Institute of Applied Physics

Friedrich-Schiller-Universität Jena

2015 Annual Report

INTERNATIONAL YEAR OF LIGHT 2015

JENA CITY OF LIGHT.

Imprint

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PHOTOS/GRAFICS	Institute of Applied Physics (IAP), Fraunhofer IOF and Friedrich Schiller University Jena [J.-P. Kasper] p.64: aboutpixel.de/Lektüre©marshi p.94/95: SPIE; P. 98/99: Tino Zippel, OTZ

Content

PREFACE

Dear colleagues,

2015 was proclaimed by UNESCO as the "Year of Light" - due to its importance as a key enabler for technology and science, business and society. Especially our Institute with its research on topics in optics and photonics has welcomed this decision of the UNESCO, and also actively supported. Since decades, we are working in the tradition of Abbe and Zeiss about solutions to overcome the great challenges facing humanity in the fields of energy, environment and health. We have therefore actively participated in the organization of events to fascinate the public about the theme and to show them the importance of light in daily life, but also to introduce simultaneously our research. Main events of the year have been the grand opening show at the Sparkassen-Arena, an exhibition and interactive week in the Goethe Galerie, participation in the Sci-Fest in Joensuu / Finland and the “Highlights der Physik” of the Deutsche Physikalische Gesellschaft e. V. (DPG) in the middle of Jena.

It is gratifying, that the current OptoNet report shows the stable development of the photonics industry in Thuringia on the course for growth. Around three quarters of the companies surveyed estimate their order situation as "good to very good", and many companies have increased their sales; pointed out the annual increases in micro- and optical fiber of 10%.

For this growth sector, the IAP is an important partner in R&D, which stands for excellence in applied research, as well as in basic research. Some highlights represented here should be mentioned to substantiate this:

In the BMBF supported project “Wachstumskern Freeform Optics Plus fo+” the IAP collaborates with various companies in the region since two years about free-form surfaces in optical systems. In this technologically demanding new field, the optical principles of the description of surfaces, system concepts and benchmarking will be treated, starting from theoretical issues down to manufacturing processes. Also micro structuring and coating for arbitrarily shaped optical surfaces have been considered. The project results show an achievement of significantly better performance and additional functionality in modern symmetry free systems with these additional degrees of freedom, which is a great advantage for innovative product developments.

A completely new research field has been entered by Alexander Szameit´s research group with their first experimantal emulation of the elementary particle Majoranon. This opens a way for physicists to access phenomena that were previously described only by exotic theories. The properties of "non-physical" processes such as the abrogation of the Charge conservation law, could now be used in technological applications. A simulated Majoranon, for example, allows for significantly shorter computing times that may be achievable in future quantum computers.

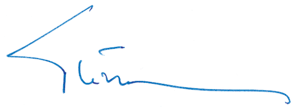
Last but not least, the concept of coherent coupling of fiber lasers developed in the group led by Jens Limpert should be mentioned too. It enables the realization of worldwide unique characteristics of ultrashort pulse lasers in the high performance area. These systems will address many important applications in science and technology in the future.

By successfully raised funding of the ERC "Advanced Grant" for research on lasers based on fiber optics, and the construction of the fiber technology center with support from the Foundation for Technology, Innovation and Research Thuringia (STIFT), we are well positioned for the coming years for further excellent contributions in R&D and up to applications.

Also in education and training effort has been made to remain attractiveness to young people, e.g. through the International Research Training Group GRK 2101 and by cooperation with the Changchun Institute of Optics, Fine Mechanics and Physics (CIOMP).

Such projects succeed only by your committed participation, which you have shown in previous years and for which I would like to thank most warmly. Here, we are and were well supported by our project partners and funding authorities.

Yours sincerely,



Prof. Dr. Andreas Tünnermann

The Institute of Applied Physics (IAP) at the Friedrich Schiller University Jena (FSU Jena) has a long-standing tradition and competence in design, fabrication and application of active and passive optical photonic elements for both optical and opto-electronical devices. Collaborative projects with companies ensure practical relevance and feasibility.

Research Profile

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

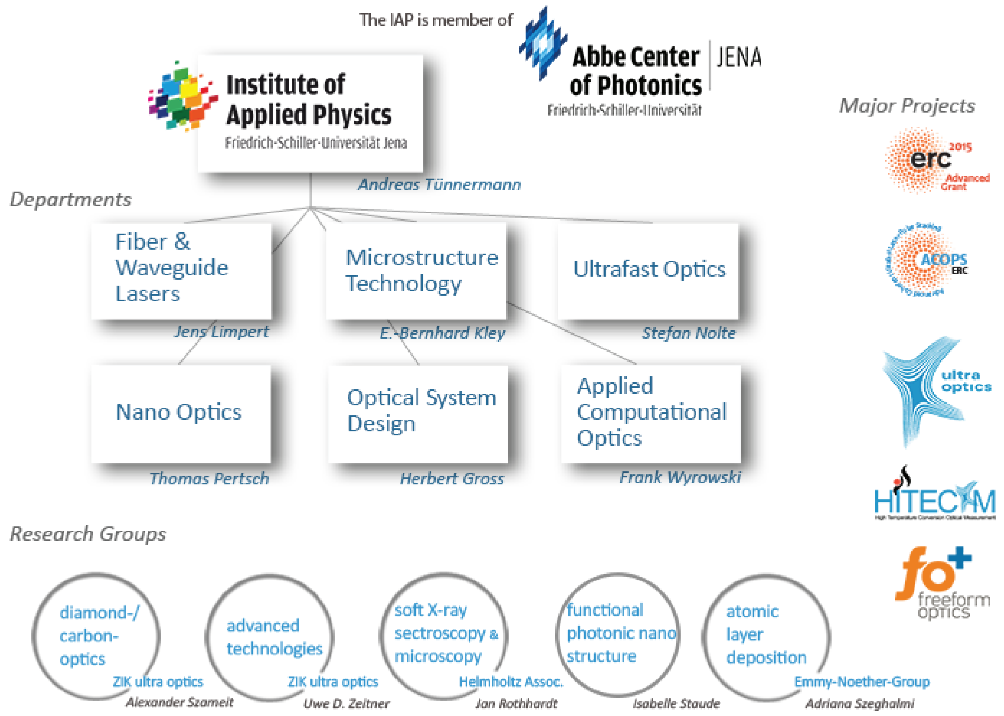
The associates develop novel optical materials, elements and concepts for information and communication technology, life science and medicine, security and mobility, environment and energy as well as process technology including material processing and optical measurement techniques.

Current research topics - treated by over 160 scientists - concern design of optical systems, as well as function, design and production of micro-and nano-optical elements. Those are e.g. resonant grating structures, metallic and dielectric polarizers, all-optical switching processes in integrated photonic elements and effective media for reduced reflection losses of surfaces. Also light propagation and nonlinear light-matter interaction in micro- and nano-structures, optical metamaterials and photonic crystals are investigated for their inherently novel fundamental physics. Further research fields are the application of femtosecond laser pulses, e.g. for material processing and micro- and nano-structuring, the development of new concepts for solid-state lasers such as fiber lasers, fiber-optic pulse shaping and the amplification of ultrashort laser pulses. Aim of other research efforts are the fundamental understanding of the propagation of optical waves in different systems, whose material parameter and structure are based on the different macroscopic manifestations of carbon. The usage of freeform optical key components due to their inherent advantages is also aim of the IAP. The design, fabrication and integration of such elements represent a scientific and technological challenge, which the scientists faces up.

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 presentation of prototypes. This expertise offers remarkable contributions to solve issues in emerging fields like energy, environment, health and communication.

Excellence in research is confirmed by the establishment of the Competence Centre ZIK ultra optics (www.ultra-optics.de) as a driver of innovation in the research fields the two areas of "Diamond- & Carbon Based Optical Systems" and "Advanced Fabrication Technologies for Micro- and Nano-Optics", in 2015 the awarded ERC Advanced Grant for "Multi-dimensional interferometric amplification of ultrashort laser pulses — MIMAS" and 2014 the ERC Consolidator Grant for "Advanced Coherent Ultrafast Laser Pulse Stacking (ACOPS)", but also the BMBF Innovation Initative for the New Länder fo+ (Freeform Optics Plus, www.fo-plus.de), which combines fundamental and applied research in a unique way.

But not only excellent research makes the Institute splendid, also outstanding laboratory equipment, an excellent staff and a high commitment in 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.

- 860 m² class 10,000 to 10 clean room area
- Electron beam and laser lithography
- Photolithography
- Dry etching facilities (RIE, RIBE, ICP)
- Spectroscopic techniques including EDX, EBSD
  - Scanning nearfield optical microscopy
  - Photoemission electron microscopy
  - Helium ion microscopy
  - Interference optical surface profilometry
  - Electron and ion beam microscopy
  - Scanning electron microscopy
- Nonlinear optical waveguide characterization
- UV-VIS spectrometry
- FTIR spectrometry
- Rigorous optical simulation
- Ultrashort pulse laser technology
- Laser micro-structuring technology
- Field tracing techniques

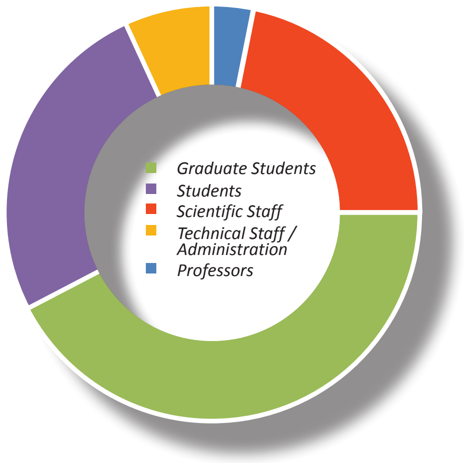
Staff

public budgetarily funded:

3.0	university professors
3.2	research associates
10.6	technical staff members

third-party funded:

1.0	university professor
1.0	endowed professor
2.0	assistant professors
95.9	research associates & Ph.D. students
2.7	technical staff members



ABBASIRAD Najmeh
ABBE Sylvia
ACKERMANN Roland
ASOUBAR Daniel
BADAR Irfan
BALADRON ZORITA Olga
BAUER Toni
BECKER Nils
BEIER Franz
BEIER Matthias
BERGNER Klaus
BETHKO Eduard
BINGEL Astrid
BISIANOV Arstan
BLUMRÖDER Ulrike
BOURGIN Yannick
BÖSEL Christoph
BRAHM Anika
BREITBARTH Andreas
BREITKOPF Sven
BRÖMEL Anika
BURMEISTER Frank
CHIPOULINE Arkadi
DEMMLER Stefan
DIENER Romina
DIETRICH Kay
DIZIAIN Séverine
DREISOW Felix
ECKSTEIN Wiebke
EICHELKRAUT Toni
EIDAM Tino
FALKNER Matthias
FASOLD Stefan
FRANKE Christian
FUCHS Hans-Jörg
FÜSSEL Daniel
GAIDA Christian
GEBHARDT Martin
GEISS Reinhard
GHAZARYAN Lilit
GOTTSCHALL Thomas
GRÄF Waltraud
GRÄFE Markus
GROSS Herbert
GUZMAN Diego
HÄDRICH Steffen
HAMBACH Ralf
HECK Maximilian
HEIDLER Nils
HEILEMANN Martin
HEILMANN René
HEINRICH Matthias
HEIST Stefan
HERFFURTH Tobias
HEUSINGER Martin
HOFFMANN Armin
JANUNTS Norik
JAUREGUI MISAS Cesar
JOBST Paul-Johannes
JOCHER Christoph
JUNGHANNS Marcus
KAISER Thomas
KAMMEL Robert
KÄMMER Helena
KÄSEBIER Thomas
KEMPER Falk
KIENEL Marco
KINAST Jan
KLEIN Angela
KLENKE Arno
KLEY Ernst-Bernhard
KLUGE Anja
KRÄMER Ria
KREBS Manuel
KROKER Stefanie
KÜHN Dominik
LANGE Nicolas
LEBUGLE Maxime
LEHNEIS Reinhold
LEHR Dennis
LIMPERT Jens
LIU Chang
LÖCHNER Franz
LU XIANG
LUDWIG Henning
LUTZKE Peter
MA Chonghuai
MACZEWSKY Lucas
MARTIN Bodo
MATTHÄUS Gabor
MATZDORF Christian
MERCKS Sebastian
MENZEL Christoph
MINARDI Stefano
MÖLLER Friedrich
MÜLLER Michael
MUSICK David
NARANTSATSRALT Bayarjargal
NATHANAEL Anne
NOLTE Stefan
OLESZKO Mateusz
ORNIGOTTI Marco
OTTO Christiane
OTTO Hans-Jürgen
PABST Oliver
PEREZ LEIJA Armando
PERTSCH Thomas
PFEIFER Kristin
PREUßER Henry
PSHENAY-SEVERIN Ekaterina
PUFFKY Oliver
QUINTERO Rafael
RATZSCH Stephan
REINHOLD Jörg
RLEGUEZUELO Pol Ribes
RICHARDT Tim
RICHTER Daniel
RICHTER Jessica
RICHTER Sören
RODRIGUEZ Asis Saad
ROCKSTROH Sabine
ROCKSTROH Werner
ROSENSTENGEL Diana
ROTHHARDT Carolin
ROTHHARDT Jan
SARAVI Sina
SCHELLE Detlef
SCHMIDT Holger
SCHREMPEL Frank
SCHULZE Marcel
SCHWINDE Stefan
SERGEEV Natali
SETZPFANDT Frank
SHAMIR Yariv
SHESTAEV Evgeny
SHI Rui
SIEFKE Thomas
SINGH Vikram
SPERRHAKE Jan
STAUDE Isabelle
STEGLICH Martin
STEINBERG Carola
STEINER Stefan
STEINERT Michael
STIHLER Christoph
STOCK Carsten
STOCK Johannes
STÜRZEBECHER Lorenz
STÜTZER Simon
STUTZKI Fabian
SZAMEIT Alexander
SZEGHALMI Adriana
TADESSE Getnet Kassa
TESSMER Manuel
TISCHNER Katrin
TOLLABI Mazraehno Mohamed
TROST Marcus
TSCHERNAJEW Maxim
TÜNNERMANN Andreas
ULLSPERGER Tobias
VETTER Christian
VETTER Julia
VOIGT Daniel
VOIGTLÄNDER Christian
WANG Zongzhao
WARZESCHKA Sandra
WEICHELT Tina
WEIMANN Steffen
WEIRAUCH Wieland
WILDE Johannes
WINKLER Ira
WOJDYR Michal
WORKU Norman Girma
WUNDERLICH Stefano
WYROWSKI Frank
YANG Liangxin
ZEITNER Uwe
ZEUNER Julia
ZHANG Site
ZHANG Yuequian
ZHONG Huiying
ZHONG Minyi
ZHONG Yi
ZILK Matthias
ZIMMERMANN Felix

THE INSTITUTE

Guests

Guests indicate the national and international visibility of research results and enrich the structures of the Institute of Applied Physics 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.

BARKOWSKI Moritz	University of Kaiserslautern, Germany
BRYNSERAEDE Yvan	Katholieke Universiteit Leuven, Belgium
CHO Sung-Hak	Korea Institute of Machinery & Materials, Daejeon, South Korea
CHOU Chun-Han	National Taiwan University of Science and Technology, Taipei, Taiwan
DECKER Manuel	Australian National University, Canberra, Australia
GORAN Isic	University of Belgrade, Serbia
GUO Rui	Australian National University, Canberra, Australia
HECHT Bert	Julius Maximilian University, Würzburg, Germany
HELMBRECHT Lukas	Gerhard Mercator University, Duisburg-Essen, Germany
HOLZBERGER Simon	Max Planck Institute, Garching, Germany
ITOH Kazuyoshi	Osaka University, Japan
LEEMANS Wim	LBNL Lawrence Berkeley National Lab, USA
LEUCHS Gerd	Max Planck Institute for the Science of Light, Erlangen, Germany
LINDLEIN Norbert	Friedrich-Alexander-University Erlangen-Nürnberg, Max Planck Institute for the Science of Light, Erlangen, Germany
LIU Ying	National Synchrotron Radiation Laboratory, University of Science and Technology of China, Hefei, China
MATHIAS Stefan	Georg August University, Göttingen, Germany
MORTENSEN Asger	Technical University of Denmark, Lyngby, Denmark
MURATSUGU Atsushi	Osaka University, Japan
PING Yia	Changchun Institute of Optics Fine Mechanics and Physics, Changchun, China
RALEVIC Uros	University of Belgrade, Serbia
ROLLES Daniel	Deutsches Elektronen-Synchrotron DESY / J.R. Macdonald Laboratory, Hamburg, Germany
RUSAK Evgenia	Karlsruhe Institute of Technology, Germany
SHAMIR Yariv	Applied Physics Division, Soreq NRC, Yavne, Israel
SHCHERBAKOV Maxim	Lomonosov Moscow State University, Russia
SONG Qiyuan	Riken Advanced Photonics Center, Keio University, Tokyo, Japan
STANKE Ladislav	Joint Laboratory of Optics, Palacky University and Institute of Physics of the Academy of Sciences, Prague, Czech Republic
STÖHLKER Thomas	GSI Atomic Physics Group, Darmstadt, Germany
SUKHORUKOV Andrey	Australian National University, Canberra, Australia
SZATKOWSKI Mateusz	Wroclaw University of Technology, Poland
TATSUNO Kimio	KRI Inc., Toronto, Japan
TETSUYA Yagi	Osaka University, Japan
VASIC Borislav	University of Belgrade, Serbia
VERHOEVEN Antonie Daniël	University of Eastern Finland, Joensuu, Finnland
WOOK KIM Dae	University of Arizona, Tucson, USA
XIA Chunqiu	Changchun Institute of Optics and Fine Mechanics and Physics, Changchun, China

Research Stays

BECKER Nils	Aston University, Birmingham, UK
DREISOW Felix	Günter-Köhler-Institut GmbH, Jena, Germany
FALKNER Matthias	University of Belgrade, Serbia
FASOLD Stefan	University of Belgrade, Serbia
GEIß Reinhard	National Central University, Jhongli, Taiwan
GROSS Herbert	Institut d'Optique, St. Etienne, France
KROKER Stefanie	Ginzton Laboratory, Stanford University, USA National Synchrotron Radiation Laboratory, Hefei, China
NOLTE Stefan	Korea Institute of Machinery & Materials, Deajeon, South Korea University of Toronto, Canada
SHESTAEV Evgeny	Université Laval, Centre d'optique, photonique et laser, Quebec, Canada Institut national de la recherche scientifique (INRS), Montreal, Canada University of Toronto, Canada
SPERRHAKE Jan	University of Belgrade, Serbia
STANICKI Jakob	National Central University, Jhongli, Taiwan
STAUDE Isabelle	Australian National University, Canberra, Australia
STIHLER Christoph	University of Toronto, Canada Université Laval, Centre d'optique, photonique et laser, Quebec, Canada Institut national de la recherche scientifique (INRS), Montreal, Canada
ZIMMERMANN Felix	Institut de Chimi Moleculaire et des Materiaux d'Orsay, France

Cooperations

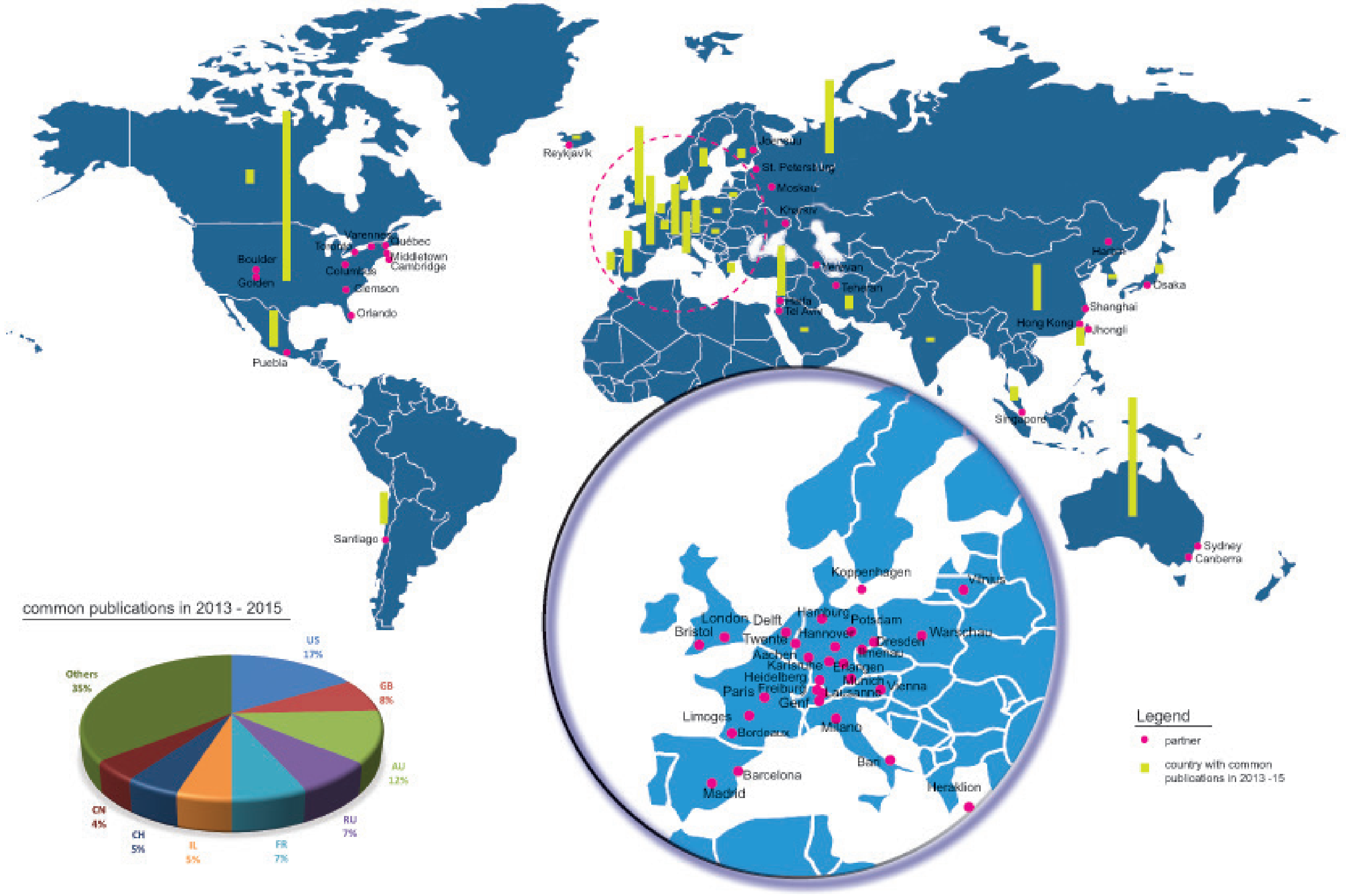
The IAP is cooperating with most of the departments of the Faculty of Physics and Astronomy at Friedrich Schiller University, 2015 in particular with the Institute of Optics and Quantum Electronics.

In our work we are connected to many important research centers of Germany, like the German Electron Synchrotron (DESY) in Hamburg, the Max-Planck-Institute for Quantum Optics in Garching and the Ludwig Maximilian University in Munich, as well as the Atomic Physics Group of the GSI Helmholtzzentrum für Schwerionenforschung, Karlsruhe Institute of Technology and Institutes of the Leibniz Association - such as the Institute for Astrophysics Potsdam (AIP) and the Institute of Photonic Technology Jena (IPHT).

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 international center of excellence for micro- and nano-structured optics as well as optical systems. Therefore, the knowledge and equipment is used commonly, to face the research challenges and to assist also industrial partners in developing new products. Such a fruitful cooperation is the collaboration with eight leading Thuringian Photonics companies in the project “Freeform Optics Plus fo+”, mostly financed by the BMBF-Initiative “Unternehmen Region”. The ambiguous aim is the development and commercial exploitation of innovative freeform optical systems by manufacturing demonstrators for special purposes.

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) and the Australian National University, as well as the University of Toronto, the Vrije Universiteit Brussel, the University of Science and Technology China, the TU Bergakademie Freiburg, Universities in Russia, Serbia, Israel, Great Britain and USA.

In 2015, the German-Canadian International Research Training Group GRK 2101 “Guided light, tightly packed” has started, in which we are cooperating with the University of Toronto, Université Laval and the Université de Recherche (INRS) – the coordination lies in the hands of our partner Abbe School of Photonics here in Jena. In addition, efforts have been made to win the Chinese Changchun Institute of Optics Fine Mechanics and Physics (CIOMP) for a partnership in the training field.



Partners of the IAP and a quantitative figure of common publications in 2013-15.

Cooperations with Joint Research Topics -Selection-

Aston University
Birmingham, UK
Sergei Turitsyn

AT Technologies
Veldhoven, The Netherlands
Mikhail Loktev

Carl Zeiss AG
Oberkochen, Germany
Daniel Krähmer

Centre d'optique, photonique et laser
Université Laval
Québec, Canada
Réal Vallée

Centre of Ultrahigh bandwidth Devices for Optical Systems, MQ Photonics Research Centre, Department of Physics and Astronomy
Macquarie University
Sydney, Australia
Michael Withford, Alex Fuerbach

Department of Electrical and Computer Engineering
University of Toronto
Toronto, Canada
Peter Herman

Department of Physics and Mathematics
University of Eastern Finland
Joensuu, Finland
Jari Turunen

Énergie, Matériaux et Télécommunications Research Center
Institut national de la recherche scientifique
Varennes, Canada
Roberto Morandotti

Engineering Center OPTICA
State University of Information, Mechanics, and Optics
St. Petersburg, Russia
Irina Livshits

ICFO-Institute of Photonic Sciences
Castelldefels, Spain
Lluis Torner

Centre for Innovation Competence
ZIK innoFSPEC
Leibniz-Institut für Astrophysik Potsdam
Potsdam, Germany
Martin Roth

Institut de Chimie Moléculaire et des Matériaux d'Orsay, Laboratoire de Physico-Chimie de L'Etat Solide
Université de Paris Sud 11
Orsay, France
Matthieu Lancry

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

Institut für Theoretische Festköperphysik
Karlruher Institut für Technologie
Karlsruhe, Germany
Carsten Rockstuhl

Laboratoire Ondes et Matière d'aquitaine
Université Bordeaux
Bordeaux, France
Lionel Canioni

Laboratory of Nanophotonics & Metamaterials
Lomonosov Moscow State University
Moscow, Russia
Andrey Fedyanin

Lawrence Berkeley National Laboratory
Berkeley, USA
Wim Leemans

Lawrence Livermore National Laboratory
Livermore, USA
Constantin Häfner

National Synchrotron Radiation Laboratory
University of Science and Technology
Hefei, China
Ying Liu

Nonlinear Physics Center
Australian National University
Canberra, Australia
Dragomir Neshev

Optical Engineering Group
Universidad Politecnico de Madrid
Madrid, Spain
Pablo Benitez

Optical Sciences Center
National Central University
Jhongli, Taiwan
Wei-Kun Chang

Optics Research Group
Delft University of Technology
Delft, The Netherlands
Paul Urbach

OSRAM GmbH
Munich, Germany
Stephan Malkmus

Sandia National Laboratories
Albuquerque, USA
Igal Brener

Soreq NRC
Applied Physics Division
Yavne, Israel
Yoav Sintov

Stellenbosch University
Stellenbosch, South Africa
Heinrich Schwörer

Technical University of Denmark
Lyngby, Denmark
Asger Mortensen

Technion
Haifa, Israel
Mordechai Segev

Weizmann-Institut für Wissenschaften
Rechovot, Israel
Yaron Silberberg

TEACHING

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 a education in interdisciplinary international Master´s degree and graduation programs, and running the International Research Training Group (GRK 2101) "Guided light, tightly packed: novel concepts, components and applications".

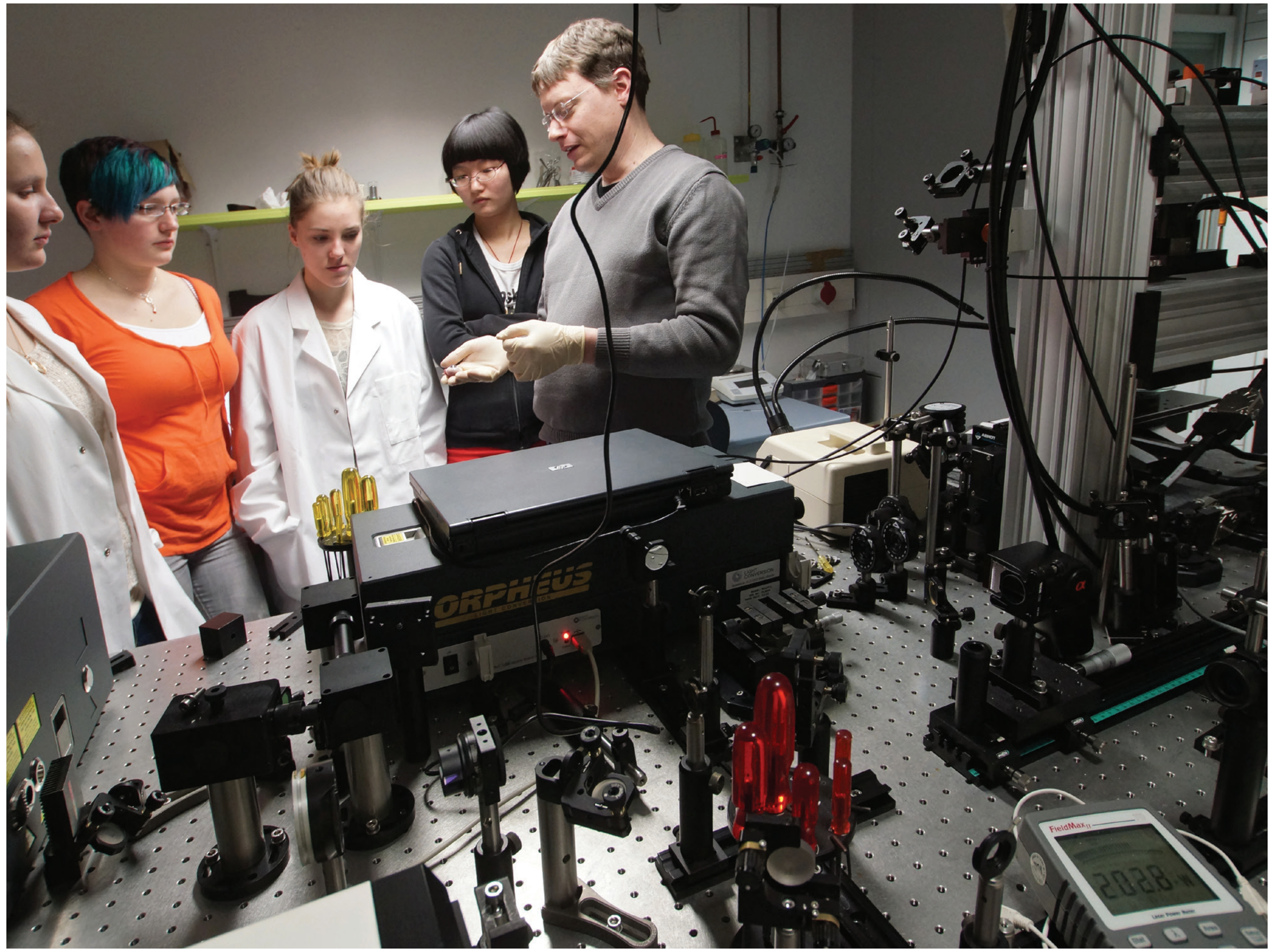
Lectures

Elective & Special Courses (Lectures & Seminars)

- Advanced Lens Design
- Astrophotonics
- Computational Photonics
- Design & Correction of Optical Systems
- Diffractive Optics
- Fundamentals of Microscopic Imaging
- Fundamentals of Modern Optics
- Fundamentals of Quantum Optics
- Grundlagen der Laserphysik
- Imaging and Aberration Theory
- Introduction to Nanooptics
- Introduction to Optical Modeling
- Lens Design
- Micro/Nanotechnology
- Optical Modeling & Design
- Thin Film Optics
- Ultrafast Optics

Seminars of the Institute & Devisions

- Advanced Fabrication Technologies Dr. Zeitner
- Applied Computational Optics Prof. Wyrowski
- Applied Physics Prof. Tünnermann, Prof. Nolte, Prof. Pertsch, Jun.-Prof. Limpert
- ASP-Seminar Applied Photonics Prof. Tünnermann together with IFTO and FhG-IOF
- Design of Optical Systems Prof. Gross
- Diamond Optics Jun.-Prof. Szameit
- Fiber Lasers Jun.-Prof. Limpert
- Microstructure Technologies - Microoptics Dr. Kley, Dr. Schrempel
- Nano Optics Prof. Pertsch
- Ultrafast Optics Prof. Nolte



Also in 2015, many activities have realized in order to attract young people to study physics - and at best optics - as here seen in the laser laboratory, supervised by Roland Ackermann.

Bachelor Theses

Toni Bauer
Mikro- und Nanostrukturierung von Diamant mit dem Helium-Ionen-Mikroskop

Clemens Kloß
Electrical characterization and study of THz-Emission from monocrystalline silicon

Kim Alina Lammers
Untersuchungen zur Ladungsträgerdynamik in Doppelpulsversuchen mit ultrakurzen Laserpulsen

Wilko Middents
Spektrale Stabilisierung von Laserdioden mittels ultrakurzpuls-geschriebener Volumen-Bragg-Gitter in Kieselglas

Friedrich Möller
Development of an FTIR spectrometer for the characterization of photonic nanostructures

Konrad Naumann
Untersuchung von induzierten Spannungen an direkt gefügten Kristallen

Tom Pertermann
Mikrostrukturierung von Glas mit ultrakurzen Laserpulsen

Sönke Ziemer
Comparison of propagation models of ultrashort pulses

Master Theses

Ernest Ahiavi
Nucleation studies and nanolaminates for x-ray mirrors

Nils Becker
Adaptive pulse measurement using a pulse shaper

Méabh Garrick
Spectrally resolved laser-induced damage testing

Li Guangrui
Gold nanostructures fabricated by nanoshere lithography

Samuel Haase (Exam Theses in Educational Physics)
Realisierung von Mikrokanälen in Fasern mittels ultrakurzer Laserpulse

Fabian Heisler
Characterization and application of the resonant properties of out-diffused silver nanoislands

Robert Klas
Measurement of the Magneto-Optical Kerr-Effect with High Repetition Rate High Harmonic Sources

Chang Liu
Design of a near-infrared broadband microscopic objective

Diinesh Lokanathan
Investigations of induced aberrations in optical systems

Gregor Matz
Correction of microscopic endoscope objectives

Sergii Morozov
Relaxation dynamics of quantum systems in the vicinity of plasmonic structures

Marcin Olecki
Dynamic low-order correction by active optical compensators

Rafael Quintero-Bermudez
Parametric frequency conversion in nanostructured waveguides

Marc Reig Escalé
Mapping the guided light distribution in nanowires

Olga Rodenko
Autofluorescence modeling in microscopy

Immam Setiawan Wahyutama
Table-Top Coherent Imaging - Towards Nanometer Resolution

Evgeny Shestaev
Femtosecond oscillators for non-steady-state enhancement cavities

Svetlana Shestaeva
Atomic layer deposition of dielectric materials for optical coatings

Getnet Kassa Tadesse
Spectral Beam Combining by Femtosecond Laser Written 2D Volume Bragg Gratings in Fused Silica

Maxim Tschernajew
High Harmonic Sources

Zongzhao Wang
Analytical Handling of Optical Wavefront

Kai Wang
Aharonov-Anandan Geometric Phase in Glauber-Bloch Photonic Lattices

Xiaohan Wang
Field enhancement using plasmonic nanoparticles and their use in integrated optical spectroscopy

Michal Wojdyr
Investigations of novel schemes of spatial and temporal combining of ultrashort pulses

Norman Worku
Simulation of pulse propagation through optical systems

Yueqian Zhang
Design of camera lens for vision sensor

Doctoral Theses

Anika Brahm
Terahertz-Computer-Tomographie mit Zeitbereichsspektroskopie-Systemen

Stefan Demmler
High Average-Power Few-Cycle OPCPA System for Strong-Field Applications

Wiebke Eckstein
Computergenerierte Hologramme auf Basis binärer Subwellenlängenstrukturen

Nils Heidler (TU Ilmenau)
Untersuchungen zylindrischer Gasführungselemente für Hochvakuumanwendugen

Tobias Herffurth
Light scattering and roughness analysis of optical surfaces and thin films

Christoph Jocher
Generation, Amplification and Characterization of Cylindrical Vector Beams in Optical Fibers

Robert Kammel
Tailored Femtosecond Laser Structuring for Intraocular Surgery

Angela Klein
Scanning Near-Field Optical Microscopy: From Single-Tip to Dual-Tip Operation

Nicolas Lange
Lithografisch hergestellte, polymerbasierte elektrostatische Aktuatoren ohne Pull-In-Effekt

Reinhold Lehneis
Pulse shortening of passively Q-switched microchip lasers

Hans-Jürgen Otto
Modeninstabilitäten in Hochleistungsfaserlasern

Stephan Ratzsch
Untersuchung der plasmaunterstützen Atomlagenabscheidung für das Auftragen von optischen Schichten

Stefan Steiner
Richtungsselektive optische Filterelemente auf Basis von Gitterstrukturen

Lorenz Stürzebecher
Beugungslithographie zur Fertigung optischer Nanostrukturen

Fabian Stutzki
Yb- and Tm-based ultrashort-pulse fiber-laser systems

Marcus Trost
Light scattering and roughness properties of optical components

Christian Voigtländer
Bandbreitenkontrolle von Femtosekundenpuls-induzierten Faser-Bragg-Gittern

Habilitations

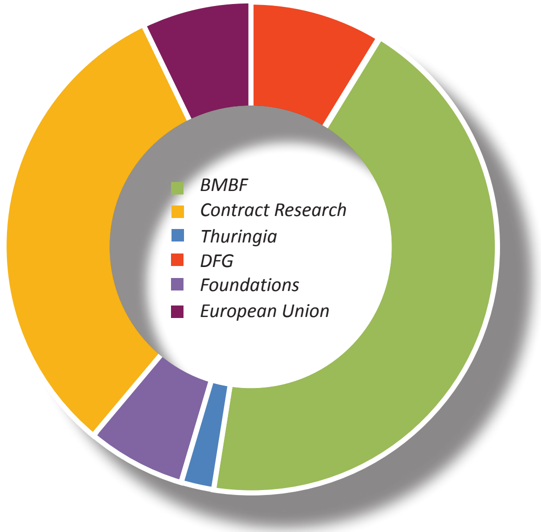
Alexander Szameit
Dirac Dynamics in Photonic Waveguide Arrays

Arkadi Chipouline
Analytical Modeling of Optical Metamaterials

Andreas Tünnermann and Herbert Gross in conversation with the President of the Friedrich Schiller University Walter Rosenthal about the Project Freeform Optics Plus fo+.

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 cooperations expanded. Thus, the IAP can continuously link the results at the value chain and transfer these results from basic research into innovative and novel demonstrators.



External funding

DFG (German Research Society)	€	776 k
BMBF/BMWI (Federal Ministries)	€	3,902 k
State of Thuringia	€	197 k
Foundations	€	580 k
Contract Research	€	2,819 k
European Union	€	644 k
Total:	**€**	**8,918 k**

BMBF/ BMWI

Federal Ministry of Educaion and Research/Federal Ministry for Economic Affairs and Energy

ZIK Ultra Optics 2015

- Forschergruppe Fertigungstechnologien für hoch entwickelte Mikro- und Nano-Optiken
- Nachwuchsgruppe Design und Realisierung komplexer mikro- u. nanostrukturierter photonischer Systeme basierend auf Diamant- u. Kohlenstoffoptiken

Verbund-ZIK Hitecom - Spektroskopische Untersuchungen zur Vergasung von Kokspartikeln unter Hochdruck- und Hochtemperaturbedingungen

Wachstumskern fo+ - Untersuchung ultrapräziser Freiformsysteme

Program "Zwangzig20" - Project "3Dsensation":

- FastDetect - Methoden zur ultraschnellen dreidimensionalen Detektion zeitveränderlicher Lichtfelder
- Untersuchungen zur Visualisierung von 3D-Objekten im freien Raum mittels Laser
- 3D-NanoVisual - Dreidimensionale Visualisierungssysteme auf der Basis photonischer Nanomaterialien
- OMNIdetect - Redundanzfreie omnimodale 3D-Detektionstechnologie

T4nPV - Tailored for next PV, UKP-Laserstrukturierung von dünnen Schichten für PV-Anwendungen

NEXUS - Kompakte Ultrakurzpulslaser basierend auf kohärenter Kombination

MEDUSA - Mehrdimesionale Ultrakurzpulssynthese für Faserlaser der TW-Klasse

NanoInt - Verbundprojekt Integrierte Nanooptik

ALSI - Advanced Laser-writing for Stellar Interferometry

SITARA - Selbstadaptierende intelligente Multiaperturkamera-Module

SolarNano - Nanostructured plasmonic reflectors for efficient thin film solar cells

TEHFA - Erforschung thermo-optischer Wellenleitereffekte in monolithischen Hochleistungs-laserfasern, Moden und hochleistungsstabile Komponenten für Faserlaser

Verbund APPA R&D: Licht-Materie-Wechselwirkung mit hochgeladenen Ionen

HoruS - Hochrobuste ultrakurzpulsgeschriebene Fasersensorarrays

MonOCrom - Moderne optische Technologien zur Crosstalk-Minimierung in Silizium-Photomultipliern

Ultrakurzpulslaser-Bearbeitung von Gläsern mit biologisch aktiven Oberflächen; Ultrakurzpulslaser- Bearbeitung von Glassubstraten

FieldTracing - Einführung von Field Tracing Verfahren für anisotrope und nichtlineare Medien

Design optischer Komponenten zur flexiblen Lichtformung mit Anwendungen für Weißlicht LEDs

Integriert-optische Module durch neue Bondtechnologien

European Union

ERC Advanced Grant MIMAS - Multi-dimensional interferometric amplification of ultrashort la-ser pulses

ERC Consolidator Grant ACOPS - Program „Ideas“,; Advanced coherent ultrafast laser pulse stacking

Marie Curie Initial Training Network PICQUE - Photonic Integrated Compound Quantum Encoding

ADOPSYS - Advanced Optical System Design

QuILMI - Quantum Integrated Light Matter Interface

DFG - German Research Foundation

Priority Program SPP

- Optisch erzeugte Sub-100-nm-Strukturen für biomedizinische und technische Zwecke
- Ultrakurzpuls–induzierte Erzeugung periodischer Nanostrukturen im Volumen transparenter Festkörper
- Aktive Mikrooptik: Adaptierbare plenoptische Kameras: Design, Herstellung, Integration
- Nonlinear optics plasmonic nanoantennas from Lithium Niobate
- Kontrolle der Streufeldwechselwirkung in ungeordneten zweidimensionalen Anordnungen von Silizium-Nanopartikeln

Research Training Group

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

Research Units

- Laserbasierte Simulation von Hochgeschwindigkeitskollissionen und strukturelle Zustände des Staubs in Trümmerscheiben

Emmy Noether-Programm

- Optische Beschichtung mittels ALD - Beschichtung nanostrukturierter Substrate und Adsorption von Flüssigkristallen an dünnen Schichten

Lineare und nichtlineare Lichtausbreitung in Wellenleiterarrays bei komplexen Anregungsprofilen

Emulation der Graphenstruktur mittels Photonik

Investigation on near-plane varied-line-spacing gratings made by electron beam lithography and near field holography

Metamaterialien in flüssiger Phase

Foundations/Other Sources

Stiftungsprofessur Theorie optischer Systeme (endowed professorship)

GIF Grantee - Luminous fluid flow in 2d structures: experiment and theory

8x Carl-Zeiss-Scholarships

1x TRUMPF-Scholarship

DAAD exchange programs (Australia, Taiwan, Serbia)

State of Thuringia

Thuringian Ministry of Economy, Science and Digital Society

ProExz., ACP Explore - Intelligentes Laserskalpell für die Diagnose und Therapie von Tumoren

ProExz., ACP Explore - Einzelmolekülfalle (ABEL trap) zum ultrasensitiven Nachweis löslicher Marker und Wirkstoffe gegen Autoimmunerkrankungen

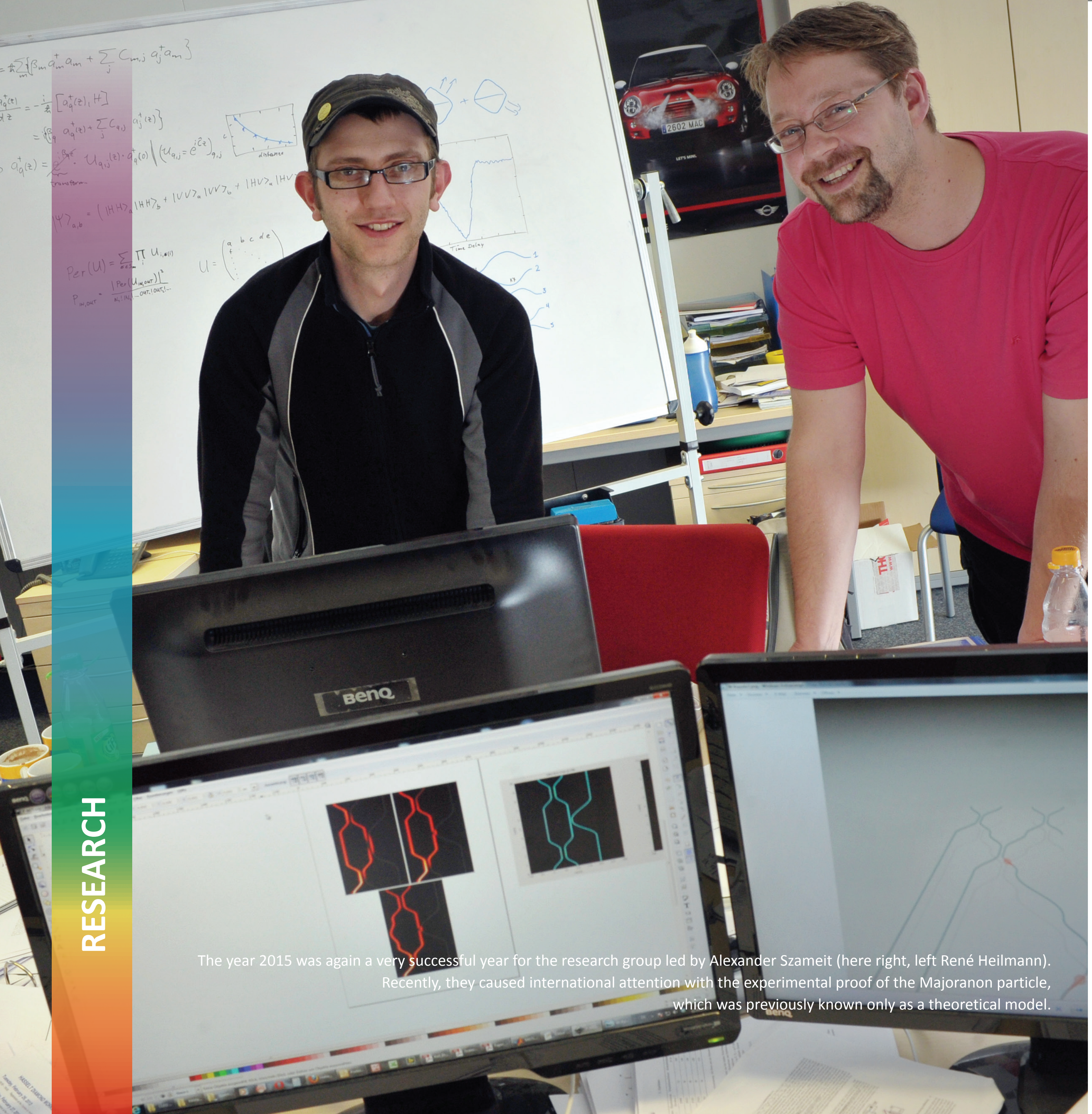
ProExz., ACP-Explore - Enlightening New States of Matter

ProExz., ACP-Explore - Integration of Molybdenum Disulfide Monolayers with Photonic Nanostructures

ProExz., ACP2020 – Agenda für exzellente Photonik

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 ORAFOL Fresnel Optics GmbH, Layertec GmbH, Carl Zeiss AG, TRUMPF GmbH + Co. KG or the European Space Agency (ESA).



The year 2015 was again a very successful year for the research group led by Alexander Szameit (here right, left René Heilmann). Recently, they caused international attention with the experimental proof of the Majoranon particle, which was previously known only as a theoretical model.

RESEARCH - Achievements & Results

An intense engagement with research topics of the institute ultimately leads through 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.

Fiber & Waveguide Lasers

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jens.limpert@uni-jena.de

Since 2015, the post doctorand Jan Rothhardt got the position as a leader of the junior reasearch group "Soft X-ray Spectroscopy and Microscopy". His work combines the theoretical and experimental resarch themes of the IAP and Helmholtz Institute Jena.

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
- Picosecond µ-chip-lasers
- High Harmonic Generation and Applications in Imaging and Spectroscopy

Authors:
Jens Limpert, Christian Gaida, Cesar Jauregui and Martin Gebhardt

Ultrafast fiber lasers in the infrared spectral region

High-energetic laser pulses with pulse duration of a few femto-seconds to pico-seconds at simultaneously high average power and excellent beam quality are of central importance for various applications in research and industry. For example extremely challenging applications such as electron spectroscopy, diffractive imaging or particle acceleration are, due to the lack of high power laser sources, limited to demonstration experiments only. In this respect the fiber laser has proven to be an outstanding laser concept at 1 µm wavelength to meet the continuously rising requirements for the development of novel application fields. However, many applications would greatly benefit from a longer laser wavelength.

The fiber laser was established as high power laser based on fiber-doping with ytterbium. An alternative, promising material is thulium-doped fused silica, which provides a broad emission between 1800-2050 nm. The generation of ultrashort pulses in the 2 µm wavelength regime is currently investigated based on thulium-doped fibers for amplification.

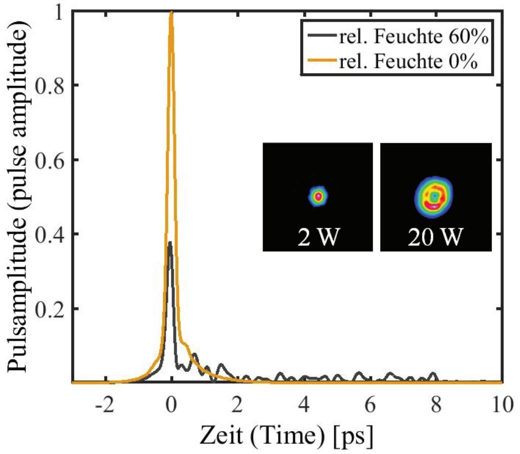

Figure 1: Pulse- and beam deformations by atmospheric water absorption.

A longer wavelength is – besides the application-oriented demand- also of interest for scaling peak- and average power in fiber lasers. The detrimental influence of important nonlinear effects are linearly or quadratically reduced with wavelength. In addition the mode-field diameter can be scaled quadratically for similar tolerances of the refractive index profile. In combination it should be feasible to scale the output power by an order of magnitude by switching the signal wavelength from 1 µm to 2 µm.

The in-house realization of highly efficient dielectric reflection gratings allowed for average powers of 152 W and peak powers of more than 200 MW at pulse duration of a few hundred femtoseconds /1/. The only limitation for further power scaling and diffraction-limited beam quality was the presence of detrimental atmospheric water absorption (figure 1) /2/. In a subsequent experiment in dry atmosphere the nonlinear compression in a solid-core fiber enabled pulse durations of 24 fs (less than 4 optical cylces, figure 2) at non-preceded average powers of 24 W. Current research focusses on increasing the peak power by spectral broadening in hollow-core capillaries and subsequent pulse compression. These systems will reach several GW peak power and simultaneously high average powers of a few 100 W, which will eventually be used to address challenging and very promising application fields for the first time.

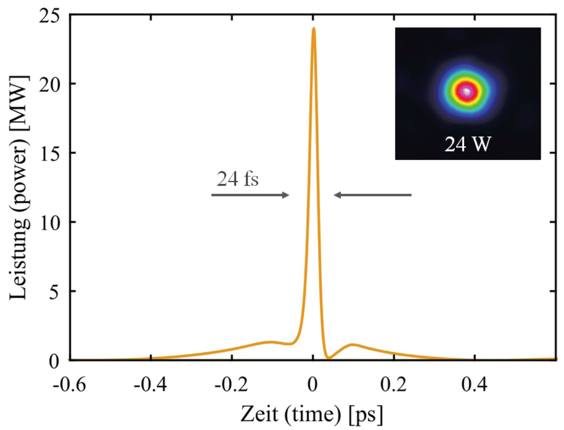

Figure 2: Compressed pulse with 24 fs duration and excellent beam quality.

/1/ F. Stutzki, C. Gaida, M. Gebhardt, F. Jansen, C. Jauregui, J. Limpert, A. Tünnermann: "Tm-based fiber-laser system with more than 200 MW peak power", Opt. Lett. 40, 9-12 (2015)

/2/ M. Gebhardt, C. Gaida, F. Stutzki, S. Hädrich, C. Jauregui, J. Limpert, A. Tünnermann: "Impact of atmospheric molecular absorption on the temporal and spatial evolution of ultra-short optical pulses", Opt. Express 23, 13776-13787 (2015)

/3/ C. Gaida, M. Gebhardt, F. Stutzki, C. Jauregui, J. Limpert, A. Tünnermann: "Self-compression in a solid fiber to 24 MW peak power with few-cycle pulses at 2 µm wavelength", Opt. Lett. 40, 5160-5163 (2015)

Authors:
Jan Rothhardt, Getnet Kassa Tadesse, I. Wahyutama, Steffen Hädrich and Jens Limpert

Soft X-ray Spectroscopy and Microscopy Group

The research group, led by Dr. Rothhardt, investigates matter on smallest spatial and temporal scales by using modern laser-based XUV and soft x-ray sources. There are strong cooperations between the Helmholtz-Institute Jena and our Institute, depended on the common research interests, like:

- laser-based short wavelength sources
- nanometer scale imaging techniques
- ultrafast spectroscopy
- XUV spectroscopy of highly-charged ions

Research methods

The group utilizes a variety of modern imaging and spectroscopy techniques including:

- coherent diffraction imaging and holographic techniques
- XUV Laser spectroscopy
- pump-probe spectroscopy

The group utilizes modern experimental equipment including:

- high average power femtosecond lasers
- high photon flux table-top XUV and soft x-ray sources
- XUV and soft x-ray spectrometers and detectors

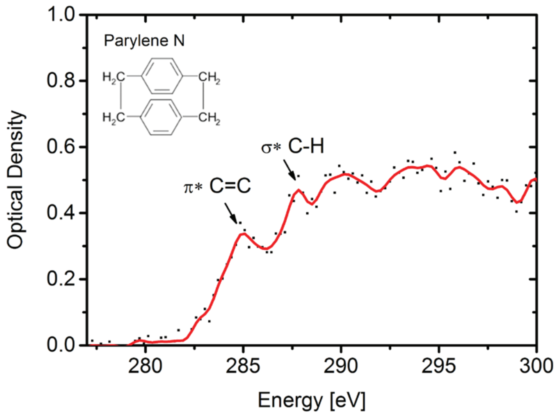

Figure 1:
Measured optical density of a Parylene filter, unveiling the fine structure of the carbon K-edge and contributions from different binding orbitals (black points = raw data; red curve = Fourier-filtered curve).

High photon flux table-top soft X-ray sources and applications

Efficient high harmonic generation into the soft x-ray region requires driving laser pulses with only a few optical cycles in duration. Nonlinear compression of a femtosecond fiber laser allowed us to generate 8 fs pulses with >0.35 mJ pulse energy at up to 150 kHz repetition rate [1]. This world's most powerful few-cycle laser, in terms of average output power, enabled high harmonic generation up to the so-called "water window" beyond the carbon absorption edges (~283 eV). With helium as nonlinear medium more than 106 photons/s are generated within the water window spectral region. Instead neon generates more than 109 photons/s within a 1% bandwidth in the spectral region between 100 and 150 eV [1].

These novel table-top soft X-ray sources are particularly interesting for near edge x-ray absorption fine-structure spectroscopy (NEXAFS), which allows determining the structure and composition of organic samples and the chemical state of their building blocks. Figure 1 displays the measured optical density of a 0.5 µm thick Parylene filter close to the carbon K-edge. This proof of principle experiment already demonstrates that different peaks (e.g. at 285 eV and 288 eV) can clearly be assigned to contributions from two different binding orbitals. In combination with pump-probe experiments this technique will allow seminal studies of ultrafast electronic and chemical dynamics on shortest time scales.

In addition, the short wavelength and high spatial coherence of the table-top soft X-ray source holds promise to imaging with a few-nano-meter resolution. A first proof of principle experiment demon-strated the feasibility. Figure 2 displays a measured diffraction pattern (a)), a SEM-image of the test sample (b)) and the sample reconstruction obtained from the measured data (c)). Currently, the achieved resolution is limited to 65 nm by the available photon flux. In future, the ever rising power of the driving lasers and the resulting soft X-ray sources will enable table-top imaging with sub-10 nm resolution, which until now was exclusively feasible at synchrotrons and free-electron lasers.

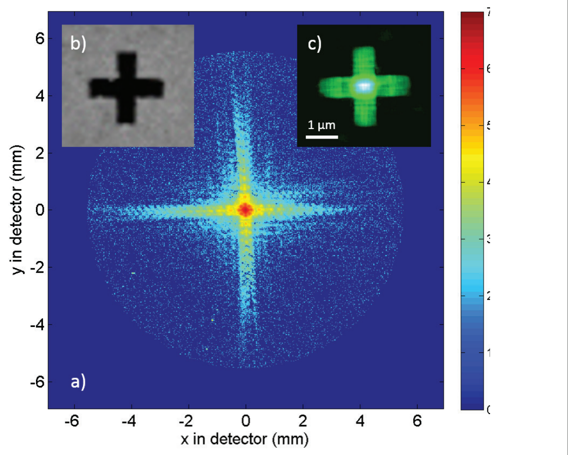

Figure 2:
Coherent diffractive imaging at 150 eV photon energy.
a) Measured diffraction pattern, b) SEM image of the sample,
c) Reconstructed amplitude. The achieved resolution is ~ 65 nm.

/1/ J. Rothhardt, S. Hädrich, A. Klenke, S. Demmler, A. Hoffmann, T. Gotschall, T. Eidam, M. Krebs, J. Limpert, A. Tünnermann: "53 W average power few-cycle fiber laser system generating soft x rays up to the water window.," Opt. Lett. 39, 5224–7 (2014).

/2/ G. Tadesse, J. Rothhardt, S. Hädrich, R. Klas, J. Limpert, A. Tünnermann, "High Brightness Soft X-ray Source for Nanometer Scale Imaging", Ultrafast Optics Conference, Bejing (2015).

Microstructure Technology & Microoptics

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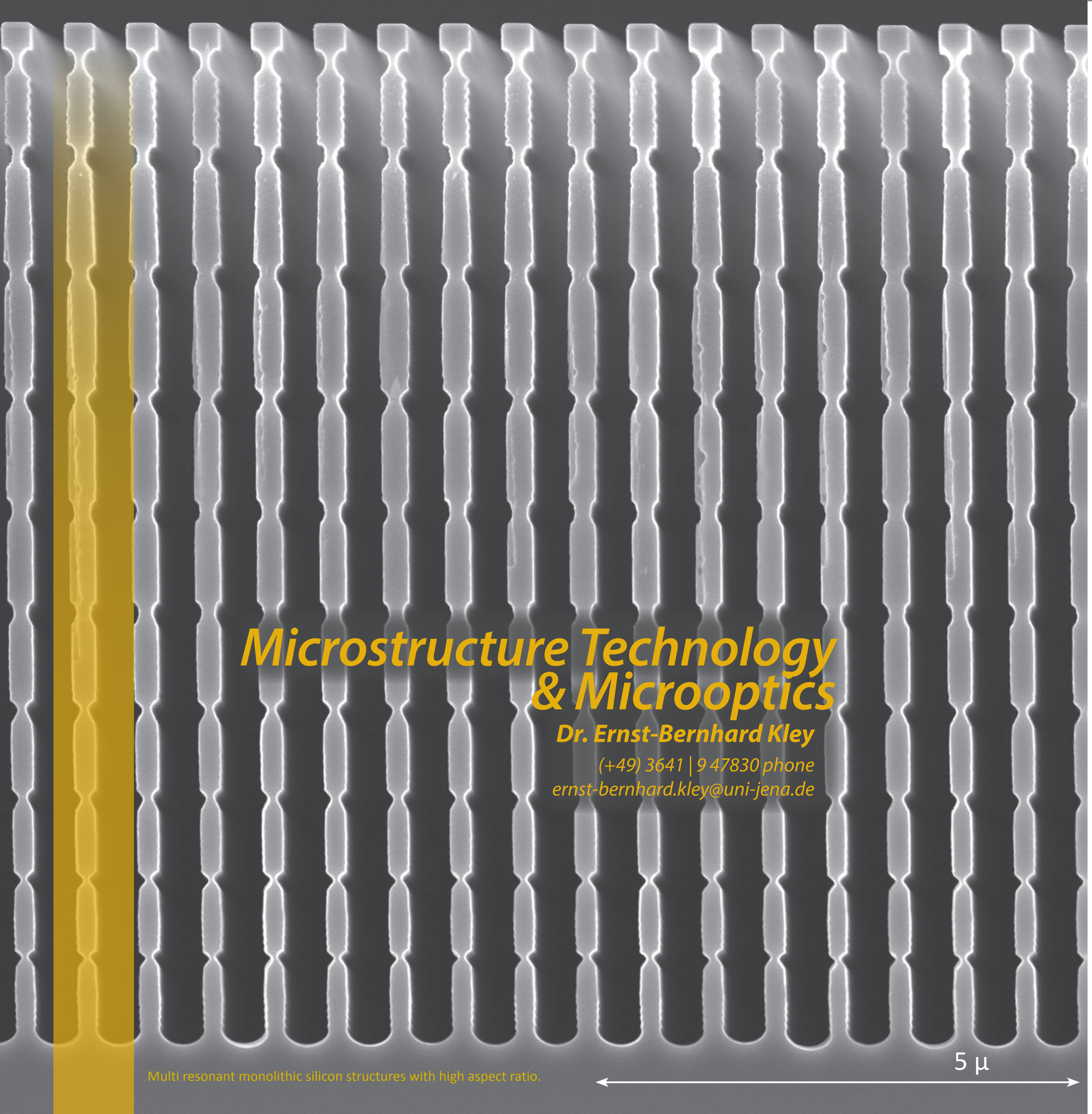

Multi resonant monolithic silicon structures with high aspect ratio.

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
- Material-scientific aspects

Authors:
Stefan Steiner and Ernst-Bernhard Kley

Asymmetric direction selective filter based on grating structures

In order to improve the accuracy of highly integrated sensor assemblies using detectors made of semiconductors, e.g. to detect particles in gases or fluids, novel optical filters are of interest, which provide an asymmetric transmission behavior concerning the incidence angle. Because of the combination of filter element and detector, further requirements regarding structure and material arise. These are the possibility for integration on waver scale, e.g. using lithographic methods, and materials, which are compatible with common semiconductor technology.

A novel approach to realize the desired filter function utilizes the very special characteristics of resonant waveguide gratings. Their resonance is based on gratings with periods in the order of the wavelength of the used light, in combination with high index materials. In order to achieve an asymmetric behavior, an effective refraction index gradient inside each grating period is introduced. A possibility to attain this effective index gradient is the application of three grating ridges with increasing width. Due to this asymmetric layout and a light propagation length of only one period, the required transmission behavior can be reached /1/.

For the fabrication a 500 nm thick layer of amorphous silicon was structured using electron beam lithography and a chromium etch mask. The grating period of this sample (fig. 1 and 2) is 750 nm, where the widths of the grating ridges are 72 nm, 140 nm and 250 nm. Optimizing the asymmetric transmission function residues of the chromium etch mask were exploited as absorbing structures.

The measurement of a sample at a wavelength of 850 nm (fig. 3) exhibits a distinct asymmetric transmission and a maximum of up to 70% at incidence angles in an interval between -52° and -31°. On the contrary the transmission for positive angles is below 10%.

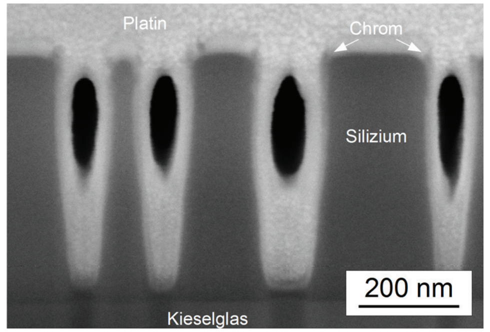

Figure 1:
SEM image of a realized filter (cross sectional view).

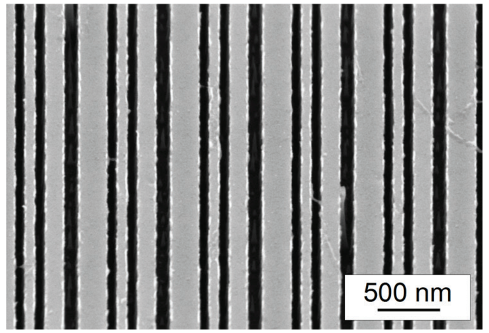

Figure 2:
SEM image of a realized filter (top view).

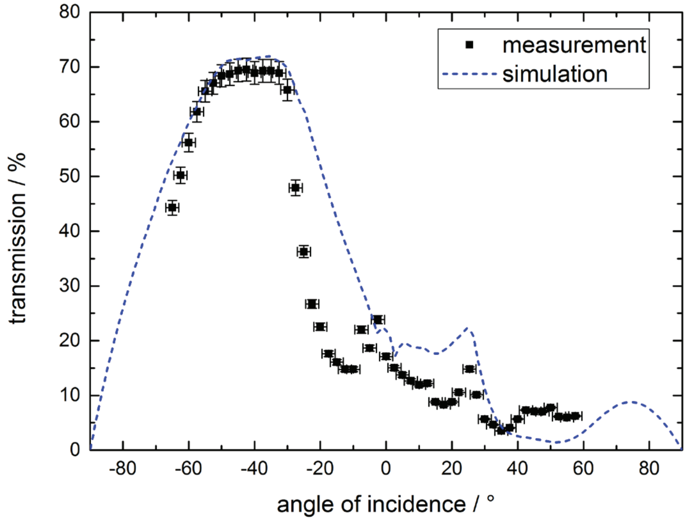

Figure 3:
Comparison between the simulated and measured transmission characteristic.

/1/ S. Steiner, E.-B. Kley:
Patent application
DE 10 2011 084 055 A1

Author:
Uwe D. Zeitner

ZIK ultra optics: Manufacturing Technologies for Advanced Micro-and Nano-Optics

As an example of the works in 2015 the following will be presented:

Amongst others, diffractive mask-aligner lithography has been used for printing structures that have a sub-micrometer resolution by using non-contact mode. As the diffractive photo masks require a polarized illumination we proposed a mask design that includes a wire-grid polarizer (WGP) on the top side of a photo-mask and a diffractive element on the bottom one to print a 350 nm period grating by using a classical mask-aligner in proximity exposure mode. Generating locally a linearly polarized illumination from an unpolarized incident beam is only possible by using a WGP on the top side of the mask. This configuration opens the possibility to use different linear polarization orientation on a single mask and allows to print high resolution structures with different orientation within one exposure.

Mask design

The diffractive element that generates the high resolution intensity distribution is located on the bottom side of the mask. The transfer of the diffraction grating during the lithography step is performed by using the two-beam interference lithography principle. In order to obtain a high interference contrast and a large undisturbed propagation depth of the two-beam interference it is essential to almost completely cancel the zeroth-diffraction order of the grating. This has been achieved by a special rigorously optimized design of the SiO_2 grating structures.

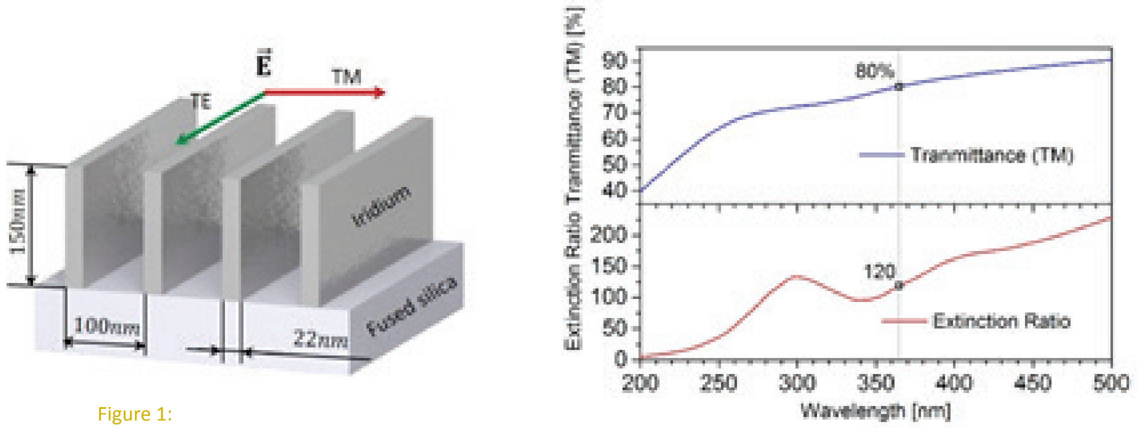

Figure 1:
Left: Schematic view of the wire grid polarizer. The arrows show the electric field vector direction for TM (red) and TE (green) polarization. Right: Simulated transmittance of TM polarized light and extinction ratio for an iridium wire gird polarizer with a period of 100 nm a ridge width of 22 nm and a height of 150 nm.

Polarizer design

Although WGPs are challenging in fabrication, they have been chosen for their beneficial properties such as large acceptance angle and work over a large spectral band. It is, so far the optimal component to efficiently obtain linear polarized light with a wavelength in the UV range and allows integration into a mask. In some particular applications, a local variation of the polarizer´s direction may be required; which cannot be achieved by conventional solutions. To ensure durability also in harsh production environment, iridium is utilized as material for the polarizing grating bars.

For the exposure wavelength of the mask aligner at λ=365nm an extinction ratio of 120 at a TM-transmission of 80% can be theoretically expected. The experimentally realized wire grid polarizer has been characterized to have a TM transmission of 75.3% and an extinction ratio of 74 at the Mask-Aligner wavelength.

Results

The double sided mask has been used to print gratings with 350nm period in a conventional mask-aligner [Süss MicroTec). The exposed and developed resist structures have been transferred into the silicon substrate by reactive ion etching (RIE).

The mask design presented here has shown that it is possible to obtain sufficiently linear polarized light from an unpolarized UV incident beam by including a wire grid polarizer on the upper side of a photo-mask, and generate a high resolution intensity distribution pattern under the latter by using a phase-mask on its bottom side. This approach shows that such an approach can be used for the mass production of high resolution structures, using proximity lithography and a relatively small modification needed to the illumination setup due to the integration of the polarizer directly on the mask.

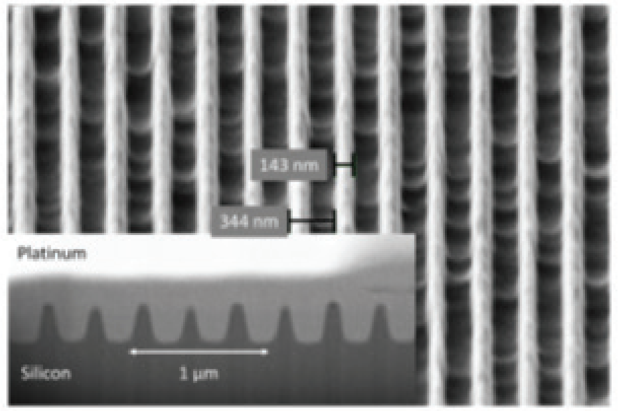

Figure 2:
SEM micrograph of a 350 nm period grating printed by the double sided mask and transferred into the silicon wafer by RIE. The sub-window shows the grating profile obtained by FIB.

/1/ Y. Bourgin, T. Siefke, T. Käsebier, P. Genevée, A. Szeghalmi, E.-B. Kley, U. D. Zeitner:
Optics Express, 23 (13), 16628-16637 (2015)

Authors:
Lilit Ghazaryan, Ernst-Bernhard Kley and Adriana Szeghalmi

Junior Research Group: Atomic Layer Deposition - Emmy Noether Group

Atomic layer deposition (ALD) is a thin film coating technology based on self-limiting surface reactions. The thickness of ALD films is controlled with sub-nanometer precision by the number of ALD cycles. The films manifest high uniformity and low roughness. The decisive advantage of ALD over other established coating techniques is its ability of conformal coating on curved and high aspect ratio substrates. A wide range of materials, including oxides, nitrides, fluorides, sulfides, metals and hybrid organic-inorganic composites, can be deposited via the ALD and molecular layer deposition (MLD) techniques. Additionally, composite materials with tailored composition and material properties are possible. The above-mentioned materials find numerous applications in the fields of photovoltaics, electronics, catalysis, biotechnology, display technology, and photonics.

We aim to establish this technology for the development of novel and improved optical elements. We currently focus on developing atomic layer deposited coatings for:

- low and high refractive index materials
- porous materials
- advanced nanostructuring technologies
- interference coatings
- functional coatings for diffractive optical elements
- space & laser technology, spectrometry, UV-VIS, DUV, EUV, BEUV, x-ray optics
- understanding chemical reactions during nucleation and film growth.

Research methods

The ALD facility led by Dr. Szeghalmi has two plasma-enhanced atomic layer deposition reactors at hand. Both are located in a clean room environment and are equipped with in situ monitoring techniques for experimental characterization by means of spectroscopic ellipsometry in the 245…1700 nm spectral range. The equipment comprises:

- OpAL PEALD, Oxford Plasma Technologies
- Sunale R200, Picosun Oy
- J. A. Woollam spectroscopic ellipsometer.

Funding

DFG Emmy Noether Program, Friedrich Schiller University ProChance Program, Carl Zeiss Stiftung, TMBWK, European Space Agency, Fraunhofer Gesellschaft Attract Program

Emmy Noether-Programm
Deutsche Forschungsgemeinschaft
DFG

Nanoporous SiO_2 made by atomic layer deposition (ALD)

Nanoporous materials are essential in wide range of applications ranging from membrane technology for e.g. separation und purification, to semiconducting and photonic industry, as low-k and low-n materials. The established methods for the synthesis of nanoporous layers encounter their limits especially if conformal coatings on high aspect ratio surfaces are required. We developed a new route to produce nanoporous silica (SiO_2) films by mixing ALD Al_2O_3 and SiO_2 in an Å-scale and subsequently removing the Al_2O_3. The composition of the alloy films can be varied by simply adjusting the number of ALD cycles for Al_2O_3 (X-times) and for SiO_2 (Y-times) during the process (Fig. 1 (left)). The alumina is selectively removed in H_3PO_4 solution and the formation of nanoporous SiO_2 films is observed. The porosity and subsequently, the refractive index of the nanoporous SiO_2 films can be precisely tailored by the initial composition of the alloys (Fig. 1 (right)). On the other hand, no change of the refractive index and no porosity evolution could be observed in the mixture 10:10, indicating that the 10 cycles of ALD SiO_2 (~ 1nm) forms nearly a barrier layer preventing the penetration of the etching solution into the film.

The nanoporous SiO_2 layers were applied as antireflection coating for a quartz substrate. Over 98 % transmission could be achieved in the whole visible wavelength range by a double side, single layer nanoporous SiO2 coating (Fig. 2 (left)). Moreover, the layers were successfully used as diffusion layers to encapsulate optical gratings, which are widely used in various optical systems for the enhancement of their performance. The result of the encapsulation is shown in Fig. 2 (right) /1/.

/1/ L. Ghazaryan, E.-B. Kley, A. Szeghalmi: Patent DE 10 2015 203 307.4

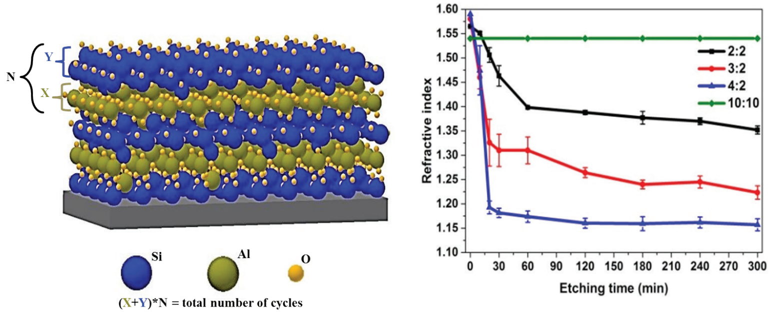

Figure 1: (left) Schematic view of the ALD Al2O$_3$:SiO$_2$ composite layer, (right) the dependence of the effective refractive index of the alloys on the etching time.

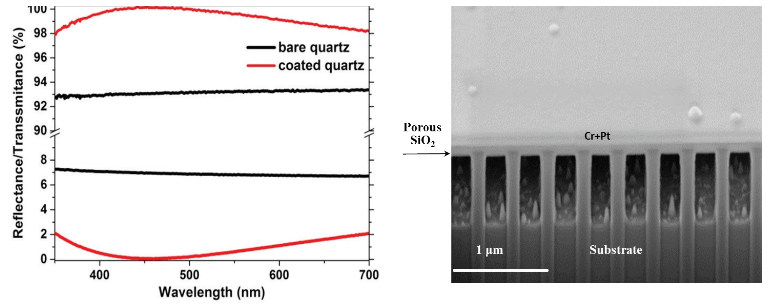

Figure 2: (left) Schematic view of the (left) Reflectance and transmittance spectra of the quartz substrate as a function of the wavelength without coating and double-side coated with porous SiO_2, measured at 6° light incidence angle, (right) cross-sectional SEM images of the encapsulated grating.

Ultrafast Optics

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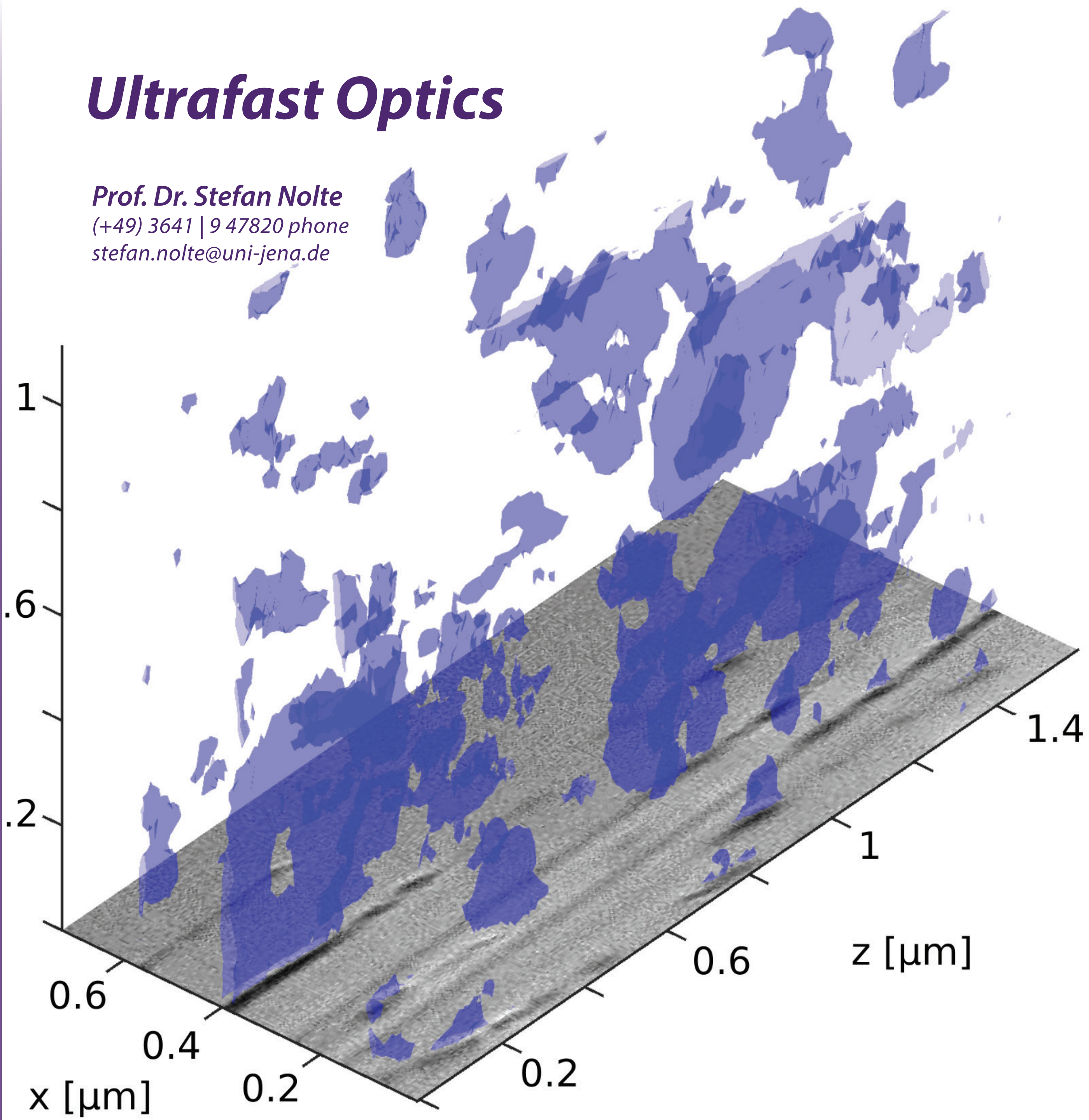


3D reconstruction of nanogratings in fused silica based on 90 FIB-SEM images. An exemplary SEM image is shown in the x-z-plane.

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 interaction processes between light and matter
- Micro- and nanostructuring with ultrashort laser pulses
- Sub-wavelengths structuring
- Fiber Bragg Gratings (FBG), Volume Bragg Gratings (VBG)
- Linear and nonlinear optics in discrete systems
- Medical laser applications
- THz technology
- Spectroscopic methods for gas analysis

In 2015, some outstanding results were:

• demonstration of fs-written VBGs in fused silica for narrow-linewidth stabilization of diode lasers with reduced thermal shift • inscription of FBGs in active and passive fibers with tailored optical and improved thermal properties • cutting of hardened and unhardened glass • ultrastable welding of glass without optical contacting (bridging gaps) • scribing of thin-film solar cells resulting in improved efficiency • structural analysis of laser induced nanogratings in different glasses• spatially and temporally resolved measurement of the free electron density evolution inside bulk glass after fs-pulse irradiation • first experimental demonstration of an unphysical event • first demonstration of quantum Bloch oscillations of N00N-states • theoretical prediction of ultrashort x-waves with angular momentum •demonstration of generalized multi-photon quantum interference

Authors:
Felix Zimmermann and Stefan Nolte

Nanogratings – artificial local birefringence in glasses

The micromachining of transparent materials with ultrashort laser pulses allows to fabricate photonic devices with feature sizes smaller than the wavelength of light. By focusing ultrashort laser pulses in the bulk of glasses self-assembled structures, so-called nanogratings, can be induced. While the amount and direction of the induced briefringence can be set by the laser parameters and polarization orientation, respectively, laser scanning allows to arbitrarily arrange the structures within the bulk. This facilitates the fabrication of photonic functionalities, ranging from microfluidics, optical data storage to the generation of optical vortex beams for high-resolution microscopy.

In particular, nanograting-based waveplates are used to extend the well-known structured illumination microscopy (SIM; see Fig. 1) /1/. Based on the tailored arrangement of nanogratings (see Fig. 2) optical sectioning can be performed in a single exposure. Consequently, rapidly changing samples such as biological tissue can be imaged in-situ.

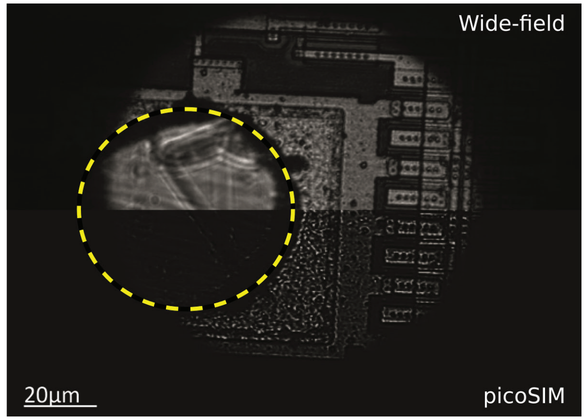


Figure 1:
Comparison of a ceramic chip imaged with conventional wide-field (upper) and polarization-coded structured illumination microscopy (lower). The latter significantly reduces the out-of-focus light (marking).

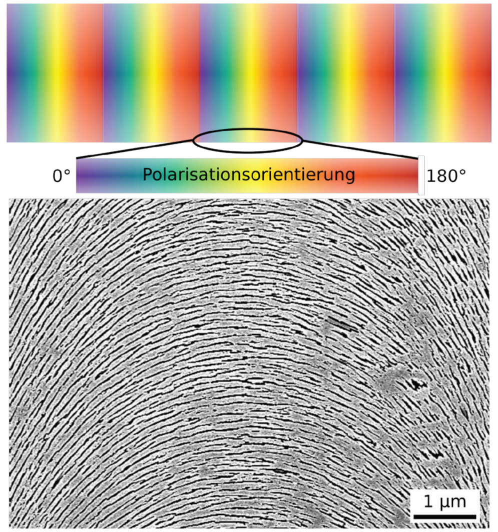


Figure 2:
Above: Desired polarization distribution for polarization encoded optical sectioning microscopy; Lower: SEM micrograph of the inscribed nanograting structure.

Despite the various applications of nanogratings the fundamental formation process is still not fully understood. One challenging aspect is the non-invasive structural investigation of the buried material modification. Typical methods base on time-consuming sample preparation techniques such as polishing and etching which also destroys fine structural details such as nanometric pores.

To overcome these challenges a combination of small-angle X-ray scattering (SAXS) as well as focused ion beam milling and SEM imaging was used /1/. The latter allows for imaging the three-dimensional distribution of the nanoporous structure without harming the structural morphology. Moreover, SAXS reveals average feature sizes, shape and total pore number as function of the laser parameters without any sample preparation. Thus, the growth of pores and their arrangement in periodic grating planes was comprehensively analyzed. This facilitates a better understanding of the complex physical mechanism of the nanograting formation and allows to further optimize the induced birefringence for tailored photonic functionalities /2/.

/1/ F. Zimmermann, S. Richter, R. Buschlinger, S. Shukla, R. Heintzmann, U. Peschel, S. Nolte: Ultrashort pulse-induced periodic nanostructures in bulk glass - from fundamentals to applications in high-resolution microscopy, book title: "Optically Induced Nanostructures: Biomedical and Technical Applications", Ed.: K. König, Ed.: A. Ostendorf, Berlin: De Gruyter, ISBN: 9783110354324, 93-116 (2015)

/2/ F. Zimmermann, A. Plech, S. Richter, A. Tünnermann, S. Nolte: On the rewriting of ultrashort pulse induced nanogratings, Optics Letters 40, 2049-2052 (2015)

Author:
Alexander Szameit

ZIK ultra optics: Diamond-/Carbon-based Optical Systems

The works of the research group in the year 2015 have found extraordinary international recognition, which is emphasized in 16 original publications in prestigious scientific journals (including 1x "Nature", 1x "Nature Physics", 1x "Nature Communications", and 3x "Physical Review Letters"), 56 conference papers, 21 invited talks and six colloquia. In addition, the research group leader Alexander Szameit was dignified by the Rudolf Kaiser Award.

Two results of last year are particularly emphasized in this report.

A highly regarded work has been published in Science Bulletin about the generation of quantum W-state /1/. Since their variety of possible applications, ranging from quantum computation to genuine random number generation, W-state class are of growing interest. The work represents an universal setup to generate high-order single photon W-states based on three-dimensional integrated-photonic waveguide structures. The focus lay on a specific class of states, where a single photon is shared among N=8 optical modes and forms a W-state. Their challenging generation could be realized by using on-chip waveguide structures. Additionally, it has been presented a novel method to characterize the device's unitary by means of classical light only.

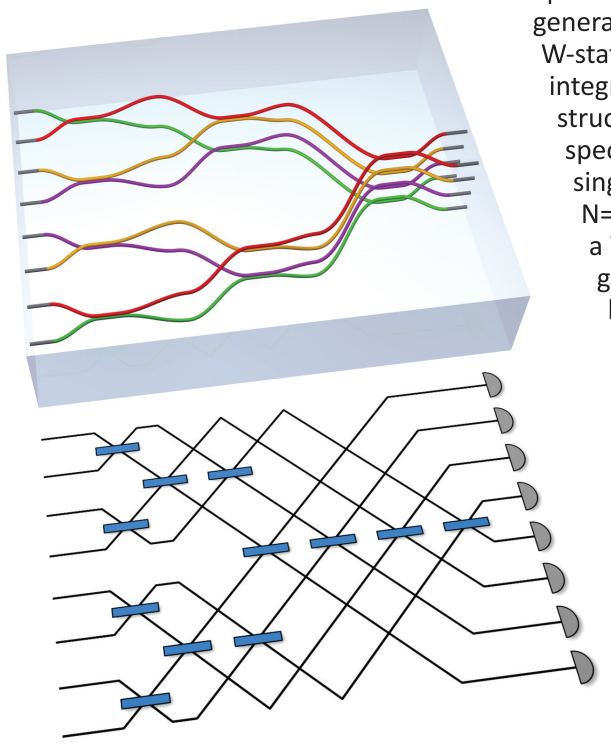
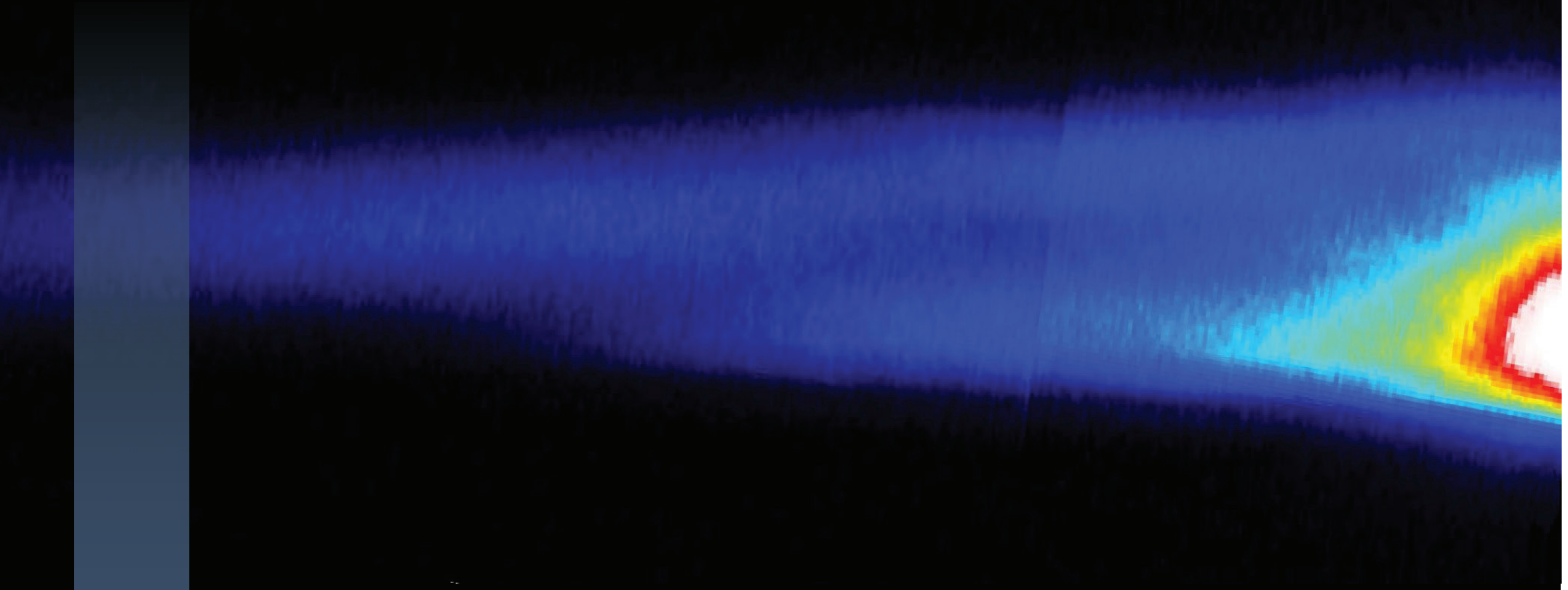


Figure 1:
Sketch of an integrated 8-arm-interferometer for the generation of N=8 W-states (top) and the schematic diagram of this interferometer (bottom).

The here presented second result is a new class of nondiffracting optical pulses exhibiting orbital angular momentum, published in /2/. By generalizing the X-wave solution of the Maxwell´s equations, we discover the coupling between angular momentum and the temporal degrees of freedom of ultrashort pulses. The spatial twist of propagation invariant light pulses turns out to be directly related to the number of optical cycles. Our results may trigger the development of novel multilevel classical and quantum transmission channels free of dispersion and diffraction. They may also find application in the manipulation of nanostructured objects by ultrashort pulses and for novel approaches to the spatiotemporal measurements in ultrafast photonics.

/1/ R. Heilmann, M. Gräfe, S. Nolte, A. Szameit, Sci. Bull. 60(1), 96-100 (2015).

/2/ M. Ornigotti, C. Conti, A. Szameit, Phys. Rev. Lett. 115(10), 100401 (2015).



Nano Optics

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Dual-SNOM image of a gold strip waveguide (width: 2.5µm, light wavelength: 663 nm). The illumination tip is near the left edge of the image.

The research group Nano Optics deals with light propagation and nonlinear light-matter interaction in micro and nano structures, optical metamaterials as well as photonic crystals.

The scientific emphasis lies on:

- Light-matter interaction in microstructured and nanostructured matter
- Optical metamaterials, photonic crystals, plasmonics, near field optics, high-Q nonlinear optical microresonators,
- Nonlinear spatio-temporal dynamics, quantum phenomena, opto-optical processes in integrated optics, all-optical signal processing
- Multi-tip scanning optical nearfield microscopy (SNOM), photoemission electron microscopy (PEEM)
- Multi-functional diffractive optical elements based on photonic nanomaterials
- Application of advanced photonic concepts for astronomical instruments
- Application of optical nanostructures for efficiency enhancement of photovoltaic elements

Authors:
Frank Setzpfandt and Thomas Pertsch

Coupled nonlinear waveguides for the generation of photonic quantum states

Photonic quantum states enable the realization of quantum optical simulators and computers, which can be used for unbreakable cryptography and powerful computer algorithms. Together with collaborators from the Australian National University Canberra we experimentally realized a new paradigm for the flexible generation of such quantum states by using coupled nonlinear waveguides made from lithium niobate as integrated quantum state sources. In such waveguides, photon-pairs are generated by spontaneous parametric down-conversion. The interplay between the nonlinear generation of photon pairs and the linear light dynamics in the system of coupled waveguides leads to a number of novel ways to create two-photon quantum states.

To demonstrate the power of this concept for the generation of nonclassical photon states /1/, classical pump light was coupled to a single waveguide of a periodic arrangement of many coupled waveguides, namely a waveguide array. Photon pairs generated along the pumped waveguide can couple to other waveguides, thus undergoing a quantum walk. Quantum interference of photon pairs generated at different positions in the pumped waveguide leads to cascaded quantum walks, which can be manipulated by changing the parameters of the pump light and waveguide array. Thus, control of the output quantum state can be achieved. We experimentally demonstrated such control by generating nonclassical as well as classical quantum light states by tuning the wavelength of the pump light.

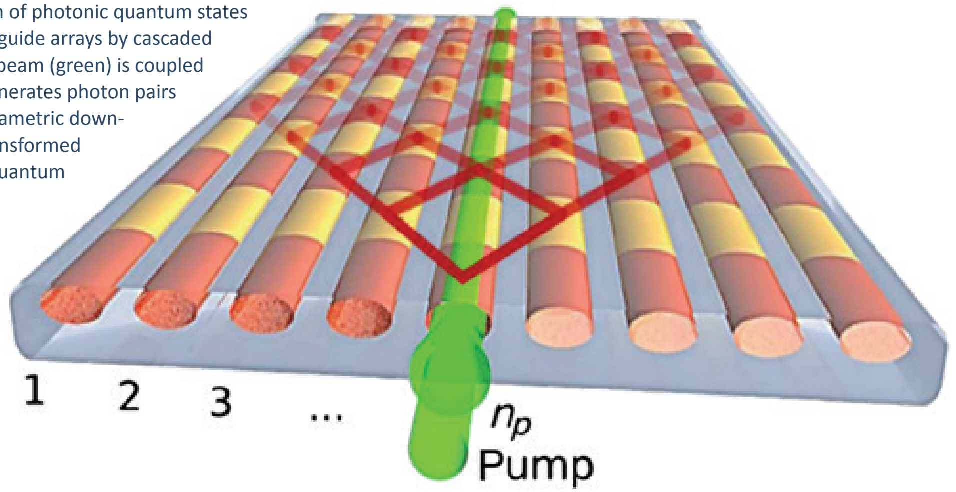


Figure 1:
Scheme of the generation of photonic quantum states in nonlinear optical waveguide arrays by cascaded quantum walks. A pump beam (green) is coupled to one waveguide and generates photon pairs (red) by spontaneous parametric down-conversion, which are transformed into the desired output quantum state.

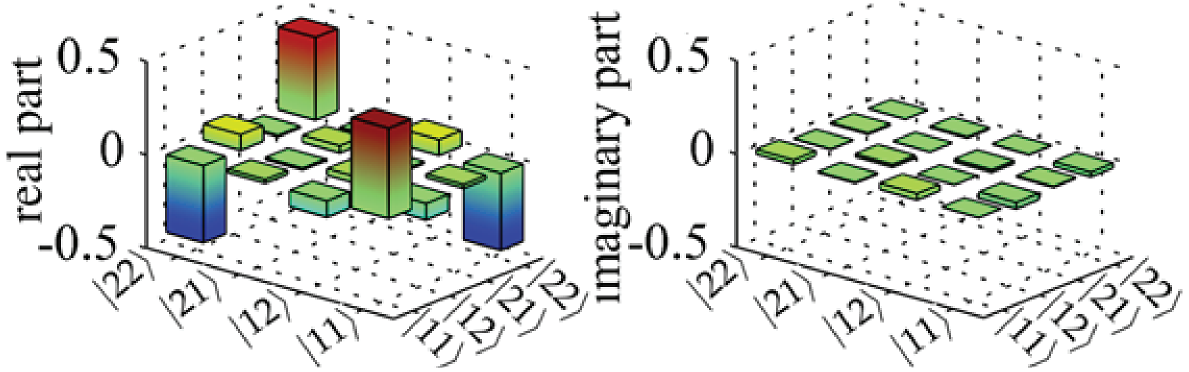


Figure 2:
Scheme of the generation of photonic quantum states in nonlinear optical waveguide arrays by cascaded quantum walks. A pump beam (green) is coupled to one waveguide and generates photon pairs (red) by spontaneous parametric down-conversion, which are transformed into the desired output quantum state.

Whereas the photon states generated in the waveguide array are distributed over many output waveguides, for practical applications just two spatial output modes are often sufficient. Using just two coupled waveguides to implement the concept described above, we could experimentally demonstrate a source for two-photon quantum states with all-optically tunable degree of entanglement and spatial composition /2/. Among other examples, this configuration was used to generate optical NOON-states.

The operating principle of the demonstrated quantum state sources is suitable for practical implementation of reconfigurable photon sources in on-chip quantum circuits, thus marking an important step towards the realization of a flexible integrated optical quantum architecture.

/1/ A. S. Solntsev, et al.: "Generation of Nonclassical Biphoton States through Cascaded Quantum Walks on a Nonlinear Chip", Phys. Rev. X 4, 031007 (2014)

/2/ F. Setzpfandt, et al.: "Tunable generation of entangled photons in a nonlinear directional coupler", Laser Photon. Rev. 10(1), 131-136, (2016)

Author:
Isabelle Staude

Junior Research Group: Functional Photonic Nanostructures

The research focuses lies on the use of designed photonic nanostructures which are to control the emission, absorption, and propagation of light at the nanoscale level. The research topics include:

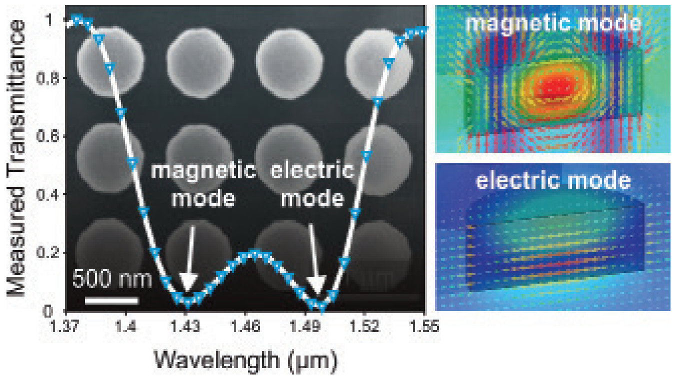
- nanophotonics, -plasmonics, and –antennas
- high-index dielectric nanoparticles
- hybrid quantum systems and quantum emitters
- nanofabrication technology
- subwavelength optics
- metamaterials and photonic crystals

Research methods

For the experimental realization and study of functional photonic nanostructures, the junior research group Functional Photonic Nanostructures employs a range of state-of-the-art nanotechnology and optical characterization techniques, including:

- electron-beam lithography based nanofabrication
- linear and nonlinear optical spectroscopy
- time-resolved photoluminescence spectroscopy
- back focal plane imaging
- assembly of hybrid nanostructures via dry transfer
- assembly of hybrid quantum systems by selective surface functionalization

Recent Research Results



Resonant nanoparticles and their assemblies can show complex and often surprising interactions with light, giving rise to phenomena such as „magnetic light“, directional scattering, Fano resonances, and strong near-field enhancements. Using the capab-ilities of modern nanotechnology, these interactions can be tailored by the size, shape, material composition, and arrangement of the nanoparticles. Resonant nanoparticle structures are a versatile research platform for investigating fundamental light-matter interactions and nanoscale coupling phenomena. Furthermore, they provide unique optical functionalities, opening new opportunities for applications like next-generation (quantum) light sources, optical communications, and truly flat optical components. In our research we combine top-down and bottom-up nanofabrication approaches to experimentally realize composite photonic systems. These systems are able to control the emission, propagation, and absorption of light - and all of its properties at the nanoscale.

Recently we have focused on nano-particles composed of highly transparent, high-refractive-index dielectrics. Such nanoparticles support localized electric and magnetic Mie-type resonances (see image), thereby providing a low-loss alternative to plasmonic nanostructures /1/. Most prominently, highly efficient functional nanosurfaces /2/, e.g., for resonant wavefront shaping /3/, nonlinear frequency generation /4/ and spectral filtering /5/ can be created by dedicated arrangements of designed dielectric nanoresonators on a plane. Active tuneability of dielectric nanosurfaces has been achieved using liquid crystals /6/. Furthermore, we have studied the use of Mie-resonant all-dielectric nanoparticles as high-radiation efficiency nanoantennas for spontaneous emission control /1, 7/.

/1/ Staude et al., ACS Nano 7, 7824 (2013).

/2/ Decker et al., Adv. Opt. Mater. 3, 813 (2015)

/3/ Chong et al., Nano Lett. 15, 5369 (2015)

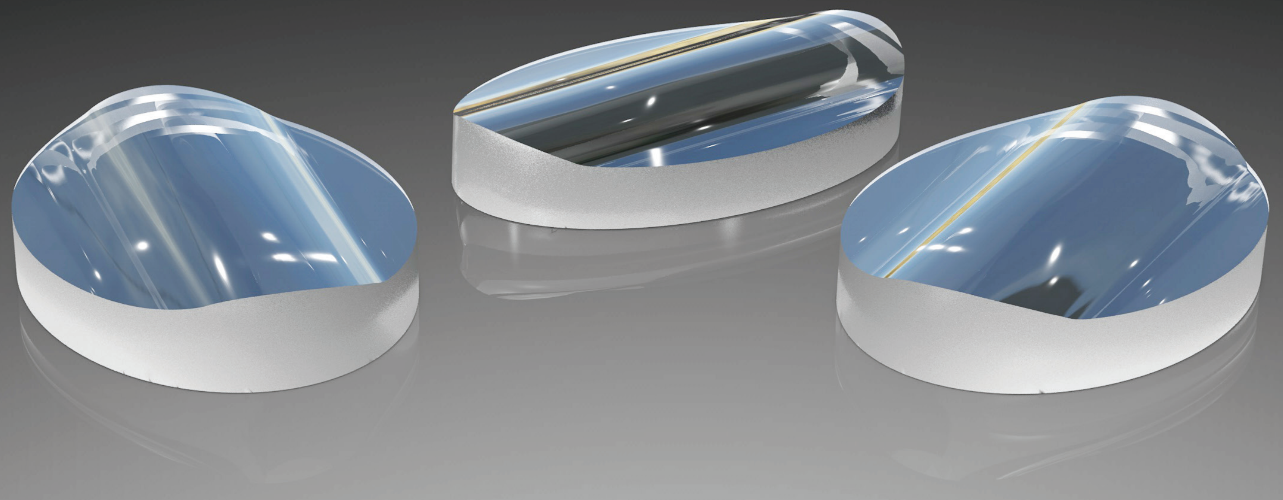
/4/ Shcherbakov et al., Nano Lett. 14, 6488 (2014)

/5/ Chong et al., Small 10, 1985 (2014)

/6/ Sautter et al., ACS Nano 9, 4308 (2015)

/7/ Staude et al., ACS Photonics 2, 172 (2015)

Optical System Design



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Visualisation of several free-form lenses.

The research priorities of this working group can be divided into two main areas. In classical optics design, especially the following topics will be addressed:

- Design of modern optical system
- Aberration theory
- Quality evaluation of optical systems
- Measurement of the performance of optical systems
- Design of laser and delivery systems
- Design and evaluation of freeform optical systems for imaging and illumination
- Optimization 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 systems
- Partial coherent imaging and beam propagation
- Point spread function engineering and Fourier optics.

The endowed professorship Theory of Optical Systems aims to support small and medium-sized optical companies of the region around Jena in their development and training. Amongst others, this could be reached in the project “Freeform Optics Plus (fo+)”, which combines research on the brand new technology field of freeforms in optics but also vocational education and training.

Authors:
Christoph Bösel and Herbert Gross

Generation of arbitrary illumination distributions

In recent years the development of fast algorithms for the design of freeform surfaces attracted a great deal of interest. The goal of these design methods is the calculation of reflective and refractive surfaces, which can transform arbitrary input and output intensities into each other.

Despite there being a vast number of publications on freeform surface design methods for nonimaging applications, it is still hard to find fully detailed algorithms in the literature for the calculation of continuous lenses and mirrors, which can generate complex illumination patterns.

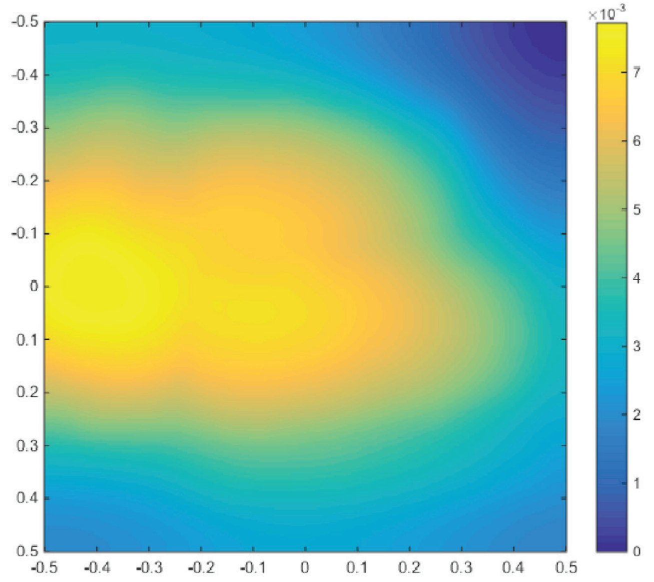


Figure 1:
Surface sag of a lens transforming a collimated input beam into the IOF Logo.

We developed a numerical method for the calculation of continuous freeform surfaces for collimated beam shaping. It is based on the decomposition of the design problem into two separate steps. At first a proper ray mapping is calculated via optimal transport. And in the second step the freeform surface is constructed by solving a linear advection equation. This provides us with an efficient and easy way to implement the calculation of freeform surfaces, which has a variety of applications like laser beam shaping for the acceleration of particles, creation of special structured beam profiles for metrology, trapping purposes or laser beam shaping for material machining with high quality cutting edges. But also in practical areas of incoherent illumination, where an efficient illumination control is desired such as street lighting or the automotive industry, freeform surfaces are also very useful but not easy to calculate.

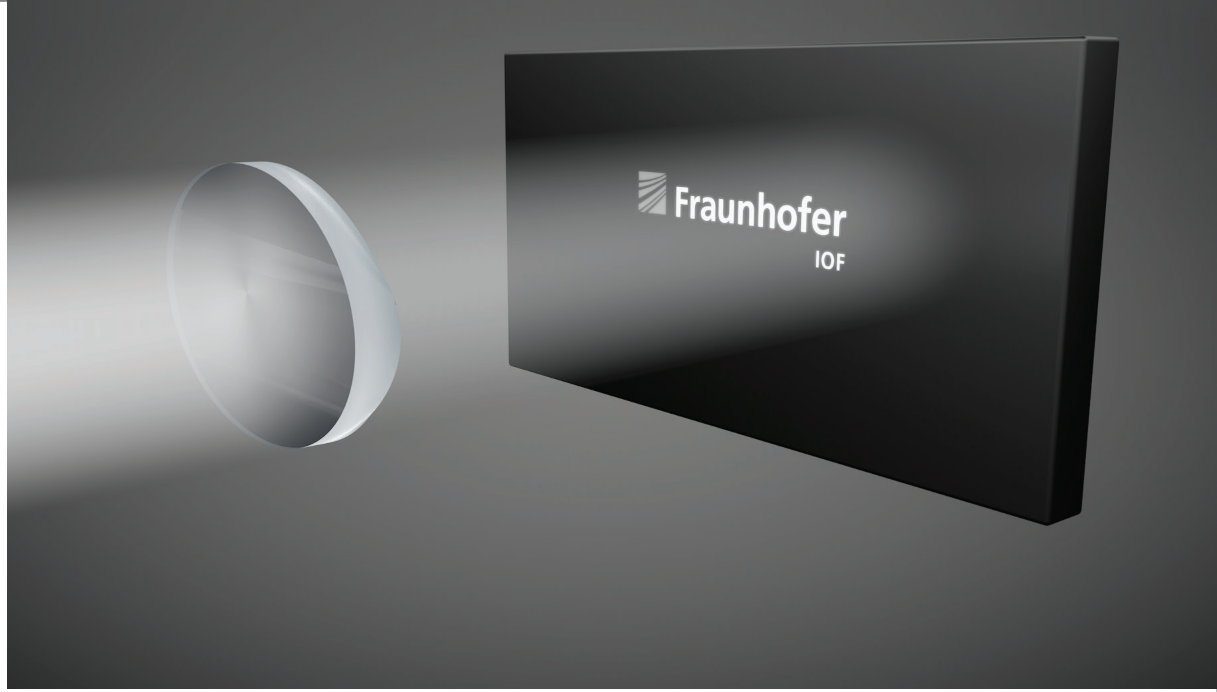
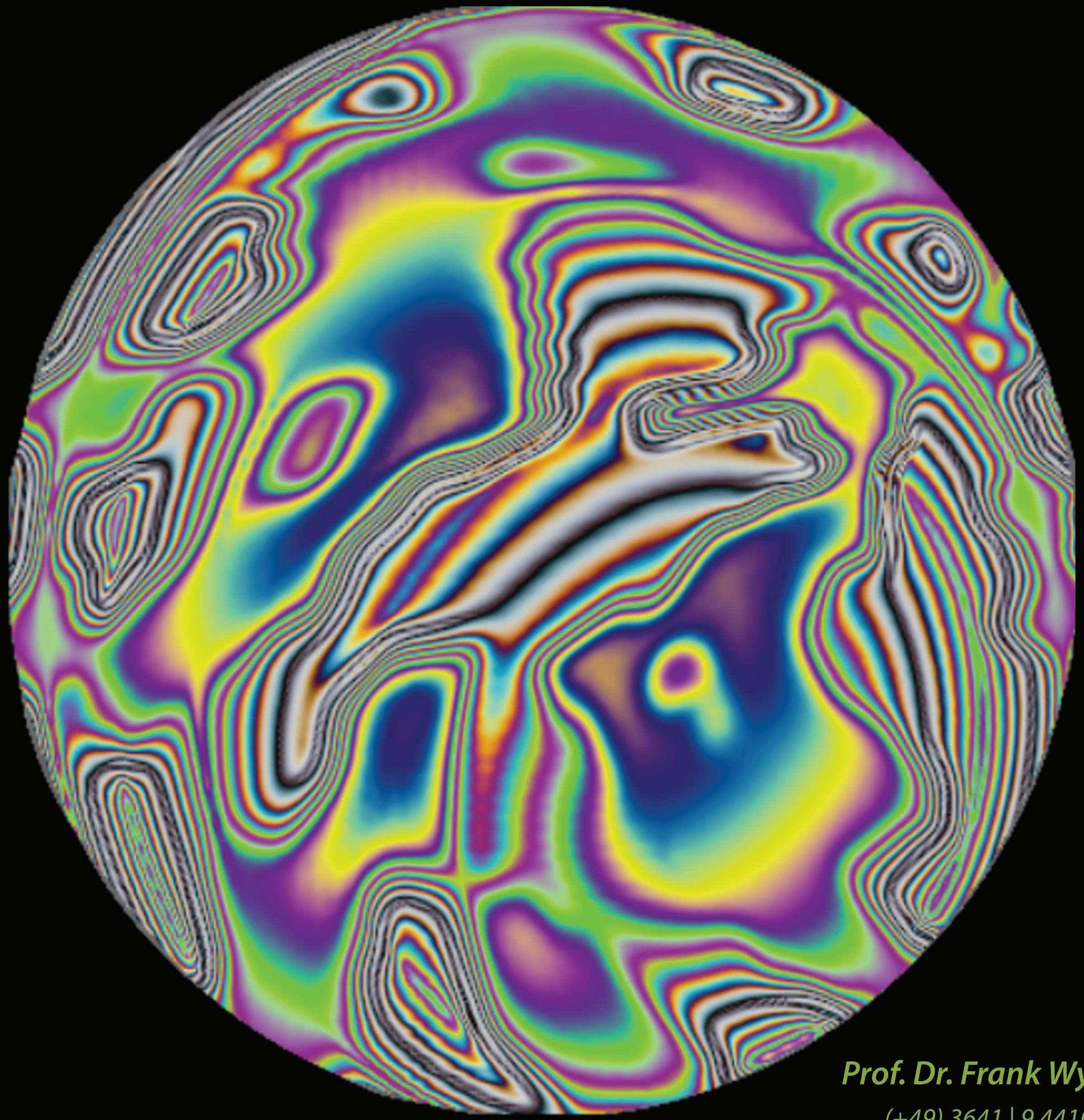


Figure 2:
Surface sag of a lens transforming a collimated input beam into the Fraunhofer IOF Logo.

Applied Computational Optics



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The Applied Computational Optics Group deals with various optical modeling techniques, ranging from geometrical optics to rigorous solutions like the Fourier modal method. All of them deal with solutions of Maxwell's equations and are combined by the concept of unified field tracing.

In 2015, the following research and development (R&D) topics have been investigated, among others:

- Development of geometric field tracing
- Investigation of the transition from diffractive to geometric modeling
- Geometric optics modeling of freeform surfaces
- Spline interpolation of smooth functions in optical modeling
- Design of light shaping elements by mesh design concepts
- Diffractive lens design and analysis
- Holographic optical element design
- Mie scattering
- Light propagation through anisotropic media
- Light propagation through inhomogeneous media
- Nonlinear-optics modeling including Kerr effect and SHG
- Spatio-temporal simulation of ultrashort pulses
- Fully vectorial laser resonator analysis and its acceleration with vector extrapolation

Several topics have been developed in cooperation with LightTrans GmbH and Wyrowski Photonics UG using the optics software VirtualLab Fusion.

Author:
Frank Wyrowski

Geometric field tracing in graded-index media and multi-mode fibers

The theory of geometric field tracing is derived from Maxwell's equations by using the geometric field approximation /1/. It traces smart rays, which include both ray information and field properties, e.g. polarization, intensity and coherence. Besides, the mesh concept is used to interpolate the detected electric field to achieve a well-sampled electromagnetic field. By using the concept of geometric field tracing, graded-index (GRIN) media can be modeled /2/.

Example 1:
Geometric field tracing in a GRIN lens

An x-polarized plane wave is focused by a GRIN lens (Lunburg ball lens) with radially graded refractive index. The results are shown in Figure 1. Geometrical optics cannot calculate the field in the focal region, which is expressed as mesh degeneration in our algorithm. However, after the focal region the degeneration in the mesh disappears. Therefore, the field in the focal plane can be calculated by combining geometric field tracing with diffractive field tracing: (a) Geometric field tracing is used to trace the rays to 10 µm after the focal plane and a well sampled electromagnetic field is obtained; (b) Diffractive field tracing (inverse far field operator) traces the field inversely to the focal plane. The fields in both planes show elliptical shape because the polarization effect is included in both field tracing engines: When a linearly polarized field goes through a rotationally symmetric optical system, the output field shows a more obviously non-rotationally symmetric shape as the numerical aperture becomes larger.

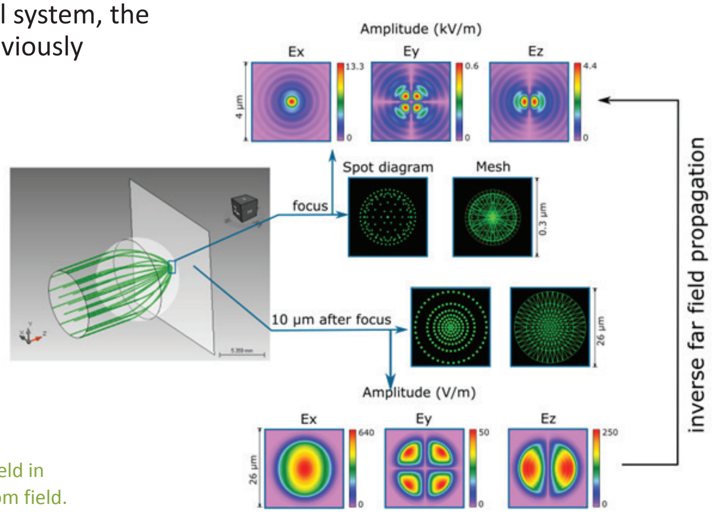

Figure 1:
The figure on the left shows that the ray paths go through the ball lens and focus in the rear vertex. The figure also shows the spot diagram, mesh, amplitude of electric field in the focus plane and 10 µm after the focus plane. The black array shows the calculation process: we use the inverse far field propagation operator to calculate the field in the focus (upper figures) from the bottom field.

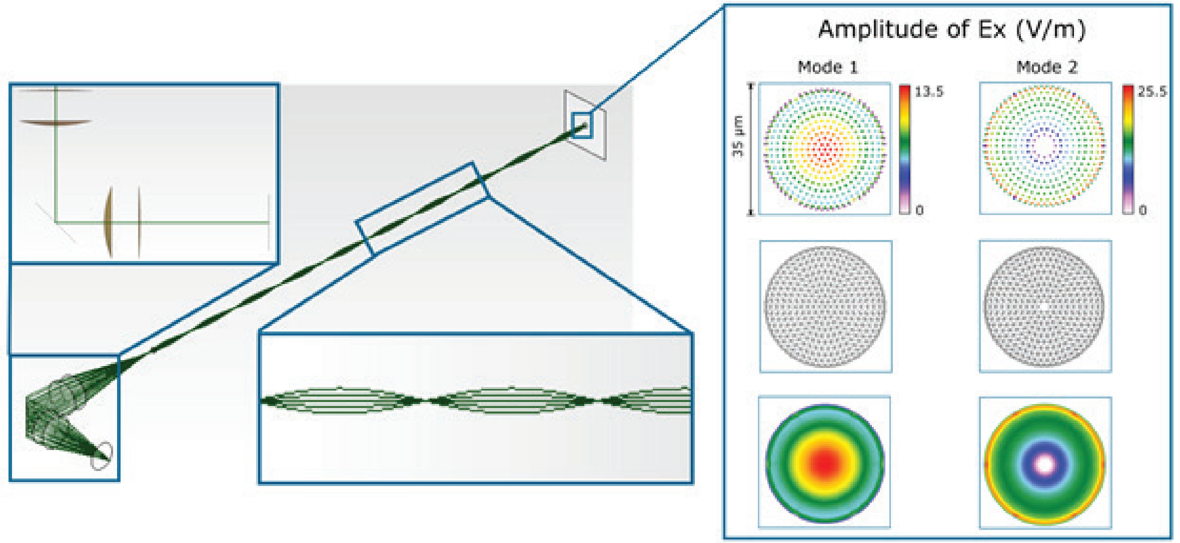

Figure 2:
The figure on the left shows that the ray paths go through the coupling lens and multimode fiber. The figures on the right show the spot diagram, mesh and amplitude of Ex.

Example 2:
Geometric field tracing in multi-mode fibers with GRIN profile

In this example, we model an optical system with a multimode fiber: the light source is a VCSEL beam with two Gaussian Laguerre modes; the fiber is of graded index profile; the length of the fiber is just 4.4 mm. The result is shown in Figure 2. The rays are curves and go through many focus points. Here we show the spot diagram, which gives the amplitude of Ex on each point: as we said in the beginning, we trace smart rays that contain not only ray information but also field properties. After applying the mesh concept, continuous fields are interpolated as shown in the figure on the bottom right.

/1/ F. Wyrowski, et al.: Approximate solution of Maxwell's equations by geometrical optics," Proc. SPIE, volume 9360, p. 963009 (2015)

/2/ H. Zhong, et al.: Comparison of modelling techniques for multimode fibers and its application to VCSEL source coupling, Proc. DGaO (2015)

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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Conference Contributions

Invited Contributions

A. Perez-Leija, M. Gräfe, R. Heilmann, A. Szameit: On-chip laser written photonic circuits for quantum applications, Progress In Electromagnetics Research Symposium (PIERS), Prague, Czech Republic, 06 – 09 July 2015.

A. Szameit: Topological Anderson Insulators for Light, Workshop on Waves and Imaging in Random Media, Paris, France, 09 – 10 Nov. 2015.

A. Szameit: Quantum optical analogies in coupled waveguide lattices, PICQUE Roma Scientific School: Integrated Quantum Photonics Applications: from Simulation to Sensing, Rome, Italy, 06 – 10 July 2015.

A. Szameit: Photonic Topological Insulators, 1st International Symposium on Green Photonics at Nazarbayev University, Astana, Kazakhstan, 29 – 30 Oct. 2015.

A. Szameit: Laser-written integrated photonic quantum circuits, PICQUE Workshop in Integrated Quantum Photonics, Oxford, UK, 07 – 09 Jan. 2015.

A. Szameit: Integrated laser-written quantum photonics, Complex Nanophotonics Science Camp, Cumberland Lodge, UK, 18 – 21 Aug. 2015.

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Patents

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(DE 102012206472B4)

F. Jansen, C. Jauregui Misas, J. Limpert, F. Stutzki, A. Tünnermann
Structured double-sheath fiber
(US 9065245B2)

C. Jauregui Misas, J. Limpert, D. Nodop, A. Tünnermann
Effiziente Frequenzkonversion
(EP 2656141B1)

N. Kaiser, H. Ludwig, P. Munzert, U. Schulz
Verfahren zur Herstellung einer Entspiegelungsschicht auf einem Substrat und Substrat mit einer Entspiegelungsschicht
(DE 102013103075B4)

J. Limpert, T. Eidam, C. Jauregui Misas, F. Röser, A. Tünnermann
Single-mode propagation in microstructured optical fibers
(US 9170368B2)

J. Limpert, A. Tünnermann, E. Seise, D. Schimpf, T. Eidam
Device for amplifying transporting electromagnetic radiation
(US 8982453B2)

D. Nodop, Dirk, A. Steinmetz, J. Limpert, A. Tünnermann
Lasersystem with nonlinear compression
(US 8948219B2)

Published Patent

A. Klenke, J. Limpert, H.-J. Otto, A. Tünnermann
Optische Anordnung mit Strahlaufteilung
(PCT/EP2015/052204 and DE 10 2014 001 252 A1)

A lot of fun with pupils from Finland and Russia at our Do-It-Yourself booth in the SciFest event hall of Joensuu. Together with the Fraunhofer Institute we presented scientific bricolages and the research location Jena.

INTERNATIONAL YEAR OF LIGHT 2015 JENA CITY OF LIGHT.

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.

Beside this involvement, more and more it is a concern to involve the public in the work we do. We want to attract people for our topics to show them the significance of research for daily life but also reach the interest of young persons to encourage young scientific talents.

In 2015, our Institute has been involved in a variety of events that took place in the context of the so called "International Year of Light", proclaimed by the UNESCO.

2015 "International Year of Light" of the UNESCO (IYL)

Jena lights - Hands-on research in the Year of Light

The particular commitment of the IAP and the Fraunhofer IOF in this special year is not only substantiated in the tradition of Jena, but mainly because light inspires our research for decades: We are using light as a tool, searching for new fields of application through the deliberate manipulation of its properties, or providing a basis for new solutions with light with our continuing groundwork.

This fascination we wanted make touchable with various events. The big interactive show "Lichtphänomene” was the prelude to the IYL 2015. For us it was in particularly important to bring the joy of experimenting with light especially closer to the children. So kids from 4-14 years could get on to optical phenomena in the Goethe Gallery, in the University for Children and at the SciFest in Finland. The highlight of Jena´s Year of Light was the week-long event "Highlights der Physik" by the German Research Society (DFG) in the heart of the city (more information you will find also under www.lichtstadt-jena.de).

Perhaps we have succeeded to inspire one or two young people for optics, so that we can welcome them one day as colleagues.

Photonik Akademie 2015

The “Photonik Akademie” has been organized commonly by the Fraunhofer IOF and the Institute of Applied Physics in the so-called City of Light –Jena. Sixteen selected students of engineering and science has been offered the opportunity to discover closer the optical industry and research at site and to potter at photonics intensively.

The highlight of the academy week was the development and design of own optical microscopes at our Institute. Made of LEGO, 3D printings, LEDs and lenses 16 microscopes originated with 40 times magnification each. In addition, the participants visited the production facilities and development departments of leading companies in the photonics industry in Jena and around.

In addition to cultural and sporting events, the participants met with decision-makers from industry and science. With these "old hands", the students could share and receive tips for a successful career in the photonics industry.

Events in the IYL (right): 1) Knowing and guessing at the Pub Quiz in the evenings, 2) Clear sight with the self-made microscope at the Photonik Akademie, 3) The look into the infinity at the Goethe Gallery, 4) Fascinating lecture about light at the Kinder Universität, 5) 2 big shows with the famous presentors Ralph Caspers and Ranga Yogeshwar took place in the Sparkassenarena, 6 & 10) Having fun with tiny optical experiments for each age in the Goethe Gallery, 7-9 & 12) In Joensuu, Finland, for one week the biggest wooden hall of the country is the place for kids, mainly from Finland and Russia, to discover the fascination of applied science, 11) Andreas Tünnermann explain the effect of bundling light with lenses to set fire in the Show "Lichtphänomene".


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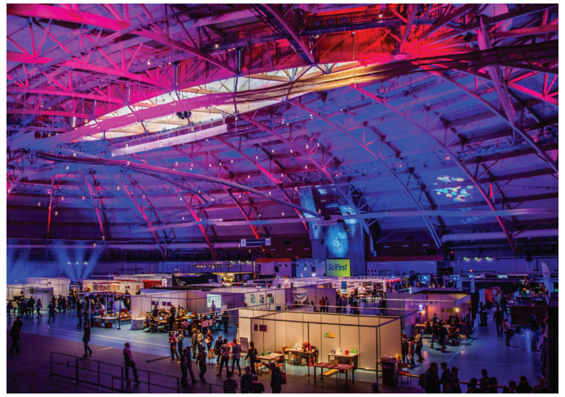
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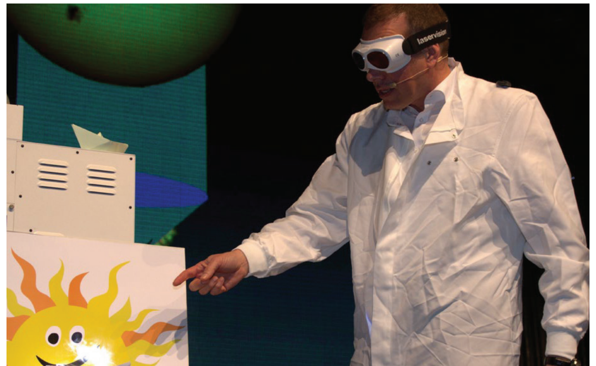


Awards

Andreas Tünnermann
European Research Council Advanced Grant
„Multi-dimensional interferometric amplification of ultrashort laser pulses“

Thomas Pertsch
Appointment to Optical Society Association Fellow, OSA

Sven Döring
Green Photonics Exceptional Price Thuringia (STIFT)
Best Dissertation
„Analysis of the Hole Shape Evolution in Ultrashort Pulse Laser Drilling“

Falk Eilenberger
Award of the Faculty of Physics and Astronomy of the Friedrich Schiller University Jena endowed by Rohde & Schwarz, Best Dissertation
„Spatiotemporal, Nonlinear Optics and the Quest for the Observation of Discrete Light Bullets“

Stefanie Kroker
Award of the Friedrich Schiller University Jena
Best Dissertation
„Siliziumbasierte resonante Wellenleitergitter für rauscharme interferometrische Resonatorkomponenten“

Martin Heilemann
Green Photonics Exceptional Price Thuringia (STIFT)
Best Master’s Thesis
„Siliziumoberflächenmodifikation durch Laserstrukturierung zur Herstellung hochempfindlicher Photodetektoren“

Marco Kienel
1st Place Best Student Presentation
Photonics West, „Fiber Lasers: Technology, Systems, and Applications“, SPIE
„Experimental demonstration of multi-dimensional amplification of ultrashort pulses“

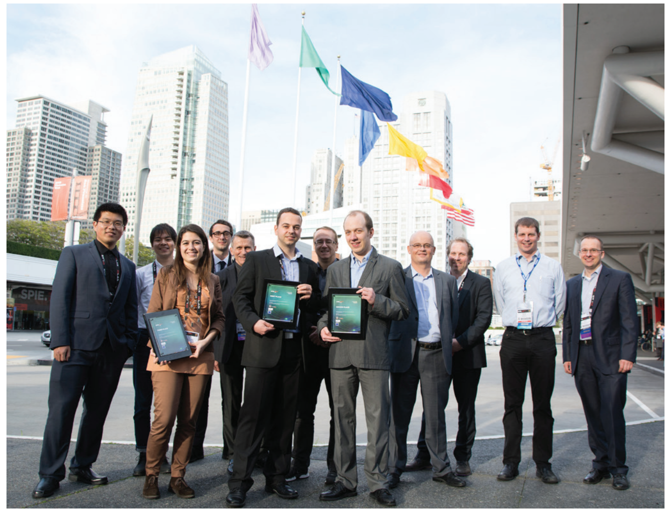
Fabian Stutzki (5th from left) receives his distinction at the Photonics21 Conference.

Felix Zimmermann
Best Student Presentation
Photonics West, "Frontiers in Ultrafast optics: biomedical, scientific and industrial applications XV", SPIE
„Realisierung eines mit Ultrakurzpulsen induzierten Nanogitters in Glas zur Erzeugung einer künstlichen Doppelbrechung“

Christian Gaida
2nd Place Best Student Presentation
Photonics West, „Fiber Lasers: Technology, Systems, and Applications”, SPIE
„Entwicklung von Thulium-dotierten Faserlasern bei 2 µmWellenlänge mit hoher Ausgangsleistung“

Fabian Stutzki
2nd Place Photonics21
Student Innovation Award „Runner-Up“, Photonics 21
„Yb- und Tm-basierte Ultrakurzpuls-Faserlaser, auf Grundlage unseres Faserkonzeptes „Large-Pitch Laser“

The Best Dissertation Award of our Faculty won Falk Eilenberger in 2015.



Felix Zimmermann (6th from left) with international colleagues in San Francisco.

Arno Klenke
3rd Place Best Student Presentation
Photonics West, „Fiber Lasers: Technology, Systems, and Applications“, OSA
„5.7 mJ fiber-CPA system delivering 22 GW of peak power“

Martin Steglich and Ernst-Bernhard Kley
2nd Place AMA Innovationspreis
AMA Verband für Sensorik & Messtechnik e.V.
„Ge-on-Si-Photodiode mit Black-Silicon-Lichtfalle“

Organizing Activities

Herbert Gross

- Referee of several scientific journals
- Member of the program committe SPIE „Optical Systems Design“
- Member in the expert committee of the Baden-Würtemberg foundation of Optical Technologies

E.-Bernhard Kley

- Member of the Program Committee SPIE Photonics West Conference "Advanced Fabrication Technologies for Micro / Nano Optics and Photonics"
- Member of the Program Committee SPIE Photonics West Conference "High Contrast Metastructures"
- Member of the GMM-Technical Committee meeting FA 4.7 Micro-Nano Integration
- Referee for several scientific journals

Jens Limpert

- Member of the Program Committee SPIE Photonics West Conference "LASE 2015"
- Referee for several scientific journals

Stefan Nolte

- Coordinator of the BMBF Association "Ultrashort Pulse Laser for High Precision Machining"
- Conference Chair of the SPIE Photonics West Conference "Frontiers in Ultrafast Optics: Biomedical, Scientific and Industrial Applications (LASE)"
- Member of Scientific Committee “Lasers in Manufacturing (LIM)”
- Member of Scientific Committee CLEO Europe, Materials Processing with Lasers
- Member of jury “Jugend forscht”
- Chair of the Faculty´s Budget Commission and member of the Budget Board of the Senate
- Person responsible for EU-US Atlantis Program, Cooperation in higher Education and Training, „MILMI“ - International Master Degree in Laser, Material Science and Interaction, Univ. Bordeaux, FSU Jena, Univ. Central Florida and Clemson Univ.
- Member Optical Society (OSA)
- Member of SPIE
- Member of Deutsche Physikalische Gesellschaft (DPG)
- Referee for several scientific journals

Thomas Pertsch

- Vice Dean of the Faculty of Physics and Astronomy
- Member of the board directors of the Abbe Center of Photonics
- Spokesman of the Abbe School of Photonics
- Spokesman of the research initiative "Photonic Nanomaterials PhoNa"
- Coordinator of the study program "Master of Science in Photonics"
- Local coordinator of Erasmus Mundus Program – NANOPHI – Nonlinear Nanophotonics
- Fellow of the Optical Society of America (OSA)
- Referee for several international journals
- Member of conference program committees: ETOP - Education and Training in Optics & Photonics, Bordeaux

Jan Rothhardt

- Member of the extended directory board of the Helmholtz Institute Jena
- Program committee for CLEO Europe conference
- Program committee for IEEE photonics conference
- Member Optical Society of America (OSA)
- Referee for Optics Letters, Optics Express, J Phys B, Appl. Phys B, Applied Optics, European Physical Journal D
- Lecturer at the 3rd Joint HGS-HIRe & RS-APS Lecture Week on Atomic and Laser/Plasma Physics

Frank Schrempel

- Coordinaton of the IAP at the Beutenberg Campus e.V
- Member of the Faculty Board
- Referee for several scientific journals

ACTIVITIES

Isabelle Staude

- Organizer of a focus session at the PIERS conference in Prague, Czech Republic (Progress in Electromagnetic Research; focus session title: SC3: Optical Properties of Resonant Dielectric and Plasmonic Nanostructures)
- Session Chair at SPIE Micro & Nano Materials, Devices and Applications (Sydney), PIERS (Prague), CLEO/Europe-EQEC (Munich)
- Reviewer for several scientific journals including Nature Materials., ACS Nano, Advanced Materials and Optica.
- Member of Deutsche Physikalische Gesellschaft (DPG)

Alexander Szameit

- Program committee for CLEO/QELS conference FS5: Nonlinear optics and novel phenomena
- Member Optical Society of America (OSA)
- Member of Deutsche Physikalische Gesellschaft (DPG)
- Referee for several scientific journals, including Nature, Nature Photonics, and Nature Physics

Andreas Tünnermann

- Council member of the Faculty
- Member of program committee „Optische Technologien“, BMBF
- Member of the technical council Fraunhofer Gesellschaft
- Member of the steering committee Fraunhofer Gesellschaft
- Member of the VDI / VDE-GMA Advisory Board FB 8 "Optical Technologies of the Society for Measurement and Automation"
- Board of trustees MPA, Heidelberg
- Board of trustees IOM, Leipzig
- Board of trustees MPQ, Garching
- Chairman „AG Naturwissenschaften“, Wissenschaftliche Gesellschaft Lasertechnik
- Member of acatech „Deutsche Akademie der Technikwissenschaften“
- Member of Honor „International Society of Optics and Photonics SPIE“
- Stakeholder Photonics 21-Plattform
- Spokesman Abbe Center of Photonics, FSU Jena
- Member of the executive Board OptoNet e. V.
- Referee for several scientific journals
- Editor Applied Physics B

Andreas Tünnermann (right) in a conversation with Minister Wolfgang Tiefensee (left). © Tino Zippel, OTZ

Frank Wyrowski

- Visiting Professor at the Chinese Academy of Science, China
- Visiting Professor at the Institute of Technology (HIT), China
- Conference Co-Chair: SPIE Conference on Optical Modelling and Design
- Member of the Technical Program Committee SPIE Conference on Optics and Photonics for Information Processing
- Member of the Technical Program Committee: OSA Conference on Digital Holography and 3D Imaging
- Member of the Technical Program Committee: EOS Topical Meeting on Diffractive Optics
- Referee for several scientific journals
- Study Advisor of the Faculty of Physics and Astronomy
- President of the LightTrans GmbH
- President of Wyrowski Photonics UG

Uwe D. Zeitner

- Referee for several scientific journals

LOCATION

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