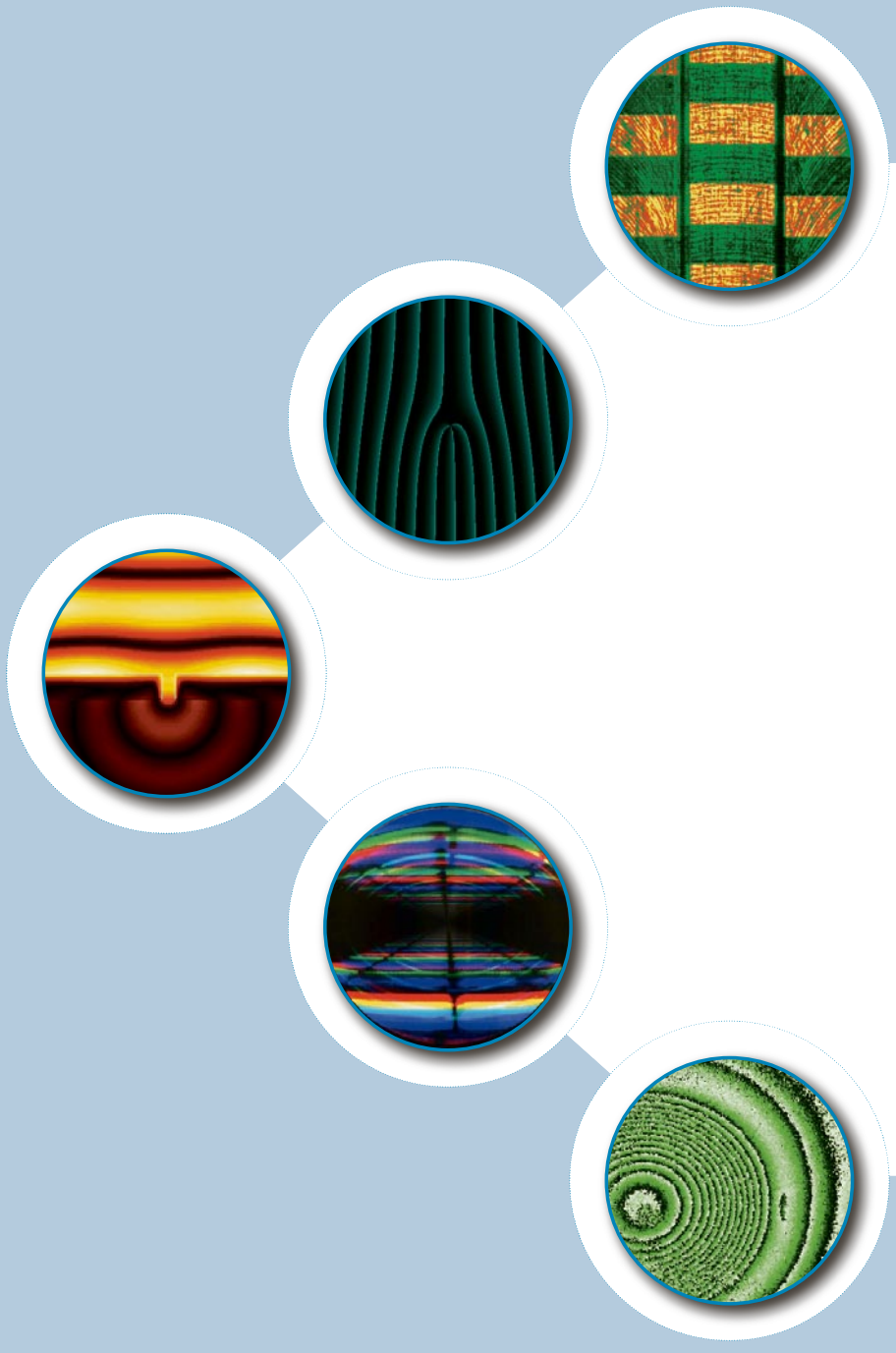
annual report
2007 / 2008

INSTITUT FÜR
TECHNISCHE OPTIK
UNIVERSITÄT STUTTGART



Universität Stuttgart

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ANNUAL REPORT 2007/2008

Dear Reader,

Another two years filled with many activities in different fields and enriched with fruitful national and world wide cooperation have passed since the ITO staff reported in 2007 in such a comprehensive report about their research activities. Thus it is again time to inform our partners, sponsors and customers about our recent advances in the field of Applied Optics.

The basic understanding that determines our work remains unchanged: striving for excellence in research and teaching, together with a good balance of continuity and systematic renewing. Modernization of our environment and equipment is still an ongoing process. For instance, our clean room, the centre of many of our research activities in diffractive optics and high resolution metrology, is now equipped with a new ion etching facility. The installation of a state of the art focused ion beam (FIB) tool is on the way. Both tools widen our possibilities in the field of nanotechnology considerably. However, all of our activities are also accompanied by new initiatives that are embedded in challenging timescales. Two years ago we have reported about our commitment to the Excellence Initiative of the Federation and the States in Germany. Now we can proudly report that ITO is an active member of both successful initiatives of the University Stuttgart, the Cluster of Excellence "Simulation Technology" and the Excellence Graduate School for Advanced Manufacturing Engineering GSaME. Another initiative focuses on the location of Stuttgart as a strong centre of photonic technologies. Eight institutes from the engineering and natural sciences faculties have founded the "Stuttgart Research Centre of Photonic Engineering SCoPE". SCoPE is dedicated to concerted work between engineers and physicists with respect to the next generation of larger joint and ambitious projects in photonic technologies. Several projects are already running and the preparation of a collaborative research centre under the roof of the German Research Association DFG has started recently. Such interdisciplinary cooperation in larger scientific networks, assembled to meet ambitious mid- and long-term targets, is gaining more and more in importance. ITO is here on a good path.

As member of the Faculty of Mechanical Engineering, the Institute represents Stuttgart University in the field of Engineering Optics in research and education. Together with our national and international partners, our research work focuses on the exploration of new measurement and design principles and their implementation in new optical components, sensors and sensor systems. One of our central goals is the extension of existing limits by combining modelling, simulation and experimental data acquisition in the context of actively driven measurement processes. Several ambitious objectives are on our agenda such as the enhancement of the robustness and resolution of optical sensors, the miniaturization of components and systems, the in-line integration of optical sensors in production processes and machine tools, and the improved exploitation of all information channels of electro-magnetic waves. All these activities are embedded in the five main research directions of ITO

- 3D-Surface Metrology
- Active Optical Systems and Computational Imaging,
- High-Resolution Metrology and Simulation,
- Interferometry and Diffractive Optics, and
- Coherent Metrology

that are driven by the five research groups which make up the Institute. Together with strong interactions between these groups, this gives the Institute a strength in depth over a broad range of optics activities. The considerable number of research projects that are referred to in this report reflects again the success of this approach.

To cope with our ambitious and extensive approach to Applied Optics a deep understanding of the physics of optics needs to be combined with practical engineering implementation. The fulfilment of this boundary condition means a daily challenge for all members of the staff. However, a good mixture of graduates in physics and engineering, a vital and innovative scientific climate, that considers the interdisciplinary cooperation with numerous national and international institutes, and a continuous observation of the technological and scientific progress – the traditional features of the ITO - are a good basis to meet these and future challenges. May this report once again convince our sponsors, customers and partners of this and may this report be received with deep thanks for the good cooperation and the substantial support over the past two years.

Wolfgang Osten

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High Resolution Metrology and Simulation

Interferometry and Diffractive Optics

Coherent Metrology

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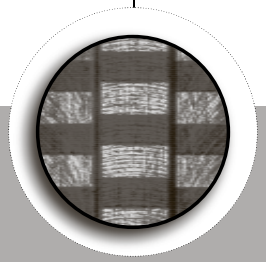
Institute structure

ito-Structure

Teaching
E. Steinbeißer

Chair
Prof. Dr. W. Osten

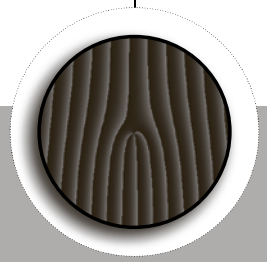
Deputy
Dr. T. Haist



3D-Surface Metrology

Dr. T. Haist

- Macro and Micro Metrology
- White Light Interferometry
- Spectral Interferom.
- Confocal Microscopy
- Fringe Projection
- Sensorfusion and Measurement Strategies



Active Optical Systems and Computational Imaging

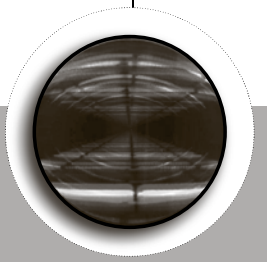
S. Zwick

- Active Wavefront Modulation and Sensors
- Adaptive Optics
- Dynamic Holography
- Optical Tweezers
- Components, Algorithms and Strategies
- Waveoptical Computing

High Resolution Metrology and Simulation

K. Frenner

- Modelling and Rigorous Simulation
- Inverse Problems
- High Resolution Microscopy
- Scatterometry
- Optical Metamaterials



Interferometry and Diffractive Optics

Ch. Pruß

- Testing of Aspheres and Freeform Surfaces
- Design and Fabrication of Diffractive Optics
- Microoptical Systems
- Tailored Optics for Metrology Applications
- Wavefront Sensors

Coherent Metrology

Dr. G. Pedrini

- Digital Holography
- Shape and Deformation Measurement
- Dynam. Holography and Microscopy
- Non-destructive Testing
- Phase Retrieval

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Dr. Yu Fu _____ left on 31.12.2007

Dr. Unnikrishnan Gopinathan ___ left on 31.12.2008

Dr. Roger Groves _____ left on 31.10.2008

Xavier Schwab _____ left on 31.03.2008

Dr. Quiaofeng Tan _____ left on 31.12.2007

Dr. Dayong Wang _____ left on 30.11.2007

Dr. Fucai Zhang _____ left on 30.11.2007

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Guest Scientists

Dr. Arun Anand	Institute for Plasma Research, Gujarat (India)	5/2006 – 5/2007
Dimitri Denk	Academy of Sciences, Novosibirsk (Russia)	11/2007 – 12/2007
Dr. Yu Fu*	Dep. of Mech. Eng., Nat. University (Singapore)	1/2007 – 12/2007
Dr. Unnikrishnan Gopinathan*	Instrument R & D Establishment, Dehradun (India)	8/2007 – 12/2008
Prof. Dr. Bahram Javidi**	University of Connecticut (USA)	6/2008 – 8/2008
Jun Ma	Nanjing University (China)	since 3/2009
Cristian Israel Mendez	Centro d. Investigationes en Optica, Leon (Mexiko)	7/2007 – 3/2008
Dr. Guohai Situ*	Chinese Academic of Sciences, Bejing (China)	since 3/2008
Dr. Quiaofeng Tan	Tsinghua University, Bejing (China)	3/2007 – 12/2007
Prof. Dayong Wang*	College of Applied Sciences, Bejing (China)	12/2006 – 11/2007
Dr. Yong Yang	Nankai University (China)	1/2008 – 12/2008

Foreign Guests visiting the Institute: 2007 - 2008

Prof. Dr. Xiaoyuan He	Southeast University (China)	Juli 2007
Prof. Dr. Hans-Peter Herzig	Univ. Neuchatel (Suisse)	September 2007
Dr. Vivi Tornari	F.O.R.T.H., Heraklion (Greece)	Oktober 2007
Dr. Vadime Vanine	ASML Veldhoven (Netherlands)	Oktober 2007
Prof. Dr. Gao	Nanjing Univ., Nanjing (China)	Juni 2008

* Humboldt fellowship ** Humboldt prize-winner and stays at the ITO for altogether one year

Project partners

Project collaboration with the following companies and organisations (and many others):

ASML Netherlands B.V. Veldhoven, Netherlands

Carl Zeiss AG Oberkochen

Carl Zeiss SMT AG Oberkochen

Daimler AG Untertürkheim

Diamant-Gesellschaft Tesch GmbH Ludwigsburg

Fisba Optik AG Berlin; St. Gallen, Switzerland

FOS Messtechnik GmbH Schacht-Audorf

Fraunhofer-Institut Produktionstechnologie IPT Aachen

GEFASOFT Automatisierung und Software GmbH Regensburg

GFMesstechnik GmbH (GFM) Teltow bei Berlin

Holoeye Photonics AG Berlin

IMOS Gubela GmbH Renchen

Jenoptik LOS Jena

Johann Fischer Präzisionswerk GmbH & Co. KG Aschaffenburg

La Vision GmbH Göttingen

LT Ultra-PrecisionTechnology GmbH Herdwangen-Schönach

Mahr GmbH Göttingen

National Gallery_Alexandros Soutzos Museum Athens, Greece

Optrion s.a. Liège, Belgium

Polytec GmbH Waldbronn

Qimonda AG Dresden

Robert Bosch GmbH Gerlingen

Schneider Optikmaschinen GmbH Steffenberg

Singulus Mastering BV Eindhoven, NL

Tate Gallery London, England

Till Photonics GmbH Gräfelfing

Trumpf GmbH+ Co. KG Ditzingen

UPT-Optik Wodak GmbH Nürnberg

VW AG Wolfsburg

Studying optics

Our curriculum is primarily directed towards the students in upper-level courses ("Hauptdiplom") of Mechanical Engineering, Cybernetic Engineering, Mechatronics, and Technology Management. We especially recommend the course "Microsystems and precision engineering". We also welcome students from other courses, such as "Physics" and "Electrical Engineering and Information Technology".

Concerning the main subject "Engineering Optics" we offer the following

Core subjects:

- **Fundamentals of Engineering Optics** (Prof. Dr. W. Osten)

  basic laws and components: optical imaging with lenses, mirrors, and prism; basic optical set-ups; optical systems and devices (the human eye, magnifying glass, microscope, and telescope); physical optics, physical limits of optical images, resolution of optical devices; geometrical and chromatic aberrations and their influence on picture quality, basic laws of photometry.

- **Optical Measurement Techniques and Procedures** (Prof. Dr. W. Osten / Dr. Körner)

  basics in geometrical optics and physical optics; holography; speckle; components and systems: light sources, lenses, mirrors, prism, stops, light modulators, the human eye and other detectors; measuring errors;
  measuring techniques based on geometrical optics: measuring microscopes and telescopes, structured illumination, application of moiré-phenomenon;
  measuring techniques based on physical optics: interferometrical measurement techniques, holografic interferometry, speckle measurement techniques.

- **Optical Information Processing** (Prof. Dr. W. Osten)

  fourier theory of optical imaging; basics of the wave theory, coherence, frequency analysis of optical systems, holography and speckle, spectrum-analysis and optical filtering; digital image processing: basics as far as methods and applications.

Elective subjects:

- Optical Phenomena in Nature and Everyday Life (Dr. T. Haist)
- Opto-Electronical Image-Sensor and Digital Photography (Dr. K. Lenhardt; Schneider, Kreuznach)
- Coherence and Polarisation in Optics / Optics of Thin Films, Surfaces and Crystals (Dr. K. Leonhardt)
- Measuring Techniques for Micro-Structures (Dr. M. Totzeck; Zeiss)
- Design and Calculation of Optical Systems (Dr. Ch. Menke; Zeiss)
- Optoelectronic Devices and Fibre Sensors (Dr. R. Groves)

Additional studies:

- project work and thesis within our fields of research
- practical course "Optic-Laboratory"
  – speckle measurement
  – digital image processing
  – computer aided design of optical systems
  – measurement of the spectral power distribution
- practical course "Optical Measurement Techniques"
  – 3D surface measurement applying fringe projection
  – digital holography
  – 2D-interferometry and measurement
  – quality inspection of photo-objectives with the MTF measuring system
- common lab for mechanical engineering (APMB)

The research groups

3D-Surface Metrology

The objective of the group is the analysis and the implementation of new principles for the acquisition of optical 3D-surface data of engineering and biological objects over a wide scale. Our main focus is on the enhancement of the metering capacity by a combination of physical models and optimized system design.

Current research activities are:
- 3D-measurement applying fringe projection and deflectometry (macroscopic and microscopic)
- adaptive techniques using spatial light modulators
- confocal microscopy
- white light interferometry
- spectral interferometry
- sensorfusion and data interpretation strategies

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Active Optical Systems and Computational Imaging

The objective of our work is the development of flexible optical systems in order to enable new applications, especially within the field of scientific and industrial metrology. To achieve this goal, we make use of different modern light modulation technologies and computer-based methods. One focus of our work lies in the application of holographic methods based on liquid crystal displays and micromechanical systems for various applications ranging from optical tweezers to aberration control and testing of aspherical surfaces.

Main research areas:
- active wavefront modulation and sensors
- adaptive optics
- active wavefront sensors
- dynamic holography
- components, algorithms, and strategies
- waveoptical computing

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High Resolution Metrology and Simulation

The goal of this research group is the investigation of the interaction of light with 3d object structures in the micro and nano domain. Along with experimental research, one major aspect is the rigorous modelling and simulation as an integral part of the active metrology process. The analysis of all information channels of the electromagnetic field (intensity, phase, polarisation state of light) allows us to obtain subwavelength information about the structure.

Current research areas:
- modelling and rigorous simulation
- inverse problems
- high resolution microscopy
- scatterometry
- optical metamaterials

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Interferometry and Diffractive Optics

The goal of our research activity is to explore new measurement concepts using diffractive optics. One important application is the testing of optical surfaces, in particular, aspheric lenses. For this purpose we design and produce computer generated holograms (CGH). At the same time, we develop flexible measurement techniques that enhance or even replace static null correctors. In addition to CGH for interferometry, our in house production facilities allow us to produce diffractive elements and micro-optics for a wide variety of applications such as UV-measurement systems, beam shaping applications and wavefront sensing.

Our research areas include:
- design, fabrication and testing of hybrid refractive/diffractive systems
- testing of aspheric surfaces and freeform surfaces
- fabrication of diffractive optics
- interferometry
- dynamic wavefront coding
- wavefront sensors
- tailored optics for metrology applications

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Coherent Metrology

Our research objective is the analysis and application of methods based on coherent optics for the measurement of 3D-shape and deformation and to determine the material properties of technical objects and biological tissues. Aside from the quantitative measurements of form and deformation, methods for non-destructive material testing are also analysed and applied.

Research areas include:
- digital holography
- pulsed holographic interferometry
- dynamic strain measurements on biological samples
- shape measurement
- wavefront reconstruction
- holographic non-destructive testing
- endoscopy
- THz technique for non-destructive testing

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