

We are Fraunhofer ITWM



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Main Focus

- Surface and Material Characterization
- Quality Assurance and Optimization
- Virtual Image Processing
- Industrial Image Learning
- Quantum Image Processing
- Condition Monitoring and Predictive Maintenance

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Image Processing

What does your department deal with and what constitutes its research work?

Our department develops image analysis algorithms and converts them into industrial-grade software in production. The application areas include sophisticated surface inspection and analysis of microstructures. We develop both new methods and domain-specific machine learning algorithms.

What potential does your department’s research have for a better future?

Many methods, especially AI processes, enable savings in resources and energy in production. These topics are becoming increasingly important. But also tasks related to nature conservation and sustainability are solvable by our algorithms.

Where do you see your department in five years?

In five years, AI algorithms will be used in all industrial projects of our department, but also linked to model-based approaches. Many complex quality tests will only become possible in the next few years as a result of developments in AI and hardware. Sustainability issues will become as important as other industry goals, such as cost savings, higher production speed or less waste.

Which three keywords best describe your department?

- Industry-oriented – pragmatic – goal-oriented

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- Clear the Way for Modular Inspection Platform. S. 25
- Virtual Inspection of Filter Nonwovens S. 27
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Main Focus

- Billing Audit
- Retirement and Life Insurance
- Flexible Loads on the Energy Market
- Data Science
- Quantum Computing

Financial Mathematics

What does your department deal with and what constitutes its research work?

We simulate pension contracts and optimize investment strategies for life insurance policies. We use statistical methods and data science to identify anomalies in billing. And we save costs and energy by optimizing load shedding.

What potential does your department’s research have for a better future?

We have broad expertise in fraud prevention and also the right software, for example in the billing of care services. The same applies to secure financial markets, also with regard to consumer protection. Saving energy is a key social and economic issue. We take this into account with our work on the flexible use of energy in industrial companies.

Where do you see your department in five years?

We have continued to expand our expertise in current research areas. Since quantum computers have demonstrated their superiority over classical computers and we are already conducting research in this area, we will be an established partner for applications of quantum computing in the financial industry. Presumably, we have other research fields that are not yet visible to us today.

Which three keywords best describe your department?

- Team spirit – success – fun

Department topics in this report:

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- Quantum Leaps in Science and Careers S. 34
- Enterprise Lab: Through Modern Working Methods to Mathematical Success . . . S. 46
- Mathematics Creates Transparency – Making Secure Provision for Old Age S. 48
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Main Focus

- Green by IT
- Parallel File System (BeeGFS)
- Visualization
- Seismic Data Processing
- Data Analysis and Machine Learning
- Scalable Parallel Programming
- Quantum Computing

High Performance Computing

The High Performance Computing leadership team consists of Dr. Valeria Bartsch, Dr. Norman Ettrich, Dr. Daniel Grünewald, Dr. Janis Keuper, Matthias Klein-Schlöbl, Dr. Jens Krüger, Dr. Mirko Rahn and Dr. Rui Mário da Silva Machado. In the following Dr. Valeria Bartsch and Dr. Jens Krüger, as spokesperson, will answer the questions:

What does your department deal with and what constitutes its research work?

We are a globally recognized partner when it comes to the development of new technologies especially for distributed and high-performance computing. We are committed to holistic and future-oriented development, optimization and research. Our topics include efficient and scalable hardware and software solutions, as well as methods for addressing industrial and societal challenges.

What potential does your department’s research have for a better future?

We drive the current state of the art in high performance computing. We are courageous and break new ground when it comes to novel solution. We are not afraid to think outside the box and we are making a decisive contribution to the transformation to a sustainable society.

Where do you see your department in five years?

We will have developed a complete supercomputing hardware and software stack. We integrate quantum computing into HPC systems successfully. We are open to the unexpected and will develop new ideas over the next five years.

Which three keywords best describe your department?

- Holistic – sustainable – courageous

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■ European Data Cloud for Mobility of the Future	S. 28
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Main Focus

- Teratec Application Center
- Coating Thickness Measurement
- Optical Measurement
- Chemical Analysis
- Non-destructive Testing
- Quantum Computing

Materials Characterization and Testing

What does your department deal with and what constitutes its research work?

Our work focuses on non-destructive testing for quality control in the industrial manufacturing process. Our applications range from pipe wall thickness measurement to the characterization of multilayer coating systems and insulation around wires. For this purpose, we use electromagnetic waves in the entire spectral range from visible light to the terahertz wave range and use both quantum-inspired measurement technology and the possibilities of machine learning to achieve the best possible results.

What potential does your department’s research have for a better future?

Non-destructive testing and quality control reduces the number of defective parts. This saves companies time, money, and resources, and gives their customers the certainty of receiving products of the highest quality. Our systems are easy to operate and can be integrated into existing processes. This secures the basis for investment and jobs. Through our research, we generate innovations that guarantee the technological edge needed to survive in global competition.

Where do you see your department in five years?

The department continues to build on its leadership position for the use of terahertz technology in nondestructive testing and will expand it to include quantum-inspired measurement technology. Testing techniques will cover the entire spectral range and be supported by machine learning in evaluation to reliably identify the widest possible variety of defects. This will allow us to open up new application scenarios that are currently not within reach.

Which three keywords best describe your department?

- Customer-oriented – innovative – precise

Department topics in this report:

- Radome Application Example: Safety Thanks to Terahertz Technology. S. 24
- Rhineland-Palatinate Promotes Competence Center for Quantum Computing S. 31
- T-KOS: Terahertz Technology for Reliable Communications S. 45
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- ViDestoP S. 66

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Main Focus

- Digital Environmental Data
- Load Data and Durability
- Dynamics and System Simulation
- Human Models and Human-Machine Interaction
- Cables, Hoses and Flexible Structures
- Tire Models – CDTire
- Technical Center: Human Machine Interaction and Driving Simulators



Mathematics for Vehicle Engineering

What does your division deal with and what constitutes its research work?

The division is divided into two departments as well as the project group "Tire Simulation" and the cross-sectional unit "MF-Technikum", which takes care of the test and measurement technology.

In the department "Dynamics, Loads and Environmental Data", we develop methods and tools for system simulation, incorporating environmental data and usage variability. In this way, we address the main aspects in vehicle engineering: operational stability, reliability, energy efficiency and ADAS/AD.

The department "Mathematics for the digital factory" bundles the activities for the design of software tools for the virtual development of products; this includes, for example, IPS Cable Simulation: With this software family, the assembly of cables, cable harnesses and hoses can be designed virtually and validated in operation.

What potential does your division's research have for a better future?

Vehicle development is currently facing a number of challenges. In addition to the need to make product development and production more efficient, there is also the trend toward ever to ever more advanced assistance (ADAS) through to autonomous driving, as well as the development and qualification of alternative drive systems that are as emission-free as possible. The research focus of our division is geared to these three challenges.

Where do you see your division in five years?

Although the vehicle industry as a whole is going through a crisis, we believe we are well positioned with the focus described above. We expect the area to be in a good position both scientifically and economically in five years' time with three departments and the technical center.

Which three keywords best describe your department?

- Innovative – interdisciplinary – professional

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- The Pilot Plant: Link Between Reality and Simulation S. 20
- Planning – Controlling – Regulating Traffic Flows S. 22
- What New Drive Concepts Do We Need? S. 23
- "CDtire": Realistic Simulation of Tires S. 26

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Main Focus

- Process Engineering
- Machine Learning and Hybrid Models
- Arrangement and Decomposition Problems
- Supply Chain
- Energy and Supply
- Production Planning and Control
- Optimization in Life Sciences
- Quantum Computing

Optimization

What does your department deal with and what constitutes its research work?

The “Optimization# area deals with the model-based simulation and optimization of complex technical and organizational processes. The goal here is to master complexity by making promising solutions interactively accessible. We make improvement potentials transparent and comprehensible, so that users can quickly recognize them.

What potential does your department’s research offer for a better future?

The combination of knowledge-based and data-based approaches to model-based optimization holds enormous potential, precisely because data is available on an increasingly large scale. At the same time, the need for traceability and transparency in decision-making processes is increasing. Both are trends that we are happy to support.

In addition, we are positioned across all industries. This ensures stability as well as an exciting and interdisciplinary innovation climate.

Where do you see your department in five years?

The business unit keeps growing, largely thanks to long-term industrial partnerships. Surprising them again and again with innovative solutions and winning new customers is an important challenge. We also need creative minds who have high standards for innovative solutions and their implementation. If both succeed, “Optimization” will be able to further increase its visible impact.

Which three keywords best describe your department?

- Innovative – customer-oriented – with high standards for ourselves

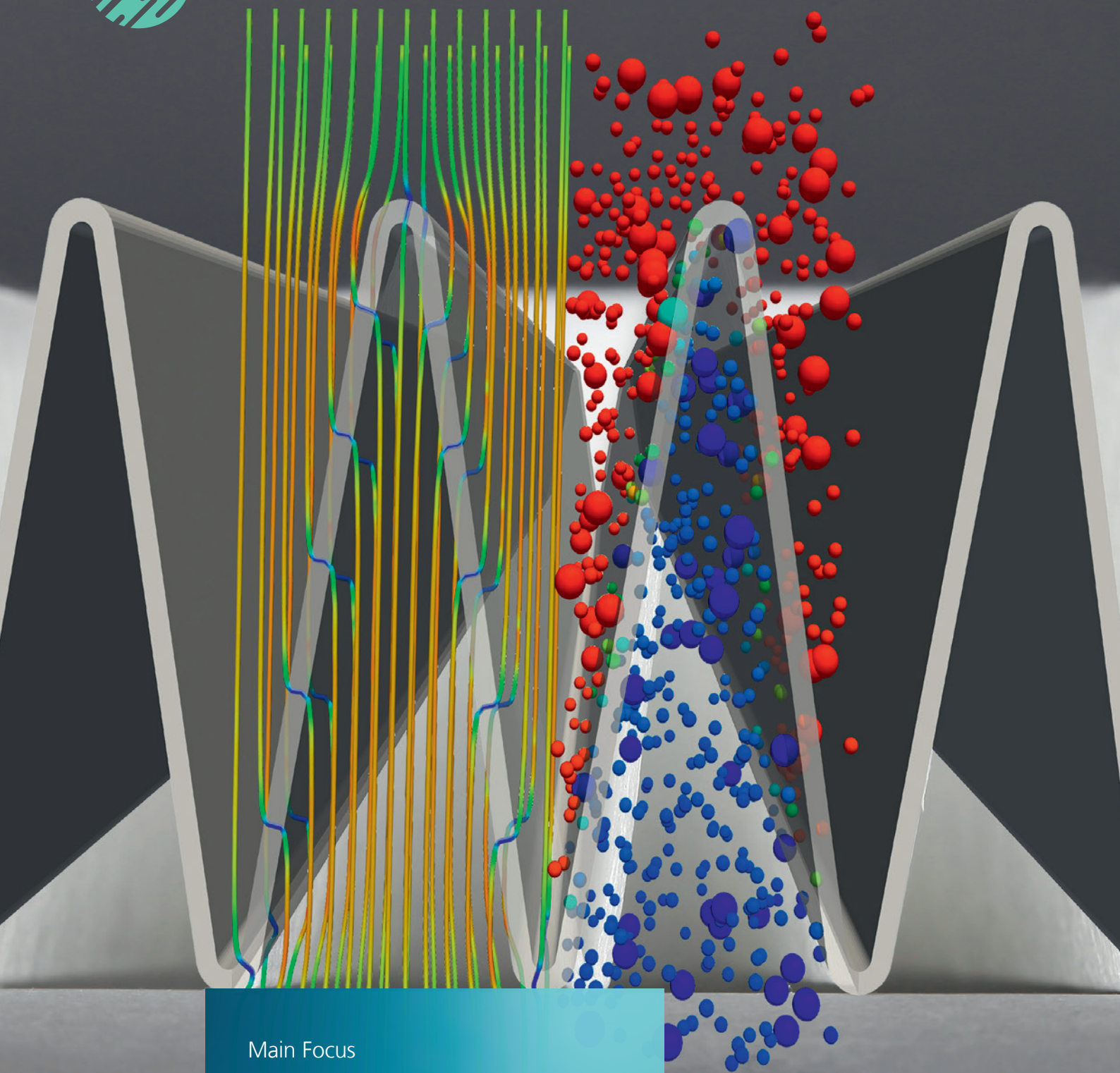
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Main Focus

- Technical Textiles and Nonwovens
- Microstructure Simulation and Virtual Material Design
- Lightweight Construction and Insulating Materials
- Filtration and Separation
- Complex Fluids and Multiphase Flow
- Electrochemistry and Batteries

Flow and Material Simulation

What does your department deal with and what constitutes its research work?

We design and implement method and software solutions for the development, production and improvement of innovative, sustainable materials, including so-called programmable materials. In doing so, we develop industrially suitable multiscale and multiphysics methods and customer-specific software solutions. Our simulation tools use latest research results such as model reduction methods, automatic parameter identification and machine learning to increase efficiency.

What potential does your department’s research have for a better future?

The digitalization of material development – from manufacturing to life cycle assessment and recycling – is accelerating the development of innovative, sustainable materials. This is demonstrated by our new projects on material substitution through biobased and biohybrid textiles, foams and composites in lightweight construction, efficient and alternative battery concepts for electromobility, and self-cleaning particle filters.

Where do you see your department in five years?

The aim of our method and software development is to enable our customers to digitally accompany the design of their sustainable products and the associated process development from start to finish in five years’ time, i.e. to have so-called digital twins down to the material level. These enable rapid testing of variants and innovations, without having to produce real prototypes. Digital twins can also be used for the quantitative evaluation of raw material and energy balances. In this way, we support sustainability and conserve resources.

Which three keywords best describe your department?

- Multiscale – efficient – robust

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- ALMA: Lightweighting and Ecological Design in Electric Vehicles S. 26
- Battery Cells for E-mobility S. 26
- Virtual Testing of Filter Nonwovens S. 27
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Main Focus

- Power Generation and Distribution
- Real-time Plant Operation and Drive Technology
- Biosensors and Medical Devices
- Machine Learning
- Control of Complex Systems
- Model Identification and State Estimation

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System Analysis, Prognosis and Control

What does your department deal with and what constitutes its research work?

We develop digital twins for real-time monitoring, predictive maintenance and energy-efficient control for production plants and drive trains. Together with our customers, we develop and adapt customized solutions using artificial intelligence methods. In doing so, we make use of the large toolbox with methods from signal analysis, system and control theory, automation, and machine learning.

What potential does your department’s research have for a better future?

Many companies are ready for digitalization. The volume of different data and information that this generates opens up the possibility for us to develop innovative, precisely tailored solutions for the sustainable operation of production plants and drive trains. This enables the simultaneous optimization of quality and quantity, the efficient use of energy and raw materials, and the condition-oriented operation of production plants and drive trains.

Where do you see your department in five years?

In Five Years, the department will offer even more holistic solutions – from supporting the integration of sensors and actuators to implementing custom-fit methods and algorithms on embedded systems or in microelectronic devices.

Which three keywords best describe your department?

- Innovative – close to hardware – experienced

Department topics in this report:

- District Heating – Math Heats Up S. 54
- Digitalization and Artificial Intelligence for Energy Management 2.0. S. 56

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Main Focus

- Flexible Structures
- Fluid Dynamic Process Design
- Lattice-Free Methods
- Energy Grids and Model Reduction

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Transport Processes

What does your department deal with and what constitutes its research work?

We model complex industrial problems and develop efficient algorithms for the numerical simulation and optimization of these problems. The problems are mostly in the context of fluid dynamics, structural mechanics, radiative transfer, optics etc. From the point of view of our industrial customers, it is about the design of production processes and the optimization of products.

What potential does your department's research have for a better future?

Techniques for automatic differentiation allow the identification of systems and their optimization with previously unimaginable quality and efficiency – it was this background that made it possible to develop epidemiological models for an extremely dynamic infection event with the start of the Corona pandemic. For industry, we have created MESHFREE, a software that describes processes and products with complex and highly variable flow dynamics very well. Current urgent problems such as energy grids and energy efficiency have played a have also played a relevant role in our research for years.

Where do you see your department in five years?

We will increasingly develop, use and license our own software tools. The associated growth requires adapted structures, which will be implemented in the course of the upcoming change in department management.

Which three keywords best describes your department?

- Flexible methods – problem-oriented – customer-oriented

Department topics in this report:

- Checking Filter Nonwovens Virtually S. 27
- MESHFREE: Water Management Application Example S. 27
- Corona Pandemic: Fraunhofer ITWM Advises Rhineland-Palatinate State Government...S. 42
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