

Mobility – A Field of Research With Many Facets



“With our research, we are contributing to the future-oriented development of mobility in very different areas.”

Prof. Dr. Anita Schöbel

Director of the Fraunhofer Institute for Industrial Mathematics ITWM

Dear readers,

mobility is a central achievement of our society; it guarantees us freedom and brings us closer together globally in many areas. But it comes at a price and requires a lot of energy. This also makes it a significant factor in a prominent issue of our time, climate change.

Our Annual Report 2021/2022 focuses on the topic of “mobility”. First and foremost, we want to demonstrate our expertise in this area and present the research projects that address various aspects from different perspectives.

For us, moreover, the theme for 2021/2022 has particular symbolic power: Despite the ongoing Corona pandemic, significantly more movement was possible again. Mobility is therefore not only of professional relevance for us, but this year it also stands for the recovery of the accustomed everyday life.

We at the Fraunhofer ITWM deal with many facets: This concerns first of all our large department “Mathematics for Vehicle Engineering”. Many other departments also deal with specific aspects – from the maintenance of trains to the storage of energy for the opera-

tion of electric vehicles to the dispersion of aerosols in airplanes and the optimization of public transport. With our research, we contribute at very different points to the further development of mobility in a future-oriented way.

As the AI Pilot for Mobility of Rhineland-Palatinate, I advise science and companies together with my advisor Dr. Henrike Stephani on how they can incorporate artificial intelligence (AI) into their processes. We make our know-how accessible to science, business and industry, present projects and methods that use AI particularly successfully in the field of "mobility" and thus want to enable the use of AI where added value can be expected. This is an exciting transfer that we have enjoyed driving forward in recent months.

The mobility industry is one of the defined lead markets of the Fraunhofer-Gesellschaft. We contribute to many other sectors and, as in the previous year, our annual report is structured according to these. You also learn about our current projects for the lead markets of health and medicine, digitization, energy, mechanical engineering, and process engineering, as well as about the strategic research field of quantum technology.

The passion for science and research has united us at Fraunhofer ITWM for 25 years now – 2021 was our anniversary year. Due to the pandemic, the activities around this event, which is significant for us, turned out to be smaller than we had imagined. Nevertheless, we have managed to recognize and celebrate the successes of a quarter of a century. Naturally, we are also devoting attention to this special birthday in our annual report – and linking the anniversary to the theme of "mobility" on our cover.

I wish you an enjoyable read with profitable insights. If you have any questions, please do not hesitate to contact us at Fraunhofer ITWM. Please do not hesitate to contact the mentioned persons of our institute either!

Kind regards



Prof. Dr. Anita Schöbel

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The Institute in Profile

Computer simulations are indispensable in designing and optimizing products and processes. Real models are replaced by virtual models. Mathematics plays a fundamental role in the development of this digital world. It is the technology that generates these images and efficiently converts them into software, the raw material of models and the core of every computer simulation.

Applied Mathematics as a Key Technology

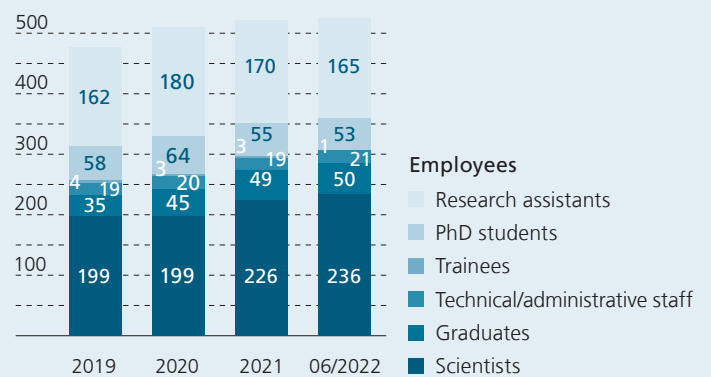
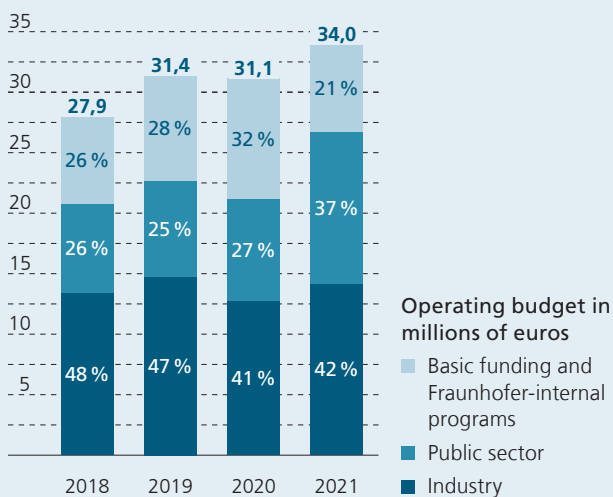
Many small and medium-sized companies use simulation to reduce costs. We support these companies in particular with consulting and computing power. They profit on the market through the use of simulation in terms of innovation and quality assurance of products. Of course we also work with large companies, especially in the automotive industry, mechanical engineering, the textile industry, micro-electronics, the computer industry and in the financial sector. Integral components of our research and development projects are consulting and implementation, support in the application of high-performance computing technology and provision of customized software solutions. We not only use simulation software, but develop it ourselves, often in cooperation with leading companies.

34
 Million euros
 Budget –
 Networking
 pays off

Our versatile core competences

- Processing of data from experiments and observations
- Setting up mathematical models
- Conversion of the mathematical problem solutions into numerical algorithms
- Summarizing data, models and algorithms in simulation programs
- Optimizing solutions in interaction with the simulation
- Visualize simulations

As Fraunhofer ITWM we do not only want to be the bridge between the real and the virtual world, but also to build a link between university mathematics and its practical implementation. Therefore, the close connection to the Department of Mathematics at the University of Kaiserslautern plays a special role.





Industries – who do we work for?

The competencies of our departments and the broad spectrum of their application fields are used in numerous industries.

With our core competencies in the areas of modeling and simulation, optimization and decision support, data analysis and visualization, we address companies and organizations in the following industries:

- Process engineering, Mechanical/plant engineering
- Automotive industry and suppliers

- Medicine and medical technology
- Energy and raw materials industry
- Technical textiles
- Information technology
- Finance industry

Through many years of cooperation with our regular customers, we have developed a strong domain competence in subsectors of individual industries. The following applies to all industries:

The modeling and simulation competence of the Fraunhofer ITWM generates real competitive advantages on the market.

Board of Trustees

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(Status: September 2021)

Networking in the Fraunhofer-Gesellschaft

A large network and bright minds are crucial for the success of projects. Our specific mathematical competencies make us a sought-after and valued cooperation partner within the Fraunhofer-Gesellschaft.

Fraunhofer Alliances

Related institutes organize themselves into research alliances and operate jointly in the R&D market. They participate in the corporate policy as well as in the implementation of the functional and financing model of the Fraunhofer Gesellschaft. The Fraunhofer ITWM is a member of the Alliance for Information and Communication Technology IUK and has guest status at the Alliance MATERIALS.

Fraunhofer Cluster of Excellence

These clusters promote the cooperative development and processing of system-relevant topics through a cross-institutional research structure spread across several locations. We are involved in the following clusters:

- Fraunhofer Cluster of Excellence Advanced Photon Sources CAPS
- Fraunhofer Cluster of Excellence Cognitive Internet Technologies CCIT
- Fraunhofer Cluster of Excellence Programmable Materials CPM

Fraunhofer Strategic Research Fields

They bundle the essential future fields of application-oriented research. Institute Director Prof. Dr. Anita Schöbel is the spokesperson for the Fraunhofer Strategic Research Area "Next Generation Computing" and, together with Prof. Dr. Manfred Hauswirth (Fraunhofer FOKUS), is responsible for the topic of "Quantum Computing" at Fraunhofer. The Rhineland-Palatinate competence center focusing on "Quantum High Performance Computing" is located at our institute.

Lead Market-Oriented Alliances

With the defined lead markets, Fraunhofer pursues the goal of addressing industries with

high relevance for innovative strength and creating added value through offers for system solutions and cross-institutional transfer. The most important for us are:

- Plant, mechanical and vehicle construction
- Health care industry
- Chemical industry
- Mobility economy
- Digital economy
- Energy industry

Fraunhofer Lead Projects: Preliminary Research in the Group

Thematically, they are oriented to current fields of industry and bundle the competencies of different competencies of various institutes for efficient preliminary research.

Leading projects with ITWM participation are currently:

- ML4P – Machine Learning for Production
- QUILT – Quantum Methods for Advanced Imaging Solutions
- COGNAC – Cognitive Agriculture
- ShaPID – Shaping the Future of Green Chemistry by Process Intensification and Digitalization
- SUBI²MA – Sustainable, Simulation-guided Biobased and Biohybrid Materials

FCC – Strong Partnership in Sweden

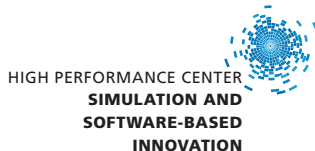
One of our most important international partners is the "Fraunhofer Chalmers Research Centre for Industrial Mathematics", or FCC for short, founded in 2001 by the Fraunhofer Gesellschaft and Chalmers University in Gothenburg. In 2021, 61 employees worked on topics such as multiphysics simulation, geometry, modeling of biological systems and data mining. The budget was just under 7 million euros.

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Trade fairs and events



Center of Excellence Simulation and Software-Based Innovation



Digital solutions are driving energy-efficient and resource-conserving production decisively. To this end, new results and ideas must be transferred into practice as quickly as possible. This is one of the central tasks to which the Simulation and Software-based Innovation Center is dedicated. In the so-called transfer centers of the high performance center, the scientific results of research are transformed into innovations and requirements from industry and society are directly addressed.

The Fraunhofer ITWM and Fraunhofer IESE, the TU Kaiserslautern, and the Kaiserslautern University of Applied Sciences bundle their competencies in the performance center. In addition, there is a cooperation with the German Research Center for Artificial Intelligence DFKI and the Leibniz Institute for Composite Materials IVW as well as other associations and initiatives. The cooperating companies from the business community include more than 30 regional and at least as many national companies. Among others, BASF, Daimler Trucks, BioNTech and John Deere are involved in the development work.

of products, the challenges of AI in practice, and new computer and memory architectures for embedded systems and for high-performance computing. The four transfer centers “Process Engineering/Chemistry”, “Mobility”, “Production Processes/Energy Efficiency” and “Biotechnology/Health” focus on the exploitation of the methods in the industry.

Research on the Pulse of Time

“With the new structure of the performance center, we keep our finger on the pulse of the times”, says Dr. Konrad Steiner, department head at Fraunhofer ITWM and managing director of the performance center. “The new thematic orientation ensures that we target the future topics which are of highest relevance for industry and society now and in the next years.” Base funding of one million euros annually has been secured from the Fraunhofer Gesellschaft. The total annual budget of more than 10 million euros is supported by funding projects from the state of Rhineland-Palatinate and primarily by industrial projects.

Fit for the Future With a New Structure

The performance center is divided into research and development labs and transfer centers. The R&D labs work methodically and develop concepts and algorithms as basic technologies for the transfer centers. After six years of successful research and transfer work, the time has come to tackle new problem areas in 2022. The existing R&D labs and transfer centers have been expanded and realigned in terms of content. The three new R&D labs “Digital Twins,” “Data Analysis and Artificial Intelligence,” and “Next Generation Computing” are dedicated to the digitization

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More information at www.leistungszentrum-simulation-software.de/en

Spin-Offs and Other Collaborations

Spin-Offs of the Fraunhofer ITWM

- **flexstructures** – specific engineering projects and services for the simulation of flexible components
- **Math2Market** – comprehensive software services, such as GeoDict®, an innovative simulation software for digital materials research and development
- **Product information office for old-age provision PIA** – neutral body for the opportunity risk classification of subsidized retirement provision products
- **Sharp Reflections** – Big-Data computing technologies for the future of seismics
- **ThinkParQ** – fast and scalable solutions for all performance-oriented environments such as HPC, AI and Deep Learning
- **Wendeware AG** – software ecosystem for the energy transition

Promotion of Young Talent

The **Felix Klein Center for Mathematics (FKZM)** is an institutional connection between the Department of Mathematics of the TU Kaiserslautern and the Fraunhofer ITWM. The focus is on the promotion of young scientists, for example with modeling weeks for schools, scholarships, and a mentoring program for mathematics students. Scholarship holders are not only supported financially, they can also combine practice and theory. Students in advanced semesters and doctoral students can take part in advanced training courses lasting several days, and they can also listen to lectures by top-class researchers. The monthly “Thinking outside the box” of the Felix Klein Center offers interesting insights into different topics from science and culture.

The Competence Center for Mathematical Modeling in STEM Projects in Schools (KOMMS) is primarily aimed at teachers. It is located at the TU Kaiserslautern and combines the areas of school projects, education and training, and research.

The national **Excellence school network MINT-EC** aims to get students excited about STEM subjects. In the course of the cooperation, regular events such as the Math Talent School are offered.

Embedded in the Location

The **Science and Innovation Alliance Kaiserslautern (SIAK)** forms a network for digital transformation, innovation and interdisciplinary research. It is regionally anchored through its members from science (universities and research institutes) and business, especially from small and medium-sized enterprises.

Networking in Europe

In the **European Consortium for Mathematics in Industry (ECMI)**, scientific institutions and industrial companies in Europe have joined forces with the aim of bringing mathematical modeling, simulation and optimization even more strongly into economic application. An important role is played by the training of industrial mathematicians, because their expertise in particular is used.

107
new jobs
have been
created by our
Spin-Offs



More information at www.itwm.fraunhofer.de/networks

2021: A Quarter of a Century Fraunhofer ITWM



For 25 years, we have been using mathematics as a key technology to optimize products and processes. Founded in January 1996 as a state institute, Fraunhofer ITWM has proven itself as a place of innovation and was incorporated into the Fraunhofer-Gesellschaft in 2001. In the meantime, it has become one of the largest mathematical research institutes worldwide, also thanks to intensive networking, regionally as well as internationally.

The anniversary year was held under the motto "GrowingTogether. The motto can be read in different ways and refers both to the joint growth, the expansion of our institute, and to the coming together and growing together with partners such as the TU Kaiserslautern, the city itself, and many local research institutions. We are proud of this and look forward to the challenges of the coming years.

Mathematical Diversity Also Visible to the Outside

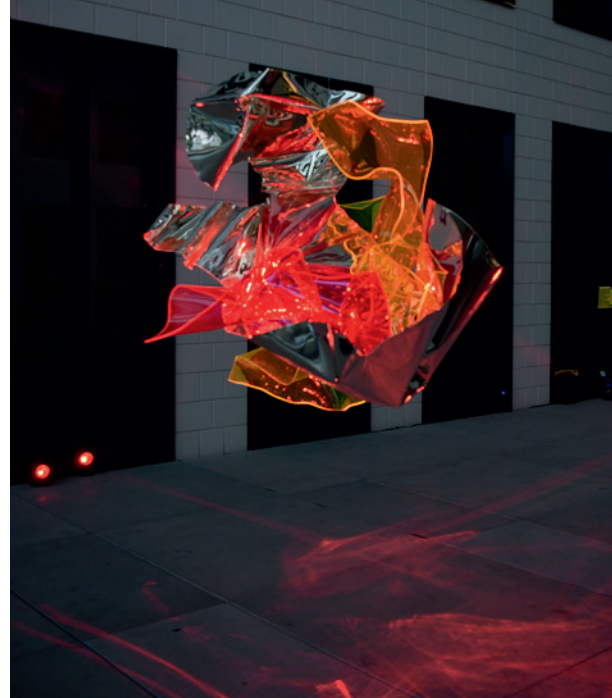
Especially the passers-by of the Trippstadter street in Kaiserslautern might have noticed them: Colorful window pictures with slogans like "Math makes you rich", "Math is hot", and "Math fills you up" have been decorating the facade of the Fraunhofer ITWM since March 2021. Behind these 25 posters, digital "little doors" are hidden, which lead to proj-

ect websites of our departments. An exciting insight into our institute, illustrating the thematic range of our nine departments. Our anniversary was not only noticeable right on our own doorstep, but throughout the city! On the streets of Kaiserslautern, a bus is still driving today, which – completely wrapped in the Fraunhofer design – in addition to the large number 25 in thick letters also announced our motto for the year 2021: "GrowingTogether.

Combining Science and Art

A particularly vivid contribution to the anniversary year was the light and sound installation "Brainpatterns" in the atrium, which scientifically interested and art lovers could experience after dark in September. Through the glass front of the institute, one could see an organically intertwined sculpture made of acrylic





elements, which glowed in a colorful play of colors from the inside and created the impression of an artificial intelligence. Parallel to this visual staging, viewers were able to connect to a synchronized sound installation via QR code and smartphone, which added a second sensory level to the action. The artwork was created by the artist Tatjana Busch, in cooperation with the media studio "E".

Light Installation Impresses

Behind this visual and acoustic spectacle is the interdisciplinary project "Brainpalace – Brainpatterns", which explores the potential of combining art and neurofeedback. The approach in the first part of the project "Brain-

patterns" was to measure brain activity in the course of perceiving an audiovisual and spatial light installation: parameters were extracted from EEG signals and then fed back to the installation as feedback. This created an interactive interaction between the viewers and the artwork, whose play of colors reacted to these signals. In "Brainpalace", the second part of the project, these measurements were to be extended to whole groups of spectators at Fraunhofer ITWM.

25 years of success with mathematics: The year was heralded with waving anniversary flags and was accompanied by numerous activities: 25 math motifs were dedicated to the exciting ideas of our researchers. The light installation could be admired as a highlight in the fall. Here, computer simulations of the Fraunhofer ITWM were turned became real art.

 www.itwm.fraunhofer.de/en/25



Review: Highlights 2021



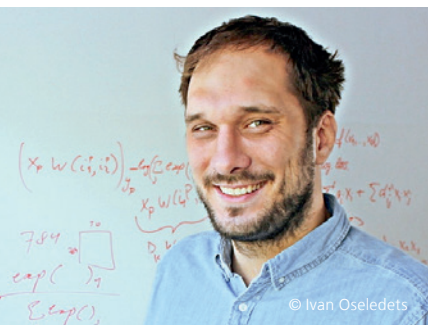
ECMI: Machine Learning and Big Data for Cable Simulation

Our area “Mathematics for Vehicle Engineering” is involved in ECMI – the European Consortium for Mathematics in Industry – 2021, among other things with the webinar “Math for Industry 4.0 – Models, Methods and Big

Data”. The focus was on “cable simulation” and “digital human modeling”. With the software package IPS Cable Simulation, an established tool for the simulation of cables and hoses, we are well positioned here.



www.itwm.fraunhofer.de/ecmi-online-conference



© Ivan Oseledets

Humboldt Award Winner Prof. Ivan Oseledets at the Fraunhofer ITWM

The Humboldt Society for Science, Art and Education promotes worldwide scientific exchange, including research stays in Germany. Ivan Oseledets, professor at the Skolkovo Institute of Technology in Moscow, received one of the coveted fellowships for a stay at our institute. He is no stranger here: Oseledets works

with the “Optimization” department as well as the “Flow and Material Simulation” department. His areas of interest are “Big Data and Artificial Intelligence (AI)”, which is why he is involved in industrial projects at the institute to model various physical processes using AI technologies and Machine Learning (ML).

Guest at the Fraunhofer ITWM: Prof. Ivan Oseledets



www.itwm.fraunhofer.de/Oseledets [only available in German]

Awards for Outstanding Research in Financial Mathematics

Two honors went to “Financial Mathematics” in 2021: Prof. Dr. Ralf Korn, ITWM consultant and member of our Scientific Advisory Board, was elected Chairman of the German Society for Insurance and Financial Mathematics (DGVFM), and our colleague Franziska Diez received the GAUSS Young Investigator Award. Every year, the DGVFM and the German Actuarial Association (DAV) award three GAUSS

Young Investigator Awards for outstanding scientific work. Franziska Diez, a researcher in the “Financial Mathematics” department, was honored for her dissertation. The thesis on “Yield Curves and Chance Risk Classification: Modeling, Forecasting, and Pension Product Portfolios” was particularly praised for its impressive combination of theory and application in the field of pension products.



Dr. Franziska Diez receives GAUSS Young Investigator Award for outstanding doctoral thesis.



www.itwm.fraunhofer.de/gauss_prize

Prof. Dr. Anita Schöbel Becomes President of the European or Societies

In July 2021, the Council of the Association of European Operational Research Societies (EURO) unanimously elected our institute director as its new president. The EURO is the European section of the “International Federation of Operational Research Societies” (IFORS) and aims to promote Operations Research (OR) throughout Europe.

Anita Schöbel researches and teaches in the field and especially emphasizes the application aspect: “For me, Operations Research is an important research topic at the university, but also in the practice of Fraunhofer ITWM. We use OR methods in many projects, such as in healthcare, logistics, production or energy optimization.”



 www.itwm.fraunhofer.de/euro-president

Targeted Assistance in the Event of a Disaster

In a disaster, every second counts to care for those in need. The teams of relief organizations have to find their way very quickly in devastated areas. Researchers in our “Image Processing” department are developing a software that gets humanitarian aid to the right destination faster. They are using drone images that are analyzed in real time with artificial intelligence (AI). The scientists are combining specially developed image processing and

deep-learning algorithms to enable fully automated analysis of the drone images. In order for the artificial intelligence to start the independent learning process, it is “fed” with data. For this purpose, the researchers draw on satellite imagery from earthquake zones, for example. The system works without an Internet connection and on commercially available notebooks and can therefore also be reliably used in devastated areas without infrastructure.



Drones provide image data on the extent of the disaster in a short time.

 www.itwm.fraunhofer.de/edda-pm-en

International Exchange at KLAIM – Kaiserslautern Applied and Industrial Mathematics Days

A new event format brought together many researchers in October 2021 after a long hiatus: More than sixty international scientists accepted the invitation of Prof. Dr. Anita Schöbel and Prof. Dr. Bernd Simeon from the Department of Mathematics at TU Kaiserslautern. The KLAIM conference provides a forum for mathematicians from universities, research

laboratories, and industry to exchange ideas and present the latest results. The first edition of KLAIM focused on the role of applied mathematics in the development of digital twins. Forty short talks and extensive discussion sessions provided a multifaceted look at the topic. In the future, the conference will be held every two years.



 www.itwm.fraunhofer.de/klaim-pm-en

New Work – This Is How We Work at the Fraunhofer ITWM



Hybrid conferences are part of our new everyday working life. Some employees are already booking shared office space. some employees already do.

The research of the Fraunhofer ITWM shapes the future in many areas. The working environment must be right in order for our employees to achieve top results together with their research partners. The way to this is paved by our “New Work” team, which deals with modern working.

The Corona pandemic changed the working world from one day to the next and thus became an endurance test with respect to topics such as mobile working, online meetings, and leading at a distance. The “New Work” team is concerned with permanently designing the conditions at Fraunhofer ITWM in such a way that there is plenty of room for research activities and creative thinking, and at the same time the needs of the individual employee can be reconciled with the requirements of the teams in the best possible way.

Back at the Institute – But More Flexible

“Over the past two years, our employees have shown that they can shape their working environment individually without teamwork internally or collaboration with external parties falling by the wayside,” says Institute Director Prof. Dr. Anita Schöbel, looking back on the experience of the Corona pandemic. “Even though we are very happy about the return to the institute and to the more familiar working environment with many personal encounters, we want to maintain a certain flexibility that we have tested. So, we offer an agile, modern work environment at the Institute.”

The “New Normal” is being tested at Fraunhofer ITWM with a company agreement that combines the advantages of familiar and new forms of work. This was developed based on an online survey of the “New-Work” team and revealed: The majority of the employees at Fraunhofer ITWM would like to work mobile at least two days per week. This was mainly justified by the advantages of time savings, flexibility, and concentrated work. Disadvantages of mobile working were seen in the loss of contact with colleagues, the loss of work-life balance, and the fact that too many online meetings were held.



Share Management Tasks

However, “Working World 4.0” involves more than just questioning time and space constraints. Due to the strong growth of the institute in recent years and the simultaneous increase in working from home, topics such as the sharing of workplaces and new communication formats are also coming into focus. In addition, the demands on managers and their wishes for the design of their tasks are changing.

One example is the topic of “shared leadership,” which the “High Performance Computing” (HPC) area is already living. Step by step, the tasks performed here by long-time head Dr. Franz-Josef Pfreundt have been transferred to several shoulders. “HPC consists of many different groups that work very independently. With the retirement of our division manager due to age, the question arose as to how the HPC would position itself in the future,” says Matthias Klein-Schlöbl, head of the “Green by IT” team, explaining how the division’s multi-member management team came about. “We feel we belong together and therefore wanted to remain as one unit,” he says. “The result is the “F-Team,” in which eight executives are each responsible for specific focus areas, such as finance or science management. The process is very democratic: “We make decisions that affect everyone together and strive for a unanimous vote here,” says Klein-Schlöbl. “We’ve done very well with that so far!”

Increase the Proportion of Women at the Institute

New working and organizational models are considered by experts to be important factors for equal opportunities. They are thus a lever for more diversity and equal opportunities; a significant topic also at Fraunhofer ITWM: “We want to win more women for us, because the STEM subjects and especially mathematics with their versatile applications are an exciting field of work for everyone,” emphasizes Schöbel. “We offer an environment that makes it possible to balance research and family well, and we want to make even more possible.”

Working with a child is possible on site at the Fraunhofer ITWM since many years already in the parent-child office