

Blue laser light from flow measurements in a multi-stage axial-flow compressor with water injection

© Photo: Chair of Turbomachinery – Tobias Dörr

Faculty of Engineering

The Faculty of Engineering at the University of Duisburg-Essen is made up of four closely integrated departments, Civil Engineering, Electrical Engineering and Information Technology, Computer Science and Applied Cognitive Science, and Mechanical and Process Engineering. To ensure focused research despite the remarkable breadth of topics covered at the Faculty, the research activities of these departments are consolidated into four interdisciplinary research profiles: Tailored Materials, Human-Centred Cyber-Physical Systems, Smart Engineering, and Energy and Resource Engineering (<https://www.uni-due.de/iw/de/forschung/psp.php>). They are closely related to seven teaching units, in which the Faculty provides instruction at the highest level: our numerous internationally oriented bachelor's and master's degree programmes are currently host to around 10,800 young people from more than 110 countries. This large student body, combined with 92 professorships in 73 institutes and chairs, make the UDE's Faculty of Engineering one of the largest of its kind in Germany.

Supported by seven affiliated institutes and further collaborating organisations, the Faculty works with members of other national and international research institutions as well as players from business and industry to produce research results and effectively translate them into practice. It is not only for this reason that engineering at the University of Duisburg-Essen has an excellent global reputation in many subdisciplines. It occupies leading positions in nano-technology and combustion research and conducts top-level research in automotive engineering, energy, environmental process engineering and solid-state electronics, optimisation of communications, radio and radar systems, energy grids, and optoelectronics and interactive media systems. In association with the Development Centre for Ship Technology and Transport Systems (DST), with which it is affiliated, the Faculty runs one of the largest university institutes for ship technology and ocean engineering in Germany. In Industrial Engineering, highly skilled graduates are trained at the interface of engineering and management with a focus on the automotive industry. Our Department of Civil Engineering occupies leading positions in the CHE ranking. At the University of Duisburg-Essen, cognitive scientists and psychologists are part of the Faculty of Engineering, too. No matter what technical advances are made, it is still people who control devices and programme machines, and human-machine interaction continues to be an important part of research in this field.

Mechanical and Process Engineering

The Department of Mechanical and Process Engineering (MBVT) comprises the teaching units of Mechanical Engineering and Industrial Engineering, whose 31 professors represent a diverse range of subjects in teaching and research. The internal institutes work closely with the UDE's affiliates: The Institute for Energy and Environmental Technology (IUTA e.V.), the IWW Water Centre, the Development Centre for Ship Technology and Transport Systems (DST e.V.) and the Fuel Cell Research Center (ZBT). Their direct collaboration promotes and underscores the applied nature of engineering research.

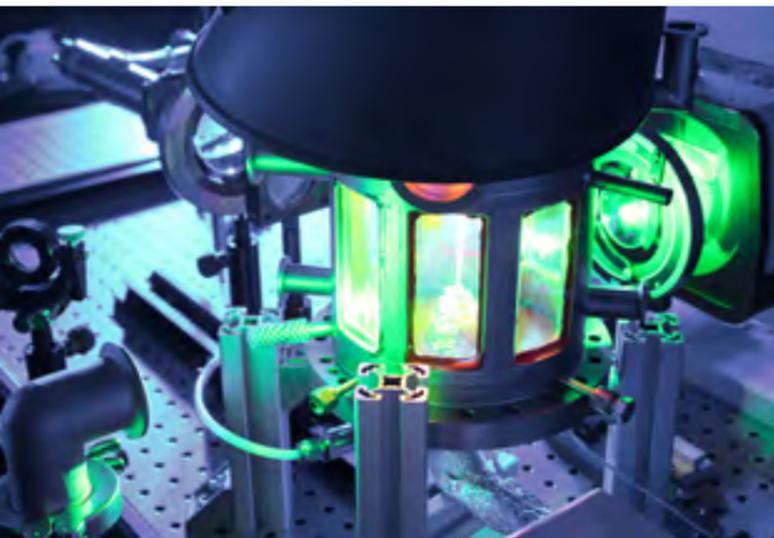
Research highlights

DFG Research Unit 1993, 'Multifunctional Conversion of Chemical Species and Energy' (spokesperson: Professor Burak Atakan, Chair of Thermodynamics), has entered its third phase. The group studies the use of reciprocating engines as chemical reactors in the production of basic chemicals. Through closely coordinated simulations and experiments, the researchers were able to shed light on the way additives behave in the fuel-rich conversion of methane to syngas. Their current research explores concepts for reducing the amounts of additives required and the chemical implementation and utilisation of CO₂ in combustion engines. Another three renowned researchers recently joined the research unit as Mercator Fellows: Professor Eric Peterson (Texas A&M University, USA), Professor Sergey Cheskis (Tel Aviv University, Israel) and Professor Ali Güngör (Ege University, Turkey).

The Chair of Reactive Fluids focuses on fundamental research into combustion processes and particle synthesis in the gas phase. In the DFG Priority Programme 1980, 'SpraySyn', a group of researchers coordinated by Professor Christof Schulz examines the synthesis of functional materials in spray flames. Following a successful evaluation in 2020, the project has secured 7.6 million euros in funding for the next three-year period. Eight of the 18 funded periods are based at the Department of Mechanical and Process Engineering. Within the scope of this priority programme and Research Unit 2284, headed by Professor Schulz, the Faculty organised the 4th International Symposium on Gas-phase Synthesis of Functional Nanomaterials in 2020. The online event was attended by 180 visitors from around the world.

The recent appointment of Junior Professor Doris Segets plays an important role in the processing of said materials into functional layers for use in batteries and fuel cells, for example. Her specialism complements the department's existing range of research areas and strengthens the connection between material synthesis and applications.

Members of the Chair of Reactive Fluids have developed a new anode material for batteries based on carbon and silicon. In collaboration with Evonik Industries, the team is currently



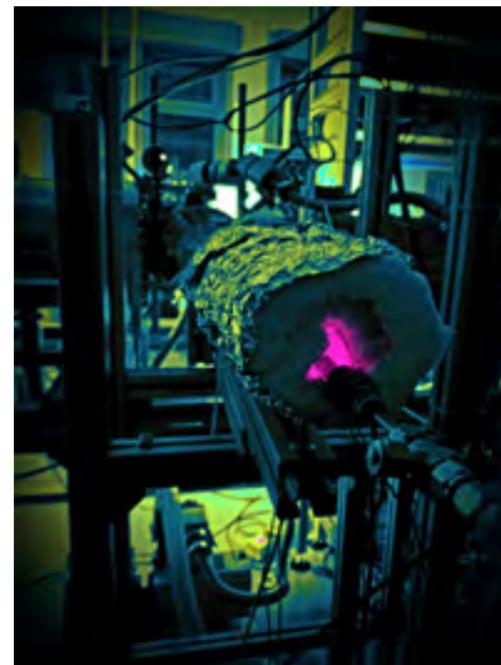
Laser-induced breakdown spectroscopy

© Photo: Sacha Lau, Chair of Thermodynamics



Turbomachinery. Its objective is to develop a $s\text{CO}_2$ -based power plant and demonstrate its operational flexibility, reliability and suitability for temperatures above 350°C . The project team is working with industry partners to produce a prototype. CO2OLHEAT is based on similar EU-funded projects under UDE leadership, during which the basic concepts, proper functioning and sophistication of the system were proven both in theory and on the test bed. Another EU-funded project in the same field is 'sCO₂-4-NPP'. It is dedicated to the development of an innovative, $s\text{CO}_2$ -based heat removal system intended to improve the safety of nuclear power plants.

The Institute of Ship Technology, Ocean Engineering and Transport Systems (ISMT) focuses on numerical and experimental research of multiphase flows and fluid-structure interactions in the maritime context. Its members have carried out and published many studies into sloshing, cavitation and vortex-induced oscillations, including new methods of predicting cavitation-induced erosion. In partnership with the Department of Physics at Novosibirsk State University, the Institute has conducted experiments on passive cavitation control.



Hot tube-furnace reactor

© Photo: Dennis Kaczmarek, Chair of Thermodynamics

working on advancing the manufacturing process and moving it to an industrial scale. The three-year project 'HOSALIB – High-Performance Silicon-Carbon Composite as Anode Material for Lithium-Ion Batteries' has secured 2.3 million euros in funding from the Federal Ministry of Economics and Technology. It focuses on manufacturing and processing the materials in question. The EU project Hyflexpower is dedicated to the study of another important aspect of future energy systems: led by Siemens, the consortium researches the use of hydrogen in gas turbines while building the world's first power-to-x-to-power demonstration plant with a hydrogen gas turbine. Within the scope of this project, the Chair of Reactive Fluids is developing ways of using endoscopic methods to measure flame positions and surface temperatures in the combustion chambers.

The Chair of Thermal Process Engineering focuses on fundamental research into the separation technique of adsorption. It secured three new DFG-funded projects in 2019 and 2020.

Supercritical carbon dioxide ($s\text{CO}_2$) is a fluid whose particular properties facilitate innovative solutions in heat and material transfer. CO2OLHEAT is the fourth project of Horizon 2020, the EU Framework Programme for Research and Innovation, that is based at the Chair of

Inland shipping on rivers and canals is a competitive and sustainable transportation system that has always been a crucial location factor for industry in North Rhine-Westphalia and beyond. That is why the Department of Mechanical and Process Engineering (MBVT) has recently launched several major collaborative projects that will make inland vessels fit for the digital twenty-first century. The Chair of Mechatronics, the ISMT, and the Chair of Dynamics and Control collaborate closely with the DST and their international industry partners. Funding is provided by the State of North Rhine-Westphalia, the Federal Government and the European Union.

The team behind the project 'AutoBin – Simulation and Demonstration of Automated Driving in Inland Navigation' works on equipping an inland vessel with an extensive sensor and actuator system. ('AutoBin' is short for *autonomes Binnenschiff*, autonomous inland vessel.) Using a simulator, they are developing an AI-based navigation system that can safely steer a vessel from its point of departure to its destination. After training the AI in the simulator, the researchers test and demonstrate the navigation system using the fully equipped inland vessel.

The 'FernBin' (remote-controlled, coordinated piloting in inland navigation) project team develops methods and assistance systems for controlling inland vessels remotely. They are also working on an onshore control station with interfaces to the vessel, operating elements and user interfaces. Not only are they using a real test vessel, they are simultaneously developing a digital twin ship, which faithfully mirrors the handling of the original. This digital twin will be used as an onshore control station for testing, development and ship crew training purposes.

The Test and Management Centre for Autonomous Inland Waterway Vessels (VeLABi) at the Ministry of Transport of North Rhine-Westphalia was proposed and established in the context of this project. With a diameter of eight metres, the simulator is a 360° projection of a ship's bridge. It generates a seamless, stereoscopic 3D image on a projection surface of approximately 67 m^2 . In addition to this projection technique, the researchers use virtual and augmented reality glasses enabling them to interact directly with the virtual environment.



Dean: Professor Dr.-Ing. Dieter Schramm

The Chair of Energy Technology focuses on three key research areas. The first is dedicated to modelling and analysing energy systems, in particular, cogeneration and innovative heating networks. Its members have carried out various projects within the scope of the development of the large housing development of Duisburg-Wedau. In the second key research area, researchers carry out scientific analyses of the use of hydrogen, such as its storage as gas in high-pressure tanks or its storage as liquid ammonia. The third key research area revolves around the development of electrochemical energy converters – specifically, fuel cells and new battery technologies – in partnership with Grillo and Varta Microbattery.

The Chair of Environmental Process Engineering and Plant Design researches future energy supply systems and plants that use renewable



This is what entering the Duisburg port will look like in the river ship simulator.

© Photo: Daniel Schumann

energy sources to provide electricity, heat and consumables (fuels, basic chemicals). For the project 'Bicarb2Fuel', funded by the Federal Ministry of Economics and Technology, the Chair of Environmental Process Engineering and Plant Design collaborates with Mitsubishi Power Europe GmbH. Its objective is to demonstrate an energy-efficient method of carbon capture and subsequent methane and methanol synthesis. The members of the Chair are developing a pilot plant that carries out all required steps in the absorption-desorption process. At the same time, thermodynamic and reaction-kinetic data are captured in a laboratory in order to facilitate precise catalyst and process optimisation and model simulations.

The Chair of Materials Science and Engineering has been working with Professor Alexander Hartmaier of the Interdisciplinary Centre for Advanced Materials Simulation (ICAMS) at Ruhr University Bochum on researching deformation and failure mechanisms in austenitic steel under

coupled compressive and torsional loading since 2020. This DFG-funded collaborative project uses high-resolution electron microscopy to examine damage at the microstructural level. Its insights inform micromechanical models that make the behaviour of austenitic steels under complex pressure significantly more predictable.

Awards

Shortly after joining UDE, Professor Doris Segets 2020 was admitted to the Junge Akademie at the Berlin-Brandenburg Academy of Sciences and Humanities and the German National Academy of Sciences Leopoldina. Professor Burak Atakan was conferred the lifetime honorific title of Fellow of The Combustion Institute in 2020.

Several doctoral candidates of the Faculty have won awards for their outstanding dissertations:

- Dr Dennis Roskosch won the MegaWATT Award in 2019
- Dr Andreas Peters won the Georg Weinblum Award in 2020

- Dr Marcel Richter and Dr Florian Möllenbruck won the VGB Innovation Award in 2019 and 2020, respectively.

Prizes have been awarded for shorter formats presented at conferences, too:

- Sebastian Grimm won a prize for the best poster at Euro-CVD 2019 in Luxembourg
- Florian Möllenbruck won the Werner von Boie Award at the Power Plant Technology Congress 2019 in Dresden
- Jonas Ambrosy and his co-authors won the poster prize of the 2020 annual conference of the ProcessNet subject divisions of Fluid Separations, Extraction and Adsorption in Berchtesgaden.
- Christian Mauer and his co-authors won the poster prize of the 2020 annual conference of ProcessNet in Aachen.
- Qi Deng and her co-authors won the Student Paper Award of the IEEE Conference on Cognitive and Computational Aspects of Situation Management 2020, organised online by the University of Victoria (BC, Canada)
- Roland Boumann and his co-authors won the Best Research Paper Award of the 6th International Symposium on Robotics and Mechatronics 2020 in Taipei (Taiwan).

Partnerships and international affairs

In April 2020, Professor Dieter Schramm of the Chair of Mechatronics became a visiting professor at the Dalian University of Technology (China). Dr Frederic Kracht, also from the Chair of Mechatronics, is a visiting scholar at the same institution. The partnership is dedicated to research into the mechanical load on fuel cell vehicles as conditioned by driving dynamics and environmental factors. It also involves the development of a platform for designing vehicles and driving simulators based on digital twins.

Members of the Faculty participate actively in their scientific communities and organise important conferences. In 2019, the VDI/ProcessNet Thermodynamics Colloquium took place at the University of Duisburg-Essen. More than 200 visitors attended the event, which featured early-career researchers from German institutions reporting on their research in thermodynamics. The Chair of General Business Administration

and International Automotive Management organised the 11th Wissenschaftsforum Mobilität in 2019. Due to the immense growth of the forum, its 400 participants from the academic, business and political spheres gathered at the City Palais Duisburg, rather than the University, to discuss more than 80 contributions. For the first time since the inception of the event, an exhibition was set up in the city centre to educate the interested public about new approaches to mobility. The Institute of Ship Technology, Ocean Engineering and Transport Systems organised two international conferences: the Autonomous Inland and Short Sea Shipping Conference 2019 and the 14th OpenFOAM Workshop.

In a multidisciplinary consortium comprising the social sciences, economic sciences and engineering sciences, researchers of the University Alliance (UA) Ruhr explore ways of making mobility in the Ruhr Area sustainable. The 'InnaMoRuhr' project aims to improve the network between the four sites of the UA Ruhr without producing additional emissions in order to achieve a lasting, positive change in the mobility behaviour of its students and employees. The Ministry of Transport of North Rhine-Westphalia is funding the project with 2.4 million euros for a three-year period. From our faculty, the Chair of General Business Administration and International Automotive Management participates in InnaMoRuhr.

The virtual institute KWK.NRW is an important collaboration of the Chair of Energy Technology. In this project, the Gas- und Wärme-Institut Essen e.V., the Fuel Cell Research Center (ZBT) and several chairs of the University of Duisburg-Essen work on pooling cogeneration expertise from across the State of North Rhine-Westphalia. Many other university institutes, associations and companies support the virtual institute as affiliated partners.

Transfer and sustainability

Three employees of the Chair of General Business Administration and International Automotive Management, Dr Florian Knobbe, Stefan Sommer and Gregor Szybisty, have come together to offer smart, wireless charging systems. They founded a business named gapcharge, which won national and international start-up competitions.



Professors

Professor Dr Burak Atakan
 Professor Dr rer. nat. Gerd Bacher
 Professor Dr -Ing. Jan Balzer
 Professor Dr Dieter Bathen
 Professor Dr -Ing. Niels Benson
 Professor Dr Carolin Birk
 Professor Dr Joachim Bluhm
 Professor Dr Daniel Bodemer
 Professor Dr Matthias Alexander Brand
 Professor Dr Dieter Brillert
 Professor Dr Oliver Bernd Büttner
 Professor Dr Mohamed Amine Chatti
 Professor Dr -Ing. Andreas Czulwik
 Professor Dr Rüdiger Deike
 Professor Dr Johannes-Martin Denecke
 Professor Dr -Ing. Bettina Detmann
 Professor Dr -Ing. Steven X. Ding
 Professor Dr Ferdinand Walter Dudenhöffer
 Professor Dr Ellen Enkel
 Professor Dr sc. techn. Daniel Erni
 Professor Dr Dina Fattakhova-Rohlfing
 Professor Dr Stefan Fletcher
 Professor Dr Norbert Fuhr
 Professor Dr Jutta Geldermann
 Professor Dr Johannes Gottschling
 Professor Dr rer. nat. Anton Franz Grabmaier
 Professor Dr Klaus Görner
 Professor Dr Wilhelm Heinrichs
 Professor Dr Angelika Heinzel

Professor Dr Maritta Heisel
 Professor Dr Holger Hirsch
 Professor Dr -Ing. Axel Hunger
 Professor Dr -Ing. Peter Jung
 Professor Dr Sebastian Kaiser
 Professor Dr -Ing. Thomas Kaiser
 Professor Dr Tina Kasper
 Professor Dr Andrés George Kecskeméthy
 Professor Dr Andreas Markus Kempf
 Prof. Dr-Ing. Thomas Kirchartz
 Prof. Dr-Ing. Rainer Kokozinski
 Professor Dr Wojciech Grzegorz Kowalczyk
 Prof. Dr-Ing. Frank Einar Kruis
 Professor Dr Nicole Claudia Krämer-Mertens
 Professor Dr Jens Harald Krüger
 Professor Dr Barbara König
 Professor Dr Martin Lang
 Professor Dr Frank Lobeck
 Professor Dr Doru Constantin Lupascu
 Professor Dr Alexander Neithardt Malkwitz
 Professor Dr Maic Oliver Masuch
 Professor Dr Jochen Menkenhagen
 Professor Dr Kahdijeh Mohri
 Professor Dr rer. nat. Franziska Muckel
 Professor Dr -Ing Arun Nagarajah
 Professor Dr André Niemann
 Professor Dr Bernd Noche
 Professor Dr Stefan Panglisch
 Professor Dr Josef Pauli
 Professor Dr Eugen Perau

Professor Dr Heike Proff
 Professor Dr Gregor Alexander Schiele
 Professor Dr Reinhard Schiffers
 Professor Dr rer. nat. Roland Schmechel
 Professor Dr Frank Schmidt
 Professor Dr Martina Schnellenbach-Held
 Professor Dr Dieter Schramm
 Professor Dr Jörg Schröder
 Professor Dr Christof Werner Schulz
 Professor Dr -Ing. Doris Segets
 Prof. Dr-Ing. Karsten Seidl
 Professor Dr -Ing. Klaus Solbach
 Professor Dr Stefan Uwe Stieglitz
 Professor Dr Natalie Stranghöner
 Prof. Dr-Ing. Andreas Stöhr
 Professor Dr Dirk Söffker
 Prof. Dr-Ing. Hendrik Vennegeerts
 Professor Dr Holger Vogt
 Professor Dr Janis Voigtländer
 Prof. Nils Weimann, Ph. D.
 Professor Dr Torben Weis
 Professor Dr Renatus Widmann
 Prof. Dr-Ing. Hans-Ingolf Willms
 Professor Dr Markus Winterer
 Professor Dr Gerd Witt
 Professor Dr Dirk Wittowsky
 Professor Dr Andreas Wömpener
 Professor Dr -Ing. Torsten Zesch
 Professor Dr Jürgen Ernst Ziegler
 Professor Dr Ould Abdallah el Moctar
 Prof. Dr-Ing. Stefan van Waasen

A prototype of their charging system was released in May 2020; it already features some additional digital functions. In August 2020, gapcharge was accepted into the High-Tech.NRW accelerator programme. Its founders are poised to start serial production of their system in 2021. The Chair of Energy Technology has produced its first successful start-up, too: Lagom Energy GmbH provides energy system analyses.

The Chair of Turbomachinery actively promotes the productive, pioneering exchange and

transfer of knowledge between industry and research. With the establishment of CoRE, the Center of Rotating Equipment, the University of Duisburg-Essen and Siemens Energy jointly created a globally unique research, education and training centre dedicated to turbomachinery. Their partnership boosts transfer and exchange activities between theory, practice and industry in turbomachinery, a field in which Germany has an outstanding density of resources that make it a leader at the global level.

Work involving industry standards often leads the way for new economic and technical developments. Professor Doris Segets of the Chair of Reactive Fluids coordinates the ‘NoRu’ project, which seeks to standardise the characterisation of carbon blacks for fuel cells and batteries. It is funded by the Federal Ministry of Economics and Technology. The researchers behind NoRu are developing the foundation of a DIN/ISO standard for carbon materials used in batteries and fuel cells. The Chair of Energy Technology, the Fuel Cell Research Center (ZBT) and the Berlin-based company LUM GmbH are members of the consortium.

Outlook

Due to the close relationship between issues in energy technology and issues in economics, the benefits of collaboration between the corresponding chairs are self-evident. The project initiated by Professor Christof Schulz, Professor Jutta Geldermann and Professor Angelika Heinzel in collaboration with partners from Ruhr University Bochum within the framework of the Clusters4Future initiative of the Federal Ministry of Education and Research constitutes a highly promising, concrete future opportunity in the field of functional materials. The consortium has reached the final stage of the initiative’s application process with its proposal ‘WISDOM4E – Knowledge-based design of complex materials and systems for sustainable electrochemical energy storage and conversion’. The proposed research topic belongs to a field that is of strategic importance for UDE and the University Alliance (UA) Ruhr. It has received 500,000 euros in funding to prepare a full proposal. The final selection round will take place in 2021; the winning project will be funded for up to nine years with up to 5 million euros per year.

Professor Steven Ding’s (EIT) and Professor Dirk Söffker’s (MBVT) chairs focus on control systems and automation, in particular, error detection, damage diagnostics and prognoses of the behaviour of technical systems. It stands to reason that there should be a degree programme representing the research topics of both chairs. The new ‘Automation and Safety’ programme has been established with two separate pathways: ‘Automation Control Engineering’ and ‘Safe Systems’.

Automated waterway traffic holds great potential, but acceptance of self-driving vehicles depends largely on inherent risks. Safety improvements over manual driving will be the main benchmark for future developments in this field, and they are the primary objective of the proposed project ‘SafeBin’. It focuses on assessing the risks of (partially) automated inland vessels with regard to system malfunctions, any danger which automated systems may pose to humans and the environment, potential risk reduction measures, and ways of detecting and overcoming hazardous situations and malfunctions during operation.

The Chair of Turbomachinery operates a four-stage axial compressor to study wet compression. It has recently been granted approximately 1 million euros in funding for equipment to process the ambient air and injected water. This will allow the researchers to study the flow in axial compressors operating with water vapour at inlet temperatures of up to 100° C.

The Institute of Ship Technology, Ocean Engineering and Transport Systems plans to intensify its research activities in the fields of sloshing, cavitation and fluid-structure interactions. Multiple research proposals on these topics have been submitted. A laser laboratory for the experimental study of cavitation at the microscopic level will soon begin operations.

Electrical Engineering and Information Technology

The Department of Electrical Engineering and Information Technology focuses on five research areas: energy technology, medical technology, terahertz systems, mikroelektronics and photonics. Its 24 professors collaborate with the Fraunhofer Institute for Microelectronic Circuits and Systems (IMS) in Duisburg, Forschungszentrum Jülich, the German Aerospace Center (DLR) in Cologne and IMST GmbH in Kamp-Lintfort.

Research highlights

The department’s most successful research activities in the field of medical technology include the development of an ultrabroadband, self-tuning high-frequency coil for functional 7-Tesla magnetic resonance imaging (MRI) by the Chair of General and Theoretical Electrical



Engineering. It is based on a leaky-mode approach and facilitates the simultaneous stimulation of nuclear magnetic resonances in multiple elements. The results have been accepted for publication in *Nature Communications*. The Chair of Electronic Components and Circuits has successfully developed a non-invasive, wearable sensor system that detects human moods. This project was part of the interdisciplinary research training group 'PAnalytics', which is funded by the Federal Ministry of Education and Research. The 'DeePPG' project team researches a depth-selective, light-based method for pulse transit time measurement at a single measuring position. Pulse transit time is a basic parameter of non-invasive mood and blood pressure measurement. Within the scope of the research profile on Tailored Materials, the 'EWALD' project researches innovative surface coating and structuring methods on the basis of atomic-layer deposition. These methods can influence the wetting properties of liquids electrically, allowing

the researchers to manipulate minuscule amounts of liquids on surfaces, for example, in micro-laboratory diagnostics.

In the field of mobile radio and terahertz systems, the Chair of Communication Technology has developed wireless ad-hoc networks for emergency communications, researched security-relevant applications involving the wireless audio transmission of digital information, and measured the corresponding acoustic communication channel. The Chair of General and Theoretical Electrical Engineering has developed a robotised antenna measuring station for spherical millimetre waves within the scope of CRC/TRR 196 'MARIE'. It is the world's only site of its kind, and the project team intends to extend its capacity to support operation at 500 GHz in the medium term. The Chair of Optoelectronics has developed a terahertz imaging system based on photonic methods. This system exhibits the lowest level of phase noise of all known frequency range systems in the terahertz range and has won an IEEE Best Paper Award. The same researchers have demonstrated millimetre wave and terahertz radio systems with a spectral efficiency of approximately 8 bit/s/Hz, which has facilitated transmission rates of 100 Gbit/s in a frequency band that has already been licensed in the United States. Another development of the Chair of Optoelectronics is a milestone for future applications in terahertz communications: a terahertz beam control system with chip-integrated antenna elements.

In the field of micro-, nano- and optoelectronics, the Chair of Electronic Materials and Nanostructures has appointed Franziska Muckel as the new junior professor of electroenergetic functional materials. Professor Einar Kruis of the Chair of Technology for Nanostructures (NST) spearheads various projects in the Research Unit FOR 2284 'Model-based scalable gas-phase synthesis of complex nanoparticle' and in the Priority Programme SPP 1980 'SpraySyn'. The Chair of Optoelectronics has successfully established TERAOPTICS, an European graduate school for research in terahertz photonics. It will be coordinated by the UDE's Centre for Semiconductor Technology and Optoelectronics until 2023.

In the field of energy technology, the Chair of Electrical Energy Systems appointed Professor

Hendrik Vennegeerts as its new head in 2019. For the 'NEXTGRID' project, a testing lab with power hardware-in-the-loop capability has been established at the chair in order to simulate future regulation and management concepts of the continental European electricity supply system. The project is funded by the Federal Ministry of Economics and Technology. This allows researchers to simulate large parts of the system in real time on a purpose-built computer; an amplifier interface is used to integrate scaled system components, such as wind turbines, photovoltaic systems and battery storage units. The system provides practical proof that the operational concepts and the regulations developed at the chair continue to work reliably in the event of communication latency or measuring errors. Through collaboration with the DLR in Cologne and a newly established junior professorship, the department is intensifying its activities in the field of thermoelectrics. Its members have produced a comparative study of the physical limits of high-temperature thermoelectrical concepts and thermophotovoltaics with the Faculty of Physics and the Chair of Technology for Nanostructures (NST). The 'EStros' project, funded by the Federal Ministry of Education and Research and conducted by the Chair of Energy Transport and Storage in partnership with a medium-sized enterprise, has been completed successfully. Its objective was to develop and realise a highly precise measurement system for measuring large flows (6 kA) with frequencies of up to 100 kHz. The results facilitate improvements in the regulation and protection of high-voltage, direct-current electric power transmission system.

In the research profile on Smart Engineering, the Chair of Automatic Control and Complex Systems has intensified its focus on cyber-physical systems with embedded smart components and distributed system and information infrastructures. The Chair is successfully participating in the 'GreenEnergyFirst' research alliance, which develops novel concepts and methods for energy-optimised smart buildings.

Partnerships and international affairs

Members of the Department of Electrical Engineering and Information Technology work directly with many partners from research and

Selected Publications

Okanimba Tedah, A., F. Maculewicz, D.E. Wolf, R. Schmechel (2019): Thermoelectrics versus thermophotovoltaics: two approaches to convert heat fluxes into electricity. *J. Phys. D: Appl. Phys.* 52, 275501, doi: 10.1088/1361-6463/ab1833.

Sievert, B., J.T. Svejda, D. Erni, A. Rennings (2020): Spherical mm-Wave/THz Antenna Measurement System. *IEEE Access.* 8, 89680-89691, doi: 10.1109/ACCESS.2020.2993698.

Atakan, B., S.A. Kaiser, J. Herzler, S. Porras, K. Banke, O. Deutschmann, T. Kasper, M. Fikri, R. Schießl, D. Schröder, C. Rudolph, D. Kaczmarek, H. Gossler, S. Drost, V. Bykov, U. Maas, C. Schulz (2020): Flexible energy conversion and storage via high-temperature gas-phase reactions: The piston engine as a polygeneration reactor. *Renewable and Sustainable Energy Reviews* 133, 110264, doi: 10.1016/j.rser.2020.110264.

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Hacks, A.J., S. Schuster, D. Brillert (2019): Stabilizing Effects of Supercritical CO₂ Fluid Properties on Compressor Operation. *International Journal of Turbomachinery, Propulsion and Power* 4(3), doi: 10.3390/ijtpp4030020.

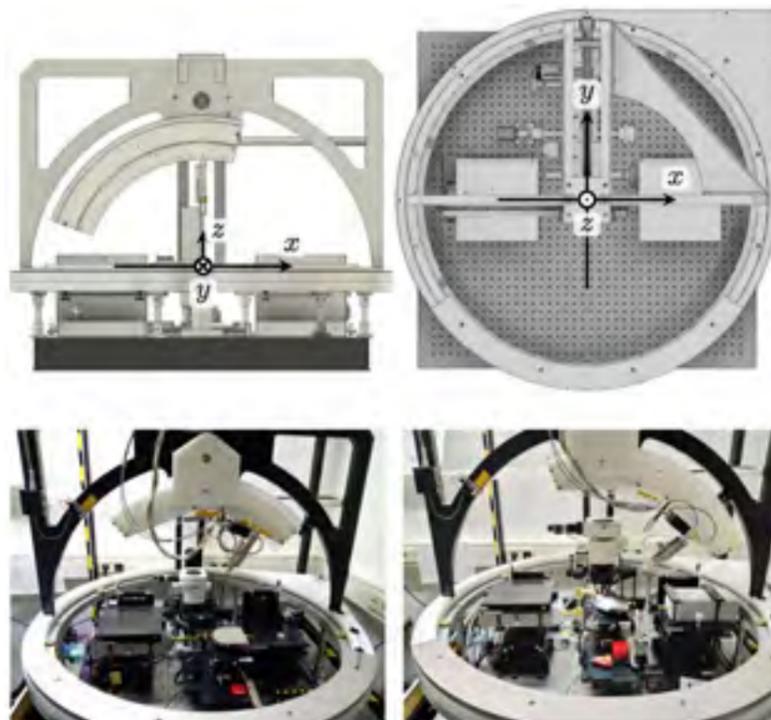
Sajjad, H.M., S. Hanke, S. Güler, H. ul Hassan, A. Fischer, A. Hartmaier (2019): Modelling cyclic behaviour of martensitic steel with J2 plasticity and crystal plasticity. *Materials* 12(11), 1767, doi: 10.3390/ma12111767

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Uhlemann, J., F. Surholt, A. Westerhoff, N. Stranghöner, M. Motevalli, D. Balzani (2020): Saturation of the stress-strain behaviour of architectural fabrics. *Materials and Design* 191 108584, doi: 10.1016/j.matdes.2020.108584.

Schwittmann, L., M. Wander, T. Weis (2019): Domain impersonation is feasible: a study of CA domain validation weaknesses. *4th IEEE European Symposium on Security and Privacy*.

Mirbabaie, M., D. Bunker, S. Stieglitz, J. Marx, C. Ehnis (2020): Social media in times of crisis: Learning from Hurricane Harvey for the coronavirus disease 2019 pandemic response. *Journal of Information Technology* 35, 195-215, doi: 10.1177/0268396220929258.



Characterization of antennas for millimetre waves with frequencies from 75 to 330 GHz – technical design drawings and photos from the actual experiment in the lab.

© Photo: Chair of General and Theoretical Electrical Engineering



industry. They include the following domestic and international academic and industry players: Rohde & Schwarz, Deutsche Bahn, ESA, II-VI, VODAFONE, Nokia, CORNING, SIKLU, THALES, DAS Photonics and RAL. Based in Duisburg, the Department of Electrical Engineering and Information Technology coordinates the photonics developments for 5G in the European EUMWP-COST network with more than 50 international partners. It also manages the UDE's first graduate school, which hosts 15 doctoral candidates who conduct research into terahertz photonics. The Centre for Semiconductor Technology and Optoelectronics supports joint laboratories with the Ferdinand-Braun-Institut für Höchstfrequenzelektronik in Berlin, TU Darmstadt and the Fraunhofer Institute for Telecommunications. It also maintains research partnerships with ITMO University in Saint Petersburg (Professor Stanislav Glybovski), the University Medical Center Utrecht and TU Eindhoven.

Awards

- Professor Steven X. Ding was honoured as a 'highly cited researcher' by Clarivate Analytics in 2019 and 2020.

- Dr Franziska Muckel (now a junior professor) received the 2019 VDE Dissertation Prize for her dissertation on magnetic, solvent-based semiconductor quantum dots ('Magnetisch dotierte Halbleiter-Quantenpunkte aus lösungsmittelbasierter Herstellung: Von der Funktionalität zum Bauelement')
- Dr Benjamin Willsch received the Sparkasse am Niederrhein's 2020 Innovation Prize for his dissertation 'Integration of Physically Unclonable Functions (PUFs) in CMOS'.
- Sebastian Dülme won the IEEE Best Student Paper Award for his contribution to the International Microwave Photonics Conference 2019.
- Professor Andreas Stöhr was appointed to the technical committee on transmitting and receiving equipment for radiocommunications (TC103/WG6) as the German representative of the International Electrotechnical Commission (IEC).

Transfer and sustainability

The company airCode UG was founded by members of the department in 2019. In this start-up, Marc Hoffmann, Professor Niels Benson, Professor Daniel Erni, Professor Thomas Kaiser and Professor Roland Schmechel develop flexible, printable, chip-less radio frequency identification tags with Schottky diodes based on silicon nanoparticles for operating frequencies in the multi-GHz range. A novel training device for the diagnosis and treatment of vestibular vertigo developed at the Chair of Electronic Components and Circuits in collaboration with the Fraunhofer Institute for Microelectronic Circuits and Systems, the otorhinolaryngologists' association of North Rhine-Westphalia and Gesellschaft für Elektronik und Design mbH was authorised as a medical product in 2020 following a development and certification period of several years. The story of this headphone-like product, which was initially funded by the Federal Ministry of Economics and Technology, from the initial idea to the final authorisation is a great example of successful technology and knowledge transfer.

Outlook

With the joint 'smartBeam' application, the contributing chairs of the Department of

Electrical Engineering and Information Technology have successfully participated in the ForLab research tender, a part of the Federal Government's high-tech strategy. In January 2019, work began to expand the Centre for Semiconductor Technology and Optoelectronics into Germany's central research laboratory for terahertz beam steering. The expansion project has attracted 3.9 million euros in funding. At the same time, the EU, the State of North Rhine-Westphalia and the University of Duisburg-Essen are providing 7.5 million euros in funding for the establishment of a novel terahertz integration centre in the same building. It will facilitate the integration of maximum-frequency electronic and photonic circuits in future.

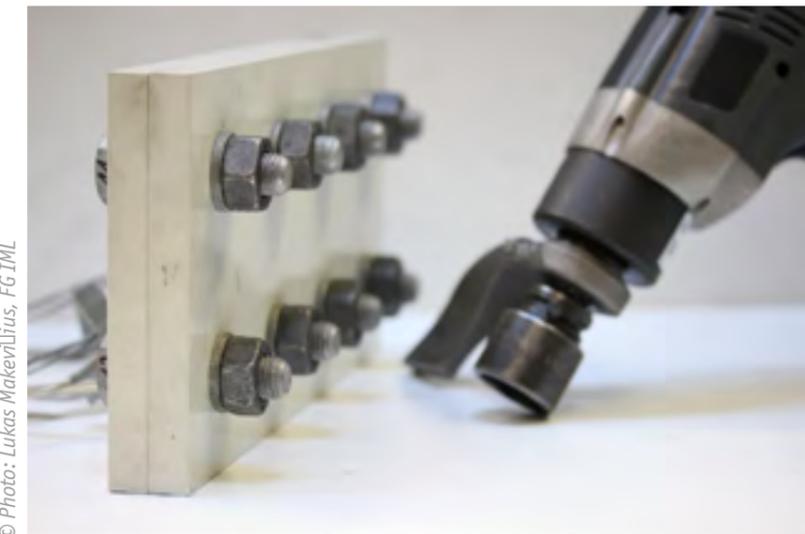
The Collaborative Research Centre/Transregio 196 'MARIE – Mobile Material Characterization and Localization by Electromagnetic Sensing' has been extended successfully. This opens up long-term research perspectives for the contributing chairs from the Department of Electrical Engineering and Information Technology and their collaboration partners.

Civil Engineering

In addition to its traditional tasks, the Department of Civil Engineering studies virtual and icy worlds. Through national and international projects, it has established and intensified multiple research partnerships. The department's research portfolio covers a great deal of ground from the robustness of small steel screws to the structure of the Antarctic ice sheet, from direct applications to the theoretical foundations of molecular structures.

Research highlights

The Chair of Mechanics will be coordinating the second funding period of the DFG Priority Programme SPP 1748 'Reliable Simulation Techniques in Solid Mechanics. Development of Non-standard Discretization Methods, Mechanical and Mathematical Analysis'. It also contributes two projects itself and is represented in two other Priority Programmes. In SPP 2013 'Targeted Use of Forming Induced Residual Stresses in Metal Components', the Chair researches the numerical representation of residual stresses in forging.



Power-coated test plates with screw joints for experiments on settling and creeping.

© Photo: Lukas Makevičius, FG IMI

Within the scope of SPP 2020 'Cyclic deterioration of High-Performance Concrete in an experimental-virtual lab', the Chair advances computer-supported modelling of deterioration processes in fibre-reinforced high-performance concretes. Members of the Chair also contribute to projects in CRC/TRR 270, where they analyse magneto-mechanical meso structures produced through additive manufacturing, and SPP 2256, where they study homogenisation for the prediction of complex phenomena in micro-structural materials.

Within the scope of the Federal Ministry of Education and Research's funding programme for research into condensed matter and as part of the ISOPAC project, the Chair of Materials Science has been operating the solid-state beamline at the CERN's ISOLDE (Isotope mass Separator On-Line) facility for four years. Researchers at the beamline examine solid structures using the nuclear measurement method PAC (Perturbed gamma-gamma-Angular Correlation). They have recently secured 1.2 million euros in funding for a new measuring station for magnetically and electrically ordered crystals. Their research is highly relevant for data storage technologies.

Textile membranes in construction are one of the key research areas of the Chair of Metal and Lightweight Structures. In the past, the Chair has collaborated with the Chair of Continuum



Microscopic 3D analysis of a photo-lithographically produced structure in the clean room of the Centre for Semiconductor Technology and Opto-Electronics.

© Photo: Chair of Opto-Electronics



Mechanics at Ruhr University Bochum in a DFG-funded project. The follow-up project now focuses on the development of adaptive numerical simulation methods and the history dependence and shear stiffness of architectural membranes. In another project funded by the DFG, members of the Chair are experimentally researching the mechanical load-bearing behaviour of sustainably produced ETFE films and structures. Preparations are currently underway for experiments on the roof of the UDE's Essen campus to examine the long-term weathering properties of membrane materials.

The Chair of Mobility and Urban Planning works on the topic of cities and mobility in two transdisciplinary projects. The project 'Spurwechsel Zollverein' of the Innogy Foundation investigates which forms of mobility people choose, why they make those choices, and how a lasting, socially just transformation of traffic in the north of Essen can be achieved. Today, the region between Duisburg, Düsseldorf, Wuppertal and the Rhine County of Neuss is already home to many competences that will be relevant to hydrogen-powered mobility in the near future. 'Kompetenzregion Wasserstoff – Düssel.Rhein.Wupper', the winning project in the state competition on hydrogen-powered mobility, is picking up speed. So far, the project team has established a developmental space for a comprehensive forecasting concept on the topic of hydrogen-based mobility.

At the Chair of Structural Concrete, the development and optimisation of high-performance materials and bearing structures constitute key research areas. The high-performance aerogel concrete (HPAC), a stable, heat-insulating, lightweight concrete developed in collaboration with the German Aerospace Center, has been optimised to suit building components under bending stress by testing reinforced HPAC test pieces for their moment and shear force bearing capacity. In a collaborative research project undertaken with the Chair of Theoretical Physics of the University of Cologne, members of the department are examining the setting behaviour of concrete in zero gravity. This endeavour will involve experiments on the International Space Station (ISS).

The Chair of Structural Analysis of Plates and Shells develops efficient methods of automating discretisation and calculation processes for

structure-mechanical and multi-physical questions. These projects belong to two key research areas: Tailored Materials at the Faculty and Materials Chain at the UA Ruhr. The DFG funds the development of a radiation-based measuring system for characterising highly anisotropic, viscoelastic polymers. This project is conducted in partnership with the Chair of Measurement Engineering at Paderborn University. Another DFG-funded project focuses on the development of efficient methods of automated mesh generation and the simulation of wave propagation processes in three-dimensional, highly heterogeneous continua. Such processes are important when designing security-critical infrastructure and radiation-based processes for geological exploration.

The Chair of Structural Analysis and Design focuses on constructive glazing and fire risk assessments. In the former field, it studies extensions of the DIN 18008 glass standard that govern the bearing capacity and fitness for purpose of point-fixed glazing. As fire safety regulations become more complex, they also become more interesting to researchers. Building components that are subject to fire safety regulations must be tested experimentally. This leads to the development of more precise fire models, which take the impact of sprinkler systems into account, for example. In particular, they facilitate more economical assessments of delicate hall structures built from steel.

Transfer and sustainability

Among other endeavours, the Department of Civil Engineering transfers its knowledge through partnerships with local authorities and charitable organisations. The Chair of Urban Water and Waste Management has begun a collaborative project with the Emschergenossenschaft. It uses existing data to develop concepts for artificial intelligence and machine learning. The researchers aim to teach water treatment plants to detect patterns and use them to develop energy management solutions and forecasts. On behalf of the Federal Ministry of Transport and Digital Infrastructure, the Chair of Mobility and Urban Planning maintains the research information server for the field of integrated mobility services in urban areas. As of May 2019, the Deutsches

Institut für Bautechnik (DIBt) officially recognises the Chair of Metal and Lightweight Structures as a monitoring body. It is now an inspection, monitoring and certification body (identification no. NRW71) as per the state building regulations.

Awards

- Dr Carina Nisters has been accepted to the Global Young Faculty.
- Dr Sarah Zydorczyk received an honour for the best dissertation in the engineering sciences in 2019.
- Sonja Uebing received the Best Poster Award – Second Prize of the German Association for Computational Mechanics in 2019.
- Christoph Abraham received the 'Heitkamp Ingenieur- und Kraftwerksbau' prize for his master's thesis in 2019.
- Lukas Makevicius received the audience prize of the International Association for Bridge and Structural Engineering (IABSE) for his presentation at the 6th Young Engineers Colloquium in 2019.
- The article 'Sprödbruchverhalten hochfester Schrauben großer Abmessungen bei tiefen Temperaturen' ('Brittle fracture of high-strength bolts of large diameters at low temperatures') by Professor Natalie Stranghöner et al. was among the 10% most frequently downloaded publications in the STAHLBAU journal between 2018 and 2019.

Partnerships and international affairs

Professor Jörg Schröder, Dr Carina Nisters, Tommy Mielke and Felix Paul (Chair of Mechanics and Chair of Materials Science) joined an expedition to the Antarctic on the South African research vessel Agulhas II. Their participation in this undertaking was doubtlessly one of the year's highlights in the area of international collaboration and research. It initiated a series of project proposals in partnership with the University of Cape Town. The research aims to examine and describe the mechanical properties of the Antarctic ice in a multi-scale process using methods from civil engineering.

Professor Jörg Schröder worked at the University of California, Berkeley as a visiting scholar in 2019. Professor Carolin Birk is collaborating with Professor Ean Tat Ooi of the Federation

University in Ballarat, Australia on the project 'Computational modelling of multi-physics structural damage'. The Chair of Mechanics played a major role in planning the international conference 'European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS) – Modern Finite Element Technologies 2019'.

Outlook

Professor Dirk Wittowsky now heads the Chair of Mobility and Urban Planning. Mobility in urban spaces will be a key research topic of the chair in future.

In collaboration with the Faculties of Biology, Chemistry, Engineering Sciences and Physics, Professor Jörg Schröder has submitted an application for around 7.3 million euros in funding to acquire a new, massively parallel high-performance computer with fast connectivity to the DFG and the State of North Rhine-Westphalia as per Article 91b GG.

As mentioned in the section on international affairs, the Department plans to establish and coordinate a new, pioneering field of research focusing on the sea ice of the Southern (Antarctic) Ocean in partnership with the University of Cape Town. The project team is currently applying for an international research training group.

The Chair of Urban Water and Waste Management under Professor Renuar Widman coordinates the project management, implementation and continuous optimisation of potential uses for the new building of the FutureWaterCampus. A funding recommendation and a recommendation for starting the project measures ahead of schedule have been issued. The Centre for Water and Environmental Research (ZWU) coordinates this interdisciplinary project.

Computer Science and Applied Cognitive Science

The Department of Computer Science and Applied Cognitive Science (INKO) comprises two teaching units that study computer systems from various perspectives and with various methods. Computer science focuses on technology, while the cognitive sciences concentrate on humans. This dual view of technology and



humans is highly relevant in a world like ours, where computers are ubiquitous and merge with the environment nearly imperceptibly. Rather than merely function, modern technical systems need to be accepted into society.

Research highlights

The team of Professor Maic Masuch's (Chair of Media Informatics) NRW flagship project 'VR-RLX – Virtual-Reality System for the Reduction of Children's Anxiety during MRI Scans' has developed a system that reduces stress and anxiety in children undergoing MRI scans. It has been funded by EFRE, and the publication of the project work has been honoured with the CHI Play Mention Award.

Professor Norbert Fuhr (Chair of Information Systems), Professor Nicole Krämer (Chair of Social Psychology) and Professor Torsten Zesch (Chair of Language Technology) participate in the recently approved DFG research training group GRK 2535/1 'Knowledge- and Data-driven Personalization of Medicine at the Point of Care'. It studies artificial intelligence and clinical decision support systems using malignant melanoma as an example. The application was submitted in partnership with the Dortmund University

of Applied Sciences and Arts and the Faculty of Medicine at the University of Duisburg-Essen.

The Faculty has actively advanced the topic of research data management. In addition to various doctoral training programmes within the research training groups 'User Centred Social Media', the Department was granted various projects involving Professor Stefan Stieglitz (Chair of Professional Communication in Electronic Media). In the UNEKE project, funded by the Federal Ministry of Education and Research, a criteria-driven decision-making model for the structure of research data infrastructures was developed in collaboration with RWTH Aachen University. Further, the DFG currently funds the project 'sciebo Research Data Services (II)', which is carried out in collaboration with the University of Münster.

The Department was also awarded a large number of collaborative projects by the EU and the Federal Ministry of Education and Research. In late 2019, for example, the Federal Ministry of Education and Research granted it the KI-LiveS project. In it, the Chair of Embedded Systems of Computer Science and the Chair of Distributed Systems, both from the Department of Computer Science and Applied Cognitive Science, work

on issues in artificial intelligence (AI) with the Faculty of Medicine, the Faculty of Business Administration and Economics, and TU Dortmund. The IMPACT project, funded by the Volkswagen Foundation, has been underway since 2019. Headed by Professor Nicole Krämer, the project is an interdisciplinary collaboration of psychology, computer science, ethics and law. It studies the impact of artificial-intelligence systems, such as voice services, on interpersonal communication and relationships.

Members of INKO also participate in major industrial research projects. They are providing scientific support in the digital transformation of the Evonik corporation under a recently concluded strategic agreement, for example. Four projects by Professor Nicole Krämer, Professor Daniel Bodemer (Chair of Research Methods in Psychology – Media-Based Knowledge Construction), Ulrich Hoppe (Chair of Collaborative Learning in Intelligent Distributed Environments) and Torben Weis (Chair of Distributed Systems) are funded in this context.

Awards

Professor Norbert Fuhr has been appointed a member of the Academy of the Special Interest Group Information Retrieval SIGIR, which was newly founded in June 2020. The SIGIR Academy honours researchers who have made significant cumulative contributions to the development of Information Retrieval as a field of research.

Partnerships and international affairs

The Department has been awarded the four-year project RISE_SMA 'Social Media Analytics for Society and Crisis Communication' within the scope of the EU programme 'Horizon 2020'. The project is headed by Professor Stefan Stieglitz. Its objective is to expand research methods for social-media contents and examine current phenomena, such as social bots and the impact of disinformation during the coronavirus pandemic, by collecting and evaluating data. It is a collaborative endeavour involving computer science, business information systems and media studies. Universities, authorities and companies from Germany, Norway, The Netherlands, Brazil, Indonesia and Australia are participating in it.

Transfer and sustainability

In collaboration with the North Rhine-Westphalia State Office for Central Police Services, the Department has developed a solution for securely storing data in the cloud and sharing it with other groups and authorities. The results of the SecureCloud research project, which was headed by Professor Torben Weis, have been licensed by a spin-off of the University of Duisburg-Essen, which will make the software fit for commercial operations. The foundation of the start-up Rhein-ByteSystems GmbH was funded by the EXIST programme of the Federal Ministry of Education and Research and the European Social Fund.

Outlook

In mid-2021, the DFG will be establishing a new transregional research group, FOR 2974 'Affective and Cognitive Mechanisms of Specific Internet-Use Disorders'. Professor Matthias Brand, head of the Chair of General Psychology: Cognition, will be its head. The Department of Computer Science and Applied Cognitive Science will be involved in five sub-projects of the new research group, which examines the impact of stress on affective and cognitive processing capabilities in people with internet-use disorders.



The "Pingu" is a game-style virtual reality app that helps children prepare for an MRI examination

© Maic Masuch, Chair of Media Informatics / Entertainment Computing

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