Dresden University of Technology

MST
Chair of Measurement and Sensor System Technique

Faculty of Electrical and Computer Engineering

MST | Czarske Lab Annual Report 2025

BIOLAS
BIOMEDICAL COMPUTATIONAL LASER SYSTEMS

DRESDEN concept
SCIENCE AND INNOVATION CAMPUS

Table of Contents

Preamble

Dear friends and partners of the Chair MST / Czarske Lab,

The Chair of Measurement and Sensor Systems (MST) / Czarske Lab celebrates the anniversary of 21 years. We look back on an eventful, enjoyable, and successful year. It is a great pleasure, honor, and privilege to report on our activities this year. The students and staff of the Czarske Lab have once again received awards. In total, MST has received over 125 honors, prizes, and awards, including the Berta Benz Prize for doctoral candidate Katrin Philip, endowed with €10,000 by the Daimler and Benz Foundation, and the Koerber Prize for Stefan Rothe (over 700 nominations, only 3 prizes in natural sciences, mathematics, and engineering). We are also pleased to announce that an alumnus (Andreas Fischer, Bremen) has received an ERC grant and Jiawei Sun became Full Professor, just two years after completing his doctorate. Of particular note is the commercial success of the laser profile sensor for speed and temperature measurements, which was significantly further developed by Lars Buettner. A further patent for temperature profile measurements was transferred to ILA R&D GmbH, Jülich. This successful innovation was recognized with the Berthold Leibinger Innovation Prize from Trumpf.

It is also appropriate to look back on our achievements over the past three years. After several postponements, the ICO-25-OWLS-16 World Congress 2022 was held as an in-person event with great success and unexpectedly high international participation and quality. The participants from 55 countries across the five main regions of Africa, the Americas, Asia, Australia, and Europe, as well as the exceptional quality of the event, which was attended by three Nobel laureates, deserve special mention. We thank all supporters and contributors, especially Dr Nektarios Koukourakis and Dr Lars Buettner. Our special thanks also go to Michael Pfeffer and Wolfgang Osten for their commitment to the local organization and the scientific program, respectively. Information about the World Congress ICO-25-OWLS-16, taking place from September 5th to 9th, 2022 in Dresden under the motto "Advancing Society with Light," can be found on the website https://www.ico25.org and at lasermetrology.de

The Czarske Lab has successfully acquired projects. Notably, MST even received a project research prize: „Physics-Informed Deep Learning Systems for Secure Information Transmission with Multimode Fibers (Phys-Deep-Fiber)" of German Science Foundation, see below *. Projects in the field of second-generation quantum technology have also been acquired. Artificial intelligence, machine learning, and deep learning are playing an increasingly important role for BIOLAS as well. Biomedical Computational Laser Systems (BIOLAS) was co-founded by Dr Koukourakis. Thanks to generous funding from the Federal Ministry of Education and Research (BMFTR), projects such as ENOWA I, ENOWA II, KORONA, Quiet, 6GLife, and Go-Bio have been realized. PhD student Bing Yang was very successful with finishing his work on 3D imaging of flows with a paper, just accepted by Experiments in Fluids, "High-Resolution Single-Camera Measurement of Near-Wall Film Flow at Spray Cleaning Process using a Double Helix Point Spread Function". William Naundorf, a student supervised by Clemens Bilsing, not only defended a bachelor's thesis awarded top marks of 1.0, but also submitted a paper for the SPIE Strasbourg conference. David Krause and Neki Koukourakis, along with co-authors, published a paper in Nature Photonics. Jakob Dremel's invited talk at SPIE Digital Technologies was another notable achievement. Also worth mentioning are the best paper SPIE award of Kinga Żołnacz and further numerous excellent activities in collaboration with Poland. Stefan Krause's contributions to two proposals at the BMFTR, one for quantum imaging and one for quantum communication, should also be noted.

Measurement systems engineering plays a central role at the Faculty of Electrical Engineering and Information Technology (EE) at TU Dresden. Controlling systems is impossible without measurements, and measurement and sensor systems are an essential component of automation, measurement, and control engineering (AMR), information systems engineering, biomedicine, and quantum technology. The Czarske Laboratory is an integral part of the degree programs in Electrical Engineering, Mechatronics, Biomedical Engineering, Computer Science, and especially AMR. From the 4th semester onward, students are taught the fundamentals of measurement data analysis and sensor technology. In the 5th semester, approaches to digital measurement technology, measurement systems theory, and advanced sensor technologies for biomedicine are introduced. Advanced lectures are offered in the later semesters for specialization in computer-aided metrology for technical processes and biomedicine. Since 2019, the

Czarske Laboratory has offered the lecture course "Biomedical Systems and Optogenetics" (9th semester), which is now taught in English. It is intended to be integrated into modules of the Physics of Life study cluster. E-learning plays a crucial role in modern teaching, especially since the COVID-19 pandemic. For the "Measurement Systems I" lecture in the 4th semester, we offer a supplementary digital exam. In the "Measurement Systems II" lecture in the 5th semester, a Python programming assignment is included as an online bonus. Overall, the Czarske Lab has supervised over 15,000 exams and more than 200 student projects and theses. The extraordinary dedication of the staff deserves recognition. It is very gratifying that all Czarske Lab courses could be offered digitally, particularly during the COVID-19 pandemic. I thank the fantastic team for their outstanding collaboration. In cooperation with the OPTICA-SPIE student chapter, research-oriented teaching has been established to support students in optics and photonics. At the Czarske Lab, we follow the Humboldtian ideal of optimally combining research and study. Even at the bachelor's level, students are actively involved in research through participation in conferences. Regular excursions to companies in the region, such as SICK Engineering GmbH in Ottendorf-Okrilla, are offered. Our employees and partners actively contribute to scientific success and technology transfer every day. The computer-aided adaptive measurement systems enable a wide range of sophisticated applications in biomedicine, fiber optic communication, and other fields. With the BIOLAS Center, we aim to translate novel adaptive laser systems into practical applications in biomedicine. To continue our successful trajectory, we are seeking dedicated physicists, engineers, and other employees who will further develop the Czarske Lab with their innovative ideas.

I acknowledge the students and team members for the committed research and teaching and our partners for the efficient and effective cooperation.

Stay healthy, thank you and all the best

Prof Juergen Czarske

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https://digitalhealth.tu-dresden.de/second-reinhart-koselleck-project-for-prof-jurgen-czarske/
https://ahmt.de/ahmt-mitglied-erhaelt-ein-reinhart-koselleck-projekt-der-deutschen-forschungsgemeinschaft-dfg/
https://www.juraforum.de/news/erfolg-im-reinhart-koselleck-programm-der-dfg-tud-prof-czarske-wirbt-renommierte-forschungsfoerderung-ein_266979
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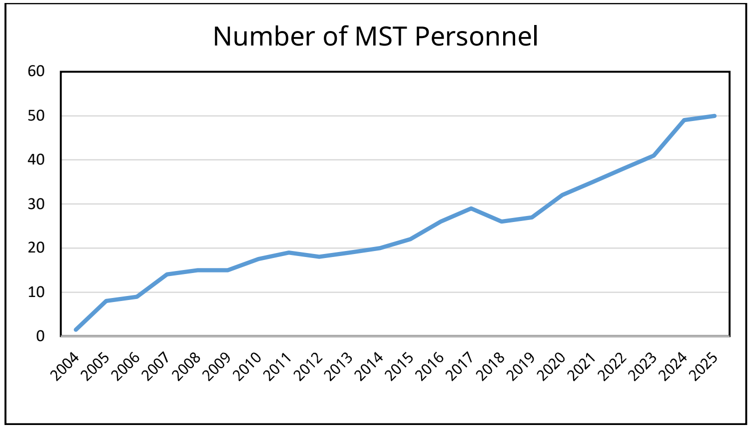
https://6g-life.de/reinhart-koselleck-excellence-project-for-professor-juergen-czarske/
https://news.semivoice.com/post/377ba07840
https://www.linkedin.com/posts/tu-dresden_success-in-the-dfgs-reinhart-koselleck-program-activity-7356678003692642304-n3De/
https://tu-dresden.de/ing/elektrotechnik/iee/mst/ressourcen/dateien/jobs/Czarske_WIMI_Fiber-Information-Transmission-May05-2025_JC.pdf?lang=de

STAFF

No.	Name	Title	Position
1	Al-Khouri, Gabriel		Student Assistant
2	Balyan, Shavik		Student Assistant
3	Bilsing, Clemens	Dr.	Postdoc
4	Bischoff, Hannes	M.Sc.	Research a Assistant
5	Böhm, John	M.Sc.	PhD student
6	Büttner, Lars	Dr. rer. nat.	Postdoc, Senior Research Fellow; Head of Department „ Adaptive Laser Systems“
7	Czarske, Jürgen	Prof. Prof. h.c. Dr.-Ing. habil.	Full Professor, Head of MST Director of the Czarske Lab Director of BIOLAS Center
8	Dou, Zehua	Dr.	Postdoc
9	Dremel, Jakob	Dipl.-Ing.	PhD student, Head of Group “Laser Systems for Biomedicine”
10	Emmerich, Hannes	Dipl.-Ing.	PhD student
11	Fatta Schober, Aissa		Team Assistant, part-time
12	Fleischmann, Jakob		Student Assistant
13	Glosemeyer, Tom	Dipl.-Ing.	PhD student
14	Gong, Mingming		Student Assistant
15	Gürtler, Johannes	Dr.-Ing.	Postdoc / Research Assistant
16	Hilz, Maxim		Research Assistant
17	Hoppe, Johanna	Dipl. Ing.	Research Assistant
18	Kirchberger, Felix		Student Assistant
19	Koukourakis, Nektarios	Dr.-Ing.	Postdoc, Research Fellow, Head of Department “Bio-photonics and Laser Metrology”, CEO of BIOLAS center
20	Krause, David	Dipl.-Ing.	PhD student
21	Krause, Stefan	Dr.-Ing.	Postdoc
22	Kuschmierz, Robert	Dr.-Ing.	Postdoc, Research Fellow, Head of Group “Laser Systems for Biomedicine”
23	Ließ, Konrad		Student Assistant

No.	Name	Title	Position
24	Lin, Yunwei		Student Assistant
25	Liu, Zhaoyi	M. Sc.	Visiting Researcher / PhD student
26	Miao, Yu	Dipl. Ing.	Research Assistant
27	Miller, Moritz		Student Assistant
28	Othmani, Cherif	Dr.	Postdoctoral researcher
29	Otto, Solveig	B.A.	Assistent / Project Manager
30	Pani, Souman Kumar		Student Assistant
31	Plewnia, Peter Paul		Student Assistant
32	Pohle, Dennis	Dipl. -Ing.	PhD student
33	Riemann, Piet		Student Assistant
34	Schmidt, Katharina	M. Sc.	PhD student
35	Schmieder, Felix	Dr.-Ing.	Postdoc / Research Assistant
36	Sun, Jiali	Dipl.-Ing.	PhD student
37	Tag, Martha		Student Assistant
38	Wang, Tijue	M. Sc.	PhD student
39	Wendland, Robert	Dipl.-Ing.	PhD student
40	Yang, Bin	Dipl.-Ing.	PhD student
41	Yang, Bowen	Dipl.-Ing.	PhD student
42	Zamir, Zainab		Student Assistant
43	Zhang, Jie	Dipl.-Ing.	PhD student
44	Zhang, Qian	Dr.	Postdoc
45	Zhang, Ying	B.S.	Visiting Researcher / PhD student
46	Zhang, Yiqun	B.S.	Visiting Researcher / PhD student
47	Zhang, Yuedi	M. Sc.	Research Assistant
48	Zolnacz, Kinga	Ph.D.	Guest Scientist
49	Sun, Jiawei	Prof.	External staff member
50	Zena, Yared	M. Sc.	External PhD student

History of the Czarske lab members in total each year:



Number of staff members, excluding adminstration and technical members of the workshop etc.

SPIE. OPTICA Formerly OSA

Student Chapter TU Dresden

The SPIE+OPTICA student chapter of TU Dresden is a group of undergraduate and graduate students in Dresden, Germany, with an interest in Optics and Photonics. Since September 2017, we belong to a worldwide network of student chapters supported by SPIE (The international society of optics and photonics, Washington, USA) and since 2022 additionally supported by OPTICA. We maintain contacts to other international student chapters in South Africa, Poland, Czech Republic, UK and Germany. Several pre-diploma students are members of the SPIE+OPTICA chapter. Our objective is to establish and intensify the contact between students and faculty at different optics-related groups and institutes in the Dresden area. Therefore, we host regular public lecture series with speakers from research groups and institutes relevant to optics and photonics. Besides that, we are organizing excursions to nearby companies. The highlights of this year have been the excursion to Thorlabs and Coherent in Lübeck as well as the numerous talks that were given by external speakers.

The student chapter of TU Dresden is a unique opportunity for students to build knowledge and their own network in optics and photonics. We are looking forward to further planned activities and new chapter members in 2025.

The OPTICA-SPIE Student Chapter of TU Dresden with visiting lecturer
Prof. Igor Meglinski (Aston University, Birmingham, UK)

TEACHING

Fundamentals in measurement 4. Sem.	L: Prof. Czarske, Dr. Kuschmierz E: C. Bilsing, R. Wendland	10	87
Measurement and Sensor Technique 5. Sem.	L: Prof. Czarske, Dr. Kuschmierz E: C. Bilsing	97	12
Lab Excercise – measurement technique 5.+6. Sem.	E: Z. Dou, Prof. Czarske et al	38	18
Measurement System Technique 6. Sem.	L: Prof. Czarske, Dr. Kuschmierz E: K. Schmidt, T. Glosemeyer	-	16
Lasermesstechnik 8. Sem.	L: Prof. Czarske E: Dr. Büttner	-	21
Mechatronische Lasersensoren 8. Sem.	L: Dr. Büttner, Prof. Czarske	-	18
Lasermesssysteme für die Fluidtechnik 9. Sem.	L: Dr. Büttner, Prof. Czarske	8	1
Digital holography and image processing 9. Sem.	L: Dr. Koukourakis, Prof. Czarske	6	4
Biomedical Lasersystems and Optoge- netics	L: Dr. Kuschmierz, Prof. Czarske, Dr. Zolnacz, K. Schmidt	9	-
Lab Excercise - Lasersensors	E: Dr. Krause, T. Wang, Prof. Czarske	-	6
Hauptseminar AMR	E: Dr. Othmani, Prof. Czarske	20	-
Lab Exercise – Neural Networks for im- age processing	E: T. Glosemeyer, D. Pohle, Q. Zhang	37	
	Sub-Total:	**225**	**193**
	Total:	**418**	

Total number of exams in 21 years: 18153

Modules at MST

Automatisierungs- und Messtechnik (3/2/0) (ET, MT)

Hauptseminar AMR (0/2/0) (ET)

Mess- und Sensortechnik (2/1/1) (ET, MT)

Prozessleittechnik (6/2/2) (ET)

Lasersensorik (4/1/1) ET

Oberseminar Messsystemtechnik (0/2/0) (ET, MT, PHY, NES, POL, CMS)

Photonische Messsystemtechnik (4/2/0) (ET)

Sensoren u. Messsysteme-Grundlagen (5/2/0) (MT)

Sensoren u. Messsysteme-Vertiefung (3/0/2)

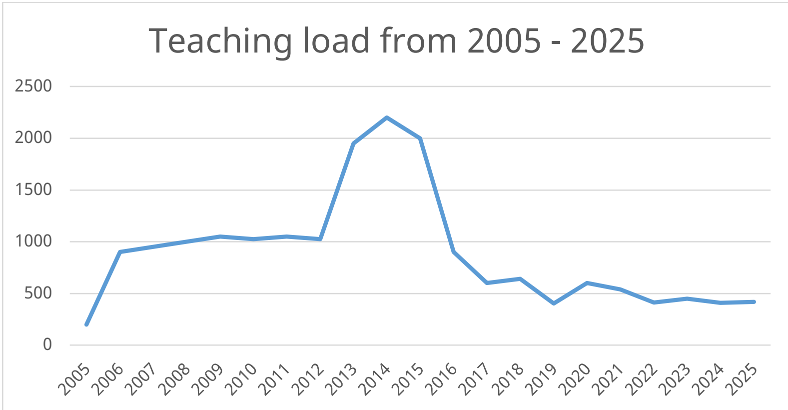
Optische Prozessmesstechnik (4/2/0) (RES)

Non-Physics Supplement (7/2/0) (PHY)

Computational Laser Metrology – Fundamentals (1/3/1) (INF)

Coputational Laser Metrology – Advances (6/4/0) (INF)

ET	- Electrical engineering (Diplom/ Master)
MT	- Mechatronics
RES	- Regenerative Energiesysteme
PHY	- Physics
INF	- Informatics
NES	- Nanoelektronic Systems
POL	- Physics of Life
CMS	- Computational Modeling and Simulation



INVITED TALKS

Date	Guest Speaker	Topic
07 Januar 2025	Prof. Dr. Roman Schnabel University of Hamburg, Institute of Quantum physics	From interferometers using squeezed states of light to the generation of microscopic Schrödinger cat states
17 March 2025	Prof. Qing Yang & Langqing Li State Key Laboratory of Modern Optical Instrumentation, Department of Optical Engineering, Zhejiang University, Hangzhou, China	Super-resolution imaging in a lumen
15 April 2025	An Pan Xi'an Institute of Optics and Precision Mechanics, China	Fourier ptychographic microscopy and its applications in pathology and remote imaging
06 May 2025	Katarzyna Komolibus Tyndall National Institute, Ireland	Applications of nanoparticles in deep imaging and immunohistochemistry
22 May 2025	Igor Meglinsky Aston University, UK	Orbital angular momentum in scattering media
27 May 2025	Gavrielle Untracht Technical University of Denmark, Lyngby, Denmark	Light tissue interaction for optical imaging to-wards translational imaging tools
02 June 2025	Yared Zena, Dr. Caspar Hopfmann, IFW	Efficient sources of entangled photon pairs for industrial environments using GaAs quantum dots
03 June 2025	Isabelle Allegro Jenoptik	Transitioning from academia into industry + Career Q&A
22 September 2025	Prof. Dr. Mario Chemnitz Leibniz-IPHT, Jena	The Infinite Journey to Understand the Expressivity of Nonlinear Fiber-Optical Extreme Learning Machines

Awards, Prizes, Honors and Elections

Jürgen Czarske	International Fellow Award of Chinese Optical Society, Beijing, 12 October 2025
Wenting Geng	Prize on Digital Technology of BASF, Schwarzheide for best Diploma/Master Thesis with the title „High-dimensional Quantum Information Transmission using Few-mode Fibers“, August 2025
Jürgen Czarske	“The 12th Talk at BMEF Keling TOP Scientists Forum”, Chinese Academy of Sciences (CAS), Suzhou, 18 August 2025
Robert Wendland	Dr.-Ing. Siegfried Werth Prize for an outstanding diploma theses in the field of coordinate measuring technology (1000 EUR donation) 07/2025
Jürgen Czarske	Reinhart Koselleck project of German Science Foundation (DFG) "Physics-Informed Deep Learning Systems for Secure Information Transmission with Multimode Fibers", The Koselleck programme enables outstanding researchers with a proven scientific track record to pursue exceptionally innovative, higher-risk projects. 07/2025
Lars Büttner	Senior Member of OPTICA, Washington D.C., elected based on 2 reviews of OPTICA Fellows, 10 July 2025
Jiawei Sun, Bin Yang, Xibin Yang and Jürgen Czarske	Award for best paper (highly selected compared to best poster) by Light Conference, 12 June 2025 “Ultra-thin AI-driven fiber probe for optical manipulation and isotropic 3D tomography” by J. Sun, B. Yang, N. Koukourakis, X. Yang, J.W. Czarske
Jürgen Czarske	Light Outstanding Reviewer Award as a special honor on June 10th, 2025. He was the only person to be honored with 2 awards at the international conference Light 2025, organized by the Nature Journal LSA. The journal LSA is among the top 5 in the world for the area of optics and photonics. At LSA only 6 editors are from Germany. The double prize presentation with the Light Outstanding Editor Award and the Light Outstanding Reviewer Award from LSA forms also a good basis to motivate the next generation to submit to this high-profile journal of Nature Family.

	
Jürgen Czarske	Election as editor of Advanced Imaging, 5th June 2025
Jiali Sun	Young Talent Award of the Gisela and Erwin Sick Foundation, 500 Euros, Feb. 2025
Robert Wendland	Prize for Measurement and Sensor Systems of the Gisela and Erwin Sick Foundation, 2250 Euros, Feb. 2025
Katharina Schmidt	Student Paper Award for the paper "Understanding Virtual Fluorescent Staining for Connective Tissue", Optica Biophotonics Congress, 21 - 24, April, 2025
Kinga Zolnacz	Awarded Best Paper by the Conference Committee for a talk titled "Multicore fiber modified via ablation and thermal treatment for lensless endoscopic imaging", K. Zolnacz, J. Dremel, R. Stephan, M. Steinke, T. Antrack, J. Benduhn, K. Leo, J.W. Czarske, R. Kuschmierz, SPIE Photonics West Conference, BIOS, 25 January 2025

Accomplishments and achievements or the Czarske lab

Total number of elections, honors, prizes and awards from 2008 to 2025: 140

GENERAL CONGRESS ICO-25-OWLS-16

Photo gallery (All Photos by MST)-Looking back to the World Congress

Group photo of the SPIE STUDENT CHAPTER from Technische Universität Dresden - employees of the Chair of Measurement and Sensor Systems/Czarske Lab, including K. Schmidt, Dr. J. Sun, Dipl. Ing, G. Ning, from left: E. Scharf, Dr. J. Liech, Dr. J. Dremel, Q. Zhang, D. Pohle, D. Krause, Dr. Stefan Rothe, Dr. F. Bürkle, T. Glosemeyer, et al.

Left: Program chair of OWLS, Prof. Alex Heisterkamp
Right: Program chair of ICO, Prof. Wolfgang Osten

Prof. Michal Lipson is the Eugene Higgins Professor of Electrical Engineering and Professor of Applied Physics at Columbia University

Jürgen Czarske and Karsten Danzmann Stefan Hell, Andrea Alù, Leszek Sirko

General Assembly of ICO

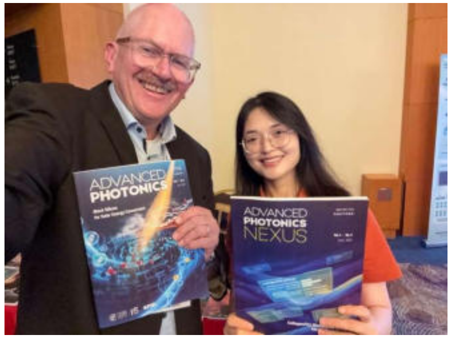
Map of countries participating at ICO-25, in total 55 from 5A:
Africa, America, Australia, Asia, Amazing Europe

Nobel Laureate Gérard Mourou and General Chair Juergen Czarske (from left)

Nobel Laureate Stefan Hell and General Chair Juergen Czarske (from left)

Nobel Laureate Reinhard Genzel and General Chair Juergen Czarske (from right)

NEWS AND HIGHLIGHTS IN 2025



Election as editor of Advanced Photonics (Impact 19), left. Right: Invited Talk at SIBET. Top scientist forum with 445 online participants and 50 in-person participants

Advertisement for Advanced Imaging at the University of Tokyo, Japan

Meeting with Nobel laureate Prof Eric A. Cornell (Boulder) in San Francisco. Celebration with Nobel laureate Prof Gérard Albert Mourou and his wife the awarding of the COS fellow.

COS Fellowship Award Ceremony (only 10 Fellows, including 3 international fellows, in 2025, at over 20 000 members of COS)

SYMPOSIUM 20 YEARS ANNIVERSARY OF MST: FROM BIOMEDICAL TO QUANTUM SYSTEMS, 4 APRIL

The Chair of Measurement and Sensor System Technique celebrated the 20th Anniversary of its founding with a symposium with experts of the field, partners and collaborators. With this symposium we strengthened our future research by discussing challenges and novel concepts from Biomedical systems to Quantum Systems. The idea was to bring together experts from different communities and review the most recent advances in their field of expertise.

Agenda

13:00 – 13:05 Greeting by the dean of the Faculty of Electrical and Computer Engineering, TUD, **Andreas Richter**

13:05 – 13:20 **Juergen Czarske,** "20th Anniversary of MST: History, Present and Future"

Session 1: Biomedical & Fiber Measurement Systems, Session Chair: Wolfgang Osten

13:20 – 13:40 **Wolfgang Osten**, Universität Stuttgart, "The wide scale of optical sensing and metrology"

13:40 – 13:50 **Lars Büttner,** MST, "Advancements for Metrology and Optogenetics by Wavefront Shaping towards BIOLAS" - BIOLAS: Biomedical Computational Laser Systems Competence Center

13:50 – 14:10 **Caroline Murawski**, Professur für biomedizinische Sensorik, TUD, "Bright Ideas: Organic Optoelectronics for Bioimaging and Optogenetics"

14:10 – 14:20 **Jakob Dremel**, MST, "Advancements for Medicine by Multicore Fiber Endoscopy towards BIOLAS and EKFZ" - EKFZ: Else Kröner Fresenius Center for Digital Medicine

14:20 – 14:40 **Stefan Rothe**, Yale University, USA, "High-power single-frequency multimode fiber amplifier with tailored output profile"

14:40 – 15:00 **Filipe Marques Ferreira**, University College London, UK, "Pushing the Limits of High Speed Data Transmission: Unlocking Capacity in Graded-Index Multimode Fibres"

15:00 – 15:30 Coffee Break

Session 2: Quantum Technology of 2nd Generation - IYQ, Session Chair: Juergen Czarske

15:30 – 15:50 **Markus Gräfe**, TU Darmstadt, Institute for Applied Physics, „Quantum sensing with undetected light - IYQ" - IYQ: The 2025 International Year of Quantum Science and Technology (IYQ) of UNESCO recognizes 100 years since the initial development of quantum mechanics.

15:50 - 16:05 **Kambiz Jamshidi,** Chair of Radio Frequency and Photonics Engineering, TUD, "CMOS compatible Photonics for Non-classical Applications towards Quantum Sensing, Computing and Communication - IYQ"

16:05 – 16:20 **Riccardo Bassoli**, Deutsche Telekom Chair of Communication Networks and Head of the Quantum Communication Networks Research Group, TUD, "6G-quantum communication networks: communication, sensing, and computing - IYQ"

16:20 – 16:35 **Kay-Uwe Giering,** Fraunhofer-Institut für Integrierte Schaltungen IIS, Institutsteil Entwicklung Adaptiver Systeme EAS, "Quantum Communication Systems for Specialized Applications - IYQ"

16:35 Transfer to MST, Barkhausen-Bau, BAR 17, Helmholtz Str. 18, 01069 Dresden

16:45 – 17:45 **Lab-Tour**

17:45 – 20:45 **Reception & get-together**

The Symposium "From Classical to Quantum Measurement Systems" was an official event of the "International Year of Quantum Science and Technology, Quantum2025" by Jürgen Czarske (opening speech), Andreas Richter, Dean and Professor at TUD, left (greetings), Wolfgang Osten, Professor based at Univ. Stuttgart, right (first presentation at the conference). The official event is listed at the websites of DPG and UNESCO.
https://www.quantum2025.de/
https://www.unesco.org/en/quantum-science-technology/about?hub=167999
https://quantum2025.org/news-link/unesco-2025-international-year-of-quantum-science-and-technology-launches-quantum-100-initiative-to-recognize-and-champion-the-global-quantum-community/#:~:text=The%20UN%20declared%202025%20the%20International%20Year%20of,science%20and%20applications%20on%20all%20aspects%20of%20life.
https://quantum2025.org/events/

Symposium "From Classical to Quantum Measurement Systems", talks by Jakob Dremel (TUD) and Stefan Rothe (Yale University, USA)

Networking

Social events of the Czarske lab

MST- Christmas Party,
9 December, 2025

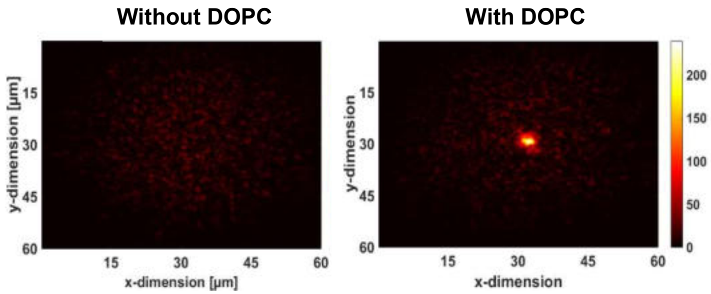
Visit of the Christmas market, 16 December 2025

RESEARCH PROJECTS

DFG **Focusing light through scattering tissue / Adaptive laser system for targeted cell ablation in deep-tissue**

Staff: N. Koukourakis, J Böhm, J.W. Czarske

Aim: Targeted light-delivery through scattering tissue is strongly limited by light scrambling. However, the technological improvement in hardware, computational power and methodology in recent years made it possible to control light inside or behind scattering media, by shaping the wavefront using a spatial light modulator before the light enters the scattering media. The main hurdle is to determine an adequate mask that allows prescrambling the light, so that the desired light pattern is delivered to the region of interest after scrambling. These are for example iterative optimization of the wave front, measurement of the transmission matrix, and digital optical phase conjugation (DOPC). DOPC has the advantage that it does not require time-consuming iterations or time-consuming calibration measurements, but instead enables direct shaping with a single measurement. Commonly guide stars are used to probe the light scrambling. The phase of the guide star light is recorded by quantitative phase measurements, e.g., performed by digital holography, and a phase mask of the phase conjugate is displayed on the spatial light modulator. This approach enables to time reverse the scrambling effects and to recreate the guide star. We applied DOPC for example, to focus light through 400 µm thick part of a mouse skull. While without DOPC strong scattering is observable (Figure, left), DOPC allows focusing through mouse skull with high quality (Figure, right). Such an approach is important for the optogenetic stimulation.



Partner: Max Planck Institute of Molecular Cell Biology and Genetics, Dr. M. Kreysing

Focusing through mouse skull, (left) without digital optical phase conjugation and (right) with digital optical phase conjugation.

N. Koukourakis, M. Kreysing, J.W. Czarske, "Wave front shaping method to focus through mouse skull", OSA Imaging and Applied Optics, Contribution OW2J.3, 25.–28.6.18, Orlando/USA

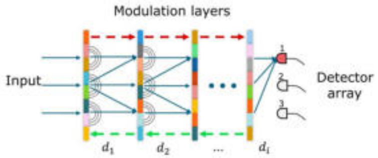
N. Koukourakis; M. Kreysing; J.W. Czarske, „Focusing Through Mouse Skull Using Wave front Shaping", OSA, Biophotonics Congress: Biomedical Optics, 03.-06.04.2018, Hollywood, Florida, USA

Azaam Aziz, Stefano Pane, Veronica Iacovacci, Nektarios Koukourakis, J.W. Czarske, Arianna Menciassi, Mariana Medina-Sánchez, and Oliver G. Schmidt, „Medical Imaging of Microrobots: Towards In Vivo Applications"; ACS Nano, 09/2020; DOI: 10.1021/acsnano.0c05530Kayvan Forouhesh Tehrani; Nektarios Koukourakis; J.W. Czarske; Luke J Mortensen, "In situ measurement of the isoplanatic patch for imaging through intact bone", Journal of Biophotonics; 08/2020

DFG **KOSELLECK: Physics-Informed Deep Learning Systems for Secure In formation Transmission with Multimode Fibers (Phys-Deep-Fiber)**

Staff: Q. Zhang, J. Zhang, B. Yang, J. Sun, J.W. Czarske

Aim: The aim of the Reinhart Koselleck project is to pursue exceptionally innovative and risky investigations on novel measurement systems to exploit scattering processes in multi-mode fibers (MMF) using physics-informed deep learning towards paradigm-shifts for secure information transmission. Fiberoptic communication technology forms the backbone of the Internet. Advances are not only important for further exponential growth of data rates, but especially for data security. Using the mode space of MMF compared to single-mode fibers enables an increase in data rates through spatial multiplexing. However, there are obstacles to information transmission in MMF due to mode crosstalk, which leads to mixing of the information channels in particular at large fiber lengths. This challenge is addressed in the Koselleck project by novel AI-based measurement systems. Artificial neural networks mimic the function of biological neural networks and are intended to be used to measure the transmission matrix (TM) of the MMF, but the learnable parameters increase exponentially with the mode number. A paradigm shift on physics-informed deep learning is pursued by both, “Physics Prior”, merging data driven algorithms with physical models, and “Physics in the Network”, an optical diffractive deep neural network (ODNN), that combines deep learning with diffractive optics. Real-time measurement of the transformation matrix (TM) of MMF by physics-based neural networks provides channel information between participants, which is exploited with the inverse TM through Physical Layer Security (PLS). It provides quantum-safe encryption as opposed to classical cryptography. Instead of post-quantum cryptography, physical laws are exploited not only with PLS but especially with quantum key distribution (QKD) using non-classical light, which guarantees data security due to the no-cloning theorem of single photons. The vision of the project is to explore and exploit terra incognita in information transmission through MMF using novel measurement systems and classical and non-classical light to improve the capacity and security of communications.



This principle of optical diffractive neural networks is a physical mechanism for implementing deep learning algorithms for information transmission using multimode fibers. It involves multiple diffraction layers, each corresponding to a hidden layer in a fully connected neural network (all neurons are connected to every neuron in the layers)

Period: 01/2026 – 12/2030

Partner: UCL London, USST, SIOM, TUM, TUB, Creol Florida, Fraunhofer Gesellschaft, Deutsche Telecom Chair, Toptica, qutools GmbH, etc.

Unlocking mode programming with multi-plane light conversion using computer-generated hologram optimisation, S Rothe, FA Barbosa, JW Czarske, FM Ferreira, Journal of Physics: Photonics 7 (1), 015002, 2024

Multimode optical interconnects on silicon interposer enable confidential hardware-to-hardware communication, Q Zhang, S Charania, S Rothe, N. Koukourakis, N Neumann, ..., JW Czarske, Sensors 23 (13), 6076, 2023

Securing data in multimode fibers by exploiting mode-dependent light propagation effects, S Rothe, KL Besser, D Krause, R. Kuschmierz, N. Koukourakis, ..., JW Czarske, Research 6, 0065, 2023

Intelligent self calibration tool for adaptive few-mode fiber multiplexers using multiplane light conversion, D Pohle, FA Barbosa, FM Ferreira, J Czarske, S Rothe, Journal of the European Optical Society-Rapid Publications 19, 2023

Secret Key Generation Over Multi-Mode Fiber: Channel Measurements, Key Rate Analysis, and System Implementation, PH Lin, P Nowitzki, EA Jorswieck, D Pohle, J Czarske, IEEE Open Journal of the Communications Society, 2025

Q. Zhang, Y. Zhang, and J. W. Czarske, "FPGA-accelerated mode decomposition for multimode fiber-based communication", Light: Advanced Manufacturing, 2025

Fei Wang, Juergen W. Czarske, and Guohai Situ, Deep learning for computational imaging: from data-driven to physics-enhanced approaches, Advanced Photonics, 2025

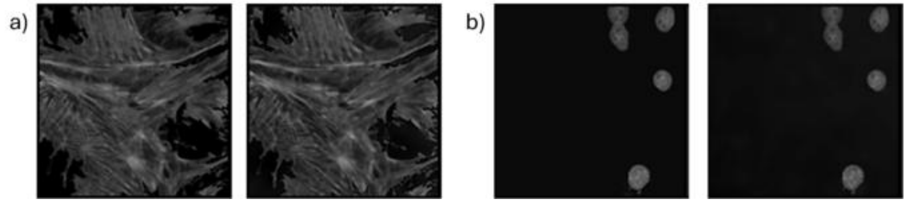
BIOLAS **Volumetric hybrid illumination microscopy using neural networks**

Staff: N. Koukourakis, K. Schmidt, J.W. Czarske

Aim: Wide field microscopy is well established in biological and medical applications. However, its reduced depth sectioning capability leads to background signals originating outside the depth of interest that degrade the contrast and limit the usability. To solve this limitation, a variety of microscopic techniques offering adequate depth sectioning have been introduced, the most prominent one being confocal microscopy. However, although confocal microscopy is advantageous, it is a pointwise technique and thus requires scanning in three dimensions to obtain 3D information.

Hybrid illumination microscopy enables to record optically sectioned wide field images by analyzing the spatial frequency content of the recorded image. As the maximum spatial frequency bandwidth is transported through the system for in-focus sample parts, high-spatial frequencies that inherently occur from the specimen, already lead to an optical sectioning. To get access to the low spatial frequency part of the focal region, a speckled illumination can be used, to artificially introduce high spatial frequencies. Thus, the combination of an uniform and a non-uniform illumination bears the potential to record optically sectioned images, with a strongly reduced scanning requirement. Just one axial scan is required. Using adaptive lenses allows to circumvent any mechanical scanning and to implement fast axial scanning without moving parts enabling rapid volumetric recordings. The reconstruction of the optically sectioned image is performed using a U-Net trained on images with structured and uniform illumination.

Partner: Helmholtz Zentrum für Umweltforschung, Leipzig, Dr. Stefan Scholz; SIBET



Examples from the HiLo-imaging Testdataset, a and b show different test images on the left side along with the corresponding network prediction on the right.

N. Koukourakis, K. Philipp, M. Stürmer, F. Lemke, M. Wapler, U. Wallrabe, J.W. Czarske, “Adaptive lenses for axial scanning in HiLo microscopy”, Optics in the Life Sciences Congress, OSA, 2-Page-Paper: BoTu1A.2, San Diego, CA, USA, 02.04.-05.04 (2017).

J. W. Czarske, K. Philipp, N. Koukourakis, „Structured illumination 3D microscopy using adaptive lenses and multimode fibers“, SPIE Digital Optical Technologies, Proceedings pp. [10335-44], Munich, Germany, 26.06. – 28.06.2017 (2017).

K. Philipp, A. Smolarski, N. Koukourakis, A. Fischer, M. Stürmer, U. Wallrabe, and J. W. Czarske, „Volumetric HiLo microscopy employing an electrically tunable lens,“ Opt. Express 24, No 13, 15029 (2016).

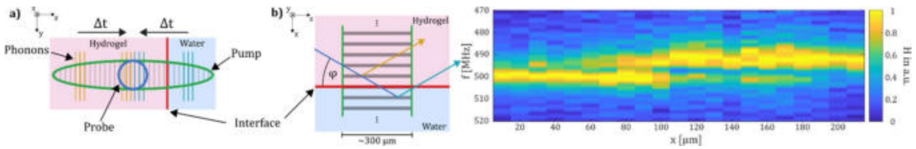
DFG **Investigations on Brillouin elastography using a pulsed laser for biomedical applications**

Staff: D. Krause, L. Liebig, N. Koukourakis, J.W. Czarske

Aim: The measurement of the elasticity of cells and tissues plays a major role in the investigation of pathological processes. Since the first report on non-contact, three-dimensional in-situ measurements of the elasticity of biological tissue using the spontaneous scattering between light and sound waves, great attention has been paid to Brillouin microscopy. Spontaneous Brillouin scattering is used, which allows locally high-resolution measurements but requires long integration times for each measuring point. The related technique of Impulsive Stimulated Brillouin Spectroscopy (ISBS) allows the measurement of the same tissue properties with a significantly increased time resolution. Imaging in real-time video resolution is therefore conceivable.
With ISBS, a standing acoustic wave is excited by a pulse laser in the measuring volume. The superposition of the pulse laser, which is divided into two beams, produces an intensity-striped pattern, which generates a force effect via electrostriction and thus the standing acoustic wave. By this standing wave, a second continuous wave laser is reflected and evaluated on a detector. The reflected beam is modulated according to the frequency of the standing wave. The strip spacing d given by the geometry, the frequency of the intensity of the reflected beam f and the speed of sound in the material v are related as follows: $v = 0.5\, f\, d$. Thus, the measured frequency can be used to determine the speed of sound and therefore the modulus of elasticity of the material. For initial measurements and the characterization of such a measuring system, measurements on reference liquids such as methanol, ethanol and water were successfully carried out. Measurements on biological reference samples, e.g., hydrogels were also accomplished. Brillioun-microscopy based on impulsive stimulation is particularly promising for scanning imaging but also high-speed measurements such as in the field of cytometry.

Period: 05/2019 – 04/2024

Partner: BIOTEC, Dresden, Prof. Jochen Guck



Left: ISBS excitation at interface. Right: Brillouin frequencies at the interface of water/hydrogel

Giuseppe Antonacci, Timon Beck, Alberto Bilenca, J.W. Czarske, Kareem Elsayad, Jochen Guck. Kyoohyun Kim, Benedikt Krug, Francesca Palombo, Robert Prevedel, Giuliano Scarcelli, "Recent progress and current opinions in Brillouin Microscopy for life science Applications", Biophysical Reviews, 2020
Impulsive stimulated Brillouin microscopy for non-contact, fast mechanical investigations of hydrogels, B Krug, N. Koukourakis, JW Czarske - Optics express, 2019 - osapublishing.org
B Krug, N. Koukourakis, J Guck, J Czarske, „Nonlinear microscopy using impulsive stimulated Brillouin scattering for high-speed elastography," Optics Express **30** (4), 4748-4758 (2022).

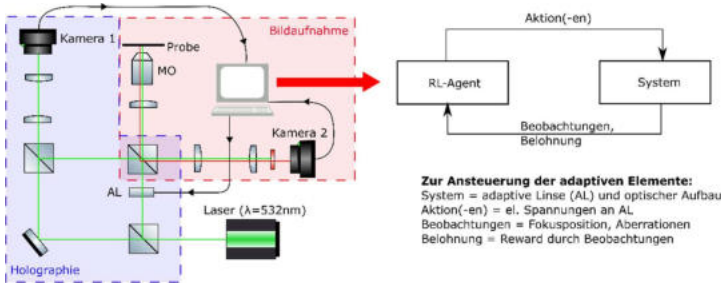
DFG **Aberration correction for real-time measurements in adaptive confocal microscope**

Staff: K. Schmidt, N. Koukourakis, J.W. Czarske

Aim: Microscopic techniques with high spatial and temporal resolution are required for measuring biological cells and tissues. For 3D measurements inside the sample deep imaging is required, which is realized by using confocal or two-photon microscopy. The sample tissue, which is in the imaging path of deep imaging will deform the wavefront and thereby introduce aberrations to the measurement. Aberrations can be addressed by using adaptive optical elements. Furthermore, adaptive elements allow for fast scanning. The aim of the project is to create a fully-adaptive two-photon microscope, which enables both fast scanning and high spatial resolution due to aberration correction. For this purpose, customized adaptive lenses from IMTEK (University of Freiburg) with integrated aberration correction are developed and used to create the axial scanning. These lenses enable to compensate for both symmetric (spherical, defocus) und asymmetric (astigmatism, coma)-aberrations. Furthermore, adaptive achromatic lenses for the correction of chromatic aberrations are developed. For lateral scanning adaptive prisms are used, which enable fast lateral scans with less aberrations and compact setup. Using the novel adaptive devices opens up the possibility to miniaturize the setup and to create a compact microscope.
However, including more adaptive elements driven by piezo-actors in the setup leads to a more complex control problem of the microscope components. To overcome this, machine learning methods such as neural networks and reinforcement learning agents are used to drive the adaptive optical elements for scanning and aberration correction.

Period: 10/2019 – 09/2025

Partner: Universität Freiburg, Prof. Wallrabe; UFZ Leibzig, Dr. Stefan Scholz



Ansteuerung einer adaptiven Linse (AL) mithilfe eines Reinforcmement Learning (RL) Agenten. Die Beobachtungen werden über digitale Holographie ermöglicht und die errechneten Aberrationen bzw. die Phase der Wellenfront an den RL-Agenten übergeben. Der Agent berechnet daraus die Spannungen, welche für eine Aberrationskorrektur bzw. einen Scan als nächstes an die AL anzulegen sind.

K. Philipp, A. Smolarski, N. Koukourakis, A. Fischer, M. Stürmer, U. Wallrabe, J.W. Czarske "Volumetric HiLo microscopy employing an electrically tunable lens", Opt. Express 24(13), 15029-15041 (2016).
W. Wang, K. Schmidt, M.C. Wapler, U. Wallrabe, J.W. Czarske, N. Koukourakis, „Fully refractive telecentric f-theta microscope based on adaptive elements for raster scanning of biological tissues", *Opt. Express. Vol*(31), 29703-29715 (2023)
K. Schmidt, N. Guo, W. Wang, J.W. Czarske, N. Koukourakis, "Chromatic aberration correction employing reinforcement learning", *Optics Express. Vol* (10), 31 (2023)

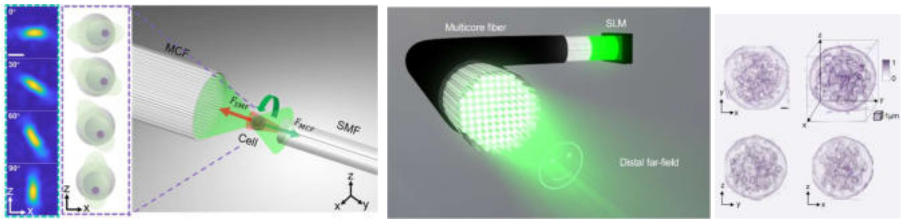
DFG **Tomographic refractive index measurement using Adaptive fiber-optical cell ROTation (TAROT)**

Staff: J. Sun, D. Krause, N. Koukourakis, J.W. Czarske

Aim: The three-dimensional refractive index (RI) distribution of biological cells contains rich information on the metabolism, health and on intracellular structure. An important biophysical parameter that can be accessed without invasive cell staining by quantitative phase imaging (QPI). As QPI techniques are sensitive to integral path-length information the reconstruction of the three-dimensional refractive index requires a multitude of projections under varying angles to enable 3D reconstruction using tomographic approaches. Changing the illumination angle via rotation of the specimen bears maximum spatial frequency coverage and is therefore advantageous compared to variation of the illumination angle. In this project, we aim to realize a versatile adaptive optical platform based on a novel dual-beam trap that enables for the first-time targeted cell-rotation about arbitrary axes in all spatial dimensions. The unique feature of our dual-beam trap is that light-delivery is accomplished by multi-core fibers (MCF) as key components of the system. Using an in-situ calibration by digital optical phase conjugation allows tailoring any desired light field distribution. To rotate the cells about the optical axis at least one beam has to have an asymmetric intensity profile to break the trap symmetry. Adaptively rotating this intensity profile results in a cell-rotation. The full light-field control further enables to induce additional targeted rotation by misaligning the traps or by illuminating with tailored intensity-gradients, enabling rotation in three dimensions. Quantitative phase imaging with full cell-rotation about two perpendicular axes will be realizable for the first time with fiber-based endoscopes.

Partner: Max Planck Institute for the Science of Light, Prof. Jochen Guck; SIBET

Period: 11/2018 – 01/2026



J. Sun, J. Wu, S. Wu, L. Cao, R. Goswami, S. Girardo, J. Guck, N. Koukourakis, J.W. Czarske, “Quantitative phase imaging through an ultra-thin lensless fiber endoscope,” Light Science & Applications, 2022
J. Sun, J. Wu, N. Koukourakis, L. Cao, R. Kuschmierz and J.W. Czarske, “Real-time complex light field generation through a multi-core fiber with deep learning,” Scientific Reports, 2022
J. Sun, N. Koukourakis, J. Guck and J. W. Czarske, “Rapid computational cell-rotation around arbitrary axes in 3D with multi-core fiber,” Biomedical Optics Express, 2021
J. Sun, N. Koukourakis and J. W. Czarske, “Complex wavefront shaping through a multi-core fiber,” Applied Sciences, 2021

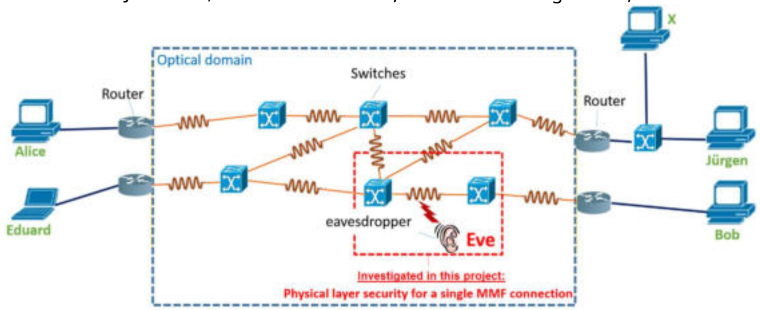
DFG **Physical Layer Security of Multimode Optical Fiber Transmission Systems**

Staff: B. Yang, D. Pohle, J.W. Czarske

Aim: Optical networks are the backbone of our information and communication society. The data traffic includes not only user data but also mission critical communication services, which are sensitive to eavesdropping and jamming attacks. This project studies the fundamental limits of physical layer security for data transmission through optical multimode fibers (MMF). In contrast to cryptographic security whose security is derived from the computational complexity of a cryptographic algorithm, in our project we are looking at the information theoretic security of the system, which guarantees secrecy regardless of the computation power available at the eavesdropper. Hence, this project concentrates on the fundamental limits of the security rate of MMFs between two legitimate nodes. Experiments will be conducted at the Chair of Measurement and Sensor System Technique (MST) to determine the relationship between input and output modes of the MMF, i.e. the transmission matrix, to obtain reliable channel information, which will help the Communications Theory Chair (TNT) setting up and optimizing channel models, with the aim to maximize the confidelity of communication and prohibit that the eavesdropper gains any valuable knowledge of the transmitted data. To prohibit that the eavesdropper gains any information of the channels during calibration, a public key method will be initially used. Finally, a demonstration of the feasibility of physical layer security using MIMO-SDM will be conducted.

Period: 09/2018 – 11/2025

Partner: Technische Universität Braunschweig, Institute for Communications Technology (IfN), Prof. E. Jorswieck, M. Sc. A. Lonnstrom/M. Sc. Karl-Ludwig Besser/Ph.D. P.-H. Lin



Optical network. In this project together with our partner, the physical layer security for a single MMF connection between two network nodes is investigated.

S. Rothe, N. Koukourakis, H. Radner, A. Lonnstrom, E. Jorswieck, J.W. Czarske, "Physical Layer Security in Multimode Fiber Optical Networks." Scientific Reports, 2020
S. Rothe, Q. Zhang, N. Koukourakis, J.W. Czarske, “Intensity-only Mode Decomposition on Multimode Fibers using a Densely Connected Convolutional Network”, Journal of Lightwave Technology, DOI: 10.1109/JLT.2020.3041374 (2021).
S. Rothe, K. L. Besser, D. Krause, R. Kuschmierz, N. Koukourakis, E. Jorswieck, J. W. Czarske, „Securing data in multimode fibers by exploiting mode-dependent light propagation effects.” Research, 6, 0065 (2023)
D. Pohle, S. Rothe, N. Koukourakis, J.W. Czarske, "Surveillance of few-mode fiber-communication channels with a single hidden layer neural network." Optics Letters, 47(5), 1275-1278 (2022)
P. H. Lin, P. Nowitzki, E. A. Jorswieck, D. Pohle, J.W. Czarske, J. “Secret Key Generation in Multi-Mode Fiber Channels: Channel Measurements and Achievable Rates.” In ICC 2024-IEEE International Conference on Communications (pp. 4973-4978). IEEE. (2024)

BMBF **6G Life Hub**

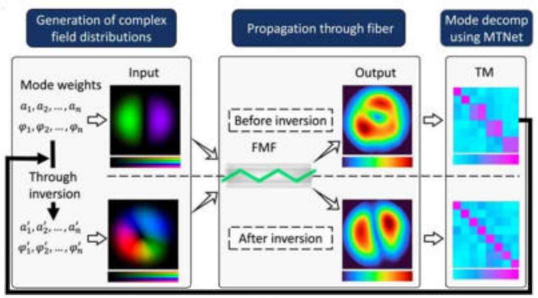
Staff: Q. Zhang, D. Pohle, J. Sun, J.W. Czarske

Aim: Digitalization, or digital transformation, is one of the next great challenges facing humanity after the Neolithic and Industrial Revolutions. The future standard of mobile communications 6G will play a central role in this revolution. With 5G, the gateway to digitization in industry has been thrown wide open. While its predecessors 2G, 3G and 4G exclusively covered the consumer sector, 5G also supports the control of machines. 5G makes the Internet of Things possible in real time. However, a major drawback with 5G communication networks is the limited use of novel technologies. The Project, 6G-life, will drive cutting-edge research for 6G communication networks with a focus on human-machine collaboration. 6G-life provides new approaches for sustainability, security, resilience and latency.

The research hub 6G-life is spanned by the TU Dresden (TUD) and TU Munich (TUM). The Chair of Measurement and Sensor System Technique (MST) is working on optical communication. MST will concentrate on Physical Layer Security (PLS) with optical MIMO systems, especially few-mode and multimode fiber using advanced deep neural networks such as the MTNet. Instead of increasing the security via mathematical approaches, the laws of physics can be used, as single photons cannot be measured without destruction. However, transmission over the spatial domain of multi-mode optical fibers requires further research. Using single-photon sources (e.g. Q-Dots), the goal is to make a sustainable 6G contribution to quantum communications. The vision is to bring modern computer-based aberration correction methods of optics and photonics into the 6G quantum testbed.

Period: 09/2021 – 09/2025

Partner: TU Munich, Institute for Communications Engineering
Prof. Gerhard Kramer, Prof. Dr.-Ing. Norbert Hanik, Dr. Carmen Mas Machuca
TU Dresden, Chair of radio frequency and photonics engineering
Prof. Dirk Plettemeier, Prof. Kambiz Jamshidi



6G-life

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

Controlling light propagation through a few-mode fiber using intelligent mode decomposition.

D. Pohle, S. Rothe, N. Koukourakis and J.W. Czarske, "Surveillance of few-mode fiber-communication channels with a single hidden layer neural network.", Optics Letters 47 (5), 1275-1278, 2022
Q. Zhang, S. Rothe, N. Koukourakis and J.W. Czarske, “Learning the matrix of few-mode fibers for high-fidelity spatial mode transmission”, APL Photonics, 7(6), 066104, 2022

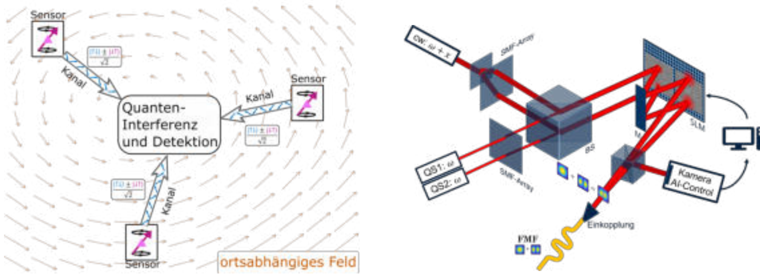
BMBF **Quantum Internet of Things (QUIET)**

Staff: Q Zhang, D. Pohle, J Zhang, J.W. Czarske

Aim: In current 5G and future 6G networks, a data explosion is expected due to massive machine communication, involving thousands of sensors. The increasing energy consumption associated with data growth can also only be managed with strongly performance-enhancing innovations. Quantum characteristics such as entanglement provide the feature of generating perfectly distributed and private randomness, which is a valuable resource for overcoming above mentioned challenges in quantum communications. In addition, quantum computing and quantum sensing provide opportunities on the basis of which quantum communication networks can deliver unique added value by distributing resources locally - and thus transferring them to a cloud. The object of the QUIET project is therefore the prototypical design and realization of an end-to-end system solution that implements the new approaches of quantum technologies in IoT communication networks, from IoT sensors or IoT sensor networks to smart networks and cloud applications, to solve the above-mentioned hurdles. Lab MST focuses on the transmission of quantum signals provided by a sensor to a network node or central server via optical fibers. Maintenance of quantum states necessitates transmission with as little loss as possible. Few-mode fibers (FMF) are suitable for transmission, because they have lower coupling losses compared to conventional single-mode fibers. FMFs support multiple transverse modes, which can be used as spatial parallel channels and are proposed for quantum signal transmission. Since only one physical fiber channel is required for simultaneous transmission of multiple quantum states, they can reduce both space and resources per channel. Using an SLM and Multiplane Light Conversion, a translation of distributed quantum signals towards a superposition of modes shall be achieved.

Period: 06/2022 – 06/2025

Partner: Deutsche Telekom AG (Dr.-Ing. Oliver Holschke), TU Munich (Prof. Holger Boche, Dr.-Math. Christian Deppe, Dr. rer. nat. Janis Nötzel), IFW Dresden (Dr. rer. nat. Caspar Hopfmann), TU Dresden (Prof. Fitzek, Prof. Jamshidi, Prof. Plettemeier)



Left: Concept of spatially distributed quantum sensing as an IoT network service. Spin qubits serve as sensors, which transmit the quantum information in the form of photons superimposed at a central server. Right: envisaged approach to translate distributed quantum signals (QS) to a superposition of modes using an SLM and multiplane light conversion.

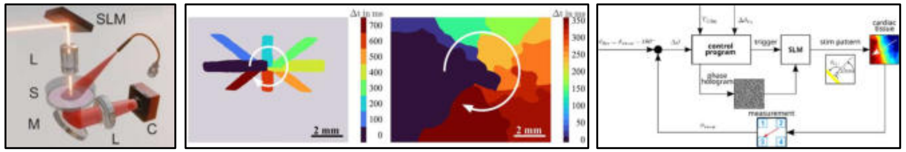
Q. Zhang, S. Rothe, N. Koukourakis and J.W. Czarske, “Learning the matrix of few-mode fibers for high-fidelity spatial mode transmission”, APL Photonics, 7(6), 066104, 2022
D. Pohle, F.A. Barbosa, F. M. Ferreira, J.W. Czarske, S. Rothe, “Intelligent self calibration tool for adaptive few-mode fiber multiplexers using multiplane light conversion.” *Journal of the European Optical Society-Rapid Publications*, *19*(1), 29. (2023)

BIOLAS **All-Optical Label-Free Closed-Loop Control of Human Cardiomyocytes**

Staff: R. Wendland, F. Schmieder, L. Büttner, J.W. Czarske

Aim: A central aspect of cardiac dysfunction is the disruption of the normal cardiac rhythm. Such disturbances are associated with characteristic spatiotemporal contraction patterns in the cardiac tissue. Understanding the dynamics of pathological contraction patterns is crucial for the development of targeted therapeutic strategies. In this context, optogenetics has emerged as a powerful tool. Optogenetics is a set of methods for the control of the activity of genetically altered cells expressing light-sensitive membrane ion channels. Optical stimulation approaches offer significant advantages over conventional electrical stimulation – e.g., higher spatiotemporal precision. We set up an optical system, combining SLM-based holographic stimulation of human induced stem cell-derived cardiomyocyte monolayers with speckle-based label-free imaging of excitation waves. This enables the dye-free investigation of cardiac dynamics – e.g., by the optical induction of pathological rotating contraction patterns via defined stimulation. Utilizing a method, we developed for reconstructing wavefront characteristics based on sparsely sampled cardiac activity, we were able to realize an all-optical real-time closed-loop control over excitation wavefronts. This allows for the feedback-controlled investigation of cardiac wavefront interactions, possibly improving our understanding of arrhythmia mechanisms and supporting the investigation of optical cardioversion strategies. Future work will extend these imaging and control strategies towards tissue slices or organoids to investigate three-dimensional cardiac phenomena.

Partner: Olaf Bergmann, Muhammad Atif Sikandar, Research Group Cell-based Model Systems, Department of Pharmacology and Toxicology, University Medical Center Göttingen



Left: Schematic of a holographic illumination setup for the stimulation and all-optical label-free recording of optogenetically excited contraction waves in genetically light-sensitized cells. Center: Via optical stimulation induced rotating contraction pattern, where the stimulation pattern was a rotating stripe. It can be seen that the rotating illumination leads to a rotating contraction. Right: All-optical closed-loop control of human to alter the optogenetic stimulation based on the label-free measured ongoing cardiac activity.

R. Wendland, F. Schmieder, M. A. Sikandar, W. H. Zimmermann, L. Büttner, O. Bergmann, J. W. Czarske, Label-Free Microscopy for Optogenetic Investigations of Arrhythmia in Hu-man Cardiomyocyte Networks Expressing Chrimson, European Conferences on Biomedical Optics, SPIE, OPTICA – Munich, June 2025.

L. Buettner, R. Wendland, F. Schmieder, M. Sikandar, W.-H. Zimmermann, O. Bergmann, J.W. Czarske, “Label-Free Sensing and Real-Time Holographic Optogenetic Control of Cardiac Excitation Wavefronts”, presentation FM1B.2, Frontiers in Optics, 26-30 Oct. 2025, Denver, Colorado, USA

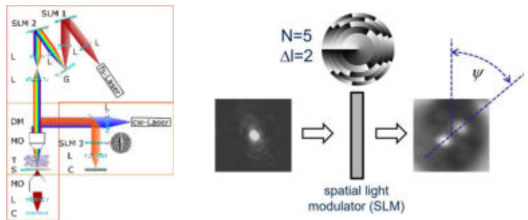
DFG **Optogenetic Stimulation and Cell Localisation in Three-Dimensional Cell Structures**

Staff: F. Schmieder, R. Wendland, L. Büttner, J.W. Czarske

Aim: Disturbances in the signal transmission are a main cause for heart arrhythmia and deadly ventricular fibrillation. However, the processes generating and interrupting these events are not fully understood yet. Optogenetics – a set of methods encompassing genetic and optical tools for the light-mediated control of cell characteristics – is a promising approach to induce, observe and control irregular signal transmission in in-vitro experiments in a spatially and temporally targeted manner for a deeper phenomenological understanding. The goal of this project is to provide the necessary tools for understanding signal transmission in three-dimensional in vitro cardiomyocyte cell structures. To this end, several approaches will be followed. First, three-dimensional optogenetic stimulation will be realized using non-linear two-photon processes to achieve cell-sized optical confinement in deep tissue (hundreds of microns). This approach will be extended using the method of temporal focusing to achieve a simultaneous stimulation of larger cell patches or volumes, guaranteeing the necessary temporal resolution for a 3d control of excitation waves in cardiac tissue.
To observe excited contraction waves in three dimensions without scanning for high temporal resolution, we will apply 3d localization microscopy and tracking of fluorescently labeled cell nuclei using the approach of point spread function engineering. Here, we will initially employ the method of the double helix point spread function, which is quite established in localization microscopy and flow measurement. Using deep neural networks for location deconvolution, we will investigate limitations regarding achievable observation depth in relation to scatter/fluorescent particle density.

Period: 10/2023 – 10/2026

Partner: Olaf Bergmann, Research Group Cell-based Model Systems, Department of Pharmacology and Toxicology, University Medical Center Göttingen



Left: Schematic of setup for simultaneous 3d targeted single cell stimulation and single shot 3d localization microscopy. Right: Principle of 3d localization microscopy with point spread function engineering. Single image points are converted to double spots using a special phase mask in fourier space. The depth of the light source can be estimated from the orientation angle ψ between the double spots which changes along the optical axis.

Felix Schmieder, Robert Wendland, Muhammad Atif Sikandar, Wolfram-Hubertus Zimmermann, Lars Büttner, Olaf Bergmann, J.W. Czarske, Excitation wavefront tracking and control of in vitro human induced cardiomyocytes using a digital holographic stimulation system, 25 January 2025, San Francisco

DFG **3D Quantum imaging with undetected light and wavefront control**

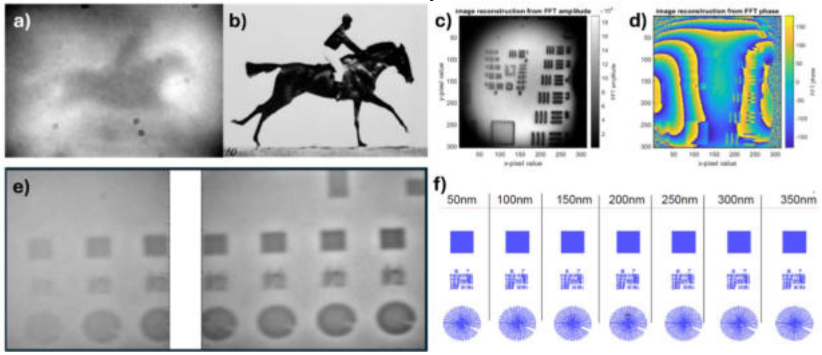
Staff: S. Krause, L. Büttner, J.W. Czarske

Aim: In the course of second-generation quantum technologies, quantum physical effects of light offer completely new methodological approaches also in optical imaging. The principle of induced coherence with entangled photon pairs of different wavelengths is particularly promising. The spectral separation of light illuminating the tissue and detected light represents a paradigm shift in optical imaging. Infrared photons interact with a biological sample, while the visible signal photons are detected with a camera. The measurement is performed with photons that never interact with the object. By detecting in the visual spectral range with silicon cameras, the signal quality is strongly improved. The aim of the project is to investigate the principles of wavefront manipulation and correction for the first time in quantum imaging with non-detected light in a non-linear interferometer and thus to enable gentle, marker-free 3D imaging of deep tissue with high contrast in the infrared spectral range.

However, the imaging of biological tissue exhibits some special features such as sample-induced aberrations or the three-dimensionality of the samples. For the first time, three-dimensional imaging and aberration correction with separate but entangled camera and object photons are being investigated. 3D single-shot imaging with single photons will be achieved by modified point spread functions. System-related and sample-induced aberrations are corrected by the use of adaptive optical elements. The expected scientific progress lies in the gentle examination of tissue by means of sensitive, marker-free, chemical-selective 3D imaging with visual light.

Period: 2024 – 2027

Partner: Prof. Markus Gräfe, Technical University of Darmstadt



a) Image of a horse probed with NIR-photons and imaged with entangled photons in the visible range. b) Original image displayed on an SLM. c) and d) Reconstructed Fourir-amplitude and phase image, respectively. e) Quantitative phase images of a phase calibration target measured with undetected light. f) Schematic of the phase target for comparison. The phase changes result from different heights of transparent polymer structures.

L. Büttner, J.W. Czarske, M. Gräfe, „Quantum Imaging with Undetected Light – A New IR Imaging Modality", Workshop "Optische in-Prozess Sensorik, Sensornetze und Sensorfusion, Quantensensorik", Bremer Institut für Angewandte Strahltechnik (BIAS), Bremen, 20.11.2024

S. Krause, J. Vasikonis, L. Büttner, M. Gräfe, J.W. Czarske, „Quantum Imaging with Wavefront Shaping", Conference „Unconventional Optical Imaging V 2025", Straßburg.

DLR **Liquid Transport through Oscillating Film Flows – Development of an Adaptive Measurement Method and a Process with Defined Wave Characteristics**

Staff: C. Bilsing, L. Büttner, J.W. Czarske

Aim: The project explores how wavy liquid films can enhance cleaning and material transport on technical surfaces. Such film flows are found in many industrial processes — including coating, oil separation, distillation, and cleaning in the food and pharmaceutical industries. Despite their importance, the interaction between a primary flowing film and a secondary liquid phase, such as droplets or rivulets, is still insufficiently understood due to the lack of suitable measurement techniques. To address this, researchers are developing an adaptive, high-resolution optical measurement system capable of capturing three-dimensional flow and shear stress data through dynamically curved liquid interfaces. This novel approach uses adaptive optics and a 3D Particle Tracking Velocimetry (PTV) technique to correct optical distortions in real time, enabling accurate measurements even on opaque surfaces. By linking these detailed flow data with the observed movement of liquid films and droplets, the project will provide new insights into fluid transport and cleaning mechanisms. The results will support the development of innovative, energy-efficient cleaning and separation processes, offering significant technological and economic benefits to small and medium-sized enterprises in process, measurement, and fluid engineering.

Period: 08/2025 – 12/2027

Partners: Dr. Sebastian Burgmann, Prof. Uwe Janoske, Lehrstuhl Strömungsmechanik, Bergische Universität Wuppertal

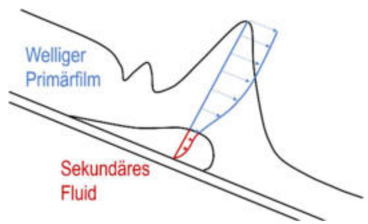


Fig. 1: Representation of the configuration to be investigated of a wavy primary film over a secondary liquid accumulation (here: droplets) and the presumed velocity profiles

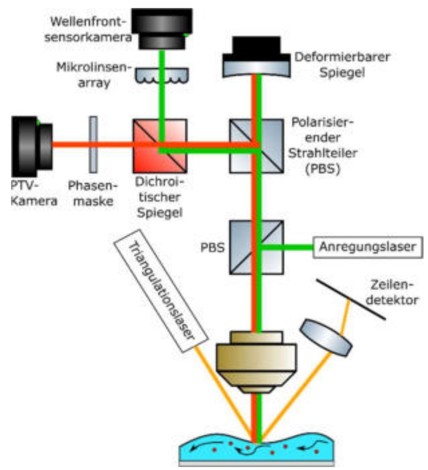


Fig. 2: Schematic diagram of the overall system with HS wavefront sensor, water level measurement using triangulation, deformable mirror, and 3D PTV system

Bilsing, C., Janoske, U., Czarske, J., Büttner, L., & Burgmann, S. (2025). 3D-3C measurements of flow reversal in small sessile drops in shear flow. International Journal of Multiphase Flow, 182, 105017.

DLR **Measurement methods and modeling spray cleaning – Development and application of an adaptive 3D camera measurement system for the semi-analytic modeling of spray cleaning processes.**

Staff: B. Yang, C. Bilsing, R. Wendland, L. Büttner, J.W. Czarske

Aim: Spray cleaning is an essential process step in the manufacturing industry for food, beverages and pharmaceuticals. More efficient processes lead to increased efficiency, economics and decreased ecological impact. In this project, we want to analyze the process parameters and develop methods to acquire for the first-time high-resolution data throughout the cleaning process, including the film flows and the dirt removal. A novel high-speed 3D camera based technique using engineered double-helix point spread function reveals the dynamics in the most relevant processes in spray cleaning. In the first step, the film flow near the substrate is measured three-dimensionally. Secondly, we analyze the motion of dirt during removal with a spray cleaner. Following this, we measure the liquid flow and the dirt removal simultaneously.

Period: 01/2022 – 09/2025

Partners: Dr. Hannes Köhler, Manuel Helbig, Prof. Jens-Peter Majschak
Professur für Verarbeitungsmaschinen / Verarbeitungstechnik (VAT), TU Dresden

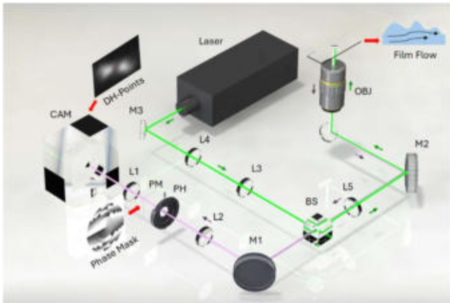


Fig. 1: Sketch of the experiment setup for 3D particles tracking in film flow using a DH-PSF system. Laser, diode-pumped solid-state (DPSS) laser

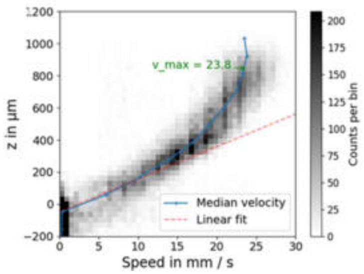


Fig. 2: Measured time-averaged flow profile of the film flow. The wall-shear stress can be estimated from the near-wall measurement data.

B. Yang, M. Helbig, C. Bilsing, H. Köhler, D. Lu, J. W. Czarske, L. Büttner „High-Resolution Single-Camera Measurement of Near-Wall Film Flow at Spray Cleaning Process using a Double Helix Point Spread Function", Accepted for Publication by Experiments in Fluids

DFG **Investigation of the transition of aerosol particles in liquids with an adaptive optical measurement technique for highly dynamic phase boundaries**

Staff: C. Bilsing, L. Büttner, J.W. Czarske

Aim: In many industrial and medical applications, the transport of aerosol particles in gas flows and their transfer into a liquid phase are of major importance. Wet scrubbers, for example, provide a cost-efficient method to remove fine dust from exhaust gases or aerosols from metal coating processes by guiding particle-laden air through a washing liquid. Similar concepts can be applied to filter viral particles, and future miniaturized separators may support pandemic mitigation. However, current models of particle separation are insufficiently accurate for micrometer-sized particles. Previous studies suggest a strong dependence on flow structures and the geometry of the gas–liquid interface, which are not yet adequately considered. Investigating flows inside gas bubbles with dynamically changing surfaces therefore requires adaptive optical systems to correct refraction-induced aberrations. In this work, a camera-based three-dimensional measurement method is implemented to measure flow fields inside gas bubbles and in the surrounding liquid, with particular focus on stabilized Taylor bubbles. Additionally, particle separation on a fixed droplet in an air flow is studied.

Period: 07/2022 – 12/2025

Partners: Rhandrey Maestri, Dr. Grégory Lecrivain, Prof. Uwe Hampel
Institute of Fluid Dynamics, Helmholtz-Zentrum Dresden-Rossendorf (HZDR)

Fig 1: Taylor bubble in glas tube with constriction

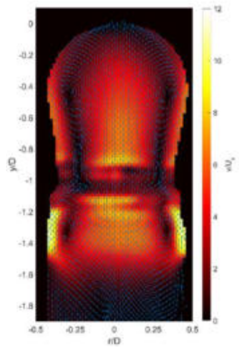


Fig. 2: Measured flow field in Taylor bubble

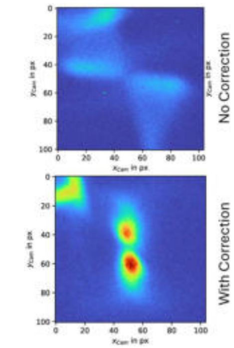


Fig. 3: Top: Particle image with aberrations due to refraction at drop surface Bottom: Particle image with Adaptive-Optical Correction

Bürkle, F., Maestri, R., Lecrivain, G., Hampel, U., Büttner, L., & Czarske, J. (2025). Investigation of the gas and film flow of Taylor bubble in a tube with a short constriction employing 3D particle tracking. Experimental and Computational Multiphase Flow, 1-11.

Maestri, R., Bilsing, C., Büttner, L., Czarske, J., Hampel, U., & Lecrivain, G. (2025). Experimental investigation of aerosol separation in a rising Taylor bubble. Journal of Aerosol Science, 106675.

DFG **Lensless holographic endoscopy with self-calibration**

Staff: T Wang, J. Dremel, R. Kuschmierz, J.W. Czarske

Aim: Flexible endoscopes are used in medicine and industrial applications for minimal invasive imaging. They employ miniaturized optics in the probe tip and a coherent fiber bundle (CFB) with 10,000 to 100,000 fiber cores for transferring the image outwards. The working principle and setup result in a pixelated image due to the limited core number as well as a fixed image plane. Furthermore, the optics in the probe tip limit the minimum diameter of the probe tip to several millimeters. With the approach of the lensless holographic endoscope, it is possible to eliminate or greatly improve the disadvantages of pixilation, fixed image plane and limited minimal diameter. The holographic endoscope does not use the single fibers to transfer single image points out of the sample. They are used to transport light from a laser into the interior of the sample. Due to the multitude of fibers and the wave character of light, the lensless probe tip can be regarded as a phased array. Using a Spatial Light Modulator (SLM) outside of the CFB it is possible to control the phase through each fiber core individually. While a new calibration is needed after each movement of the CFB, we found a way to calibrate continuously and in-vivo, without access to the probe tip. One single fiber core acts as a guide star through a semi-reflective plane (see Fig. 1). Such that, the relative phase delays between neighboring cores are determinable via holography. The SLM is used to compensate distortions within the CFB and to shape the out coming beam. Thus, it is possible to create a free-moving focus to scan the object. Like the functionality of a scanning microscope, an image can be assembled from the backscattered light of the individual focus positions. The approach enables setups with sub-millimeter diameters, sub-micron resolution and 3D imaging capability. In addition to its use as an endoscope, this technology can also be used for laser surgery, optogenetics and optical tweezers.

Period: 11/2020 – 12/2024

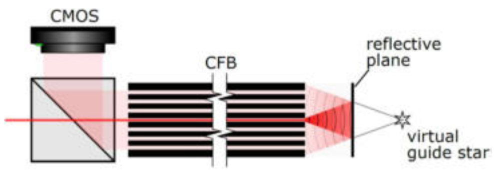


Fig. 1

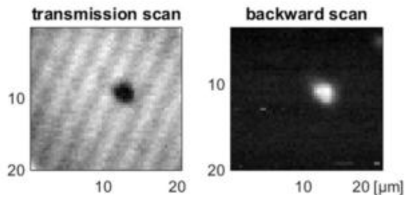


Fig. 2

Left: Scheme virtual guide star calibration. Right: Endoscopic scan of fluorescent particle with diameter of 1 µm.

R. Kuschmierz, E. Scharf, N. Koukourakis, and J.W. Czarske, “Self-calibration of lensless holographic endoscope using programmable guide stars”, Opt. Lett. 43, 2997-3000 (2018).
E. Scharf, J. Dremel, R. Kuschmierz, J.W. Czarske, “Video-rate lensless endoscope with self-calibration using wavefront shaping”, Optics Letters 45(13), 3629-3632, 2020
R. Kuschmierz, E. Scharf, D. F. Ortegón-González, T. Glosemeyer, J.W. Czarske. Ultra-thin 3D lensless fiber endoscopy using diffractive optical elements and deep neural networks. Light: Advanced Manufacturing
Dremel, Jakob, Scharf, Elias, Kuschmierz, Robert and Czarske, Jürgen. "Minimal-invasive faseroptische Endomikroskopie für die Medizin" tm - Technisches Messen, vol. 89, no. s1, 2022, pp. 25-30. https://doi.org/10.1515/teme-2022-0068

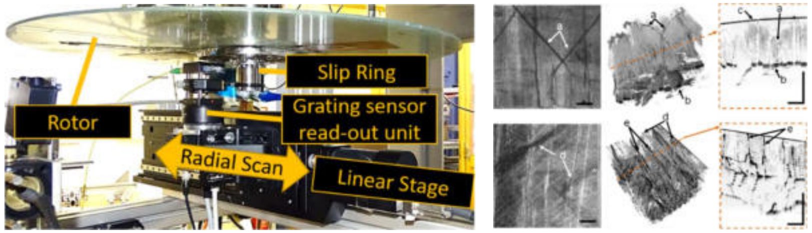
DFG **Investigation of damaged fibre-reinforced high-speed rotors using in-situ measurement systems**

Staff: R. Kuschmierz, J.W. Czarske

Aim: Fibre-reinforced composites offer excellent properties such as very high specific strength and stiffness as well as high freedom of design due to their anisotropy and gradual damage behavior. Therefore, they are predestined for new high-performance rotors, for example in turbomachinery or centrifuges. However, problem-oriented design tools for the reliable prediction on durability, reliability and energy efficiency of the rotor are still lacking. The aim of the project is to find the fundamental relationship between damage state and dynamic behavior of fast rotating fibre-reinforced rotors. This requires the development of novel measurement systems that allow the simultaneous in-situ measurement of damage state and modal behavior during rotation. Rotor expansion is measured with submicron uncertainty by our unique Multipoint-Laser-Doppler-Distance Sensor. We additionally measure the in-plane strain field and the out-of-plane vibration by reading out diffraction gratings on the rotor surface. To validate and calibrate numerical models developed by our partner “Institut für Leichtbau und Kunstofftechnik”, we further reduce the measurement uncertainty of the Diffraction Grating Sensor and expand its applicability to complex rotor geometries. Furthermore, techniques for the volumetric measurement of local deformations and damages will be qualified and applied for the first time at fast rotating structures together with our partner “Klinisches Sensoring und Monitoring”.

Period: 10/2017 – 04/2021, 11/2021 – 09/2025

Partner: Institut für Leichtbau und Kunststofftechnik - TU Dresden, Prof. Gude
Arbeitsgruppe Klinisches Sensoring und Monitoring – TU Dresden, Prof. Koch



Diffraction Grating Sensors measuring in- and out-of-plane FRP rotor deformation field and vibration at >270 m/s with 20 µε and 15 µrad precision (left). OCT images of internal FRP rotor structure, showing delamination (b) and cracks (e) (right) due to overload.

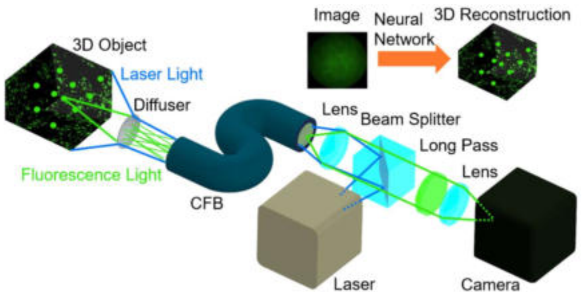
Lich, Julian, et al. "Spatially Resolved Experimental Modal Analysis on High-Speed Composite Rotors Using a Non-Contact, Non-Rotating Sensor." *Sensors* 21.14 (2021): 4705.
Filippatos, Angelos, et al. "Design and testing of polar-orthotropic multi-layered composites under rotational load." *Materials & Design* (2021): 109853.
Julian Lich, Tino Wollmann, Angelos Filippatos, Maik Gude, J.W. Czarske, Robert Kuschmierz, “Diffraction-grating based in situ displacement, tilt and strain measurements on high-speed composite rotors”, Applied Optics, 58(29), 8021-8030, (2019)

DFG **Minimally Invasive 3D-Imaging using a diffuser and neural networks**

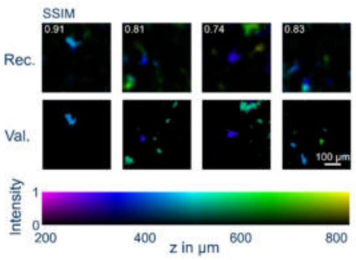
Staff: T. Glosemeyer, J Dremel, R. Kuschmierz, J.W. Czarske

Aim: Minimally invasive endoscopy offers a high potential for biomedical imaging applications. Many microscopic techniques can be transferred to endoscopy by using imaging waveguides. However, conventional fiberoptic endoscopes are based on the transmission of intensity patterns and require lens systems which are not suitable for real-time 3D imaging. In this project, a diffuser is utilized instead for passively encoding incoherent 3D objects into 2D speckle patterns. These patterns are then transmitted through imaging waveguides. Neural networks are employed for fast computational image reconstruction beyond the optical memory effect. By calibrating physics-informed network architectures with the varying point spread functions of the system, the reconstruction performance can be improved further. Illumination of fluorescent samples with a laser through the endoscope enables a paradigm shift towards single-shot 3D incoherent fiber imaging with keyhole access at video rate. Applying the diffuser fiber endoscope for fluorescence imaging is promising for in vivo deep brain diagnostics with cellular resolution, e.g. by calcium imaging.

Period: 05/2021-04/2025



The 3D object is encoded by a diffuser to a 2D speckle pattern which is transmitted through a CFB to a camera. The 3D object is then reconstructed by a neural network.



Fluorescence imaging with proximal laser illumination demonstrates application of diffuser endoscope for single-shot 3D incoherent imaging.

R. Kuschmierz, E. Scharf, D. F. Ortegón-González, T. Glosemeyer, J.W. Czarske. Ultra-thin 3D lensless fiber endoscopy using diffractive optical elements and deep neural networks, [J]. Light: Advanced Manufacturing. doi: 10.37188/lam.2021.030, (2021)

J.Lich, T. Glosemeyer, J.W. Czarske. Single-shot 3D incoherent imaging with diffuser endoscopy, [J]. Light: Advanced Manufacturing. doi: 10.37188/lam.2024.015, (2024)

EKFZ **In vivo brain tumor diagnostics by adaptive computational lensless fiber endoscopy (BrainAce)**

Follow-up: SAB **Fiber-based autofluorescence imaging and AI-supported tissue analysis for precise in situ diagnosis and therapy: Seeing and acting in neurosurgery (SHINE-Path)**

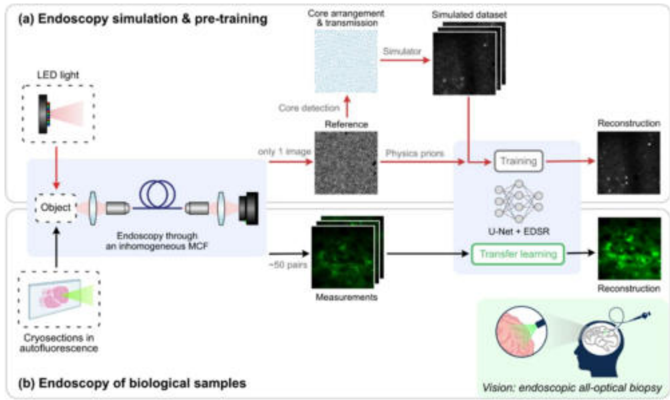
Staff: J. Dremel, T. Wang, R. Kuschmierz, J.W. Czarske

Aim: In patients with inoperable brain tumors located in eloquent brain regions, histological diagnosis is a prerequisite for the determination of the adjuvant treatment. This requires a minimal-invasive biopsy for histology that requires some days to provide an integrated diagnosis for further clinical decision-making. As a consequence, if the suspicious tissue turns out to be an aggressive brain tumor, the adequate therapy is delayed with negative impact on the patient's prognosis. The development of strategies for direct tumor diagnosis bypassing tissue removal and lengthy pathological evaluation would allow the immediate therapy of affected patients.

We aim to develop and test a prototype of a novel tiny endoscope that probes autofluorescence of brain tissue and allows optical biopsies in situ. In the project, we will research the spectral characteristics of brain tumor fluorescence and miniaturize an endoscopic system while preserving high optical properties. This is achieved by implementation of recent advances in computational optics and programmable light. The development of tissue classification and strategies for integration of AI-supported diagnosis into the clinical workflow will allow successful translation. Moreover, the research may pave the way for future automated brain tumor diagnosis and tumor removal by laser ablation.

Period: BrainAce: 01/2022 – 12/2024 SHINE-Path: 10/2025 – 12/2027

Partners: University Hospital Carl Gustav Carus, Neurosurgery & Division of Medical Biology
Dr. S. Richter, Dr. W. Polanski, Prof. G. Schackert, Dr. O. Uckermann, advanced fiber tools GmbH; Prof. Dr. Georg Kuka, Effigos AG; Dr. Jens Grosche, neongrau OHG; Cindy Marquardt



Workflow of biopsy diagnosis and end-to-end diagnosis

Wu, J., Wang, T., Uckermann, O., Galli, R., Schackert, G., Cao, L., Czarske, J., Kuschmierz, R., 2022. Learned end-to-end high-resolution lensless fiber imaging towards real-time cancer diagnosis. Sci Rep 12, 18846
Tijue Wang, J. Dremel J, S. Richter, et al. "Resolution-enhanced multi-core fiber imaging learned on a digital twin for cancer diagnosis". Neurophotonics, 2024, 11(S1): S11505-S11505.

DFG - Fraunhofer | **High-speed holographic interferometry for keyhole evaluation in laser material processing (KEEN)**

Staff: A. Thees, R. Kuschmierz, J. Dremel, J.W. Czarske

Aim: Laser material processing is increasingly important in industrial manufacturing due to its precision and efficiency. Laser welding is widely used in automotive and e-mobility applications, where weld quality and process stability are critical. In deep penetration welding, a vapor capillary ("keyhole") forms and moves along the weld path. Its stability directly affects weld quality. However, materials like aluminum castings and copper alloys often cause keyhole fluctuations due to volatile elements, making real-time monitoring essential.

Current optical and acoustic sensors are insufficient for reliable, high-speed keyhole detection. Optical Coherence Tomography (OCT) is used to measure keyhole depth but lacks the speed and lateral resolution for full 3D analysis.

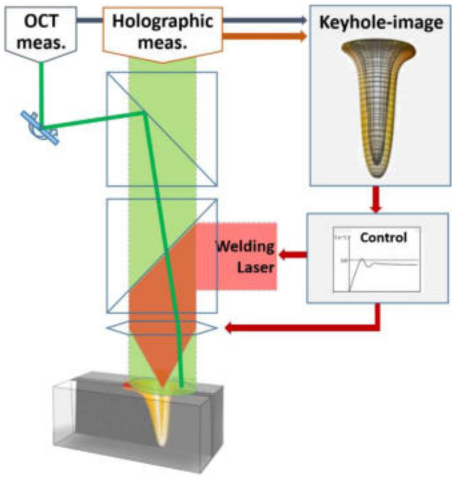
The KEEN project introduces digital holographic interferometry for in-situ 3D keyhole analysis using high-speed cameras. Building on previous work, the system achieves high spatial and temporal resolution. By adding a second laser source and synthetic wavelength generation, it enables single-shot 3D surface measurements at high data rates. AI-based data analysis methods are also being developed.

Project Goals:

- Develop a holographic high-speed 3D keyhole monitoring system with ≥5×5 mm lateral and 8 mm axial field.
- Integrate and test the system in a laser welding setup, validated with 3D metallography.
- Create real-time measurement and control algorithms for keyhole characterization and process stabilization.
- Validate industrial applicability, especially for copper components in e-mobility manufacturing.

Period: 12/2025-12/2028

Partners: Fraunhofer Institut Werkstoff und Strahltechnik IWS Dresden; Dr. Andreas Wetzig
Lessmüller Lasertechnik GmbH; Richard Steinbrecht
ZF Group; Peter Schömig



DFG | **Ultrasound measurements through multimode-waveguide based on time reversal for imaging in hot metallic melts**

Staff: C. Othmani, Z. Dou, L. Büttner, J.W. Czarske

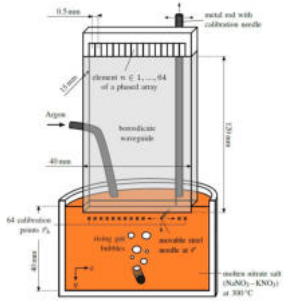
Aim: In industrial processes, such as continuous steel casting, the quality of the end products depends on the melt flow and structure. Therefore, in situ imaging of opaque melts under harsh conditions is important. Conventional ultrasound measurement systems, which are usually suitable for imaging in opaque fluids, cannot be operated at temperatures beyond Curie temperature of the ultrasound transducer.

An approach is to use a multimode waveguide as a temperature gradient, which spatially separates the sensor from the hot measurement fluid. To overcome the complex ultrasound propagation through the waveguide the time reversal method is used. The time invariance of the wave equation in an unknown, linear and nearly lossless medium allows spatiotemporal refocusing to the initial point. However, the planar imaging would require costly in situ calibration, because each point of interest need to be calibrated with a beacon.

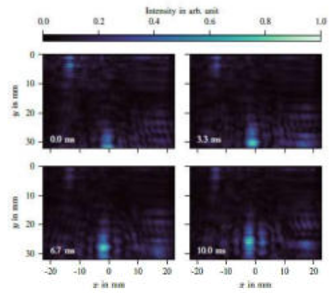
A reduced, non-invasive, ex situ calibration can be achieved by applying the time reversal virtual array method. Therefore, only a limited set of pre-calibrated points at the waveguide-measurement volume interface are needed, which form the virtual array. The virtual array can be conceptually treated as a phased-array for the imaging behind the waveguide. This allows the application of conventional signal processing strategies, such as transmit and receive beamforming to increase the resolution of an image and ultrasound Doppler velocimetry for flow estimations.

Period: 12/2023 – 11/2026

Partner: Helmholtz-Zentrum Dresden-Rossendorf, Dr. S. Eckert



Cross-section of the experimental setup: A phased array was connected to the end of a borosilicate waveguide and calibrated in the hot melt with a moving needle.



Observation of rising gas bubbles in molten salt at 300 °C.

L. Grüter, R. Nauber, J.W. Czarske, „Ultrasonic Bubble Imaging in Molten Salt Using a Multi-Mode Waveguide and Time Reversal", IEEE Transactions on Instrumentation and Measurement 71, 2022, Art. no. 4501810.
Z. Dou, L. Grüter, D. Weik, J.W. Czarske, "Ultrasound Tracking of Gas Bubbles Through a Multi-Mode Waveguide in Hot Melts", 2022 IEEE International Ultrasonics Symposium (IUS), Oct. 2022.
Patent A 5296DE, "Kalibrierverfahren von Multimode-Wellenleitern zur Bildgebung mit Ultraschall-Endoskopen

BMBF **HEAD – Erkennung von Hirnblutungen in der NotfAllDiagnostik.**
Sub-Project: Physics-based neural networks for high-performance ultrasound tomography of cerebral hemorrhages in emergency diagnostics

Staff: C. Othmani, Z. Dou, L. Büttner, J.W. Czarske

Aim: In clinical practice, the distinction between a hemorrhagic and an ischemic stroke is ensured by means of an X-ray computed tomography (CT) scan of the entire brain. However, mobile CT systems suitable for emergency diagnostics entail extremely high acquisition costs and are impractical due to their considerable technical complexity.

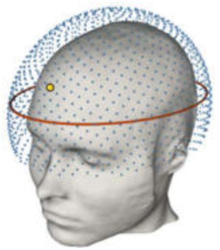
This project aims to pursue a novel approach to acoustic tomography based on waveform inversion. Here, multiple low-frequency ultrasound transducers (approximately 200–400 kHz) are distributed around the skull. Each transducer emits a pulse sequentially, while all transducers record the resulting signals. The image reconstruction in waveform inversion is performed via acoustic field simulations, in which the brain model is iteratively updated to match the measured signals.

Compared with conventional ultrasound systems, this approach offers the promising capability of imaging the entire brain. The primary obstacle for emergency diagnostics lies in the computational effort: waveform inversion typically requires several hours of calculation time. As a unique feature of this subproject, neural networks will be employed to accelerate these computations. Physics-informed neural networks can estimate the acoustic properties of the target object orders of magnitude faster, enabling the generation of highly reliable and sensitive diagnostic images after only a few iterations. This development is intended to make the method suitable for emergency physicians, allowing brain hemorrhages to be safely diagnosed directly on site and enabling rapid initiation of appropriate treatment.

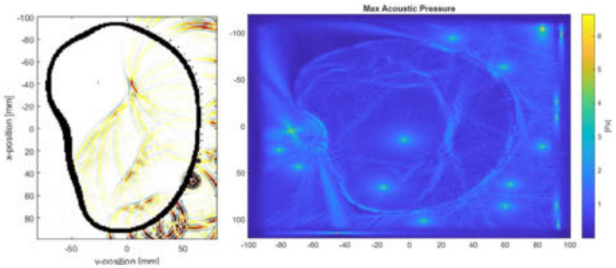
The project consortium is interdisciplinary and distributed across multiple institutions. The collaboration between clinicians, engineers, mathematicians, and natural scientists enables targeted research and development of a novel ultrasound device. The ambitious objective is to be achieved by a team with decades of experience in the research, development, and application of ultrasound technologies.

Period: 11/2025 – 10/2028

Partner: Universität Leipzig, SONOTEC GmbH



Three-dimensional array of transducers used for data generation and subsequent inversion.



Initial simulation of ultrasonic waves on a 2D Brain model using K-Wave.

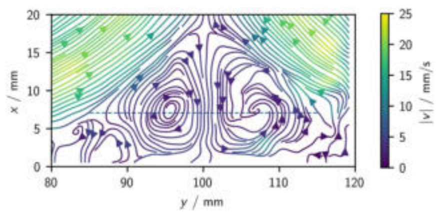
DFG **Investigation of thermal boundary layer dynamics in turbulent liquid metal convection by ultrasound localization microscopy of near-wall velocity fields and temperature measurements**

Staff: D. Weik, H. Bischoff, L. Büttner, J.W. Czarske

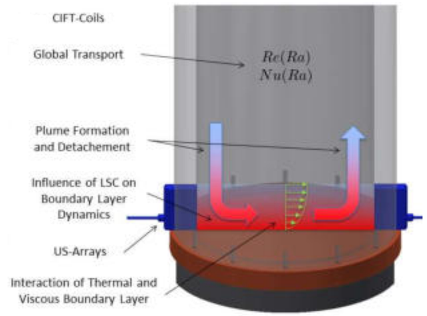
Aim: The dynamics and interaction of thermal and viscous boundary layers (BL's) will be studied experimentally in highly turbulent liquid metal convection at small Prandtl numbers using the ternary alloy GaInSn ($\mathrm{Pr} = 0.03$). Rayleigh-Bénard convection at large Rayleigh numbers of up to $\mathrm{Ra} \cong 5 \times 10^9$ is characterized by a fully turbulent flow field, with the temperature field exhibiting significantly more coherence than the velocity field due to the high thermal diffusivity. A crucial role for heat transport in turbulent convection is played by the BL's. Here, a special feature of liquid metals becomes apparent, which has hardly been researched so far: The much thinner viscous boundary layer is embedded in the thermal BL. Therefore, the thermal BL and thus the convective heat transport are strongly influenced by the turbulent large-scale convection (LSC). By means of *Ultrasound Localization Microscopy* (ULM) of near-wall velocities and high-resolution temperature measurements using fiber optic sensors, the interaction between BL's and LSC will be investigated in detail for the first time in liquid metal laboratory experiments. This parameter range has so far been inaccessible by direct numerical simulations. The experiments, in which near-wall temperatures and flow velocities are measured in liquid metals with high resolution, set a new milestone for the understanding of convective transport processes in fluids at small Pr with their numerous applications in geo- and astrophysical flows as well as in engineering systems.

Period: 04/2023 – 03/2026

Partner: Dr. S. Eckert, Dr. T. Vogt, Helmholtz-Zentrum Dresden-Rossendorf



Super-resolution vector flow imaging of a recirculation area in a liquid metal convection.



Projected convection experiment for thermal and viscose boundary layer measurements.

D. Weik, L. Grüter, D. Räbiger, S. Singh, T. Vogt, S. Eckert, J.W. Czarske, L. Büttner, „Ultrasound Localization Microscopy in Liquid Metal Flows", Applied Sciences 12.9, 4517, 2022.

D. Weik, L. Grüter, D. Räbiger, S. Singh, T. Vogt, S. Eckert, J.W. Czarske, "Ultrasound Localization Microscopy by Nonlinear Adaptive Beamforming – a Case Study for Super-Resolved Flow Fields in Liquid Metal Experiments", 2022 IEEE International Ultrasonics Symposium (IUS), Oct. 2022.

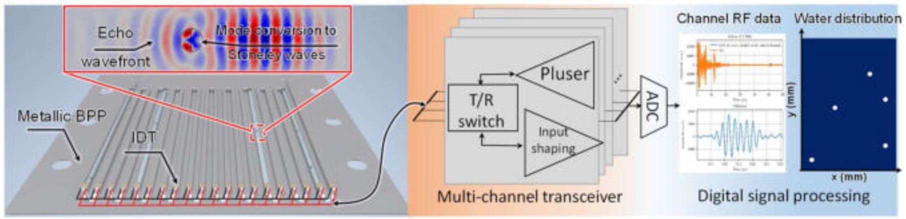
AIF **Monitoring the water content in polymer electrolyte membrane fuel cells using surface acoustic waves**

Staff: Z. Dou, D. Weik, L. Büttner, J.W. Czarske

Aim: Optimizing water management is crucial for enhancing the lifespan and efficiency of low-temperature polymer electrolyte membrane fuel cells (NT-PEMFCs). Current methods for assessing water balance are expensive, complex, and lack real-time monitoring capabilities. In our research project, we're investigating a cost-effective method to detect water distribution with high temporal and spatial resolution during NT-PEMFC operation.
Our novel approach relies on measuring changes in the propagation properties of surface waves in the fuel cell when droplets are present in the channel. This enables us to detect the position and quantity of water droplets within the channel. By employing interdigital transducers across multiple transmission paths, we can deduce water distribution within the cell. This method has the potential to be cost-effective and widely applicable in NT-PEMFCs with metallic bipolar plates.
The collaborative project involves TU Dresden, ZBT, and IFW, aiming to develop a functional demonstratror for measuring water coverage on a fuel cell up to TRL 4. This includes the development of highly integrated ultrasonic transducers in the complex fuel cell system, along with validation and calibration processes. The practical relevance of the project will be demonstrated by applying the method in an operational fuel cell.
The diversity of companies in the project advisory committee highlights the project's promise for small and medium-sized enterprises. Significant advancements are expected in areas such as sensor technology, bipolar plate optimization, and fuel cell design. Given the high integration of components, close collaboration within the industry is essential, with the project advisory committee serving as an ideal platform for fostering partnerships and knowledge exchange.

Period: 12/2023 – 5/2026

Partner: ZBT Duisburg, Dr. L. Tropf, Dr. V. Lukasek
IFW Dresden, Dr. H. Schmidt



Schematic of the proposed measurement system. Pulse-echo-localization of water droplets is condected by means of surface acoustic waves and a transducer array.

Z. Dou, B. Fang, L. Tropf, H. Hoster, H. Schmidt, J.W. Czarske and D. Weik, "A Water Monitoring System for Proton Exchange Membrane Fuel cells Based on Ultrasonic Lamb Waves: An Ex-situ Proof of Concept", IEEE Transactions on Instrumentation and Measurement 72 (2023), 9601112

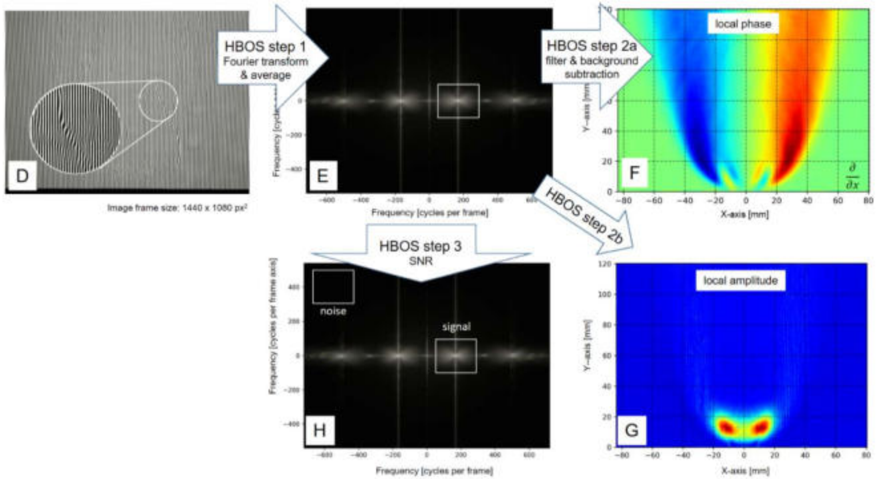
DFG **High-speed 4D measurement of thermoacoustic oscillations**

Staff: J. Gürtler, R. Kuschmierz, J.W. Czarske

Aim: During the combustion of sustainable fuels, such as green hydrogen for stationary gas turbines, instabilities occur in the form of thermoacoustic oscillations. To ensure safe and efficient turbine operation, a deeper understanding of these oscillations is necessary.
For this purpose, scientists from the Chair of Measurement and Sensor Systems Engineering at TU Dresden and the Institute of Thermal Turbomachinery and Machine Dynamics at TU Graz want to develop and apply new measurement and evaluation techniques. Using modern high-speed camera technology and deep learning based tomographic reconstruction.
The aim of the project is to perform laser-optical measurements inside such oscillating flames, with high demands on the measurement technology due to the necessary spatial (3D, ≤ 500 µm³) and temporal (≤ 10 µs) resolutions. The cooperation project is funded by the Deutsche Forschungsgemeinschaft (DFG) as well as the Austrian Science Fund (FWF) under the project numbers CZ 55/50-1 and I 5392-N.

Period: 11/2022 – 12/2026

Partner: TU Graz, Prof. Woisetschläger



Heterodyne Background Oriented Schlieren measurement of a swirl stabilized flame based on Fourier domain.

Greiffenhagen, F., Woisetschläger, J., Gürtler, J., Czarske, J., „Quantitative measurement of density fluctuations with a full-field laser interferometric vibrometer“. In: Exp. Fluids 61.1 (2020), S. 9. doi: 10.1007/s00348-019-2842-y.

Gürtler, J., Greiffenhagen, F., Woisetschläger, J., Kuschmierz, R., Czarske, J., „Seedingless measurement of density fluctuations and flow velocity using high-speed holographic interferometry in a swirl-stabilized flame“. In: Opt. Lasers Eng. 139.September (2021), S. 106481. doi: 10.1016/j.optlaseng.2020.106481.

Tasmany, S., Kaiser, D., Woisetschläger, J., Gürtler, J., Kuschmierz, R., Czarske, J., “Heterodyne background-oriented schlieren for the measurement of thermoacoustic oscillations in flames.” Exp Fluids 65, 151 (2024)

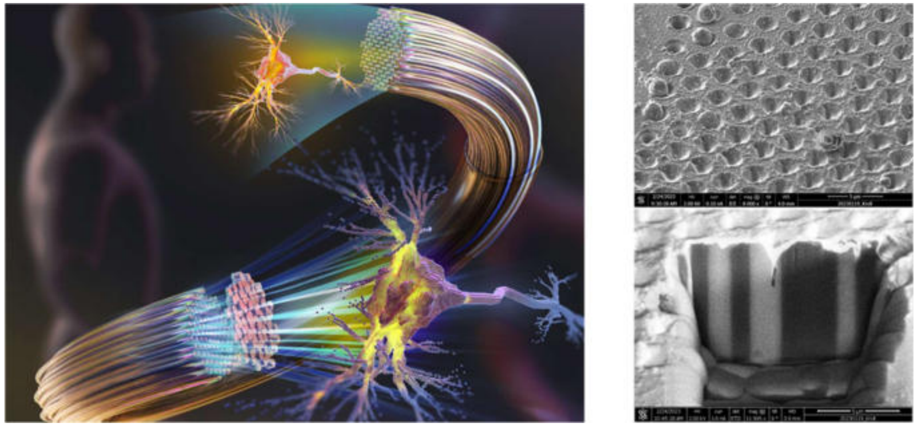
EFRE/SAB Minimally invasive fiber endoscopy using laser structured waveguides

Staff: K. Zolnacz, R. Kuschmierz, J.W. Czarske

Aim: The thinnest and simplest endoscopes can be realized based on image waveguides (CFBs). Research is currently underway worldwide on CFB endoscopes without complex imaging optics in the measuring head. As a result, the endoscope diameter is only limited to <500 µm by the fiber diameter. However, strong and different aberrations (phase disturbances) occur for each CFB. Transmission of light through CFBs. With conventional endoscopes, only the light intensity can be controlled evaluated, the important phase information is lost. But this only includes 2D recordings fixed image plane and a few 1,000-100,000 pixels possible. The most studied approach for an unpixelated 3D imaging consists of measuring the aberrations of the CFB and their compensation (DOPC, digital optical phase conjugation) using programmable, digital, optical Area light modulators. This enabled impressive and relevant applications to be demonstrated will, among other things, Fluorescence microscopy, 2-photon microscopy, CARS, cell ablation, single cell rotation and -Tomography. However, the structures presented are extremely complex, expensive and sensitive compared to misalignment, so that they do not yet make their way out of the optics laboratory and into realistic ones Conditions of application have been found.

The aim is to expand commercial image waveguide components for the pure transmission of images (i.e. the light intensity) to components for the transmission of the complete light information from light intensity and light phase. For the first time, this should not be done with digital modulators, but with advances be used in optical manufacturing technology. The realized fibers are monolithic and therefore robust. They can therefore be used by a wide range of users and can be integrated into existing microscopes insert to expand their range of applications from ex vitro to in vivo, for example for minimally invasive and label-free histopathology in the brain.

Period: 10/2023 – 12/2024



Left: Sketch of a Holographic 3D fiber bundle endoscope. A diffractive optical element is used to compensate the inherent phase scrambling of the fiber. Right: SEM image of a fiber facette after laserablation for DOE manufacturing.

K. Zolnacz, R. Stephan, J. Dremel, K. Hausmann, M. Liessmann, M. Steinke, J.W. Czarske, R. Kuschmierz, „Multicore fiber with thermally expanded cores for increased collection efficiency in endoscopic imaging," Light Advanced Manufacturing 49 (2024)

SAB Optical inspection for the Scala Tympani for 3D real-time acquisition (OPTISCALA)

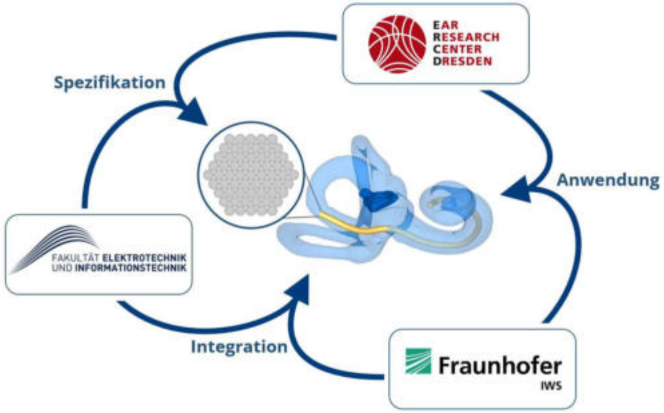
Staff: J. Dremel, R. Kuschmierz, J.W. Czarske

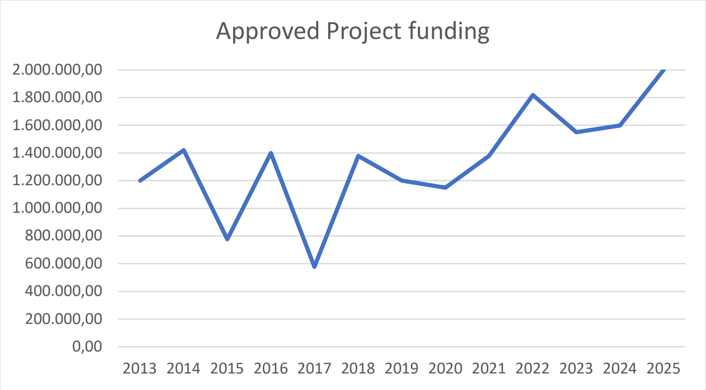
Aim: *The development of an innovative, optical, fiber-based procedure for minimally invasive 3D real-time detection of intracochlear structures*

This procedure should enable automated CI-ET insertion into the Scala tympani under direct vision and with AI-supported real-time position correction of the electrode for the first time in the future. The sensitivity and specificity in the detection of cochlear trauma and ET malpositions should be significantly increased and their absolute occurrence significantly reduced. The proposed project aims to develop and test a multi-core fiber probe (10,000 cores, total diameter of the fiber bundle incl. attachment: 450µm) for support and 3D imaging during the insertion of implant insertion. Such small and flexible endoscopes are currently not available. The imaging probe is based on lenless holographic fiber imaging and to be tested in an additively manufactured model of the human cochlea as well as in a human temporal bone.

Partner: Prof. Dr. T. Zahnert & Dr. C. Müller, Ear Research Center Dresden
Prof. Dr. P. Hartmann & Dr. J. Golde, Fraunhofer AZOM Zwickau

Period: Q2/2024 – Q2/2027





Project volume based on fundamental research (DFG, etc.), applied research (BMBF, SAB, AiF/ZIM) and industry projects

Dr.-Ing. David Weik

"Computational Ultrasound using Nonlinear Beamforming and Compressive Waveguides towards Superresolution Imaging"

Abstract:
Liquid metal convection is integral to numerous natural and industrial processes. This includes the Earth's dynamo effect as well as solutions for a renewable energy infrastructure such as solar thermal power plants and liquid metal batteries. Despite its importance, the complex behavior of liquid metal convection, such as the formation of large coherent flow structures and the dynamics of heat and momentum transport, remains not fully understood. Investigations in this field are conducted in magnetohydrodynamics (MHDs) by lab-scale experiments of low-melting-point alloys. Wherat, turbulent convection flow is a process challenging to measure, as it requires high temporal resolution > 10 Hz for the dynamics and high spatial resolution < 1 mm for the small-scale structures in the opaque liquid.
This dissertation investigates ultrasound imaging techniques to advance open questions in this field. Based on adaptive sound fields, a computational ultrasound imaging system is proposed that incorporates three main approaches. For obtaining temporal resolved data, the method of ultrasound image velocimetry (UIV) was investigated. As demonstrated in a convection experiment, the measurement system with UIV enables the decomposition of for liquid metal characteristic oscillations, which directly allow to validate fluid dynamic scaling laws from theory and simulation.
The UIV velocity vectors cannot be resolved arbitrarily small due to a required minimum size of the interrogation areas. The method of ultrasound localization microscopy (ULM) is able to overcome this restraint to further enhance the spatial resolution, which was firstly transferred to magnetohydrodynamic (MHD) studies in this work. The system using ULM is able to measure vector flow maps with a spatial resolution of up to 188 µm, which is a 40-fold improvement over state-of-the art used single probes and a 20-fold improvement over UIV. As an outcome, ULM enables the experimental observation of the recirculation area and flow velocities within the viscous boundary layer, regions, which were not yet quantified by any other instrumentation effort.
Adaptive ultrasound imaging methods are limited for long term measurements or when enhanced to volumetric imaging by an extremely large amount of data. In this work, a novel compression technique called external angle-dependent resonator (EAR) was investigated. This method uses compressive multimode waveguides, where the spatial information of an approaching echo is coded onto the temporal signal that can be received by a single element. A demonstration of effective target tracking was given with only 1.5 % of the data used, compared to a typical transducer array. The EAR technique is promising for cost-effective volumetric imaging solutions and innovative probe designs, potentially applied in long-term flow studies and industrial applications.
This dissertation incorporates significant advancements in ultrasound imaging for state-of the art and future MHD flow studies. Furthermore, the investigated compression technique can enhance the application of volumetric medical imaging by using only a few receiving elements.

Date of defense: 26.02.2025

Chairman: Prof. Dr.-Ing. habil. Ercan Altinsoy
Reviewers: Prof. h. c. Prof. Dr.-Ing. habil. J.W. Czarske
Prof. Dr. Georg Schmitz

Examination: apl. Prof. Dr. rer. nat. et Ing. habil. Elfgard Kühnicke
Prof. Dr.-Ing. habil. Prof. h. c. J.W. Czarske

Prof. Czarske, Dr. Weik, Prof. Schmitz (digital), Prof. Kühnicke (digital), Prof. Altinsoy (from left)

Gathering of MST chair members and further guests

Dr. Weik

Dr.-Ing. Benedikt Krug

“Investigation of impulsively stimulated Brillouin microscopy for non-contact measurement of mechanical properties in biomedical samples”

Abstract:
Mechanische Messgrößen spielen eine immer wichtigere Rolle in der Biomedizin, insbesondere bei der Zellentwicklung und für die Diagnostik. In dieser Arbeit wird die Bedeutung mechanischer Messgrößen in der Biomedizin hervorgehoben, insbesondere deren Rolle in der Zellentwicklung und Diagnostik. Die Erfassung dieser Größen stellt jedoch eine Herausforderung dar, da viele etablierte Verfahren die Anforderungen der Biomedizin, wie hohe räumlicher Auflösung und Kompatibilität mit den Proben, nicht erfüllen können. %Die Erfassung dieser Größen stellt jedoch eine Herausforderung dar, da viele etablierte Verfahren den Anforderungen der Biomedizin nicht genügen. %Rein optische Verfahren, wie die spontane Brillouin-Mikroskopie, sind vielversprechend, da sie kontaktlose Messungen mit hoher räumlicher Auflösung ermöglichen, ohne die Proben zu modifizieren, haben jedoch Herausforderungen in der zeitlichen Auflösung. Rein optische Verfahren, wie die spontane Brillouin"=Mikroskopie, sind vielversprechend, da sie kontaktlose Messungen mit subzellulärer Auflösung ermöglichen, ohne die Proben zu modifizieren, haben jedoch mit einer langen Punktmessdauer ($\sim$ \SI{200}{ms}) Herausforderungen in der zeitlichen Auflösung. Die impulsiv stimulierte Brillouin"=Mikroskopie (ISBM) stellt eine Weiterentwicklung in Richtung aktiver Anregung dar und verspricht die genannten Vorteile der optischen Verfahren mit kürzeren Messdauern zu vereinen. Durch die Überlagerung von Ultrakurzpuls"=Laserstrahlen wird ein Interferenzstreifenmuster erzeugt. Dieses Muster führt zu Bildung stehender akustischer Wellen, die sowohl die Dichte als auch den Brechungsindex des Materials modulieren. Die Messung erfolgt kontaktlos durch einen Ausleselaser und ermöglicht die Erfassung des longitudinalen Moduls. Die Arbeit bietet einen umfassenden Überblick über den Stand der Technik und untersucht die Anwendbarkeit der ISBM in der Biomedizin. Die Designentscheidungen für das Messsystem werden erläutert und die Funktionalität wird anhand der proportionalen Brillouin-Frequenzverschiebungen bei Messungen an Proben mit bekannten Eigenschaften nachgewiesen. Im Weiteren erfolgt die Untersuchung von Kernparameter wie: Mittelungsanzahl, Ausleselaserleistung, Anregepulsenergie, Pulslänge, Repetitionsrate und Messvolumengröße. Aus dieser ergeben sich Erkenntnisse über den Parameterraum, in dem das Messsystem für verschiedene Anwendungen ausgelegt und angepasst werden kann. Beispielsweise wird die Verkleinerung des Messvolumens auf \SI{10}{\micro m} x \SI{23}{\micro m} x \SI{230}{\micro m} demonstriert, somit erreicht die laterale räumliche Auflösung die Größe einzelner Zellen. Durch Referenzmessungen am biologischen Modellmaterial Polyacrylamid"=Hydrogel konnte die biomedizinische Tauglichkeit des Messsystems gezeigt werden. Es wird eine relative Unsicherheit der Brillouinfrequenz von \SI{0.5}{\%} bei einer Messdauer von \SI{0.8}{ms} ermittelt, was einer deutlichen Reduktion der Punktmessdauer im Vergleich mit etablierten Verfahren entspricht. Das Alleinstellungsmerkmal der Schallausbreitung in lateraler Richtung eröffnet neue Möglichkeiten zur Erfassung von Anisotropie in biologischen Proben und ist Teil des möglichen Entwicklungspfads der ISBM. Das Haupteinsatzgebiet von ISBM sind Anwendungen, welche hohe Anforderungen an die zeitliche Auflösung stellen. Zukünftig sollte auf einen breiteren Einsatz der Technik in der Biomedizin durch eine Reduktion der technischen Einstiegshürden hingearbeitet werden. Zukünftige Arbeiten sollten auf die

breitere Anwendung der Technik in der Biomedizin hinarbeiten und die technischen Einstiegshürden für Anwender senken. Die ISBM-Technik ist vielversprechend für Anwendungen, welche eine hohe Anforderung an die zeitliche Auflösung haben, wie die Durchflusszytometrie.

Date of defense: 08.07.2025

Chairman:	Prof. Dr.-Ing. Hagen Malberg
Reviewers:	Prof. Prof. h. c. Dr. J.W. Czarske
	Prof. Dr. Oliver Otto
Further member:	Prof. Dr. Uwe Hampel
Examination:	Prof. Dr.-Ing. Hagen Malberg
	Prof. Dr.-Ing. Dr.-Ing. habil. J.W. Czarske


Prof. Czarske, Dr. Krug, Prof. Malberg (from left)

Prof. Czarske, Dr. Krug

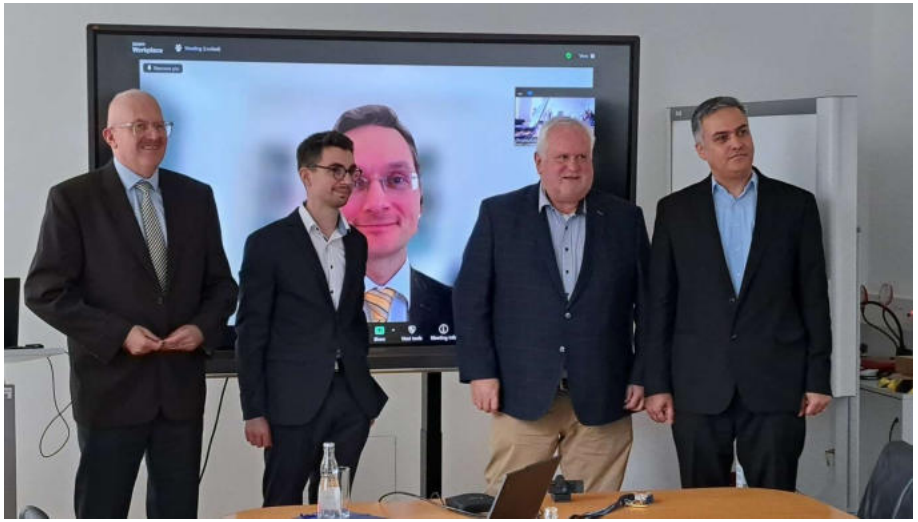
Dr.-Ing. Clemens Matthias Bilsing

„3D-Lokalisierungsmikroskopie mit adaptiv-optischer Echtzeitkorrektur für mikrofluidische Mehrphasenströmungen“

Microscopic multiphase flows play an important role in many technical applications as for instance the water management of fuel cells, the production of hydrogen with electrolyzers or in biochemical microreactors. Nonetheless, the behavior of multiphase flows is still not well understood which manifests in a lack of models for the optimization of many technical processes. One reason for this is the difficulty to conduct flow measurements in such multiphase flows, which is mainly caused by the low optical accessibility, the strong three-dimensional character of the flow field, the microscopic dimensions of the flow structures as well as the comparatively fast dynamics of the flow phenomena with frequencies up to several hundred Hertz. Temporally varying liquid-gas interfaces are often the only optical access for many flows on opaque substrates. However, because of the temporally varying refraction of light, optical imaging through fluctuating interfaces introduces dynamical aberrations that increase the measurement uncertainty. In this thesis, methods were investigated to address these challenges using the inner flow of sessile drops in a gaseous shear flow as a representative case study. The presented solution is a combination of three-dimensional localization microscopy with adaptive optics. The microscopy system is based on the Double-Helix Point Spread Function and allows the three-dimensional localization of particles with a single optical access. It was found that its random axial position uncertainty of 0,072 % is smaller by a factor of 3 compared to similar measurement techniques. Using this method, three-dimensional flow measurements inside oscillating drops were conducted for the first time, initially with acrylic glass serving as the substrate. Thus, it was shown for the first time that two counter-rotating vortex tubes form in the drop, one at the windward side and one at the leeward side. Each vortex tube corresponds to one double vortex whose size depends on the Reynolds number. Furthermore, the complete spatial structure of the flow reversal inside the drop was revealed. The already studied strong upstream motion in the center of the drop is accompanied by a previously unknown strong downstream motion at the lateral part of the drop. Additionally, the periodic flow fields corresponding to the first and second drop eigenmodes were measured experimentally for the first time. In order to measure the inner flow of drops on opaque substrates through their fluctuating liquid-gas surface, an adaptive-optical system was investigated that corrects the adverse effects of the oscillating interface in real time. It consists of a deformable mirror, a Hartmann-Shack wavefront sensor and an electronic control unit. The correction performance of the adaptive-optical system was characterized with immobilized particles that sticked to the substrate inside a drop. Their lateral position uncertainty increased by 270 % as a result of the fluctuating interface. It was found that the real-time correction can decrease this additional uncertainty by 28,3 % for all frequencies and by 58,5 % up to the first drop eigenfrequency. This technique allowed it for the first time to measure the flow inside a drop on an opaque substrate solely through its fluctuating surface while correcting the influence of the oscillating liquid-gas interface. It was found that the temporally varying refraction at the drop surface causes a systematic underestimation of the flow magnitude corresponding to the first drop eigenmode. This occurs because the inner flow of the drop and its surface motion are coupled, which indicates that a similar behavior might also exist for higher eigenmodes. The adaptive-optical system corrected this systematic error successfully. As a result, the measured signal power corresponding to the first eigenmode was ca. 70 % larger with correction than without. The fluid mechanical findings of this thesis can contribute to more precise models for predicting the motion of drops. Prospectively, the insights gained about the investigated measurement technique could also be employed to measure in similar multiphase flows such as film flows or hydrogen bubbles. The three-dimensional measurement of microscopic multiphase flows through a single fluctuating liquid-gas interface offers the potential to access flows where currently measurements are difficult or not feasible. Thus, the investigations in this work could contribute to a technological leap that makes it possible to find a variety of new phenomena.

Date of defense: 25.08.2025

Chairman:	Prof. Dr.-Ing. Kambiz Jamshidi
Reviewers:	Prof. Dr. Ing. habil. Prof. h c. J.W. Czarske
	Prof. Dr. Ing. habil. Andreas Fischer (Universität Bremen)
Further member:	Prof. Dr.-Ing. Hubert Lakner (TU Dresden)
Examination:	Prof. Dr.-Ing. Hubert Lakner
	Prof. Dr. J.W. Czarske


Prof. Czarske, Dr. Bilsing, Prof. Fischer (digital), Prof. Lakner, Prof. Jamshidi, (from left)


Dr. Bilsing

Dr.-Ing. Q. Zhang

"Seeing through disorder in multimode fibers via physics-informed deep learning towards information transmission"

With the accelerating digital transformation, driven by emerging technologies such as the Internet of Things, 6G, edge computing, and autonomous vehicles, the demand for dense, low-latency data exchange continues to surge. As the backbone of the modern internet, single-mode fiber networks are approaching their theoretical capacity limits, which has intensified the research for next-generation technologies capable of meeting the ever-growing bandwidth requirements of individuals, enterprises, and public authorities. Space-division multiplexing using multimode fibers has emerged as a promising technique offering significantly enhanced data throughput. However, the use of multimode fibers introduces modal crosstalk due to complex transmission behavior within the parallel channels. Accessing the exact modal amplitude and phase weights via mode decomposition enables a full understanding of fiber transmission behavior and facilitates precise control of light propagation, enabling high-dimensional information transmission over optical fibers without distortion. Nevertheless, achieving fast, simple, and scalable mode decomposition remains a significant challenge.

This dissertation presents a comprehensive investigation of artificial intelligence (AI)–based approaches for characterization of optical field in multimode fibers using pure intensity measurements towards high-dimensional information transmission. By integrating AI algorithms with photonics, three strategies are proposed to achieve accurate, scalable, and real-time mode decomposition. The data-driven approach incorporates physical constraints into the training data, enabling accurate mode decomposition up to 910 Hz on 23 modes, which can be applied for fast and reference-free calibration of multimode fibers. Unlike data-driven models, physics-informed models integrate physical priors directly into the optimization process, allowing decomposition of hundreds to over one thousand modes. Furthermore, a hybrid pre-training approach combining data-driven and physics-informed strategies can further improve decomposition accuracy and robustness. These numerical models demonstrate strong generalizability, operating effectively over fiber lengths ranging from 1 meter to 1 kilometer. For physics-in-network models, optical diffractive neural networks are digitally trained and physically implemented, enabling mode decomposition at the speed of light. Thanks to the tailored training process, optical diffractive neural networks are capable of extracting both amplitude and phase weights.

These achievements in reference-less characterization and real-time demultiplexing of multimode fibers are expected to boost optical communication and high-dimensional quantum communication. Furthermore, these techniques are anticipated to broaden their impact across a range of applications, including integrated photonic devices, fiber sensing, computational endoscopic imaging, optical computing, and reservoir computing.

Date of defense: 22.09.2025

Chairman:	Prof. Dr.-Ing. Rafael Felix Schaefer
Reviewers:	Prof. Dr. Ing. habil. Prof. h. c. J. W. Czarske Prof. Dr. Min Gu (University of Shanghai for Science and Technology) Jun. Prof. Dr. Mario Chemnitz (FSU Jena)
Further member:	Prof. Dr. Björn Andres
Examination:	Prof. Dr. Björn Andres Prof. Dr. Ing. habil. J. W. Czarske

Prof. Chemnitz, Prof. Wu (digital), Dr. Zhang, Prof. Czarske, Prof. Schaefer (from left)

Dr. Zhang

Dr.-Ing. Zehua Dou

„Adaptive Ultrasound Imaging of Fluid Transport in Green Hydrogen Energy Systems"

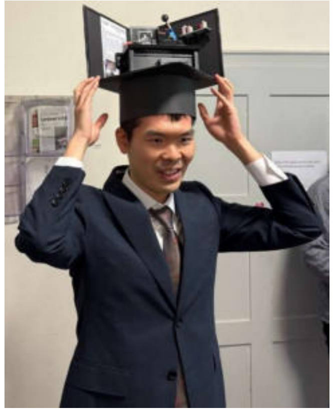
Green hydrogen energy presents a promising but far-reachable future in the era of climate change. The energy losses in state-of-the-art water electrolyzers and fuel cells due to gas/liquid transport pose one of the most critical challenges hindering cost effective green hydrogen energy. Analytical technologies for understanding the gas/liquid transport in operating electrolyzers and fuel cells are therefore greatly demanded. However, available analytical tools either exhibit serious drawbacks regarding costs and ease of access, or compromised by the spatial resolutions and the penetration depths. Aiming for addressing these drawbacks, this dissertation investigates different suitable high-resolution ultrasonic measurement techniques, dedicated for enriching the knowledge of gas/liquid transport on the different heterogenous scales in practical water electrolyzers and fuel cells, ranging from 100's µm in the electrodes to 100's mm in the flow field.
First, volumetric scanning acoustic microscopy (SAM) imaging for quantifying gas/liquid transport in the porous electrodes of water electrolyzers was investigated. Volumetric images of technically relevant porous Nickel electrodes were acquired in a test cell during alkaline water electrolysis. Scanning the focal zone of a high frequency spherically focused ultrasound beam over the imaging volume, high spatial resolutions of 10's µm were achieved with an imaging speed of 180 s in a volume of 30 mm × 30 mm × 1.185 mm. Such high resolution allowed for visualizing the electrolysis produced bubbles in the electrodes, and quantifying their volumes, which are directly related to the efficiency loss. SAM imaging revealed significant insights into the influences of electrodes' configurations, cell design and operating conditions to the electrolysis performance, guiding the developments of future optimal electrolyzers.
Aiming for real-time volumetric ultrasound imaging in large volumes, an acoustic hologram based compressive imaging scheme was investigated. In short, each volumetric image was encoded as a unique time signal, using spatiotemporally scrambled acoustic fields transmitted and received by a single transducer equipped with a phase encoding mask. With a prior knowledge on such scrambled acoustic fields, the volumetric images were then reconstructed with a matched filter based so-call time reversal approach. This scheme drastically increases

the temporal resolution by several orders of magnitude over the SAM imaging. High spatial resolutions down to the diffraction limit can be achieved with rationally designed phase masks. Ultrasonic guided waves (UGWs) echo localization-based techniques were investigated for monitoring the water droplets and gas bubbles in the entire flow fields of large scale electrolyzers and fuel cells. To conform with their unique flow field structures and working environment, Lamb waves and Scholte waves were explored, respectively. UGWs propagating along the flow channels were excited by ultrasonic transducers mounted from the back side of the bipolar plates (BPPs), out of the flow fields, using a regular medical ultrasound imaging like instrumentation. The UGWs are scattered by any presences of water droplets or gas bubbles in the flow channels. With the knowledge of UGWs' propagation velocities, droplets as small as 50 nL and tiny bubbles with diameters of 150 µm were accurately echo-localized with errors less than 500 µm. In R&D scale BPPs, high spatiotemporal resolutions at sub-millimeter and millisecond levels were simultaneously achieved. Meanwhile, the flow regimes ranging from droplet/bubbly flows to slug/plug flows were able to be determined by the echo intensities.
Ultrasonic measurement techniques enable high-performance imaging and monitoring of gas/liquid transport in electrolyzers and fuel cells using affordable and accessible instrumentations and on a regular laboratory base. Such quantitative knowledge provides important insights into developing more efficient and reliable electrolyzers and fuel cells, which may eventually pave the way for a wide range applications of green hydrogen energy.

Date of defense: 06.10.2025

Chairman:	Prof. Dr.-Ing. Peter Birkholz
Reviewers:	Prof. Dr. Ing. habil. Prof. h.c. J. W. Czarske
	Prof. Dr. Stefan Rupitsch (Universität Freiburg)
	Prof. Dr. Kerstin Eckert
Examination:	Prof. Dr. Ing. habil. Prof. h.c. J.W. Czarske
	Prof. Dr. Andreas Richter

Prof. Birkholz, Prof. Rupitsch (digital), Dr. Dou, Prof. Czarske, Prof. Eckert (from left)



Dr. Dou

Diploma and Master Theses

Leon Stiffel „Optische Vermessung von Flammen und tomografische Rekonstruktion durch Neuronale Netze mit physikalischer Verlustfunktion", 01/25.

Vireak Dam "Reinforcement Learning based Adaptive Optics for Axial Scanning and Aberration Correction", 03/25.

Jie Zhang, "Illumination scanning tomography towards label-free 3D imaging of organoids" 03/25.

Jingchun Hua, "Unsupervised fiber imaging enhancement using physics-based autoencoders", 04/25.

Zixuan Cai, "Diffuser-based fiber endoscopy with end-to-end optimization by physic-informed neural networks", 04/25.

Eric Lischinski, "Einsatz von Generative Adversarial Networks (GAN) zur Verbesserung der semantischen Segmentierung landwirtschaftlicher Referenzparzellen auf Basis digitaler Orthophotos (DOP)", 05/25.

Veronika Volkova „Characterization of thermally modified multi-core fibers", 05/25.

Bowen Yang, „Reference-less digital optical phase conjugation for multimode fibers", 06/25

Diksha Avhad "Development of a USB3 Vision infrastructure for a firmware IP to transfer images to generic USB3 Vision application", 07/25.

Xiaocheng Liang, "Physics-based noise modeling and denoising for fiber endoscopy using deep learning", 07/25.

Felix Wahler, "Deep learning-based imaging modality transformation for fiber endoscopy", 08/25.

Yuezhen Xu, ''Compressive 4D Ultrasound Imaging using a Single Element Transducer'', 10/25.

Konrad Ließ, ‘‘Physics model of multimode waveguide-based ultrasound imaging in hot melts’’, 11/25.

Wuming Zheng, "Predicting Optical Forces on Arbitrarily Shaped Organoids Using Deep Learning", 12/25.

Bachelor and Student Theses - 2025

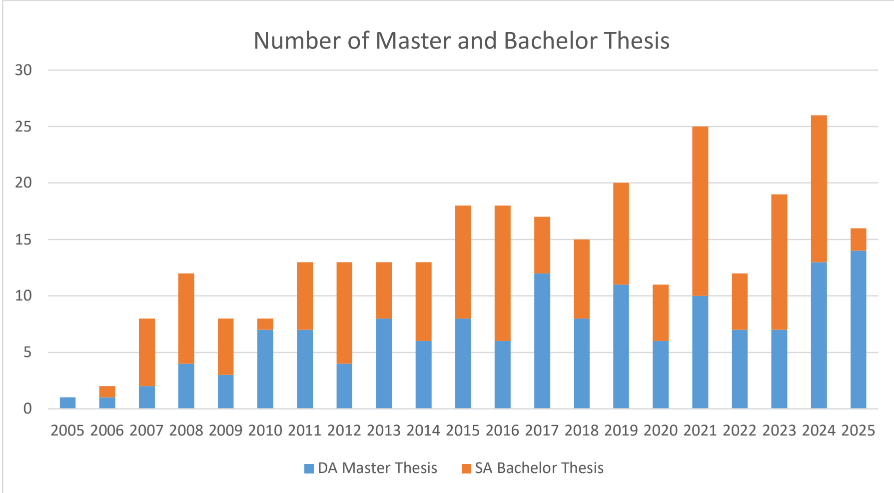
Xiaocheng Liang "Physics-based noise modeling and denoising for fiber endoscopy using deep learning",

Soumya Gilroy Mampallil, "Optical computing for multimode fiber phase retrieval using phase to intensity encoding", Project work (nanoelectronic systems), 09/25.

Felix Wahler, BA "Deep learning-based imaging modality transformation for fiber endoscopy ", 08/25.

Shiyue Chen "All-in-One Diffractive Neural Networks for Multidimensional Optical Input Processing" 10/25.

Jialong Zhang, ''Compressive Ultrasonic Sensing Through Stochastic Open Cell Foam Materials'', 11/25.



Total in 21 years: over 300 Theses (131 Bachelor Theses (SA), 141 Master Theses (DA), over 30 PhD)

PUBLICATIONS AND TALKS

SCI-Publications in journals with peer review process

D. Krause, L. Liebig, J. Böhm, N. Koukourakis, J.W. Czarske, "Single-shot impulsive stimulated Brillouin microscopy by tailored ultrashort pulses", Journal of the European Optical Society Rapid Publications, 2025.

C. Bilsing, U. Janoske, J.W. Czarske, L. Büttner, S. Burgmann, "3D-3C Measurements of Flow Reversal in Small Sessile Drops in Shear Flow", International Journal of Multiphase Flow 182, 105017, 01.2025.

C. Pan, T. Wang, J. Fan, Z. Jin, H. Luo, J.W. Czarske, R. Kuschmierz, X. Li, K. Kosiba, "Machine learning-assisted fabrication for CoCrNi-TiCx composite coatings: process parameters, microstructure and properties", Ceramics International, 2025.

Q. Zhang, Y. Zhang, and J. W. Czarske, "FPGA-accelerated mode decomposition for multimode fiber-based communication", Light: Advanced Manufacturing, 2025.

J. Dremel, E. Scharf, S. Richter, J. W. Czarske, R. Kuschmierz, "Lensless single-shot multicore fiber endomicroscopy using a single multispectral hologram", Light: Advanced Manufacturing, 2025.

P.-H. Lin, P. Nowitzki, E. A. Jorswieck, D. Pohle, J. W. Czarske, "Secret Key Generation over Multi-Mode Fiber: Channel Measurements, Key Rate Analysis, and System Implementation", IEEE Open Journal of the Communications Society, 2025.

...., D. Krause, N. Koukourakis, J.W. Czarske, ..., "Consensus Statement on Brillouin Light Scattering Microscopy of Biological Materials", Consensus Statement, Nature Photonics, 2025.

Z. Chen, J. Sun, X. Yang, X. Ye, B. Zhao, X. Li, J. W. Czarske, "Diffusion-driven lensless fiber endomicroscopic quantitative phase imaging towards digital pathology", Advanced Imaging, 2025.

R. Stephan, E. Scharf, K. Zolnacz, W. Urbanczyk, K. Hausmann, M. Ließmann, J. Gürtler, T. Glosemeyer, J.W. Czarske, M. Steinke, R. Kuschmierz, "Bendable Fiber Lens for Minimally Invasive Endoscopy". Laser Photonics Rev., 2401757, 2025.

A. Bashkatov, F. Bürkle, Ç. Demirkır, W. Ding, V. Sanjay, A. Babich, X. Yang, G. Mutschke, J. W. Czarske, D. Lohse, D. Krug, L. Büttner, K. Eckert, "Electrolyte droplet spraying in H2 bubbles during water electrolysis under normal and microgravity conditions", Nature Communications 16, 4580, 2025.

R. Maestri, C. Bilsing, L. Büttner, J.W. Czarske, U. Hampel, G. Lecrivain, "Experimental investigation of aerosol separation in a rising Taylor bubble", Journal of Aerosol Science, 2025.

S. Shi, X. Li, Y. Wu, R. Kuschmierz, X. Yin and J. W. Czarske, "Investigation and modeling of the uncertainty in laser-Doppler-velocimeter-based radius measurement", Measurement Science and Technology,2025.

S. Tasmany, J. Woisetschläger, J. Gürtler, R. Kuschmierz, J. W. Czarske, "Reconstruction of refractive index gradients in a reactive turbulent flow based on U-Net supervised reconstruction toward the investigation of thermoacoustic oscillations", Opt. Eng. 64(9), 094107, 2025.

T. Glosemeyer, Y. Ma, R. Kuschmierz, J. Wu, L. Cao, J. W. Czarske, „Real-time physics-informed neural network images reconstruction for a see-through camera via an AR lightguide", Advanced Imaging, 2025.

F. Wang, J. W. Czarske, and G. Situ, "Deep learning for computational imaging: from data-driven to physics-enhanced approaches", Advanced Photonics, 2025.

T. Wollmann, R. Baumann, J. Lich, E. Kunze, R. Kuschmierz, M. Gude, A. F. Lasagni, and J.W. Czarske, "Laser-based application of diffraction grating sensors for full-field strain measurements during the manufacturing process of a composite structure," Materials Letters 139681, 2025.

F. Bürkle, R. Maestri, G. Lecrivain, U. Hampel, L. Büttner, J.W. Czarske, "Investigation of the gas and film flow of Taylor bubble in a tube with a short constriction employing 3D particle tracking". Experimental and Computational Multiphase Flow, 1-11, 2025.

Invited talks at conferences (with proceedings) and seminars (without proceedings)

J. W. Czarske, Q. Zhang, J. Sun, M. Yu, Digital holography and physics-informed neural networks for mode decomposition of multimode fibers towards classical and quantum communication, invited talk, at OPTO-SPIE Photonics West, 29 January 2025 • 3:00 PM - 3:30 PM PST | Moscone Center, Room 2006 (Level 2 West).

J.W. Czarske, T. Wang, J. Dremel, R. Kuschmierz, S Richter, W. Polanski, I. Eyüpoglu, O. Uckermann, Brain cancer diagnosis using lensbased multicore-fiber endoscopy with a learning-based digital twin, invited by F. Willomitzer, University of Arizona, 3. Feb. 2025.

J. Sun, X. Yang, D. Krause and J.W. Czarske, AI-driven fiber-optic cell rotation for tomographic imaging, invited talk at Optica Biophotonics, Coronado, USA, 20.-24.04.2025.

J.W. Czarske, J. Dremel, L. Buettner, Anniversary 20 years of MST and celebration of international year of quantum science and technology (official event of UNESCO), Dresden, 4 April 2025.

J.W. Czarske, J. Zhang, N. Koukourakis, J. Sun, "Quantitative Phase Imaging by Endomicroscopy exploiting Deep Holography towards Microelectronics and Biomedicine, World Interferometer Day to celebrate the anniversary of A Michelson" (invited by Prof. Manske and Prof. Osten), Ilmenau, 9 April 2025.

J.W. Czarske, Q. Zhang, J. Sun, M. Yu, L. Buettner, N. Koukourakis, "Intelligent Photonics for Information Processing in Biomedical Diagnostics and Fiber Communication", SIOM seminar, Shanghai, June 4, 2025

J.W. Czarske, T. Glosemeyer, Q. Zhang, R. Kuschmierz, "Theory-Trained Neural Networks for advancements of waveguide-based applications towards augmented reality (AR), fiber endomicroscopy and quantum fiber communication", Light Conference of Nature, Changchun, 9-13 June 2025.

J. Dremel, R. Kuschmierz, J. W. Czarske, "Multispectral holography for lensless single-shot 3D imaging in biomedicine using fiber endoscopy" (Invited Paper), 13573-6, SPIE Digital Optical Technologies, Munich, 23-26 June 2025.

J.W. Czarske, T. Glosemeyer, R. Kuschmierz, "Advancements for waveguide-based augmented reality (AR) and diffuser endomicroscopy by Theory-Trained Neural Networks" (Invited Paper), 13573-19, SPIE Digital Optical Technologies, Munich, 23-26 June 2025.

J.W. Czarske, T. Glosemeyer, R. Kuschmierz, Q. Zhang, J. Sun, B. Yang, "Theory-Trained Neural Networks for advancements of computational imaging in biomedicine and fiber communication", Keynote talk, Xi´an, Optics Frontier—The 16th International Conference on Information Optics and Photonics

(CIOP 2025), Sessions Optical Imaging, Display and Storage / Photonics for AI +AI for Photonics, 10-14 August, 2025.

J.W. Czarske, R. Wendland, J. Dremel, T. Wang, R. Kuschmierz, N. Koukourakis, J. Sun, Computational lensless 3D imaging for advancing biomedicine, SIBET, Suzhou, August 18, 2025.

J.W. Czarske, J. Dremel, T. Wang, R. Kuschmierz, N. Koukourakis, J. Sun, Computational 3D single-shot imaging with keyhole access for paradigm shifts in biomedicine and engineering, Nanjing, invited by Prof. Chao Zuo, August 19, 2025.

J.W. Czarske, L. Buettner, F. Schmieder, R. Wendland, N. Koukourakis, J. Sun, "Computational 3D single-shot imaging with keyhole access for paradigm shifts in biomedicine", SIOM seminar, Shanghai, invited by Fei Wang, August 20, 2025.

J.W. Czarske, "Modern laser metrology for advancements in manufacturing, flow engineering and biomedicine, Shanghai Institute of Laser Material Processing", invited by the general manager Prof Guohai Situ, August 21, 2025.

J.W. Czarske, J. Dremel, T. Glosemeyer, R. Kuschmierz, N. Koukourakis, J. Sun, L. Büttner, "Quantitative Phase Imaging by Lensless Endomicroscopy exploiting Deep Holography towards Biomedicine", Taichung City, Feng Chia University Taiwan, September 1, 2025.

J.W. Czarske, T. Glosemeyer, R. Kuschmierz, N. Koukourakis, J. Sun, "Physics-informed deep learning for paradigm shifts in biomedicine and engineering", NCKU, Taiwan, September 2, 2025.

J.W. Czarske, Q. Zhang, T. Glosemeyer, R. Kuschmierz, J. Dremel, "Intelligent Photonics for Information Processing in Biomedical Imaging and Fiber Communication", Plenary Speaker Invitation of Information Photonics 2025 to Information Photonics 2025 (IP2025) and conference, 3D Systems and Applications (3DSA), National Taiwan University, Taipei, Taiwan, September 3-4, 2025.

J. Dremel, T. Wang, T. Glosemeyer, R. Kuschmierz, J.W. Czarske, "Lensless single-shot imaging in biomedicine using fiber endoscopy", 19. Auswärtsseminar der Arbeitsgruppe Optische Technologien der Westsächsischen Hochschule Zwickau und des Fraunhofer-Anwendungszentrums, Schilbach, Germany, September 3-5, 2025.

J.W. Czarske, T. Wang, R. Kuschmierz, L. Buettner, F. Schmieder, "Intelligent Photonics, Deep Holography, and Phase Retrieval towards Biomedicine", Seminar for Medical Doctors, National Taiwan University, Taipei, Taiwan, September 4, 2025.

J.W. Czarske, J. Dremel, T. Glosemeyer, R. Kuschmierz, R. Wendland, F. Schmieder, L. Buettner, "Intelligent Photonics towards Biomedicine: A Disruptive Technology to Shape Computational Imaging, Optogenetics and Endomicroscopy", CORE, University of Utsunomiya (invited by Prof Otani and Prof Yatagai), Sep 8, 2025.

J.W. Czarske, J. Dremel, T. Glosemeyer, R. Kuschmierz, R. Wendland, F. Schmieder, L. Büttner, J. Sun, "Quantitative Phase Imaging exploiting Microfluidics and Deep Holography towards Biomedicine", Invitation of Optica Student Chapter (Prof. Goda), University of Tokyo, Sep 9, 2025.

J.W. Czarske, J. Dremel, T. Glosemeyer, R. Kuschmierz, L. Büttner, J. Sun, "Deep Holography, Quantum Imaging and Lensless 3D Endomicroscopy towards Advances in Biomedicine", Jiao Tong University, Shanghai, October 9, 2025.

J. W. Czarske, Q. Zhang, J. Sun, Y. Zhang, B. Yang, Y. Sui, L. Büttner, S. Krause, "Theory-trained deep holography for mode decomposition towards multimode fiber-based information transmission", SPIE/COS Photonics Asia, Beijing, October 12, 2025.

J.W. Czarske, J. Dremel, T. Glosemeyer, R. Kuschmierz, L. Büttner, S. Krause , "Advancing computational imaging using physics-informed deep learning towards biomedicine, quantum technology and metaverse", Tsinghua University (invited by Liangcai Cao), Beijing, October 15, 2025.

J.W. Czarske, J. Dremel, T. Glosemeyer, T Wang, R. Kuschmierz, L. Buettner, "Deep Holography towards Advances in Computational Imaging and Biomedicine", Beijing Institute of Technology, Beijing, October 15, 2025.

J.W. Czarske, J. Dremel, T. Glosemeyer, R. Kuschmierz, L. Buettner, F. Schmieder, R. Wendland, S. Krause, "Advancing computational imaging exploiting optogenetics and quantum technology for biomedicine and metaverse", University of Arizona Wyant College of Optical Sciences, Tucson, 24 October 2025.

J. Sun, Q. Zhang, J.W. Czarske, "Deep learning-based mode decomposition in multi-mode fibers: a paradigm shift from data-driven to physics-driven", Frontiers in Optics + Laser Science meeting, , Denver, Colorado, USA, 26-30 October 2025.

J.W. Czarske, "Neuromorphic information processing exploiting physics-informed deep learning, quantum technology and optical diffractive neural network", SPIE-CLP Conference on Advanced Photonics 2025, AI Photonics Session, November 15, 2025, Hong Kong.

J.W. Czarske, "Advancing computational imaging using physics-informed deep learning towards biomedicine and metaverse", SPIE-CLP Conference on Advanced Photonics 2025, AI Photonics Session, November 16, 2025, Hong Kong.

Q. Zhang, J.W. Czarske, "Seeing through the distortions of multimode fiber towards high fidelity information Transmission", SPIE-CLP Conference on Advanced Photonics 2025, AI Photonics Session, November 16, 2025, Hong Kong.

Conferences (reviewed)

Y. G. Zena, M. Pal, M. Langer, D. Sai, A. Rahimi, R. Bassoli, A. A. Bayelgn, J. W. Czarske, C. Hopfmann, "Enhanced emission of GaAs quantum dots in bend nanomembranes," Proc. SPIE 13618, Quantum Communications and Quantum Imaging XXIII, 136180J (18 September 2025); https://doi.org/10.1117/12.3065657.

R. Wendland, F. Schmieder, M. A. Sikandar, W. H. Zimmermann, L. Büttner, O. Bergmann, J. W. Czarske, "Label-Free Microscopy for Optogenetic Investigations of Arrhythmia in Human Cardiomyocyte Networks Expressing Chrimson", European Conferences on Biomedical Optics, SPIE, OPTICA – Munich, June 2025.

Q. Zhang, Y. Zhang, J.W. Czarske, "Digital in Design: FPGA-based Implementation of Deep Learning for Demultiplexing and Mode Decomposition of Structured Light", SPIE Digital Optical Technologies, 13573-3, Munich, 23 June 2025.

J. Sun, Q. Zhang, J.W. Czarske, "Physics-informed neural network with pretraining for mode decomposition of 1-km long multimode fiber", 13573-15, SPIE Digital Optical Technologies, Munich, June 2025.

J. Böhm, D. Krause, L.M. Eng, N. Koukourakis, J.W. Czarske, "Digital optical phase conjugation exploiting second harmonic generation for deep tissue imaging", 13573-30, SPIE Digital Optical Technologies, Munich, June 2025.

C. Bilsing, S. Burgmann, U. Janoske, J.W. Czarske, L. Büttner, "High-Speed 3D Localisation Microscopy with Dynamic Aberration Correction for Enhancing Imaging", 13573-31, SPIE Digital Optical Technologies, Munich, June 2025.

K. Schmidt, M. von Witzleben, N. Koukourakis, M. Gelinsky, J.W. Czarske „Understanding Virtual Fluorescent Staining for Connective Tissue" Optica Biophotonics Congress, paper OTh2D.3 (BEST PAPER AWARD of OPTICA) 2025.

D. Krause, J. Sun, B. Yang, N. Koukourakis and J.W. Czarske "Comparative analysis of optical diffraction tomography cell rotation techniques for isotropic resolution" Optica Biophotonics Congress, paper AW2D.2, 2025.

S. Biswas, Q. Zhang, H. Tunc, J.W. Czarske, R. Bassoli, and F. H. P. Fitzek, "Hybrid scheduler on single-mode fiber and multimode fiber for quantum-classical co-transmission", In IEEE Wireless Communications and Networking Conference (WCNC), Milan, Italy, March 2025.

K. Zolnacz, J. Dremel, R. Stephan, M. Steinke, T. Antrack, J. Benduhn, K. Leo, J.W. Czarske, R. Kuschmierz, "Multicore fiber modified via ablation and thermal treatment for lensless endoscopic imaging", San Francisco, SPIE Photonics West 2025 (Best Paper Award of SPIE), 25 January 2025.

J. Dremel, K. Zolnacz, T. Glosemeyer, J.W. Czarske, R. Kuschmierz, "Endomicroscopy through a multicore fiber using a static multispectral hologram for wavefront shaping", SPIE Photonics West 2025, San Francisco, 26 January 2025.

P. Liu, M. M. Balaji, P. W. Cornwall, J.W. Czarske, F. Willomitzer, "Multimode fiber endoscopy using synthetic wavelengths", Moscone Center, San Francisco26 January 2025.

T. Wang, J. Dremel, S. Richter, W. Polanski, O. Uckermann, I. Eyüpoglu, R. Kuschmierz, J.W. Czarske, "End-to-end brain cancer diagnosis using high-resolution fiber endoscopy with a learning-based digital twin", San Francisco, 26 January 2025.

T. Glosemeyer, R. Kuschmierz, J.W. Czarske, "Computational 3D fiber endoscopy with end-to-end optimization by physics-informed deep learning", San Francisco, 26 January 2025.

F. Schmieder, R. Wendland, M. A. Sikandar, W.-H. Zimmermann, L. Büttner, O. Bergmann, J.W. Czarske, "Excitation wavefront tracking and control of in vitro human induced cardiomyocytes using a digital holographic stimulation system", San Francisco, 25 January 2025.

S. Tasmany, J. Woisetschläger, J. Gürtler, R. Kuschmierz, J.W. Czarske, "Heterodyne Background-Oriented Schlieren for Diagnostics of Reactive Flows", ASME Turbo Expo 2025, GT2025-152641, Memphis, Tennessee June 16-20, 2025.

R. Kuschmierz, K. Żołnacz, J.W. Czarske, „Femtosecond Laser and CO_2 Laser Processing for Fiber Lens Manufacturing", LiM 2025, WLT, Munich, June 2025.

D. Pohle, D. Fröming, J.W. Czarske, E. Jorswieck, "In-network Optical Reservoir Computing for Spatial Channel Recovery of Multimode Fibers", IEEE-SUM 2025, IEEE Photonics Society, Berlin, July 2025.

Q. Zhang, Y. Miao, J. Sun, Y. Sui, S. Rothe, and J.W. Czarske, "Digital design of mode decomposition systems for multimode fibers using physics-informed neural network," SPIE Optics and Photonics, Emerging Topics in Artificial Intelligence (ETAI), San Diego, California, US, 07 August 2025.

T. Wang, J. Dremel, S. Richter, W. Polanski, O. Uckermann, I. Eyüpoglu, R. Kuschmierz, J. W. Czarske, "Learning-based digital twin for high-resolution fiber endoscopy towards brain cancer diagnostics", Optica Frontiers in Optics + Laser Science meeting, Denver, Colorado, USA, 26-30 October 2025.

L. Büttner, R. Wendland, F. Schmieder, M. Sikandar, W.-H. Zimmermann, O. Bergmann, J. W. Czarske, "Label-Free Sensing and Real-Time Holographic Optogenetic Control of Cardiac Excitation Wavefronts", Frontiers in Optics + Laser Science meeting, Denver, Colorado, USA, 26-30 October 2025.

Book Chapters, Books, Editorials

Z. Amiri, R. Bassoli, H. Boche, S.A. Charania, J. W. Czarske, S. Das, C. Deppe, S. Dev, F. H. P. Fitzek, M.I. Habibie, J. Hawellek, M. He, K. Jamshidi, D. Li Calsi, S. Maheshwari, S.S. Nande, K. Nilesh, J. Nötzel, D. Plettemeier, A. Shetewy, C. Upadhyay, Q. Zhang, "Quantum Technologies for 6G Networks", Chapter 18, 6G-life Unveiling the Future of Digital Sovereignty, Sustainability, and Trustworthiness, Edited by
F. H. P. Fitzek, H. Boche, W. Kellerer, P. Seeling, Springer, 2025.

Z. Amiri, R. Bassoli, H. Boche, S. A. Charania, J. W. Czarske, S. Das, C. Deppe, D. L. Calsi, S. Maheshwari, S.S. Nande, K. Nilesh, J. Nötzel, Q. Zhang, "Quantum Technology Applications for 6G Networks", Chapter 19, 6G-life Unveiling the Future of Digital Sovereignty, Sustainability, and Trustworthiness, Edited by F. H. P. Fitzek, H. Boche, W. Kellerer, P. Seeling, Springer, 2025.

S. Amjad, B. Baran-Akin, P. Carniello, J.W. Czarske, N. Hanik, A. Jäger, C. Mas Machuca, D. Pohle, S. Rothe, M. Samonaki, "The Role of Optical Communication Networks as Service Enabler, for Quantum Communications, and Physical Layer Security", Chapter 9, 6G-life Unveiling the Future of Digital Sovereignty, Sustainability, and Trustworthiness, Edited by F. H. P. Fitzek, H. Boche, W. Kellerer, P. Seeling, Springer, 2025.

M. Wiese, M. Pehl, D. Pohle, L. Torres-Figueroa, J. Voichtleitner, Ullrich J. Mönich, D. Seifert, H. Boche, J.W. Czarske, R.F. Schaefer, and G. Sigl, "Physical Layer Security for 6G", chapter 20, 6G-life Unveiling the Future of Digital Sovereignty, Sustainability, and Trustworthiness, Edited by F. H. P. Fitzek, H. Boche, W. Kellerer, P. Seeling, Springer, 2025.

Patents and Patent Applications

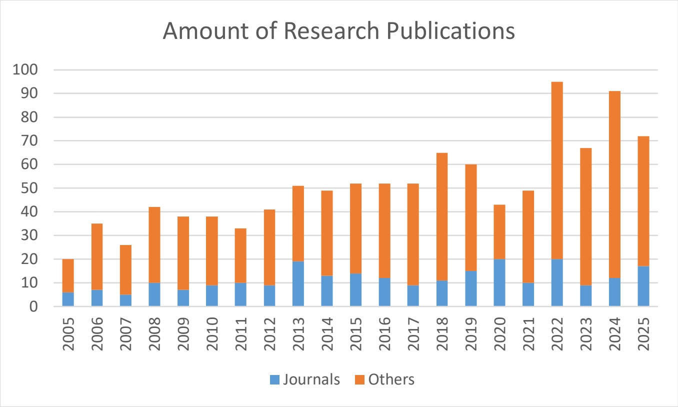
R. Kuschmierz, J.W. Czarske, E. Scharf, M. Kroll, "Method for compensating the travel time differences of image waveguides", 2025, US Patent filed.

Transferred patents

P. Warkusz, R. Kuschmierz, J. Lich, J.W. Czarske, „Bore inspection device", DE Patent, submitted and transferred to JENOPTIK Industrial Metrology Germany GmbH.

J.W. Czarske, L. Büttner, "Device and method for determining velocity profiles in arbitrarily directed flows", transferred to ILA R&D GmbH.

L. Büttner, J.W. Czarske, "Method for determining the fluid temperature", transferred to ILA R&D GmbH.



Amount of research publications from 2005 to 2025

ACTIVITIES

Prof. Czarske:

Program committees include (TPC, technical program committee):
TPC of OPTO / Sensor Conferences (AMA), Nürnberg
TPC of ITG / GMA-Fachtagung „Sensoren und Messsysteme“, Nürnberg

IMEKO Symp. Laser Metr. For Precision Meas. And Inspection in Industry
SPIE Photonics Europe, Photonics, Optics, Lasers, Micro- and Nanotechn., Optical Micro- and Nanometrology, Unconventional Imaging; Strasbourg, France
SPIE Photonics West, San Francisco
Conference of DGaO, Deutsche Gesellschaft für angewandte Optik e.V.
OSA conference on Optical Sensors, Barcelona, Spain
International Symposium on Optomechatronic Technologies, Seattle, USA
SPIE Opt. Meas. Syst. For Industr. Inspection,
icOPEN, Singapore,
European Optical Society Conferences
Organization of a conference in Dresden on all stages (financial issues, management with the agencies, advertisement for the congress, invitations with quality check points, generation of the program, orga for the venue, etc.): World Congress of Optics and Photonics of International Commission for Optics (ICO) and Optics Within Life Sciences (OWLS), Theme: Advancing Society with Light, ICO-25-OWLS-16-Dresden-Germany-5-9-Sep-2022, www.ico25.org
Co-chair of DIGITAL optical technologies, Munich, SPIE

Memberships include:
Fellow of International Society of Optical Engineering (SPIE), Washington USA
Fellow of European Optical Society (EOS), Finland
Fellow of Optical Society of America (OSA/Optica), DC USA
Fellow of IET (former IEE), London, UK
Fellow of IoP, London, UK
Society for Imaging Science and Technology, London
Member of Arbeitskreis der Hochschullehrer für Messtechnik eV. (AHMT);
Senior Member of IEEE;
Forschungsgesellschaft f. Messtechnik, Sensorik u. Medizintechnik e. V. (fms);
Member of Dechema
Board of Trustees of GALA (German Association of Laser Anemometry);
German Physical Society (DPG);
Verband der Elektrotechnik, Elektronik und Informationstechnik (VDE);
Board of German Society of Applied Optics (DGaO);
Full Member of Fraunhofer Society
Member of Excellence Cluster Physics of Life-PoL
Member of EKFZ for Digital Health
Elected Member of SAW – Saxon Academy of Sciences
Elected Vice President of ICO – International Commission for Optics, Paris, France and Miami, USA

Service as Reviewer - Granting Agencies (partial list)
German Research Foundation (DFG: Individual Grants Programs, Priority Programs, Research Training Groups, Collaborative Research Centers, Core Facilities, Research Units, etc.), BMBF, AIF, The Netherlands Organization for Scientific Research (NWO), Israel Science Foundation (ISF), King Faisal Foundation Saudi Arabia, National Science Foundation US

Service as Consultant and Advisor includes
Member Program Committee Sensor and Measurement Systems; Member Review Board System Engineering DFG (2012-2020); Member of review committee at Nanyang Technological University Singapore

Review of journal contributions (peer-review):
“Measurement Science and Technology”, “Applied Optics”, „Opt. Engineering“, „Pure Opt.“, „Opt. Letters“, “Opt. Express”, “Opt. Communications”, “Experiments in Fluids”, “Journal of Physics D: Applied Physics”, “Optics and Lasers in Engineering”, “Review of Scientific Instruments”, “Mechanical Systems

and Signal Processing", "Journal of the Optical Society of America A", "IEEE Transactions on Instrumentation & Measurement", „Flow Measurement and Instrumentation", etc.

Member of the Editorial Board:
tm - Technisches Messen, Open Journal of Fluid Dynamics, Journal of the European Optical Society - Rapid publications, LAM of Nature Publishing, Applied Sciences, Photonics, etc.

"Akademische Selbstverwaltung" of TUD:
Member of the Senate, the Faculty Council, the PhD committee and the Study committee of the Faculty of Electrical Engineering and Information Technology, etc.

Co-opted Professor for Physics

Group Leaders

Dr. Lars Büttner:

- Studied Physics at Clausthal University of Technology, received a Ph.D. degree at Leibniz University Hanover
- Member of SPIE – The International Society for Optics and Photonics; the German Association for Laser Anemometry – GALA e. V.; the German Physical Society – DPG e.V.
  Senior Member of OPTICA, Washington, DC, USA
- Supporting an MST key topic on computational metrology, especially the translation research in co-operation with renewable energy systems and magnetohydrodynamics.
- Reviewer activities at journals (Advanced Photonics, Light: Science & Applications, Optics and Lasers in Engineering, Optics and Laser Technology, Flow Measurement and Instrumentation,) and project proposals (German Research Foundation DFG)
- Co-Recipient of the 2008 Berthold Leibinger Innovation Award (3. Prize)
- Guest Editor of mdpi Appl. Sci. 2022 Special Issue "Computational Ultrasound Imaging and Applications"
- Member of Technical Program Committee of Optica´s Frontiers in Optics Conference, Denver, USA 2025

Dr. Nektarios Koukourakis:

- Member of OPTICA (formerly OSA – The Optical Society), SPIE, DGaO, German Physical Society (DPG)
- Supporting an MST key topic on computational adaptive microscopy, translation research in cooperation with biomedical engineering, nanotechnology and microsystem engineering.
- Guest Editor of the journal Applied Sciences.
- Reviewer activities include journals such as Optics Express, Optics Letters, Applied Optics, Applied Physics Letters, Applied Physics B, Optics Communications
- Awarded by the OSA, Florida, USA
- Several invited talks

Dr. Robert Kuschmierz:

- Member of SPIE & OPTICA
- Supporting an MST key topic on computational and adaptive microendoscopy for biomedical imaging
- Guest Editor of the journal Applied Sciences.
- Reviewer activities include Optics Express, Light: advanced manufacturing, Nature Communications, LSA
- Received awards for his Ph.D. thesis on *interferometric in-process metrology* by company SICK and Siegfried Werth Foundation and supervised multiple award-winning students in the field of computational endoscopy

Dipl.-Ing. Jakob Dremel

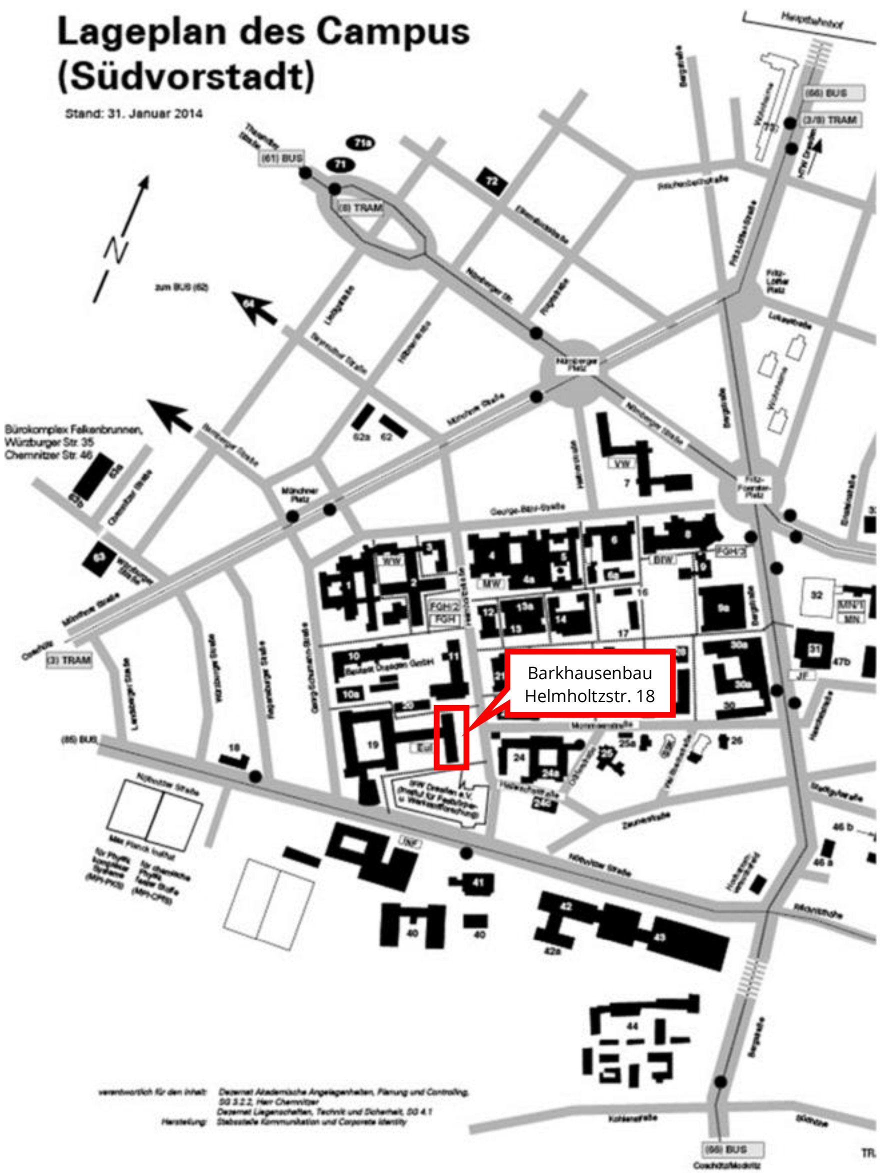
- Interdisciplinary EKFZ Group: N-Vision Lab (nvision-lab.com)
- Member of SPIE & OPTICA and former student chapter president
- Supporting an MST key topic on computational and adaptive microendoscopy for biomedical imaging and the transfer into clinical application
- Reviewer activities include Advanced Photonics, Light: Science & Applications
- Received the Theodore-Maiman-Scholarship by WLT, for outstanding Bachelor Thesis / Student thesis "Characterization of different fiber bundles for the application in an optical cell rotator"
- Awarded as 2 % best graduates of TU Dresden by TUD's rector Prof.in Dr. Ursula M. Staudinger

Prof. Prof. h.c. Dr. Dipl.-Ing. Juergen Czarske

see above

Our Partners (selection)

Lageplan


Lageplan des Campus
(Südvorstadt)
Stand: 31. Januar 2014
Bürokomplex Falkenbrunnen,
Würzburger Str. 35
Chemnitzer Str. 46
Barkhausenbau
Helmholtzstr. 18

Laboratory of Measurement and Sensor System Technique (MST) / Czarske Lab

Head: Prof. h. c. Prof. Dr.-Ing. habil. Juergen Czarske

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http://lasermetrology.de

BIOLAS
BIOMEDICAL COMPUTATIONAL LASER SYSTEMS

DRESDEN concept
SCIENCE AND INNOVATION CAMPUS