ANNUAL REPORT
2010

INSTITUTE OF APPLIED PHYSICS

at Friedrich Schiller University Jena

Impressum

POSTAL ADDRESS
Friedrich-Schiller-Universität Jena
Institut für Angewandte Physik
Max-Wien-Platz 1
07743 Jena

CHAIR
Prof. Dr. Andreas Tünnermann

CONTACT
andreas.tuennermann@uni-jena.de
Phone (+49) 3641 I 9 47800
Fax (+49) 3641 I 9 47802

WEBSITE
www.iap.uni-jena.de

AUTHORS
A. Tünnermann, E.B. Kley, J. Limpert, S. Nolte, T. Pertsch, F. Wyrowski, F. Schrempel, I. Winkler

PHOTOS/GRAFICS
IAP and Friedrich Schiller University Jena [J.-P. Kasper]

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PREFACE

Today, German companies are among the world´s market leaders in many areas of optics/photonics and industry which in Germany has emerged from the economic crises with new strength. The signs are currently indicating growth, resting on a foundation of exemplary cooperation among business, science and politics in Germany and the creative innovation of our industry.

Research at IAP focuses just on the declared megatrends by the Federal Government - production, life sciences and health, communications, lighting, and energy. The institute pays contributions to both; basic research and production-related development with industrial partners.
By the reputation of the results not only the number of research tasks are growing, but also the number of employees. In addition, the IAP campaign for a solid and interdisciplinary training, so that 2010 a new institute extension was built and opened, which accommodates new workplace, laboratories and a seminar room.
Especially to accentuate are the achievements in strengthening the university´s research profile „Optics, Photonics and Photonic Technologies“ by the successful strategy development of the Center of Innovation Competence (ZIK) ultra optics. Thus, starting from 2011, two junior research groups can take new paths for optical micro and nano-systems and technologies, which are based on diamond and carbon materials.
Another highlight was certainly the international PhoNa workshop in March 2010. More than 80 renowned scientists from the fields of nano-optics, plasmonics, nano-chemistry and nanofabrication of more than 10 counties followed the invitation and debated on linear and nonlinear photonic nanomaterials, such as metamaterials, photonic crystals, diffractive structures and their applications.

My thanks go to our partners in business and science for their excellent cooperation and the German federal ministry of education and research, the Thuringian ministries and the German research foundation for their unfailing support.
Particular credit, appreciation and thanks go to my employees for their outstanding work, commitments and ideas. Their work forms the basis for the continual development of the Institute of Applied Physics.

Prof. Dr. Andreas Tünnermann

22nd September 2010, opening ceremony for the IAP extension, left to right: T. Deufel (State secretary TMBWK), K. Bartholmé (FSU Chancellor), A. Tünnermann.

THE INSTITUTE

The Institute of Applied Physics at the Friedrich Schiller University Jena has a longstanding tradition and competence in design, fabrication and application of active and passive optical photonic elements for both, optical and optoelectronical devices. Collaborative projects with companies ensure practical relevance and feasibility.

Research Profile

The Institute practices fundamental and applied research in the fields of micro- and nano-optics, fiber and waveguide optics and ultrafast optics. It develops 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 60 scientists - concern function, design and production of micro-and nano-optical elements. Those are e.g. resonant grating structures, metallic and dielectric polarizers and effective media to reduce reflection of surfaces. Also light propagation and nonlinear light-matter interaction in micro- and nano-structures, optical meta materials and photonic crystals are fundamentally examined. Further research fields are application of femtosecond laser pulses, e.g. for material processing and micro- and nano-structuring, development of new concepts for solid-state lasers such as fiber lasers, fiber-optic pulse shaping and amplification of ultrashort laser pulses.

With these skills and supported by cooperating institutions (strong connection to the Fraunhofer IOF) and companies the IAP covers far parts of the innovation chain - from interdisciplinary basic 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 confirms the establishment of the Competence Center ultra optics (www.ultra-optics.de) as a driver of innovation in the interdisciplinary research field of laser physics and nano-optics, the research initiative on Photonic Nanomaterials PhoNa (www.phona.uni-jena.de) and also the project “KD OptiMi” (www.optimi.uni-jena.de), which combines basic and applied research in a unique way.

But not only excellent research makes the Institute conspicuous, also outstanding laboratory equipment, an excellentstaff and a high commitment in the training of students and scientists belongs to the self understanding of the IAP.

Head of IAP
Andreas Tünnermann
andreas.tuennermann@uni-jena.de
(+49) 3641 | 9 47800

Fiber & Waveguide Lasers
Jens Limpert
jens.limpert@uni-jena.de
(+49) 3641 | 9 47811

Microstructure Technology & Micooptics
Ernst-Bernhard Kley
ernst-bernhard.kley@uni-jena.de
(+49) 3641 | 9 47830

Nano Optics
Thomas Pertsch
thomas.pertsch@uni-jena.de
(+49) 3641 | 9 47840

Optical Engineering
Frank Wyrowski
frank.wyrowski@uni-jena.de
(+49) 3641 | 9 47803

Ultrafast Optics
Stefan Nolte
stefan.nolte@uni-jena.de
(+49) 3641 | 9 47820

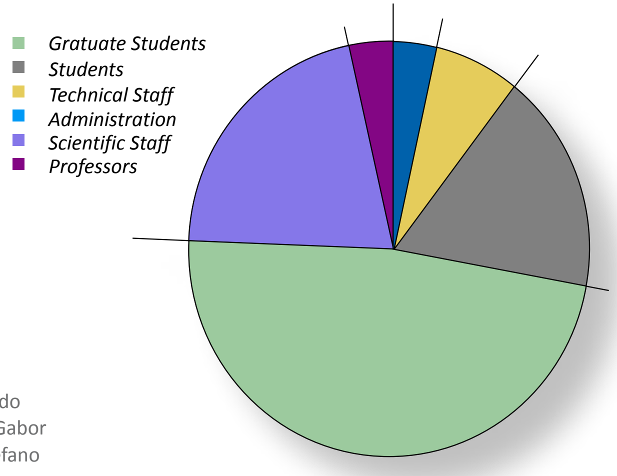
Research Facilities / Resources

Excellency in research requires high quality equipment for experimental questions and analysis. The high standard technical infrastructure will be driven constantly foreward by aquired adaptions for scientific questions.

Clean room
Electron beam and Laser Lithography
Dry etching
Cross beam, scanning electron microscopy
Photolitography
Interference optical surface profilometry
Scanning nearfield optical microscopy
Nonlinear optical waveguide characterization
UV-VIS spectrometry
FTIR spectrometry
Rigorous optical simulation
Ultrashort pulse laser technology
Laser micro-structuring technology
Field tracing technics

Staff

budgetarily financed:	4	university professors
	2,42	scientific staff
	10	technical /admin. staff
externally funded:	0,96	junior professor
	66,45	scientific staff
	5,46	technical /admin. staff



ABBE Sylvia
ACKERMANN Roland
BAUMGARTL Martin
BECKER Ria
BLUMRÖDER Ulrike
BRAIG Christoph
BRÜCKNER Frank
BÜHREN Stephanie
CHIPOULINE Arkadi
DAMM Michael
DIETRICH Kay
DIZIAN Séverine
DÖRING Sven
DREISOW Felix
EIDAM Tino
EILENBERGER Falk
ETRICH Christoph
FAHR Stephan
FREESE Wiebke
FUCHS Christin
FUCHS Frank
FUCHS Jörg
FUCHS Ulrike
FÜCHSEL Kevin
GEIß Reinhard
GOTTSCHALL Thomas
GRÄF Waltraud
HÄDRICH Steffen
HARTUNG Holger
HASAN Shakeeb Bin
HEINRICH Matthias
HELGERT Christian
HÖFFLING Benjamin
HOLZ Manuela
ILIEW Rumen
JANSEN Floian
JANUNTS Norik
JAUREGUI MISAS Cesar
JOCHER Christoph
KAISER Thomas
KAMMEL Robert
KÄSEBIER Thomas
KAZANTSEV Dmitri
KEIL Robert
KEPPLER Sebastian
KIEFER Thomas
KLEIN Angela
KLEY Ernst-Bernhard
KREBS Manuel
KRETSCHMER
KROKER Stefanie
KROLL Matthias
KUHN
LANG Claudia
LEHR Dennis
LIMPERT Jens
MARTIN Bodo
MATTHÄUS Gabor
MINARDI Stefano
NODOP Dirk
NOLTE Stefan
OTTO Christiane
OTTO Hans-Jürgen
PABST Oliver
PERTSCH Thomas
PETSCHULAT Jörg
PFEIFER Beate
PSHENAY-SEVERIN Ekaterina
RATZSCH Stephan
REINHOLD Jörg
RICHTER Daniel
RICHTER Sören
ROCKSTROH Sabine
ROCKSTROH Werner
ROTHHARDT Jan
SAUERBREY Philip
SCHAMBACH Doreen
SCHELLE Detlef
SCHIMPF Damian
SCHINKÖTH Marc
SCHLÜTTER Florian
SCHMIDT Carsten
SCHMIDT Holger
SCHMIDT Oliver
SCHNEPP Matthias
SCHREMPEL Frank
SCHULZE Marcel
SEISE Enrico
SETZPFANDT Frank
STEINBERG Carola
STEINER Stefan
STEINERT Michael
STEINMETZ Alexander
STOCK Katrin
STUTZKI Fabian
THOMAS Jens
TÜNNERMANN Andreas
VOIGTLÄNDER Christian
WACHS Rico
WALTHER Benny
WEBER Thomas
WEBER Christin
WINKLER Ira
WYROWSKI Frank
ZAPFE Annelie

Guests

Guests are the flagship of the reputation of an institution. They indicate the national and international visibility of research results and enrich the structures of the IAP with new thinking and perspectives - not only in research, but also open eyes to other cultures and strengthen the network by personal relations.

ASSANTO Gaetano	University Roma Tre
BACHE Morten	Department of Photonics Engineering, DTU, Denmark
CHANG-HASNAIN Connie J.	University of California, Berkeley
DEYCH Lev	Queens College of CUNY, NY, USA
GARANOVICH Ivan	Australian National University, Canberra
GRANGE Rachel	EPFL, Lausanne
KABAKOVA Irina	CUDOS, University of Sydney, Australia
MINOVICH Aliaksandr	Australian National University, Canberra
NERKARARYAN Khachatur	Yerevan State University, Armenia
OH Kyunghwan	Yonsei University, Seoul, South Korea
PLUM Eric	ORC, University of Southampton
POWELL David	Australian National University, Canberra
SAKHNENKO Nataliya	Kharkov National University, Ukraine
SCHIEK Roland	University of Applied Science, Regensburg
SHCHERBAKOV Maxim	Moscow State University, Russia
SOLNTSEV Alexander	Australian National University, Canberra
TEMNOV Vasily	Massachusetts Institute of Technology

Research Stay

SZAMEIT Alexander	Physics Department, Technion, Haifa, Israel
VOIGTLÄNDER Christian	CUDOS, Macquarie University, Australia

Cooperations

The IAP is cooperating with all institutions of the Physical-Astronomical Faculty at Friedrich Schiller University in context of research projects. Strategic collaborations that go far beyond the project work are, in particular with the Institute of Solid State Theory and Optics, and the Institute of Optics and Quantum Electronics. Cooperative relations within the FSU exist in particular to individual departments within the Chemical - Geoscientific Faculty.

Moreover, there are more than 100 external partners in science and industry. Of special importance are regional co-operations with the Fraunhofer Institute for Applied Optics and Precision Engineering (IOF) and the Institute of Photonic Technology Jena (IPHT).

Representives of the Quebéc Gouvernment during a visitation of the IAP in October 2010

Here, for the development of the IAP cooperation with the Fraunhofer Institute is of fundamental importance. Objective is to develop an outstanding international center of excellence for micro- and nano-structured optics as well as optical systems on basis of a close intermeshing of the two institutes.

Within the Collaborative Research Center (SFB) „Gravitational Wave Astronomy“ the IAP works together with groups from Hannover, Tübingen, Garching, Potsdam and Jena on issues of reflective optical components for interferometer-based gravitational wave detectors.

Beyond that, together with the Max Planck Institute for Quantum Optics in Garching there was also a close cooperation to high-power fiber lasers for resonator-internal superelevation and generation of high harmonics (HHG). Aim is to generate short-wave length radiation with Megahertz repetition rates. For this purpose, at the IAP a fiber-CPA system with 50 W output power and 30 fs pulse duration has been realized. Now the system is situated in Garching and will be used for joint experiments at exaggeration resonators located in a vacuum. There have already been achieved impressive results, including the demonstration of 70 kW intracavity power with ultra-short pulses or the extremely accurate measurement of the dispersion inside the resonator using a novel interferometric method.

The competence in Jena for the production of high-energy few-cycle pulses with high repetition rates is linked with the possibility of the application of these pulses at the free electron laser (FEL) in Hamburg (FLASH) in cooperation with the German Electron Synchrotron (DESY). The aim of that cooperation is to develop laser systems for seeding of the FEL. Thereby infrared few-cycle pulses are to be amplified with repetition rates up to 1 MHz to high pulse energies into the millijoule range. These pulses can produce coherent XUV radiation by extreme nonlinear effects, which is to serve the FEL as seed.

Apart from numerous national collaborations, in 2010 important international cooperation were established and/or deepened. These are cooperations with the College of Optics and Photonics, CREOL & FPCE, Florida, USA, the ICFO-Institute of Photonic Sciences in Barcelona, Spain, and the Australian Research Council Center of Excellence for Ultrahigh-Bandwidth Devices for Optical Systems (CUDOS) and the Nonlinear Physics Centre, Australian National University in Canberra, Australia. Besides staff exchanges, joint work on current issues in light propagation in discrete systems have been conducted.

By an exchange program, promoted by the DAAD, more undergraduate and graduate students as well as postdoctoral researchers from ICFO and IAP could participate at research themes of the other institution than in recent years. This lively exchange has contributed to a broadening of common work fields. Other important partners in education are the Imperial College London, Warsaw University, Delft University and the Institut d‘Optique (Orsay-Palaiseau, Paris) in the international Erasmus Mundus Masters Program OpSciTech; also the University of Bordeaux, the College of Optics and Photonics, CREOL & FPCE, Florida and Clemson University, South Carolina in the international master degree program “MILMI: International Master in Lasers, Materials Science and Interactions“ in the context of the EU-US Atlantis program.

List of Cooperations with common Research Topics

Institute of Optics, Information and Photonics,
Friedrich-Alexander-University
Erlangen-Nürnberg, Erlangen (U. Peschel)

Klinik für Augenheilkunde,
Helios-Klinikum Erfurt (M. Blum, K. Kunert)

Institut für Festkörpertheorie und –optik, Jena
(F. Lederer)

Fraunhofer Institut für Angewandte Optik und
Feinmechanik, Jena

Institut für Versuchstierkunde und Tierschutz,
Jena (H. Schubert)

Dipartimento di Fisica and Istituto di Fotonica e
Nanotecnologie del CNR, Politecnico di Milano,
Milano, Italy (S. Longhi)

CNR-INFM Regional Laboratory "LIT3",
Bari, Italy (A. Ancona)

College of Optics and Photonics, CREOL
& FPCE, University of Central Florida,
Orlando,
Florida, USA (M. Richardson, D.
Christodoulides, B. Salah, A. Abouraddy))

ICFO-Institute of Photonic Sciences,
Castelldefels (Barcelona), Spain (L. Torner,
Y. Kartashov)

Nonlinear Physics Center, Research School
of Physics and Engineering,
Australian National University,
Canberra, Australia
(Y. Kivshar, W. Krolikowski)

University BORDEAUX 1,
France (L. Sarger, B. Bouget))

CLEMSON University,
Material science division,
Clemson, SC, USA (K. Richardson)

Physics Department,
Technion, Haifa, Israel
(A. Szameit, M. Segev)

Courant Institute,
New York University,
New York, USA (M. Rechtsman)

Departmento de Física, Facultad de Ciencias,
Universidad de Chile,
Santiago, Chile (M. Molina)

Centre for Quantum Photonics,
University of Bristol,
Bristol, UK (J. O'Brien)

INAOE, Coordinacion de Optica,
Puebla, Mexico (H. Moya Cessa)

MQ Photonics Research Centre and Centre for
Ultrahigh bandwidth Devices for Optical Systems
(CUDOS), Department of Physics and Astronomy,
Macquarie University (Nemanja Jovanovic,
Graham Marshall, Mike Steel, Michael Withford)

National Central University,
Taiwan (NCU), (C.-C. Chen, Y.-H. Chen)

Queens College,
New York, USA (L. Deych)

Centre of Excellence for Ultrahigh-
bandwidth Devices for Optical
Systems (CUDOS),
University of Sydney,
Australia (CUDOS), (B. Eggleton)

University of Eastern Finland
(J. Turunen)

Stundents in internships at the IAP

TEACHING

An essential part of the IAP concept is the training of young scientists at the interface of physics, chemistry and material science.
Additively to this purpose, interdisciplinary international master and graduation programs, like MILMI and OMiTec, have been integrated into the Abbe School of Photonics.

Lectures

Courses (L- Lectures, S- Seminars, T- Training)

L/S: Atom- und Molekülphysik
Atom- und Molekülphysik für Lehramt
Computational Physics I
Laser Physics
Optical Modelling and Design I

L: Miniaturisierte Optik (FH Jena)
S: Fundamentals of modern optics
T: Physikalisches Grundpraktikum
Labwork Optics

Elective Courses

L/S: Grundlagen der Laserphysik
Optical Modelling and Design II
Optical Modelling and Design III
Optics in Nanostructures
Ultrafast optics

L/S: Astrophotonics
Computiational Photonics
Introduction to Nanooptics
Theoretical Nanooptics
Thin Film Optics

Tutorials

Department: Nano optics
Ultrafast Optics
Microstructure Technologies - Microoptics
Faserlaser
Field Tracing

Institute: Angewandte Physik
Super tutorials: Abbe School of Photonics
(together with IFTO, FhG-IOF, IOQ, IAO)
Optik
Physikalisches Kolloquium

Diploma Theses

Ria Becker
Maßgeschneiderte Faser-Bragg-Gitter durch Wellenfrontformung ultrakurzer Pulse

Astrid Bingel
Leitfähige und transparente aluminiumdotierte ZnO-Schichten

Stefan Demmler
Skalierung Faserlaser-gepumpter parametrischer Verstärker zu Pulsen mit wenigen optischen Zyklen

Stefan Hanf
Untersuchung der Verstärkungscharakteristik von Ytterbium-dotierten Ultrakurzpulsfaserlasern

Vinzenz Hilbert
Ultrakurzpulsinduzierte QPM-Strukturen in Lithiumniobat

Jan Kinast
Untersuchungen zum thermischen Verhalten von amorphen Chemisch Nickel-Schichten für hochpräzise Metalloptiken

Arno Klenke
Kohärentes Kombinieren ultrakurzer Pulse

Manuel Krebs
Erzeugung höherer Harmonischer mittels Kurzpuls- Faserlasersystemen

Dennis Lehr
Effektive Medien zur Entspiegelung im ultravioletten Spektralbereich - Simulation und interferenzlithografische Herstellung von lateralen Antireflex-Strukturen

Matthes Liebsch
Untersuchung zu Wechselwirkungen optischer Mikroresonatoren mit externen Störungen

Torsten Mai
Optisch-geometrische Charakterisierung von ex-vivo Tieraugen zur Behandlung der Presbyopie mittels ultrakurzen Laserpulsen

Julia Meyer
Entwicklung eines hochauflösenden Multiapertur-Abbildungssystems

Hans-Jürgen Otto
Modenanalyse optischer Fasern durch räumlich und spektral aufgelöste Interferometrie

Stephan Ratzsch
Modellierung der elektronenstrahllithographischen Strukturerzeugung in dem chemisch verstärkten Resist FEP 171

Robert Riedel
Realization of Channel Waveguides in Zinc-substituted Lithium Niobate Films by Means of Heavy Ion Irradiation

Carolin Rothhardt
Experimentelle Untersuchungen zur Nanotopografie und Benetzung hydrophober Schichten auf Glas

Marc Schinköth
Herstellung von optischen Nanostrukturen mit CMP-Technologie

David Schmitz
Untersuchung von Survece-Defekten an optischen Oberflächen

Markus Schoeler
Optische und funktionale Eigenschaften nanoporöser Sol-Gel-Schichten

Lorenz Stürzebecher
Beugungslithographie zur Herstellung von hochaufgelösten periodischen Mikrostrukturen in einem Mask Aligner

Sebastian Werner
Entspiegelung von optischen Oberflächen und Beugungsgittern mit eindimensionalen Gitterstrukturen

Ingmar Zink
Untersuchungen zur Bildung und messtechnischen Charakterisierung mittels LAVA-Verfahren hergestellter Nanopartikel

Master Theses

Andreas Martin
Parametervariation und thermische Untersuchung gütegeschalteter Kurzpulslaser (Microchiplaser)

Bachelor Theses

Tobias Tieß
Longitudinale Charakterisierung von Faser-Bragg-Gittern

Steffen Weimann
Optimierung eines Linsendehnapparates zur Charakterisierung von in-vitro-Linsen

Examination Theses

Michael Vogel
Selektives Ätzen von Glas nach Bestrahlung mit ultrakurzen Pulsen

Doctoral Theses

Claudia Brückner
THz-Optiken für Bildgebungssysteme

Felix Dreisow
Waveguide lattices as a model system for solid state phenomena

Stephan Gräf
Untersuchungen zum Laserstrahlschweißen mit dynamischer Polarisation

Holger Hartung
Mikro- und Nanostrukturierung von Lithiumniobat

Jan Rothardt
High power ultra-short pulse lasers based on fiber driven OPCPA

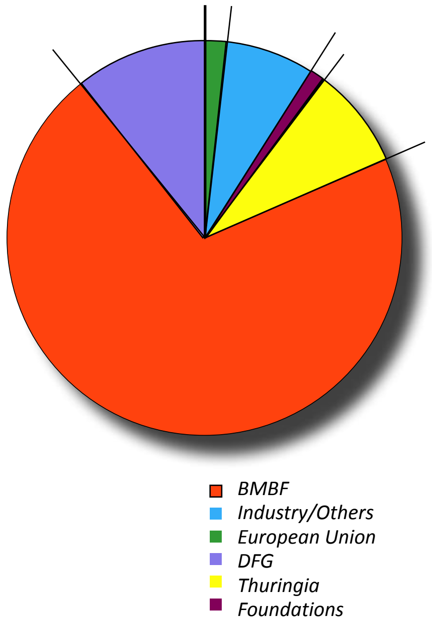
Damian Schimpf
Pulse-shaping strategies in short-pulse fiber amplifiers

Oliver Schmidt
Leistungsskalierung kurzgepulster Faserlasersysteme

Project Meeting NanoSIS

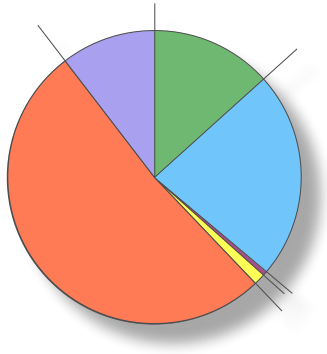
PROJECTS

„Applied Physics“ is implemented in numerous projects that contain basic research as well as application specifics. 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 products.



Statistics

External Funds (Revenues 2010):	
DFG (German Rasearch Society)	781.747 €
BMBF (Federal Ministry of Education and Research)	5.208.696 €
Thuringian Ministries	626.812 €
Foundations	71.500 €
Industry/Others	542.573 €
Europian Union	125.224 €
Total:	**7.356.552 €**



Comparison 2009

DFG- German Research Society

„Design und Herstellung nanostrukturierter opt. Schichtsysteme zur Optimierung des Wirkungsgrades photovoltaischer Elemente (NanoSun)“
Duration: 04/06 - 03/13

Leibniz Preis: „Nanophotonik - Künstliche Medien für die Optik, Design-Herstellung-Applikation“
Duration: 11/05 - 10/12

„Untersuchung der Kopplung dielektrischer und plasmonischer Resonanzen an optischen Metamaterialien in Wellenleitergeometrien“
Duration: 04/09 - 03/12

„Aktive Mikrooptik“
Duration: 10/08 - 09/11

„Neue Strategien der Mess- und Prüftechnik für die Produktion von Mikrosystemen und Nanostrukturen, Phase III“
Duration: 12/08 - 11/10

„Monolithische Integration photonischer Bauelemente auf der Basis der Flüssigkeitsepitaxie“
Duration: 11/07 - 04/10

„Optisch erzeugte Sub-100-nm-Strukturen für biomed.u. techn. Zwecke“
Duration: 02/09 - 01/12

„Optisch erzeugte Sub-100-nm-Strukturen für biomed. u. techn. Zwecke - Ultrakurzpuls-induzierte Erzeugung periodescher Nanostrukturen im Volumen transparenter Festkörper“
Duration: 01/09 - 12/11

„Forschergruppe Zentralprojekt: Nonlinear spatio-temporal dynamics in dissipative and discrete optical systems“
Duration: 10/07 - 09/10

„Forschergruppe Teilprojekt B: Nonlinear spatio-temporal dynamics in dissipative and discrete optical systems“
Duration: 07/07 – 06/10

„Forschergruppe Teilprojekt C: Dicrete spatio-temporal dynamics in nonlinear microstructured resonators“
Duration: 08/07 - 07/10

„Forschergruppe Teilprojekt D: Dissipative temporal structures in mode-locked fibre lasers“
Duration: 07/07 - 12/10

„Forschergruppe Teilprojekt F: Discrete spatio-temporal dynamics in waveguide arrays with quadratic nonlinearity“
Duration: 12/07 - 03/11

„Ultrafast Nanooptics - Nonlinear optics in metallic nanowaveguides in Lithium Niobate
Duration: 04/10 - 03/13

„Jena School for Microbioal Communication (JSMC); TP 14“
Duration: 03/08 – 02/11

European Union

„Powerful and Efficient EUV Coherent Light Sources (PECS)“
Duration: 11/09 - 10/13

„EU-US Atlantis Programm, Cooperation in higher Education and Training: International Master degree in Laser, Material science and Interaction (MILMI)“

„Erasmus Mundus Programm: Optics in Science and Technology (OpSciTech)“

„Marie-Curie-Projekt (IRSES): e-FLAG“

„Large Area Fabric. of 3D Negative Index Materials by Nanoimprint Lithography (NIM-NIL)“
Duration: 12/09 - 01/13

BMBF-Projects

Federal Ministry of Educaion and Research

„Faserlaser höchster Brillanz (FaBri) - Teilvorhaben: Grundlegende Untersuchungen zur Kontrolle nichtlinearer Effekte in Hochleistungs-Faserlasern“
Duration: 03/07 - 08/10

„Faseroptisch integrierte Nanosekundenstrahlquelle hoher Leistung für die Mikromaterialbearbeitung (ALFAMOS) - Teilvorhaben: Nanosekunden-Faserlasersysteme mit variabler Pulsform“ Verbundprojekt
Duration: 03/07 - 02/10

„Neue Bonding- u. Integrationsverfahren für einen Pikosekunden-Mikrochiplaser mit integriertem Faserverstärker und Hochleistungsfrequenzkonversion (BIVMIFF) - Teilvorhaben: Faserbasierte Verstärkung von Pikosekunden Mikrochip-Lasern“
Duration: 05/08 - 04/11

„Nanostrukturierte Siliziumgrenzflächen“ - Black Silicon - NanoSIS (Programm ForMaT)“
Duration: 10/09 - 03/10

„Grundlagen der CARS-Mikroskopie in der Neurochirurgie (MEDICARS) - Teilvorhaben: Grundlagen faser-integrierter Lasersysteme für die CARS-Mikroskopie“
Duration: 10/09 - 09/12

Schonendes Operieren mit innovativer Technik (SOMIT) - Kopfchirurgisches Zentrum (CoHS), Teilvorhaben „Minimalinvasive Femtosekunden-Laserchirurgie an der Augenlinse chirurgisches Zentrum“
Duration: 09/05 - 08/11

„ZIK ultra optics Nanooptik– Projekt: Design und Realisierung hochfunktioneller optischer Metamaterialien durch Nanostrukturierung sowie deren Anwendung in komplexen photonischen Systemen“
Duration: 04/05 - 03/10

„Novel Optics-09: Photonmanagement durch gezielte Interfacemodifizierung in Optoelektronischen Bauelementen (PHIOBE) - Teilvorhaben: Kontrolle optischer und elektronischer Eigenschaften nanostrukturierter Interfaces (NANOFACES)“
Duration: 05/08 - 12/11

„HyPoSolar-Hybridsolarzelle aus halbleitenden Polymeren und Si-Nanowirestrukturen - Teilvorhaben: Simulation und Optimerung der Lighttrapping-Eigenschaften von Hybridsolarzellen mit Si-Nanowirestrukturen“
Duration: 08/08 - 07/11 €

„Verbundprojekt METAMAT: Photonische Metamaterialien - Teilvorhaben: Gestapelte Metamaterialien“
Duration: 10/08 - 09/11

„Verbundprojekt onCOOPtics - Teilvorhaben: Physikalisch-technische Grundlagen von Hochintensitätslasern für die Radioonkologie und Aufbau eines Charakterisierungs- und Herstellungslabors für Hochleistungskomponenten“
Duration: 04/07 - 03/12

„Verbundprojekt Effektive Medien für die Mikrooptik (EFFET) - Teilvorhaben: Elektroneninstallithographie und anisotrope Ätztechniken zur Hstg. effektiver opt. Medien“
Duration: 04/08 - 03/11

„Verbundprojekt Verbesserte Herstellungstechniken für tagestaugliche Bildschirmhologramme (VHTB) - Teilvorhaben: Hstg-technologien für Masterhologramme“
Duration: 07/08 - 06/12

„Verbundprojekt Kompetenzdreieck Optische Mikrosysteme - KD OptiMi; TV: Adaptive und vielkanalige optische Mikrosysteme“
Duration: 07/08 - 03/11

„Photonische Nanomaterialien“
Duration: 12/09 - 11/14

„Ultra Optics 2015 - Strategische Investitionen für das Zentrum für Innovtionskompetenz“
Duration: 07/08 - 03/11

„ASP - International Promovieren in Deutschland“
Duration: 07/08 - 03/11

Thuringian Projects

Thuringian Ministry of Education, Economics and Culture (TMBWK) &
Thuringian Ministry of Economics, Labour and Technology (TMWAT)

„Innovative nanostrukturierte Materialien für die Optik – Basisinnovation für den Cluster CoOPTICS (MeMa)“
Duration: 01/09 - 12/13

„Optische Technolgien für die nächste Generation Silizium Dünnschicht Photovoltaik SolLux - Teilthema: Untersuchungen zum Photonmanagement in Dünnschichtsolarzellen“
Duration: 02/09 - 02/12

„Modenfeldstabilisierung in Hochleistungsfaserlaser und –verstärkersystemen (MOFA)“
Duration: 07/09 - 05/12

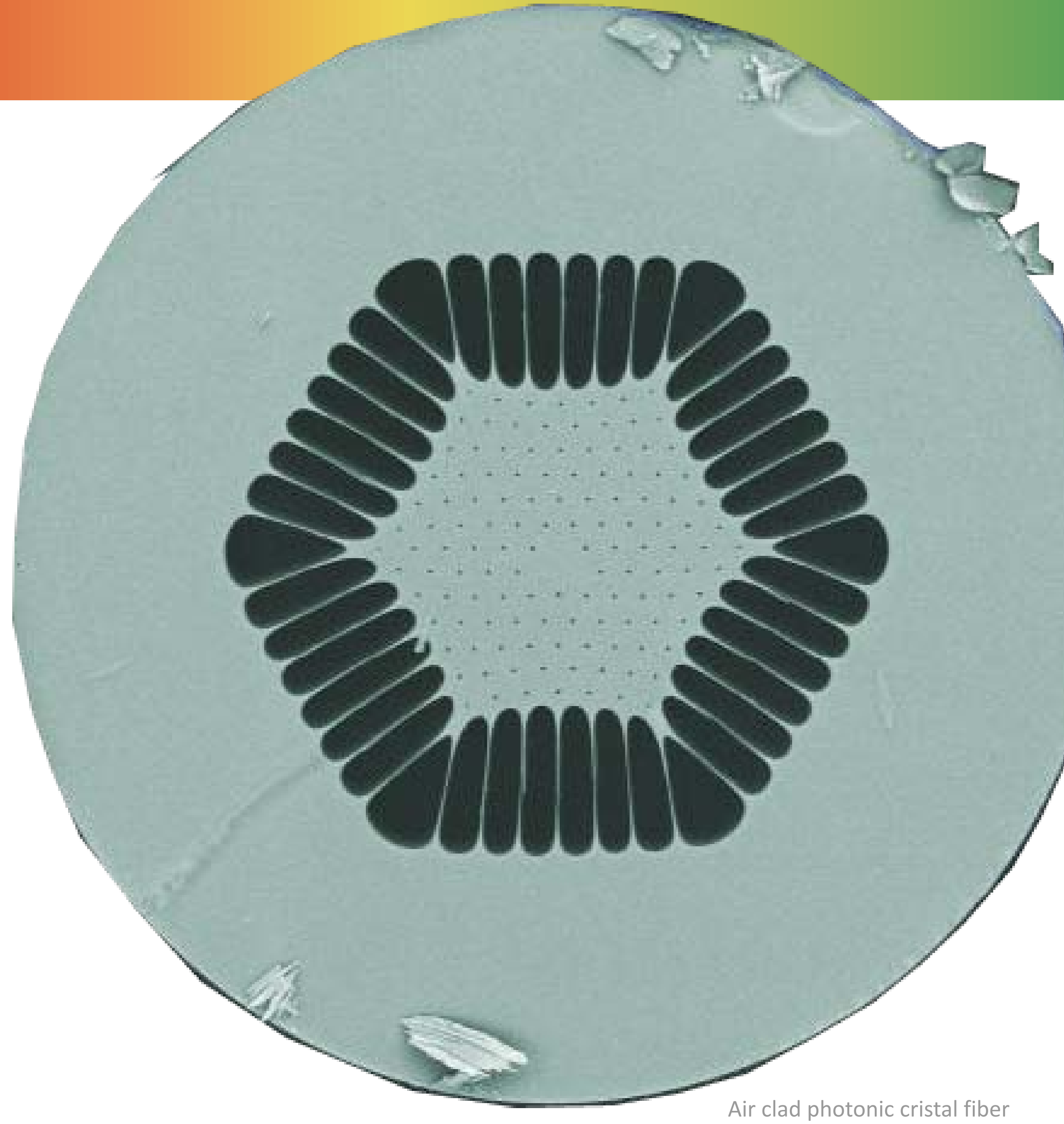
„Entwicklung eines Verfahrens zum Laserbohren von Mikrofunktionsbohrungen für die Aktiventlüftung und Ausformunterstützung in komplexen Spritzgießwerkzeugen für die Verarbeitung von Kunststoffen, Keramiken und Verbundstoffen“ Teilprojekt: Ereugung von Entlüftungsbohrungen in Spritzgußwerkzeugen mit ultrakurzen Laserpulsen
Duration: 12/08 - 03/11

„Koordination der Initiative PhoNa - Photonische NanoMaterialien“ im Bundesprogramm „Spitzenforschung und Innovation in den Neuen Ländern“
Duration: 10/09 - 12/13

„Ultra Optics 2015, Infrastrukturelles Investitionsprogramm“ - Anschaffung Helium-Ionen Mikroskop (HIM) und Laserbearbeitungsstation zur 3D Volumenstrukturierung
Duration: 06/10 - 12/12

Foundations

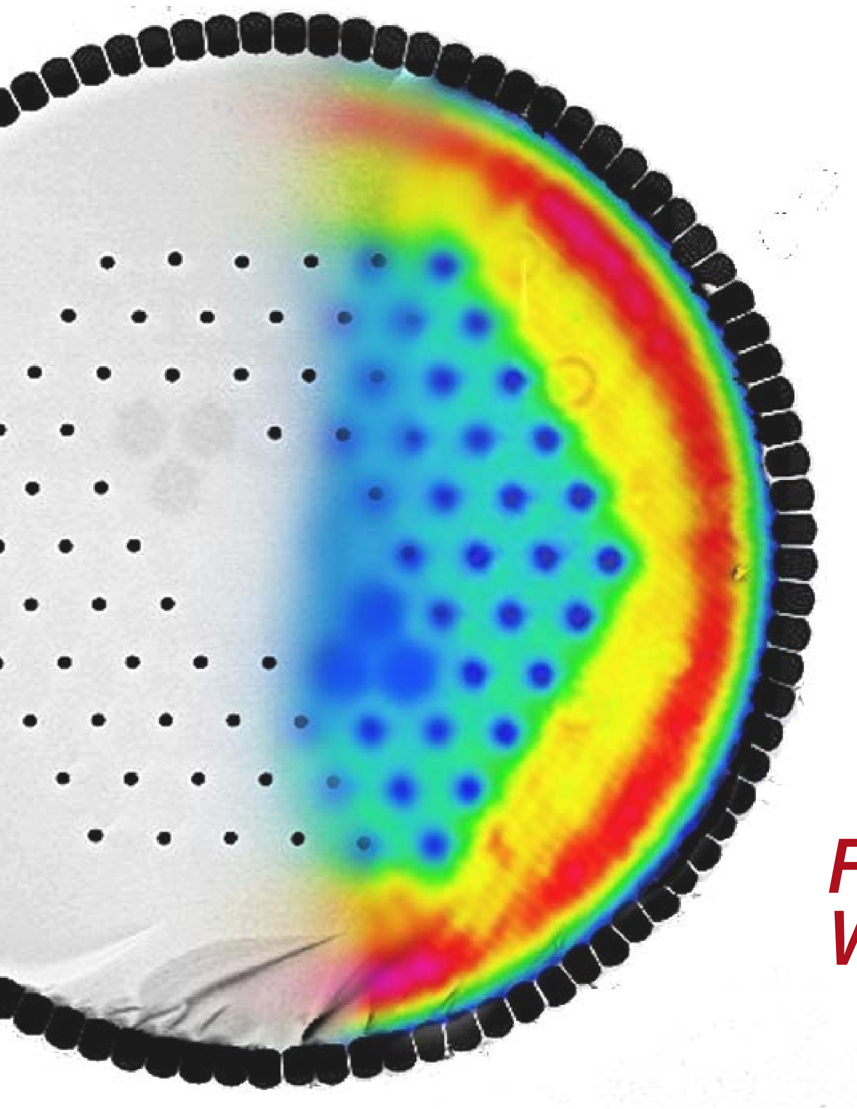
Carl-Zeiss-Stipendien
HESCHO
Stipendien der Merkle-Stiftung



Air clad photonic cristal fiber

RESEARCH - Achievements & Results

Evidence of intensive engagement with research topics of the Institute is the spezialization of the seperate research groups on key problems. In turn, these groups contribute 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*

* *Prof. Dr. Jens Limpert*
(+49) 3641 | 9 47811 phone
jens.limpert@uni-jena.de

This research group is working on the development of new concepts for solid-state lasers such as fiber lasers, pulse shaping and fiber-optical intensification of ultrashort laser pulses.

Scientific focus lies on:

- Combination of pulsed laser radiation
- Fiber optical enhancement of ultra-short laser pulses
- Fiber laser - pumped parametric short-pulse amplification
- Conception of novel large core diameter fibers
- Suppression of non-linear effects in high-performance fiber lasers
- Pulse shaping in fiber amplifiers
- pico-second µchip-lasers
- Generation of Harmonics with fiber lasers.

High repetition Rate few-cycle Pulse Generation for high-field Physics

High intensity ultrashort laser pulses enable, among others, the generation of coherent radiation in the extreme ultraviolet region of the spectrum. Due to this remarkable properties of the radiation it has the potential to be used for time-resovled, three dimensional investigation of small structures, e.g. cells [1]. However, their applicability is limited, since the driving laser systems that are typically used are limited in repetition rate.

Combining the fiber laser concept with the concept of optical parametric amplification ultrashort, high intensity pulses can be obtained at unprecedented repetition rates [2].

For this purpose, a Titanium:Sapphire oscillator can used by splitting its output in two parts (fig. 1). One part can be shifted to the gain wavelength of the fiber amplifiers by exploiting a nonlinear interaction in a photonic crystal fiber. The amplifiers increase the pulse energy to 1 mJ at a pulse duration of 700 fs. Frequency doubling is used to generate the pump pulses for the optical parametric amplifier. The second part of the oscillator traverses a pulse shaper and pulse stretcher to match the pump pulse duration of about 700 fs. A two stage optical parametric amplifier increases the pulse energy to 135 µJ. Precise compression close to the physical limit is made possible by using the pulse shaper. In consequence, sub-5 fs pulses with 12 GW peak power are generated at 30 kHz repetition rate (Figure 1).

[1] K.S. Raines, S. Salha, R.L. Sandberg, H. Jiang, J.A. Rodriguez, B.P. Fahimian, H.C. Kapteyn, J. Du, J. Miao: "Three-dimensional structure determination from a single view" Nature 463, 214-217 (2010).

[2] J. Rothhardt, S. Hädrich, E. Seise, M. Krebs, F. Tavella, A. Willner, S. Düsterer, H. Schlarb, J. Feldhaus, J. Limpert, J. Rossbach, A. Tünnermann: "High average power few-cycle laser pulses delivered by fiber pumped OPCPA system" Opt. Express 18, 12719-12726 (2010).

Authors:
Steffen Hädrich
Jan Rothardt
Stefan Demmler
Christoph Jocher
Jens Limpert

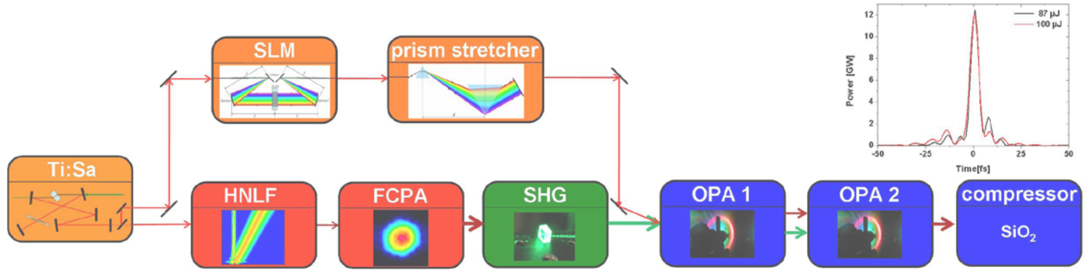


Figure 1:
Schematic experimental setup of the few-cycle optical parametric chirped pulse amplification systems. The inset shows the compressed pulses.

Suppression of stimulated Raman scattering in DC Fiber Amplifieres

Master oscillator power amplifier (MOPA) systems based on double clad (DC) fiber amplifiers are the current source of choice for diffraction limited laser systems with high average power. One of the main limits for further power scaling is stimulated Raman scattering (SRS). The possibility of lining up LPGs along a double clad fiber amplifier to couple the Stokes wavelength out of the fiber core and into the cladding is a new and very promising approach. Since an extinction of more than 20dB per LPG for the Stokes wavelength can be easily achieved, employing e.g. one LPG per meter in a fiber amplifier would result in an effective attenuation of the Stokes wavelength of 20 dB/m, which is much higher than that provided by any other spectrally selective fiber designs proposed up to now. We have developed a setup to write LPGs in undoped double clad fibers with low insertion losses at the signal wavelength by using a CO_2 laser. These LPGs were spliced into a double clad fiber pulse amplifier (Figure 2).

Figure 3 shows the output spectra that were recorded without and with the LPGs as shown in Figure 2. The spectra reveal clearly that the amount of power converted to the Raman wavelength could be reduced substantially at the same output power. We were able to effectively double the amount of extractable, Raman free output power with this approach [3]. A simulation solving the coupled rate equations for the amplifier setups shows excellent agreement with the experiment. The low signal insertion losses of the LPGs lead to a negligible decrease of amplifier efficiency.

[3] D. Nodop, C. Jauregui, F. Jansen, J. Limpert, A. Tünnermann: "Suppression of stimulated Raman scattering employing long period gratings in double-clad fiber amplifiers" Opt. Lett. , Vol. 35, No. 17, 2982-2984 (2010).

Authors:
Dirk Nodop
Florian Jansen
Cesar Jauregui
Jens Limpert

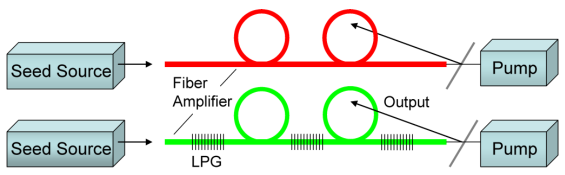


Figure 2:
Test setup for Raman suppression with long period gratings (LPGs)

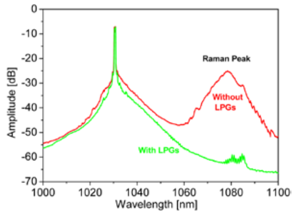
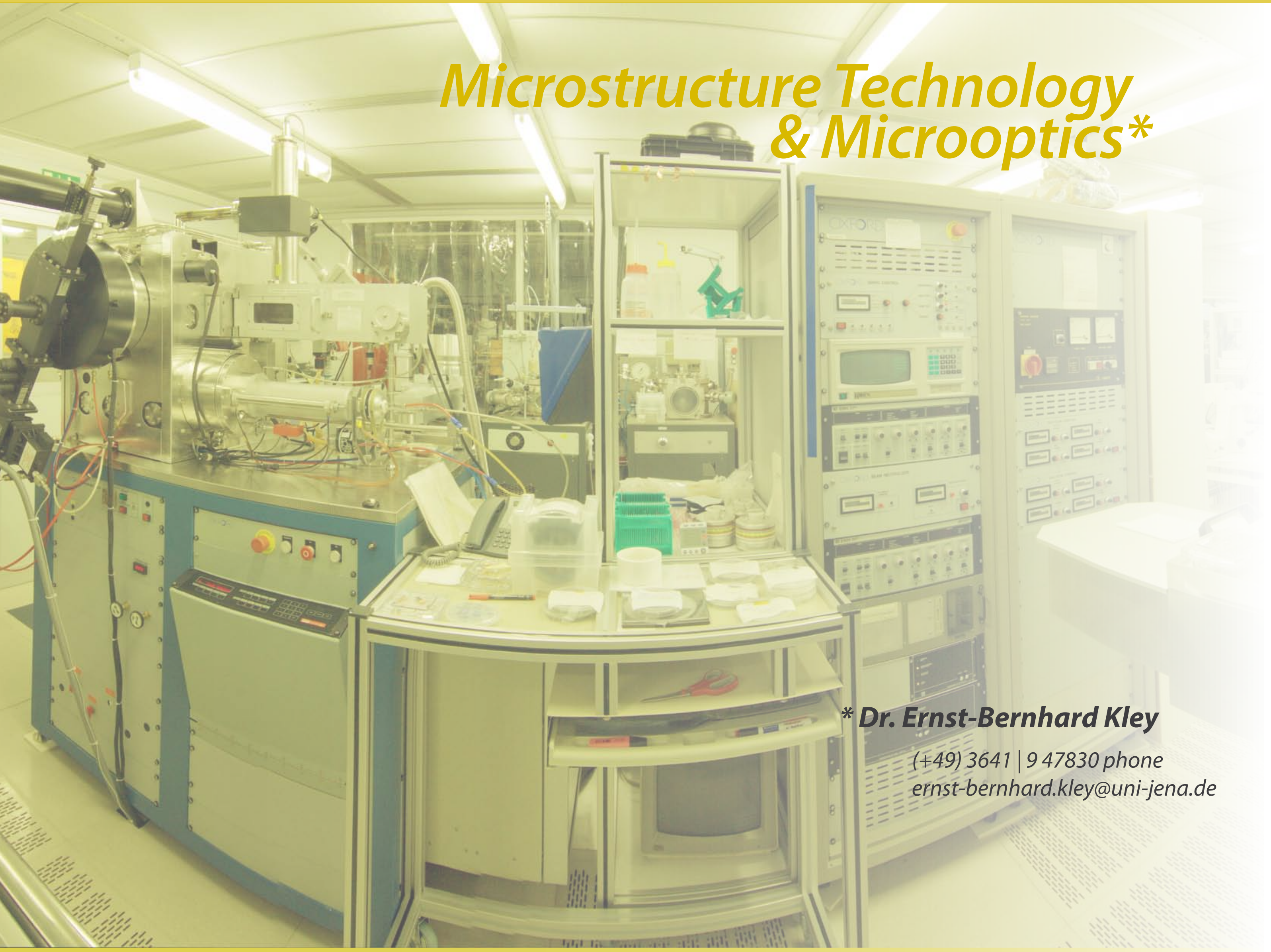


Figure 3:
Output Spectrum of the same fiber amplifier without and with LPGs at equal peak power

*Microstructure Technology & Microoptics**

*** Dr. Ernst-Bernhard Kley**

(+49) 3641 | 9 47830 phone
ernst-bernhard.kley@uni-jena.de



Ion beam etch and deposition tool

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

2010 the following research priorities have been edited:

- Plasmonic resonant nanometric metal rings
- Resonant reflective monolithic grating structures
- Transmissive reflective and diffractive elements based on effective media
- Metallic and dielectric polarizers from IR to DUV rage
- 3D nano-structuring of crystals with ion beam enhanced etchings
- Effective media for reflection reduction of smooth and micro-structured surfaces
- Material-scientific aspects

Amongst others, outstanding results are: 3D nanostructures in Lithumniobat • broadband DUV polarizer based on metal strip gratings up to 190nm wavelength • highly reflective monolithic dielectric resonant mirrors • high-efficient mulltilevel-phase structures for nonparaxial diffractive elements and reflection-reduced pulse compressor gratings.

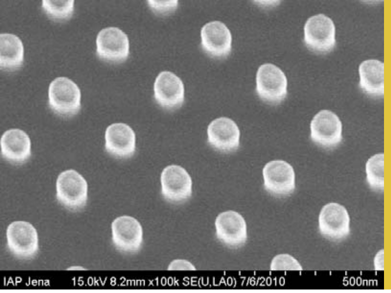


Figure 1: REM-Picture of produced aluminum nanorings with a diameter of 100 nm and a period of 290 nm.

Plasmonic resonant nanorings

Metallic nanorings with diameters below 100 nm (Figure1) show plasmonic resonances leading to different color effects. These resonances rely on coherent oscillations of conduction electrons and range down to the visible spectral range. The resonances' form can be controlled by well-designed structuring. Arranged in a periodic array, each ring represents a so-called metaatom and together form a so called metamaterial. The dispersion properties of light are influenced by the shape of these resonances and can be tailored by the geometry of the nanorings. For this reason, it is possible to create material properties which cannot be found in natural materials.
The rings are created with electron beam lithography. They can be realized with little effort by choosing suitable etching and metallization technologies. It is possible to further reduce this effort by changing the type of lithography. One example is the so-called block copolymer nano lithography, based on self-organization processes.
The process developed here enables the allocation of nanomaterials for research and industrial applications. For instance, it is possible to create color filters based on these nanorings (Figure2). Other geometries will be created in the future to enable the construction of more complex metamaterials, such as negative index materials. Moreover, the process will be developed further to make volume materials available.

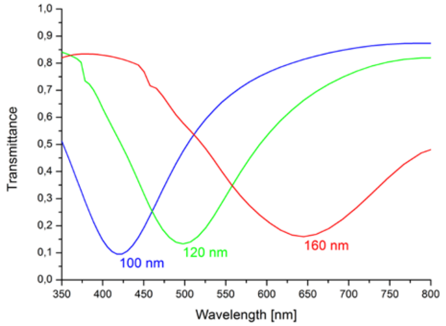


Figure 2: Simulation of the transmission of aluminium nanorings with different diameters.

Authors:
Dennis Lehr
Ernst-Bernhard Kley

Figure 3: Photo of a winter landscape.
Left: exposure perpendicular though the element,
right: element is tilted 10°

Angular selective diffusion panel

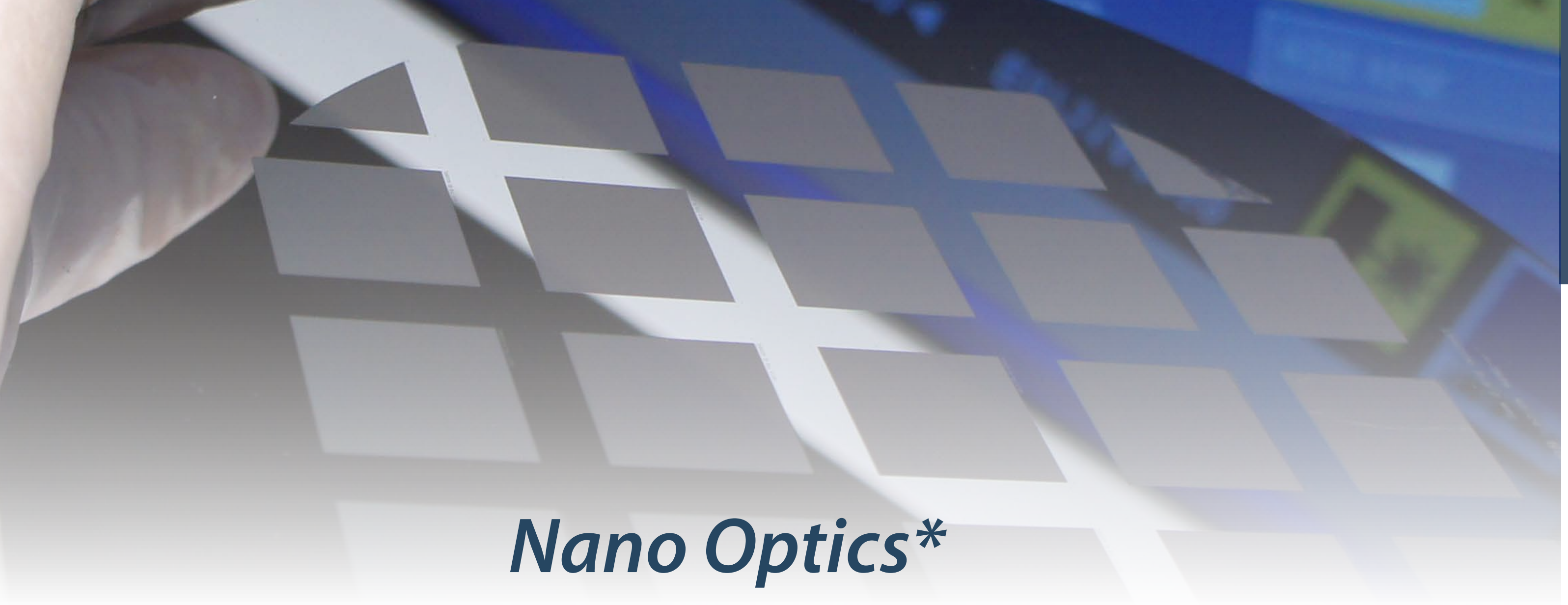
Optical elements with a transparency which changes its characteristic depending on the angle of incoming light are of considerable interest, e.g. for the restriction of the field of view of screens.

The optical element must feature a direction selective transparency. Incoming light from a specific direction should pass the element unhindered, in contrast to light from another direction. The light from the other directions can be absorbed or diffused, for instance, whereby diffusion has to be preferred because no energy loss occurs.

The diffusion effect is often realized by the use of a rough surface, a diffusion panel. Here, the wave front of the incoming light is altered in its phase by the height profile of the surface, so the light is scattered in directions not contained in the incoming light. The incoming light is diffused. Ongoing propagation of the light at large distances results in the desired diffusion effect. Just behind the diffusion surface, the phase distribution of the light is defined by the geometry of the surface. Up to a certain distance from the diffusion panel, the light distribution can be transformed back to an even phase distribution by a matched element for a defined incoming light direction. The diffusion effect of the first - rough - surface is neutralized. This creates an optical element which has a diffusion effect or is transparent, depending on the direction of the incoming light. The magnitude of the diffusion effect as well as the angular acceptance range of the transparency can be adjusted by the geometric parameters of both surfaces and the distance between them.

[1] T. Kämpfe, J. Reinhold, E.-B. Kley: Patent DE (submitted) „Anordnung zur Erzeugung winkel-selektiver optischer Transparenz."

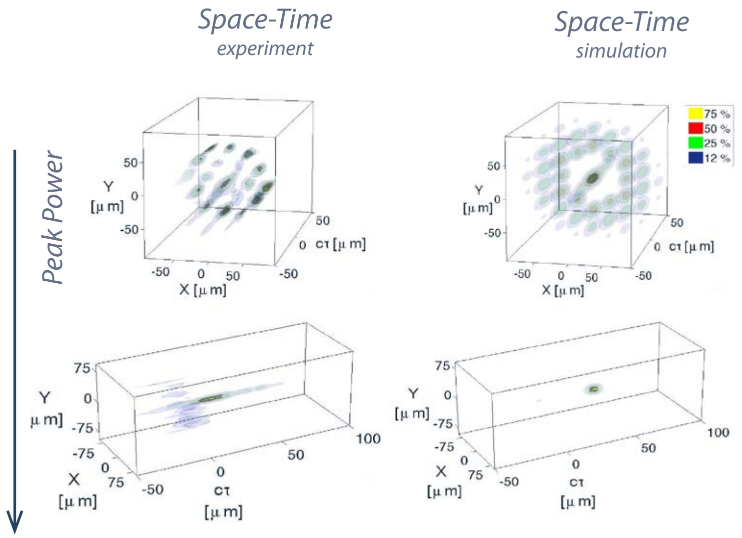
Authors:
Holger Hartung
Ernst-Bernhard Kley



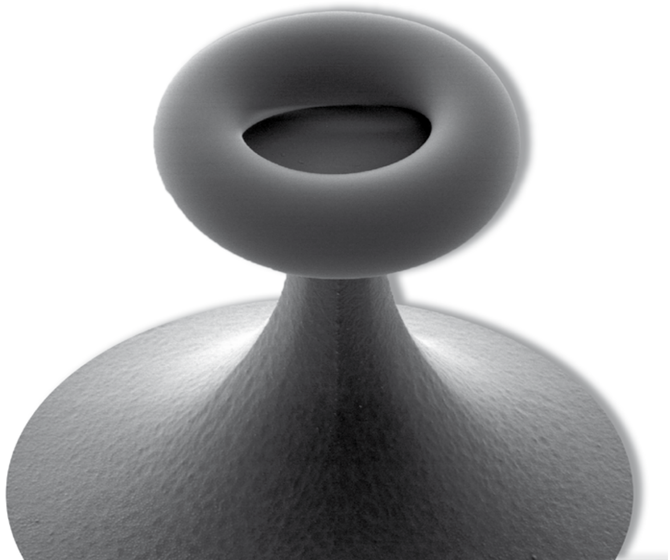
Nano Optics*

*** Prof. Dr. Thomas Pertsch**

(+49) 3641 | 9 47840 phone
thomas.pertsch@uni-jena.de



First experimental observation of Light Bullets.



Micro resonator [200 µm]

The work group Nano Optics deals with light propagation and nonlinear light-matter interaction in micro and nano structures, optical meta materials as well as photonic crystals. Aim of the group is the combination of specific design methods with advanced micro- and nanostructure technologies for the production of artificial, not naturally occurring structures. Such photonic materials allow to control the propagation characteristics of light almost independently from the basic properties of the used raw materials.

2010 the scientific emphasis was on:

- Plasmonics and near-field optics, scanning optical nearfield microscopy
- Nanostructured optical metamaterials
- Nonlinear light-matter interaction at high optical intensities in micro- and nanostructures, nonlinear dynamics
- Opto-optical switching processes in integrated optics
- Photonic Bloch oscillations, optical Zener tunneling
- Spatio-temporal nonlinear localization (light bullets) in micro structured fibres
- Efficiency enhancement of photovoltaic elements with optical nanostructures
- Application of optical communications systems for astronomical interferometers

Some outstanding results are: first realization of a polarization-insensitive negative index material in the NIR • development of an analytical model of photonic nano materials based on multipoles • experimental proof of Light Bullets • realization of coupled micro resonators using lithographic techniques • demonstration of an integrated-optical solution for the stabilization of white light interferometers in astronomy.

Figure 1: Astronomical Interferometers such as the Very Large Telescope Interferometer (VLTI) at Cerro Paranal in Chile deliver images with the resolution of a telescope of 100 meter diameter, by means of a few smaller telescope (diameters: 1.8 m or 8 m).

3D Photonics for astronomical interferometry

Photonic technologies play a central role in new-generation ground- and space-based instruments for astronomy, due to their outstanding performance in manipulating light on a microscopic scale [1].

In particular, fiber optics components have considerably improved the quality of optical astronomical interferometry [2], a technique delivering high resolution images through interferometric combination of starlight beams collected by several distant telescopes (Figure 1). While simultaneous combination of 3 to 4 telescopes is possible today, interferometric imaging of fast astronomical events such as exoplanet transits or flares around supermassive black holes would greatly benefit from the simultaneous combination of tens of telescopes, as is currently possible in radioastronomy. However, existing planar photonic circuits cannot be easily scaled up to simultaneous combination of more than 8 telescopes, which would require full three-dimensional (3D) circuit geometry.

In our work, we investigated the potential of 3D photonic components to deliver scalable interferometric combination of multiple beams on a single chip. We found numerically that even a simple two-dimensional array of coupled waveguides can be used to uniquely determine the mutual coherence properties for up to four, suitably injected fields [3]. The scheme (named Discrete Beam Combiner, or DBC) is based on the properties of light propagating in two-dimensional arrays of waveguides (optical lattices). Because of the evanescent field coupling, light injected in a waveguide of the lattice will leak to the neighboring waveguides (sites). This effect can be described with the formalism of discrete diffraction [4]. If selected sites of the array are excited simultaneously, interferometric mixing of the input signals will occur upon propagation and generate an output intensity pattern which can be uniquely related to the mutual coherence properties of the injected light. In DBCs (Figure 2), the light collected by the 4 telescopes of an astronomical interferometer is injected and combined in an optical lattice featuring 16 sites, thus allowing the accurate retrieval of the coherence parameters for all possible combinations of the injected fields. As compared to other beam combiners, the DBC distributes light over a minimal set of pixels, thus potentially enabling the observation of fainter targets than possible today.

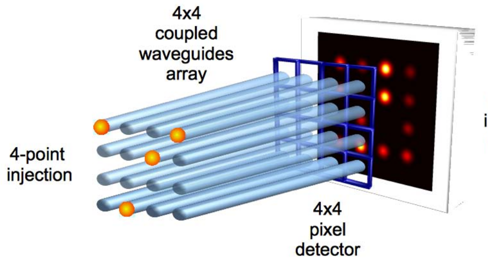


Figure 2: Sheme of the Discrete Beam Combiner for 4 telescopes.

The DBC shares the advantages of integrated photonic beam combiners (i.e. thermo-mechanical stability) but is superior in terms of scalability to interferometric combination of a large number of telescopes. In fact, the DBC fully exploits the potential of 3D integrated photonics, allowing a straightforward roadmap for the combination of an arbitrary number of telescopes.

We are currently testing the DBC scheme experimentally on laser-written square arrays of waveguides [5] and evaluating the impact on performance of different lattice geometries and technological platforms, in view of the implementation of DBCs in real astronomical instruments.

Authors:
Stefano Mirandi
Thomas Pertsch

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[3] S. Minardi, T. Pertsch: „Interferometric beam combination with discrete optics“ Opt. Lett. 35, 3009 (2010).

[4] F. Lederer, et al.: „Discrete solitons in optics“ Phys. Rep. 463, 1 (2008).

[5] T. Pertsch, et al.: „Discrete diffraction in two-dimensional arrays of coupled waveguides in silica“ Opt. Lett. 29, 468 (2004).

*Optical Engineering**

***Prof. Dr. Frank Wyrowski**

(+49) 3641 | 9 47803 phone
frank.wyrowski@uni-jena.de

The group of Optical Engineering deals with the development of novel approaches for modelling and design of optical systems. These concepts are based on the approach of field tracings, in which electromagnetic harmonic fields are propagated through the system.

In 2010, important developments on the following topics would be achieved:

- Source modelling: Together with colleagues at the University of Eastern Finland an electromagnetic model has been developed to describe non-paraxial partially coherent radiation. This approach is particularly suitable for modelling of LED radiation in context of field tracings. The radiation is fractionalized into harmonious elementary modes, which are set to each other incoherently. Moreover, a general source concept for field tracing was developed, that allows the modelling of general radiation including partial polarization and coherency. In addition a four-dimensional mode space is defined.
- Field tracing techniques: Together with colleagues from the LightTrans GmbH, the concept of field tracings was formulated mathematically. In addition, various tracing techniques were developed. Special attention was paid to the integration of geometrical optics into field tracing. In this context, the new concept of the boundary operators was introduced. Those can be understood as a generalization of the known optics transmission functions from the Fourier optics and allows just for micro-optics a very flexible modeling approach.
- Design: In addition to the analysis of optical systems the design is of fundamental practical importance. It requires developments of optimization techniques for field tracing. This was started in 2010 and successfully tested for the system design of non-paraxial beam shaping.

Unified Optical Modeling by Field Tracing

In 2010 the Optical Engineering Group continued the development of basic concepts of field tracing as well as tracing techniques to enable unified optical modelling. The team at the LightTrans GmbH implements the concepts and techniques of field tracing in the field tracer software VirtualLab™.

Field Tracing

Advanced optical systems often combine conventional optical components like lenses and prisms with micro- and nanostructured components. Nowadays there exists no single modeling technique that allows the complete analysis of such systems. Ray tracing is fast but is not accurate enough for the simulation of most micro- and nanostructured components. Rigorous solvers of Maxwell's equations like finite element methods (FEM) enable the modeling of all components in general, but for system simulation they require far too much computer resources even in face of recent developments. Besides this technical limitation it is not reasonable to apply a Maxwell solver for propagating, for instance, a laser beam through a lens also from a principal point of view. It is much more efficient and accurate enough to select suitable modeling techniques for different components of a system, e.g. geometrical optics for propagating a laser beam through a lens, the Rayleigh Sommerfeld integral to obtain the beam in the focus of the lens and FEM to model the scattering of the focused beam at some microstructure. In modern optics we have a great variety of such situations. In all of them a smooth combination of diverse modeling techniques is demanded. A unified optical modeling approach is required. Field tracing is introduced to tackle this challenge.

In field tracing electromagnetic harmonic fields are traced through the system. This approach provides three fundamental advantages of practical concern: (1) Field tracing enables unified optical modeling. Its concept allows the utilization of any modeling technique which is formulated for vectorial harmonic fields in different subdomains of the system. (2) The use of vectorial harmonic fields as basis of field tracing permits a great flexibility in source modeling. By propagating sets of harmonic field modes through the system, partially temporally and spatially coherent light as well as ultrashort pulses can be investigated. (3) In system modeling and design the evaluation of any type of detector function is crucial. The use of vectorially formulated harmonic fields provides unrestricted access to all field parameters and therefore it allows the introduction and evaluation of any type of detector. In 2010 the Optical Engineering Group has developed field tracing concepts with emphasis on general light source modeling and geometrical optics based field tracing techniques. In addition a new type of diffuser concept has been developed.

Source Modelling

The work on source modeling was done together with Jari Turunen, Pasi Vahimaa and Jani Tervo from the University of Eastern Finland. A representation of partially spatially coherent and partially polarized stationary electromagnetic fields is given in terms of mutually uncorrelated, transversely shifted, fully coherent, and polarized elementary electric-field modes. This representation allows one to propagate non-paraxial partially coherent vector fields using techniques for spatially fully coherent fields, which are numerically far more efficient than methods for propagating correlation functions. A procedure is given to determine the elementary modes from the radiant intensity and the far-zone polarization properties of the entire field. We applied the technique to quasi-homogeneous fields with rotationally symmetric $\cos^n\theta$ radiant intensity distributions (θ being the diffraction angle with respect to the optical axis and n being an integer). This is an adequate model for fields emitted by, e.g., many light-emitting diodes.

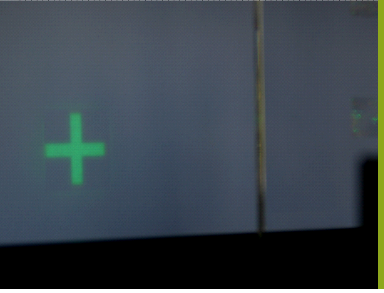


Figure 1: A grating cell diffuser is illuminated with LED light and generates a cross as a light pattern.

Geometrical Optics

Ray tracing can be understood as field propagation based on geometrical optics applied to a field that is represented by a ray bundle. We have introduced field tracing as the natural generalization of ray tracing: (1) the ray bundle representation of light is replaced by vectorial harmonic fields. (2) The field propagation is not restricted to geometrical optics. However, the success of ray tracing indicates, that geometrical optics has to be introduced as optional technique also in field tracing. In 2010 we developed a geometrical optics field tracing concept. It can be understood as an extended ray tracing concept, which includes all vectorial effects. The tracing is done between boundaries. At each boundary we have introduced so called boundary operators, which allow a very flexible modeling of micro-structures on smooth boundaries. The boundary operators can be understood as a generalization of the transmission function concept of Fourier optics.

Diffusers for shaping light with a multichannel concept

Diffusers for spatially shaping of light are of increasing importance for illumination and display applications. The use of the Iterative Fourier Transform Algorithm is a well-established design technique. However for the design of diffusers for non-paraxial and non-monochromatic light, e.g. in case of LED’s, this iterative technique causes some problems. (1) The numerical effort for the design can be very high. (2) Also the simulation of its effect for partially coherent light is time consuming. (3) The appearance of vortexes does not allow the reduction of a high wavelength dependency. In 2010 we have introduced a concept, which separates the function of the diffuser in a multichannel concept. Examples are grating cell diffusers and also the use of beam shaping elements in laterally separated channels.

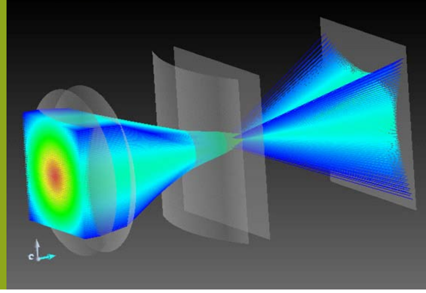


Figure 2: Ray tracing is one essential ingredient for a geometrical optics based field tracing technique.

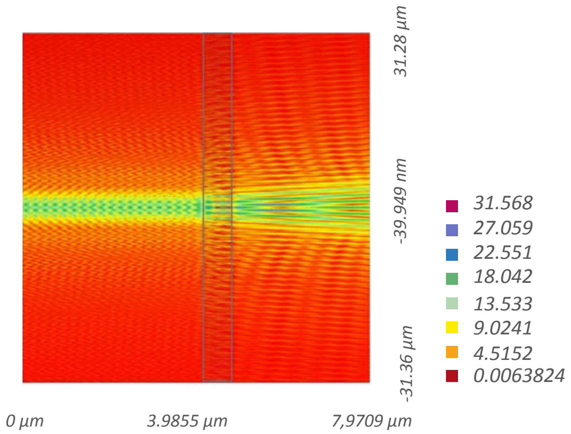


Figure 3: Combination of different modelling techniques for field tracing of a laser beam.

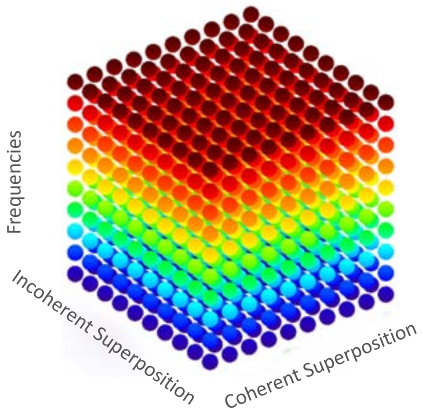
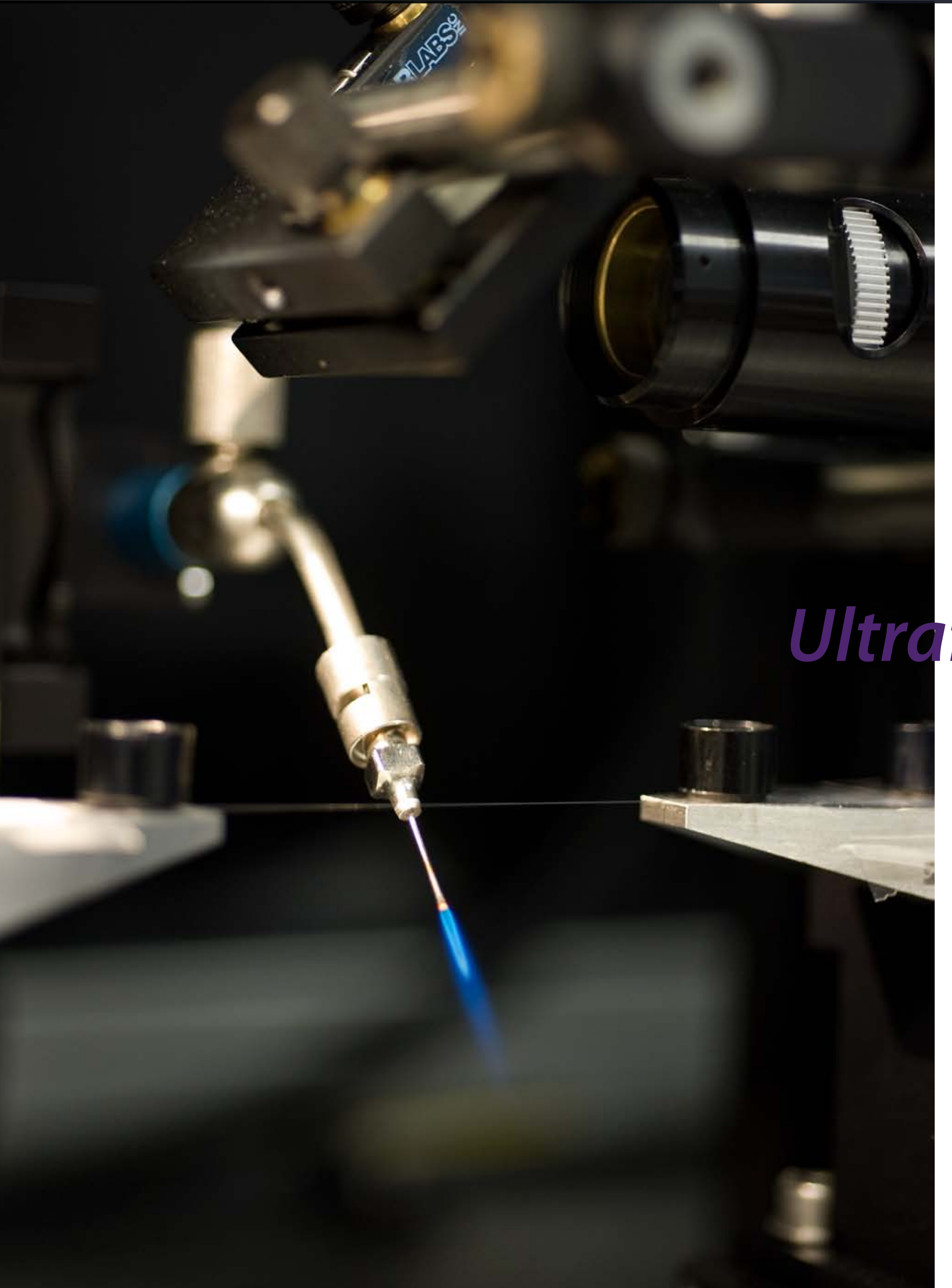


Figure 4: Concept of a Light Cube.

Field tracing allows the combination of different modeling techniques. In this example geometrical optics was used to propagate a laser beam through a lens. Then physical optics propagation was applied to obtain the focal region of the beam, in which a grating is located. Finite Element Method (FEM) is then used to model the effect of the grating.

For modeling light from general sources we developed the concept of the Light Cube. Each sphere in the cube represents an electromagnetic harmonic field mode. Horizontally all modes have the same frequency, but are correlated or not correlated.

Author:
Frank Wyrowski



*Ultrafast Optics**

* ***Prof. Dr. Stefan Nolte***

(+49) 3641 | 9 47820 phone
stefan.nolte@uni-jena.de

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 in 2010 were:

- Micro-and nanostructuring with ultrashort laser pulses
- 3D structures inside glasses and crystals
- Linear and nonlinear optics in discrete systems
- Fiber Bragg Gratings
- Ultrafast laser applications in ophthalmology
- Ultra-short pulse laser technology
- THz generation

In 2010, some outstanding results are: direct visualization of the hole drilling of opaque materials with ultrashort laser pulses • realization of high-strength bonds in glass by local laser welding with ultrashort pulses • realization of Fiber Bragg gratings in multimode fibers with ultrashort laser pulses • realization of volume Bragg gratings in fused silica with ultrashort laser pulses • investigation of discrete optical effects in fs written two-dimensional waveguide array • experimental simulation of the relativistic oscillatory motion in fs written waveguide array • analysis of photon correlations in two-dimensional waveguide arrays • optimization of cutting geometry in eye surgery with ultrashort laser pulses.

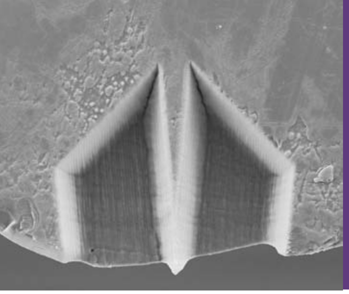


Figure 1: Prototype of a grooving tool,
length: 200 µm, width: 20 µm,
aspect ratio 1:10

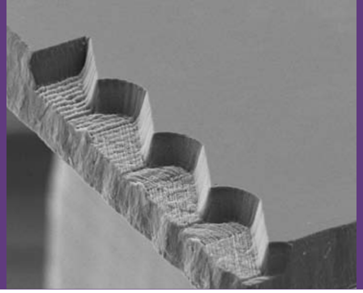


Figure 2: Prototype of a saw-tooth-like
structure for a diamond micro mill,
Dimensions: 100 µm x 30 µm

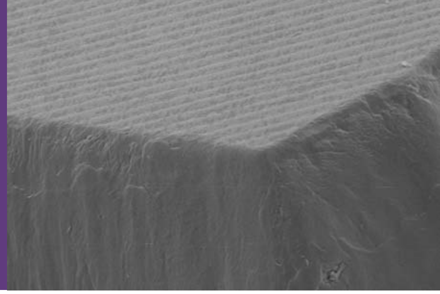


Figure 3: Microscopic chip guiding structure (period 5 µm)
with superimposed nanoscopic tern (period 400 nm)
on a diamond surface

Laserstructuring of Poly- and monocrystalline Diamond Tools

Its outstanding thermal conductivity and mechanical hardness make diamond the preferred material for tools for ultra-precision manufacturing of metals, metal alloys, plastics and semi-conductors. However, in turn these properties make it hard to manufacture or to refurbish diamond tools. On the one hand, the spectrum of possible tool geometries is technologically limited. On the other, generating the tool tips with commonly used abrasive techniques like grinding, lapping and polishing is a time-consuming and material-intensive process. Laser contouring and manufacturing by ultra-short laser pulses is a promising alternative technology to overcome some of these limitations [1].
This technique allows a fast processing of the diamond independent of its crystal orientation to generate almost every arbitrary shape. Furthermore, the application of energy within femtoseconds is confined both locally and temporary, reducing damage to the diamond to a minimum [2]. This technique is therefore suitable for ultra-precision processing.

The laser beam is focussed directly onto the diamond surface by a microscope objective without any prior beam shaping or preparation. The extreme high intensity leads to ultra-fast material removal within some picoseconds in the laser focus area [3]. Within this period of time, diffusion of heat and mechanical stress is negligible. The applied energy in the nanojoule domain minimizes the amount of energy inside the diamond and therefore limits the ablation volume. Hence one single laser shot only removes some cubic microns of diamond material.

Moving the diamond in up to three dimensions (x,y,z) while processing, almost every arbitrary shape can be carved into the diamond surface as well as into the bulk material. Structures with micrometer-sized, filigree contours and shapes are representable. So far, some prototypes of possible tool geometries have been produced, e.g. needle-like shapes in single crystal diamond as a prototype for a diamond grooving tool (Fig. 1) for UP-turning or -milling as well as saw-tooth-like shapes in polycrystalline diamond as a prototype of a micro mill (Fig. 2). The structures can be sized down to the mircometer domain with a surface roughness as small as 30 nm (rms). Cutting edges show a sharpness (edge radius) as small as 400 nm.

The easily accessible surface of the diamond can be manufactured by the laser with sub-micrometer precision. Furthermore, nanoscopic surface structures can be generated by choosing appropriate process parameters like laser pulse energy and writing speed. On the chip face of a diamond tool, the right combination of microscopic structures superimposed by a nanoscopic pattern (Fig. 3) can guide chips while UP-turning and adhere or guide cooling lubricant as well.

The investigations show that the structuring of diamond into almost any shape is possible with the ultra-short pulse laser technique.
At the present time, this technique is capable of generating high-precision diamond micro mills. The laser processing is also suitable for manufacturing diamond turning tools by precision-cutting the tool shape by the laser, if an additional polishing step for finishing is applied.

Authors:
Andreas Joswig
Stefan Nolte
Stefan Risse (IOF)
Ramona Eberhardt (IOF)

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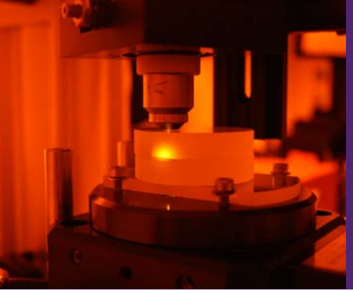

Figure 1: Local welding of glass with ultrashort laser pulses

Figure 2: Bonded glass blanks after the laser welding

Local welding using ultrashort Laser Pulses

Today, optical elements have to fulfill versatile requirements which often can only be achieved by hybrid integration. The long-term stable bonding of these different components is a particular challenge. Techniques such as optical contacting or anodic bonding are either not stable enough or result in other problems due to the necessary annealing step. Even intermediate layers, as required by soldering or adhesive bonding, may induce problems with long-term stability or resistance to heat.

A new option is the application of ultrashort laser pulses for local welding [1,2]. Due to the high peak power, nonlinear absorption occurs at the laser focus and leads to a defined local energy deposition [1]. By using high-repetition-rate laser systems, the short time between two subsequent pulses results in heat accumulation and hence in local melting of the material [2]. This melting process may be used as welding technique if the laser focus is placed at the interface between two transparent components. Due to only localized heating, thermal stress within the samples is minimized. A movement of the laser focus along specific routes allows tailored welding and the realization of potentially gas-proof bonds.

To date, we have been able to achieve a breaking stress of up to 75 % of the bulk material in fused silica. Furthermore, we realized strong welds even between different glasses. This flexible, adhesive–free, and custom-designed bonding method opens up new possibilities in different fields as microoptics, sensor technology, and photovoltaics.

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Authors:
Sören Richter
Sven Döring
Stefan Nolte
Andreas Tünnermann

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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C. Rockstuhl, C. Etrich, C. Helgert,
C. Menzel, T. Paul, S. Fahr, T. Pertsch,
F. Lederer:
Large scale simulations in the realm of nanooptics,
SPIE Photonics West,
San Francisco, USA, 23 - 28 January 2010

W. Freese, T. Kämpfe, E.-B. Kley:
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C. Voigtländer, D. Richter, J. Thomas, S. Nolte, A. Tünnermann:
Efficient VBG in fused silica induced by femtosecond laser pulses, Bragg Gratings, Photosensitivity and Poling in Glass Waveguides (BGPP),
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J.U. Thomas, N. Jovanovic, G.D. Marshall, R. Becker, C. Voigtländer, M. Steel, M.J. Withford, S. Nolte, A. Tünnermann:
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A. A. Sukhorukov, F. Setzpfandt, D. N. Neshev, R. Schiek, A. Tünnermann, Y. S. Kivshar, T. Pertsch:
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M. Heinrich, Y. V. Kartashov, L. P. R. Ramirez, A. Szameit, F. Dreisow, R. Keil, S. Nolte, A. Tünnermann, V. A. Vysloukh, L. Torner:
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A. Szameit, M. Rechtsman, F. Dreisow, M. Heinrich, R. Keil, S. Nolte, M. Segev:
Amorphous photonic lattices: disorder, band gaps, and effective mass,
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S. Bin Hasan, J. Reinhold, T. Paul, C. Helgert, A. Chipouline, C. Rockstuhl, T. Pertsch:
Intrinsic and Extrinsic Nonlinearities of Nanooptical Systems,
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Bad Dürkheim, Germany, 27 - 30 June 2010

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F. Tavella, A. Willner, S. Hädrich, J. Rothhardt, E. Seise, J. Limpert, S. Düsterer, H. Schlarb, J. Feldhaus, J. Roßbach, A. Tünnermann:
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A. Klein:
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N. Janunts:
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S. Diziain:
Light propagation in free standing lithium niobate photonic crystal membranes,
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A. Chipouline:
Multipole Model for Metamaterial Homogenization,
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C. Menzel, J. Petschulat, J. Yang, S. Mühlig, A. Chipouline, C. Rockstuhl, P. Lalanne, T. Pertsch, F. Lederer:
Scattering properties of 3D metaatoms,
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Karlsruhe, Germany, 13 - 16 September 2010

A. Chipouline:
Homogenization of metamaterials based on multipole approach,
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Karlsruhe, Germany, 13 - 16 September 2010

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A. Merzlikin, A. Vinogradov, A. Chipouline, T. Pertsch, Y. Strelniker, D. Bergman, A. Lagarkov:
Homogenization of refractive index in heterogeneous systems: interconnection between homogenization and Anderson localization,
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Stacked fishnet and Swiss cross samples fabricated by NIL,
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E. Pshenay-Severin, M. Falkner, B. Walther, C. Helgert, A. Chipouline, A. Tünnermann, T. Pertsch:
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Genua, Italy, 19 - 22 September 2010

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Jens Limpert:
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A. Ancona, S. Döring, S. Hädrich, J. Limpert, S. Nolte, A. Tünnermann:
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Scaling of fiber laser systems based on novel components and high power capable packaging and joining technologies,
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J. Limpert, A. Tünnermann:
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C. Rockstuhl, C. Menzel, S. Mühlig, C. Helgert, B. Walther, A. Chipouline, C. Etrich, A. Cunningham, T. Bürgi, E.-B. Kley, T. Pertsch, F. Lederer:
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A. Szameit, Y. V. Kartashov, P. Zeil, F. Dreisow, M. Heinrich, R. Keil, S. Nolte, A. Tünnermann, V. A. Vysloukh, L. Torner:
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A. Szameit, F. Dreisow, M. Heinrich, R. Keil, S. Nolte, A. Tünnermann, S. Longhi:
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Different methods for generating antirflecting nanostructures on optical components,
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A. Tünnermann:
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Berlin, Germany, 5 - 6 November 2010

S. Richter, S.Döring, S. Nolte, A. Tünnermann:
Lokales Schweißen transparenter Werkstoffe mit ultrakurzen Pulsen,
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Jena, Germany, 25 - 26 November 2010

A. Tünnermann:
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Analystenkonferenz SPECTARIS, 2010

A. Szameit, M. Rechtsman, F. Dreisow, M. Heinrich, R. Keil, S. Nolte, M. Segev:
Amorphous photonic lattices: fundamentals and applications,
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Patent Applications

Füchsel, K.; Kley, E.-B.; Käsebier, T.; Kroll, M.; Pertsch, T.
Strukturierte Siliziumschicht für ein optoelektronisches Bauelement und optoelektronisches Bauelement (DE 10 2010 012044.8)

Füchsel, K.; Nolte, S.; Gabor, M.; Hoyer, P.
Verfahren zur Charakterisierung von Materialparametern an Halbleitergrenzflächen mittels THz-Strahlung (DE 10 2010 056 098.7)

Jáuregui, C.; Tünnermann, A.; Limpert, J.; Nodop, D.
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Limpert, J.; Tünnermann, A.; Jáuregui, C.; Stutzki, F.; Jansen, F.
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Erdmann, T.; Kley, E.-B.; Tünnermann, A.
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Limpert, J.; Tünnermann, A.; Schreiber, T.; Ortec, B.; Nielsen, C.
Faserlaser (DE 10 2005 042 073 B4)

Defence of the doctor´s theses H. Hartung

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 - at the participation at conferences and at co-operation 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 jounals.

Awards

Jens Thomas
Best Student Paper, 2nd Place
„Mode selective fiber bragg gratings“
Photonics West, San Francisco 2010

Steffen Hädrich
Best Student Paper
“High peak power ultrashort laser pulses from fiber based systems”
Photonics West, San Francisco 2010
and
HEPTAGON - Sven Bühling - Forschungsförderpreis
“Entwicklung hochrepetierender Ultrakurzpulslaser und deren Anwendung zur Erzeugung hoher Harmonischer”

Damian Schimpf
Best Student Poster
“Advantage of circularly polarized light in nonlinear fiber-amplifiers”
Photonics West, San Francisco 2010

Robert Keil
Incubic/Milton Chang Travel Award
Optical Society of America (OSA) 2010

Christian Voigtländer
Oversea Scholarship DAAD

Detlef Schelle
Gratuity for Special Involvement

Thomas Pertsch
Dean’s Teaching Price of the Faculty of Physics and Astronomy, FSU Jena

Jens Thomas, Christian Voigtländer, Daniel Richter, Stefan Nolte and Andreas Tünnermann
“Bragg Gratings, Photosensitivity and Poling in Glass Waveguides (BGPP)” Optics Visualized Award, 7th Place, Karlsruhe, 2010

Ceremony at the Photonics West,
3rd from left Jens Thomas, right: Nobel laureate Charles Townes
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Organizing Activities

Prof. Dr. Tünnermann

Council member of the Faculty

Member of program committee „Optische Technologien“, BMBF

Board of trustees MPA, Heidelberg

Board of trustees MPQ, Garching

Board of trustees „Physik Journal“

Board of trustees IOM, Leipzig

Chairman „AG Naturwissenschaften“, Wissenschaftliche Gesellschaft Lasertechnik

Guest-Editor Applied Physics B

Stakeholder Photonics 21-Plattform

Member of the seering committee Fraunhofer Gesellschaft

Member of the executive Board OptoNet e. V.

Referee for several scientific journals

Prof. Dr. Nolte

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 (France), FSU Jena, Univ. Central Florida und Clemson Univ. (USA)

Member Optical Society of America, Deutsche Physikalische Gesellschaft

Referee for several scientific journals

Member of program committee : ICALEO (Laser Microprocessing)

Conference Chair: Photonics West/ LASE (Frontiers in Ultrafast Optics: Biomedical, Scientific and Industrial Applications)

Prof. Dr. Pertsch

Member of the Faculty Board

Person in charge for course of studies „Master of Science in Photonics“

Member of the program committee of the workshop “Entrepreneurship and Business Innovation in PhD Education” at EOS Annual Meeting, October 29, 2010, Paris

Member of the Technical Program Committee of Metamaterials 2011

Member of the Technical Program Committee of CLEO Pacific Rim 2011

Vice-speaker Abbe School of Photonics

Referee for several scientific journals (Physical Review Letters, Physical Review E, Nature Photonics, Physics Report, Optics Letters, IEEE Journal of Lightwave Technology, Optics Communication, Applied Physics Letters, Applied Physics B, and Journal of Physics B)

Referee of German Research Society DFG

Prof. Dr. Wyrowski

Referee for several scientific journals

Member of the Board of Journal of Modern Optics (JMO)

Editor, together with Prof. Rockstuhl, of Special Issues on Computational Optics and Photonics des JMO

Conference Chair: SPIE Conference on Optical Modelling and Design, 12 - 16 April 2010, Brussels, Belgium

Member of the Program Committee: SPIE Conference on Optics and Photonics for Information Processing IV, 1 - 5 August 2010, San Diego, California, USA

Member of the Program Committee: OSA Conference on Digital Holography and Three-Dimensional Imaging, April 12-14, 2010, Miami, USA

L.eft to right: S.Nolte, F.Schrempel, E.-B.Kley

Dr. Kley

Referee for several scientific journals (Optics Express, Appl. Optics)

Member of program committee SPIE Photonics West

Prof. Dr. Limpert

Referee for several scientific journals (OE, OL, Appl. Phys. B, JOSA A/B, Opt. Comm,)

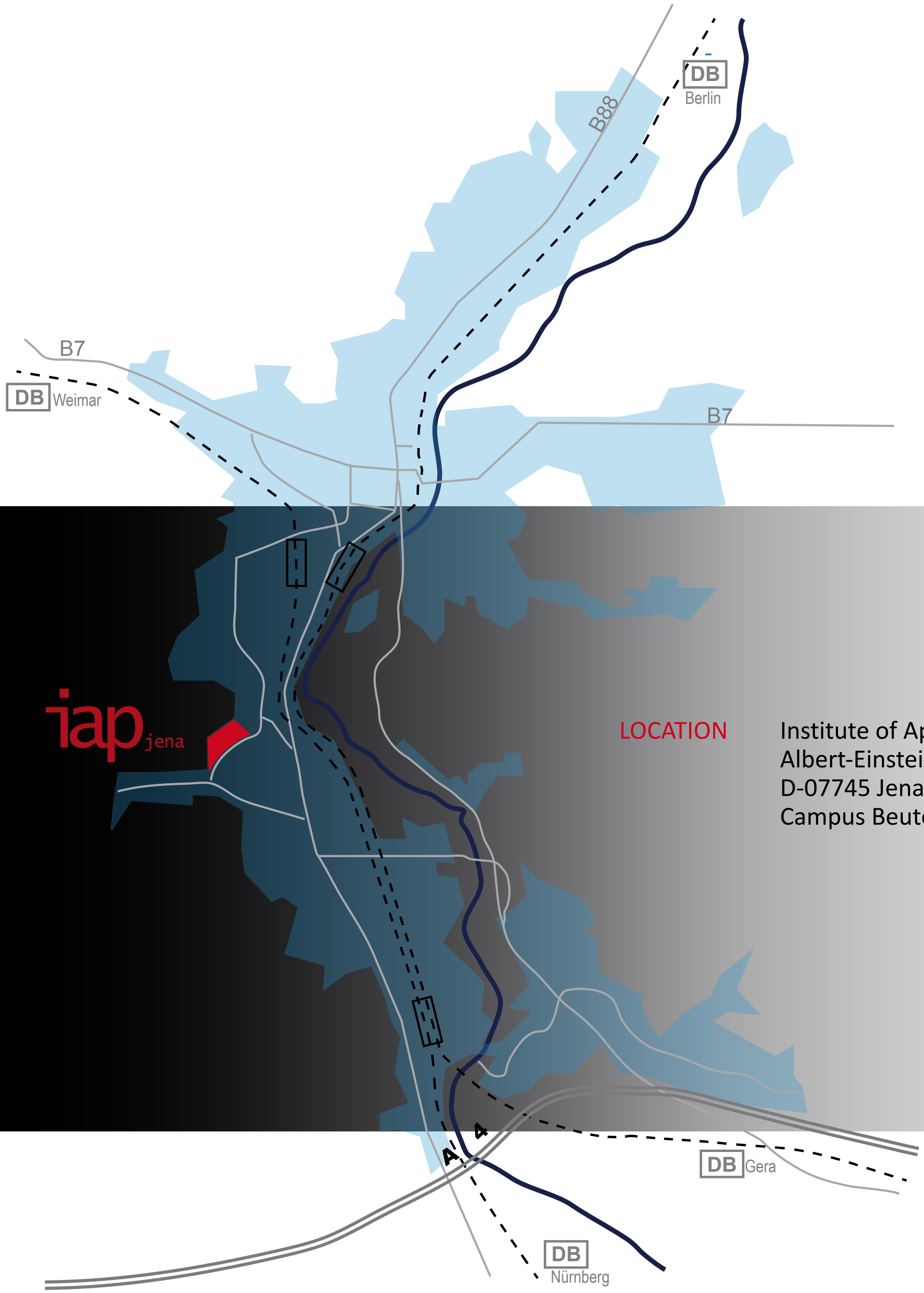
Member of program committee ASSP, CLEO

Dr. Schrempel

Member of the Faculty Board

Referee for several scientific journals (Optical Materials, phys. stat. sol., Nucl. Instr. and Meth. B)

Coordinator of the IAP at the Beutenberg Campus e.V.



LOCATION

Institute of Applied Physics
Albert-Einstein-Straße 15
D-07745 Jena
Campus Beutenberg