

RESEARCH AT TU KAISERSLAUTERN  
Shaping the future through science and technology



# RESEARCH AT TU KAISERSLAUTERN

Technische Universität Kaiserslautern is a hub for innovative research. Whether on a fundamental quest for knowledge or developing practical solutions transferred to application right away, our researchers are inspired to pursue societal and technological challenges in an interdisciplinary and collaborative environment.

Dear Reader,



Research helps us to deeper understand the world and to find better answers to central challenges of our time. Technische Universität Kaiserslautern (TUK) successfully contributes new and innovative research ideas and results to the international scientific communities, both in basic research and in application-oriented research. Following the Humboldtian ideal, we also consider research as an excellent field to challenge and educate the next generation of scientists, teachers and academic leaders.

To illustrate TUK's successes in research, I would like to highlight a few key facts: The strength of our basic research is represented in particular by the coordinated programs of the German Research Foundation (DFG), above all through our Collaborative Research Centers. We are proud that we currently have support for six such centers. The Collaborative Research Center 926 Component Surfaces is run by researchers from TUK alone, the other five are in cooperation with excellent partner universities in Germany. We are particularly happy about the two new research buildings we have been able to acquire funding for in recent years. The Laboratory for Advanced Spin Engineering (LASE) and the Laboratory for Ultra-Precision and Micro Engineering (LPME) open up far-reaching perspectives for us. These and other central achievements are listed under the respective strategic research fields in this brochure. With respect to applied research, I would like to point out that we have many successful industrial cooperations ranging from regional small start-up companies to international world-leading players. With many applied research partners and companies, we collaborate in the framework of the High-Performance Center Simulation and Software Based Innovation operated by the Fraunhofer ITWM. Communication technology, such as wireless 5G and 6G data transmission, is one of our core applied research activities.

Our research is made possible by a wide range of sponsors. First of all, the research initiative by the State of Rhineland-Palatinate provides a generous framework for sustainable profile building. We receive extensive third-party funding from the DFG, from various programs of the federal government, as well as from the EU. In addition to other

international funding organizations, I would also like to acknowledge our many cooperation partners from science, society and industry, without whom our research would not be possible. Finally, I would like to point out our cooperation partners in Kaiserslautern – first and foremost the institutes in the immediate neighborhood on our campus. Their foundation and impressive development over the years is also evidence for the research strength of TU Kaiserslautern and has given the entire research hub a significant boost and opened up new possibilities. Also, regional industrial partners are important cooperation partners, with many of whom we cooperate within the framework of the Science and Innovation Alliance Kaiserslautern (SIAK).

Further prospects for our research will open up by the upcoming merger with the Campus Landau of the University of Koblenz-Landau planned for the beginning of 2023. The core scientific-technical orientation of TUK's research will be supplemented by new research fields in psychology and in the social and educational sciences, as well as further research in natural and environmental sciences.

With this brochure we would like to present an overview of our research. Further aspects and details are provided by our other dissemination channels in science communication.

I wish you an informative and entertaining reading!

A handwritten signature in blue ink, which appears to read "Arnd Poetzsch-Heffter". The signature is fluid and cursive.

Prof. Dr. Arnd Poetzsch-Heffter  
President of TU Kaiserslautern

Dear Reader,



Ever since TUK defined its first four key areas of research in the 1980s, research and innovation have been important parts of the university's overall strategy. Three DFG funded Collaborative Research Centers (CRC) were initially established along with the foundation of the German Research Center for Artificial Intelligence (DFKI) and the Institute for Surface and Layer Analysis (IFOS), the first steps towards establishing our strong research reputation. This progress continued in the 1990s with the foundation of the Institute for Composite Materials (IVW, becoming part of the Leibniz Association in 2020), the Institute for Technology and Work (ITA), the Institute for Industrial Mathematics (becoming the Fraunhofer ITWM in 2001), and the Fraunhofer Institute for Experimental Software Engineering IESE. We also saw a steady increase of third-party funding, another CRC and the first Research Training Groups (RTG) funded by the DFG.

At the beginning of the new millennium, the university changed its name to "Technische Universität" to express our scientific orientation and new key areas of research were defined. The Rhineland-Palatinate Research Initiative was launched in 2008, building on state programs, and continues to be an important part of TUK's research strategy. Within a decade, the fruits of the research initiative were visible: seven CRCs or Transregional CRCs and two International Research Training Groups (IRTG) had been established, thanks to the state's investment and the commitment of our researchers. Parallel to this development, TUK also became very successful in raising European funds. Beside several collaborative projects within EU-framework programs, seven European Research Council (ERC) Grants have been awarded to TUK scientists.

In 2018, six strategic research fields were newly defined within the University Development Plan, mainly corresponding with the key areas of the research initiative. Despite the challenges caused by the Corona pandemic, research continued in 2020 and 2021, further strengthening TUK's profile.

The next big milestone in our overall development is the up-coming merger with the Campus Landau of the University of Koblenz-Landau. Together, we will form a new research strategy for the joint university to enable an even richer re-

search program than the two campuses could perform individually. An initial plan for seven strategic research fields has been outlined and joint projects are already underway, advancing this process.

The brochure you are holding in your hands will take you through TUK's current research by highlighting different aspects, such as TUK's strategic research fields, its international networks and the research institutes around TUK. In order to give you a very lively insight into TUK's research, we asked representative researchers of the six strategic research fields to answer three questions about their work. To show you the international face of TUK, we introduce you to our international networks and the University of the Greater Region (UniGR), which is both an international as well as a regional collaboration. In the Stories chapter, you will gain insight in what is possible at TUK regarding new and dual career paths, networks, advising policymakers and innovation. At the same time, the chapter shows perspectives from both within and outside TUK. All these activities are supported by our research services, which we also highlight. In the end, spotlight is directed at the scientific foci of the institutes situated in the area surrounding TUK, as they are long-time partners for very close and fruitful cooperations in research and innovation.

I would like to thank the Public Relations Office, the Office for Research and Early Career Support, Photo-Repro-Print Division, science writer Laura Petersen and of course all colleagues at TUK who have made this brochure possible.

Please enjoy browsing through the brochure.

A handwritten signature in blue ink, which appears to read "W. Thiel". The signature is fluid and cursive.

Prof. Dr. Werner R. Thiel  
Vice President for Research and Technology  
of TU Kaiserslautern



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# TECHNISCHE UNIVERSITÄT KAISERSLAUTERN

Technische Universität Kaiserslautern (TUK) is a leader in interdisciplinary, collaborative and innovative research and education that is shaping the future of technology, digitalization and science. Our students and professors conduct fundamental and applied research, working closely with a vibrant community of industry and institutional partners, several of them based in the international community of Kaiserslautern as well as with collaboration partners from around the world.

Offering more than 100 study programs, TUK excels in natural and engineering sciences, with strong integration of social sciences, economics, planning, and education training. Specifically, our 12 departments are: Architecture, Biology, Business Studies and Economics, Chemistry, Civil Engineering, Computer Science, Electrical and Computer Engineering, Mathematics, Mechanical and Process Engineering, Physics, Social Sciences, Spatial and Environmental Planning.

TUK is a medium-sized university, with nearly 15,000 students, 2,500 employees and 210 professors. The intimate environment ensures high-quality interactions between professors, students and research teams, who all regularly collaborate across departments and disciplines. TUK also offers one of the largest distance learning programs in Germany.

Our campus hosts premiere research institutes, including the Max Planck Institute for Software Systems (MPI-SWS), the Fraunhofer Institute for Industrial Mathematics ITWM, the Fraunhofer Institute for Experimental Software Engineering IESE, the German Research Center for Artificial Intelligence (DFKI) and the Leibniz Institute for Composite Materials (IVW). Our close relationships with these institutions provide valuable opportunities for undergraduate and graduate students to work on real world problems and gain industry experience. There are countless opportuni-

ties to transfer applied research to industry applications, such as through joint programs with the High-Performance Center Simulation and Software Based Innovation.

We place a strong emphasis on excellent graduate education and support for early career researchers. TUK is home to numerous Collaborative Research Centers (CRC), one of the most prestigious research programs in Germany. We offer several Research Training Groups (RTG) funded by the German Research Foundation (DFG) or the EU, which include national and international research exchanges. We collaborate closely with other German and international universities in joint graduate and master programs. Additionally, TUK is part of the University of the Greater Region (UniGR), which is a dynamically evolving alliance of universities cooperating in research, teaching, and development. UniGR spans the border region between France, Belgium, Luxembourg, and Germany.

We are home to thousands of students and researchers from more than 100 countries. Our service teams provide total support for international students and researchers, from admissions and visas, to housing, language training, cultural programs, skills training, job hunting, and much more. We have a special focus on organisation support and career promotion, be it for PhD students or junior professors. TUK is well established as host institution for students as well as junior and experienced scientists alike.

Located in the heart of Europe, TUK campus provides easy access to international train stations and airports. A low cost of living and the natural surroundings of the Palatinate Forest, part of a UNESCO Biosphere Reserve and one of the largest forests in Europe, provide an ideal place to live, work and study.



# STRATEGIC RESEARCH FIELDS

Six strategic research fields form the center of TUK's interdisciplinary research profile as part of the University Development Plan:

- Interactions between Light, Spin and Matter – Quantum Phenomena, Model Systems and Technologies
- Membrane Biology and Systems Biology, Bioanalytics
- Advanced Materials, Composites and Production Engineering
- Resource Efficiency and Sustainable Development
- Mathematical Modeling, Algorithms and Simulation
- Digital Transformation of Economy and Society



# FUNDAMENTAL PHYSICS MEETS FUTURE TECHNOLOGIES

Physicists, chemists, engineers and materials scientists explore some of the most fundamental properties of the physical world, and use those insights to develop new types of technologies and devices.

At its core, our researchers use the full spectrum of light, from ultra-fast and short laser bursts to continuous waves, to explore motions and behaviors of different types of matter and systems, from cells down to single atoms. Using both theoretical and experimental approaches, we study puzzling questions about magnetism, ultracold quantum gases, catalysis, and about dynamical processes in photochemistry, clusters, nanoparticles, and novel 2D materials.

TUK is a global leader in spin research. Spin, the internal angular momentum of a particle, helps determine a particle's magnetic properties. However, much about spin remains a mystery. Our teams are investigating both the basic questions of how it works, as well as how spin and magnetism can be used for the next generation of computers, data processors and other devices.

The Profile Area OPTIMAS of the Rhineland-Palatinate Research Initiative serves as the backbone for national and international projects, collaborations, research facilities and training programs. Excellent research facilities, including the new Laboratory for Advanced Spin Engineering (LASE) and the expanded Nano Structuring Center (NSC) enable researchers from across departments to share the latest tools and equipment, and space for interdisciplinary collaboration. While this is designed to accelerate advancements, it also helps ensure an outstanding educational experience for students in quantum optics, photonics, spintronics, molecular materials, magnetism and nanostructures. Additionally, our overall expertise is enhanced by the cooperation with the adjacent Institute for Surface and Layer Analysis (IFOS), the Photonic Center Kaiserslautern (PZKL) and the Leibniz Institute for Composite Materials (IVW).

TUK provides the ideal environment for exploring the fundamental questions of light, spin and matter and their potential applications. This collaborative approach is essential for creating new, life-changing technologies that can help make society more sustainable and secure.

## COLLABORATIVE ACTIVITIES

- Research Building Laboratory for Advanced Spin Engineering (LASE)
- CRC/TRR 88 Cooperative Effects in Homo- and Heterometallic Complexes (3MET)
- CRC/TRR 173 Spin in its Collective Environment (Spin+X)
- NFDI FAIRMat – FAIR Data Infrastructure for Condensed Matter Physics and Chemical Physics of Solids
- CRC/TRR 185 Open System Control of Atomic and Photonic Matter (OSCAR)
- Profile Area Center for Optics und Materials Sciences (OPTIMAS)
- Max Planck Graduate Center with the Johannes Gutenberg University (MPGC)
- Nano Structuring Center (NSC)



## Interactions between Light, Spin and Matter

### Three questions to...



**Prof. Dr. Martin Aeschlimann** is head of the Ultrafast Phenomena at Surfaces group in the Department of Physics. He is speaker of the Profile Area Center for Optics and Materials Sciences (OPTIMAS) within the Rhineland-Palatinate Research Initiative.

### What are the three research highlights of the last three years?

“The most elementary sensor conceivable is a single atom. A team of CRC/TRR 185 OSCAR, led by Prof. A. Widera, has managed to immerse single cesium atoms into an ultracold rubidium gas almost at absolute zero temperature, and to map temperature information onto the single atom. The technique opens new routes to employ quantum properties to substantially improve sensing methods.

The Kaiserslautern site offers excellent research at an outstanding level. This is clearly demonstrated by three ERC grants awarded to Prof. B. Hillebrands, Dr. A. Chumak and Dr. M. Cinchetti. It should be emphasized that the latter two scientists subsequently transitioned to full professorships in Dortmund and Vienna.

New computer concepts including a much reduced power consumption are developed on the basis of spin-waves, so-called magnons. Scientists of the CRC/TRR 173 Spin+X, led by Prof. B. Hillebrands and Jun. Prof. P. Pirro, made a major breakthrough on the way to build a magnonic computer. They were able to scale down the spin-wave logic element to the sub-100nm range. This is sufficient to compete with currently used CMOS elements in terms of footprint.”

### What is unique at TU Kaiserslautern?

“As a driving force for coordinated projects, the research initiative OPTIMAS plays an important role for profiling research at TUK. This is strongly supported by the Nano Structuring Center, and the new Laboratory for Advanced Spin Engineering (LASE). Another key issue is the close and well established collaboration between the different departments at TUK including many institutes on and near the campus.”

### What is next?

“Topology is a strongly rising research field and attracted a lot of interest in recent years. Within the research initiative TopDyn, we investigate the dynamical manipulation of a systems topology being a key point for upcoming applications. As a member of the national initiative to store big data in a findable, accessible, interoperable and reusable manner (FAIRmat), we strongly boost this urgent movement by convincing scientists to tackle this issue, reform their way of data collection, and by supporting them through advice and training.”

# BIOLOGY MEETS BIG DATA

Advancements in genetic sequencing, mass spectrometry and cellular imaging technologies are enabling scientists to investigate the biological world in increasingly greater detail – from tracking the activities of single cells, to understanding not just what genes are active at precise moments, but also proteins and metabolites. While this wealth of information provides extremely high-resolution insights, it is also producing mountains and mountains of data.

To help make sense of all, our life scientists at TUK are teaming up with computer scientists, mathematicians, engineers and physicists for the Profile Area BioComp of the Rhineland-Palatinate Research Initiative. Together, we figure out ways to analyze and organize extremely large data sets and answer interdisciplinary questions across the life sciences and biotechnology.

Specifically, computer scientists are developing computational tools to process biological data, helping identify patterns and pick out key findings. They also consider how to label and store data in sustainable ways that will allow other researchers to use it to explore their own questions. These activities are performed in close cooperation with researchers from the German Research Center for Artificial Intelligence (DFKI).

TUK biologists are investigating how cells cope with and respond to stress in microorganisms, plants and humans. For example, our plant scientists are unraveling how plants acclimate to changing environmental conditions, especially the role of chloroplasts. Many researchers are looking at membranes separating cellular compartments and study, for example, how transporters selectively allow passage of proteins and metabolites across them. Another common theme is to understand how proteins physically fold and are kept in a functional folded state, which is key to fight neurodegenerative diseases, such as Alzheimer's.

The BioComp consortium is highly interdisciplinary, bringing together researchers that might not normally collaborate and offers a nurturing training environment for students and young investigators. Being at the forefront of the fields of big data production and handling has made TUK a valuable partner in other consortia with institutions across Germany and internationally, such as the DataPLANT initiative and the Green Hub consortium funded by the German Research Foundation (DFG).

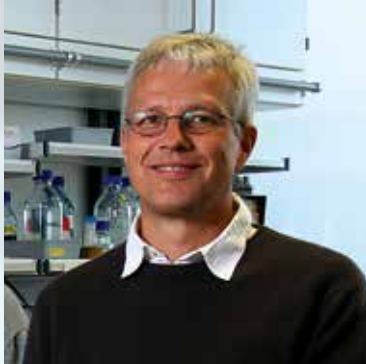
The future of biology lies in big data, and the future of big data is at TUK.

## COLLABORATIVE ACTIVITIES

- CRC/TRR 175 The Green Hub – Central Coordinator of Acclimation in Plants
- IRTG 1830 Complex Membrane Proteins in Cellular Development and Disease
- NFDI 110 DataPLANT – Data in plant research
- Profile Area Complex Data Analysis in Life Sciences and Biotechnology (BioComp)
- RTG 2737 STRESSistance: Molecular Mechanisms to Preserve the Functionality of Membranes and Compartments during Stress Conditions



### Three questions to...



**Prof. Dr. Michael Schroda** is head of the Molecular Biotechnology and Systems Biology group in the Department of Biology. He is speaker of the Profile Area Complex Data Analysis in Life Sciences and Biotechnology (BioComp) within the Rhineland-Palatinate Research Initiative.

What are the three research highlights of the last three years?

“Most proteins in mitochondria are made in the cytosol and imported into mitochondria via transporters. BioComp member Prof. Johannes Herrmann asked what would happen to cells if the pores of these transporters are clogged? They found that the accumulating import precursors disturb protein homeostasis in the entire cell (Boos et al., 2019, Nat Cell Biol).

The first iGEM team at TUK was formed in 2019, supervised by three BioComp members. iGEM is an international competition in the field of Synthetic Biology. The TUK team engineered a microalga to secrete two enzymes for the degradation of PET plastic. They reached the third place of >370 teams and won four main prizes.

Chloroplasts harbor a protein called VIPP1. If it is missing, no thylakoid membranes are formed. Thylakoids convert light energy into chemical energy, the basis of most life on earth. In a team effort with colleagues in Munich, we found that VIPP1 forms rods that can engulf membranes. These connect chloroplast envelope membranes with thylakoids, explaining VIPP1's essential role in thylakoid formation (Gupta et al., 2021, Cell).“

What is unique at TU Kaiserslautern?

“At TUK we have established the technology platforms to produce ‘big data’ in life sciences, including high-end microscopes and mass spectrometers. Moreover, we have the knowhow to handle, evaluate and sustainably store such data. This knowhow in quantitative biology is constantly expanded by interdisciplinary teamwork with computer scientists and mathematicians as well as by its application to excellent research questions with a clear focus on membrane biology and stress responses.“

What is next?

“We wish to manifest our unique expertise with ‘big data’ by expanding the infrastructure in analytics and data handling, but also by hiring brilliant heads. By setting up a graduate school dedicated to quantitative biology, we want to establish a solid basis for educating our best graduate students. Our unique expertise will enable successful applications for further coordinated programs.“

## SURFACES MATTER

When it comes to developing materials that are stronger, lighter and longer-lasting, TUK engineers and materials scientists join forces and take a dual approach. We look for ways to optimize both material combinations and manufacturing processes to produce components with desired properties. This combination helps save time, energy, resources and ultimately, costs, and is a key feature of the Profile Area Advanced Materials Engineering of the Rhineland-Palatinate Research Initiative.

Our work is highly interdisciplinary. Materials scientists work with process engineers to develop new machining techniques that reduce heat and deformation, while increasing strength of stainless-steel surface layers. We've developed a new ultrasonic welding technique that will enable ultra-light fiber reinforced plastic tubes to be integrated into metal fittings in airplanes.

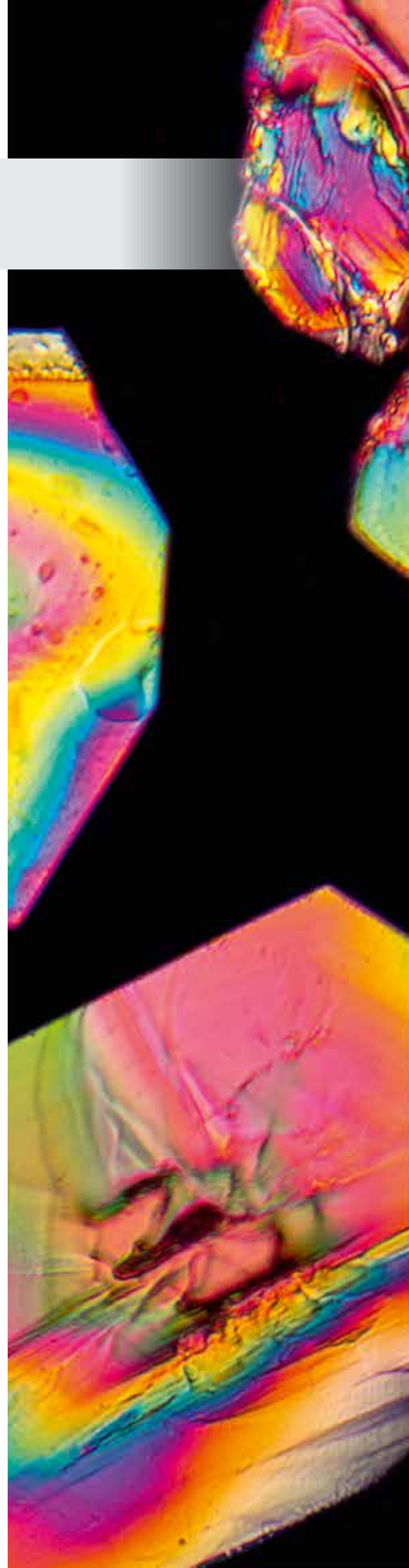
Materials scientists and engineers collaborate with biologists and biochemists to develop materials and surfaces that encourage better growth of biofilms, that can produce antibiotics. We work with physicists to develop methods to measure a material's remaining lifespan using magnetism. We are working with computer scientists to design sensors and algorithms that can automatically adjust a machine's settings, so that even as the cutting tool wears down, product quality remains consistent.

A key focus of our work is surfaces – the surface of a material, especially the microstructures within it, are what gives a material its defining features. Can it withstand corrosion, abrasion and fatigue? How long a material can last largely depends on the characteristics of its surface. We look at how to get the most out of materials and surfaces, together with our colleagues at the adjacent Institute for Surface and Layer Analysis (IFOS) and the Leibniz Institute for Composite Materials (IVW).

To sustainably address the development challenges of our societies, we need high-performing materials and more efficient production processes. Together, we are engineering solutions for the future.

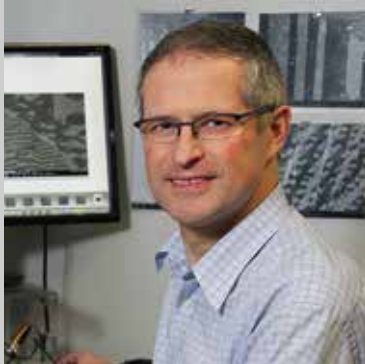
## COLLABORATIVE ACTIVITIES

- Research Building Laboratory for Ultra-Precision and Micro Engineering (LPME)
- CRC 926 Component surfaces: Morphology on a Micro Scale (MICOS)
- IRTG 2057 Physical Modeling for Virtual Manufacturing Systems and Processes
- NFDI-MatWerk: National Research Data Infrastructure for Materials Science and Materials Engineering
- Profile Area Advanced Materials Engineering (AME)



## Advanced Materials, Composites and Production Engineering

### Three questions to...



**Prof. Dr.-Ing. Tilmann Beck** is head of the Materials Science and Engineering group in the Department of Mechanical and Process Engineering. He is speaker of the Profile Area Advanced Materials Engineering (AME) of the Rhineland-Palatinate Research Initiative.

### What are the three research highlights of the last three years?

“Many products from optics and medical as well as traffic engineering are based on microfabrication technologies. Examples are mobile communication devices, medical diagnostic devices as well as sensors and actuators for autonomous driving. At TUK, research is being conducted in this area in publicly funded projects, e.g. the DFG CRC 926 and industrial collaborations on micromilling as well as grinding, laser structuring and additive microfabrication.

In the DFG CRC 926, robust cryogenic turning processes were developed which, as a result of optimized surface morphology, led to increased fatigue strength of stainless Cr-Ni steels without further post-treatment. These findings are currently being transferred to high-strength rolling bearing steels and extended to include process control.

In the BMBF junior research group Topology-optimized and Resource-efficient Composites for Mobility and Transport, wet fiber laying was developed as an additive manufacturing process for fiber composite parts. At the same time, innovative lightweight construction concepts were developed by making targeted use of the material properties and manufacturing boundary conditions typical for composite materials.“

### What is unique at TU Kaiserslautern?

“We use the fact that we are a rather small university as a strategic advantage: We work together in an interdisciplinary way between the departments that are excellent in their fields of work. We discuss new, creative research topics intensively, trustfully and openly over short distances. We implement these ideas in joint projects and find sustainable solutions for current research questions in the field of materials science and production technology.“

### What is next?

“Sustainability, resource conservation and digital transformation are megatrends of social development that we help to address with our research and for which we seek joint solutions. A prominent example is our LPME research building: Here groups from production technology, mechanical engineering and materials as well as computer science will work closely together on innovative research ideas for the production technology of the future using the latest equipment.“

# RESEARCH FOR A SUSTAINABLE WORLD

Sustainability is one of the great challenges of our time, and is a major objective of TUK's research. Researchers across departments are searching for solutions that support sustainable development and increase resilience in the face of a changing climate, such as developing alternative fuel sources and new technologies that save limited resources.

For example, our engineers, chemists and physicists collaborate to develop more efficient chemical processes and catalysts as part of the NanoKat Priority Area of the Rhineland-Palatinate Research Initiative. Most products and processes in chemical industry require at least one catalyst, which triggers a chemical reaction, be it for removing harmful exhaust from tailpipes or manufacturing chemicals from alternative raw materials, such as waste from wood mills or by-products of biogas plants. Finding new catalysts or optimizing known processes can save precious resources, offering major advantages to industries and society. Oil and gas are limited resources and we need renewable energy options that reduce carbon dioxide emissions. We are especially interested in the potential of green hydrogen – hydrogen fuel produced from renewable sources. Our teams are studying how we can make this process more efficient, again with the help of catalysts.

Meanwhile, our biologists are investigating the molecular underpinnings of crops and how to make them more drought-tolerant. Our process engineers are developing new manufacturing methods that reduce waste of raw materials. Our architects and engineers are looking at how to reduce emissions from concrete and construction, such as by designing stronger and thinner walls that require less building material or by using more and more timber in construction. Our environmental planners revitalize contaminated sites in cities as well as develop innovative approaches to sustainable urban planning. Guided by the United Nations 2030 Sustainable Development Goals, economists at TUK are studying the circular economy and sustainable consumption and production. Many activities take place in close cooperation with the institutes surrounding TUK such as the Fraunhofer ITWM or the Leibniz Institute for Composite Materials (IVW).

While we love research for the simple joy of discovering new things, we are highly motivated to seek solutions that ensure a healthier future and planet for all.

## COLLABORATIVE ACTIVITIES

- EU-Project Reviving Shrinking Cities – Innovative Paths and Perspectives towards Livability for Shrinking Cities in Europe (RE-CITY)
- Priority Area Nanostructured Catalysts (NanoKat)
- Priority Area Construction Site of the Future – Automation and Digitalization
- University Priority Area Region & City
- Carls Zeiss Foundation Breakthroughs Ageing Smart – Designing Spaces Intelligently
- Research Area Wood Architecture and Wood Materials (t-lab)
- UniGR-Center for Circular Economy of Materials and Metals (CIRKLA)
- Carl Zeiss Cooperation Fund for Sustainability Research



## Resource Efficiency and Sustainable Development

### Three questions to...



#### **Prof. Dr. Roland Ulber**

is head of the Bioprocess Engineering group in the Department of Mechanical and Process Engineering. He is speaker of the Priority Area Nanostructured Catalysts (NanoKat) within the Rhineland-Palatinate Research Initiative.

#### What are the three research highlights of the last three years?

“In the Priority Area NanoKat, groups from the Departments of Chemistry, Physics, Mechanical and Process Engineering and Civil Engineering have been intensively researching a wide range of sustainability issues for more than 12 years. Several coordinated research projects have already emerged from the Priority Area, which have been able to improve processes in many areas of industrial applications in terms of sustainability.

One of the research highlights is certainly the Interreg project BioVAL, which was worked on jointly with working groups from the Department of Chemistry and the Department of Mechanical and Process Engineering. The European project coordinated partners from Germany, France, Belgium and Luxembourg. The project impressively demonstrated that side streams of food production (brewer’s spent grain) can be used for the sustainable production of basic and fine chemicals without negative impacts on food resources.

Construction processes are among the most resource-intensive activities. Gaining efficiency in this area is therefore of particular benefit in terms of conserving resources. In the field of concrete recycling and the intelligent use of wood, TUK provides innovative solutions from the Departments of Architecture and Civil Engineering.“

#### What is unique at TU Kaiserslautern?

“The close cooperation between natural sciences and engineering has contributed significantly to the fact that research and development in the field of sustainable resource utilization has been successfully carried out at TUK across disciplinary boundaries for a long time. Through the connection to the non-university research institutes, we also have an excellent environment in Kaiserslautern in the field of mathematical modeling and simulation, which is indispensable for the development of sustainable (industrial) processes.“

#### What is next?

“The merger of TUK with the Campus Landau of the University of Koblenz-Landau opens up excellent new opportunities to develop new R&D fields together with the Department of Environmental Sciences of the Landau Campus. The inclusion of environmental and socio-economic aspects is indispensable in the sense of a holistic view of sustainability. In these areas, we will experience a significant gain in national and international visibility at the new TU.“

# MATHS FOR SCIENTIFIC AND REAL-WORLD APPLICATIONS

TUK is a leader in mathematics, modeling, algorithms and simulations. Our mathematicians are solving complex problems for both fundamental research and real-world applications. They also team up with computer scientists and software engineers to develop advanced tools and simulations.

For example, as part of the SymbTools Priority Area of the Rhineland-Palatinate Research Initiative, we are developing symbolic software tools that support research in pure mathematics and its modern fields of application. Our most recent project combines the power of algebra, geometry and number theory into the computer algebra system OSCAR, which is expected to become the leading open-source platform for interdisciplinary computations in these fields, with scientists from around the world contributing to it.

Our MathApp Priority Area of the Rhineland-Palatinate Research Initiative applies math to real-world problems. Here, we aim to advance research in the engineering sciences and find efficient solutions for a variety of practical issues, from optimizing transport to finding the most efficient production methods or even the best personalized medical treatment. Our researchers also use models and algorithms to solve valuation and investment problems in finance and to classify insurance products with regards to their potential risks and reward.

Among others, we collaborate closely with our local partners, especially the Fraunhofer Institute for Industrial Mathematics ITWM, to tackle questions raised by different industries. We work on common problems, including how to process large datasets, high-dimensional data, and uncertainties.

While many of our projects focus on math for science and the real world, there is plenty of room to work on fundamental, theoretical problems – the grand questions that have yet to be solved. TUK is a perfect place for those who seek a peaceful environment, close to nature, to dive deep into challenging mathematical problems.

## COLLABORATIVE ACTIVITIES

- CRC/TRR 195 Symbolic Tools in Mathematics and their Application
- High-Performance Center Simulation and Software Based Innovation
- NFDI MaRDI: Mathematical Research Data Initiative
- Priority Area Mathematics Applied to Real-World Challenges (MathApp)
- Priority Area Symbolic Tools in Mathematics and their Application (SymbTools)



## Mathematical Modeling, Algorithms and Simulation

The strategic research field of Mathematical Modeling, Algorithms and Simulation is mainly represented by the two Priority Areas MathApp and SymbTools of the Rhineland-Palatinate Research Initiative. The speakers of both these Priority Areas are therefore answering the three questions.

### Three questions to...



#### Prof. Dr. Wolfram Decker

is one of the heads of the Algebra, Geometry and Computer Algebra group in the Department of Mathematics. He is speaker of the Priority Area Symbolic Tools in Mathematics and their Application (SymbTools) within the Rhineland-Palatinate Research Initiative.

What are the three research highlights of the last three years?

“Integrating computer algebra systems from different fields into a new system for interdisciplinary research is technically and mathematically extraordinarily challenging. Focusing on algebra, geometry and number theory, and starting from components co-developed at TUK, the evolving OSCAR project is doing precisely this. The first public OSCAR release shows all components fully interoperable, using the new programming language Julia as a common platform.

The finite simple groups and their representations are the building blocks of all symmetries arising in nature and science. The Representation Theory group at TUK is widely known for its groundbreaking work in this area, which provides the basis for important research papers worldwide. The most recent success is the proof of Brauer’s height zero conjecture for principal blocks, which had been open since 1955.

The Number Theory group at TUK claims the world record for principal ideal testing – a computation designed to attack modern cryptographic standards built to withstand quantum computers. This record is the culmination of a great deal of recent work whose underlying computational infrastructure is only available in OSCAR.”

What is unique at TU Kaiserslautern?

“The Algebra, Geometry and Computer Algebra group at TUK is one of the world’s leading centers for computer algebra. As a distinctive feature, its research combines theoretical considerations with explicit calculations using sophisticated symbolic software tools co-developed by the group, and relying on expertise which unites all levels of computer algebra – making abstract mathematical concepts constructive, designing effective algorithms, implementing them and applying them to profound research questions.”

What is next?

“A web-based atlas for decomposition numbers in representation theory and a data base of number fields will make striking new results – achieved at TUK and elsewhere – directly available to the international research community. The sustainability of research data is one of our general themes as we are a vital part of the Mathematical Research Data Initiative MaRDI within the National Research Data Infrastructure NFDI. We expect a close collaboration with the OSCAR project, with considerable synergy effects.”

### Three questions to...



#### **Prof. Dr. Martin Grothaus**

is the head of the Functional Analysis and Stochastic Analysis group in the Department of Mathematics. He is speaker of the Priority Area Mathematics Applied to Real-World Challenges (MathApp) within the Rhineland-Palatinate Research Initiative.

What are the three research highlights of the last three years?

“Calculating the equity funds of an insurance company according to the Solvency II guidelines with the common algorithms normally takes some months. Using machine learning methods together with the well-known Monte-Carlo approach led to a significant drop of calculation time down to only some hours.

Motivated by problems from industrial mathematics, the concepts of hypocoercivity were generalized. These concepts originally have been introduced by the Fields Medalist Cédric Villani and provide convergence rates to equilibrium for physically relevant evolution systems. The new results led to several publications in top journals.“

What is unique at TU Kaiserslautern?

“The Priority Area MathApp is characterized by research in applied mathematics that combines theoretically sound and innovative modeling approaches with advances in the underlying mathematical theory. We follow new trends in applied mathematics, sometimes also introduce them and on the other hand always have the real world application in mind. Recent examples are our research in modeling the dynamics of the COVID-19 spread, the development of a concept for classifying German pension products according to their chance and risk profile for the German Federal Ministry of Finance, or various machine learning applications.“

What is next?

“Two members of the Technomathematics group will participate in the DFG priority program 2311 with a project on the coupled analysis of active biological processes for meniscus tissue regeneration. Looking at the mathematical foundations of machine learning methods and also at the problem of transforming algorithms to the quantum computer are further visionary projects that will be our focus of the next years.“



# DIGITAL TRANSFORMATION STARTS HERE

TUK is a leader in artificial intelligence and computer sciences, developing the technologies and software that are transforming economies and societies. Just as importantly, we are researching how to safely and fairly implement our increasingly digitized future.

To help guide the digital transformation here in Europe and internationally, we are implementing the latest wi-fi networks, designing faster memory devices needed to keep up with computing advances, and envisioning a future of driverless vehicles. We design and build robots, electric vehicles and link together the computers and sensors embedded in just about everything around us. We're automating agricultural processes, we're developing new visualization tools for medical applications, and we're investigating how virtual reality can improve education – just to name a few examples.

We seek to accelerate the transfer of technology and provide evidence to guide well-informed policies. Our computer scientists and engineers closely collaborate with social scientists, regional planners and others to ensure the tools we develop will actually work in the real world. We offer dedicated programs that prepare students for this interdisciplinary future, such as the Digital Transformation Certificate.

Our experienced teams at TUK are a key part of the world-class research ecosystem in Kaiserslautern, which also includes the German Research Center for Artificial Intelligence (DFKI), the Fraunhofer ITWM and IESE, and the Max Planck Institute for Software Systems (MPI-SWS). Together, we are providing the necessary knowledge and tools for a fair and sustainable digital revolution.

## COLLABORATIVE ACTIVITIES

- 5G Model Region 5G for City, Country and Work (BMVI)
- 6G Research Hub Open6GHub (BMBF)
- Open Digitalization Alliance Palatinate ("Innovative Hochschule" by the federal and the states governments)
- SmartFactoryKL (Network of business and science, including EU, state, BMWi)
- Digital Farming (including Support Association for Digital Farming e.V.)
- Carl Zeiss Foundation Breakthroughs Ageing Smart – Designing Spaces Intelligently
- Priority Area Artificial Intelligence Enhanced Cognition and Learning
- Priority Area Center for Commercial Vehicle Technology (ZNT)
- University Priority Area Graduate Program Cognitive Dynamics
- University Priority Area Center for Ethics and the Digital Society (CEDIS)
- Carl Zeiss Foundation Breakthroughs Sustainable Embedded AI
- EU-Project HumanE AI Network



## Digital Transformation of Economy and Society

Many excellent researchers and programs contribute to TUK's strategic research field of Digital Transformation of Economy and Society. To give an impression of the breadth of this research field, two speakers from very different large coordinated programs at TUK are answering the questions.

### Three questions to...



**Prof. Dr. Annette Spellerberg** is head of the Urban Sociology group at the Department of Spatial and Environmental Planning. She is coordinator of Ageing Smart, an interdisciplinary project funded by the Carl Zeiss Foundation.

What are the three research highlights of the last three years?

“Recently, a large inter- and transdisciplinary joint project Ageing Smart – Designing Spaces Intelligently started, which is funded by the Carl Zeiss Foundation for € 4.3 million. Colleagues from spatial and environmental planning, mathematics, Fraunhofer IESE and DFKI are involved to develop a decision support system with different communities.

The Urban Sociology group was investigating the changes in living and working in the Corona Pandemic. The location of workplaces, spatial polarisation trends of previous years, and the uneven performance of the internet form the background for this study.

Medium-sized cities are rarely in the focus when it comes to the use of artificial intelligence. This is the central finding of the 2020 study ‘Artificial intelligence in medium-sized cities – in the center or on the outside?’, which aimed to identify obstacles to digital transformation in politics and administration, to examine technological variants and to present good examples from medium-sized cities (Urban Sociology group, DFKI, Fraunhofer IESE, funded by Entwicklungsagentur Rheinland-Pfalz e.V.).“

What is unique at TU Kaiserslautern?

“At TUK, Urban Sociology has the unique opportunity to conduct interdisciplinary research. The cooperation with colleagues of spatial planning and the institutes (DFKI and Fraunhofer IESE) is extremely positive and productive. Due to the spatial setting, the focus is on topics that are not researched to the same extent in other, more urban locations of urban sociology. Furthermore, the transdisciplinary orientation, the cooperation with users of technology as well as actors from politics, administration and civil society allow for a specific enrichment of knowledge.“

What is next?

“The project Ageing Smart – Designing Spaces Intelligently addresses the baby boomers, about whom hardly any statistical data is available. Our task is now to make strands of information tangible in a decision-making system. We investigate age-appropriate residential locations and supply structures in the areas regarding leisure and recreational activities as well as the supply of medical and related health infrastructures and services. The work on post-Corona topics will continue and hopefully be underpinned by further projects.“

### Three questions to...



#### **Prof. Dr.-Ing. Hans Schotten**

is head of the Wireless Communication and Navigation group at the Department of Electrical and Computer Engineering. He is coordinator of Open6GHub, which is part of the BMBF 6G Research Hubs.

#### What are the three research highlights of the last three years?

“From the very beginning our group has been intensively involved in the design and development of the 5th generation of mobile communications (5G). Here, our focus was to make the enormous global research efforts in mobile communications usable for professional user groups as well. 5G is now recognized as one of the most important bases for digitalization in society and business. The fact that the 5G-ACIA industry association, which I co-initiated, has become the world’s leading platform for coordinating relevant development work is a nice confirmation of our work. And the fact that our proposal for a 5G model region as a major research project of TUK for 5G networks and applications was then also able to prevail was another great success.

Because of our visibility and recent research results, we were invited to become a partner in the European lighthouse project HEXA-X, in which Europe’s leading industrial and academic partners are working on the foundations of the next generation of mobile communications, 6G. Building on this, we were also able to bring the coordination and another major research project to Kaiserslautern with the Open6GHub.“

#### What is unique at TU Kaiserslautern?

“Through our association with DFKI and the close cooperation with the Smart Factory and colleagues at TUK, we have been able to bring AI, production and robotics knowhow to the communications community, as well as building a deep understanding of a wide range of use cases.

6G is now considered the first AI-native mobile generation – unsurprisingly, we are involved. Through the large-scale projects, we continue to try to build networks that can contribute to the profile of Kaiserslautern.“

#### What is next?

“Communication technologies are the basis of successful digitalization. The societal requirements that research in this area must consider are correspondingly challenging and complex. Sustainability, technological sovereignty, security, privacy, and participation ... all these goals must be quantified and incorporated into research.

Ultimately, the topic of science communication in particular will occupy a much larger space in the engineering sciences. We will have to learn to actively solicit acceptance for our solutions.“



# INTERNATIONALIZATION

Diversity of thought and ideas is a key ingredient for successful research and innovation. TUK welcomes students and researchers from more than 100 countries to its campus, and forges strong partnerships with universities and companies around the world, helping ensure the research we do here in Kaiserslautern has a global impact.



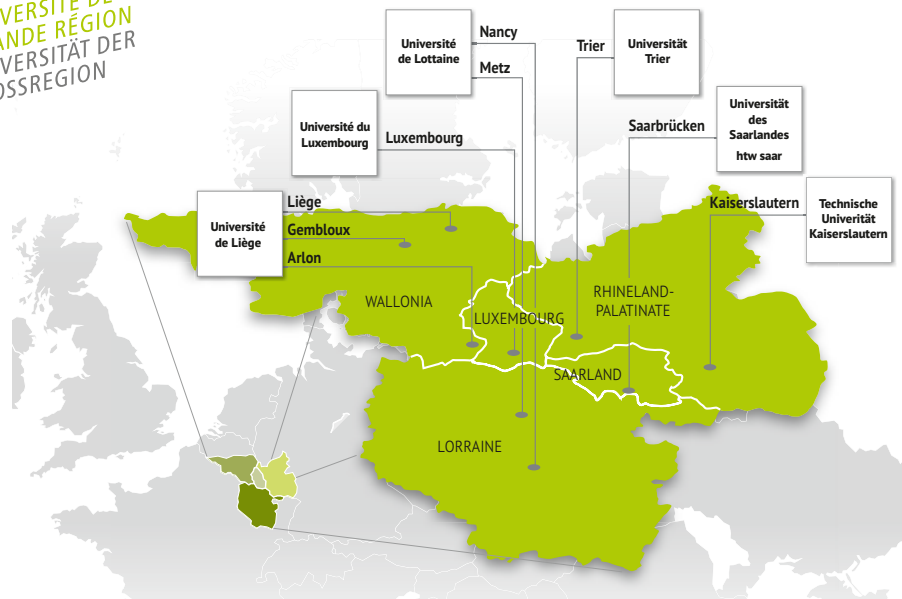
## INTERNATIONAL RESEARCH COOPERATION

TUK is an institution of comparatively young age that has rapidly evolved into an academic organisation with an advanced international network. At Kaiserslautern, international cooperation as well as global exchange and consultations constitute indispensable components of research, teaching, and learning alike.

In our teaching programs, numerous Double and Joint Degree Programs as well as two Erasmus Mundus Joint Masters demonstrate this international focus. Our researchers have been very active in the field of international collaborations, have successfully participated in projects funded under several EU Framework Programs and served both as experienced coordinators and partners in various international research networks and projects. On the one hand, TUK's research cooperation projects consist of multi-faceted collaborations and mutually beneficial interchange between our working groups and their counterparts outside Germany. Such cooperations are mostly based on in-kind contributions. On the other hand, our research teams are involved in numerous international research projects supported by various funding institutions: The European institutions and funding programs, such as the EU Framework Programs, Interreg, ERA-Nets, Joint Technology Initiatives, Research Fund for Coal and Steel or COST are our

most frequent funding schemes. European research excellence has been demonstrated by conducting multiple HORIZON 2020 projects including Marie-Sklodowska-Curie actions and winning eight grants by the European Research Council (ERC) on all levels. But also non-European funding organisations, such as the German-Israeli-Foundation (GIF), the Bill & Melinda Gates Foundation to name but a few, support TUK research activities.

We intend to develop our international visibility and networking even further: combining established assets with further internationalization efforts, we aim to be a preferred choice for researchers, students and staff from outside the region and on the international level. The University of the Greater Region (UniGR) and further international cooperations are integral parts of these efforts. Additionally, we have resolved to apply for the European Commission's Certificate for HR Excellence in Research, which requires a comprehensive and quality-managed system in accordance with the Human Resources Strategy for Researchers (HRS4R). We expect the International and European spirit to first and foremost inspire our researchers as well as our students and administrative staff with a substantial impact on research, teaching, and innovation.



## UNIVERSITY OF THE GREATER REGION: REGIONAL PLUS INTERNATIONAL – THE PERFECT COMBINATION

TUK is one of seven universities in the University of the Greater Region (UniGR), which spans the cross-border area of Germany, Belgium, France and Luxembourg. Established in 2008 with TUK as one of its founding members to support cross-border collaboration, the UniGR network is a pioneer among the European university alliances. Students take classes at partner universities, professors teach joint seminars or courses, and researchers launch joint projects.

Our students and researchers can easily broaden their expertise and scope without having to go far at all – international opportunities are available “next door” at the partner universities in one of the neighboring countries. The UniGR set-up allows to study and work regionally and at the same time internationally.

Given its unique framework spanning four neighboring countries, UniGR is a leader in cross-border studies, including the sociological, economic and cultural issues of people living and working in multiple countries. UniGR is also going to focus on the circular economy, developing social and technical solutions to ensure greater sustainability and resource efficiency in numerous sectors. Besides working across universities, the network also collaborates regularly with industry partners to advance innovation.

The UniGR network includes: TUK, Saarland University, Trier University and htw saar – University of Applied Sciences in Saarbrücken in Germany; University of Liège in Belgium; University of Lorraine in France at campuses in Metz and Nancy; and University of Luxembourg in the Grand Duchy of Luxembourg.



## STORIES ABOUT THE RESEARCH LANDSCAPE

One of the best features of doing research at TUK is the general cooperative spirit. Researchers regularly highlight how easy it is to collaborate across departments and to know almost everyone on campus. However, doing research at TUK entails even more assets. We champion support for early career investigators and are very proud to have excellent scientists at our university who meet the highest international standards. Scientific networking with national and international communities as well as communication with the public and policymakers are other important assets of our mission. Here are eight stories that represent the fabric of our research community.

# SOLVING THE TWO BODY PROBLEM ON THE INTERNATIONAL SCALE

**Professor Shanley Allen and Professor James Anglin share insights into their scientific fields and their experiences in managing their careers and family in Kaiserslautern.**

Securing a tenured professorship for one person is notoriously difficult; securing two in the same city is even harder. Known by the physical term “the two body problem”, this is a well known challenge for couples in academia. It took several years of international commuting and living apart with their two young children until linguist Shanley Allen and physicist James Anglin both became TUK professors. “We know other couples who gave up on living in Germany because universities would not consider spousal hire,” Allen says. “We were very lucky that TUK is proud to keep excellent people here and openings became available that fitted both of us.”

Anglin investigates what happens to thermodynamics when things get very small. “While physicists generally suppose that thermodynamics somehow emerge from microscopic physics as systems get larger, the dots have never been completely connected,” Anglin explains. He and his colleagues are working out mathematical equations for how energy could move inside cells, and have found something that looks like thermodynamics at this scale. “It may be that we are close to finally connecting these dots, understanding how thermodynamics relates to microscopic things, and may learn a lot more about nanobiology or nanotechnology.”

In a very interdisciplinary setting, Allen researches language acquisition and how people process multiple languages. “More than half the world speaks more than one language, but most of our linguistic research has been done with people who are monolingual and about their first language,” she says. Allen uses eye-tracking technology that measures where readers are looking 1,000 times per second to pinpoint exactly where the reader stumbles over complex grammatical structures in a second language. This helps understand how people learn languages, and can improve teaching methods for multilingual students.

Both professors highlight the benefits of working in the German university system. Professors have a lot of freedom to fill the curricula in a way they consider appropriate. While getting external research grants is as important as everywhere else, a small amount of annual core funding helps nurture projects until they are ready for a grant proposal. “It gives you a little more freedom to try crazy ideas and find out if they develop into something bigger,” Anglin says.

Kaiserslautern also offers many other benefits, they explain. The cost of living is lower, so they can afford a house close to campus and walk to work, something that would not be possible in more expensive cities. They feel much more comfortable letting their



## Professor Dr. Shanley E.M. Allen

*is a linguist and heads the Psycholinguistics and Language Development group at TUK's Department of Social Sciences. Between 2014 and 2020, she served as dean of the Department of Social Sciences. Since 2018, she has been a PI of the DFG research unit Emerging Grammars in Language Contact Situations: A Comparative Approach, and since 2021, she has been co-chair of it. Before joining TUK in 2010, she held a professorship at Boston University.*

## Professor Dr. James R. Anglin

*is a theoretical physicist and heads the Foundations of Quantum Physics group at TUK's Department of Physics. Since 2016, he has been a PI of the Transregional Collaborative Research Center Open System Control of Atomic and Photonic Matter (OSCAR) funded by the DFG. He is a member of TUK's Center for Optics and Materials Sciences (OPTIMAS). Together with his wife, Professor Allen, he coordinates TUK's exchange program with the College of Science and Technology – University of Rwanda, the former Kigali Institute of Science and Technology (KIST). Before joining TUK in 2005, he was a postdoc at MIT.*

teenage daughter take the bus here than in North American cities they have lived at, before. There is also less traffic and the pace of life is more relaxed. “If you want to have dinner with your neighbors in Boston, you have to make an appointment a month in advance,” Allen says. “Here, you can often call five minutes ahead and have a very nice dinner lasting the whole evening and no one is looking at their watch.”

# BUILDING SCIENTIFIC NETWORKS

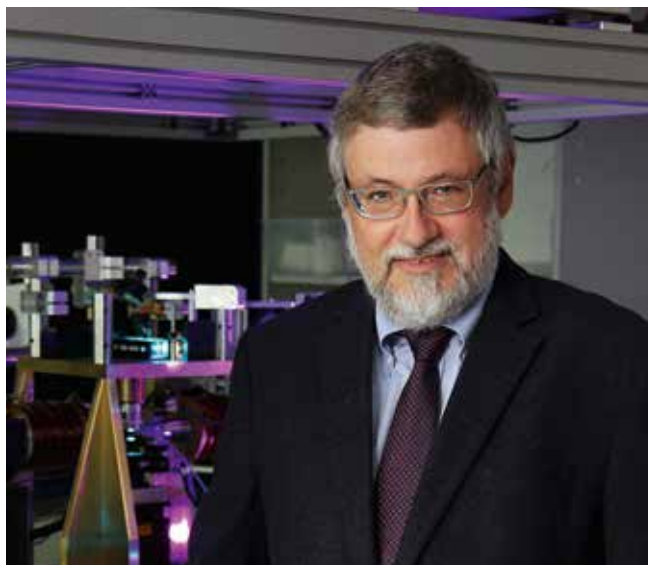
## **Professor Burkard Hillebrands shares insights into his many professional activities.**

TUK researchers are dedicated to building and strengthening scientific networks, benefiting research and students as well as society. Networking and collaborating are an essential part of the research process. “Research is to a large degree management of ideas. You cannot create all the ideas on your own,” says Burkard Hillebrands, who heads TUK’s Magnetism group. “Many ideas are born in discussions, just by sitting together over a coffee or beer.”

To help foster opportunities for researchers to network, collaborate and spark ideas, Hillebrands takes an active role in scientific societies, associations, academies and advisory boards. Notably, he helped found and is president of the European Magnetism Association, has held leadership positions in the IEEE Magnetics Society, and chairs the Commission on Magnetism for the International Union of Pure and Applied Physics. These organizations, and many others, help strengthen the scientific community by facilitating knowledge exchange, building trust, and organizing training opportunities for young scientists. They also provide a central point for industry partnerships, expertise for policymakers and public outreach.

Accepting a leadership role is both an honor, and a lot of work. Like many aspects of the German research system, it is all volunteer work. Hillebrands notes that while it does demand a fair amount of time, he prioritizes teaching and research first and foremost. The key to finding the right balance is having a supportive university like TUK that recognizes the value of the volunteer work. Ultimately, these activities help raise the profile of the university among the wider research community and beyond. This can help lead to more collaborations and funding. While the foundation of an individual scientist’s reputation is research, published papers and presentations, actively participating in these organizations helps amplify that collective effort and build a university’s reputation. “It is important to help increase the visibility of the university and take advantage of the potential we have,” Hillebrands says.

Many researchers at TUK are active in the national and international organizations for their respective disciplines as well as on regional, state and national bodies, including the German Research Foundation (DFG). Important engagements also include the National Academies like the Academy of Sciences Leopoldina, the Academy of Sciences and Literature Mainz, and the National Academy of Science and



## **Professor Dr. Burkard Hillebrands**

*is an experimental physicist and heads the Magnetism group at TUK’s Department of Physics. Between 2006 and 2014, he served as TUK’s Vice President for Research, Technology and Innovation. He is a member of the Academy of Sciences and Literature Mainz and since 2017, has been its vice president and chair of the Class of Mathematics and Natural Sciences. Since 2018, he has been member of the National Academy of Science and Engineering (acatech). He has served as chair and vice-chair in various coordinated initiatives of the DFG and the EU. He was secretary (2015-2017) and chair (2018-2021) of the C.9 Commission (Magnetism) of the International Union of Pure and Applied Physics (IUPAP). He has been a founding member of the European Magnetism Association since 2016 and, since 2019, its president. He is chair of the scientific advisory board of the Helmholtz Zentrum Dresden Rossendorf (HZDR) and member of its supervisory board. He holds an ERC Advanced Grant and is vice-speaker of the CRC/TRR 173 Spin in its Collective Environment (Spin+X). Before joining TUK in 1995, he held positions at the University of Karlsruhe and RWTH Aachen.*

Engineering acatech, which, among other activities, provide scientific advice to the government. “We are holding up our end of the deal – that with public funding for research, we have to give something back to society,” Hillebrands says. “Not just fundamental discoveries that lead to the next gadget or engineering marvel, but through communicating with policymakers and the public.”

# PAVING NEW PATHWAYS IN SCIENCE AND THE ACADEMIC SYSTEM

**Professor Kristin de Payrebrune shares insights into her scientific field and her experiences as a new professor at TUK.**

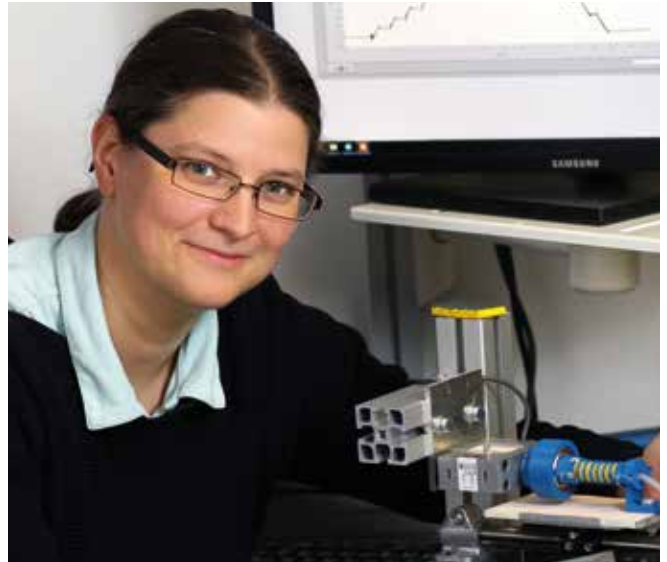
At TUK, several research groups work on new types of robots and their control as well as on new applications. Among them is the group of Kristin de Payrebrune, who holds TUK's Chair for Computational Physics in Engineering, and who had an idea for a new design for silicon robots with a soft touch. Soft robots might not be as strong as conventional robots, but they are extremely flexible and adaptable to different environments. This is particularly useful in unknown or varied terrain where a robot might need to adjust its locomotion to move around efficiently.

De Payrebrune and her team have designed silicon robots with a soft backbone connecting small hollow squares that can easily change locomotion and walk like a dog or a caterpillar. They are testing different designs with three segments moving like a snake, and four segments joined in the middle like an X. A tube attached to each segment fills the compartments with air and causes them to stiffen and move forward.

The robots can also deform so gently they can hold an egg without breaking or crushing it, without any sensors. De Payrebrune sees immense potential for future applications where humans and robots interact, such as health care, where it is critical that robots do not apply too much force. There are many challenges to solve, most notably how to remotely control the soft robots that use air to inflate and deflate without being tethered to an air source. But each phase of investigation is exciting; the field is so young, it is possible that when the team tries something new, they are the first to do so, de Payrebrune says.

Besides robotics, she and her team simulate manufacturing engineering processes, such as grinding and lapping, down to the microscopic level. De Payrebrune is part of multiple large projects like the Collaborative Research Centre 926 Microscale Morphology of Component Surfaces as well as the International Research Training Group Physical Modeling for Virtual Manufacturing Systems and Processes (IRTG 2057) for investigating ways to make manufacturing processes more efficient and less wasteful. In the latter program, TUK closely cooperates with the University of California in Berkeley and in Davis.

But de Payrebrune not only paves new science. As one of the first tenure track professors at TUK in the joint program for the promotion of early career researchers by the German Federal and State Governments (WISNA), and the first female professor in TUK's Department of Mechanical and Process Engineering,



## Professor Dr.-Ing. Kristin de Payrebrune

*is an engineer and heads the Computational Physics in Engineering group at TUK's Department of Mechanical and Process Engineering. Since 2018, she has been a PI of CRC 926 Microscale Morphology of Component Surfaces (MICOS) and the International Research Training Group Physical Modeling for Virtual Manufacturing Systems and Processes (IRTG 2057). As chair of the graduate program of CRC 926, she is also a member of the board of this coordinated program. Before joining TUK in 2017, she was a postdoc at TU Bergakademie Freiberg and at Berkeley.*

de Payrebrune is also a pioneer in TUK's academic career system. In the new type of tenure-track professorships, the career path towards a permanent professorship is more predictable and transparent for young researchers. It also enables young scientists to decide earlier than before to start an academic career. De Payrebrune is happy about her career prospects and working environment at TUK: "It is so easy to collaborate with everybody," de Payrebrune points out. "That is something I didn't experience at other universities. I think it is really special here."

# JOINING FORCES OF ACADEMIC RESEARCH, INDUSTRIAL COOPERATIONS AND ENTREPRENEURSHIP

**Professor Norbert Wehn shares insights into his scientific fields and his general research strategy as well as about the opportunities of the Kaiserslautern research landscape.**

Managing a university research group as a professor is in many respects similar to managing a small company: projects have to be acquired, employees have to be recruited and guided, and goals and long-term strategies are required. The “product” of an academic research group is thereby research results and, in many cases highly specialized methodological know-how. The entrepreneurial aspect of academic research becomes even more apparent when the research is carried out with companies as cooperation partners, as it is particularly common in engineering research groups.

In this context, it is important to have a general understanding of the goals and the general conditions of entrepreneurial activity. Norbert Wehn, professor for Design of Microelectronic Systems at TUK, is excellently prepared for this task due to his longstanding experience in various positions in industry – both in research and in operations. In his research group at TUK he is developing new design methodologies and chip designs for various applications. His basic credo is to understand and drive all research both from the fundamental side, e. g. in numerous projects of the German Research Foundation (DFG), as well as from the application side. For several developments, such as an application specific processor for wireless communication which can be found today in a commercial chip, he has laid the scientific foundation in a DFG funded project. Despite considering project funding by the DFG and scientific publications an important proof of the scientific quality and soundness of his research, the opportunities for the application of his results are what is ultimately driving Wehn.

In addition to his many bilateral research collaborations with industry, Wehn particularly appreciates the opportunities offered by collaborating with the institutes at the site and their business networks. For example, the High-Performance Center Simulation and Software Based Innovation provides an excellent framework. Wehn has a particularly fruitful relationship with Creonic, a company spun off from his research group 10 years ago, in which, as he emphasizes, he holds no shares. Depending on individual research issues, the partners can synergistically support each other in various forms of collaborations. Creonic operates very successfully in a highly specialized niche market: many of the satellites circling our globe hold important parts for maintaining communications like the DVB standard developed by Creonic



## Professor Dr.-Ing. Norbert Wehn

*is a computer engineer and heads the Microelectronic Systems Design group at TUK's Department of Electrical and Computer Engineering. Between 2013 and 2017, he served as TUK's Vice President for Studies, Teaching and International Affairs. He is chair of the European Design Automation Association and has been serving as Technology Ambassador of the City of Kaiserslautern since 2013. He has been supporting several start-up companies from his research group and has been a member of TUK's University Council since 2018. He served as chair of various European and national coordinated projects and is member of the Review Board "Rechnerarchitekturen und eingebettete Systeme" of the DFG (2020-2023). Before joining TUK in 1997, he held several positions at Siemens AG, including Head of the Product Development Section Standard Derivatives, Semiconductor Division.*

and by Wehn and his co-workers. Another “product” from his academic research group are excellently trained scientists for leading positions in industry and other areas of employment. Providing his students with the best possible education, both scientifically and by providing entrepreneurial basics, is another driving force for Wehn. This demand complements his concern for the various aspects of research perfectly: excellent basic research with high visibility through, e.g., DFG funding is of central importance in attracting excellent students to Kaiserslautern and inspiring them for our university.

# EXCHANGE WITH SOCIETY ON NEW SCIENCE AND TECHNOLOGY IS A CENTRAL MISSION OF TUK

**Professor Katharina Zweig shares insights into her scientific fields and her experiences in advising policymakers and the general public about artificial intelligence.**

Many TUK researchers are active in consulting companies, policymakers, the general educational sector as well as the broad public about the opportunities and risks of new scientific findings and new technologies. One current hot topic society still needs to learn about is artificial intelligence.

When it comes to artificial intelligence (AI), people tend to be either overly pessimistic or optimistic. “However, as almost always in life, the best usage of a new technology needs a careful balance between the freedom of innovation and regulations against foreseeable risks,” says Katharina Zweig. “I thus advocate for early technology assessment that identifies strengths and weaknesses in order to mitigate them efficiently.”

As computer scientist, Zweig researches the interaction between data science and the real world. Her lab conducts empirical research on so-called “black box algorithms” like Google’s search engine, to understand the extent of personalization that leads to different results for different users who enter the same search term. They also analyze AI systems used by courts to predict the recidivism risk of criminals and develop concepts for regulating AI systems. Working with political scientists and philosophers, they also explore what constitutes a “good and fair” decision by machines or humans.

Her research has enabled Zweig to become a respected voice advising policymakers at the local, state and national level. For example, she served on the German Parliament’s Study Commission on Artificial Intelligence from 2018 to 2020. There, 19 experts and 19 members of parliament discussed opportunities and risks of AI systems to identify trends and recommend future actions for the Parliament. Zweig also wrote a non-fiction bestselling book on the topic for lay audiences. Her dedication to science communication has been recognized by the German Research Foundation (DFG) with the national Communicator Award in 2019.

Zweig and her colleagues at TUK are at the forefront of interdisciplinary AI research between computer science, political science, economics and philosophy. Along with research, an innovative study program called “socioinformatics” offers B.Sc. and M.Sc. students the chance to study computer science, software engineering and math, as well as sociology, law and psychology. Thus, the graduates are



## Professor Dr. Katharina Zweig

*is a computer scientist and heads the Algorithm Accountability Lab at TUK’s Department of Computer Science. In 2018, she was appointed as an expert to the newly constituted Enquete Commission on Artificial Intelligence – Social Responsibility and Economic, Social and Ecological Potentials of the German Bundestag. In 2020, together with Karen Joisten and others, she founded the Center for Ethics and the Digital Society (CEDIS) at TUK. She has received several awards, among them are the appointment as Digital Head in the context of the Science Year The Digital Society (Germany, 2014), the Theodor Heuss Medal together with the other co-founders of AlgorithmWatch (2018), the Ars legendi Faculty Award in Engineering and Computer Science (2017), the Communicator Award by the DFG and the Stifterverband für die Deutsche Wissenschaft (2019). In 2020, she was appointed Artificial Intelligence Ambassador of the State of Rhineland-Palatinate.*

experts on how people will interact with or will be affected by digital technologies. Together with the closely affiliated Fraunhofer and Max Planck institutes as well as the German Research Center for Artificial Intelligence (DFKI), Kaiserslautern is thus perfectly equipped for AI research. Zweig states: “We are very well prepared to answer one of the most pressing questions of society: the question of how to design the digital transformation to support societal goals in the best possible way.”

# SUCCESSFUL INTERNATIONAL RESEARCH COOPERATION IS A MATTER OF GIVE AND TAKE

## Professor Andreas Dengel shares insights into the opportunities and requirements of successful international cooperation.

International cooperation is indispensable in many of TUK's research areas, be it for the exchange of ideas and materials, or for the exchange of students and scientists. Our collaborations involve universities and research institutions worldwide. For building mutual trust and achieving high returns, sustainable and long-term collaborations are important. One way to achieve this is by integrating students and early career researchers into our programs, in addition to senior scientists. We maintain several such valuable collaborations in various research areas with universities, research institutes and companies in Japan.

The computer scientist Andreas Dengel has recently been awarded Japan's oldest award: the high-ranking "Order of the Rising Sun on a Necklace, Golden Rays" in the name of the Japanese Empire. The country thus honoured Dengel's outstanding service to academic exchange between Japan and Germany in the field of artificial intelligence. Dengel is a sought-after advisor for science, industry and politics in Japan in the field of AI. For example, he was invited to speak to the Tokyo G-20 summit in 2019. Numerous research collaborations with academia and industry have grown over the years to a whole network, in which Dengel became an integral part of the Japanese research community. He has particularly strong ties with Osaka Prefecture University (OPU), which awarded him an honorary professorship with distinction (Distinguished Honorary Professor, *tokubetu eiyo kyoju*) and back in 2009, appointed him an honorary professor with full teaching and examination rights.

Surprisingly, building his large Japanese network did not start in the country itself, but in Puerto Rico, where as a young professor, Dengel spontaneously approached a Japanese lecturer after his exciting conference lecture. Soon after, he had the chance to invite this expert for a research stay to the DFKI. From there on, the network has grown steadily by simply being passed on to additional partners. It now even includes a German-Japanese-French sub-network and, moreover, has integrated other professors from Kaiserslautern.

Apart from the scientific and technological benefits, Dengel values absolute sincerity and reliability as well as mutual respect and thankfulness as the core elements of German-Japanese research collaborations. Dengel comments: "The Japanese-German friendship and the exchange as I have experienced it, has long been a matter close to my heart. With respect to our joint field of interest, it is deeply rooted on a common AI philosophy. With Japan as a high-tech country, we share the goal of using AI for the benefit of people and society." Next to the inspiring exchange of ideas and technologies, it is this human aspect of AI where intercultural perspectives provide



## Professor Dr. Dr. h.c. Andreas Dengel

*is a computer scientist and heads the Artificial Intelligence group at TUK's Department of Computer Science and heads the Smart Data & Knowledge Services research area at the German Research Centre for Artificial Intelligence (DFKI). In 1993, he became Scientific Director of the DFKI and was appointed to TUK; since 2020, he has been serving as Executive Director. Since 2009, he has been holding a professorship (kyakuin) at Osaka Prefecture University. Dengel coordinates DFKI's Deep Learning Competence Center, which was the only German one to be recognized through the NVAAIL Excellence Program (one of eight worldwide). In 2019, he was selected by a jury of the BMBF as one of the most influential scientists in 50 years of AI history in Germany. Dengel is founder, initiator and mentor of many start-up companies. The State of Rhineland-Palatinate appointed him as AI Ambassador in 2020. Before joining TUK and DFKI, Dengel was at IBM and Siemens, and did a research stay at Xerox PARC in Palo Alto.*

particularly valuable insights, such as in the field of cyber-physical learning environments. The fruits of the cooperation do not only benefit research. Dengel has also advanced the internationalization of our computer science degree program. Students of TUK and OPU can complete a semester abroad at the partner university, and their credits are recognized in their home universities. This program is used by TUK's students on a regular basis, e.g. for working on their bachelor or master theses. The exchange of early career scientists may also provide additional benefits: three of our former German graduate students are now happily married living in Japan.

# A VIEW OF THE KAISERSLAUTERN RESEARCH LANDSCAPE FROM THE SURROUNDING INSTITUTES

**Professor Anita Schöbel shares insights into her many duties as a director of the Fraunhofer ITWM and provides further perspectives on the whole Kaiserslautern research landscape.**

The research institutes on and near the campus are an important characteristic of TUK's research landscape. Since 2019, Anita Schöbel heads the largest of these institutes, the Fraunhofer Institute for Industrial Mathematics ITWM. The foundation of the institute's renowned expertise is mathematics and therefore there are the most and strongest ties with the corresponding department of TUK. Following the growing role of mathematics in various scientific and technological settings, the ITWM also relies on scientific personnel with a background in other disciplines, such as computer science, engineering and physics. This broad basis of expertise as well as the very solid economic foundation enable the ITWM nowadays to also tackle projects which, in addition to the economic return, focus on the sustainable impact, for science as well as for society. The latter applies, for example, to ongoing projects with the World Food Program, or to projects in health or renewable energy.

Schöbel, who is a mathematician herself, points out the fruitful scientific networking with researchers from other disciplines and across all institutions at the site. In Kaiserslautern, there is a widespread willingness for interdisciplinary collaborations, which provides an excellent breeding ground for initiating new research topics. The various players in this scientific ecosystem obviously have to consider their own interests, e.g., with regard to their institutes' missions and organizational frameworks, but there is a strong cross-cutting "Kaiserslautern spirit" of cohesion and mutual trust. "We pull together excellently and everyone contributes as agreed!" is how Schöbel summarizes this in brief and adds "With all institutions – the university as well as the institutes – we have every reason to be proud of what has been built up this way in recent years."

On top of her tight schedule in being a university professor and leading the ITWM as well as her many duties in networking, Schöbel has been assigned high-level tasks in the Fraunhofer-Gesellschaft and the international scientific community. For example, she was elected into the Standing Committee of the Scientific and Technical Council of the Fraunhofer-Gesellschaft and recently became the next president of the Association of European Operational Research Societies (EURO).

Schöbel's field of expertise is mathematical optimization, in particular robust optimization dealing with uncertainties and optimization of public transport. Here she continues to be scientifically active herself and fulfils several duties as a univer-



## Professor Dr. Anita Schöbel

*is a mathematician and heads the Fraunhofer Institute for Industrial Mathematics ITWM. She also heads the Applied Mathematics group of TUK's Department of Mathematics. She is chair of the Research Unit Integrated Planning in Public Transport of the DFG. In 2022, she is to become President of the Association of European Operational Research Societies (EURO). Since 2020, she has been co-coordinator of the Fraunhofer Competence Network Quantum Computing and also speaker of the Fraunhofer Strategic Research Field Next Generation Computing. She has been elected as a member of the main commission of the Scientific e.V. and Technical Council (STC) of the Fraunhofer-Gesellschaft. Since 2020, she has been Senator of the National Research Data Infrastructure (NFDI). She was assigned Pilot for Artificial Intelligence by the State of Rhineland-Palatinate. Before joining TUK and ITWM in 2019, she held a professorship at the University of Göttingen.*

sity teacher. When becoming deputy spokesperson of the Competence Network Quantum Computing recently, she even set up a whole mathematics-driven new lecture class in order to work up some background knowledge in this area. As the co-spokesperson of Next Generation Computing, one of only seven strategic research areas of the Fraunhofer-Gesellschaft, she also organized hands on training for the students of her class in this innovative area. As Schöbel considers the quality of the students and the trustful relationship with them as one of the major assets of the "Kaiserslautern spirit", such extra tasks are a very rewarding investment in her eyes.

# ACCELERATING THE SPEED OF INNOVATION

**Professor Dieter Rombach shares insights into the Science and Innovation Alliance Kaiserslautern (SIAK) that initiates and manages regional networking processes.**

When it comes to science and technology, Kaiserslautern has it all: two higher education institutions, research institutes, tech companies, and industry. The Science and Innovation Alliance Kaiserslautern (SIAK) brings these diverse players together around common missions, such as the digital transformation of production, construction, agriculture and vehicles.

The pace of technological change is now so fast that the traditional sequence of doing fundamental research first, followed by applied research, and then real-world implementation is no longer viable, explains Dieter Rombach, the SIAK CEO. Basic and applied researchers need to work in concert across disciplines and with industry from the beginning, innovating in parallel. “Normally academics and practitioners have to follow different basic demands in their work, therefore it is not so easy to get them together,” Rombach says. “We have created a tight and trustful network so we can react to challenges very quickly.” He adds, that it is not only important “what” you know but also “who” you know and “by whom” you are known.

Rombach is one of the founding partners of the network and has led it since 2015. He held the Chair of Software Engineering in the Department of Computer Science at TUK and founded the Fraunhofer Institute for Experimental Software Engineering (Fraunhofer IESE) in Kaiserslautern. Rombach also acts as the Chief Digital Officer of the City of Kaiserslautern.

The SIAK network, established in 2007, has strengthened the channels of communication between all the players in the region’s science and technology ecosystem. SIAK is a highly effective network in the extended science and innovation region of Kaiserslautern in the fields of mathematics, computer science, natural sciences and engineering and their application in the transformation processes of digitalization and sustainability. These combined strengths have helped attract investment and companies to the region. For example, John Deere set up its European R&D Center in Kaiserslautern in part because of the innovative, interdisciplinary research in artificial intelligence, digital transformation, as well as in engineering and commercial vehicle technology.

“Kaiserslautern provides an excellent environment with such activities as the highly specialized research operations at TUK and associated Fraunhofer institutes, providing John Deere excellent opportunities to develop interdisciplinary innovations and to recruit talented employees,” says Mark von Pentz, president of John Deere’s Worldwide Agriculture and Turf Division upon the center’s



## Professor Dr. Dr. h. c. Dieter Rombach

*is a computer scientist who headed the Software Engineering group of TUK’s Department of Computer Science until 2018. He was the Founding Director of the Fraunhofer Institute for Experimental Software Engineering IESE in Kaiserslautern from 1996 until 2014. Since 2016, he has been chair of the Board of the Science & Innovation Alliance Kaiserslautern (SIAK). In 2018, he was appointed the first Chief Digital Officer of the city of Kaiserslautern. From 2006 until 2009, he was also a member of the Executive Board of the Fraunhofer-Gesellschaft as head of the Information and Communication Network, which included 17 institutes. He has received several awards, including the Federal Cross of Merit on Ribbon of the Federal Republic of Germany (2009), the Fraunhofer Medal (2013), and the IEEE Harlan D. Mills Award for lifetime achievement (2021). Before joining TUK and IESE in 1992, he held various professorships at the University of Maryland and positions at NASA.*

opening. With the recent establishment of a Professorship in Digital Farming at TUK by a company consortium, a new chapter has been added to this success story.

Next to supporting companies in recruitment, the SIAK network is also benefitting TUK students and early career researchers who thus have direct access to companies through internships or application-oriented research projects. Work opportunities in or with the SIAK companies have already been a stepping stone for the career of many students.



## SERVICES

Our staff is dedicated to supporting researchers so they have the tools, guidance and infrastructure to be successful. Whether is it answering questions at the earliest stages of applying to study or work here, or helping with patents for a new discovery after years of research, we are here for you every step of the way.





# SERVICES FOR RESEARCH AND RESEARCHERS

TUK has been well established as host institution and is offering tailored services for young and experienced scientists alike.

The **Office for Research and Early Career Support** is our central support facility for national and international research funding, early career researchers, UniGR and international research marketing. If desired, coaching and hands-on support are available throughout the entire project life cycle, from presentation of the project idea or funding application, during project set-up process, as well as for implementation and reporting. Our Young Researchers Network (TU-Nachwuchsring) provides PhD students, Postdocs as well as junior professors with ongoing career support, including mentorship, skills training and start-up funding for independent research as well as for networking activities.

In the administration and implementation of externally funded projects, researchers are professionally supported by dedicated units at the university's **central administration**. Once funds have been granted, assistance continues with input for project partner agreements, financial statements, and project management, e.g. by the divisions for Legal and Academic Affairs or for Financial Affairs.

Our knowledge transfer office is "**Referat Technologie und Innovation (RTI)**". As a service center for researchers, inventors,

businesses, and start-ups, RTI promotes all kinds of knowledge and technology transfer initiatives. In particular, RTI facilitates university-industry collaborations, and strengthens our technology transfer networks. It supports researchers and students, who would like to commercialize their ideas and helps researchers to present their current research results at major trade fairs. RTI's PATLIB center offers patent information services such as patent searches as well as technology and competitor watches. Furthermore, it gives advice on patent strategies and practical assistance on intellectual property rights issues.

In relation to work or residency permission and living situation, substantial support is provided to ensure a successful stay and integration of international researchers and guests into the Kaiserslautern research and living habitat. The **Department of International Affairs (ISGS)** serves as an interface and a service provider aiming to increase the compatibility of your stay at TUK with international curricula. In its capacity as an advocate of internationalization and as a cross-faculty structure, ISGS facilitates further relevant infrastructure, facilities, and regulations for incoming students and researchers, by providing a broad range of highly professional services from admissions and visas, to housing, language and skills training, job hunting, and much more.



## RESEARCH INSTITUTES

TUK is part of a vibrant local research ecosystem that features numerous leading basic and applied research institutes. Several are located on campus or just a short walk down the street, making collaborations fast and easy. Each institute brings its unique expertise, and benefits from the strengths of the others. This synergy makes for an invigorating, fruitful research environment.

## GERMAN RESEARCH CENTER FOR ARTIFICIAL INTELLIGENCE (DFKI)



DFKI is Germany's leading research center for AI-based commercial software technology. Headquartered in Kaiserslautern, DFKI coordinates basic, application-oriented research conducted throughout the country around key themes, such as augmented vision technologies for autonomous vehicles, deep learning, emergency management and response, smart cities, sustainability, and wearable AI. Researchers develop products and prototypes for information and communication technology and test them in living laboratories. DFKI-affiliated research has led to 99 spin off companies and counting.

## FRAUNHOFER INSTITUTE FOR INDUSTRIAL MATHEMATICS ITWM



Fraunhofer ITWM is one of the world's largest mathematical research institutes. Like all Fraunhofer Institutes, ITWM works closely with industry to address real-world problems. The institute uses mathematics as a key technology to develop optimized solutions for industrial partners from selected lead markets. These lead markets include plant and mechanical engineering, the digital economy, the energy as well as the health and mobility sectors, and the chemical industry.



## FRAUNHOFER INSTITUTE FOR EXPERIMENTAL SOFTWARE ENGINEERING IESE

Fraunhofer IESE has been one of the leading research institutes in software, systems and innovation engineering for 25 years. Using applied research, it develops innovative solutions for the design of dependable digital ecosystems for its customers' economic and social benefit. It helps companies master challenges in the areas of Autonomous Systems, Industry 4.0, Smart Farming, and Digital Healthcare, and offers digital solutions for rural and urban areas. In over 2,000 customer projects, it has transferred cutting-edge research into sustainable business practices. Current focus topics are Dependable AI, Digital Ecosystems, Virtual Engineering, and System Modernization.



## INSTITUTE FOR SURFACE AND LAYER ANALYSIS (IFOS)

IFOS helps businesses, industry and researchers get a close look at material surfaces on the micro and nano levels. The institute analyzes the very top layer of inner and outer interfaces of a solid material – sometimes the layer is just one atom or a few atoms thick – as part of the product and process development. The scientists evaluate a surface's characteristics, its potential for damage and failure under various conditions, and how to better control production processes for best performance.



## INSTITUTE FOR TECHNOLOGY AND WORK (ITA)

ITA conducts interdisciplinary research and development for people and organizations. ITA's activities aim at shaping the future of work and at contributing to a better working world, by strengthening people, organisations and networks in their respective development potentials. New approaches to learning, leadership and collaboration in the context of technological transformation and ethical responsibility finally result in empowered individuals and teams as well as more resilient organisations.



## LEIBNIZ INSTITUTE FOR COMPOSITE MATERIALS (IVW)

IVW researches fundamentals for future applications of composite materials, which are of great importance for the mobility of the future, the fields of energy, climate and environment, production technology as well as for health care. Focus is on the entire process chain, from basic materials to characterization and simulation, from construction methods and production technology to component testing and recycling. New ideas and innovative concepts are not only an essential part of the research and further development of the institute, but also lead to spin-offs. Newly acquired knowledge is transferred into science, teaching, the interested public and industrial applications.



## MAX PLANCK INSTITUTE FOR SOFTWARE SYSTEMS (MPI-SWS)

From algorithms, theory and logic, to cyber-physical systems and distributed networks, MPI-SWS conducts foundational research in computer science. The institute studies principles of efficient, dependable, secure and user-friendly computing systems, and as well as how they interact with the physical world and societies.



## PHOTONICS CENTER KAISERSLAUTERN (PZKL)

The Photonics Center specializes in optical technologies and laser micromachining. High powered laser light can be used to create a desired feature, such as make materials water-repellant or shine in a precise way. It can also provide a faster and more precise production process. The institute aims to make modern laser technology accessible, especially to small and medium-sized companies.



# LIST OF ABBREVIATIONS

5-ACIA	5G Alliance for Connected Industries and Automation
BMBF	Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung)
BMVI	Federal Ministry of Transport and Digital Infrastructure (Bundesministerium für Verkehr und digitale Infrastruktur)
BMWi	Federal Ministry for Economic Affairs and Energy (Bundesministerium für Wirtschaft und Energie)
CMOS	Complementary Metal Oxide Semiconductor
COST	European Cooperation in Science and Technology
CRC	Collaborative Research Center (Sonderforschungsbereich, SFB)
CRC/TRR	Transregional Collaborative Research Center
DFG	German Research Foundation (Deutsche Forschungsgemeinschaft)
DFKI	German Research Center for Artificial Intelligence (Deutsches Forschungszentrum für Künstliche Intelligenz)
Erasmus Mundus	European Union funding instrument to enhance quality in higher education
ERC	European Research Council
EU	European Union
Fraunhofer IESE	Fraunhofer Institute for Experimental Software Engineering IESE (Fraunhofer-Institut für Experimentelles Software Engineering IESE)
Fraunhofer ITWM	Fraunhofer Institute for Industrial Mathematics ITWM (Fraunhofer-Institut für Techno- und Wirtschaftsmathematik ITWM)
IFOS	Institute for Surface and Layer Analysis (Institut für Oberflächen- und Schichtanalytik)
iGEM	International Genetically Engineered Machine, non-profit organization dedicated to the advancement of synthetic biology, education and competition
Interreg	European Union funding instrument to support cooperation across borders
IRTG	International Research Training Group (Internationales Graduiertenkolleg, IGK)
ITA	Institute for Technology and Work (Institut für Technologie und Arbeit)
IVW	Leibniz Institute for Composite Materials (Leibniz-Institut für Verbundwerkstoffe)
LASE	Laboratory for Advanced Spin Engineering
LPME	Laboratory for Ultra-Precision and Micro Engineering
MIT	Massachusetts Institute of Technology
MPI-SWS	Max Planck Institute for Software Systems
NFDI	National Research Data Infrastructure (Nationale Forschungsdateninfrastruktur)
NSC	Nano Structuring Center
NVAIL	NVIDIA AI Lab Program
PI	Principal Investigator
PZKL	Photonics Center Kaiserslautern (Photonik-Zentrum Kaiserslautern)
RTG	Research Training Group (Graduiertenkolleg, GRK)
SIAK	Science and Innovation Alliance Kaiserslautern
TUK	Technische Universität Kaiserslautern
UniGR	University of the Greater Region

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