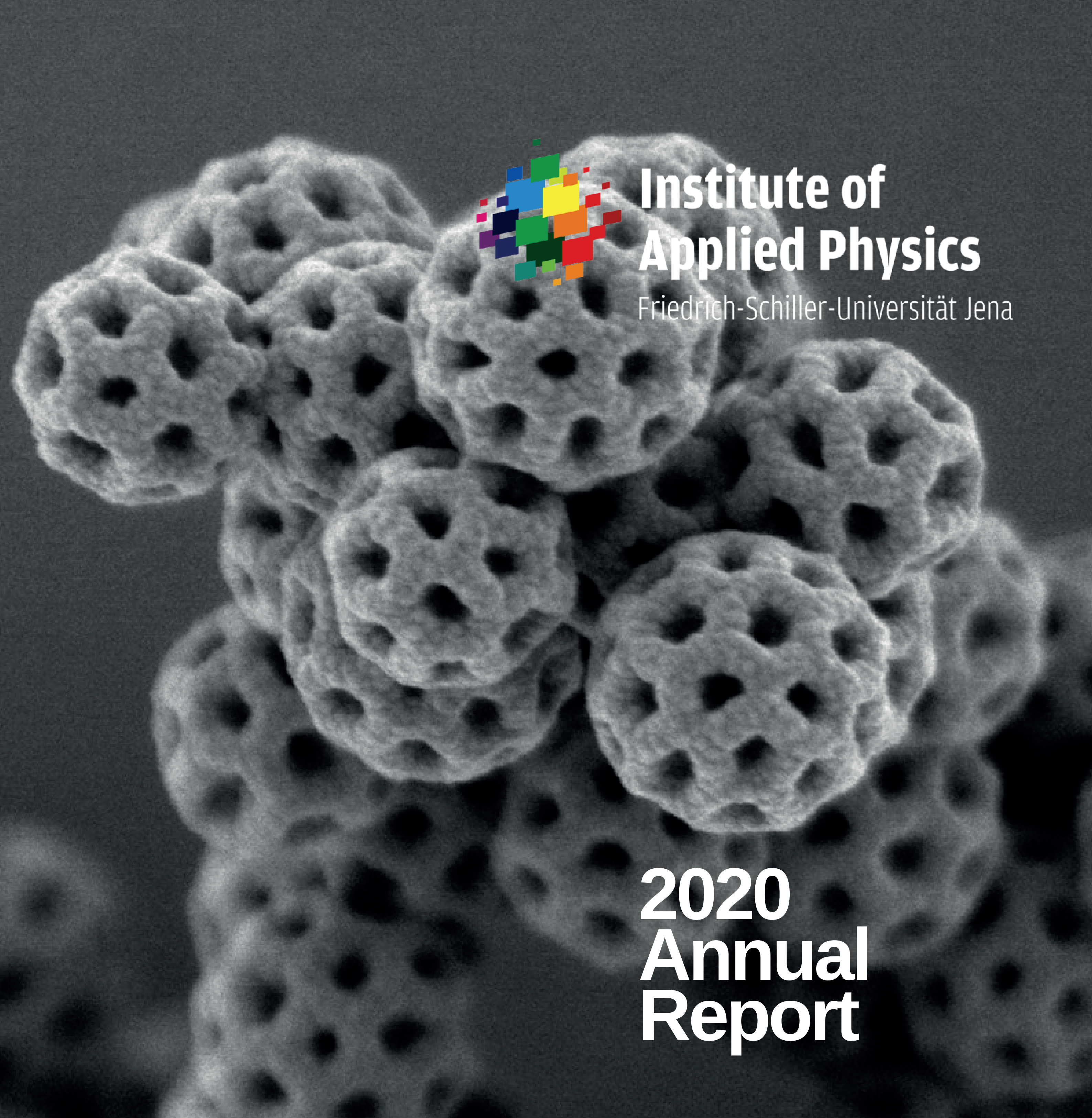

Institute of Applied Physics

Friedrich-Schiller-Universität Jena

2020 Annual Report

Imprint

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www.iap.uni-jena.de

EDITORIAL
Ira Winkler, Dr. Frank Schrempel

LAYOUT
Ira Winkler

PICTURES/ GRAFICS
Institute of Applied Physics (IAP), Fraunhofer IOF [W. Oppel, C. Süß], Friedrich Schiller University Jena [J.-P. Kasper, J. Meyer], PAF-FSU
p.60: aboutpixel.de/Lektüre©marshi

Cover: Scanning electron microscopy image of brochosomes conformally coated with 10 nm of iridium by atomic layer deposition. The picture was honourable mentioned at the 2020 OPN photo contest of the Optical Society of America (OSA).

Content

PREFACE / VORWORT

Dear colleagues,

2020 has shown what really counts: take care of each other, spending time together and being there for each other. I am convinced that we have done all of this very well as a team, together with the Fraunhofer IOF. We owe this also to your personal commitment and flexibility, despite sometimes heavy private burdens. It is therefore important for me to personally thank you all and express my appreciation and respect.

Through these personal and collegial efforts, it was also possible for us to achieve significant work across institutes in 2020. In this sense, I would like to emphasise that our young research groups led by Falk Eilenberger, Markus Gräfe, Frank Setzpfandt and Fabian Steinlechner have made highly valuable contributions to quantum research, which have been reflected in excellent publications and extraordinarily successful applications for funding. But of course the success in research is reflected in the blessing of awards in the past year: personally, I am particularly pleased with the awarding of the Röntgen Prize of the Justus Liebig University to Jan Rothhardt, as I was also privileged to receive this prize as a young scientist. I constantly take pride in the achievements of our graduates and doctoral students - through their numerous awards from the faculty, they demonstrate the performance of our two institutes and strengthen the recognition within the entire university. And last but not least, I would like to mention the smart contributions of our colleagues who participate in idea competitions every year. Particularly successful was the development of the "NeoVitalSensor" by an interdisciplinary team working with Jan Sperrhake, which enables premature babies to be medically monitored without wires and thus helps to ensure a pain-free start to life! In addition, the granting of the Zukunftspreis 2020 on the topic of "EUV lithography" to the Fraunhofer IOF is part of the IAP's success story, as the long-standing strategic cooperation between the two institutions has also stimulated developments in this field.

All of this shows that we are on the right track to help shape future topics as well - not only in research, but also in teaching, as we are developing equally here and have created a platform for advancing and testing digital teaching with the opening of the "Digital Teaching Lab" at the Max Planck School of Photonics.

Dear colleagues, with this review I hope to encourage you for the future and I am firmly convinced that, thanks to the team and all the support from the network of customers and partners, we will experience a fruitful 2021.

With all sincerity,

Andreas Tünnermnann

Liebe Kolleginnen, liebe Kollegen

2020 hat uns gezeigt, was wirklich zählt: aufeinander zu achten, Zeit miteinander zu verbringen und füreinander da zu sein. Ich bin der Überzeugung, dass uns dies als Kollegium gemeinsam mit dem Fraunhofer IOF sehr gut gelungen ist. Zu verdanken ist dies auch Ihrem persönlichen Engagement und Flexibilität, trotz zum Teil großer privater Belastungen. Daher ist es mir wichtig, persönlich meinen Dank an Sie alle zu richten und meine Wertschätzung und Hochachtung auszudrücken.

Durch diese persönlichen und kollektiven Anstrengungen war es uns möglich, auch 2020 institutsübergreifend bedeutsame Arbeit zu leisten. Dazu möchte ich herausheben, dass die jungen Forschungsgruppen um Falk Eilenberger, Markus Gräfe, Frank Setzpfandt und Fabian Steinlechner sehr wertvolle Beiträge für die Quantenforschung geleistet haben, was sich in exzellenten Publikationen und außerordentlich erfolgreichen Fördermittelbewerbungen niedergeschlagen hat. Aber natürlich zeigt sich der Erfolg in der Forschung im Auszeichnungssegen des vergangenen Jahres: persönlich freut mich die Verleihung des Röntgenpreises der Justus-Liebig-Universität an Jan Rothhardt besonders, da auch ich diesen Preis als junger Wissenschaftler entgegennehmen durfte. Stolz macht mich immer wieder die Leistung unserer Absolventen und Promovenden – durch deren zahlreiche Auszeichnungen der Fakultät, demonstrieren sie die Leistungsfähigkeit unserer beiden Institute und stärken die Wahrnehmung innerhalb der gesamten Universität. Und nicht zuletzt möchte ich die klugen Beiträge der Kolleginnen und Kollegen erwähnen, die jährlich an Ideenwettbewerben teilnehmen. Besonders erfolgreich war die Entwicklung des „NeoVitalSensors“ durch ein interdisziplinäres Team um Jan Sperrhake, der es Frühgeborenen ermöglicht, kabellos medizinisch überwacht zu werden und damit hilft, einen schmerzfreieren Lebensstart zu ermöglichen! Aber auch die Verleihung des Zukunftspreises 2020 zum Thema „EUV-Lithographie“ an das Fraunhofer IOF gehört zur Erfolgsgeschichte des IAP, da durch die langjährige strategische Zusammenarbeit der beiden Einrichtungen die Entwicklungen auch in diesem Feld befruchtet haben.

Dies alles zeigt, dass wir auf dem richtigen Weg sind, auch künftige Themen mitzugestalten – nicht nur in der Forschung, sondern auch in der Lehre, da wir uns hier genauso weiterentwickeln und mit der Eröffnung des „Digital Teaching Lab“ der Max Planck School of Photonics eine Plattform zum Vorantreiben und Testen digitaler Lehre geschaffen haben.

Liebe Kolleginnen und Kollegen, ich hoffe mit diesem Rückblick zugleich Mut für die Zukunft zu machen und bin fest davon überzeugt, dass wir Dank des Kollegiums und aller Unterstützung aus dem Netzwerk an Kunden und Partnern, ein ergebnisreiches 2021 erleben.

Herzlichst,

Prof. Dr. Andreas Tünnermann

The Institute of Applied Physics (IAP) at the Friedrich Schiller University (FSU) Jena has a long-standing tradition and competence in design, fabrication and application of active and passive optical and photonic elements. It is also very well-known for its developments in the area of high power laser technology and nowadys also in quantum optics. Collaborative projects with companies ensure practical relevance and feasibility.

Research Profile

The institute conducts fundamental and applied research in the fields of micro-, nano- and quantum optics, fiber and waveguide optics, ultrafast optics as well as optical engineering.

Our researchers develop novel optical materials, elements and concepts for information and communication technology, life science and medicine, environment and energy as well as process technology including material processing and optical measurement techniques.

Current research topics - investigated by over 150 scientists - concern function, design, fabrication and applications of micro- and nano-optical elements. Those are e.g. plasmonic resonant nanometric structures, polarizers from IR to DUV range, 3D nano-structuring of crystals with ion beam and Atomic Layer Deposition of optical coatings. Also light propagation and non-linear light-matter interaction in e.g. photonic nanomaterials, including metamaterials, photonic crystals, as well as effective media, quantum phenomena and integrated quantum optics, application of photonic nanomaterials and advanced photonic concepts for astronomical instruments are investigated.

Further research fields are the applications of femtosecond laser pulses, such as material processing and spectroscopic analyses, as well as micro- and nano-structuring, medical (laser) application and additive manufacturing usage of ultrashort laser pulses. For further aims, new concepts for solid-state lasers with focus on fiber laser technology are to be developed, such as novel large core diameter fibers, fiber optical amplification of ultra short laser pulses and Mid-IR up to soft x-ray laser sources. With those, absorption spectroscopy with ultrahigh spectral resolution, especially in the (extreme) ultraviolet (XUV) region can be realized.

Classical optical design as well as design of modern optical systems, like freeform optics, illumination systems, laser and delivery systems are considered in our research, as well as aberration theory, quality, performance and tolerancing evaluation of optical systems.

By investigating these fields of research, particularly in close cooperation with the Fraunhofer Institute of Applied Physics and Precision Engineering (IOF) as well as many partner companies, the IAP covers numerous parts of the innovation chain - from interdisciplinary fundamental research to the demonstration of prototypes. This expertise offers remarkable contributions to solve issues in the mentioned before emerging fields.

Excellence in research is confirmed by the structural anchoring of the Competence Centre (ZIK) ultra optics into one of three key research areas of the Abbe Center of Photonics (ACP), four awarded ERC Grants " Powerful and Efficient EUV Coherent Light Sources - PECS" (2009), "Advanced Coherent Ultrafast Laser Pulse Stacking - ACOPS" (2014), "Multi-dimensional interferometric amplification of ultrashort laser pulses - MIMAS" (2015) and "High-flux Synchrotron alternatives driven by powerful long-wavelength fiber lasers - SALT" (2019), the International Research Training Group GRK 2101 (2015) as well as the pilot project "Max Planck School of Photonics" (2017).

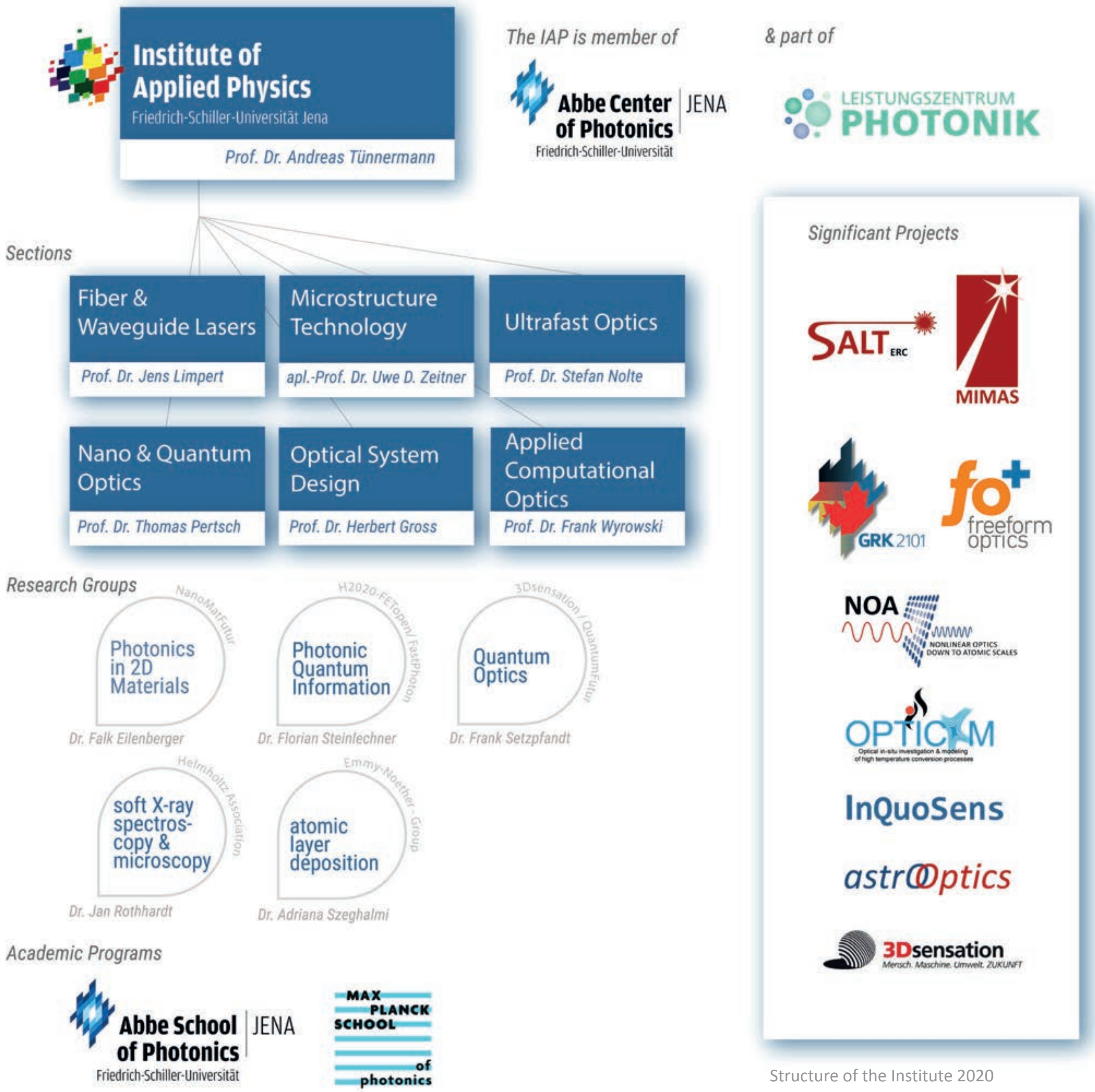
But not only excellent research makes the Institute splendid, also outstanding laboratory equipment, an excellent educated staff and an high commitment to the training of students and scientists in cooperation with the Abbe School of Photonics (www.asp.uni-jena.de) belongs to the self-understanding of the IAP.

Research Facilities / Resources

Excellence in research requires high quality equipment for experimental questions and analysis. The state-of-the-art technical infrastructure is driven constantly forward by acquired adaptions for scientific questions, done by an experianced crew.

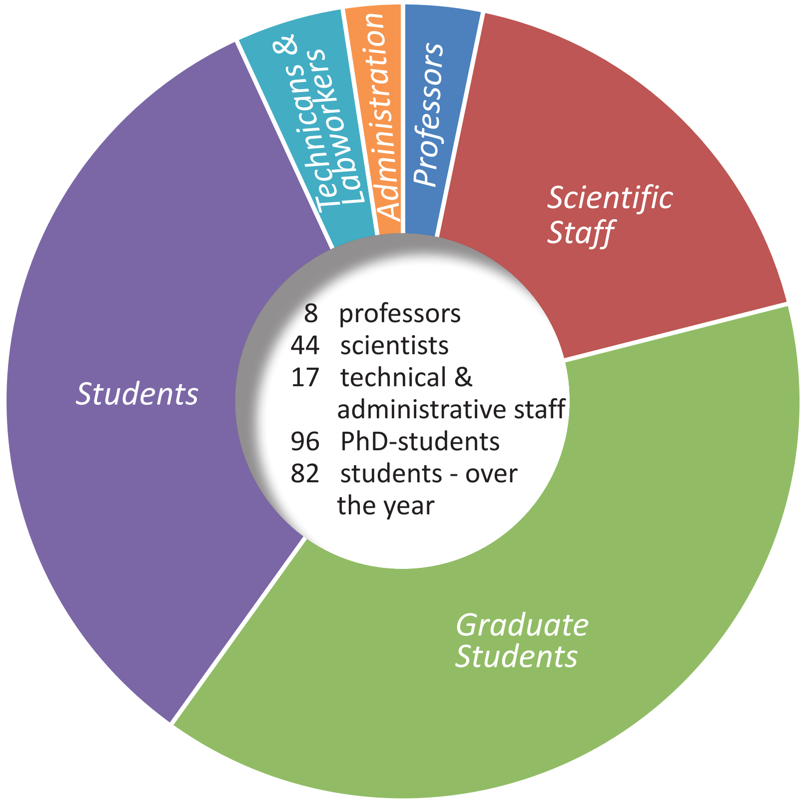
860 m² class 10,000 to 10 clean room area for:

- Electron beam lithography equipped with variable shaped beam and cell projection
- Laser lithography & Photolitography
- Coating technologies (sputtering, electron beam evaporation, ALD)
- Dry etching (RIE, RIBE, ICP)
- Cross beam, scanning electron microscopy, equipped with EDX and EBSD
- Helium ion microscopy
- Scanning nearfield optical microscopy
- Interference optical surface profilometry
- UV-VIS spectrometry & FTIR spectrometry
- Ellipsometry
- Nonlinear optical waveguide characterization
- High repetition rate ultrashort pulse laser systems (25fs to 20ps) including wavelength conversion covering the range from 4nm to 10µm
- High-precision positioning and laser scanning systems
- Laser micro-structuring and additive technology
- Rigorous optical simulation
- Field tracing techniques



Structure of the Institute 2020

Staff (*status 31.12.2020*)



ABASIFARD Mostafa
ABBASIRAD Najmeh
ABBE Sylvia
ABTAHI Fatemeh Alsadat
ACKERMANN Roland
AFSHARNIA Mina
ALAM Shawon
ALBERUCCI Alessandro
ALESHIRE Christopher
ALIA Samira
ANDRANGO ARAGUILLIN Gabriela
ANDRIYENKO Olexandr
APELL Jonatan
ARSLAN Dennis
BALAJI Vignesh
BASHIRI Ayesheh
BADAR Irfan
BALADRON ZORITA Olga
BEER Sebastian
BELADIYA Vivek
BENNER Maximilian
BELLOMO Giampiero
BERGNER Klaus
BEST Sabine
BINGOL Eda
BIRCKIGT Pascal
BLOTHE Markus
BODEN Justus
BÖRNER Stefan
BRADY Aoife
BRAMBILA-TAMAYO Emma C.
BUCHER Tobias
BULDT Joachim
CABREJO PONCE Meritxell
CAI Danyun
CHAMBONNEAU Maxime
CHANDROTH PANNIAN Jisha
CONRAD Johanna
DÖPFNER Samuel
DREYER Johannes
EILENBERGER Falk
ESCHEN Wilhelm
FALKNER Matthias
FATHEME ALSADAT Ghazale
FEDERTOVA Anna
FILIPPONI Maria
FRASCH Johannes
FUCHS Hans-Jörg
FÜßEL Daniel
GABLER Thomas
GÄBLER Tobias Bernd
GALLITSCHKE Canan
GÄRTNER Anne
GEBHARDT Martin
GEIß Reinhard
GHAZARYAN Lilith
GIERSCHKE Philipp
GILI Valerio Flavio
GOEBEL Thorsten A.
GOUR Jeetendra
GREBING Christian
GROSS Herbert
GULA Brixhilda
GUSCHAKOWSKI Vladislav
HAAS Tim Luca
HAITSCH Darius
HALEM Nabil M.
HANLIN Zheng
HAUSMANN Maximilian
HEGER Anders
HENGSTER Julia
HERRMANN Paul
HEUERMANN Tobias
HEUSINGER Martin
HILBERT Magdalena J.
HILBERT Vinzenz
HÖLZER Gesa
IMOGORE Thimothy O.
IWAMA Masaki
JAUREGUI MISAS Cesar
JUNGNICKEL Tom
JUNGHANNS Marcus
JUNGNICKEL Tom
KABIS Patrick
KAISER Thomas
KARST Maximilian
KÄSEBIER Thomas
KAUFMANN Johannes M.
KESSLER Victor
KETTERER Ryan
KHOLAIF Sobhy
KIRSCHE Alexander
KLAS Robert
KLECKNER Arno
KLENKE Arno
KLUGE Anja
KNOPF Heiko
KOHL Hagen
KRÄMER Ria
KRETZSCHMAR Johannes
KRSTI´C Aleksa
KUHNERT Sara
KÜHN Dominik
KUMAR Anand
KUMAR Mohit
KUMAR Pawan
KUNDU Rohan
KUPPDAKKATH Athira
LAHNOR Johannes
LAMMERS Kim
LAMMERS Tom
LANDMANN Martin
LEIPE Markus
LENSKI Mathias
LEON TORRES Josué R.
LEONHARDI Vincent
LI Jinhao
LI Quingfeng
LIMPERT Jens
LINß Sebastian
LIPPOLDT Tom
LIU Chang
LIU Zhishuai
LÖCHNER Franz
LOTTMANN Moritz
LU XIANG
LUGANI Jasleen
MARTIN Bodo
MATHEW Steev
MATTHÄUS Gabor
MATZDORF Christian
MAYERHOFER Tobias
MERX Sebastian
MING Lee
MINOVICH Alexander
MISHUK Mohammad
MOHAMED Ahmed E.A.
MOHANTY Sneha
MÜLLER Michael
MUNSER Anne-Sophie
NAMIG Alasgarzade
NARANTSATSRALT Bayarjargal
NOLTE Stefan
NUDING Jannik
OLBRICH Tina
OTTO Christiane
PAEZ LARIOS Francisco
PAKHOMOV Anton
PALACIOS NARRVAEZ Laura M.
PALMA VEGA Gonzalo
PAUL Pallabi
PERTSCH Thomas
PFEIFER Kristin
POHLE Lisa
RAJAEE Shakiba
RAN Yang
REINHARDT Max
REPP Daniel
RICHTER Daniel
RICHTER Sebastian
ROCKSTROH Sabine
ROCKSTROH Werner
ROTHHARDT Jan
ROUTEN Martha A.
SAFARI ARABI Masoud
SAJAN Don
SANSA PERNA Adria
SANTOS SUÁREZ Elkin André
SARAVI Sina
SAUER Gregor
SCHADE Lisa
SCHARMER Floris
SCHELLE Detlef
SCHMELZ David
SCHMIDT Holger
SCHMITT Paul
SCHMITTNER Christian
SCHREMPEL Frank
SCHUBERT Karl
SCHULZ Sophia
SCHUSTER Vittoria
SCHWARTZ Georg
SEBAK Rana K. H.
SEENIVASAGAM Poosaimani
SEKMAN Yusuf
SERGEEV Natali
SETZPFANDT Frank
SEVILLA GUITTÉRRES Carlos
SEYFARTH Brian
SHESTAEV Evgeny
SHI Rui
SIEFKE Thomas
SIEGMUND Florian
SIEMS Malte
SINGH Vikram
SIRMACI Yunus Denizhan
SPÄTHE Anna
SPERRHAKE Jan
SPIESS Christopher
STARK Lars Henning
STAUDE Isabelle
STEFANIDI Dmitrii
STEINBERG Carola
STEINERT Michael
STEINKOPFF Albrecht
STEINLECHNER Fabian
STEMPFHUBER Sven
STIHLER Christoph
STOCK Carsten
STOCK Johannes
SUGIARTI Judya
SZEGHALMI Adriana
TAM Kevin
TANAKA Katsya
TANG Ziyao
TEYMORI Pouria
THOLE Lisa
TIBRI Sara
TISCHNER Katrin
TÜNNERMANN Andreas
TURAN Tim L.
TUTAR Sarah
ULLSPERGER Tobias
VASKIN Aleksandr
VEGA PEREZ Andres R.
VETTER Julia
VOGL Tobias
VOIGT Daniel
VON LUKOWICZ Henrik
WALTHER Markus
WANG Hui
WANG Ziyao
WEIßFLOG Maximilian
WHITE Jonathon
WIDHOLZ Georg
WIDIASARI Fransiska R.
WINKLER Ira M.
WOHLFEIL Shulin
WYROWSKI Frank
XU Yuran
YOUNESI Mohammadreza
YÜREKLI Burak
ZAKOTH David
ZEITNER Uwe D.
ZHANG Jiahang
ZHANG Luosha
ZHANG Mingxuan
ZHANG Site
ZHAO Xiaodong
ZHENG Hanlin
ZHONG Huiying
ZIMMERMANN Tobias
ZOU Chengjun

Guests

Guests indicate the national and international visibility of research results and enrich the structures of the Institute with new thinking and perspectives - not only in research and teaching, but also open eyes to other cultures and strengthen the network by personal relations.

Due to the pandemic situation in 2020, intensive research visits and personal contacts were unfortunately not possible.

CAI Marcus	Australian National University, Canberra, Australia
PRZYSTAWIK Andreas	Deutsches Elektronensynchrotron DESY, Hamburg, Germany
SCHWICKERT David	Deutsches Elektronensynchrotron DESY, Hamburg, Germany
SKRUSZEWICZ Slawomir	Deutsches Elektronensynchrotron DESY, Hamburg, Germany

Cooperations

The IAP has a solid network of partners regionally, nationally, and all over the world. In the heart of Jena's optics industry, it is connected to resident international players in the economy as well as research institutions. So, it has a strong connection to most of the departments of the Faculty of Physics and Astronomy at Friedrich Schiller University, 2020 in particular with the Institute of Optics and Quantum Electronics (IOQ) and the Otto Schott Institute of Materials Research. Since many years the IAP collaborates also with the University of Applied Sciences (EAH) Jena.

Our work is connected strongly to many important research associations of Germany, such as the Max-Planck-Institutions, especially in Erlangen, Hannover and Garching, as well as the Institutes of the Leibniz and Helmholtz Association - such as the Institute for Astrophysics Potsdam (AIP) and the Leibniz Institute of Photonic Technology (IPHT), the Helmholtz Institute in Hamburg (DESY) and Jena (HIJ) – only to mention some of them. Firm European cooperation exist with French research institutions, like the Centre national de la recherche scientifique (CNRS) in Paris and the ELI-ALPS, Extreme Light Infrastructure in Szeged, Hungary.

Traditionally, the IAP is linked closely to the Fraunhofer Institute for Applied Optics and Precision Engineering (IOF). Based on this networking between the two Institutes, one major goal is to develop an outstanding research and application results for micro- and nano-structured optics, whole optical systems, lasers and Quantum optics. Beyond this co-operation, the "Leistungszentrum Photonics" was associated together with other local players, such as Abbe Center of Photonics (ACP), Leibniz Hans Knöll Institute (HKI) Helmholtz Institute Jena and the Leibniz Institute of Photonic Technology (IPHT). With both of the last mentioned, the "Fasertechnologiezentrum" is being operated to develop and produce novel fibers for worldleading lasers.

In addition, the IAP maintains close contacts to universities and research facilities nearly all over the world for years: major international collaborations exist with the Centre of Ultrahigh bandwidth Devices for Optical Systems (CUDOS), the Australian National University, as well as universities in Belgium (Brussels & Ghent), Canada (Québec, Toronto & Varennes), China (Changchun & Nanjing), Russia (Moscow, St. Petersburg), Finland, Italy, Spain, Switzerland, Taiwan, The Netherlands and USA (Berkeley, Orlando, Menlo Park).

In the framework of the German-Canadian International Research Training Group GRK 2101 “Guided light, tightly packed” we are cooperating with the University of Toronto, Université Laval and the Institut National de la Recherche Scientifique (INRS) – the coordination lies in the hands of our partner Abbe School of Photonics here in Jena. Through the Max Planck School of Photonics (MPSP) educational project, we also cooperate with many of the renowned German research institutions mentioned above.

Since years, we work also close with regional industry partners - from medium-sized to internationally operating companies; current: Carl Zeiss AG in Jena and Oberkochen, Jenoptik AG, Layertec GmbH, OSRAM Licht AG, Active Fiber Sytems GmbH and many more.

By working together with all our partners, we are constantly expanding our know-how and our focus on problems and their solutions.

Selection of Cooperations with Joint Research Topics

Albert-Einstein-Institut
Max Planck Institute for Gravitational Physics, Leibniz University
Hannover, Germany
Prof. Dr. Karsten Danzmann

AT Technologies
Veldhoven, The Netherlends
Mikhail Loktev

Brussels Photonics Team
Vrije Universiteit Brussel, Belgium
Prof. Hugo Thienpont

Centre d'optique, photonique et laser (COPL), Université Laval
Québec, Canada
Prof. Réal Vallée

Centre of Ultrahigh bandwidth Devices for Optical Systems (CUDOS),
MQPhotonics Research Centre,
Department of Physics and Astronomy
Macquarie University
Sydney, Australia
Prof. Michael Withford,
Assoc.-Prof. Alex Fuerbach

College of Optics and Photonics, CREOL & FPCE
University of Central Florida
Orlando, USA
Prof. Kathleen Richardson,
Prof. Martin Richardson,
ass.-Prof. Dr. Rodrigo Amezcua

Datalogic
Bolognia, Italy
Federico Canini

Department of Electrical & Computer Engineering
University of Toronto, Canada
Prof. Peter Herman

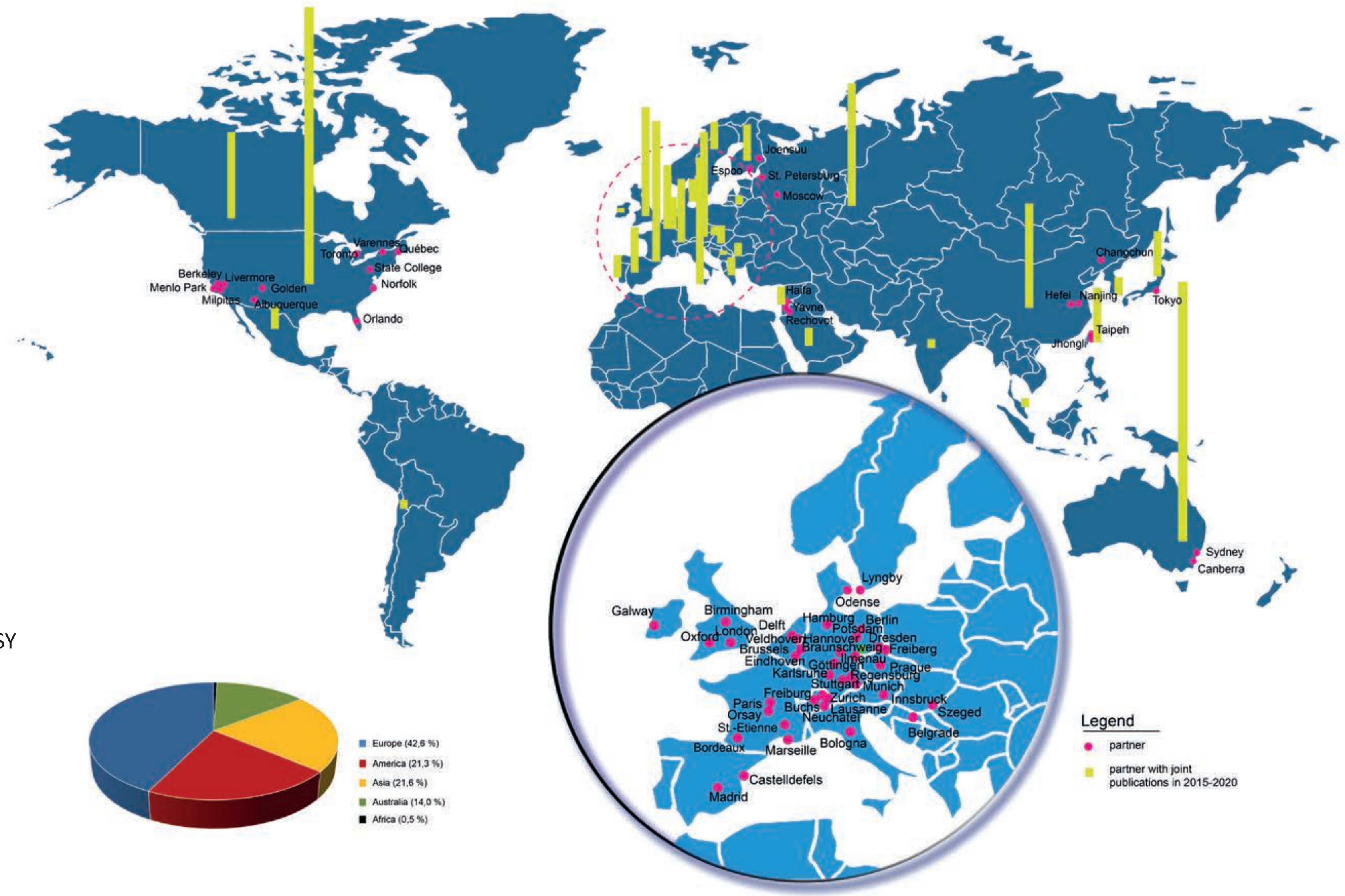
Department of Optics and Photonics
National Central University
Zhongli, Taiwan
Prof. Yen-Hung Chen

Department of Physics
ETH Zürich, Switzerland
assoc. Prof. Ursula Keller

Department of Physics & Mathematics
University of Eastern Finland, Joensuu
Prof. Jari Turunen

Deutsches Elektronen-Synchrotron DESY
The Helmholtz Association
Hamburg, Germany
Dr. Tim Laarmann

ELI-ALPS
Extreme Light Infrastructure
Szeged, Hungary
ass.-Prof. Dr. Karoly Osvay



Partners of the IAP and a quantitative figure of common publications in 2013-20.

Énergie, Matériaux et
Télécommunications Research Center
Institut national de la recherche
scientifique (INRS)
Varennes, Canada
Prof. Roberto Morandotti

Engineering Center OPTICA
State University of Information,
Mechanics
& Optics (ITMO)
St. Petersburg, Russia
Dr. Irina Livshits

Huawei
Munich Research Center
Germany
Dr. Grigory Lazarev

innoFSPEC
Leibniz-Institut für Astrophysik Potsdam
(AIP)
Potsdam, Germany
Prof. Martin Roth

Institut für Energieverfahrenstechnik
und Chemieingenieurwesen
&TU Bergakademie
Freiberg, Germany
Stefan Guhl

Institut für Kommunikation und
Navigation
Deutsches Zentrum für Luft- und
Raumfahrt (DLR)
Oberpfaffenhofen, Germany
Prof. Dr. Christoph Günther

KLA-Tencor
Milpitas, California, USA
Maarten van der Burgt

Laboratoire Ondes et Matière
d'aquitaine (LOMA)
Université Bordeaux, France
Prof. Lionel Canioni

Laboratory of Quantum Materials
and Phenomena
University Paris Diderot, France
Prof. Giuseppe Leo

Lawrence Berkeley National Labora-
tory
University of California
Berkeley, USA
Dr. Wim Leemans

LCP group
Ghent University, Belgium
Prof. Jeroen Beeckman

Light Prescriptions Innovators llc. (LPI)
Madrid, Spain
Dr. Ruben Mohedano

LP3 - Lasers, Plasmas et Procédés Photoniques
Aix-Marseille Université, CNRS, France
Dr. Olivier Uteza,
Prof. François Goudail

National Accelerator Laboratory
Stanford Linear Accelerator Center (SLAC)
Menlo Park, USA
Dr. Christian Roedel,
Dr. Frank Seiboth

Nonlinear Physics Center
Australian National University
Canberra, Australia
Prof. Yuri Kivshar,
Prof. Dragomir Neshev,
Prof. Andrey Sukhorukov

Optics Research Group
Delft University of Technology
The Netherlends
Prof. Paul Urbach

Optical Engineering Group (OEG)
Universidad Politecnico de Madrid (UPM)
Madrid, Spain
Pablo Benitez

Photonik und Medizintechnik
Hochschule für angewandte
Wissenschaft und Kunst (HAWK)
Göttingen, Germany
Prof. Christoph Russmann

EDUCATION

An essential part of the IAP is the training of young scientists on fundamental knowlegde and at the interface of physics, chemistry and material science.
Together with our partner in education - the Abbe School of Photonics (ASP) - we offer an education in interdisciplinary international Master´s degree and graduation programs, running the International Research Training Group (GRK 2101) "Guided light, tightly packed: novel concepts, components and applications" since 2015 and since 2017 the "Max Planck School of Photonics" (MPSP).

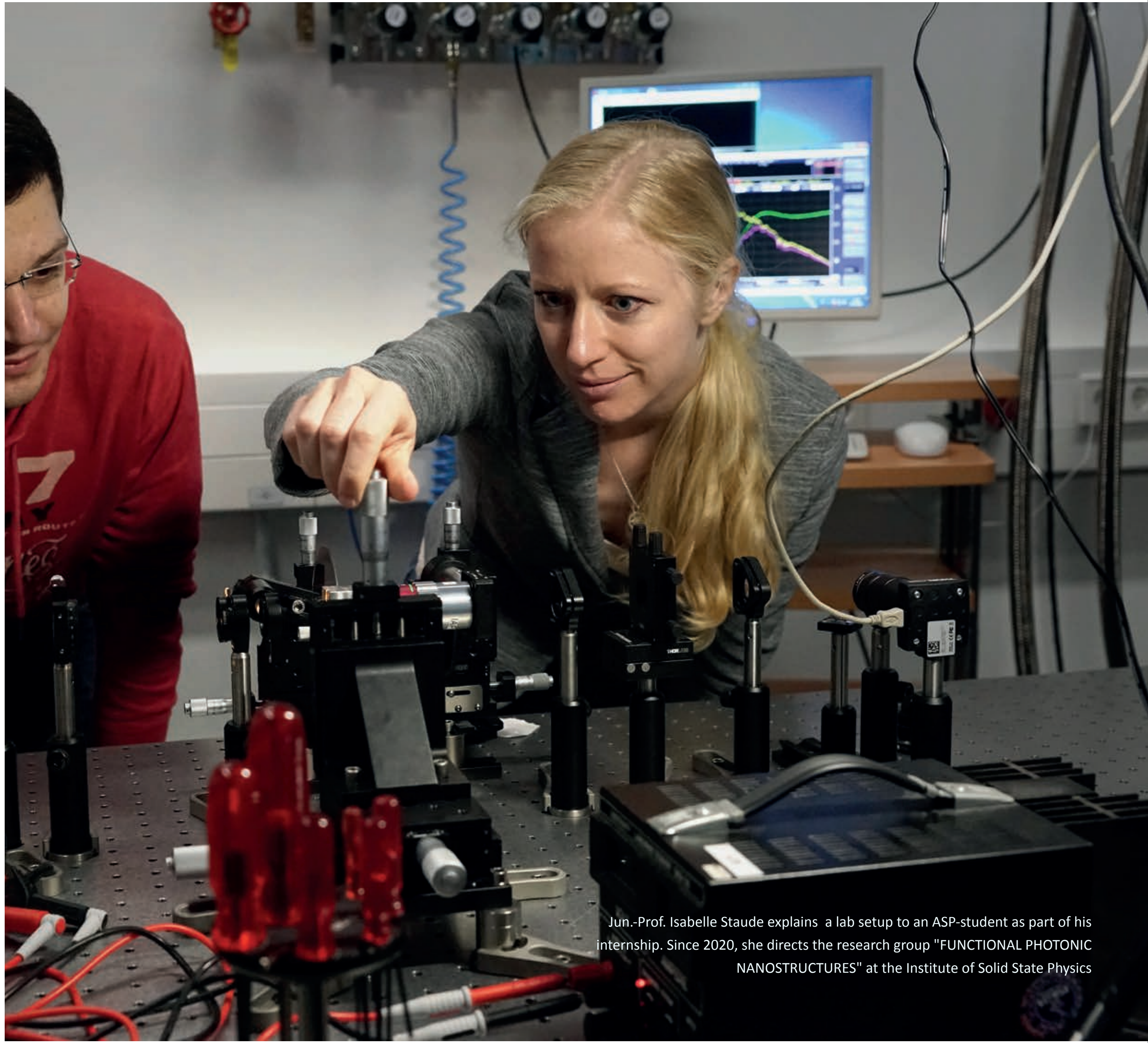
Lectures

Elective & Special Courses (Lectures & Seminars)

- Analytical Instrumentation
- Atome und Moleküle I & II
- Computational Photonics
- Computational Physics I
- Design & Correction of Optical Systems
- Fundamentals of Modern Optics
- Grundlagen der Laserphysik
- Imaging and Aberration Theory
- Integrated Quantum Photonics
- Introduction to Nanooptics
- Introduction to Optical Modeling
- Laser Physics
- Lens Design I & II
- Mathematical Methodes in Physics
- Micro/nanotechnology
- Optical Metrology and Sensing
- Physical Optics
- Quantum Communication
- Quantum Imaging and Sensing
- Quantum Optics
- Structure of Matter
- Thin Film Optics
- Ultrafast Optics

Seminars of the Institute & Devisions

- Applied Computational Optics
- Applied Physics
- Atomic Layer Deposition
- Design of Optical Systems
- Fiber Lasers
- Functional Photonic Nanostructures
- Graduate Seminar
- Microstructure Technologies - Microoptics
- Nano and Quantum Optics
- Ultrafast Optics



Jun.-Prof. Isabelle Staude explains a lab setup to an ASP-student as part of his internship. Since 2020, she directs the research group "FUNCTIONAL PHOTONIC NANOSTRUCTURES" at the Institute of Solid State Physics

TEACHING

Bachelor Theses

Hannes Richter
Charakterisierung von ultrakurzgepulsten Lasern

Georg Schwartz
Tailored side emission profile of femtosecond laser induced scattering centres in optical fibers

Tim Turan
Inverse design of metasurface stacks using convolutional neural networks

Master Theses

Saif Alnairat
Design of silicon photonic integrated optical filter based on ring resonators for noise suppression in high-speed data center interconnect applications

Vignesh Balaji
Equidistant Point Cloud Generation Using Interlaced Iterative Fourier Transform Algorithm

Marie Braasch
Image Reconstruction Algorithms for Ghost Imaging

Burak Cibuk
Evaluation of process and surface characteristics during conventional grinding of glassy ceramics

Riza Fazili
Linear Mach-Zehnder interferometric polarization-entangled photon source

Hooman Fereidoonfar
Optimization of Non-Paraxial Structured Light Generators via Rigorous Coupled-Wave Analysis

Golam Hafiz
Optical Bandgap of TiO_2 PEALD Coatings and Quantizing Structures

Maximilian Karst
Parallelized linear and nonlinear compression in ultrafast multicore fiber laser systems

Margarita Lapteva
Dielectric Interference Coatings on Highly Curved Substrates for Laser Optics at 355 nm Wavelength

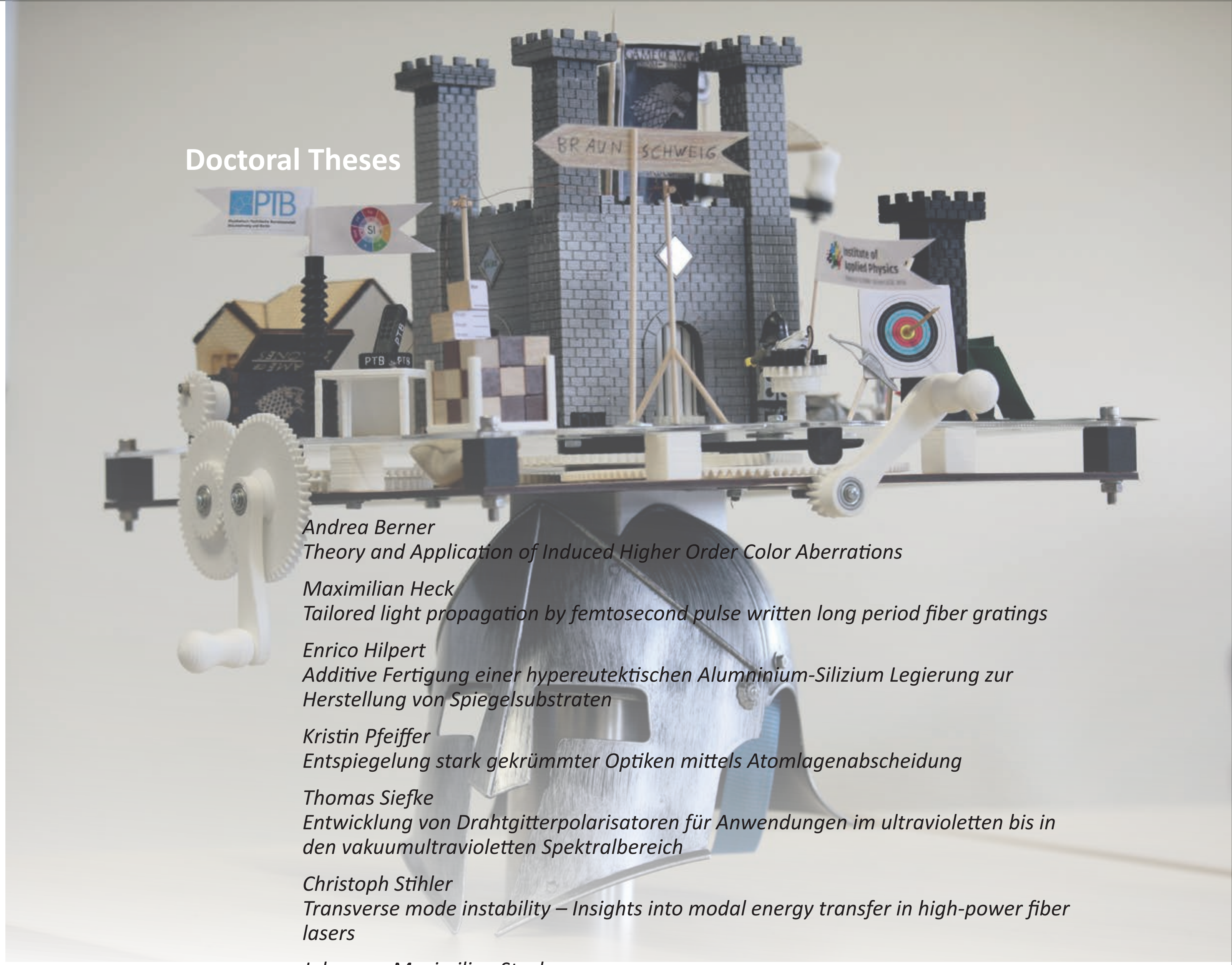
Zhouping Lyu
Factorizable photon-pair generation in microstructured liquid-core fibers

Dennis Peters
Investigation of HiLo microscopy with step index multimode fibers

Sohrab Sangini
Pattern Projection Modeling and Design Using a Microlens Array

Yiming Tu
Mode decomposition algorithms for the analysis of transverse mode instability

Sici Wang
Broadband Fourier transform holography in the visible and the extreme ultraviolet



Doctoral Theses

Andrea Berner
Theory and Application of Induced Higher Order Color Aberrations

Maximilian Heck
Tailored light propagation by femtosecond pulse written long period fiber gratings

Enrico Hilpert
Additive Fertigung einer hypereutektischen Alumninium-Silizium Legierung zur Herstellung von Spiegelsubstraten

Kristin Pfeiffer
Entspiegelung stark gekrümmter Optiken mittels Atomlagenabscheidung

Thomas Siefke
Entwicklung von Drahtgitterpolarisatoren für Anwendungen im ultravioletten bis in den vakuumultravioletten Spektralbereich

Christoph Stihler
Transverse mode instability – Insights into modal energy transfer in high-power fiber lasers

Johannes Maximilian Stock
Holistic simulation of optical systems

Aleksandr Vaskin
Controlling light emission by dielectric nanoantennas

PROJECTS

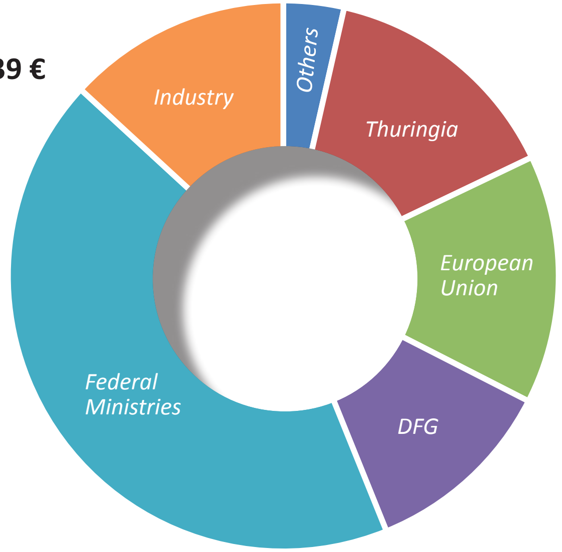
NOA spring school 2020 in Jena.
The project NOA's vision is to develop a fundamental understanding of nonlinear optical processes down to the atomic scale.
(Image: Anna Schroll)

PROJECTS

"Applied Physics" is implemented in numerous projects in different application fields that contain fundamental research as well as application aspects. Accordingly, strong partners were explored and cooperation expanded. Thus, the IAP can continuously link the results and transfer those from basic research into innovative and novel demonstrators.

Third-party expenditure

European Union	1,420,970 €
DFG (German Research Society)	1,106,169 €
Federal Ministries (BMBF, BMWi)	4,178,362 €
State of Thuringia	1,395,651 €
Contract Research	1,280,123 €
Foundations	346,114 €
Total:	**9,727,239 €**



European Union

ERC Advanced Grant: MIMAS "Multi-dimensional interferometric amplification of ultrashort laser pulses"

ERC Advanced Grant: SALT “High-Flux Synchrotron Alternatives Driven by Powerful Long-Wavelength Fiber Lasers”

Marie Skłodowska-Curie Research and Innovation Staff Exchange (MSCA-RISE): FUNGLASS “Functional Glass” & Innovative Training Networks (ITN-EID): NOLOSS “Lossless management - Optical design for manufacture at different length scales”

European Metrology Programme for Innovation and Research (EMPIR): BECOME “Light-matter interplay for optical metrology beyond the classical spatial resolution limits”

Horizon2020 "Fast quantum ghost microscopy in the mid-infrared"

DFG - German Research Foundation

Collaborative Research Center (CRC) SFB 1375: NOA „Nonlinear Optics down to atomic Scales“

International Research Training Group (IRTG) GRK 2101 "Guided light, tightly packed: novel concepts, components and applications"

Exzellenzcluster 2051: Balance of the Microverse - TP: superFOCUS - Plasmonic superfocusing microscopy & Mid-infrared microscopy with quantum light for chemical imaging of cell communities

Priority Programs (PP)

- SPP 1839 „Ausnutzung maßgeschneiderter Unordnung in dielektrischen Nanooberflächen zur Maximierung von deren Informationskapazität“
- SPP 1839 „Kontrolle der Streufeldwechselwirkung in ungeordneten zweidimensionalen Anordnungen von Silizium-Nanopartikeln“
- SPP 2122 „Neue Materialien hoher Steifigkeit für den Leichtbau durch additive Fertigung mit Ultrakurzpulslasern"

BMBF *Federal Ministry of Education and Research*

Graduate school with integrated master program: Max-Planck-School of Photonics

ZIK UltraOptics: OptiCon „Entwicklung spektroskopischer Methoden für Konversionsprozesse unter Hochdruck-/Hochtemperaturbedingungen“

Verbund APPA bei FAIR „Anwendung neuer photonischer Methoden zur Präzisionsspektroskopie an gespeicherten, hoch geladenen Ionen“

Innovative university: NUCLEUS Jena - Ein Paradies für Innovationen, TP

Innovative regional growth cores WK+fo+: „Technologieplattform VIS Freiformoptik sowie
Design und Strukturierung von Freiformflächen für neuartige Anwendungen“

Program "Zwangzig20" - Project "3Dsensation": NeoVital - Kontaktlose Überwachung der Vitalparameter Neu- und Frühgeborener durch multispektrale 3D-Messung in Echtzeit; TP2: Integrierte nanophotonische Filter für Kamerasensoren (IRIS)

Open Photonik Innovationsprozesse in der Licht-Region Jena (LichtwerkstattPro)

Verbund PINT, TP: Grundlegende Untersuchungen zur Skalierung von Mehrkernfaserverstärkern

State of Thuringia *Thuringian Ministry of Economy, Science and Digital Society*

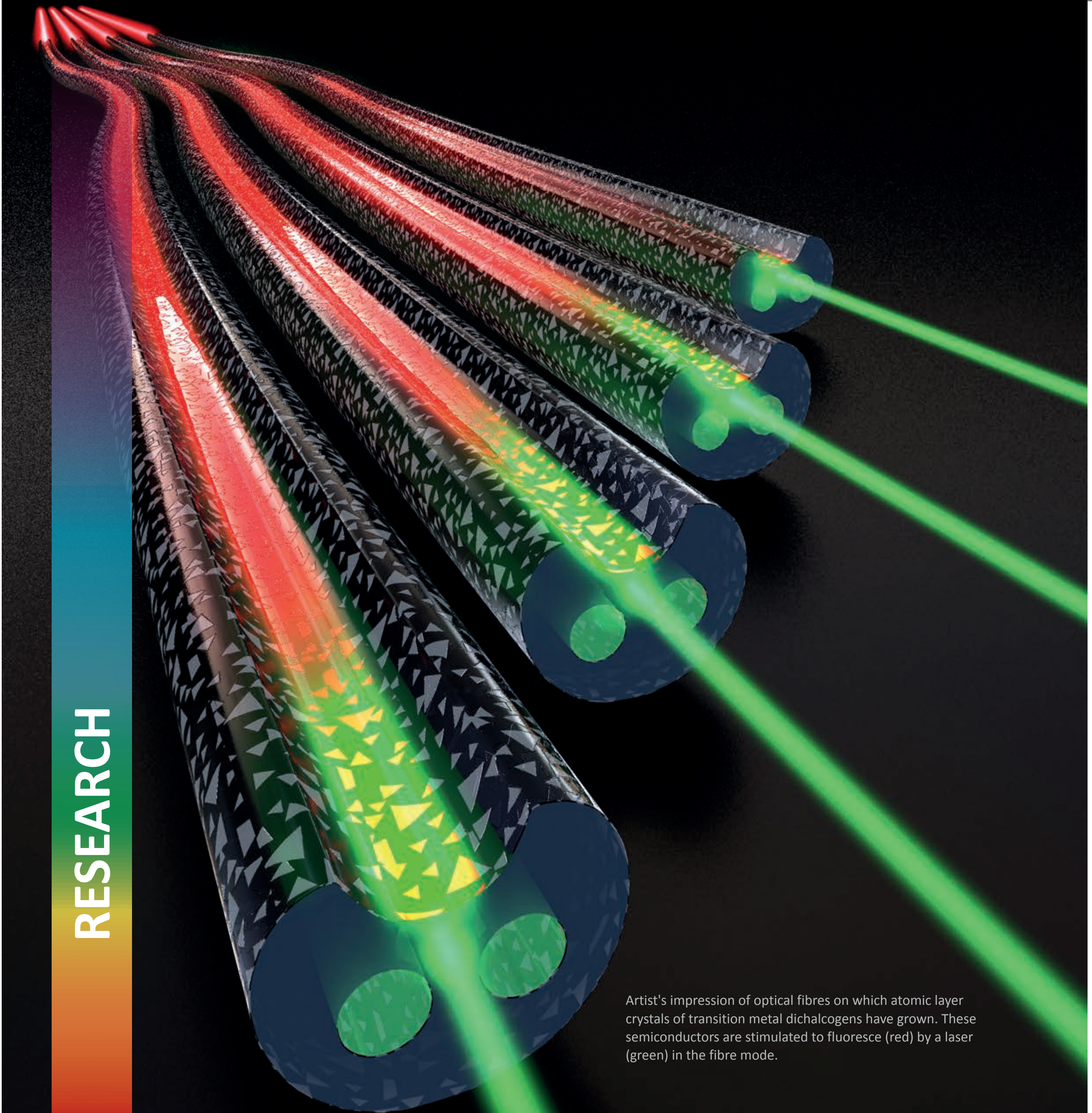
Thüringian Innovation Center „Thüringer Innovationszentrum für Quantenoptik und Sensorik“

TAB-Research Groups

- 2D-Sens
- 3D Erfassung mittels Wärmebildprojektion und Roboterhandling von transparenten komplexen Objekten für die Mensch-Maschine Interaktion und adaptive Fertigung
- RATI: Erforschung neuartiger Herstellungsverfahren für mikrostrukturierte Fasern
- Hochleistungsoptiken für (kohärente) weiche Röntgenstrahlung
- Quantenoptische Bildgebung mit verschränkten Photonen
- Ultrakurzgepulste Laserstrahlung zur flexiblen Fertigung maßgeschneiderter, optischer Komponenten für die individualisierte Produktion

Contract Research

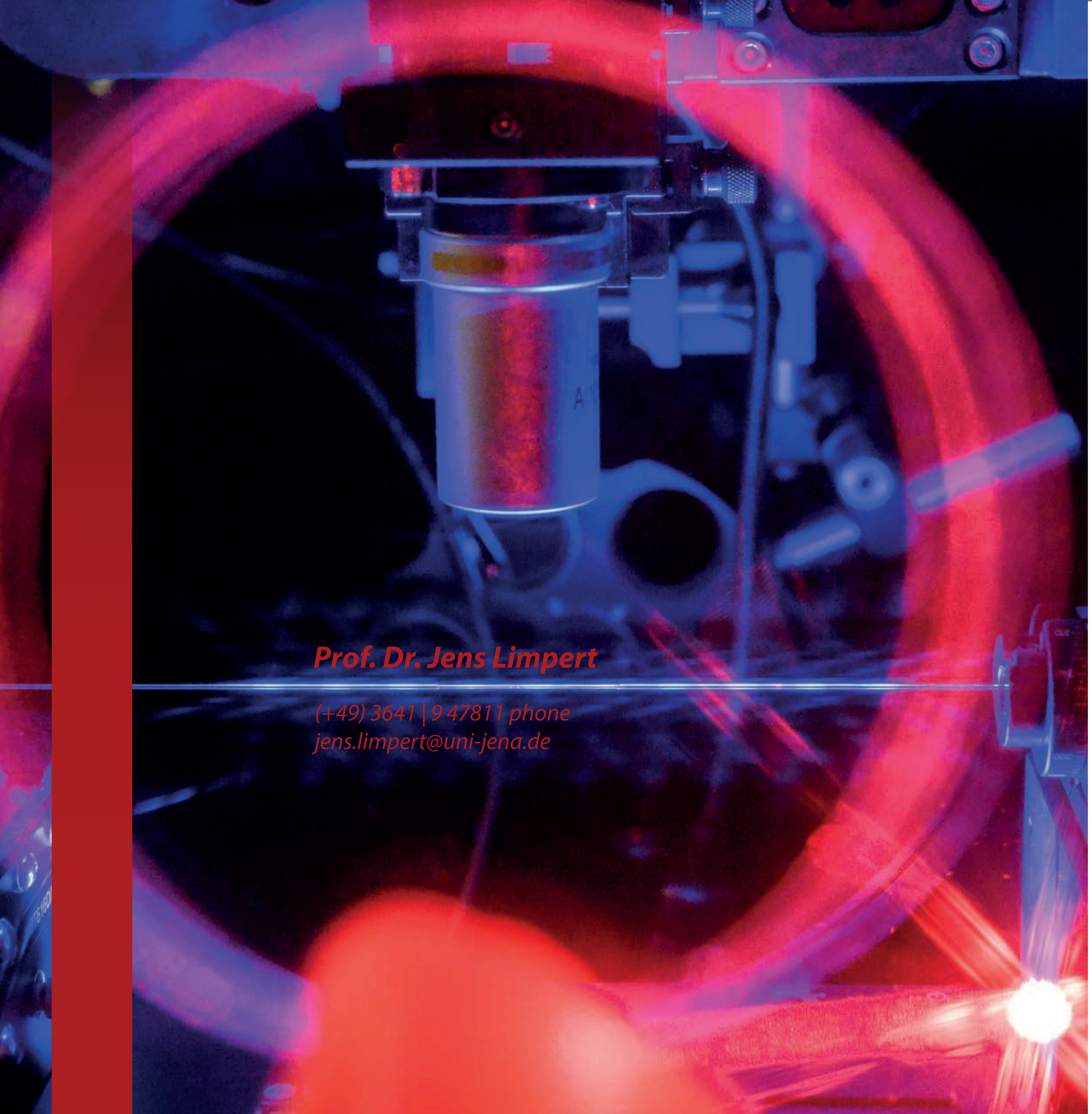
The IAP runs a very dense network of industry partners. Contract research have been made - very often in common with the Fraunhofer IOF - both with medium size regional and large size international companies, such as Layertec GmbH, Carl Zeiss AG, TRUMPF GmbH + Co. KG or the European Space Agency (ESA).



Artist's impression of optical fibres on which atomic layer crystals of transition metal dichalcogens have grown. These semiconductors are stimulated to fluoresce (red) by a laser (green) in the fibre mode.

RESEARCH - Achievements & Results

An intense engagement with all the research topics of the institute ultimately leads to the specialization of separate research groups on key challenges.
In turn, each group contributes with their results to the solution of partial tasks of the other work groups. This constantly self-fertilising approach itself leads to remarkable results. Measurably honored are such results by success in granting research contracts, the strong interest in cooperation with the IAP and the number of scientists and students who would like to work at IAP scientifically.



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Impression out of the fibre laser lab.

Fiber & Waveguide Lasers

This research group is working on the development of new concepts for solid-state lasers with focus on fiber laser technology.

Scientific focus lies on:

- Fiber optical amplification of ultra-short laser pulses
- Ultra-short pulse oscillators, few-cycle pulse generation and amplification
- Conception of novel large core diameter fibers
- Simulation of non-linear effects and amplification dynamics in active fibers
- Fiber optical frequency conversion
- Mid-IR laser sources
- High Harmonic Generation and applications in imaging and spectroscopy

Authors:
Martin Gebhardt, Tobias Heuermann, Robert Klas, Jan Rothhardt and Jens Limpert

Fiber-based, soft X-ray source

Coherent sources, providing high photon flux in the soft X-ray region, are interesting for numerous applications in fundamental research and life science. This includes applied spectroscopy of magnetic materials /1/ or imaging of biological samples /2/, potentially with nm-resolution and element specific contrast. However, such sources are currently only available at large-scale research facilities (synchrotrons and free electron lasers), or are based on complex laser technology (generation of high harmonics with very high peak power laser pulses) /3/.

Herein, we describe a user-friendly, alternative soft X-ray source, which is based on the combination of temporal laser pulse self-compression and high harmonic generation in one and the same hollow core fiber. This enables a compact, fiber-integrated setup and reasonable requirements for the driving laser technology. The experimental setup is presented in fig. 1. First, 250 µJ-, 100 fs-pulses from a thulium-doped fiber CPA (Tm:FCPA) /4/ are coupled to an antiresonant hollow core fiber, which is filled with helium gas from its optical output. The interplay of self-phase modulation and anomalous waveguide dispersion leads to a temporal compression of the pulses and to a significant increase in peak power and intensity toward the fiber end. In this scheme, it is possible to generate few-cycle pulses at the fiber end. These pulses are intense enough to significantly ionize the gas /5/. The tunnel ionization events are the necessary, initial step for the generation of high harmonics. If the gas pressure is chosen such that at the fiber end, the phase velocities of the driving laser and the harmonic radiation are equal, it is possible to generate a macroscopic photon flux. For reaching the soft X-ray spectral region (high photon energies) it is important to use a driving laser wavelength >1 µm, because the maximum phase-matched photon energy increases with longer driving laser wavelength.

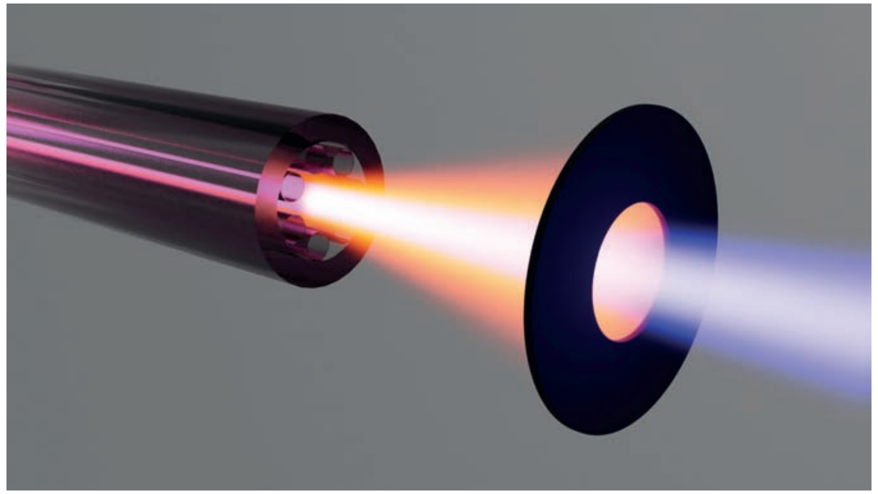


Figure 1:
It shows the output end of the antiresonant hollow-core fiber where the laser pulses are self-compressed and directly generate high-order harmonics in the soft X-ray spectral region. The majority of the driving laser power and the helium gas are blocked using a circular aperture.

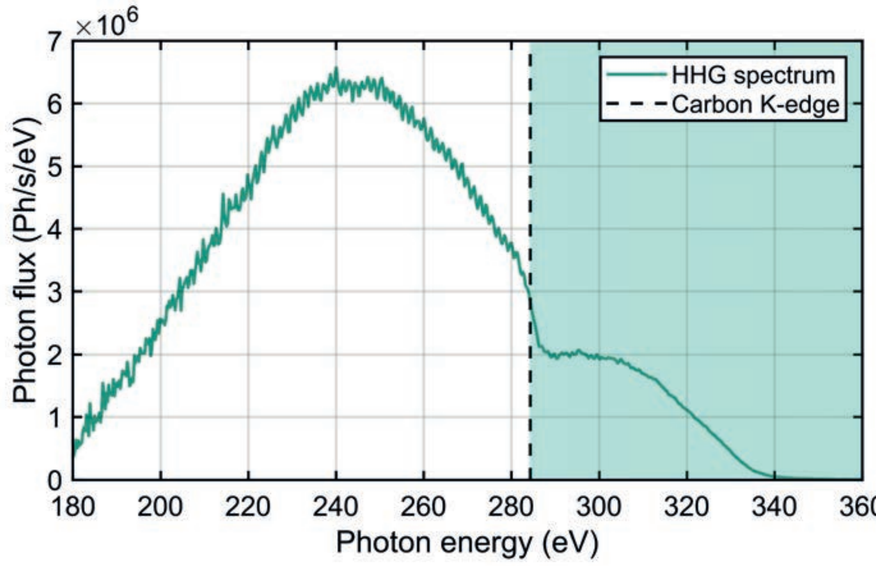


Figure 2:
Generated spectrum of the soft X-rays. The K-shell absorption edge of carbon and the beginning of the "Water Window" are marked in the figure.

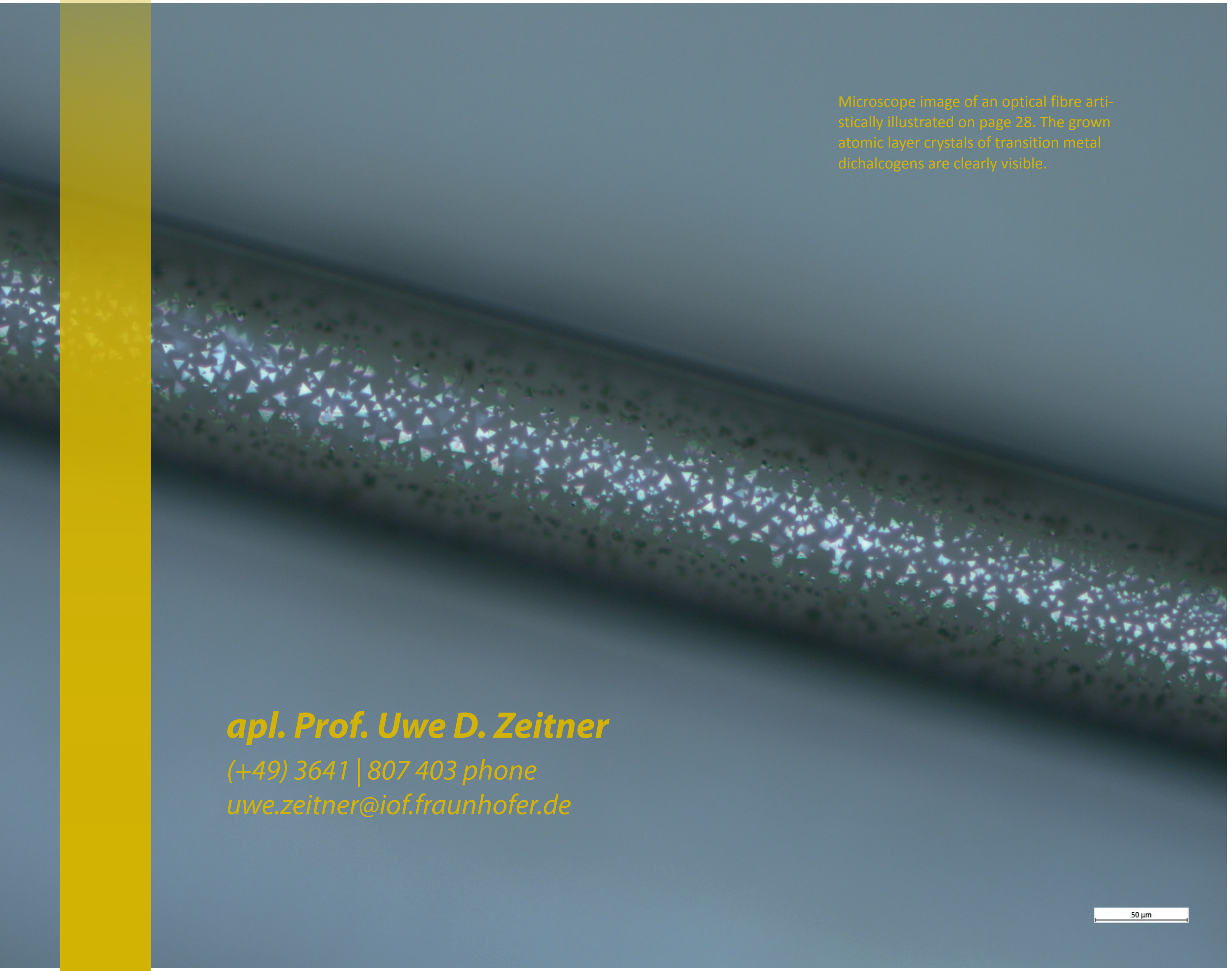
Fig. 2 presents a generated soft X-ray spectrum, which extends into the so-called "Water Window". The K-shell absorption edge of carbon is clearly visible and can be associated with hydrocarbon contaminations of the setup. At 300 eV, within the application-relevant "Water Window", we could generate a photon flux >106 Ph/s/eV. Due to the progressively increasing laser intensity within the hollow core fiber, the concept described herein is especially interesting for scaling the repetition rate (herein: 100 kHz) of table-top coherent X-ray sources. The results presented herein represent the highest demonstrated photon flux in the water window at a repetition rate >1 kHz.

/1/ D. Popmintchev, et. al: Near- and Extended-Edge X-Ray-Absorption Fine-Structure Spectroscopy Using Ultrafast Coherent High-Order Harmonic Supercontinua. Phys. Rev. Lett. 120(9), 093002, 2018.

/2/ M. Rose, et. al.: Quantitative ptychographic bio-imaging in the water window. Opt. Express 26(2), 1237, 2018.

/3/ L. Young, et al.: Roadmap of ultrafast x-ray atomic and molecular physics. J. Phys. B At. Mol. Opt. Phys. 51(3), 032003, 2018.

/4/ J. Limpert, et. al.: High performance ultrafast thulium-doped fiber lasers. Conference on Lasers and Electro-Optics Europe and European Quantum Electronics Conference, paper cj_10_1, 2019.



Microscope image of an optical fibre artistically illustrated on page 28. The grown atomic layer crystals of transition metal dichalcogens are clearly visible.

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Microstructure Technology & Microoptics

This research group concentrates fundamentally on function and design of micro- and nano-optical elements as well as applications and technology developments for micro structuring.

The following research priorities have been treated:

- Plasmonic resonant nanometric structures
- Resonant reflective monolithic gratings
- Transmissive, reflective and diffractive elements based on effective media
- Metallic and dielectric polarizers from IR to DUV range
- 3D nano-structuring of crystals with ion beam
- Optical and opto-electronic applications of antireflective fused silica and silicon surfaces
- Microoptical light-trapping in optoelectronic devices
- Functional optical layers controlled on the atomic scale
- Diamond based optical components

Authors:
Kristin Pfeiffer, Vivek Beladiya, Torsten Harzendorf, Thomas Flügel-Paul and Adriana Szeghalmi

Conformal coating for high-efficiency spectrometer gratings

High-efficiency diffractive gratings, which build the key components of earth monitoring spectrometers in the NIR / SWIR spectral range as dispersive elements, impose great challenges on the manufacturing process. High and nearly polarization-independent diffraction efficiency is achieved by embedding a fused silica grating into a high refractive index material (TiO_2) and an antireflective SiO_2 top layer (Figure 1).

High quality, homogenous and void-free coatings are required for a high efficiency. The embedding is therefore done by atomic layer deposition (ALD) (Figure 1), which can deposit conformal coatings onto deep gratings. The continuously increasing aspect ratio of the grooves is a particular challenge for their filling; thus, the deposition process must be optimized for such gratings. In addition, the refractive index and the coating thickness must be precisely controlled.

In this holistic approach, the optimization of the process parameters (precursor material, dose and purge times, plasma conditions, etc.) for the specific grating has been carried out. Plasma enhanced ALD (PEALD) processes allow TiO_2 coatings with a high refractive index. However, these coatings have a high roughness at the film thickness required for filling the grooves of above 300 nm. Smooth coatings are obtained by TiO_2/Al_2O_3 nano-laminates (AFM roughness, rms < 1 nm). In addition, the refractive index can be adapted to the optimal grating design by adjusting the amount of the Al_2O_3 in the nanolaminate. Controlling the ratio of the components in the nanolaminates and the plasma conditions allows a refractive index of 2.32+/-0.01 @2µm (Figure 2). Thus, transmission gratings with an average diffraction efficiency above 90 % and a polarization sensitivity below 4 % have been demonstrated for the entire SWIR2 channel.

/1/ L. Ghazaryan, S. Handa, P. Schmitt, V. Beladiya, V. Roddatis, A. Tünnermann, A. Szeghalmi: Structural, optical, and mechanical properties of TiO_2 nanolaminates. Nanotechnology, accepted.

Figure 1:
Photograph of an embedded grating and of the PEALD coating equipment.

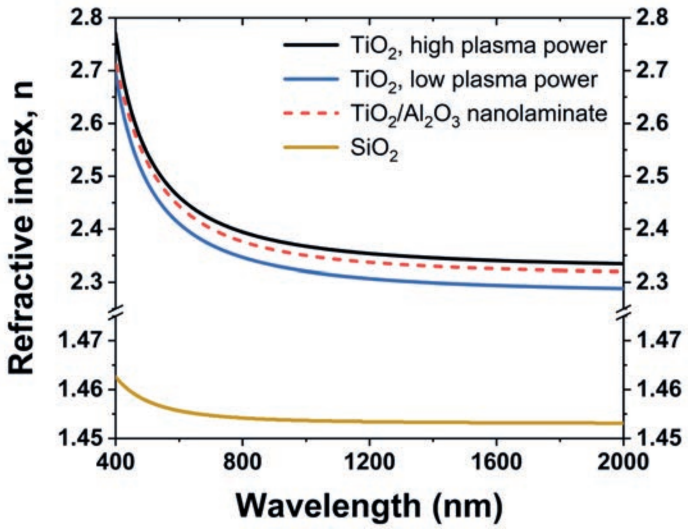

Figure 2:
Dispersion curves of SiO_2 and TiO_2 thin films and TiO_2/Al_2O_3 nanolaminate.

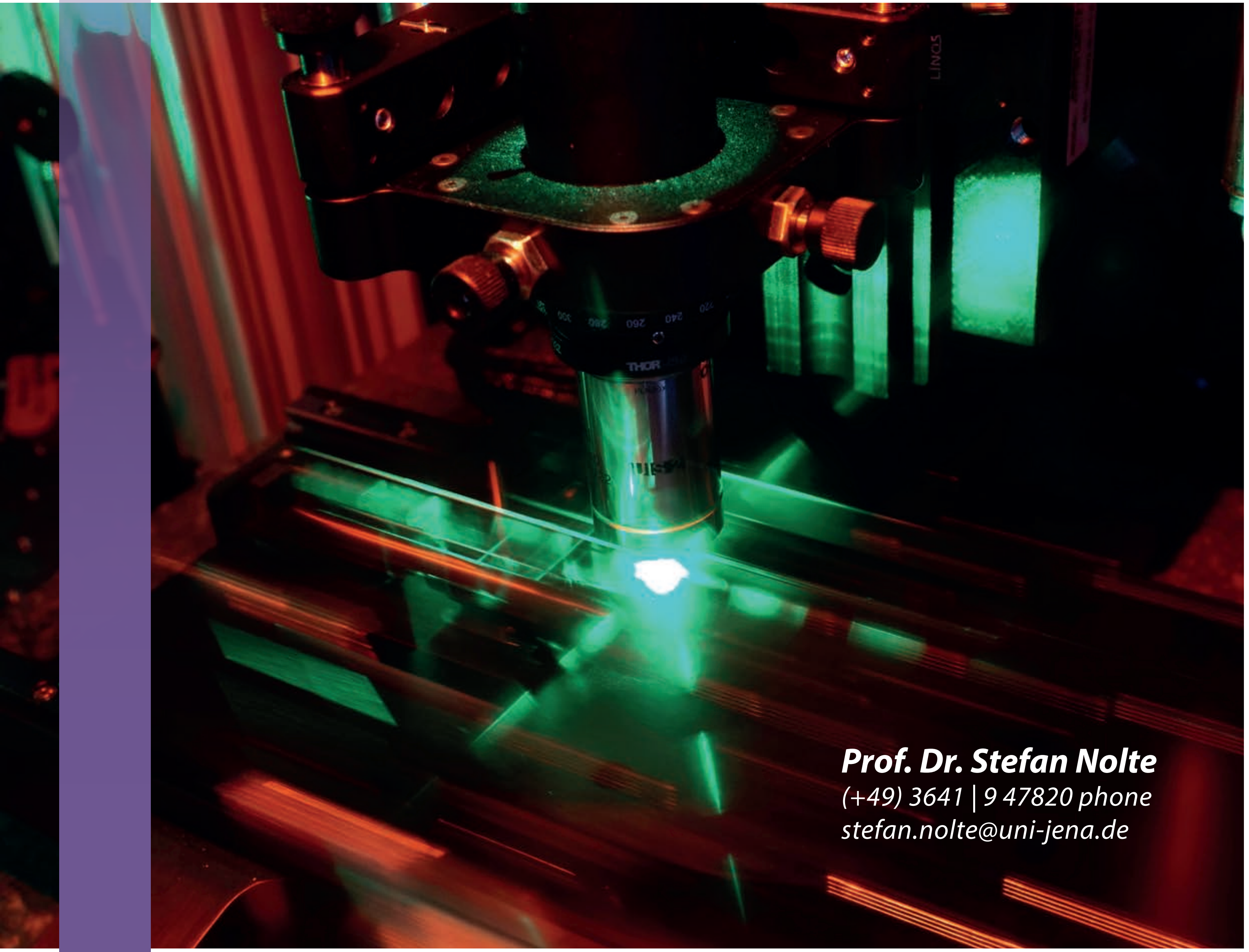

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Figure 1: (belonging to the article on p. 40)
Ultrashort laser pulses inscribe waveguides into a fused silica sample. A positioning system moves the sample with respect to the laser focus.

Ultrafast Optics

The group Ultrafast Optics works on applications of femtosecond laser pulses, such as materials processing and micro/nano structuring of optical materials.

The scientific topics are:

- Linear and nonlinear laser-matter interaction: A fundamental understanding of the interaction between ultra-short laser pulses and solids forms the basis for the work of our group. For this purpose, propagation and absorption effects as well as subsequent relaxation processes are analyzed in detail.
- Micro-and nanostructuring with ultrashort laser pulses: Ultrashort laser pulses allow high-precision structuring on the micro- to nanometer scale. Our investigations range from ablation to the defined manipulation of material properties.
- Additive manufacturing using ultrashort laser pulses: We investigate the use of ultrashort pulses for processing advanced materials like supersaturated metal alloys or materials with extreme properties like extraordinary high melting points or increased thermal conductivity, which are not accessible with conventional systems.
- Volume modifications in glasses: The nonlinear absorption inside transparent materials allows the modification of the propagation properties of light. Application examples include fiber and volume bragg gratings, waveguide systems, and artificially birefringent structures.
- Spectroscopic methods for gas analysis: Non-linear spectroscopy methods are developed for the analysis of gases under extreme conditions.

Authors:
Kim Lammers, Alessandro Alberucci and Stefan Nolte

Selective Spectral Filtering through Complex Gratings in Fibers

Integrated optical circuits show many benefits for optical quantum computing, including compactness and robustness to external perturbations. To fabricate these circuits, we use femtosecond laser direct writing, which is based on moving the focus of an ultrashort laser pulse through a transparent sample (Fig. 1, see p. 38). Due to the high intensities in the focal volume, nonlinear absorption processes can occur, allowing the material to be modified locally. When irradiating fused silica with a pulse energy just above the modification threshold, its refractive index will increase. This modification allows the fabrication of waveguides. For larger excitations of the material, the modification type "nanogratings'" will develop in fused silica. Nanogratings consist of subwavelength pores, exhibiting form birefringence. By embedding nanogratings into waveguides, they can act as integrated waveplates.

In optical quantum computing, waveplates act as quantum gates for polarization-encoded single photons. To implement this in integrated optical circuits, the waveguides must be polarization maintaining, which can be achieved in femtosecond laser writing by shaping the inscription laser beam /1/. Secondly, the birefringence properties of the embedded nanogratings have to match the desired functionality. This is controlled by the inscription parameters: the polarization of the inscription beam determines the orientation of the optical axis and the pulse energy changes the optical retardation induced by the nanogratings. To monitor the properties of the inscribed structures, a Stokes parameter analysis is performed with laser light (Fig. 2). The final characterization using single photon sources was done in collaboration with Prof. Szameit from University of Rostock. The functionality of Hadamard, Pauli-X, Pauli-Z and Pi-8th were confirmed /2/.

/1/ K. Lammers, et al.: Nanograting based birefringent retardation elements in integrated photonic circuits. Laser-based Micro-and Nanoprocessing XIV. Vol. 11268. International Society for Optics and Photonics, 2020.

/2/ K. Lammers et al.: Embedded nanograting-based waveplates for polarization control in integrated photonic circuits. Opt. Mater. Express 9.6, 2560, 2019.

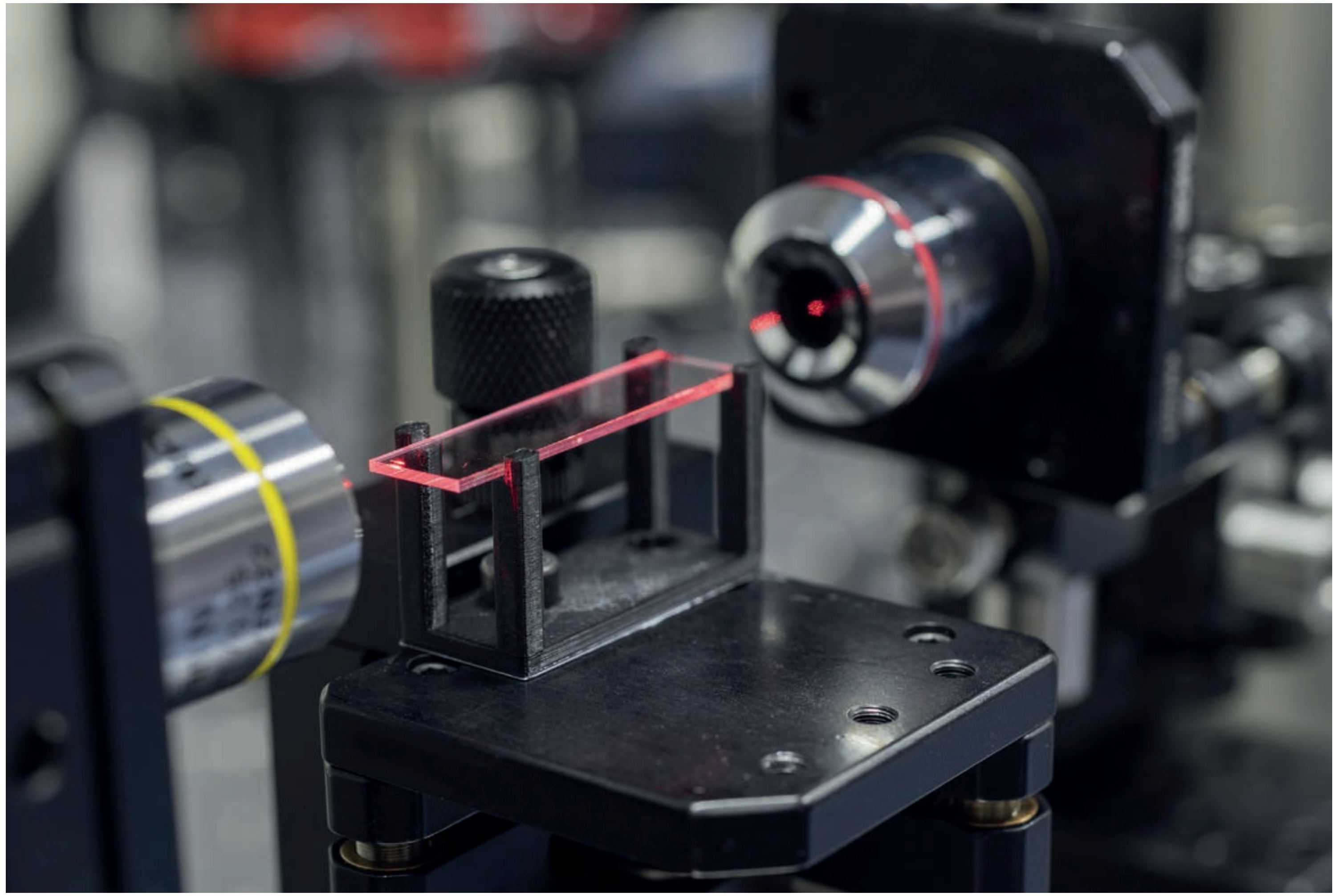

Figure 2:
Characterization of laser written waveguides using a probe laser beam to find optimal inscription parameters.

Authors:
Tobias Ullsperger, Burak Yürekli, Lisa Schade, Gabor Matthäus and Stefan Nolte

3D printing of high stiffness alloys using ultrashort laser pulses

Additive manufacturing of aluminum-based alloys allows the realization of innovative lightweight structures in combination with adapted material properties. Weight-reduced components with high dimensional accuracy and stability under mechanical and thermal load are of particular interest for various applications in optics and aerospace. Extraordinary high specific stiffness can be significantly increased by adding high concentrations of Si and Li to the alloy. Moreover, the tensile strength of Al-Si alloys can also be increased, and the coefficient of thermal expansion reduced. Li is the lightest metal with a density of 0.53 g/cm^3 and increases the specific stiffness in an Al alloy significantly.

During laser powder bed fusion rapid solidification with cooling rates of more than 10^4 K/s appear, which yield to a significant refinement of microstructure. The melt pool size and heat-affected zone using conventional continuous wave (CW) lasers are in range of several 100 µm, which limits the geometric precision and achievable cooling rates.

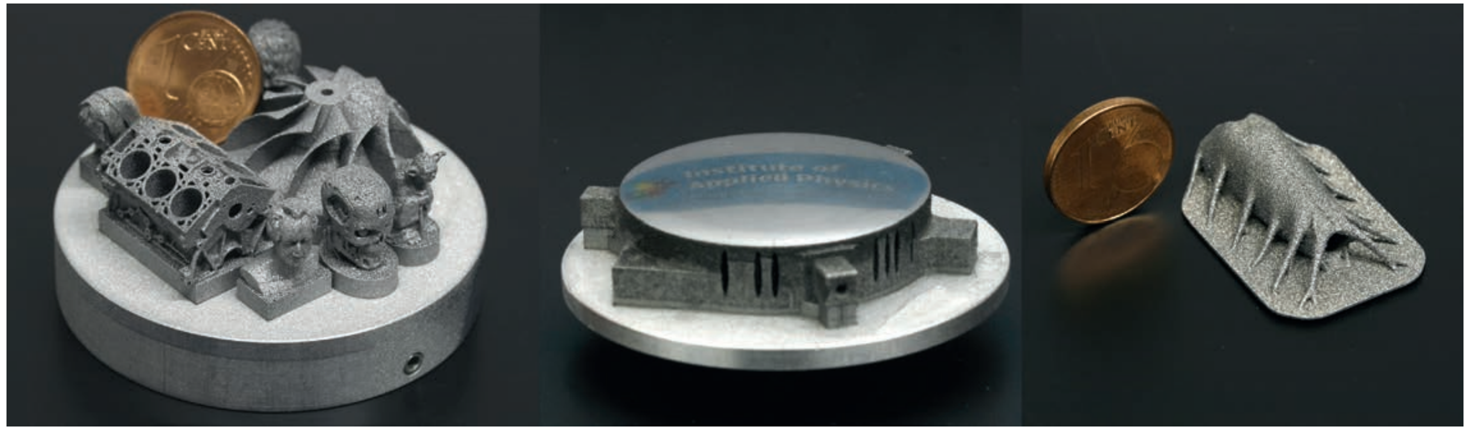

Figure 1:
Complex light-weight demonstrators made of Al-40Si (left) and Al-70Si (middle and right).

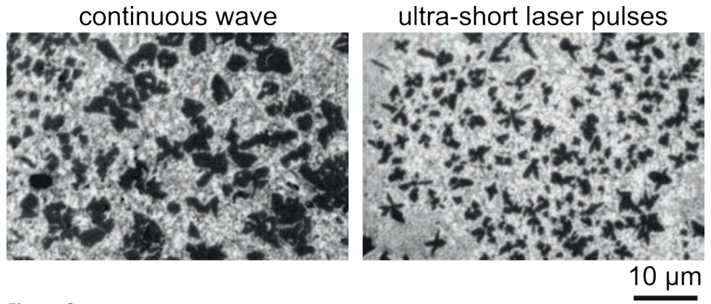

Figure 2:
Microstructural refinement of Al-40Si using fs-laser pulses.

Recently, ultrashort laser pulses were used for the first time to fuse powder-based material /1, 2/. Here, the light-matter interaction is typically in the range of a few ps to fs, whereby pulse peak power in the MW range is achieved. By adjusting the pulse energy, repetition rate and scanning velocity, the accumulated heat can be directly controlled yielding structure widths down to 50 µm.

In comparison with CW-irradiation, powder bed fusion with fs-laser pulses provides a refinement of the primary silicon phase and the eutecticum (Fig. 2) /3/, which leads to an increase of Youngs modulus and tensile strength. Furthermore, binary Al-4Li powder was produced in collaboration with the group of Prof. Rettenmayr at the Otto-Schott Institute of Materials Research for the first time and the brittle δ-AlLi phase was considerably reduced by fs-laser powder bed fusion /4/. This provides the basis for highly rigid solid components made of Al-Li alloys, where the structural properties are improved in comparison to conventional casting processes.

/1/ T. Ullsperger et al.: Selective laser melting of hypereutectic Al-Si40-powder using ultra-short laser pulses. Appl. Phys. A 123, 798, 2017.

/2/ T. Ullsperger et al.: Optimization of mechanical properties and as-built quality of additive manufactured Al-Si alloys using ultra-short laser pulses. Lasers in Manufacturing (LiM), Munich, Germany, 2019.

/3/ T. Ullsperger et al.: Ultrashort pulsed laser powder bed fusion of Al-Si alloys: Impact of the pulse duration and energy in comparison to continuous wave excitation. submitted in Additive Manufacturing, 2020.

/4/ B. Yürekli et al.: Additive manufacturing of binary Al-Li alloys. Procedia CIRP 94, pp. 69-73, 2020.

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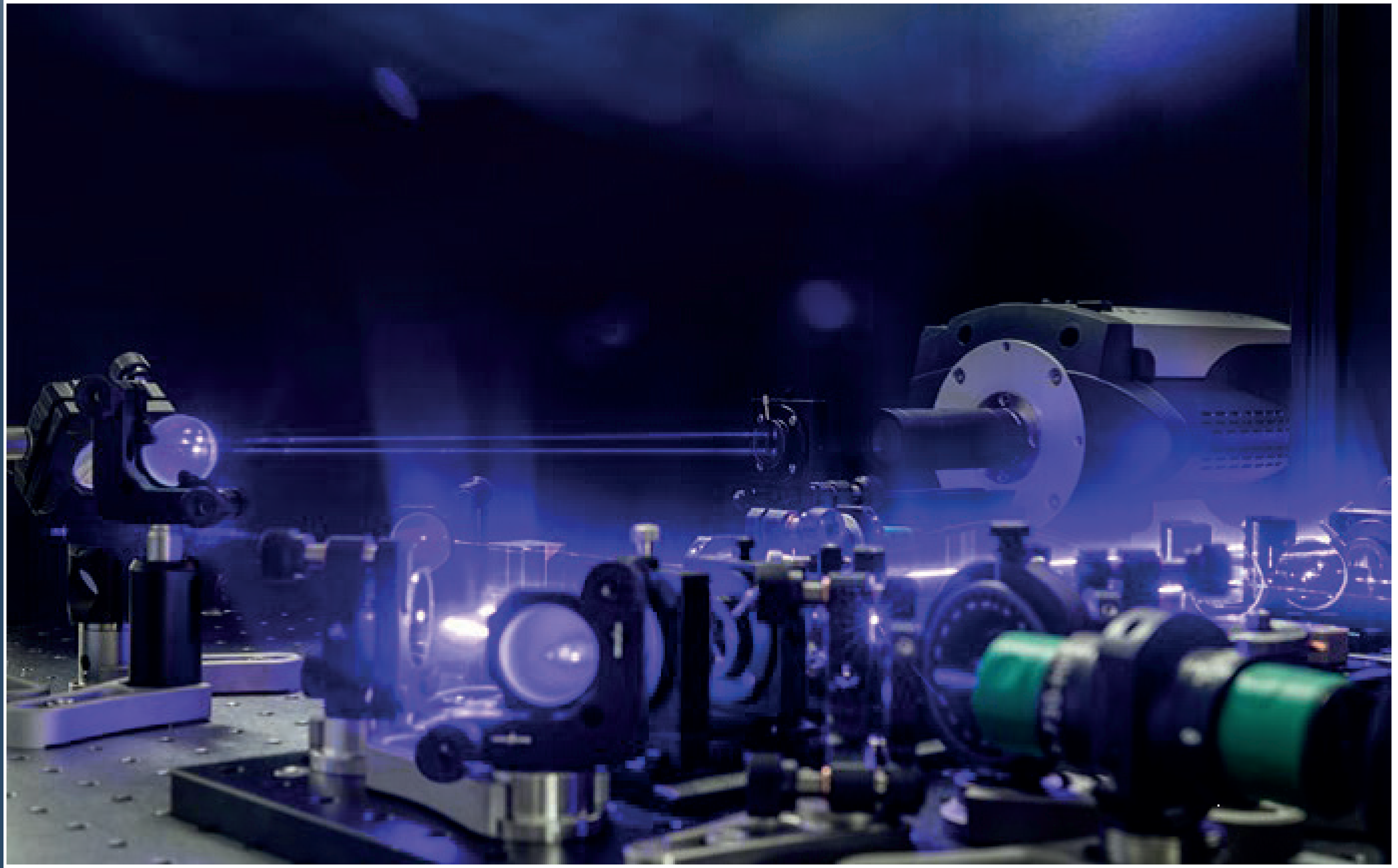

Quantum optical imaging system, which is used to investigate quantum imaging (rights: Fraunhofer-IOF.

Nano & Quantum Optics

The research group Nano & Quantum Optics deals with ultrafast light-matter interactions and optical quantum phenomena in microstructured and nanostructured matter, as e.g. photonic nanomaterials, meta-materials, photonic crystals, and effective media.

The scientific emphasis lies on:

- nonlinear spatio-temporal dynamics, integrated quantum optics, plasmonics, near field optics, high-Q nonlinear optical microresonators, opto-optical processes in integrated optics, all-optical signal processing
- Multi-tip scanning optical nearfield microscopy (SNOM), photoemission electron microscopy (PEEM)
- Application of photonic nanomaterials for multi-functional diffractive optical elements
- Application of optical nanostructures for efficiency enhance-ment of photovoltaic elements
- Application of advanced photonic concepts for astronomical instruments

Authors:
Anna Fedotova, Mohammadreza Younesi, Thomas Pertsch, Isabelle Staude, and Frank Setzpfandt

Nonlinear nanophotonics in lithium niobate metasurfaces

Lithium niobate (LN) is an established photonic material which possesses a unique combination of optical properties /1/. Its wide transparency range, spanning from the ultra-violet to the mid-infrared, and the high second-order nonlinearity make it a perfect medium for nonlinear frequency conversion processes such as second-harmonic generation, where two photons of the fundamental wavelength are converted into one photon at the second harmonic with half the wavelength. However, its nanostructuring remained a challenge until now /2/. On the other hand, making use of lithium niobate's exceptional properties in nanophotonics is highly beneficial, as it enables the miniaturization of established bulk optical devices and the realization of new functionalities by adding advanced control over the spatial and spectral properties of light.

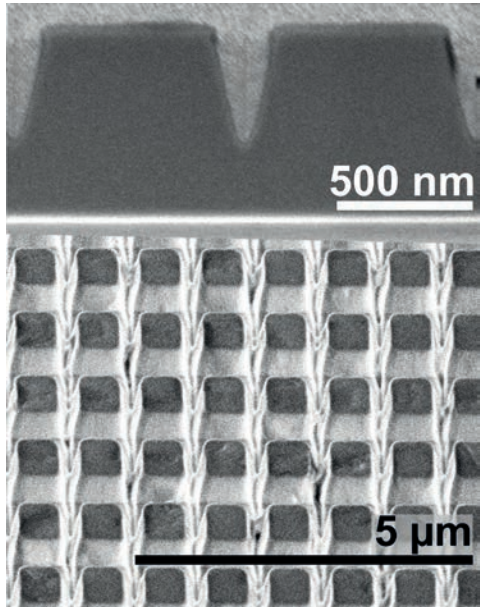

Figure 1:
Scanning electron microscope images of a lithium niobate meta-surface.

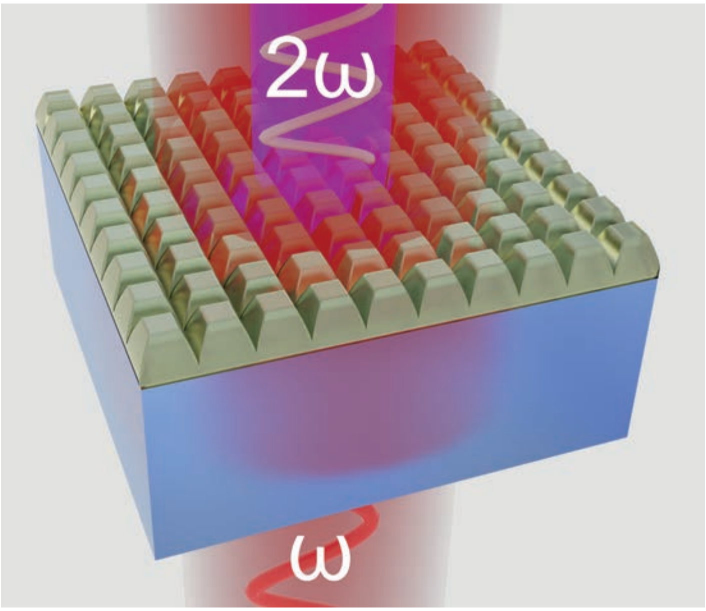

Figure 2:
Schematic visualization of the second-harmonic generation from lithium niobate metasurfaces.

We could establish a process for the realization of nanostructures from lithium niobate thin films and produced two-dimensional metasurfaces shown in Fig. 1. These periodic arrays of nanoresonators show a high quality of the individual nanostructures and small side-wall roughness. Our metasurfaces are resonant for the fundamental wavelength, where, due to the specific geometry of each nanoresonator and the coupling between them, the electromagnetic field inside the lithium niobate nanoresonators is enhanced, providing a strong second-harmonic signal. Moreover, different resonance types support different configurations of the field inside a nanoresonator, which leads to interesting polarization properties of the generated photons. Owing to the form of the nonlinear second-order susceptibility tensor of LN, a considerable amount of the generated second-harmonic is emitted in the direction normal to the sample plane as schematically shown in Figure 2, which ensures its effective collection.

Besides being efficient in classical nonlinear processes, these lithium niobate metasurfaces have the potential to serve as subwavelength sources of entangled photons generated by the quantum process of spontaneous parametric down-conversion when a single photon spontaneously decays into a pair of lower-energy photons. Thus, the fabricated lithium niobate metasurfaces are a versatile platform for classical and quantum nonlinear nanophotonics.

/1/ R. S. Weis, T. K. Gaylord: Lithium niobate: summary of physical properties and crystal structure. Applied Physics A 37.4, 191-203, 1985.

/2/ R. Geiss, S. Diziain, M. Steinert, F. Schrempel, E.B. Kley, A. Tünnermann, T. Pertsch: Photonic crystals in lithium niobate by com-bining focussed ion beam writing and ion-beam enhanced etching. Physica Status Solidi (a) 211(10), 2421-2425, 2014.

Optical System Design

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In classical optics design, especially the following topics will be addressed:

- Design of modern optical system
- Aberration theory for non-symmetrical systems
- Quality evaluation of optical systems
- Measurement of the performance of optical systems by phase retrieval
- Design of laser and delivery systems
- Design and evaluation of freeform optical systems for imaging
- Optimization and correction methods in optical design
- Tolerancing of optical systems

In somewhat more general physical issues relating to optical systems, in particular the following topics of interest are:

- Simulation of diffraction effects
- Microscopic image formation
- Calculation algorithms of wave propagation
- Straylight and scattering in optical systems
- Modelling of illuminations and beam profiling systems
- Partial coherent imaging and beam propagation
- Point spread function engineering and Fourier optics
- Simulation of ultra short pulse propagation

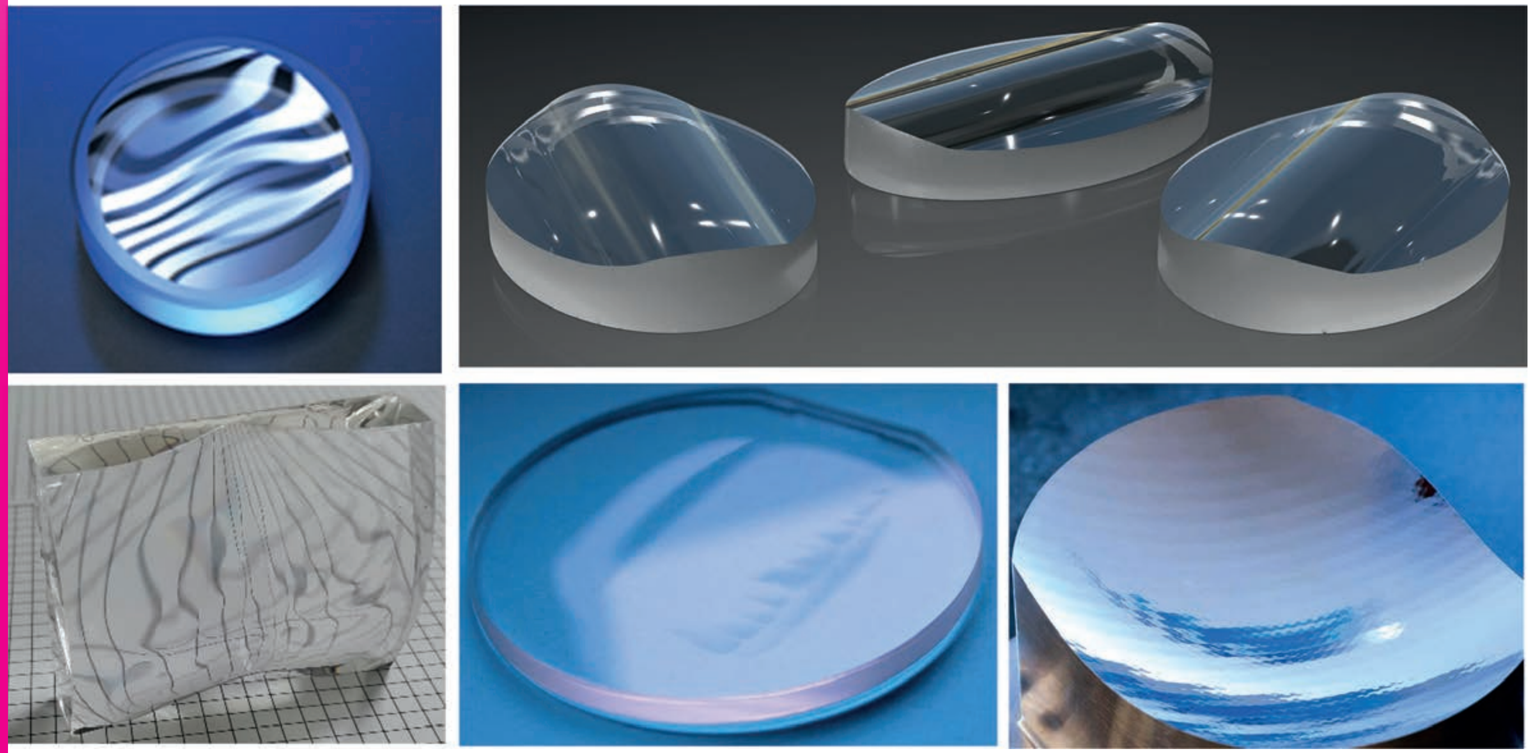

Figure 1: (belonging to the article on p. 50)
Freeform sample surfaces.

Author:
Herbert Gross

Optical Systems with Freeform Surfaces

Classical optical systems have circular symmetry, they have a straight optical axis and the surfaces are rotational symmetric. This symmetry simplifies many aspects of modelling, calculation and manufacturing, therefore historically optical systems mainly are of this type. With progress in manufacturing capabilities in particular by diamond turning, it is also possible to fabricate surfaces with more general shape. Many of the properties and methods are in this case completely new. The interest for this kind of systems grows in the last decades, because some functionalities cannot be realized by the traditional approach. From the viewpoint of basic physics, symmetry mostly is an advantage and things are becoming more complicated, if this property is lost. But in the use of optical systems there are often applications, which need geometries with reduced symmetry. Two different generalizations must be distinguished at this point. In the first case, only the optical axis is bended but the components are still circular symmetric. If in addition the components are allowed to by asymmetric, the situation becomes more challenging.

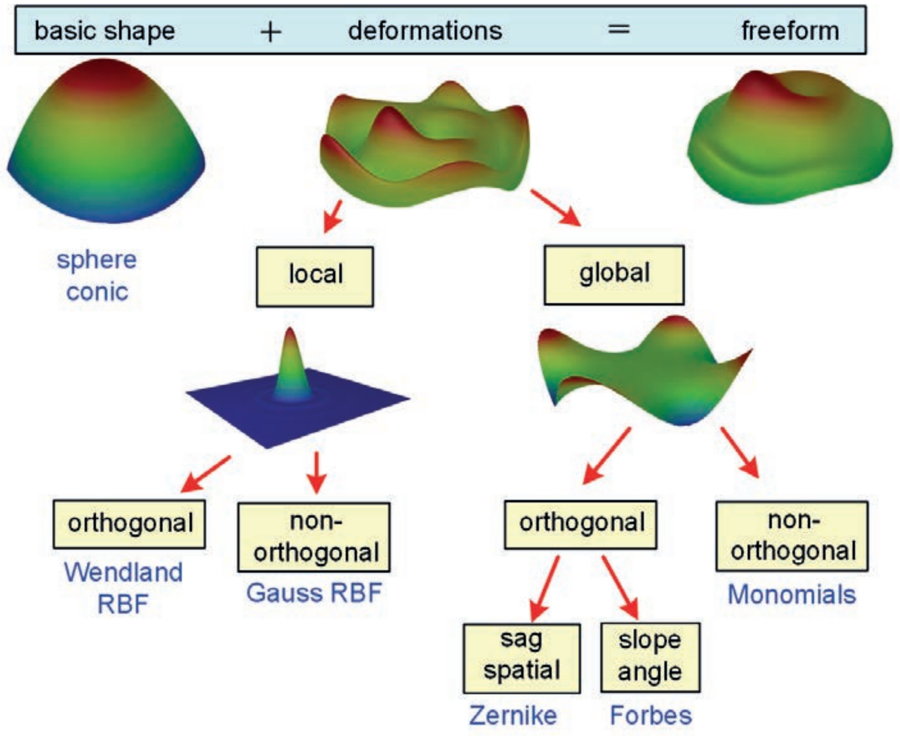

Figure 2: Mathematical description of a freeform surface.

Figure 1 (p. 48) shows some typical components with freeform surfaces. The complexity of the surfaces depends on the application behind. If the aberration correction of an imaging applications is improved by a freeform, usually the shape is smooth, if an illumination is performed by the surface with a requested complicated profile, the shape can be very complex.

The mathematical approach to describe a freeform surface uses a decomposition of a basic shape, which controls the parameter near the optical axis ray similar to the paraxial range and a second contribution containing the higher order deviations. This scheme together with some options of concrete formulation are sketched in figure 2. It is seen, that many possibilities are proposed to realize the deformations, mainly an expansion into a set of polynomial functions valid global on the area of definition is used. A local capture of deviations is more comfortable to describe real manufactured surfaces.

Some typical applications for freeforms are depicted in figure 3. Very often mirror systems are found in freeform systems, here the axis bending is needed to avoid a central obscuration. Ray bundles reflected by a curved mirror under a finite incidence suffers from huge astigmatism, therefore special methods are needed for correcting these influences.

From a more economic point of view, a freeform always corresponds to a more complex system and brings risk and additional cost. If the freeform surface is needed only in low accuracy and can be fabricated by reproduction, the cost factor is relaxed. Correspondingly today freeforms are found in commercial products most in consumer applications with low requirements like eye glasses or illumination systems or in very demanding high-performance systems like lithography or space optical telescopes, where the cost is not the main issue.

In the practical development of freeform systems, nearly all steps of the process chain are changing in a substantial way. First the surface description has to generalized form a spherical description into a full 2D formulation. In the system optimization of performance therefore a large number of parameters is occurring. The evaluation of the image quality is now a full 2-dimensional function and has one more dimension.

In addition all the tools behind like raytrace or aberration calculations must be changed. It should be noticed, that the quality is described by aberrations, which are physically nonlinearities in the behaviour, if larger fields of view and aperture cones violate the paraxiality assumptions. A quantitative measurement of the aberrations therefore uses the paraxial data as an ideal reference. In freeform systems, there is no small-angle paraxial reference and all the classical terms must be redefined. There are several aspects in the design concepts of a freeform system, which makes it complicated. There is nearly no data basis or experience available concerning a comfortable concept of these systems. Some simple applications like 3-mirror anastigmatic telescopes are discussed in detail in the literature, but clever approaches for new applications and more complicated systems must be learned from the scratch. The classical rules in optical design how to tackle existing residual aberrations and how to improve the performance cannot be simply applied, the structure and aberration compensation scheme is not very intuitive and delivers completely new insights into the principles of the freeform design in every new application. For the task of shaping the intensity distribution in a flexible way, new algorithms and tools are developed in recent time, classical tools are in no way able to solve these problems.

The lack of a unique axis is also a severe problem in the assembly and correct positioning of the surfaces in a system. Due to the more complicated manufacturing, metrology and assembly there are several constraints and limitations for the shape and accuracy of freeforms. These technological boundary conditions must be taken into account in the design phase of an optical system, otherwise the realization can never be successful.

This short sketch illustrates, that the design manufacturing and development of optical systems free of symmetry is a fascinating new branch and still needs more fundamental research as well as practical experience to be fully applicable and successful in industrial products in the future.

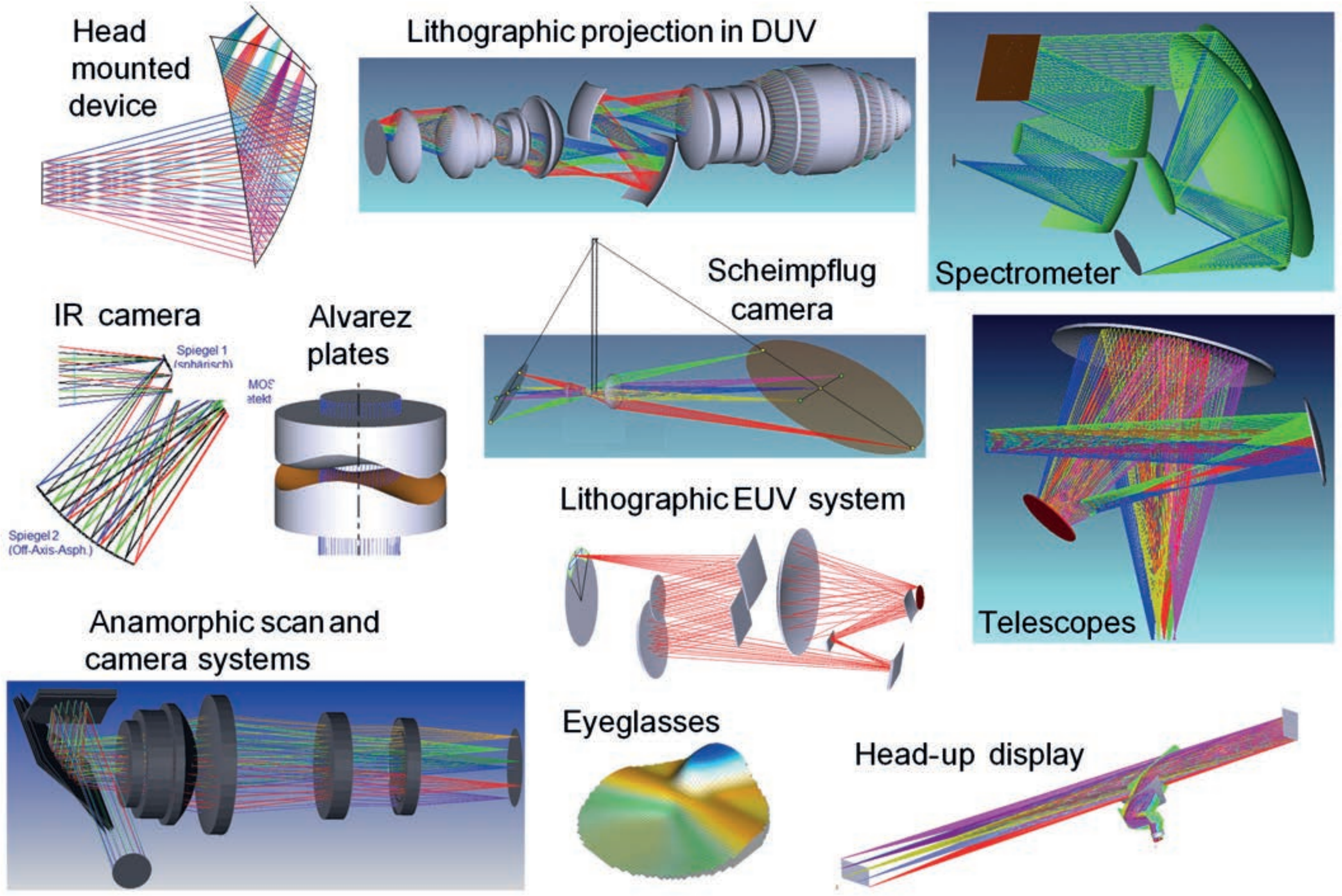

Figure 3:
Examples of freeform system with reduced or no symmetry

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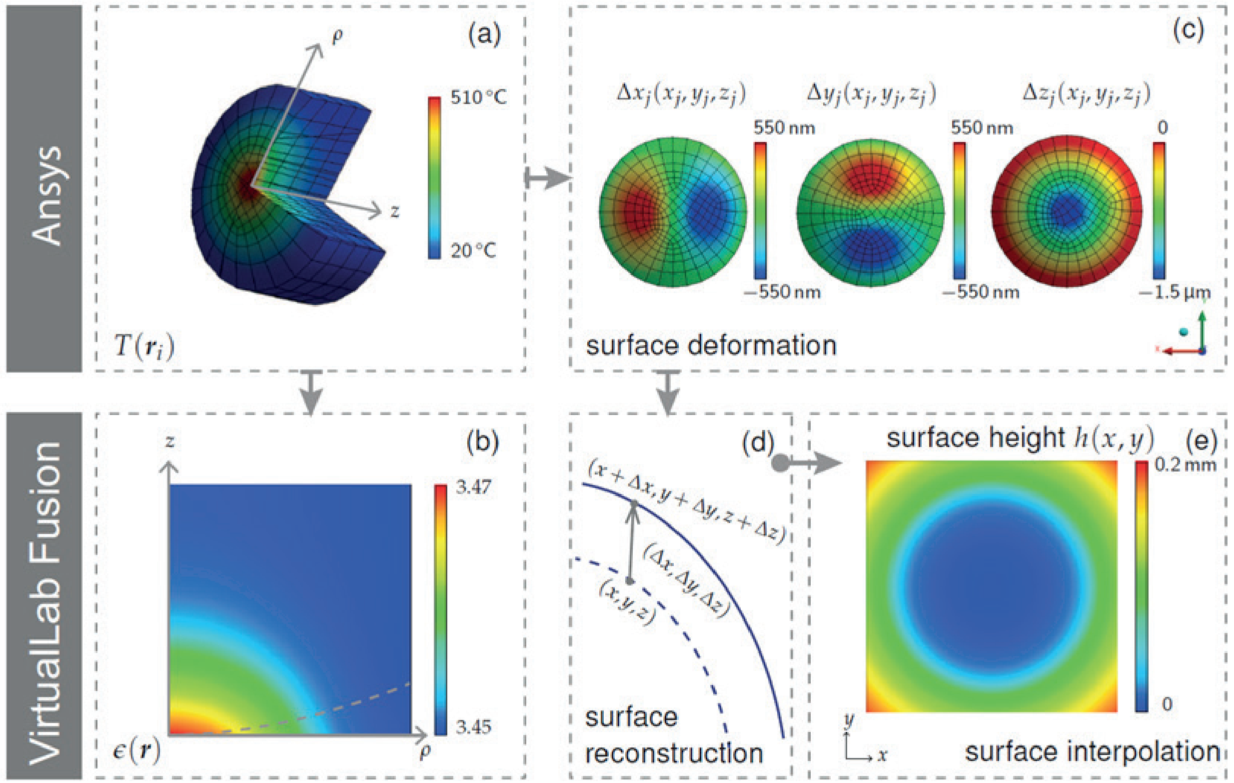

Figure 2 (concering article of p. 56):
Thermal-mechanical-optic model. In the software Ansys, thermal-mechanical analysis is performed. In the software VirtualLab Fusion, the temperature and deformed surface are interpolated, and permittivity is calculated. (a) Temperature; (b) permittivity; (c) surface deformation on the mesh nodes; (d)reconstructed surface; (e) interpolated surface.

Applied Computational Optics

The R&D work in the Applied Computational Optics Group is dedicated to a formulation of physical-optics modeling and design of optical and photonic systems which is fast enough for real-world application. That includes a seamless transition to a geometric optics regime within physical optics in all parts of a system wherever theoretically justified. We develop smart algorithms, which make decisions about modeling regimes based on mathematical criteria only. We always stay in full vectorial physical optics. Connecting different field solvers in system modeling has turned out to be the basis for fast physical optics modeling. Consequently, we investigate and develop various field solvers for different scenarios and components. The connection between the field solvers is realized by a sophisticated concept for the propagation of electromagnetic fields in homogeneous media, which encompasses and generalizes established propagation integral techniques. Our work on the further development of our unified physical optics approach in component and system modeling leads us to a vast variety of R&D topics. In 2020, research and development topics include:

- System modeling for femtosecond laser sources
- Lightguides for AR/MR glasses
- Light shaping with freeform and diffusers
- Modeling of microstructures by different approaches
- Inclusion of Bidirectional Scattering Distribution Function (BSDF) in physical optics
- Flat optics design and modeling: from diffractive to metasurface
- Lens design from a physical optics point of view
- Particle scattering & multimode fiber modeling
- Tight focusing and effects in focal region
- Field tracing in anisotropic media
- Modeling of nonlinear effects & microstructure surface modeling and connection to BSDF

Authors:
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Thermal-Mechanic-Optic Simulation of a Fiber Coupling Lens

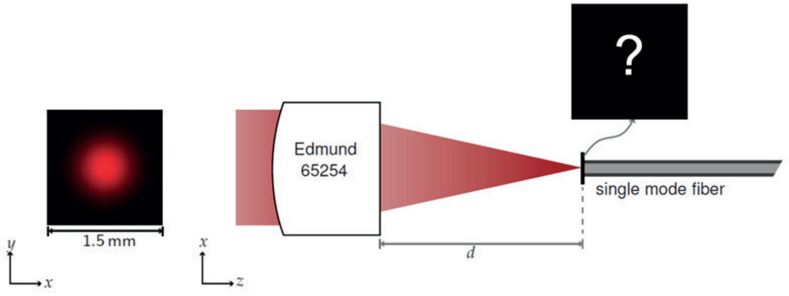

Figure 1:
Task description.
The Edmund 65254 lens is used to couple a fundamental Gaussian beam into a single-mode fiber.

When a light field has a high-power, the thermal-mechanic effects are not negligible. The incident electromagnetic field causes a heat flux distribution $\phi_q(\mathbf{r})$, with $\mathbf{r}$ the position vector, in the optical component, which then leads to its inhomogeneous temperature distribution T($\mathbf{r}$). Furthermore, T($\mathbf{r}$) causes the inhomogeneity of the relative permittivity $\epsilon(\mathbf{r})$ (square of refractive index) and the surface deformation. All of the changes affect the propagation of light. In this report, we demonstrate the thermal-mechanic-optic simulation of a fiber coupling lens /1/.

The *task description* is shown in Fig. 1. The Edmund 65254 lens /2/ is used to couple a fundamental Gaussian beam into a single-mode fiber, with d the working distance between the lens and the fiber end. The energy density in the fiber end and coupling efficiency will be calculated under the situations with/without the thermal-mechanical effects.

The *thermal-mechanic analysis* is done in the software Ansys /3/. The CAD file of the lens and the relevant parameters of the lens material can be found online /2, 4/. The heat flux on the lens surface has a similar distribution with the energy density of the incident Gaussian. In Ansys, finite element analysis is used to calculate the temperature $T(\mathbf{r}_i)$ of the lens, as shown in Fig. 2a (see page 54), with i the mesh node index. After we have $T(\mathbf{r}_i)$, surface deformation $(\Delta x_j, \Delta y_j, \Delta z_j)$, at each surface node j can be calculated, as shown in Fig. 2 (c).

Optical properties calculation is done in the software VirtualLab Fusion /5/. After obtaining $T(\mathbf{r}_i)$ and $(\Delta x_j, \Delta y_j, \Delta z_j)$, we transform them into optical properties, i.e., relative permittivity $\epsilon(\mathbf{r})$ and surface height profile h(x,y) by using interpolation and the further mathematical formula.
To calculate $\epsilon(\mathbf{r})$ shown in Fig. 2b (see page 54), the following formula is used

$$\epsilon(\mathbf{r})=\epsilon(\lambda,T_0) + d\epsilon/dT\,(\lambda,T)[T(\mathbf{r})-T_0],$$

with $d\epsilon/dT$ calculated by parameters given in /4, 6/. To calculate the height profile of the reconstructed surface h(x,y) shown in Fig. 2e (see page 54), we use spline-interpolation.

The *optical simulation of the fiber coupling lens* is performed, and the results are shown in Fig. 3. The original coupling efficiency without considering the thermal effects is 88.4%, at the working distance d=1.585 mm. After considering the thermal-mechanic effects, the coupling efficiency at the same working distance is only 31% but 96.6% when d=1.549 mm. The variance of relative permittivity $\Delta\epsilon(\mathbf{r})$ is only 0.02. So the effects are mainly caused by surface deformation.

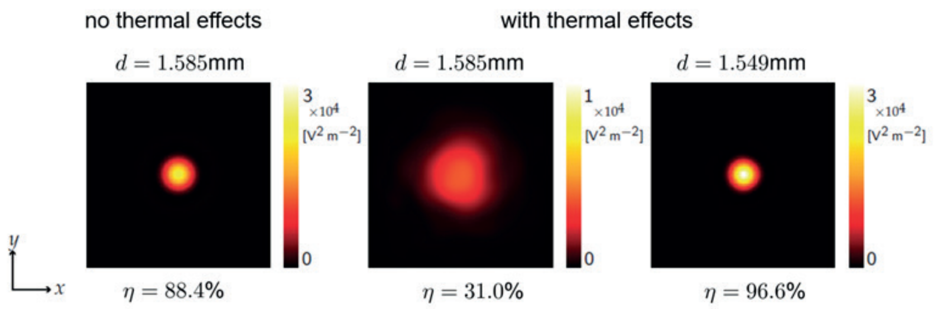

Figure 3:
The energy density and the coupling efficiency for different situations.

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/2/ Edmund Plano-Convex Lenses Edmund lens. 2020.

/3/ Ansys Inc., 2020

/4/ Data Sheets Optical Glasses from SHOTT N-LASF9. 2014.

/5/ Physical optics simulation and design software "Wyrowski VirtualLab Fusion", developed by Wyrowski Photonics UG, distributed by LightTrans GmbH, Jena, Germany.

/6/ SHOTT Technical Information TIE-19 "Temperature coefficient of refractive index".

Authors:
Rui Shi and Frank Wyrowski

Tight focusing through a spherical micro-/nano-particle by ideal and real lenses

Tight focusing through a spherical micro-/nano-particle are very important to super resolution microscopy, lithography as well as to fiber coupling. A fully vectorial physical optics modeling of high-NA microscope lens systems, both real lens and ideal lens systems combined with micro-/nano-particle, can be formulated via field tracing. /1/ The local plane interface approximation at the curved surface, the accurate free space propagation and the Mie theory for spherical micro-/nano particle are combined smoothly. By the numerical analysis of the tight focusing through spherical micro-/nano-particle, subwavelength focal spot can be obtained just behind the particle. The distorted focal spot due to the misalignment of the real system is also demonstrated.

Example 1: Tight focusing through a spherical micro-/nano-particle by ideal lens.

An ideal lens can be modeled by a B-operator. /2, 3/ It allows for various beam incidence modeling. Fig.1 shows the tightly focused spots which are energy density by an ideal lens with NA=0.95 behind a micro-/nano-particle. The focal spots are all subwavelength which is beyond the diffraction limit.

Example 2: Tight focusing through a spherical micro-/nano-particle by real lens.

Even though the real lens is designed to perform ideally, it suffers from aberrations in practice, when the misalignment of the lens system occurs. Fig. 2 shows that the subwavelength focal spots behind the micro-/nano-particles are distorted because of the misalignment of the source from a fiber. The lateral misalignment of the fiber is -200 um and 200 um in x and y directions. The real objective lens used here comes from a US patent (4384765) which has more than 10 curved surfaces. The real collimating lens comes from the commercial manufacturer, Edmund Optics (49664).

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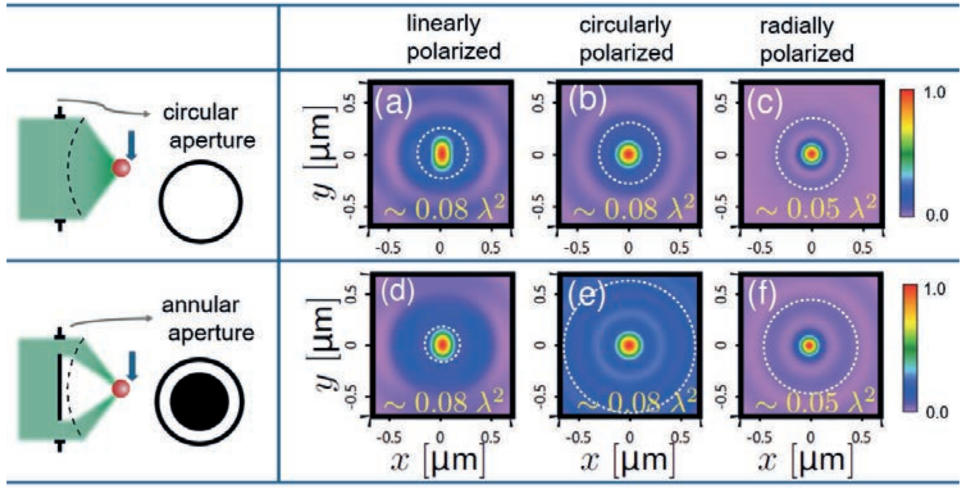

Figure 1:
The figures on the upper side show the focal spot behind the micro-/nano-particle. It is energy density with circular aperture of a Gaussian wave with wavelength of 632.8 nm. The diameter of the micro-/nano-particle is indicated by the white dashed circles. The figures on the lower side show the focal spot with annular aperture of a Gaussian wave. The polarization from left to right are linearly, circularly, radially polarized, respectively. The size of the focal spot behind the micro-/nano-particle is indicated by the numbers in yellow.

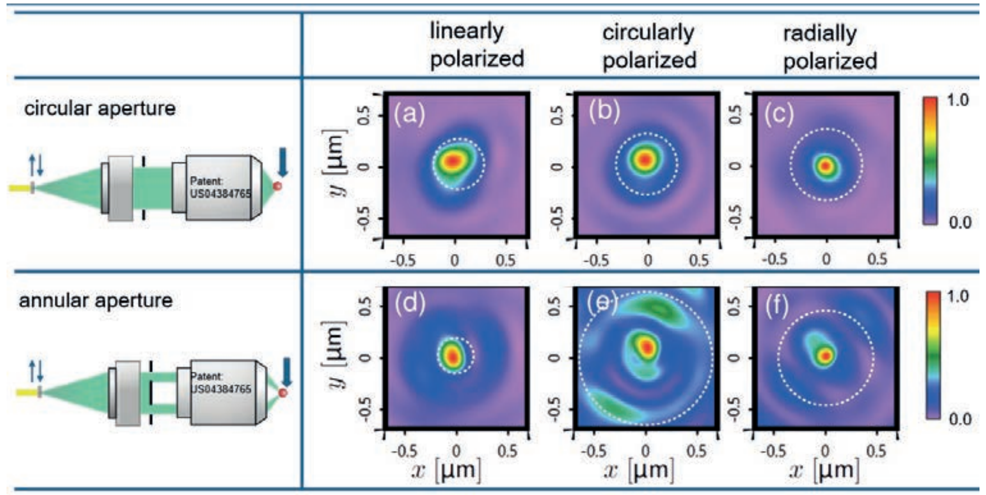

Figure 2:
The figures on the upper side show the focal spot behind the micro-/nano-particle which is energy density with circular aperture of a gaussian wave polarized in y-direction with wavelength of 632.8 nm. The lateral shift of the source is -200 um and 200 um in x and y directions. They are the corresponding figures of Fig. 1 (a)-(c). The figures on the lower side show the focal spot behind the micro-/nano-particle with annular aperture with the same incident beam. The polarization from left to right are linearly, circularly, radially polarized, respectively.

PUBLICATIONS

Aim of applied research is the implementation of the results and thus to make contributions to overcome certain problems of the future. For this reason, the research actually not only ends in itself, but their results must be discussed and adjusted with further findings. In the end again, new ideas and scientific approaches can be developed.

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PUBLICATIONS

Y. Ran, S. Nolte, A. Tünnermann, R. Ackermann,
Gas concentration measurements based on ultrabroadband coherent anti-Stokes Raman scattering using the non-resonant signal, Conference on Lasers and Electro-Optics (CLEO US), online.

Y. Tu, C. Jauregui-Misas, C. Stihler, S. Kholaif, J. Limpert, Mitigation of transverse mode instability in high-power fiberamplifiers using traveling wave, EPS-QEOD Europhoton conference, online.

Z. Wang, T. Heuermann, M. Gebhardt, M. Lenski, C. Gaida, C. Jauregui-Misas, J. Limpert, Ultrafast Tm-doped fiber CPA system delivering GW-level peak power pulses at >100 W average power, OSA Advanced Photonics Congress, online.

Colloquia

U.D. Zeitner
Micro- & Nano-structured optics and its today's applications, Huawei Optical Innovations Summit, online (2020).

J. Rothhardt
Hochauflösende linsenlose Mikroskopie mit extrem ultravioletter Strahlung, Röntgen Lecture, Universität Gießen, Gießen, Germany (2020).

Granted Patents

S. Nolte, M.P. Siems, M. Heck, D. Richter, R. Krämer, T.A. Goebel
Laserbasierte Anpassung der Eigenschaften optischer Komponenten

DE10 2018 120 568 A1

N. Kaiser, R. Müller, M. Schürmann, S. Schwinde
Method for Producing a Reflector Element and Reflector Element

US10,618,840B2

F. Setzpfand, F. Eilenberger, M. Gräfe, M. Bilaberte-Basset
Optische Anordnung für fluoreszenzmikroskopische Anwendungen

DE102018215831B4

F. Setzpfand, F. Eilenberger, M. Gräfe, M. Bilaberte-Basset
Optische Anordnung für fluoreszenzmikroskopische Anwendungen

DE102018215833B4

T. Pertsch, F. Setzpfandt, F. Eilenberger, M. Gräfe
Optische Anordnung zur hyperspektralen Beleuchtung und Auswertung eines Objektes

DE102018210777B4

D. Richter, J.U. Thomas, C. Voigtländer, S. Nolte
Optisches Bragg-Gitter

DE102015107013B4

E.-B. Kley, M. Steglich, T. Käsebier, D. Lehr
Strahlungsabsorber

DE102013108288B4

S. Nolte, D. Richter, R. Krämer, M. P. Siems, T. A. Goebel
Verfahren und Vorrichtung zur Bearbeitung mittels interferierender Laserstrahlung

DE102018105254B4

A. Szameit, M. Gräfe, R. Heilmann, A. Perez-Leija, S. Nolte
Verfahren und Vorrichtung zur Generierung von Zufallszahlen

DE 102014202312.2

S. Risse, M. Beier, D. Stumpf, A. Gebhardt
Verfahren und Vorrichtung zur interferometrischen Prüfung

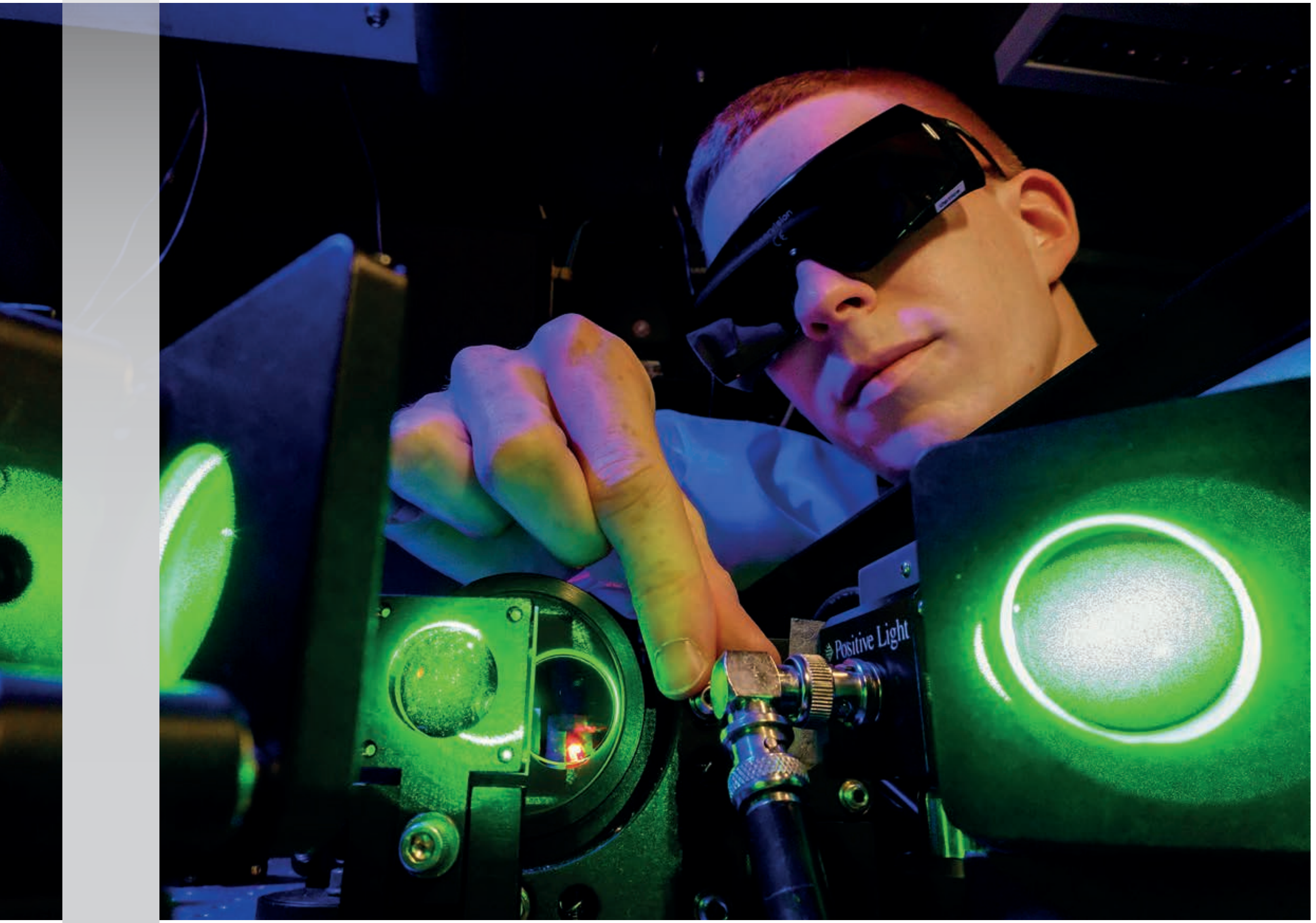
EP3224570B1

N. Kaiser, R. Müller, M. Schürmann, S. Schwinde,
Verfahren zur Herstellung eines Reflektorelements und Reflektorelement

DE102015103494B4

G. Notni, I. Schmidt, P. Lutzke, K. Srokos, P. Kühmstet, S. Heist
Vorrichtung und Verfahren zum räumlichen Vermessen von Oberflächen

EP3292371B1



Thorsten Goebel adjusts experimental equipment on an optical setup.

ACTIVITIES

A key feature of the IAP is the active and engaged exchange of its employees within the scientific community. This commitment can be measured in both the participation at conferences and at cooperation in projects with other institutions. Such community projects are the fruits of compulsory networking and strengthen the reputation of the institute within the research society and industrial associations. Appreciation of these efforts are also the call-ups of particular scientists in committees and editorial positions of academically approved journals.

Awards

Alessandro Alberucci
OSA Senior Member
The Optical Society (OSA)

Christopher Aleshire
3rd Place, IOF Photonics Days Elevator Pitch Contest
Fraunhofer IOF, Max Planck School of Photonics
The Laser Display: Using Multicore Fibers to Their Full Potential

Falk Eilenberger, Tobias Vogl, Heiko Knopf
2nd Place Elevator Pitches: First Call 2020
Digital Innovation Hub Photonics (DIHP)
Truquant: concept for the commercialization of their defect state emitters in hexagonal Boron-Nitride

Christian Gaida
Fakultätspreis Dissertation Rohde & Schwarz
Physikalisch-Astronomische Fakultät (PAF) der FSU
Power-scaling of ultrafast thulium-doped fiber laser systems

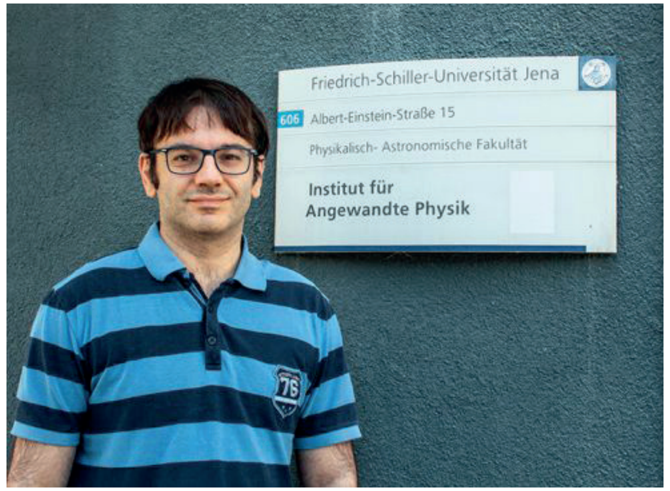
Martin Gebhardt
1st Place: Best Student Paper "Fiber Lasers XVII: Technology, Systems, and Applications"
SPIE. Photonics West
Soft x-ray high order harmonic generation driven by high repetition rate ultrafast thulium-doped fiber lasers

Maximilian Heck
Preis der Dr.-Ing. Siegfried Werth Stiftung, beste Dissertation auf dem Gebiet der optischen Messtechnik
Dr.-Ing. Siegfried Werth Stiftung
Tailored light propagation by femtosecond pulse written long period fiber gratings

Lukas Heller
Fakultätspreis Masterarbeit Rohde & Schwarz
Physikalisch-Astronomische Fakultät (PAF) der FSU
Cavity enhanced cold atom quantum memories for temporally multiplexed quantum repeater nodes

above: Ria Krämer lucky after awarding ceremony at Photonics West - one of the last events before the COVID 19 pandemic.
(Rights: M.Heck, IAP)
below: Maximilian Weißflog during the ceremony in the middle of the pandemic without an audience. (Rights: V.Helmig, FSU).

Prof. Stefan Nolte together with David Andrews, President-Elect of SPIE at Photonics West. (Rights: A.Ostendorf, RUB)



Dr. A. Alberucci was already honoured in 2019 for his excellent review work. (Rights: I. Winkler, IAP-FSU)

K. Tanaka held the seminar for the lecture "Fundamentals of Modern Optics" -The student council found him to be one of the best lecturers 2020. (Rights: L. Graf - FSU)

Martin Heusinger
Preis der Dr.-Ing. Siegfried Werth Stiftung, beste Dissertation auf dem Gebiet der optischen Messtechnik
Dr.-Ing. Siegfried Werth Stiftung
Untersuchungen zu deterministischem und stochastischem Streulicht in hocheffizienten binären Beugungsgittern

Robert Klas
OSA Student Paper Award
OSA Laser Congress
Sub-20 fs High-energy Pulse generation at 515 nm with 50 W of Average Power

Ria Krämer
2nd place "Best Paper Award - SPIE Frontiers in Ultrafast Optics"
SPIE. Photonics West
High contrast ultrashort pulse written transmission filter based on Moiré fiber grating

Michael Müller
2nd Place: Best Student Paper "Fiber Lasers XVII: Technology, Systems, and Applications"
SPIE. Photonics West
10.4 kW coherently-combined ultrafast fiber laser

Stefan Nolte
SPIE Fellow

Carolin Rothhardt
Promotionspreis der Friedrich-Schiller-Universität
Gesellschaft der Freunde und Förderer der FSU
Plasma-aktives Fügen von optischen Komponenten für Hochleistungslaser

Jan Rothhardt
Röntgenpreis
Justus-Liebig-Universität Gießen
Entwicklung und Anwendung von Laserquellen für extrem ultravioletter (XUV) Strahlung und weiche Röntgenstrahlung

Paul Schmitt
Honourable mention in 2020 OPN photo contest
Optical Society of America (OSA)
Scanning electron microscopy image of brochosomes conformally coated with 10 nm of iridium by atomic layer deposition

Jan Sperrhake, Chen Zhang, Maria Nisser
Edmund Optics Educational Award in »Gold«
Edmund Optics
NeoVitalSensor

Johannes Stock
Friedrich-Hund-Dissertationspreis
Wilhelm und Else Heraeus Stiftung
Holistic Simulation of Optical Systems

Katsuya Tanaka
Lehrpreis der Physikalisch Astronomischen Fakultät (PAF)
Fachschaftsrat der PAF
Seminar: Fundamentals of Modern Optics

Maximilian Weißflog
Examenspreis 2020 der Physikalisch-Astronomischen Fakultät der FSU
Spontaneous Parametric Down-Conversion in GaAs Nanoantennas

Left to right: Michael Müller and Martin Gebhardt successfull in San Francisco. Sven Breitkopf, former IAP researcher, handed over the prize, sponsored by the AFS GmbH. (Rights: J.Limpert, IAP)

Organizing Activities

Falk Eilenberger

- Fellow of the Max-Planck-School of Photonics
- Referee for Optica, Annalen der Physik, Opt. Comm.

Herbert Gross

- Member of the program committee conference „European Optical Society Annual Meeting"
- Referee as an expert for the Dutch Research Council NOW
- Referee of several scientific journals

Jens Limpert

- Member of Deutsche Physikalische Gesellschaft (DPG)
- Member of the Optical Society of America (OSA)
- Referee for several scientific journals

Stefan Nolte

- Deputy Director of the Institute for Applied Optics and Precision Engineering IOF
- Fellow of the Max Planck School of Photonics
- Member of the Abbe School of Photonics
- Chair of the Faculty´s Budget Commission and member of the Budget Board of the Senate
- Scientific Coordinator for International Graduate Research School GRK 2101 (DFG)
- Member of jury "Jugend forscht"
- Member of several scientific committees (e.g. Phot. West, CLEO, ICALEO, LANE, Lasertagung Jena)
- Fellow of the Optical Society of America (OSA)
- Fellow of the International Society for Optics and Photonics SPIE
- Member of Deutsche Physikalische Gesellschaft (DPG)
- Referee for several scientific journals and funding organizations

Thomas Pertsch

- Member of the board of directors of the Abbe Center of Photonics at the Friedrich Schiller University Jena
- Spokesman of the Abbe School of Photonics at the Friedrich Schiller University Jena
- Member of the board of trustees of the Center of Excellence in Photonics ("Leistungszentrum Photonik") of the Fraunhofer Society
- Member of the board of directors of the Thuringian Innovation Center for Quantum Optics and Sensing
- Coordinator of the study program "Master of Science in Photonics"
- Fellow of the Optical Society of America (OSA)
- Referee for several international journals
- Fellow of the Max Planck School of Photonics
- Member of the Undergrad Committee of the Faculty of Physics and Astronomy at the Friedrich Schiller University Jena

Jan Rothhardt

- Member of the extended directory board of the Helmholtz Institute Jena
- Member of the Program committee for CLEO Europe conference
- Member Optical Society of America (OSA)
- Referee for Nature Photonics, Nature Communications, Optics Letters, Optics Express, J Phys B, Appl. Phys B, Applied Optics, European Physical Journal D

Frank Setzpfandt

- Journal-Referee for: Advanced Optical Materials, Laser & Photonics Reviews, Materials Advances, Nanophotonics, Optica, Optics Express
- Project Referee for: Deutsche Forschungsgemeinschaft (DFG), Israel Science Foundation, Singapore National Research Foundation
- Managing Director of the „Thüringer Innovationszentrums für Quantenoptik und Sensorik"

ACTIVITIES

Isabelle Staude

- Associate Editor for Optics Express
- Member of the Editorial Advisory Board of Advanced Photonics Research (Wiley)
- Reviewer for several scientific journals including Nature, Science, Nature Materials, Nature Photonics, ACS Nano, and Optica
- Member of the Junge Akademie
- Member of Deutsche Physikalische Gesellschaft (DPG)
- Member of the Management Board of the Collaborative Research Center (SFB) “Nonlinear Optics Down to Atomic Scales (NOA)

Fabian Steinlechner

- Referee for Physical Review Letters, Nature Physics, Optica, and other international journals

Adriana Szeghalmi

- Member of Deutsche Physikalische Gesellschaft (DPG)
- Senior Member of the Optical Society of America (OSA)
- Reviewer for several scientific journals

Andreas Tünnermann

- Council member of the Faculty
- Council member of the TU Bergakademie Freiberg
- Chairman of the Technical Council Fraunhofer-Gesellschaft
- Board of Trustees MPA, Heidelberg
- Board of Directors Helmholtz Institute, Jena
- Member of the executive board of the Abbe Center of Photonics at the Friedrich Schiller University Jena
- Research Training Group GRK2101 "Guided light, tightly packed: novel concepts, components and applications"
- Council member of the DFG excellence cluster “Balance of the microverse”
- Spokesman of the Fraunhofer Innovation Cluster “Leistungszentrum Photonik”
- Spokesman of the Fraunhofer Innovation Cluster “Leitprojekt Quilt”
- Co-spokesman of the Fraunhofer cluster of excellence “Advanced photon source”
- Spokesman of the BMBF Center for Innovation Competence ZIK “ultra optics”
- Spokesman of the BMBF program Zwanzig20 “3Dsensation”
- Spokesman 3Dsensation Graduiertenforschungskolleg
- Spokesman of the Fraunhofer graduate college "Fraunhofer Graduate Research School Photonics"
- Spokesman of the “Max-Planck-School of Photonics”
- Spokesman of the Thuringian Innovation center of “Quantum optics and sensors”
- Member of the 1st scientific level of the BMBF research cluster “infectooptics”
- Member of program committee "Qantensysteme", BMBF
- Member of the Expert Council on Quantum Computing of the Federal Government
- Board of Trustees Leibinger Stiftung
- Supervisory board member Jenoptik AG
- Supervisory board member ARRI AG
- Member of Technical Council committee Docter Optics
- Chairman "AG Naturwissenschaften", Wissenschaftliche Gesellschaft Lasertechnik e .V.
- Member of acatech "Deutsche Akademie der Technikwissenschaften"
- Stakeholder Photonics 21-Platform
- Member of the Executive Board OptoNet e.V.
- Referee for several scientific journals
- Co-Editor Applied Physics B
- Editorial Advisory Board Lasers&Photonics Review
- Fellow of OSA – Optical Society of America
- Fellow of SPIE International Society of Optics and Photonics

Frank Wyrowski

- Visiting Professor at the Chinese Academy of Science, China
- Visiting Professor at the Institute of Technology (HIT), China
- Conference Co-Chair: SPIE Workshop on Light Shaping
- Conference Co-Chair: SPIE Meeting on Computational Optics
- Conference Co-Chair: EOS Topical Meeting on Diffractive Optics
- Member of the Technical Program Committee SPIE Conference on Optics and Photonics for Information Processing
- Member of the Technical Program Committee SPIE Conference on Digital Optics for Immersive Displays
- Member of the Technical Program Committee OSA Conference on Digital Holography and 3D Imaging
- President of the LightTrans GmbH
- President of Wyrowski Photonics GmbH

Uwe D. Zeitner

- Member of the Program Committee for SPIE Advanced Lithography: Optical Microlithography XXXIII
- Referee for several scientific journals

LOCATION

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