that is suitable for mass production. Most of the currently available autonomous mini-submarines are heavy and expensive custom-built vessels that require operators to go through a long period of training to learn all the complicated procedures. The lightweight AUV designed by Fraunhofer, called DEDAVE (Deep Diving AUV for Exploration), is only three and a half meters long and equipped with a CAN bus system, which greatly simplifies data handling.

Longer life for EV batteries

Electromobility is here to stay, not least because of the many technological advantages it offers. But one stumbling block remains: that of increasing the performance of energy storage systems. To reduce the strain on a vehicle's battery system in stop-and-go traffic, researchers at the Fraunhofer Institute for Manufacturing Engineering and Automation IPA have launched the SkiPper project to investigate the use of supercapacitors as a storage medium for electrical energy in automotive applications, for which they have received funding from the German Federal Ministry of Education and Research (BMBF). Supercapacitors are particularly useful in urban driving conditions, where they can capture energy from frequent



2

3

braking and reuse it to supply the extra power needed to boost engine performance during the equally frequent acceleration phases – without drawing power from the battery. This solution could potentially double the life of electric-vehicle batteries.

Sensors to improve driving safety

Automated driving places a huge burden on vehicle safety systems. They are expected to have their "eyes" everywhere and capture visual information more efficiently than human drivers, who also rely on their sense of hearing to control the vehicle. However, self-driving cars have other sensing mechanisms at their disposal to monitor their surroundings, including radar and laser scanning. Researchers at the Fraunhofer Institute for Microelectronic Circuits and Systems IMS are investigating a solution based on LiDAR technology, in which a beam of light emitted by a pulsed laser is used to scan the space around the vehicle and send back data on the distance, position and speed of other vehicles, cyclists and pedestrians, and the location of road works. Fraunhofer IMS has enhanced this technology to create flash LiDAR, which lights up the whole scene with a single flash of laser light. The sensors and the electronic circuits that analyze the captured data are contained on a single chip. This makes it possible to build a system that is so small and thin that car manufacturers can easily install it behind the windshield or the headlamps. The aim of the research project is to extend the range of flash LiDAR to up to 100 meters.

Active vibration damping 2

Engines cause vibrations that are not only annoying but can also have dangerous consequences, because over time they can result in damage to materials and structures, for example in shipping vessels. Engineers therefore go to great lengths to find solutions capable of damping the amplitude of such vibrations. One such solution involves the use of adaptronic systems. Detailed planning is needed to ensure that dampers exhibiting the required characteristics are installed in precisely the right places. The Mechanical Simulation Toolbox developed by the Fraunhofer Institute for Structural Durability and System Reliability LBF is a software tool that enables adaptronic systems for this type of application to be developed more efficiently. It also enables operating parameters to be optimized from the outset, saving time and costs by eliminating the need for expensive prototypes.

Protecting engine components against frictional wear 3

Friction is the worst enemy of engine designers because it causes wear that reduces engine life and increases fuel consumption, leading to higher operating costs and environmental pollution. A laser arc welding process co-developed by the Fraunhofer Institute for Material and Beam Technology IWS in Dresden enables moving engine parts to be coated with a superhard carbon material that significantly reduces frictional wear. The process has already been adopted or is being tested by several major auto manufacturers. Fraunhofer IWS was awarded the 2016 EARTO Innovation Prize for this work.

PRODUCTION AND SERVICES

Protective coating for 3D components

Components are often exposed to extreme stresses in the course of their operation, due to the fact that greater temperatures and pressure can boost a machine's efficiency. Here, coatings have a crucial role to play in terms of a component's functionality and durability. High-performance coatings protect components against wear and chemical and thermal degradation, and minimize the friction losses in moving systems. In order to extend these coatings to complex three-dimensional components, the Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology FEP joined forces with CREAVAG GmbH to develop and build the NOVELLA test facility. With its high coating rates, the facility offers research partners and industry customers a unique opportunity to conduct feasibility studies and coating-related material development.

Production technology for medicine 1

A person is an individual – and it is no different when it comes to medicine. Every person reacts differently, has their own specific needs and, in many cases, requires tailored treatment or "replacement parts." This includes bone implants, replacement teeth, surgical instruments and microreactors. Now, researchers have developed an extremely flexible additive manufacturing technique that allows these healthcare materials to be produced to individual requirement in almost any design. Funded by the European Union, the CerAMfacturing project began in October 2015 and will run for a total of three years. Partners from industry and research are working together on the instruments and components of personalized medicine. They are developing surgical tools such as grippers and forceps, implants for knee and back vertebrae, as well as heatable treatment agents for personalized joint therapy. The Fraunhofer Institute for Ceramic Technologies and Systems IKTS in Dresden is coordinating the project, and is responsible for the development of additive manufacturing techniques.

1

2

More robots for SMEs

Already, robots are an integral part of the production process. But with increasing numbers of variants, quality requirements, and small batch sizes, it is getting harder and harder to employ conventional robot systems economically in small and medium-sized enterprises (SMEs). With their time-consuming setup, separation from people and inflexible programming, they simply do not fit with SMEs' customer-oriented production process. In a bid to provide these companies with more automation options, the SMErobotics initiative has developed smart robot systems tailored specifically to the needs of SMEs. These systems work with and alongside their human colleagues, without the need for a protective barrier. New intuitive programming techniques and robust, sensor-monitored program execution allows companies to make efficient use of robot systems even when the number of product variants is high, and to further improve the performance and quality of their products. Coordinated by the Fraunhofer Institute for Production Engineering and Automation IPA, the EU-funded project has supplied the technological foundation for system integrators and suppliers of innovative robot systems, as well as directly implementable applications for SMEs.

Polished down to the last nook and cranny

Complicated components, too, must be ground, rounded and deburred – inside and out. It might be 3D printed metallic workpieces, medical implants, automotive injector nozzles, cooling channels in turbine blades or tools in which an erosion layer has to be removed. Flow grinding is well suited to this task but, in the case of complex interiors, one sometimes has to contend with dead-flow zones. Help is now on hand from the magneto-rheological flow grinding technique, developed by the Fraunhofer Institute for Mechanics of Materials IWM in a BMBF-funded joint research project together with industry partners and the Fraunhofer Institutes IPK and IKTS. In this process, the abrasive particles are moved along not only by the flow pressure, but also by magnetic fields. Researchers can use sophisticated simulation programs to control and plan the overall effect.

A machine to harvest cauliflower 2

When a machine harvests vegetables, it normally takes everything indiscriminately – including, in the case of cauliflower, unripe heads. As a result, it has always been human laborers who have ended up taking on this wearisome task. Harvesting cauliflower is particularly time-consuming because the white flower head is hidden beneath several leaves. Each time, the harvester must push these leaves to one side to decide whether the flower head is ripe for harvest. Every two to three days, they comb the field – up to five times in total – until the last cauliflower has been harvested. In the future, the VitaPanther machine is set to fully automate this selective harvesting process. It is being developed by the Fraunhofer Institute for Factory Operation and Automation IFF together with ai-solution GmbH and five other cooperation partners. The machine uses hyperspectral cameras to determine the maturity of the plant by its covering leaves, allowing it to make the correct harvesting decision. There are plans to develop further specialized harvesting machines for other vegetables.

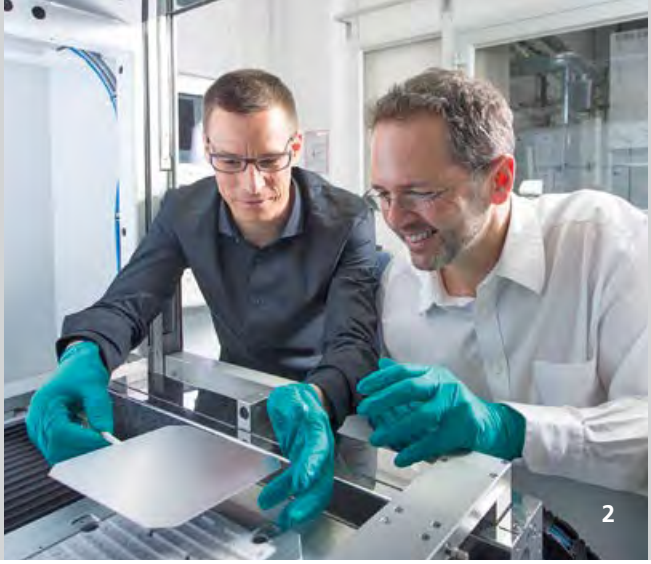
1

Cutting costs in turbine manufacturing 1

Blisks (blade integrated disks), in which blades and disks are milled from a single part, are often used in engine and turbine construction. These integrated designs mean significantly more complex geometries and more demanding machining tasks. Likewise, the utilization of new materials also calls for continuous development of manufacturing techniques. In order to ensure economic viability, techniques must be constantly assessed for their application potential, and costs balanced against each other. Together with their colleagues from RWTH Aachen's Machine Tool Laboratory WZL and EMAG ECM GmbH, researchers at the Fraunhofer Institute for Production Technology IPT in Aachen have compared various process flows from both a business and technology perspective. The result is a specially developed piece of software that makes it possible to calculate resource requirements. As a result, users can determine not only the manufacturing costs, but also the primary energy requirement and CO_2 balance. The comparison indicates that an innovative process flow can cut costs by half depending on the batch size.

Laser to stamp microstructures

Surface nano- or microstructures can significantly alter the properties of components or products. Depending on the material and the specific requirements, a whole range of techniques are used to produce functional surfaces. Lasers offer great flexibility in this regard. In a bid to improve their performance in surface structuring, the research team headed by Prof. Andrés Lasagni from the Fraunhofer Institute for Material and Beam Technology IWS has been using interference patterns from several laser beams. This makes it possible to generate millions to billions of microstructures in one go. For his innovative work, Prof. Lasagni was awarded second place in the Berthold Leibinger Innovation Prize 2016 together with Prof. Frank Mücklich from Saarland University.



2

ENERGY AND RAW MATERIALS

Joseph von Fraunhofer Prize

Solar cell technology revolution 2

Today, photovoltaics are established worldwide and are one of the pillars of a sustainable energy supply using renewable energy. In order to cut the costs involved in generating electricity, the priority is on achieving greater solar cell efficiency and reduced production costs. As we speak, around the world a new generation of highly efficient silicon solar cells, named the "Passivated Emitter and Rear Cell (PERC)," is entering into production. Dr.-Ing. Ralf Preu (right) and Dr. Jan Nekarda (left) have played their part by inventing and bringing to industrial maturity a highly efficient technique for generating local contacts – the "Laser Fired Contact (LFC)" process. In this process, the rear-side electrode is melted in situ using individual laser pulses, and electrically connected to the silicon wafer by means of an insulation wafer approximately 120 nanometers thick. It is a crucial process that enabled the first mass production of a PERC solar cell in 2012, paving the way for the global technology revolution we are witnessing today. In recognition of their work, the researchers were awarded the 2016 Joseph von Fraunhofer Prize.

Hydrogen from waste heat

With pyroelectric crystals, externally applied temperature changes lead to an electrical charge of the crystal surfaces. The resulting absorption of charge carriers from the environment to compensate for the surface charges can be harnessed to generate hydrogen from water. At the Fraunhofer Technology Center for Semiconductor Materials THM in Freiberg, researcher Rico Belitz is pursuing an approach whereby pyroelectric crystals are exposed to a temperature change in direct contact with water, allowing waste heat from industry or heating systems to be used to generate hydrogen. The pyroelectric material he has chosen is barium titanate ($BaTiO_3$), which is tetragonal and pyroelectrically active in the temperature range

1

between 0 and 120 °C – making it ideally suited to the temperatures encountered in the industrial waste heat generated by recooling systems or the return flow of heating systems. For demonstrating the efficacy of this principle at the spring meeting of the European Materials Research Society, Belitz was awarded a "Best Poster Award."

Biogas from straw 1

So far, straw has been regarded as difficult to use in biogas plants. But alongside traditional commercial fertilizers, this biological waste material is potentially one of the most sustainable, inexpensive and – with at least 8 million tons being produced annually – most available sources of biomass. What is more, straw could be used much more effectively and with much less environmental impact in biogas plants as opposed to in combustion processes. Unfortunately, it is prone to forming floating layers in the fermenters, which hinders the biogas process. On top of that, straw bales are extremely bulky to transport, and take up a lot of space considering their mass, driving up costs. The straw biogas pellets developed at the Fraunhofer Institute for Ceramic Technologies and Systems IKTS in Dresden are heavily compressed, both chemically speaking and in terms of the space they take up, thus providing a solution to these problems. In the future, these pellets will offer an alternative input platform for biogas plants. In recognition of his successful development work within the EFFIGEST research project, Björn Schwarz of Fraunhofer IKTS was awarded the German agriculture industry's 2016 prize in the research category, which comes with prize money of 10,000 euros.

Safe use of hydrogen

Hydrogen has an important role to play in the transition to a new energy economy, since it is able to serve as a storage medium and compensate for fluctuations in energy consumption and generation. In order to develop its strength as a power-to-gas resource and enable it to contribute to a stable energy supply, there is a need for a safe and reliable technology infrastructure of pipelines and plant technology. Naturally it would be beneficial to make use of existing natural gas pipelines and storage facilities to distribute and store hydrogen. The problem is that hydrogen can over time reduce the strength and toughness of materials. With hydrogen embrittlement, hydrogen atoms penetrate into the structure of metals and weaken the bonds, which can cause cracks and fractures. For this reason, researchers at the Fraunhofer Institute for Mechanics of Materials IWM are working with partners to develop PIMS, a design, evaluation and monitoring system.

2

Effective forecasting – stable grid

Sun and wind can supply a lot of energy, but not on a regular basis. This is a problem for the power grid, in which the supply of electricity must always equal demand. While network operators do have a good idea of exactly when and how much consumers will require over the course of the day, how much power is fed into the grid from photovoltaic and wind facilities can be only roughly approximated. One way to mitigate this problem would be to develop a reliable forecasting mechanism encompassing energy-relevant weather conditions, critical climate situations such as high fog fields and low-pressure areas, and the quantity of wind and solar power being fed in at specific points on the grid, using the information to forewarn and manage the other suppliers involved. In the EWeLiNE project, researchers from the Fraunhofer Institute for Wind Energy and Energy Systems IWES in Kassel are working with the German Weather Service to develop better forecasting models covering the generation of renewables.

Lightweight engineering for rotor blades 2

Offshore wind turbines are getting bigger and bigger; wind turbines with rotor blades of up to 80 meters in length and a rotor diameter of more than 160 meters are designed to ensure maximum energy yield. Since the length of the blades is limited by their weight, there is a need to develop lightweight systems made of extremely durable materials. Reducing weight facilitates the assembly and dismantling process as well as the stability of the installations at sea. Together with industry partners, Fraunhofer researchers are developing high-endurance thermoplastic foams and composites that make the blades lighter and recyclable. In the WALiD project, researchers at the Fraunhofer Institute for Chemical Technology ICT are exploring a brand new blade concept. This involves a first use of thermoplastic, meltable plastics for the blades – materials that can be efficiently processed using automated production lines. The goal is to separate out the glass and carbon fibers at the end and to reuse the thermoplastic matrix material.

Storing power underwater

One important aspect in the use of renewables is to match power generation with the time at which it is needed. Prof. Horst Schmidt-Böcking from the Goethe University in Frankfurt am Main and Prof. Gerhard Luther from the University of Saarbrücken have invented an innovative storage system. The system is based on spherical pumped storage plants that use the water pressure at great depths to pump out large hollow containers using excess power, and then harness the high pressure of the water flowing back to generate power when required. As part of the StEnSea (Stored Energy in the Sea) project, funded by the German Federal Ministry for Economic Affairs and Energy (BMWi), researchers at the Fraunhofer Institute for Wind Energy and Energy Systems IWES in Kassel brought the idea to application maturity. The system was successfully tested at the end of 2016 in a model experiment at Lake Constance.

NEW INITIATIVES AND HIGH PERFORMANCE CENTERS

Industrial Data Space e.V.

Supporting digital innovation

As digitalization sweeps through our personal and professional lives, it brings with it a research and business dynamic that thrives on the potential of data connectivity and big data analytics. This also increases the need for data protection, the secure exchange of data and safeguarded ownership of data as an economic asset. In a systematic bid to find solutions to these and other issues, the German Federal Ministry of Education and Research (BMBF) is funding the Fraunhofer-Gesellschaft's "Industrial Data Space" in this up and coming field.

The initiative targets the secure and self-determined exchange of data as a prerequisite for offering smart services and innovative business models. This will be based on a still-to-be-developed reference architecture model – known as Blaupause – that will pilot the concepts for practical implementation in use case scenarios that will involve industry partners organized within the Industrial Data Space e.V. The association was founded in Berlin on January 26, 2016 and now numbers 42 members from eight countries. The coordinator and point of contact is Prof. Boris Otto from the Fraunhofer Institute for Software and Systems Engineering ISST. A joint white paper was presented at CEBIT 2016 to German Federal Minister of Research Prof. Johanna Wanka.

Since then, Fraunhofer has developed and incorporated further aspects such as the Materials Data Space and the Medical Data Space. This provides the initiative with a broad foundation from which to support the ongoing digitalization of industrial processes.

Research Fab Microelectronics Germany

Fresh impetus for the semiconductor and electronics industry

Micro- and nanotechnology is a key technology for almost all relevant industry sectors in Germany and in Europe, which is why it must be kept at the cutting edge. The German federal government has contributed to the foundation of an "Important Project of Common European Interest (IPCEI)" for German industry.

Back in January 2016, the Fraunhofer Group for Microelectronics laid out a strategy for the long-term renewal of microelectronics infrastructure. Together with the Leibniz institute Innovation for High Performance Microelectronics (IHP) and the Ferdinand-Braun-Institut – Leibniz-Institut für Höchstfrequenztechnik (FBH), the group has developed the strategy into an overall concept for equipping business-related microelectronic research facilities in Germany. The new, customer-focused organization has been operational since April 6, 2017 as the "Research Fab Microelectronics Germany (FMD)." While the IPCEI is focused on the development of industrial production capacity, in the microelectronics research factory Fraunhofer and Leibniz will be concentrating on the accompanying research and development. The German Federal Ministry of Education and Research is supporting the initiative with funding of 280 million euros for Fraunhofer and 70 million euros for Leibniz.

The cross-institute research focuses on four future-oriented technology areas – "Silicon-based technologies," "Compound semiconductors and special substrates," "Heterointegration" and "Design, testing and reliability."

INDUSTRIAL DATA SPACE ASSOCIATION

FORSCHUNGSFABRIK MIKROELEKTRONIK DEUTSCHLAND

High Performance Centers

Optimum application of research

The idea behind Fraunhofer's High Performance Centers is to contribute to the sustainable development of research locations with strong universities at their heart. The Centers are designed to ensure the close alliance of university and non-university research with industry, and to provide thorough roadmaps for the partners involved covering Research and Teaching, Education and Training, Career Paths and Recruitment, Infrastructure, Innovation, and Knowledge Transfer. High Performance Centers maximize the utilization of research findings in all sectors of the economy, which benefits not only spin-offs and young technology companies, but small and medium-sized enterprises as well.

Following the pilot phase in 2015 with High Performance Centers in Freiburg, Erlangen and Dresden, in 2016 twelve further High Performance Centers got up and running, and are presented for you below.

Digital Transformation

The goal of the Berlin Center for Digital Transformation is to establish Berlin with its distinct and strategically valuable core competency in digital connectivity as a leading center both in Germany and internationally. The High Performance Center offers an application-oriented, inter- and cross-disciplinary platform for cross-sector systemic research and collaboration with regional and supraregional companies in the core digitalization areas of production and Industrie 4.0, mobility, health and medicine, critical infrastructure and energy. There are also four transfer centers to demonstrate prototype scenarios.

Photonics

The High Performance Center Photonics in Jena has been set up to facilitate collaboration in photonics across the sectors of ICT, production, automotive, aerospace, security and defense. At the heart of its activities is the collaboration of universities, industrial enterprise and the Fraunhofer Institute for Applied Optics and Precision Mechanics IOF in joint research projects addressing topics such as fiber lasers, high-performance optical sensors and the projection and imaging systems of the future. The High Performance Center combines top-quality research with teaching, education and training within the Fraunhofer Graduate Research School for Applied Photonics. This enables interdisciplinary dialog between life sciences and photonics in pilot projects.

Chemical and Biosystems Technology

The strategic goals of the High Performance Center Chemical and Biosystems in Halle and Leipzig are to research and optimize the process chains of the plastics processing, chemical, biotechnology and biomedical industries – from the raw material to the finished product. The aim is to come together to create synergies in the areas of chemistry, chemical engineering, biotechnology and biosystems engineering.

Mobility Systems 1

The High Performance Center Mobility Systems in Karlsruhe exists to develop and implement technologies and techniques for forward-looking mobility solutions that will demonstrate their viability in the region and can be rolled out worldwide. This encompasses networked, collaborative driving schemes as well as automated and autonomous mobility. A new mobility training concept bolsters the appeal of Karlsruhe as a city and is intended to turn the city into a leading teaching, training and further education center in the area of mobility.

Secure Connected Systems

With the High Performance Center Secure Connected Systems, Fraunhofer wants to turn the Munich metropolitan area into a leading center for the Internet of Things. The High Performance Center provides companies with a platform for cross-sector and interdisciplinary research and collaboration in core areas affected by digitalization. The Center's key pillars of research are smart sensors, tactile connectivity, data analysis and processing, and integrated security. It hopes to research and develop demonstrably more secure cyberphysical systems. Projects are split among the important social topics of Industrie 4.0, connected mobility and senior-friendly living.

1

Simulation and Software-based Innovation

The High Performance Center Simulation and Software-based Innovation in Kaiserslautern provides an application-oriented, inter- and cross-disciplinary platform for pre-competitive cross-sector research and collaboration in partnership with regional industry. The application center for MSO-based process technology targets the chemical/pharmaceutical/environmental sectors, while the center for the digital commercial vehicle industry targets the automotive sector and mechanical engineering, and the smart ecosystems center targets the energy sector and ICT technologies. R&D labs focusing on the topics of "Applied System Modeling," "High Performance Computing and Big Data" and "Algorithms and Software Systems" support the application centers with expertise in mathematical and computer science. The High Performance Center harbors a great deal of potential in generating valuable intellectual property and helps bolster the regional economy through high-tech spin offs.

Smart Production

Currently in the setup phase, the High Performance Center Smart Production in Chemnitz will focus on building up an interdisciplinary, reputation-building cluster that incorporates stakeholders from production research in the state of Saxony, research into materials and lightweight engineering, as well as electronic nanosystems in developing strategic research priorities and establishing a sustainable and prominent position internationally. Areas for action include 3D manufacturing technologies for functional integration, self-adapting autonomous systems and product-oriented auto-configuration of production flows. The High Performance Center Smart Production offers a focused and expandable platform for production research in Saxony and particularly in Chemnitz, aiding in the structuring of basic research and the transfer of successful techniques into production practice. With a broad range of influence, it will act as a central point of contact and incubator for the regional economy, particularly for small and medium-sized enterprises.

1

DYNAFLEX – Dynamic, adaptive and flexible processes and technologies for the transition in energy and raw materials

The High Performance Center DYNAFLEX has been set up to develop the greater Ruhr region into the leading national platform for process dynamics and adaptivity in energy and raw-material applications. Top-quality research, joint stakeholder dialogs, roadmapping, new use strategies, and a new direction and impetus for teaching form the basis for a long-term strategic partnership between the strong partners from research and industry, who are also important stakeholders in the transition in energy and raw materials. Research work is focusing on the "DYNAFLEX Fundamentals" foundation and methods platform as well as an application-oriented project arm called "DYNAFLEX Application." The plan is to use mathematical modeling and simulation to understand energy and raw-material supply systems in fluctuating conditions, allowing for more effective planning and operation.

Logistics and IT

The High Performance Center Logistics and IT plans to undertake two pilot projects as specialist research projects: "Digitalization" and "Autonomous Systems." The first project has to do with information logistics. Here the aim is to use a shared enterprise lab based on the architecture model of the Industrial Data Space® to identify information logistics use cases for the areas of "Real Life Evidence Data" and "Compliance for highly decentralized supply chains," and to develop prototypes implemented in test beds. The second project has a focus on agile ad hoc intralogistics systems that define the logistics hub of the future. This consists of highly flexible transport, warehousing and handling components that draw on innovative software technologies to come together as adaptable intralogistics systems.

Connected Adaptive Production 1

The primary focus of the High Performance Center Connected Adaptive Production is the development, systematic introduction and use of modern digitalization technologies for forward-looking industrial production systems and value creation chains according to the principles of Industrie 4.0. Within the framework of the overarching "Digitalization and connectivity" R&D module, the Center develops concepts for completely connected, adaptive production in the areas of "Smart Manufacturing Platforms," "Big data," "Adaptive process chains" and "Process simulation and modeling." All developments are validated in six pilot lines and implemented for demonstration purposes in the areas of energy, mobility and health using representative process chains. The integration of secure and commercially independent cloud computing systems such as the "Virtual Fort Knox" as well as open communication standards such as OPC-UA gives industrial companies an incentive to participate in the development work.

2

Security and Privacy in the Digital World

As the Internet of Things and Services grows in popularity, so too does the risk of cyber attack. So far, the technical development process has most often restricted itself to the functional aspects, while issues of cybersecurity and data privacy are confronted only further down the line. This leads to products and services that are not secure enough, or cybersecurity that is much more expensive than it ought to be. For this reason, a key goal of the High Performance Center Security and Privacy in the Digital World (LZSD) is to factor in cybersecurity and data protection at an early stage of the application development process. To this end, the LZSD will be collaborating with representatives from business as well as with other research facilities in interdisciplinary, synergistic work.

Translational Biomedical Engineering 2

The German state of Lower Saxony has decided to pursue a focus in medical technology for the Hannover-Braunschweig region. The "Translation Alliance in Lower Saxony (TRAIN)" is a local collaboration platform for closed-loop competency and value creation chains that accelerates the transfer of clinical ideas into clinical testing via experiments, technology and training, thereby cutting the time to market maturity. As a provider of research services with great credibility within industry, the High Performance Center Translational Biomedical Engineering has set itself the goal of completing the translation chain with "Conformity-based manufacturing and test method development." Particular attention is to be paid to combined products in which medical products merge with pharmaceuticals – and, therefore, from a regulatory standpoint, represent new territory.

AWARDS 2016

Alongside numerous prizes for first-class research, Fraunhofer researchers were also honored with some particularly prominent national and international awards for advances in applied research. We pay tribute to their achievement.

ERC Starting Grant: Security technology that adapts to people

The European Research Council has set itself the task of bolstering high-quality research in Europe through attractive funding programs. The aim is to support and expand Europe's leading position in science and research. Prof. Matthew Smith of the Fraunhofer Institute for Communication, Information Processing and Ergonomics FKIE in Bonn and Wachtberg and also the University of Bonn's Institute for Computer Science has been awarded the ERC Starting Grant, which comes with 1.5 million euros of research funding from the European Research Council to make IT security more user friendly.

Smith's research focus is in "Usable Security." In his new research project, he hopes to push past the current limits in the operability of computer systems. These have tended to place the emphasis on developers and administrators; now, in contrast, Smith will be putting the focus firmly on the human factor. His work aims to provide users with security-relevant information presented simply and ergonomically enough to ensure that their ability to act and their protection in cyber-space is at its maximum possible level.

Currently established SIEM (Security Information and Event Management) solutions are extremely complex and not user friendly. One of the main goals is therefore to boost system administrators' ability to act by providing a visual overview of information already available. In order to avoid mistakes in the future, technology should adapt to the user, and not the other way round.

2

German IT Security Prize: Protection for mobile devices

With prize money totaling 200,000 euros, the German IT Security Prize is one of the most generous privately funded business awards in Germany. The jury is made up of recognized IT security experts from research and industry. Through the award, the Horst Görtz Foundation aims to help consolidate and further the standing of IT security "made in Germany."

The 2016 German IT Security Prize went to (from left) Dr. Steven Arzt, Dr. Siegfried Rasthofer and Marc Miltenberger of the Fraunhofer Institute for Secure Information Technology SIT and the Technical University of Darmstadt, and Prof. Eric Bodden of the Fraunhofer Institute for Mechatronic Systems Design IEM and the University of Paderborn's Heinz Nixdorf Institute. Their "Harvester" software helps generate an overview of the security situation by automatically extracting security-relevant information from Android apps – even from apps that actively defend themselves against analysis using cloaking techniques.

Users can take advantage of the Harvester software's analysis to find out which servers an app connects to or what data are encrypted inside the app. Security analysts and prosecutors will also be able to use the app to better trace app communication patterns. The insights gained from this sort of analysis help to identify malicious online apps faster and therefore to temper the incidence of theft of personal data.

PEOPLE IN RESEARCH

Enthusiasm and expertise are the lifeblood of our success. Here we spotlight six researchers as a representation of the many others who are doing top-rate work and delivering first-class results.

DIPL. RER. COM. SABRINA LAMBERTH-COCCA

Graduate in Information Systems and Communications | Research fellow and project manager at the Fraunhofer Institute for Industrial Engineering IAO in Stuttgart

Communication is a highly dynamic process, and one that demands flexibility. The ancients realized that flexibility in body and flexibility in mind were closely related, and it's a principle that Sabrina Lamberth-Cocca lives to the full. As she says, keeping moving "keeps the mind supple." Away from work, she likes to dance, make music and play sports, while in her career she prefers to pursue unusual, challenging and creative directions over the path well trodden. As a result, it was only natural that she should decide to study communication sciences – a field that demands a high degree of personal dynamism.

While studying at the University of Hohenheim, Sabrina was able to cultivate another passion of hers, language learning. She completed a semester abroad at Jyväskylä University in Finland, providing her with the opportunity to develop a particular interest in the Finnish and Scandinavian languages. Many people view languages as a necessary labor to improve their career prospects, but for Sabrina they are primarily an aspirational, mind-training hobby.

These days, communication has a significant technological component given the prominent role of digital technology. This led Sabrina to pursue a specialization in information and communications technology – resulting in her first contact with the Fraunhofer Institute for Industrial Engineering IAO.

The interest was mutual, and there followed a diploma thesis on cloud computing undertaken at Fraunhofer IAO, finishing with a job as a research associate, first at the University of Stuttgart's Institute of Human Factors and Technology Management (IAT) and then at its partner institute, Fraunhofer IAO. She now works in the "New service development" team in the field of service engineering, electromobility services and agile development techniques.

What Sabrina values about Fraunhofer is exactly what we aim to encourage here: "I like having the space for ideas and innovation. Particularly in longer projects, there's a real opportunity to try out a new research technique or an innovative approach." One of these is the Scrum method – an additional qualification that Sabrina obtained herself. The technique draws on the insight that complex projects can seldom be planned out in detail in advance. Instead, milestones along the way allow for reorientation, resulting in a much more effective overall process.

Even with these sorts of innovative approaches, you still have to be ready to tread new paths. Flexibility is far preferable to rigid adherence to earlier plans. It's a process that seems almost made for people like Sabrina, who have directed their whole lives to the flexible training of both body and mind.

PROF. DR.-ING. HABIL. STEFAN HIERMAIER

Graduate in aerospace engineering | Director of the Fraunhofer Institute, for High-Speed Dynamics, Ernst-Mach-Institut, EMI in Freiburg, and Director of the Institute of Sustainable Systems Engineering (INATECH) at the Albert Ludwig University Freiburg

Security technology has many aspects, and aerospace is one of the most fascinating areas of application. Aerospace presents its own unique technical challenges. Particles of debris, for instance, orbit in space many times faster than the muzzle velocity of a firearm. This presents a real danger for satellites and spacecraft – and just the challenge engineer Stefan Hiermaier is looking for.

Stefan studied aerospace engineering at the University of the German Armed Forces in Munich. Back then, his dissertation focused on the fatal impact of space debris on spacecraft. The Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut, EMI possesses the best facilities in the world for conducting experiments into these kinds of processes, and so it was inevitable that the high-speed dynamics specialist would end up at Fraunhofer. Stefan has been working at Fraunhofer EMI since 1996, becoming deputy director in 1998. In 2008, he was called to the chair of High-Speed Dynamics at the University of the German Armed Forces in Munich – the first of its kind – and in 2015 he took over as director of Fraunhofer EMI. One real highlight from his work was the development of a protective shield for the International Space Station (ISS). Working together with the Italian company Alenia Spazio, his team developed a lightweight construction that cushions the impact of space debris up to a diameter of 5 centimeters and a speed of 20 kilometers per second – 72,000 kilometers per hour. The system was subsequently built and now orbits the Earth.

High-speed dynamics as one's life's work – it doesn't just sound exciting, it is in fact extremely varied. Here on Earth, we are all potentially affected by these sorts of events. Impact absorption in the case of an accident is also part of the investigations carried out by Fraunhofer EMI on behalf of industry. Here, Stefan has developed an X-ray technique that covers the institute's whole-vehicle crash research facility. This makes it possible to take snapshots of individual parts on the interior of the vehicle during the deformation process. For manufacturers, the goal is to boost safety while reducing vehicle weight. Reducing weight also means reducing fuel consumption, and touches on another focus of Stefan's work: sustainability. Since 2015, he has also headed up the newly founded Institute of Sustainable Systems Engineering (INATECH) at the Albert Ludwig University Freiburg.

In so doing, Stefan stakes his claim at the other end of the dynamics speed scale, since with sustainability everything happens much more over the long term. Effects – environmental changes, holes in the ozone layer, climate change – can be seen and felt only years or even generations later. As father to a daughter, it is an additional motivation for him to make an effort to move things in the right direction in his work.

PROF. DR. RER. NAT. HABIL. RALF B. WEHRSPOHN

Graduate in physics | Director of the Fraunhofer Institute for Microstructure of Materials and Systems IMWS in Halle and Professor of Microstructured Material Design at the Martin Luther University Halle-Wittenberg

Is impatience a virtue? Some say that impatient people are a thorn in the side of those around them, while others point to the benefits when the eager drive things forward and bring momentum to projects and structures. As a self-confessed impatient person, Ralf Wehrspohn can see both the positives and the negatives.

If you ask his employees and the research community, you get a resounding answer: Ralf Wehrspohn, Director of the Fraunhofer Institute for Microstructure of Materials and Systems IMWS, is exactly the person for the job. That is because he drives the institute forwards. Structures and portfolios are modified, and there is no waiting around for success. Since the physicist took the helm, the business of the institute has blossomed, and its staff has tripled.

On a personal level, too, Ralf has reaped the rewards of his unstinting effort. Highlights include a doctorate at the renowned École Polytechnique in France, the development of the first flat screens at Philips in England, postdoctoral qualification at the Martin Luther University Halle-Wittenberg, a professorship at the University of Paderborn, selection as one of "the 101 most innovative minds in Germany" by the Financial Times Germany, and the German Research Foundation's Heinz Maier-Leibnitz Prize – and these achievements have undoubtedly supplied the ambitious physicist with additional motivation. Then came his appointment as Director of a Fraunhofer Institute – the youngest institute director.

Ralf recalls how his predecessor Prof. Katzer told him at the time that the job was "the best you could get without being the Pope. Then I told him that since I was a protestant, it would be the best job bar none. And so it has proven."

Ralf's work focuses on materials research – a topic that he believes doesn't get the attention it deserves either in research or in the public imagination. He has resolved to change this situation, since 70 percent of all innovations in Germany have to do with materials. As a result, extra research here is of great benefit to society and the economy. Since being appointed vice chairman of the Fraunhofer Group for Materials and Components – MATERIALS, and spokesman for the Materials Data Space initiative, he has found even more of a reception for his ideas in this regard.

The materials researcher is convinced of the need to engage the public, and his communication efforts are voluntary as well as professional. He was involved, for instance, in science2public, an initiative that aimed to establish short films as a way to communicate research, and helped set up several related film festivals. Currently, he is working on allying art and science within the Fraunhofer-Gesellschaft, for instance through the "Art and science in dialog" event, which took place in the Fraunhofer Forum in June 2016. Thus, Ralf's energy and enthusiasm bears fruit far beyond his own institute – and it seems that the opening question is answered, at least for him.

PROF. DR.-ING. INA SCHIEFERDECKER

Mathematics graduate | Director of the Fraunhofer Institute for Open Communication Systems FOKUS in Berlin, Professor for Quality Engineering of Open Distributed Systems (QDS) at the Technische Universität Berlin

Whether you call it an evolution or a revolution, there is no doubt that digitalization is transforming our lives. It impacts on our working life, creates new business models and revolutionizes the way we travel. For Ina Schieferdecker, though, it also has an ethical dimension, and she is one of the voices calling for a digitalization council that would examine the impact of digitalization from an interdisciplinary perspective.

Ina's career began with studies in informatics. Her diploma thesis received the Tiburtius Prize – along with a recommendation to the Berlin universities' graduate group for "Communication-based systems." Her first professorship at the TU Berlin and her research work were supported in large part by the Alfried Krupp Award for young academics, which eventually led Ina back to the TU Berlin via a professorship at the FU Berlin – this time to head up Fraunhofer FOKUS, where she had previously led several competence centers. In this post, she is able to bring her full range of experience to bear, including stints abroad in the U.S., Norway and Australia. In 2016, Ina received the EUREKA Innovation Award, which she accepted as lead on the DIAMONDS project. DIAMONDS used numerous case studies to develop automated model-based security testing techniques of industrial relevance for security-critical systems.

Ina is well aware that, for some time now, the functionality and security of digital systems has no longer been a question of individual industries or manufacturers; these days, critical infrastructure is controlled and managed using precisely these sorts of systems. Industrie 4.0, energy and supply networks, communication and urban infrastructures – they all need to function reliably. Their resilience, that is to say their resistance to disruptions, failures and attack, has become an existential question for technology-reliant societies. As a result, the scientist has made the focus of her research into a key part of institute strategy, making important contributions with initiatives such as BSI CertLab and SINTEG WindNODE. She sees her role in a social context: "Digitalization is so fundamental that we need to make even more of an effort to consciously shape it in line with the democratic and ethical principles of our society."

Since October 2016, Ina has sat on the German federal government's scientific advisory panel on global climate change, helping as she can through the work of Fraunhofer FOKUS. At the moment, she is working on a proposal for the German Federal Ministry of Education and Research (BMBF) to set up an Internet institute based in Germany; this institute would devote itself to the societal, socio-technological and political aspects of the digital transformation – and, in line with her ideas, both its program and its staff will stand for diversity. The institute would also be sure to focus on an interdisciplinary consideration of the ethical issues.

PROF. DR. RER. NAT. HABIL. ALEXANDER BÖKER

Chemistry graduate | Director of the Fraunhofer Institute for Applied Polymer Research IAP in Potsdam and Full Professor of Polymer Materials and Polymer Technology at the University of Potsdam

Polymers can easily become a lifelong study for an aspiring researcher, since their significance can hardly be overstated. Almost everything we call plastic is made up of polymers: packaging, toys, car parts, appliances. And then there is also lignin, cellulose, starch and chitin: polymers that nature uses to build and structure organisms. Even proteins have a polymer structure, that is to say, they are made up of many identical smaller units. No wonder, then, that a creative chemist such as Alexander Böker is enraptured by polymer chemistry. Polymers are the building blocks that form and shape our natural and fabricated surroundings, and so the impact is correspondingly great when a new breakthrough is made in the field.

Having studied chemistry at the Johannes Gutenberg University in Mainz and Cornell University in Ithaca in the state of New York, Alexander completed his doctorate at the University of Bayreuth. There followed another stint as a researcher in the U.S., which the young chemist found so rewarding that he decided to commit his career to research and begin his post-graduate qualification, despite offers from industry. He was subsequently appointed Lichtenberg Professor of Colloid Chemistry in Bayreuth – a milestone in his research career. Serving seven years as deputy scientific director of the DWI – Leibniz Institute for Interactive Materials and Professor of Macromolecular Materials and Surfaces at RWTH Aachen, he became well known as a scientist and research coordinator.

Because of the universal importance of his research in polymer chemistry, an affinity for application was already part of Alexander's makeup. So when he was asked to head up the Fraunhofer Institute for Applied Polymer Research IAP, he didn't need long to make up his mind. As far as he is concerned, Fraunhofer offers the optimum work environment: "When you look past the constant pressure to acquire projects, the Fraunhofer environment is really something special. Nowhere else do you have the same opportunity to implement and play with your ideas."

It is an enthusiasm for his work that Alexander shares with the whole institute. Undoubtedly, this has something to do with the impact of polymer chemistry, since modified polymers are found in almost everything that we buy, use and consume on a daily basis. Fraunhofer IAP has plans to make even more targeted use of polymers. One way of doing this is to make identical molecule replicas as nature does with DNA. Even DNA, that carrier of a living organism's entire blueprint, is a highly specialized polymer that is able to replicate itself. Colloidal polymers that are created in a similar way transmit light of a single wavelength in just one direction – an effect that can be used to store and manage information, for instance. This opens up the possibility of extremely efficient display and storage media components in the context of Industrie 4.0. The potential is huge, and evidently the European Research Council agrees, since in 2015 Alexander was awarded the 1.9 million euro ERC Consolidator Grant – a resounding confirmation of the potential both of the scientist and of his ideas.

DR. RER. NAT. KATRIN TEICHERT

Mathematics graduate | Researcher at the Fraunhofer Institute for Industrial Mathematics ITWM in Kaiserslautern

Often, there's not all that much to separate damage and good. Doctors are particularly familiar with this truth, since they are constantly weighing up the treatment benefits against the harmful side effects of a specific surgery or medicine. Radiotherapy is a good example, whereby radiation is applied to cancerous tissue, damaging the DNA of cancerous cells. The aim is to destroy the unhealthy tissue while preserving the healthy tissue as far as possible.

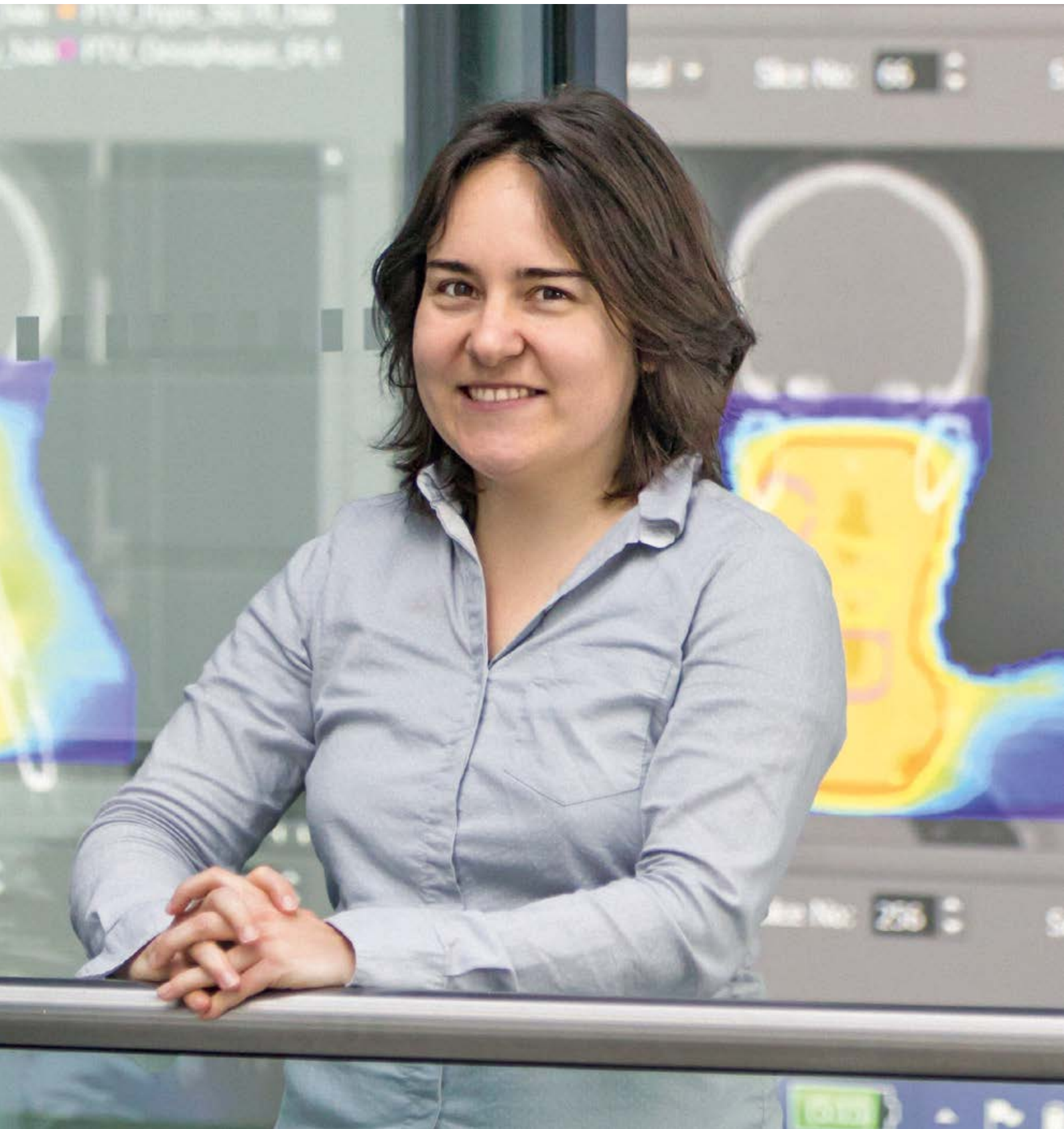
Katrin Teichert knows all about the problem – and she thinks she knows the way to solve it. She works as a mathematician at the Fraunhofer Institute for Industrial Mathematics ITWM and worked on the project that developed a fantastic piece of software that helps doctors with precisely this dilemma. Planning a course of treatment is a highly complex task that calls for modifications to individual parameters to gauge the respective effect. The result was a piece of planning software that features multi-criteria treatment planning, allowing even physicians and doctors who are unfamiliar with this technology to determine the best course of treatment for their patient – and much faster than before.

Katrin studied mathematics at the Technische Universität Dresden (TUD). When she's asked why she chose math as a career, she responds dryly: "My Dad is a physicist and my Mom is a mathematician, I didn't really have much choice…"

Her route to Fraunhofer after completing her studies was a roundabout one. First, she completed an internship at the HZDR – Helmholtz-Zentrum Dresden-Rossendorf in the field of medical imaging – an experience she found so enriching that she resolved to make working at a research institute her career goal. When she came across a web page detailing the projects at Fraunhofer ITWM, she was hooked. And it just so happened that the researchers at the institute were looking for an enthusiastic doctoral student who was well versed in mathematics and had experience of medical applications.

The partnership was made, and the collaboration proved extremely fruitful. Katrin successfully completed her doctorate, and the nine members of the research team taken from Fraunhofer ITWM, Massachusetts General Hospital, the University Hospital of Heidelberg, the German Cancer Research Center and the University of Munich were able to see through a particularly successful project. And the project's crowning glory came when it was also awarded the Stifterverband Science Prize. Today, the software is on sale around the world, and will soon be available at 60 percent of treatment planning centers worldwide.

For Katrin, the project is not yet over. She continues to work on the integration of multi-criteria planning into the systems of industrial clients. It is an aspect of her work at Fraunhofer that she values very much: the direct link to application and customers from industry.



FRAUNHOFER INSTITUTE SPIN-OFFS

Fraunhofer Institutes are prized by business and government alike because they draw existing companies into their orbit and provide the seedbed from which new companies are born. Every year, more than 50 Fraunhofer Institute employees use the expertise they have collected there to start up their own businesses. Here we present just some of the companies founded by Fraunhofer employees.

Betterspace GmbH

More efficient hotel heating

The hotel's windows are open again, and the heating is going full blast. It is a frustrating situation for hotel managers, bringing with it high energy costs and a significant strain on the environment. Betterspace GmbH, a spin-off of the Fraunhofer Institute for Wind Energy and Energy System Technology IWES, has a solution to the problem: its software uses smart algorithms to determine whether windows are open and, if they are, turns down the heating accordingly. As soon as a window is closed, the heating returns to normal. The algorithms also take into account the local weather forecast so that, for instance, rooms expecting new arrivals can be preheated in advance if there is a cold front on its way. While the software takes care of all of this fully automatically, hotel managers or guests can also adjust the heating manually at any time according to their own preferences. The software connects to the existing hotel software. It does not matter how big the hotel is, since the system is infinitely scalable. In other words, the system works just as well for small hotels with 17 rooms as it does for big hotels with 130 rooms. It is even possible for a single energy manager to centrally manage multiple hotels within a chain.

In October 2016, Betterspace GmbH merged with SD Concept GmbH. While Betterspace focuses on smart energy efficiency solutions, the company SD Concept GmbH supplies innovative information systems such as digital guest maps and lobby displays. Each room is fitted with a display that informs guests about hotel news, regional tourist attractions and entertainment services. Multiple thousands of radio thermostats and tablets are already in use.

Dispendix GmbH

Precise dispensing of the tiniest volumes of liquid

The volume of test samples in biochemical laboratories is getting smaller and smaller. For one thing, biochemical reactions are often better observed with smaller volumes, while it is also more cost effective, since less material is used. Traditionally, quantities have been measured out with a pipette that is dipped into the solution to draw out the required volume of liquid. With volumes of less than a microliter or so, however, the pipette technique is no longer effective, since the result is no longer accurate enough. Accordingly, there is a demand for a technique that allows for accurate measurement in the nanoliter range.

This gap in the market is now covered by Dispendix GmbH, a spin-off of the Fraunhofer Institute for Manufacturing Engineering and Automation IPA. The key is that the new method is non-contact, avoiding impurities, as well as highly accurate. The dispensing head consists of a small plastic dosage plate that contains 96 tiny dishes arranged in a row. In each of these dishes, researchers have drilled a tiny hole no wider than a hair. At this point, capillary force seals the hole and no liquid is able to penetrate. It is only when compressed air is applied that precisely dosed drops of liquid of two nanoliters pass through the "leak." The system can deliver 400 impulses a second, and for bigger quantities of liquid the system releases corresponding quantities of droplets.

Three such systems are already in operation, and more are on the way soon. Dispendix GmbH, in which the Fraunhofer-Gesellschaft also has a stake, currently employs five people.

Vibrosonic GmbH

Contact lenses for hearing

"What was that? Could you talk a bit louder please?" Many people who have problems hearing are reluctant to wear a hearing aid – nobody wants to feel "old," and there is still a bit of stigma around wearing hearing aids. On top of this, hearing aids distort what you hear, and voices and other sounds can sound skewed.

In the future, these shortcomings will be eradicated – at least that is the official goal of Vibrosonic GmbH, a spin-off of the Fraunhofer Institute for Manufacturing Engineering and Automation IPA and the University Hospital in Tübingen. The solution the employees at Vibrosonic GmbH are working on is a sort of contact lens for hearing. Not only does this offer a significantly improved audio experience as opposed to traditional hearing aids, it is also invisible from the outside. The hearing contact lens sits directly on the ear drum, and the plan is also to make the battery and microphone small enough that they disappear in the auditory canal. Both components will be inserted by a doctor and will remain permanently in the ear. The lens itself consists of a silicon chip onto which a piezoelectric material has been applied. When a voltage is applied, the material deforms and generates vibrations that are transferred directly to the eardrum via a silicone pad.

Vibrosonic GmbH is funded by the German Federal Ministry for Economic Affairs and Energy's Exist program until mid-2017, and talks are already underway with investors regarding follow-up funding. Testing of the hearing contact lens on pilot patients is scheduled for early 2018, and market launch for 2020.

VirtualAds

Targeted TV advertising

Internet advertising has been personalized for a good while now. If two people access the same web page, one will see a banner promoting holidays, while the other sees an ad for books. But when it comes to TV, we all watch the same advertisements.

That may be about to change thanks to the Basel-based company VirtualAds, which wants to personalize ads, at least in the live transmission of sporting events. These are becoming more and more popular, and targeted advertising would allow for multiple marketing campaigns from a single sporting event. The idea focuses on the LED banners found at the edge of the pitch. Software would be used to make these a sort of blue screen, so that the advertising displayed at the stadium could be virtually personalized for sports fans at home according to their region, country or particular interests. Viewers would see no difference between the actual and virtual advertising.

VirtualAds has left the competition behind and is currently the global leader in various tests of virtual LED banner advertising technology. Its targeted advertising has already been successfully implemented in a range of sporting events. Full commercialization began in 2017 with a launch in Hong Kong, India and the U.S. As a co-investor, the Fraunhofer-Gesellschaft is part of VirtualAds for the long term.

vibrosonic

VIRTUALADS

watttron GmbH

Conserving materials in yogurt pots and the like

The typical yogurt pot is comparatively thick at the top, and thin at its base. This is due to its production. The pots are made from a plastic film that is heated and pressed into the desired shape. In areas in which the deformation is greater, the film becomes correspondingly thinner. As a result, the physical properties are not as good as they might be. On top of that, manufacturers have to use extremely thick films to make sure that the wall thickness at the base is still sufficient. This means greater costs.

watttron GmbH, a spin-off of the Technische Universität Dresden and of the Fraunhofer Institute for Process Engineering and Packaging IVV in Dresden, is now launching a technology that, for the first time, makes it possible to control the distribution of the thickness of the container. Instead of being heated all over as before, the plastic film is now subjected to targeted heating. This means a more consistent thickness in the walls of the container, which allows manufacturers to use thinner source film while retaining the same mechanical properties. The materials saving obtained through the technique is up to 30 percent. It is all down to ceramic heating. This consists of 40x40 millimeter modules that are each made up of 5x5 millimeter heating pixels. The temperature of each heating pixel can be individually regulated. Any size of surface can be heated by connecting multiple modules.

watttron GmbH is currently conducting feasibility studies, and the innovative heating technique should be available for preliminary full-scale production in early 2018. The company currently has ten employees and is funded by the German Federal Ministry for Economic Affairs and Energy's "Exist Research Transfer" program.

FINANCIAL REPORT

BALANCE SHEET AT DECEMBER 31, 2016

INCOME STATEMENT
FOR THE FINANCIAL YEAR 2016

RECONCILIATION BETWEEN INCOME STATEMENT AND PERFORMANCE STATEMENT (CASH-BASIS ACCOUNTING)

PERFORMANCE STATEMENT FOR INDIVIDUAL FRAUNHOFER ENTITIES

EXCERPTS FROM THE NOTES
TO THE FINANCIAL STATEMENTS

INDEPENDENT AUDITOR'S REPORT

BALANCE SHEET AT DECEMBER 31, 2016

FRAUNHOFER-GESELLSCHAFT
ZUR FÖRDERUNG DER ANGEWANDTEN FORSCHUNG E. V., MÜNCHEN

ASSETS	€	€	**2016** €	**2015** €(1000)
Current assets				
Cash and cash equivalents		83,586,418.76		53,006
Marketable securities		298,871,662.72		231,202
Accounts receivable and other current assets				
Trade receivables	240,190,407.68			210,681
Receivables from the federal and state governments				
relating to base funding	35,568,023.65			29,163
relating to project billing including contract research	118,199,214.08			121,620
relating to pension and compensated absence provisions	62,378,700.00			62,001
	216,145,937.73			212,784
Accounts receivable from associated companies	13,451,740.66			383
Other current assets	122,235,380.21			117,932
		592,023,466.28		541,780
Inventories		31,356,438.57		21,043
Prepaid expenses and deferred charges		14,785,938.33		14,427
Total current assets			1,020,623,924.66	861,458
Intangible assets			10,610,576.49	11,882
Property, plant and equipment			1,898,299,776.32	1,961,400
Financial assets			22,124,963.50	21,084
Total assets			**2,951,659,240.97**	**2,855,824**
Trust assets			58,969,402.13	51,056

LIABILITIES AND EQUITY	€	€	2016 €	2015 €(1000)
Current liabilities				
Trade payables		84,080,975.36		72,626
Unappropriated grants from the federal and state governments				
relating to base funding	119,105,548.32			55,153
relating to project billing	36,031,730.14			38,470
		155,137,278.46		93,623
Accounts payable to associated companies		–		189
Other current liabilities		11,299,335.02		10,422
Total current liabilities			250,517,588.84	176,860
Deferred income			4,235,911.73	4,670
Provisions for pensions and similar obligations			9,378,700.00	9,550
Other provisions			143,261,494.00	137,008
Special reserves				
License-fee revenue reserve		298,908,285.76		258,208
Grants relating to fixed assets		1,914,730,030.17		1,978,909
Grants used to finance current assets		236,056,227.61		194,479
Present value of deferred income from patent deal		78,050,541.90		79,869
			2,527,745,085.44	2,511,465
Equity				
Capital of the non-profit organization				
Carried forward	14,927,984.68			14,693
Retained earnings	220,743.77			235
		15,148,728.45		14,928
Restricted reserve		1,371,732.51		1,343
Total equity			16,520,460.96	16,271
Total liabilities and equity			**2,951,659,240.97**	**2,855,824**
Trust liabilities			58,969,402.13	51,056

INCOME STATEMENT FOR THE FINANCIAL YEAR 2016

FRAUNHOFER-GESELLSCHAFT
ZUR FÖRDERUNG DER ANGEWANDTEN FORSCHUNG E.V., MÜNCHEN

				2016	2015
		€	€	€	€(1000)
Revenue from base funding					
Federal government			583,593,147.23		580,900
State governments			87,991,565.42		109,797
				671,584,712.65	690,697
Revenue from own activities					
Revenue from research and development activities					
Federal government:	Project funding	370,684,814.74			357,068
	Contracts	9,901,893.41			9,776
State governments:	Project funding	149,134,313.18			174,605
	Contracts	2,183,190.64			813
Business, industry and trade associations		668,460,722.42			640,705
Research funding organizations and other sources		197,535,937.20			181,066
			1,397,900,871.59		1,364,033
Other revenue			15,071,150.39		14,268
Total revenue				1,412,972,021.98	1,378,301
Increase in work in progress (prior year: decrease)			842,431.40		−12,892
Other internally constructed and capitalized assets			7,257,725.04		8,703
Other operating income			17,749,543.89		22,202
Income from equity investments			12,955,567.42		1,889
Other interest and similar income			50,320.41		2
				38,855,588.16	19,904
Total base funding and revenue from own activities				2,123,412,322.79	2,088,902
Change in special reserves					
License-fee revenue reserve			−40,700,000.00		−29,200
Grants relating to fixed assets			60,614,869.61		−35,956
Grants used to finance current assets			−41,577,213.83		26,876
				−21,662,344.22	−38,280
Total income available to cover expenditure				**2,101,749,978.57**	**2,050,622**

	€	€	2016 €	2015 €(1000)
Cost of materials		336,141,279.48		336,892
Personnel expenses		1,181,594,057.71		1,130,213
Amortization of intangible assets and depreciation of property, plant and equipment		287,192,579.51		295,407
Other operating expenses		294,595,108.85		285,556
Amortization of financial assets and current marketable securities		1,566,482.61		1,097
Interest and similar expenses		410,608.25		1,035
Total expenditure			2,101,500,116.41	2,050,200
Net income for the year			249,862.16	422
Transfer from reserves			–	5
Transfer to reserves			–29,118.39	–192
Retained earnings			220,743.77	235
Allocation to capital of the non-profit organization			–220,743.77	–235
			–	–

RECONCILIATION BETWEEN INCOME STATEMENT AND PERFORMANCE STATEMENT (CASH-BASIS ACCOUNTING)

Income/receipts	Performance statement €	Non-profit organization capital €	Reconciling items €	Income statement €
Income/receipts				
from base funding	671,206,496.65		378,216.00	671,584,712.65
from research and development activities	1,412,210,175.91		–14,309,304.32	1,397,900,871.59
from other sources	382,374.58		14,688,775.81	15,071,150.39
Increase in work in progress			842,431.40	842,431.40
Other internally constructed and capitalized assets	7,257,725.04			7,257,725.04
Other income	31,404,464.85	572,869.76	–1,221,902.89	30,755,431.72
Total income/receipts	**2,122,461,237.03**			
Change in special reserves				
License-fee revenue reserve			–40,700,000.00	–40,700,000.00
Grants relating to fixed assets				
Allocations to special reserves (capital expenditure)			– 227,984,029.36	–227,984,029.36
Reversal of special reserves (depreciation)		43,762.92	288,555,136.05	288,598,898.97
Grants used to finance current assets	–41,577,213.83			–41,577,213.83
Change in grants receivable relating to pension and compensated absence provisions	378,216.00		–378,216.00	
Total business volume (cash basis)	**2,081,262,239.20**			
		616,632.68	19,871,106.69	2,101,749,978.57

Expenditure/disbursements	Performance statement	Non-profit organization capital	Reconciling items	Income statement
	€	€	€	€
Expenditure/disbursement				
Cost of materials	306,439,901.71	25,748.12	29,675,629.65	336,141,279.48
Personnel expenses	1,193,421,591.37	640.00	–11,828,173.66	1,181,594,057.71
Amortization of intangible assets and depreciation of property, plant and equipment		195,964.77	286,996,614.74	287,192,579.51
Other operating expenses	312,709,095.76	144,417.63	–16,281,313.68	296,572,199.71
Expenditure as per the income statement				**2,101,500,116.41**
Change in special reserves				
License-fee revenue reserve	40,700,000.00		–40,700,000.00	
Capital expenditure (current and major infrastructure)	227,991,650.36		–227,991,650.36	
Net income for the year		249,862.16		249,862.16
Total business volume (cash basis)	**2,081,262,239.20**			
		616,632.68	19,871,106.69	2,101,749,978.57

PERFORMANCE STATEMENT FOR INDIVIDUAL FRAUNHOFER ENTITIES

Fraunhofer Institute/ Research Institution for		**Expenses** Operating expenses		Capital expenditure		**Income** From external sources		Base funding	
		2015 €(1000)	**2016 €(1000)**	2015 €(1000)	**2016 €(1000)**	2015 €(1000)	**2016 €(1000)**	2015 €(1000)	**2016 €(1000)**
Fraunhofer ICT Group									
Algorithms and Scientific Computing SCAI	Sankt Augustin	10,562.7	**10,509.6**	234.7	**361.7**	7,003.8	**7,707.1**	3,793.5	**3,164.2**
Applied and Integrated Security AISEC	Garching	6,701.6	**6,963.3**	215.8	**246.0**	5,618.9	**6,505.4**	1,298.4	**703.9**
Applied Information Technology FIT	Sankt Augustin	12,346.8	**14,040.5**	263.7	**620.3**	10,659.8	**12,683.4**	1,950.7	**1,977.4**
Communication, Information Processing and Ergonomics FKIE	Wachtberg	6,623.6	**7,648.0**	205.1	**352.5**	6,021.4	**6,572.0**	807.2	**1,428.6**
Computer Graphics Research IGD	Darmstadt, Rostock	17,178.8	**16,784.6**	1,237.5	**964.5**	11,275.1	**23,695.4**	7,141.3	**– 5,946.3**
Digital Media Technology IDMT	Ilmenau, Oldenburg	13,698.6	**13,102.4**	293.4	**214.2**	10,214.5	**9,380.3**	3,777.5	**3,936.4**
Embedded Systems and Communication Technologies ESK	München	5,848.7	**5,191.1**	286.6	**192.6**	4,150.5	**3,619.5**	1,984.8	**1,764.2**
Experimental Software Engineering IESE	Kaiserslautern	12,056.9	**12,279.9**	750.0	**423.2**	9,721.0	**9,795.4**	3,085.9	**2,907.7**
Industrial Engineering IAO	Stuttgart	29,120.1	**30,296.5**	1,301.4	**693.4**	25,115.3	**26,170.6**	5,306.2	**4,819.3**
Industrial Mathematics ITWM	Kaiserslautern	21,008.9	**21,454.5**	905.1	**558.0**	14,375.8	**15,946.5**	7,538.2	**6,066.0**
Intelligent Analysis and Information Systems IAIS	Sankt Augustin	14,482.5	**15,985.1**	843.9	**883.1**	12,319.3	**15,641.8**	3,007.1	**1,226.3**
Medical Image Computing MEVIS	Bremen, Lübeck	8,951.5	**8,917.1**	206.9	**406.6**	4,625.1	**4,338.0**	4,533.3	**4,985.8**
Open Communication Systems FOKUS	Berlin	29,267.3	**30,138.9**	676.2	**837.6**	20,266.8	**22,234.6**	9,676.7	**8,741.9**
Optronics, System Technologies and Image Exploitation IOSB	Karlsruhe, Ettlingen	27,882.6	**29,975.4**	1,802.1	**2.461.1**	22,569.2	**22,881.7**	7,115.5	**9,554.7**
Secure Information Technology SIT	Darmstadt	10,338.1	**10,692.3**	220.8	**292.4**	8,580.3	**8,027.9**	1,978.6	**2,956.8**
Software and Systems Engineering ISST	Dortmund	3,630.8	**3,466.2**	8.6	**126.9**	1,152.0	**2,279.5**	2,487.4	**1,313.6**
Transportation and Infrastructure Systems IVI	Dresden	9,216.2	**9,062.7**	1,264.3	**914.7**	8,094.0	**7,784.5**	2,386.5	**2,192.9**

Fraunhofer Institute/ Research Institution for		**Expenses** Operating expenses		Capital expenditure		**Income** From external sources		Base funding	
		2015 €(1000)	**2016 €(1000)**	2015 €(1000)	**2016 €(1000)**	2015 €(1000)	**2016 €(1000)**	2015 €(1000)	**2016 €(1000)**
Fraunhofer Group for Life Sciences									
Biomedical Engineering IBMT	St. Ingbert	15,203.5	**14,340.8**	798.3	**547.3**	10,830.4	**8,636.9**	5,171.4	**6,251.2**
Cell Therapy and Immunology IZI	Leipzig, Potsdam-Golm	26,911.2	**29,914.7**	5,896.9	**1,028.1**	24,360.5	**23,146.7**	8,447.7	**7,796.1**
Interfacial Engineering and Biotechnology IGB	Stuttgart, Leuna	26,037.3	**26,535.9**	1,834.7	**2,889.3**	19,660.4	**20,073.0**	8,211.7	**9,352.2**
Marine Biotechnology and Cell Technology EMB	Lübeck	3,169.4	**2,643.9**	102.8	**20.3**	1,127.4	**1,519.9**	2,144.8	**1,144.3**
Molecular Biology and Applied Ecology IME	Aachen, Schmallenberg	33,856.0	**40,332.2**	8,066.1	**8,739.1**	34,341.8	**40,286.4**	7,580.3	**8,784.9**
Process Engineering and Packaging IVV	Freising, Dresden	16,228.3	**17,694.3**	2,189.2	**925.2**	12,503.7	**13,506.9**	5,913.8	**5,112.7**
Toxicology and Experimental Medicine ITEM	Hannover	25,418.2	**28,432.5**	2,479.5	**1,709.3**	18,685.7	**20,869.4**	9,212.1	**9,272.3**
Fraunhofer Group for Light & Surfaces									
Applied Optics and Precision Engineering IOF	Jena	24,646.7	**26,810.9**	4,780.8	**7,762.1**	21,457.7	**25,661.1**	7,969.7	**8,911.9**
Laser Technology ILT	Aachen	30,960.6	**32,082.0**	4,635.9	**4,018.5**	24,069.3	**25,618.6**	11,527.2	**10,481.9**
Material and Beam Technology IWS	Dresden	27,446.6	**28,368.8**	3,576.8	**2,527.4**	22,145.3	**20,781.7**	8,878.1	**10,114.6**
Organic Electronics, Electron Beam and Plasma Technology FEP	Dresden	24,416.8	**22,734.2**	3,393.5	**1,616.2**	17,350.6	**15,967.8**	10,459.7	**8,382.6**
Physical Measurement Techniques IPM	Freiburg	17,043.8	**16,738.9**	667.9	**962.0**	12,433.0	**11,589.8**	5,278.8	**6,111.1**
Surface Engineering and Thin Films IST	Braunschweig	12,425.4	**12,216.8**	523.2	**602.1**	9,447.1	**8,071.5**	3,501.6	**4,747.4**

Performance statement for individual Fraunhofer entities

Fraunhofer Institute/ Research Institution for		**Expenses** Operating expenses		Capital expenditure		**Income** From external sources		Base funding	
		2015 €(1000)	**2016 €(1000)**	2015 €(1000)	**2016 €(1000)**	2015 €(1000)	**2016 €(1000)**	2015 €(1000)	**2016 €(1000)**
Fraunhofer Group for Materials and Components – MATERIALS									
Applied Polymer Research IAP[1]	Potsdam-Golm	16,350.6	**19,400.7**	1,323.3	**871.2**	10,779.6	**14,154.0**	6,894.3	**6,117.9**
Building Physics IBP	Stuttgart, Holzkirchen	27,629.2	**27,710.6**	3,056.4	**2,107.6**	22,307.7	**21,565.0**	8,377.9	**8,253.2**
Ceramic Technologies and Systems IKTS	Dresden, Hermsdorf	48,818.3	**50,617.6**	5,357.7	**3,020.7**	36,148.1	**38,796.0**	18,027.8	**14,842.2**
Chemical Technology ICT, Polymer Engineering Department	Pfinztal, Karlsruhe	41,524.9	**37,906.7**	3,282.5	**2,459.3**	34,983.7	**32,377.6**	9,823.6	**7,988.3**
High-Speed Dynamics, Ernst-Mach-Institut, EMI	Freiburg	8,002.2	**8,414.4**	459.2	**572.0**	6,596.8	**6,534.2**	1,864.6	**2,452.2**
Manufacturing Technology and Advanced Materials IFAM	Bremen, Dresden, Stade	41,481.2	**42,730.7**	3,177.1	**4,187.0**	34,252.8	**35,206.2**	10,405.4	**11,711.4**
Mechanics of Materials IWM	Freiburg	40,073.9	**19,299.6**	3,998.0	**983.7**	30,278.3	**14,267.3**	13,793.7	**6,016.1**
Microstructure of Materials and Systems IMWS	Halle		**19,568.2**		**1,713.7**		**16,027.1**		**5,254.7**
Nondestructive Testing IZFP	Saarbrücken	13,867.0	**13,844.7**	1,154.9	**548.0**	9,564.1	**7,822.5**	5,457.8	**6,570.1**
Silicate Research ISC	Würzburg, Bronnbach, Bayreuth	29,834.7	**29,855.3**	5,265.4	**2,600.2**	22,484.6	**22,306.2**	12,615.4	**10,149.3**
Solar Energy Systems ISE	Freiburg	73,160.2	**73,725.5**	10,831.9	**8,441.5**	67,802.8	**69,912.4**	16,189.3	**12,254.6**
Structural Durability and System Reliability LBF	Darmstadt	30,069.5	**27,737.8**	1,664.1	**1,237.8**	22,032.3	**21,993.7**	9,701.3	**6,981.9**
Systems and Innovation Research ISI	Karlsruhe	20,644.5	**22,497.8**	228.2	**303.7**	15,419.1	**19,013.4**	5,453.7	**3,788.1**
Wind Energy and Energy System Technology IWES	Bremerhaven, Kassel	34,685.7	**37,590.7**	11,158.3	**8,203.3**	38,725.8	**40,979.8**	7,118.2	**4,814.1**
Wood Research, Wilhelm-Klauditz-Institut, WKI	Braunschweig	13,105.7	**14,416.3**	981.8	**2,869.6**	11,036.8	**12,641.2**	3,050.8	**4,644.8**

1 Fraunhofer PYCO and Fraunhofer IAP merged their activities in 2016.

Fraunhofer Institute/ Research Institution for		**Expenses** Operating expenses		Capital expenditure		**Income** From external sources		Base funding	
		2015 €(1000)	**2016 €(1000)**	2015 €(1000)	**2016 €(1000)**	2015 €(1000)	**2016 €(1000)**	2015 €(1000)	**2016 €(1000)**
Fraunhofer Group for Microelectronics									
Applied Solid State Physics IAF	Freiburg	10,375.9	**11,714.0**	2,895.6	**1,631.6**	8,322.4	**9,347.1**	4,949.2	**3,998.5**
Electronic Nano Systems ENAS	Chemnitz	12,653.4	**12,411.3**	2,019.2	**1,889.6**	10,327.9	**10,430.5**	4,344.8	**3,870.4**
High Frequency Physics and Radar Techniques FHR	Wachtberg	13,283.7	**12,412.3**	724.8	**695.0**	14,113.4	**11,278.6**	– 104.8	**1,828.7**
Integrated Circuits IIS	Erlangen, Nürnberg, Dresden	154,594.9	**156,188.3**	8,849.8	**6,742.2**	129,477.0	**123,864.9**	33,967.7	**39,065.7**
Integrated Systems and Device Technology IISB	Erlangen	22,378.4	**22,939.9**	2,971.4	**3,776.2**	19,998.7	**22,308.8**	5,351.0	**4,407.3**
Microelectronic Circuits and Systems IMS	Duisburg	28,195.9	**27,119.6**	2,713.5	**831.3**	20,937.2	**20,322.9**	9,972.2	**7,628.0**
Microsystems and Solid State Technologies EMFT	München	10,561.5	**11,603.6**	196.4	**173.7**	7,688.2	**8,301.1**	3,069.7	**3,476.2**
Photonic Microsystems IPMS	Dresden	32,530.7	**34,818.4**	3,111.2	**1,516.4**	22,880.4	**25,535.1**	12,761.5	**10,799.7**
Reliability and Microintegration IZM	Berlin, Dresden	28,132.5	**29,469.8**	1,836.0	**1,336.3**	21,548.0	**25,272.8**	8,420.5	**5,533.3**
Silicon Technology ISIT	Itzehoe	24,893.4	**24,747.5**	1,012.0	**846.4**	16,514.9	**18,721.0**	9,390.4	**6,873.0**
Telecommunications, Heinrich-Hertz-Institut, HHI	Berlin, Goslar	43,047.9	**45,615.2**	6,164.7	**5,615.5**	36,939.0	**39,577.5**	12,273.6	**11,653.1**

Performance statement for individual Fraunhofer entities

Fraunhofer Institute/ Research Institution for		Expenses: Operating expenses		Expenses: Capital expenditure		Income: From external sources		Income: Base funding	
		2015 €(1000)	**2016 €(1000)**	2015 €(1000)	**2016 €(1000)**	2015 €(1000)	**2016 €(1000)**	2015 €(1000)	**2016 €(1000)**
Fraunhofer Group for Production									
Environmental, Safety and Forming Technology UMSICHT	Oberhausen, Sulzbach-Rosenberg	36,463.8	**35,602.9**	2,659.5	**3,218.2**	29,268.3	**31,519.8**	9,855.0	**7,301.3**
Factory Operation and Automation IFF	Magdeburg	17,749.9	**19,051.2**	862.3	**597.1**	12,296.1	**16,005.0**	6,316.0	**3,643.3**
Casting, Composite and Processing Technology IGCV	Augsburg, Garching		**9,080.1**		**1,696.0**		**9,736.2**		**1,039.9**
Machine Tools and Forming Technology IWU	Chemnitz, Augsburg	39,589.5	**36,254.8**	4,536.1	**2,864.9**	30,807.4	**26,476.2**	13,318.2	**12,643.4**
Manufacturing Engineering and Automation IPA	Stuttgart	64,167.2	**67,522.4**	4,042.4	**3,892.5**	49,969.1	**54,684.7**	18,240.5	**16,730.2**
Material Flow and Logistics IML	Dortmund	25,548.5	**27,316.9**	1,010.0	**1,089.7**	19,094.1	**20,469.1**	7,464.4	**7,937.5**
Mechatronic Systems Design IEM	Paderborn		**7,583.2**		**274.8**		**6,758.4**		**1,099.6**
Production Systems and Design Technology IPK	Berlin	17,357.3	**18,771.9**	2,754.0	**1,071.7**	12,101.7	**14,440.0**	8,009.6	**5,403.6**
Production Technology IPT	Aachen	33,026.5	**27,858.6**	4,334.9	**2,038.7**	26,561.4	**20,940.6**	10,800.0	**8,956.6**
Fraunhofer Group for Defense and Security VVS									
Applied Solid State Physics IAF	Freiburg	15,145.4	**14,101.7**	4,775.9	**2,083.6**	10,940.8	**7,269.1**	8,980.5	**8,916.2**
Chemical Technology ICT, Department of Energetic Materials	Pfinztal	13,469.0	**12,326.5**	1,168.1	**1,584.2**	4,394.2	**3,818.8**	10,242.9	**10,091.8**
Communication, Information Processing and Ergonomics FKIE	Wachtberg	23,369.9	**23,331.2**	2,435.5	**2,224.1**	13,834.5	**12,892.7**	11,970.9	**12,662.6**
High Frequency Physics and Radar Techniques FHR	Wachtberg	14,440.0	**14,634.0**	2,449.5	**1,494.2**	6,109.2	**5,046.6**	10,780.3	**11,081.6**
High-Speed Dynamics, Ernst-Mach-Institut, EMI	Freiburg	15,391.9	**14,872.0**	3,447.4	**1,108.1**	8,626.9	**5,375.5**	10,212.4	**10,604.6**
Optronics, System Technologies and Image Exploitation IOSB, Ettlingen branch	Ettlingen	20,452.2	**18,745.9**	3,216.9	**1,146.2**	17,399.1	**13,443.8**	6,270.0	**6,448.2**
Technological Trend Analysis INT	Euskirchen	6,186.9	**5,636.6**	1,007.2	**447.8**	2,407.6	**1,542.5**	4,786.4	**4,541.9**

Fraunhofer Institute/ Research Institution for		**Expense** Operating expenses		Capital expenditure		**Income** From external sources		Base funding	
		2015 €(1000)	**2016 €(1000)**	2015 €(1000)	**2016 €(1000)**	2015 €(1000)	**2016 €(1000)**	2015 €(1000)	**2016 €(1000)**
Other entities, not included in the Fraunhofer Groups									
Center for International Management and Knowledge Economy IMW	Leipzig	4,601.1	**4,983.9**	75.9	**81.2**	2,055.9	**2,547.4**	2,621.1	**2,517.7**
Information Center for Planning and Building IRB	Stuttgart	7,210.7	**7,023.0**	123.3	**57.2**	2,557.8	**2,766.6**	4,776.2	**4,313.6**
Polymeric Materials and Composites PYCO[1]	Teltow	3,830.5	**0.0**	351.4	**0.0**	2,808.7	**0.0**	1,373.2	**0.0**
Technological Trend Analysis INT	Euskirchen	2,456.5	**3,278.0**	109.0	**101.2**	2,118.4	**1,916.7**	447.1	**1,462.5**
Centrally managed entities									
Fraunhofer headquarters	München	23,204.4	**25,196.0**	3,518.8	**2,401.7**	3,039.7	**3,318.1**	23,683.5	**24,279.5**
Fraunhofer Institute for Integrated Publication and Information Systems	Darmstadt	243.5	**2.3**	0.0	**0.0**	0.0	**0.0**	243.5	**2.3**
Institute Center Birlinghoven	Sankt Augustin	989.6	**863.0**	27.3	**73.5**	261.1	**149.0**	755.8	**787.5**
Institute Center Stuttgart	Stuttgart	– 15.5	**– 146.0**	346.8	**339.1**	37.1	**29.3**	294.2	**163.8**
General overhead costs		55,359.4	**79,669.7**	1,624.7	**670.8**	30,386.6	**44,683.5**	26,597.5	**35,657.0**
Major infrastructure capital expenditure				153,260.9	**88,366.5**	29,061.7	**15,874.8**	124,199.3	**72,491.6**
Performance statement		1,782,813.1	**1,853,270.6**	332,232.8	**227,991.7**	1,397,472.5	**1,451,254.7**	717,573.4	**630,007.5**

1 Fraunhofer PYCO and Fraunhofer IAP merged their activities in 2016.

EXCERPTS FROM THE NOTES TO THE FINANCIAL STATEMENTS

I. General disclosures

The Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e. V., headquartered in Munich, is a non-profit organization registered with the district court of Munich under the reference code VR 4461.

The annual financial statements for the year ending December 31, 2016, were prepared voluntarily and in accordance with the requirements of the German Commercial Code (HGB) as applicable to large corporate entities and amended by the German Accounting Directive Implementation Act (BilRUG). In cases where items were restated due to application of the new BilRUG regulations, the previous year's amounts were adjusted accordingly.

The basis of the Fraunhofer-Gesellschaft's accounting is the performance statement, from which the annual financial statements are derived.

The performance statement is adapted to the requirements of the public funding authorities in terms of format and reconciliation. It provides a breakdown of operating expenses and capital expenditure at three different levels: individual institutes, headquarters, and the organization as a whole. The components of the operating budget are presented as income or expenses in accordance with generally accepted accounting principles. Capital expenditure on property, plant and equipment and on financial assets, on the other hand, is immediately recognized at the full cost of acquisition. Therefore the operating budget does not include any depreciation/amortization expenses on these items.

In order to provide full accountability for grants received from funding agencies, the performance statement for the organization as a whole is reconciled to the income statement format required by public authorities by eliminating the effect of non-cash income and expense items. The amounts presented in the income statement include items showing the changes in payables and receivables and in depreciation/amortization charges compared with the previous year. On the face of the balance sheet, these reconciliation items are included in the special reserves for grants relating to fixed assets and for grants used to finance current assets.

Annual financial statements of the Fraunhofer-Gesellschaft			Reconciliation with **income statement** format required by public funding authorities
Balance sheet	Income statement		
	Reconciliation between income statement and performance statement		
Notes to the financial statements	**Performance statement**		
	Budgeted operating expenses and capital expenditure at Fraunhofer-Gesellschaft level "total business volume"		
Management report	Individual financial statements of the institutes/headquarters		
	Operating expenses	Capital expenditure	
	Costs (excluding depreciation/amortization)	Expenses	
	Income	Income	

Presentation of annual accounts of the Fraunhofer-Gesellschaft

II. Recognition and measurement methods

Intangible assets and property, plant and equipment are measured at amortized cost, i.e. the cost of acquisition or construction less depreciation/amortization calculated on a straight-line basis.

Financial assets are measured at the lower of cost of acquisition or fair value.

Since the non-current assets presented in the ordinary accounts are financed by government grants, the special reserve for grants relating to fixed assets is reduced by an amount corresponding to the depreciation/amortization of these assets. Therefore, these adjustments have no impact on equity.

Work in progress is measured at the lower of cost of construction or fair value. Construction costs include applicable personnel expenses, cost of materials, general administrative expenses, and depreciation/amortization charges. Advance payments received (including VAT) are recognized under inventories.

Trade receivables and other current assets are recognized at their nominal value. Irrecoverable debts are revalued at the reporting date. The overall non-payment risk is limited by creating a provision for doubtful debts corresponding to 2 percent of the total amount of accounts receivable.

Current marketable securities are measured at the lower of cost of acquisition or fair value at the reporting date.

Cash and cash equivalents are recognized at their nominal value.

Payments made in the current year for which the associated benefits will be received in a future period are recognized as prepaid expenses in the balance sheet.

Excerpts from the notes
to the financial statements

The Fraunhofer-Gesellschaft makes use of the instrument provided in its financial statutes to recognize a balance sheet reserve, mainly comprising revenues from the licensing of audio-encoding technologies, that will enable the organization to use such revenues as means of financing its own pre-competitive research in areas of importance to its medium-term strategy.

Funding used to finance non-current assets is allocated to the special reserve for grants relating to fixed assets. A separate special reserve is used to account for grants used to finance current assets.

Provisions for pensions and similar obligations for which the Fraunhofer-Gesellschaft has a reinsurance policy in place are measured on the basis of the capitalized amount calculated by the insurance company at the reporting date. If there is no reinsurance policy in place, or if the settlement cost of the pension obligations exceeds the capitalized amount calculated by the reinsurer, the amount recognized as a provision is calculated according to an expert opinion based on actuarial evidence.

Other provisions consist of amounts set aside to cover all identifiable risks and contingent liabilities. These provisions are measured in accordance with Section 253 para. 1 of the German Commercial Code (HGB) on the basis of a reasonable estimate of the most probable outcome. Other provisions for liabilities due in more than one year are discounted at the average market interest rate for loans of a similar residual maturity as calculated by the Deutsche Bundesbank in December 2016, pursuant to Section 253 para. 2 of the German Commercial Code (HGB).

Liabilities are measured at the settlement amount.

Payments received in the current year for benefits to be delivered in a future period are recognized in the balance sheet as deferred income.

Amounts recognized for transactions in foreign currencies are translated at the corresponding hedging rate. In the annual financial statements, foreign currency holdings are translated at the average spot exchange rate prevailing on the reporting date.

Items in transit are noted in a separate line at the foot of the balance sheet for the Fraunhofer-Gesellschaft as trust assets and trust liabilities.

INDEPENDENT AUDITOR'S REPORT

We have audited the annual financial statements, comprising the balance sheet, the income statement and the notes to the financial statements together with the bookkeeping system, and the management report of the Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e. V., Munich, for the business year from January 1 to December 31, 2016. The maintenance of the books and records and the preparation of the annual financial statements and management report in accordance with German commercial law and supplementary provisions of the articles of incorporation are the responsibility of the Company's management. Our responsibility is to express an opinion on the annual financial statements, together with the bookkeeping system and the management report based on our audit.

We conducted our audit of the annual financial statements in accordance with § 317 HGB (German Commercial Code) and German generally accepted standards for the audit of financial statements promulgated by the Institute of Public Auditors in Germany (Institut der Wirtschaftsprüfer, IDW). Those standards require that we plan and perform the audit such that misstatements materially affecting the presentation of the net assets, financial position and results of operations in the annual financial statements in accordance with principles of proper accounting and in the management report are detected with reasonable assurance. Knowledge of the business activities and the economic and legal environment of the Company and expectations as to possible misstatements are taken into account in the determination of audit procedures. The effectiveness of the accounting-related internal control system and the evidence supporting the disclosures in the books and records, the annual financial statements and the management report are examined primarily on a test basis within the framework of the audit. The audit includes assessing the accounting principles used and significant estimates made by management, as well as evaluating the overall presentation of the annual financial statements and management report. We believe that our audit provides a reasonable basis for our opinion.

Our audit has not led to any reservations.

In our opinion, based on the findings of our audit, the annual financial statements comply with the legal requirements and supplementary provisions of the articles of incorporation and give a true and fair view of the net assets, financial position and results of operations of the Company in accordance with principles of proper accounting. The management report is consistent with the annual financial statements, complies with legal requirements, as a whole provides a suitable view of the Company's position and suitably presents the opportunities and risks of future development.

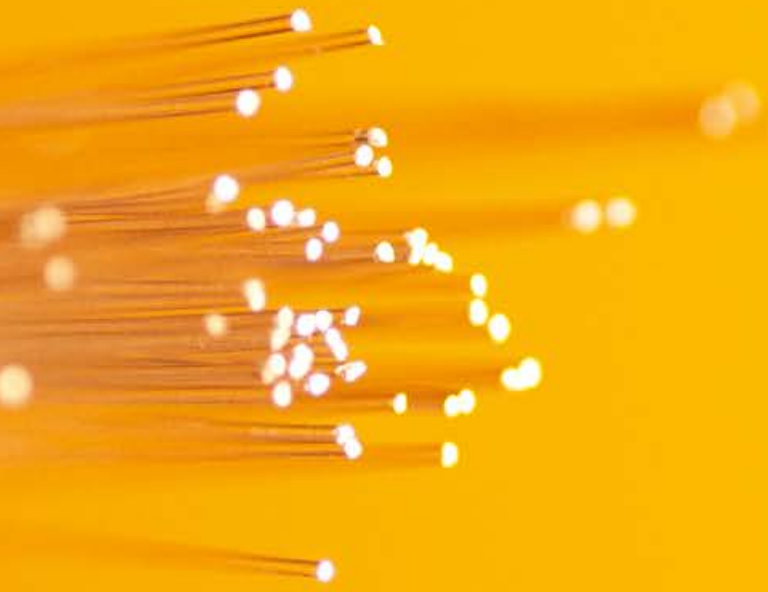
Nuremberg, March 22, 2017

Rödl & Partner GmbH
Wirtschaftsprüfungsgesellschaft, Steuerberatungsgesellschaft
(Auditors, Tax Consultants)

Vogel	Hahn
Wirtschaftsprüfer (Auditor)	Wirtschaftsprüfer (Auditor)

The auditor's report issued in German refers not to the foreign language version of the balance sheet and income statement, which are enclosed hereto as appendices, but to the original version of the complete financial statements and management report prepared in the German language.

SERVICE



STRUCTURE OF THE FRAUNHOFER-GESELLSCHAFT

MEMBERS, CONSTITUENT BODIES, COMMITTEES

FRAUNHOFER GROUPS

FRAUNHOFER ALLIANCES

ADDRESSES IN GERMANY

INTERNATIONAL ADDRESSES

EDITORIAL NOTES

STRUCTURE OF THE FRAUNHOFER-GESELLSCHAFT

Constituent bodies and their tasks

The **Executive Board** consists of the President and several other full-time members. Its duties include managing the Fraunhofer-Gesellschaft and representing its interests both inside and outside the organization. It formulates the basic principles of the Fraunhofer-Gesellschaft's science and research policy, plans its growth and its finances, ensures its base funding, organizes the distribution of funds among the individual institutes, and appoints the institute directors.

A total of 69 **institutes and research institutions** at locations across Germany operate under the umbrella of the Fraunhofer-Gesellschaft. Each cultivates its own market presence and manages its own budget. They are organized in seven **Fraunhofer Groups**, each devoted to a specific area of technology and tasked with coordinating thematically related areas within the Fraunhofer-Gesellschaft and harmonizing the market presence of the respective group members. The chairs of the seven Fraunhofer Groups, together with the members of the Executive Board, make up the Presidential Council of the Fraunhofer-Gesellschaft. The **Presidential Council** participates in Executive Board decision-making processes and, as such, is entitled to make proposals and recommendations and has the right to be heard.

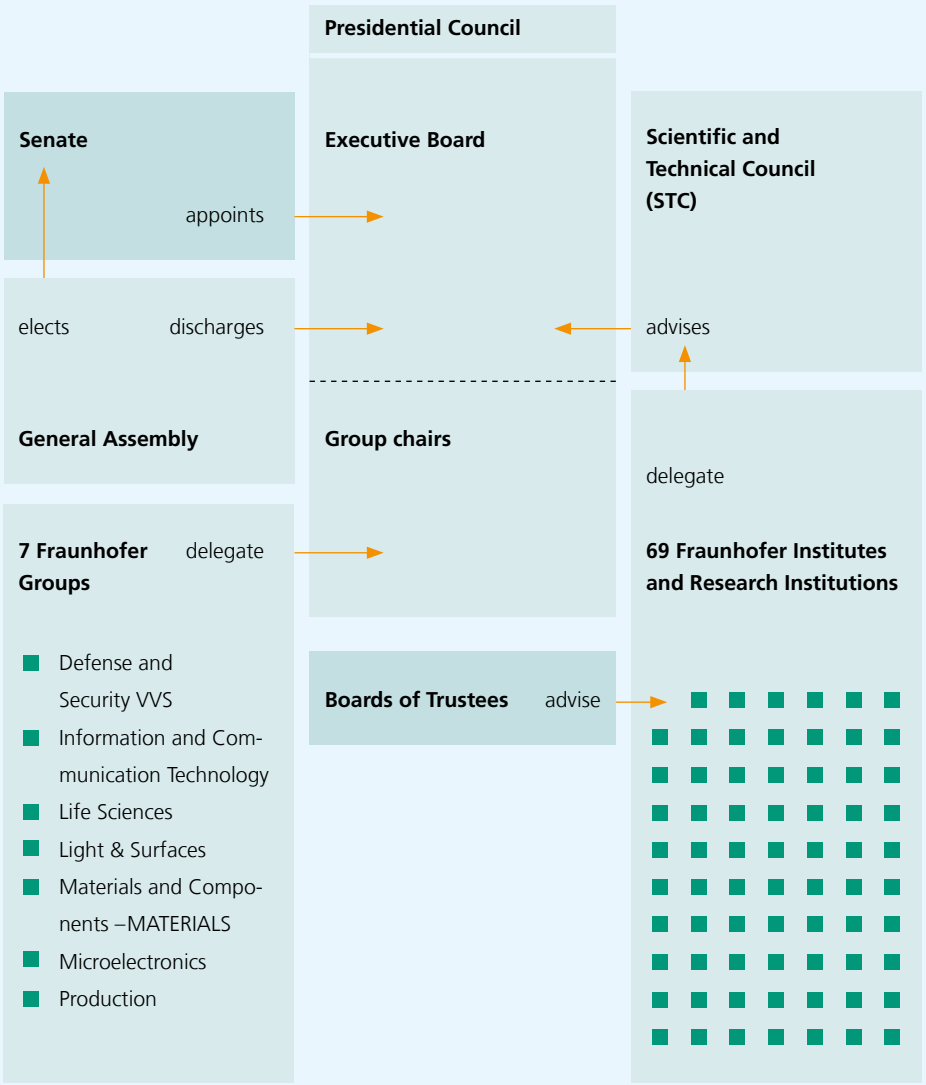
The **Senate** has around 30 members, comprising eminent figures from the worlds of science, business and public life, representatives of the federal and state governments, and members of the Scientific and Technical Council. The Senate's duties include appointing members of the Executive Board, defining the outlines of Fraunhofer's science and research policy, and formulating decisions concerning the establishment, devolution, merger or dissolution of research entities belonging to the Fraunhofer-Gesellschaft.

The **General Assembly** is made up of the members of the Fraunhofer-Gesellschaft. Official membership is open to members of the Senate, the Executive Board, institute directors and senior management, and the Boards of Trustees. Ordinary membership is open to individuals and legal entities who wish to support the work of the Fraunhofer-Gesellschaft. Honorary members may be elected from among the research staff and patrons of the Fraunhofer-Gesellschaft in recognition of outstanding services to the organization. The General Assembly elects the members of the Senate, discharges the Executive Board of its functions, and formulates decisions concerning amendments to the Statute.

The **Scientific and Technical Council** (STC) is the organization's internal advisory body. It consists of the directors and senior management of the institutes and an elected representative of the scientific and technical staff of each institute. The STC provides advice to the Executive Board and other constituent bodies in matters of fundamental importance. It makes recommendations concerning research and HR policy, expresses its opinions regarding the creation of new institutes or the closure of existing institutes, and participates in the appointment of new institute directors.

The **Boards of Trustees** are external advisory bodies of the institutes. They consist of representatives of science, business and public life. For each institute, approximately twelve members are appointed to the Board of Trustees by the Executive Board with the approval of the director(s) of the institute. The Boards of Trustees act as advisors to the institute directors and the Executive Board on matters concerning the research orientation and any structural changes to the institute.

Structure of the Fraunhofer-Gesellschaft



Although the Fraunhofer-Gesellschaft is basically a decentralized organization, its structure also allows for a centrally agreed strategy and effective centralized management. Various constituent bodies are responsible for coordination, consultation and leadership across theorganization as a whole.

MEMBERS, CONSTITUENT BODIES, COMMITTEES

Members

The Fraunhofer-Gesellschaft has 1125 members, comprising 212 ordinary members, 902 official members, 2 honorary senators and 11 honorary members. (Some members have multiple functions.)

Honorary members

- Dr.-Ing. Peter Draheim
- Dr. h. c. mult. Dipl.-Ing. Hermann Franz (†)
- Dr. Alfred Hauff
- Dr. Axel Homburg
- Dr.-Ing. Horst Nasko
- Dr. Dirk-Meints Polter
- Prof. Dr.-Ing. Dr.-Ing. E. h. Dr. h. c. Ekkehard D. Schulz
- Prof. Dr. rer. nat. Erwin Sommer
- Prof. Klaus-Dieter Vöhringer
- Prof. em. Dr.-Ing. Prof. h. c mult. Dr. h. c. mult. Dr.-Ing. E. h. Hans-Jürgen Warnecke
- Dr. rer. pol. Hans-Ulrich Wiese

Senate

Members from the science and business communities, and from public life

- Prof. Dr.-Ing. Heinz Jörg Fuhrmann
  Chair of the Senate of the Fraunhofer-Gesellschaft, Chairman of the Executive Board, Salzgitter AG
- Prof. Dr. phil. habil. Dr.-Ing. Birgit Spanner-Ulmer
  Deputy chair of the Senate of the Fraunhofer-Gesellschaft, Director of Production and Technology, Bayerischer Rundfunk
- Prof. Dr.-Ing. Hubert Waltl
  Deputy chair of the Senate of the Fraunhofer-Gesellschaft, Board Member for Production and Logistics, Audi AG
- Dr. Lutz Bertling
  Former President, Bombardier Transportation GmbH
- Dr.-Ing. E. h. Michael von Bronk
  Member of the Management Board, Lausitz Energie Bergbau AG
- Prof. Dr.-Ing. habil. Prof. e. h. mult. Dr. h. c. mult. Hans-Jörg Bullinger
  Professor of Industrial Science and Technology Management, University of Stuttgart
- Dr. Sabine Herlitschka
  CEO, Infineon Technologies Austria AG
- Dr. Nicola Leibinger-Kammüller
  President and Chairwoman of the Managing Board, TRUMPF GmbH & Co. KG
- Dr.-Ing. E. h. Friedhelm Loh
  Owner and Chairman of the Board of Management, Friedhelm Loh Group
- Hildegard Müller
  Chief Operating Officer Grid and Infrastructure, innogy SE
- Prof. Dr.-Ing. E. h. Hans J. Naumann
  Chairman and CEO, NILES-SIMMONS Industrieanlagen GmbH
- Prof. Dr. Siegfried Russwurm
  Member of the Managing Board, Siemens AG
- Tankred Schipanski
  Member of the German Bundestag, CDU/CSU parliamentary group
- Carsten Schneider
  Member of the German Bundestag, SPD parliamentary group
- Prof. Dr. Wiltrud Treffenfeldt
  Chief Technology Officer Europe, Middle East, Africa and India, Dow Europe GmbH
- Prof. Dr. rer. nat. Christiane Vaeßen
  Managing director, Zweckverband Region Aachen
- Michael Vassiliadis
  National Chairman of the industrial trade union IG Bergbau, Chemie, Energie
- Prof. Dr. Dr. h. c. mult. Martin Winterkorn

Members representing government institutions

- Dr. Thomas Grünewald
  State secretary, Ministry of Innovation, Science and Research, Nordrhein-Westfalen
- Hans-Joachim Hennings
  Director, Ministry of Research and Economy of the State of Sachsen-Anhalt
- Dr. Ole Janssen
  Director, German Federal Ministry for Economic Affairs and Energy (BMWi)
- Thomas Rachel
  Parliamentary secretary, German Federal Ministry of Education and Research (BMBF)

- Harald Stein
  President, German Federal Office of Bundeswehr Equipment, Information Technology and In-Service Support
- Dr. Manfred Wolter
  Director, Bavarian Ministry of Economic Affairs and Media, Energy and Technology

Members delegated by the Scientific and Technical Council (STC)

- Prof. Dr. rer. nat. habil. Andreas Tünnermann
  Director of the Fraunhofer Institute for Applied Optics and Precision Engineering IOF, Chair of the STC
- Dipl.-Ing. Stefan Schmidt
  Fraunhofer Institute for Material Flow and Logistics IML, Deputy Chair of the STC
- Prof. Dr. Peter Gumbsch
  Director of the Fraunhofer Institute for Mechanics of Materials IWM

Honorary senators

- Prof. Dr.-Ing. Dr.-Ing. E. h. Dr. h. c. Ekkehard D. Schulz
- Prof. em. Dr.-Ing. Prof. h. c mult. Dr. h. c. mult. Dr.-Ing. E. h. Hans-Jürgen Warnecke

Permanent guests

- Dr. Rolf Bernhardt
  Director, Hessen State Ministry of Higher Education, Research and the Arts
- Prof. Dr. Pascale Ehrenfreund
  Chair of the Executive Board, German Aerospace Center (DLR)
- Dipl.-Ing. Wolfgang Lux
  Deputy Chairman, Fraunhofer-Gesellschaft general works council
- Prof. Dr. Manfred Prenzel
  Chairman, German Council of Science and Humanities
- Dr. Hans Reckers
  State secretary, Senate Department for Economics, Technology and Research, Berlin
- Manfred Scheifele
  Chairman, Fraunhofer-Gesellschaft general works council
- Prof. Dr. Martin Stratmann
  President of the Max Planck Society for the Advancement of Science

Boards of Trustees

In total, the Boards of Trustees of the institutes consist of 788 members, some of whom hold seats on the Boards of Trustees of more than one institute.

Scientific and Technical Council (STC)

The STC has 150 members, 85 of whom are delegated institute directors or senior managers, while 65 are elected representatives of the scientific and technical staff of each institute.

Chair of the STC:

- Prof. Dr. rer. nat. habil. Andreas Tünnermann
  Director of the Fraunhofer Institute for Applied Optics and Precision Engineering IOF

Presidential Council

The Presidential Council of the Fraunhofer-Gesellschaft is made up of the members of the Executive Board and the chairs of the seven Fraunhofer Groups, named below:

- Prof. Dr.-Ing. Peter Elsner
  Fraunhofer Institute for Chemical Technology ICT
- Prof. Dr. techn. Dieter W. Fellner
  Fraunhofer Institute for Computer Graphics Research IGD
- Prof. Dr. Rainer Fischer
  Fraunhofer Institute for Molecular Biology and Applied Ecology IME
- Prof. Dr.-Ing. Dipl.-Phys. Hubert Lakner
  Fraunhofer Institute for Photonic Microsystems IPMS
- Prof. Dr. rer. nat. Reinhart Poprawe
  Fraunhofer Institute for Laser Technology ILT
- Prof. Dr.-Ing. habil. Prof. e. h. Dr. h. c. mult. Michael Schenk
  Fraunhofer Institute for Factory Operation and Automation IFF
- Prof. Dr.-Ing. Jürgen Beyerer (Guest member)
  Fraunhofer Institute for Optronics, System Technologies and Image Exploitation IOSB

Executive Board

- Prof. Dr.-Ing. habil. Prof. E. h. Dr.-Ing. E. h. mult. Dr. h. c. mult. Reimund Neugebauer (President)
- Prof. (Univ. Stellenbosch) Dr. rer. pol. Alfred Gossner
- Prof. Dr. rer. publ. ass. iur. Alexander Kurz
- Prof. Dr. rer. nat. Georg Rosenfeld (since April 1, 2016)

Listed information valid as at January 1, 2017

FRAUNHOFER GROUPS

The Fraunhofer Groups are organizational units of the Fraunhofer-Gesellschaft in which institutes and research institutions specializing in related areas of technology have joined together to coordinate their research and development activities and present a single face to the market. They also help to formulate the organization's business policy and to implement its working methods and funding model.

For further information on the Fraunhofer Groups, please consult our website:

www.fraunhofer.de

- Fraunhofer Group for Defense and Security VVS
  www.vvs.fraunhofer.de
- Fraunhofer ICT Group
  www.iuk.fraunhofer.de
- Fraunhofer Group for Life Sciences
  www.lifesciences.fraunhofer.de
- Fraunhofer Group for Light & Surfaces
  www.light-and-surfaces.fraunhofer.de
- Fraunhofer Group for Materials
  and Components – MATERIALS
  www.vwb.fraunhofer.de
- Fraunhofer Group for Microelectronics
  www.mikroelektronik.fraunhofer.de
- Fraunhofer Group for Production
  www.produktion.fraunhofer.de

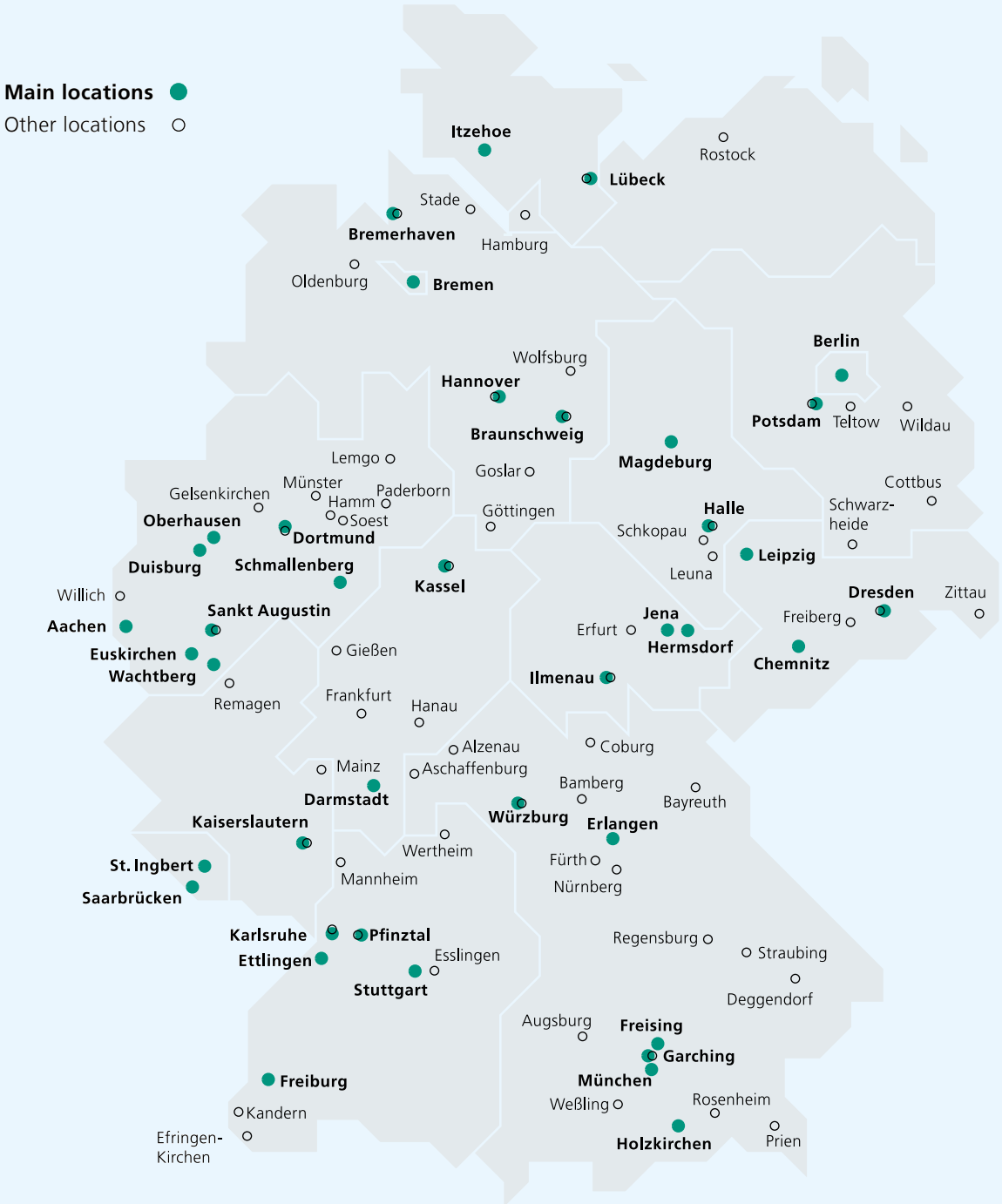
FRAUNHOFER ALLIANCES

Interdisciplinary alliances have been established between Fraunhofer Institutes or individual research departments to enable them to jointly develop and market solutions for specific business sectors.

For further information on the Fraunhofer Alliances, please consult our website:

www.fraunhofer.de

Fraunhofer Adaptronics Alliance
Fraunhofer Additive Manufacturing Alliance
Fraunhofer AdvanCer Alliance
Fraunhofer Ambient Assisted Living Alliance AAL
Fraunhofer AutoMOBILE Production Alliance
Fraunhofer Battery Alliance
Fraunhofer Big Data Alliance
Fraunhofer Building Innovation Alliance
Fraunhofer Cleaning Technology Alliance
Fraunhofer Cloud Computing Alliance
Fraunhofer Digital Media Alliance
Fraunhofer Embedded Systems Alliance
Fraunhofer Energy Alliance
Fraunhofer Food Chain Management Alliance
Fraunhofer Lightweight Design Alliance
Fraunhofer Nanotechnology Alliance
Fraunhofer Photocatalysis Alliance
Fraunhofer Polymer Surfaces Alliance POLO®
Fraunhofer Simulation Alliance
Fraunhofer Space Alliance
Fraunhofer Technical Textiles Alliance
Fraunhofer Traffic and Transportation Alliance
Fraunhofer Vision Alliance
Fraunhofer Water Systems Alliance (SysWasser)


Main locations
Other locations
Itzehoe
Rostock
Lübeck
Stade
Bremerhaven
Hamburg
Oldenburg
Bremen
Berlin
Wolfsburg
Hannover
Potsdam
Teltow
Wildau
Braunschweig
Magdeburg
Lemgo
Goslar
Gelsenkirchen
Münster
Paderborn
Hamm
Soest
Oberhausen
Dortmund
Göttingen
Halle
Schkopau
Cottbus
Schwarz-
heide
Leipzig
Leuna
Duisburg
Schmallenberg
Kassel
Willich
Sankt Augustin
Aachen
Dresden
Zittau
Freiberg
Erfurt
Jena
Hermsdorf
Chemnitz
Euskirchen
Wachtberg
Gießen
Ilmenau
Remagen
Frankfurt
Hanau
Alzenau
Coburg
Mainz
Aschaffenburg
Bamberg
Bayreuth
Darmstadt
Würzburg
Erlangen
Kaiserslautern
Wertheim
Fürth
St. Ingbert
Mannheim
Nürnberg
Saarbrücken
Karlsruhe
Pfinztal
Regensburg
Straubing
Ettlingen
Esslingen
Deggendorf
Stuttgart
Augsburg
Freising
Garching
Freiburg
München
Kandern
Weßling
Rosenheim
Efringen-
Kirchen
Holzkirchen
Prien

ADDRESSES IN GERMANY

The Fraunhofer-Gesellschaft

Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e. V.

Postal address
Postfach 20 07 33
80007 München
Germany
Phone +49 89 1205-0
Fax +49 89 1205-7531
info@fraunhofer.de

Address for visitors
Hansastrasse 27c
80686 München
Germany

Executive Board

President of the Fraunhofer-Gesellschaft,
Corporate Policy and Research Management:
Prof. Dr.-Ing. habil. Prof. E. h. Dr.-Ing. E. h. mult.
Dr. h. c. mult. Reimund Neugebauer

Executive Vice President Technology Marketing
and Business Models:
Prof. Dr. rer. nat. Georg Rosenfeld

Executive Vice President Finance, Controlling
and Information Systems:
Prof. (Univ. Stellenbosch) Dr. rer. pol. Alfred Gossner

Executive Vice President Human Resources,
Legal Affairs and IP Management:
Prof. Dr. rer. publ. ass. iur. Alexander Kurz

Information on fields of research, links to all
Fraunhofer Institutes and Research Institutions,
as well as to the Fraunhofer Groups and Alliances,
and contacts for the central departments are
available on both the German and English versions
of the Fraunhofer website:

www.fraunhofer.de

Historic
Fraunhofer Glassworks
Fraunhoferstrasse 1
83671 Benediktbeuern
Germany


Gothenburg
Glasgow
Dublin
Brussels
Brookline
Boston
East Lansing
Munich
Vienna
Budapest
San José
Plymouth
Storrs
Bolzano
Graz
Porto
Ercolano
Beijing
Seoul
Tokyo
Newark
College Park
Lavon
Cairo
Dubai
Bangalore
Ampang
Jakarta
Pretoria
São Paulo
Santiago
Stellenbosch

INTERNATIONAL ADDRESSES

Fraunhofer International

Contact in Germany
Fraunhofer-Gesellschaft
International Business Development
Thomas Dickert
Phone +49 89 1205-4700
Fax +49 89 1205-77-4700
thomas.dickert@zv.fraunhofer.de
Hansastrasse 27c
80686 München
Germany

Contact in Brussels
Fraunhofer-Gesellschaft
Brussels Office
Mathias Rauch
Phone +32 2 50642-42
Fax +32 2 50642-49
mathias.rauch@zv.fraunhofer.de
http://bruessel.fraunhofer.de
Rue Royale 94
1000 Brussels/Bruxelles, Belgium

The Fraunhofer-Gesellschaft operates subsidiaries in Europe, North America and South America. In other regions, Fraunhofer Representative Offices and Fraunhofer Senior Advisors form a bridge to local markets worldwide. The Fraunhofer Office in Brussels serves as an interface between Fraunhofer and the institutions of the European Union. For contact addresses, please consult our website:

www.fraunhofer.de

Editorial notes

Editorial team
Dr. Martin Thum (editor in chief)
Markus Jürgens (picture editor)

Production
Jürgen Mosler

Design concept
Markus Jürgens
Jürgen Mosler
vsp | vogt | sedlmeir | pfeiffer

Layout
vsp | vogt | sedlmeir | pfeiffer

English edition
Burton, Van Iersel & Whitney GmbH, Munich

Information on fields of research, links to all Fraunhofer Institutes and Research Institutions, as well as to the Fraunhofer Groups and Alliances, and contacts for the central departments are available on both the German and English versions of the Fraunhofer website:

www.fraunhofer.de

Editorial address
Fraunhofer-Gesellschaft
Hansastrasse 27c
80686 München
Germany
Dr. Martin Thum
Internal and External Communication
Phone +49 89 1205-1367
martin.thum@zv.fraunhofer.de

Photo acknowledgments
Title page, pages 6/7, 56/57, 58, 67, 69, 76, 91, 106, 110/111, 128/129: iStockphoto
Page 5/6: Fotolia
Pages 8, 9 ,10, 11: Bernhard Huber
Page 51: Frank Bierstedt
Page 52: Tobias Koch
Page 56: Peter Rigaud
Page 70: Fraunhofer / Marc Müller
Page 71: Fraunhofer / Dirk Mahler
Page 73: Zurich Opera House
Page 74: Kai-Uwe Wudtke
Page 75: Baltic Taucherei- und Bergungsbetrieb Rostock GmbH
Page 76: Shutterstock
Page 77: Osram
Page 78: Manfred Zentsch, indigo
Page 81: ai-solution GmbH
Page 83: Dirk Mahler
Page 92: personal
Page 93: Mareike Schaaf
Pages 94, 97, 98, 101, 102, 105: Jürgen Lösel

All other photos:
© Fraunhofer-Gesellschaft e. V.