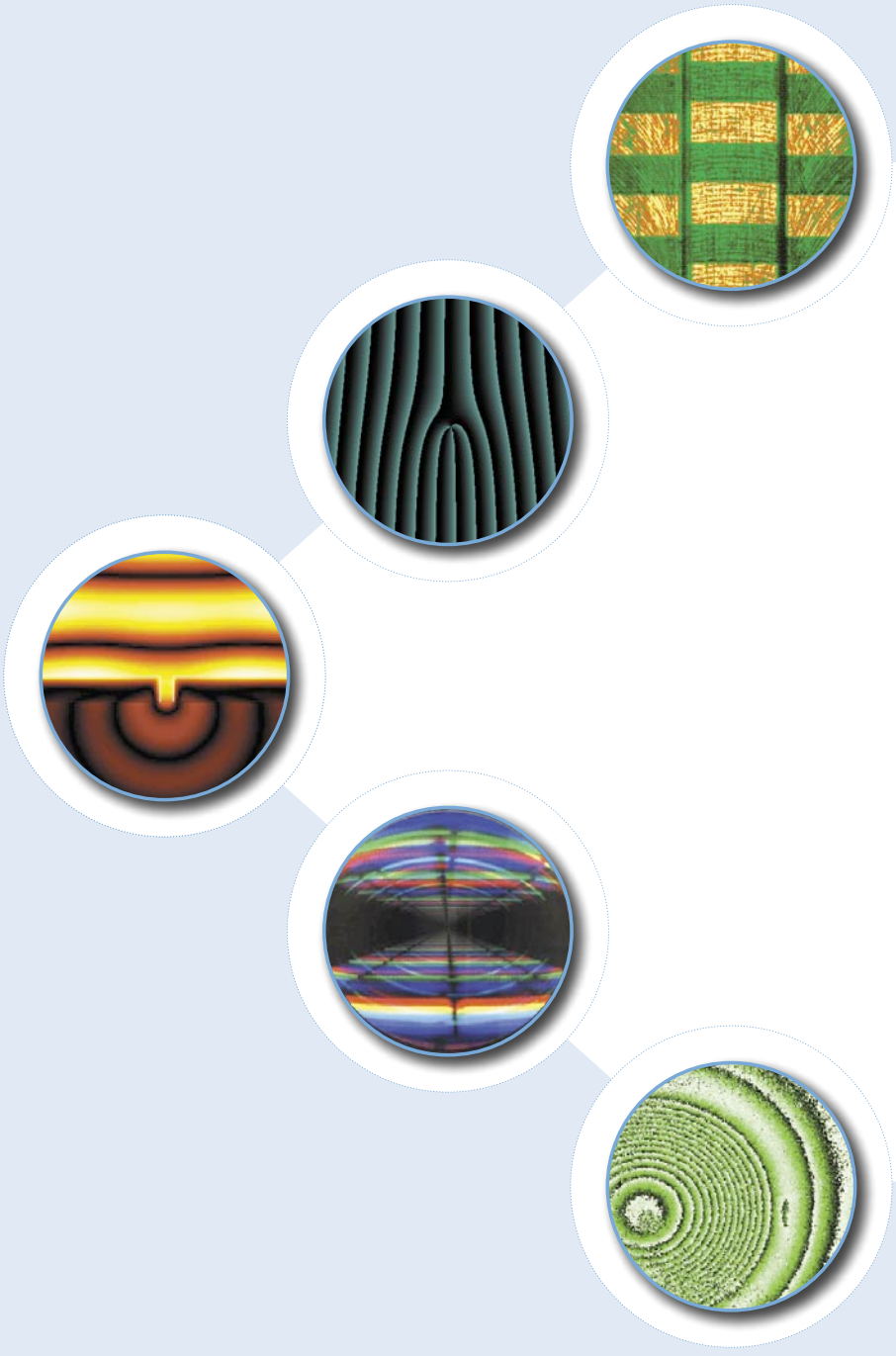
annual report
2005 / 2006

INSTITUT FÜR
TECHNISCHE OPTIK
UNIVERSITÄT STUTTGART



Universität Stuttgart

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ANNUAL REPORT 2005/2006

Dear Reader,

Two years filled with many activities in different fields and enriched with fruitful world wide cooperations have passed since the ITO staff reported about their previous research activities in the form of such a comprehensive report. 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 behaviour remains unchanged: striving for excellence in research and teaching, together with continuity and the systematic renewing and modernization of our environment. However, the growing number of ambitious research projects and the fortunately increasing world wide cooperation with key players in the field of optical technologies are accompanied by new initiatives and challenging timescales. In comparison with the past we are faced with stronger competition and faster changing boundary conditions.

The last two rounds in the *Excellence Initiative of the Federation and the States* convinced us that personal and institutional expertise are only necessary preconditions in an intensified competition for recognition and substantial funding. 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 the partner in pending applications for a Cluster of Excellence and for a Graduate School we are still in the game. Further initiatives for the installation of Collaborative Research Centres and Priority Programs are part of our future strategy.

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 electromagnetic waves. The five main research directions of ITO

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

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 the success of this approach.

Along with the fulfilment of these research projects the Institute has been undergoing a considerable modernisation of the equipment and infrastructure over the past 3 years to maintain and to improve its efficiency. The most important activity - the installation of a new class 100 cleanroom, where the fabrication of diffractive optical elements and the high resolution optical metrology find an adequate technological basis and environment, was completed in early summer 2006. The still ongoing installation of some sophisticated infrastructure will complete that process in the near future.

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 Measurement Techniques

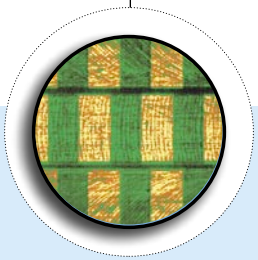
Institute structure

ito-Structure

Teaching
E. Steinbeißer

Chair
Prof. Dr. W. Osten

Deputy
Dr. T. Haist

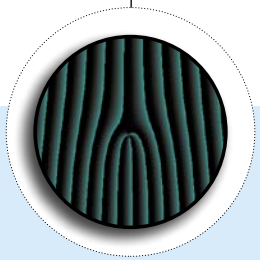


3D-Surface Metrology

Dr. K. Körner

3D-Macro- and Micro-Topometry

- White-Light Interferometry
- Spectral Interferom.
- Confocal Microscopy
- Fringe Projection
- Combined Systems

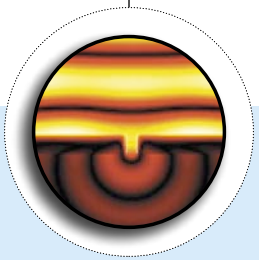


Active Optical Systems

Dr. T. Haist

Modulation of Light

- Adaptive Optics
- Dynamic Holography
- Optical Tweezers
- Active Feedback Loops

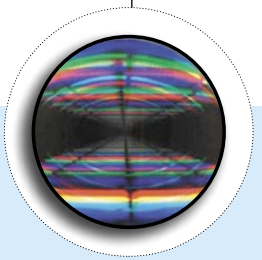


High Resolution Metrology and Simulation

K. Frenner

Interaction Light-Object

- Microscopy
- Super-Resolution
- Scatterometry/ Diffractometry
- Simulation
- Reconstruction

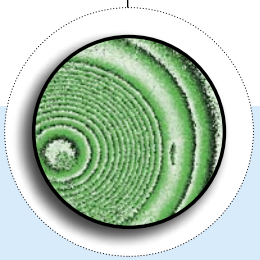


Interferometry and Diffractive Optics

Ch. Pruß

Technology & Components

- Testing of Aspheres
- Microoptics
- Design and Production of DOE
- Wavefront Sensors



Coherent Measurement Techniques

Dr. G. Pedrini

Shape- & Deformation Measurement

- Speckle-Interferom.
- Digital Holography
- Dynam. Processes
- HNDT
- Hologr. Endoscopy
- Hologr. Microscopy

Administration, Software Engineering & Technical Support

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Guest Scientists

Dr. Tonatiuh Saucedo Centro de Investigationes en Optica (Mexico) 1/2005 – 7/2005

Prof. Mikhail Gusev Kaliningrad State University (Russia) 3/2005 – 5/2005

Dr. Cristina Trillo University of Vigo (Spain) 4/2005 – 6/2005

Prof. Wenge Wang Hunan University; PR China 10/2005 - 9/2006

Prof. Percival Almoro University of the Philippines (Philippines) 10/2005 – 9/2006

Dr. Lingfeng Yu * Beckman Laser Institute (USA) 12/2005 – 7/2006

* Humboldt fellowship

Dr. Yoko Miyamoto University of Electro-Communications (JAPAN) 3/2006 - 5/2006

Prof. Leonid Yaroslavsky Tel Aviv University (Israel) 4/2006 – 5/2006

Prof. Chittur Narayanamurthy University of Baroda (India) 4/2006 – 6/2006

Dr. Arun Anand Institute of Plasma Research (India) 5/2006 – 5/2007

Prof. Dayong Wang Bejing University of Technology (China) 12/2006 – 11/2007

Foreign Guests visiting the Institute: 2005 - 2006

Dr. Peter de Groot	ZYGO Corp., Middlefield, USA	April 2005
Dr. Victor Korolkov	Academy of Sciences, Novosibirsk, Russia	Mai 2005
Prof. Charles Joenathan	Rose-Hulman-Univ., USA	Juni 2005
Prof. Mitsuo Takeda	Univ. of Electro-Comm.Tokyo, Japan	September 2005
Prof. Ichirou Yamaguchi	Gunma Univ. Kiryu, Japan	September 2005
Prof. Toyohiko Yatagai	Univ. of Tsukuba, Japan	September 2005
Prof. Malgorzata Kujawinska	Warzaw Univ., Poland	September 2005
Dr. Peter de Groot	ZYGO Corp., Middlefield, USA	December 2005
Dr. Carl Zanoni	ZYGO Corp., Middlefield, USA	December 2005
Dr. Wei Wang	Univ. of Electro-Comm.Tokyo, Japan	March 2006
Dr. Yoko Miyamoto	Univ. of Electro-Comm.Tokyo, Japan	March-May 2006
Prof. Leonid Yaroslavski	Tel Aviv Univ., Israel	April 2006
Prof. Colin Sheppard	National Univ. of Singapore, Singapore	May 2006
Dr. Fernando Mendoza Sanzoyo	CIOP Leon, Mexico	June 2006
Prof. Alexander Poleshchuk	IAE, Novosibirsk, Russia	June 2006
Prof. Malgorzata Kujawinska	Warzaw Univ., Poland	July 2006
Dr. Arie den Boef	ASML Veldhoven, Netherlands	November 2006
Dr. Vadim Banine	ASML Veldhoven, Netherlands	November 2006
Prof. Ventseslav Sainov	CLOSPI, Sofia, Bulgaria	Dezember 2006

Project partners

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

Automotive Lighting GmbH Reutlingen

Carl Zeiss AG Oberkochen

Carl Zeiss SMT AG Oberkochen

DaimlerChrysler AG Germany

Dantec-Dynamic GmbH Ulm

Diehl GmbH Germany

Fisba Optik AG St. Gallen, Switzerland

Heidelberger Druckmaschinen AG Heidelberg

Holoeye Photonics AG Berlin

Innovatis AG Bielefeld

Jenoptik LOS Jena

Leica Microsystems GmbH Wetzlar

Mahr GmbH Göttingen

National Gallery-Alexandros Soutzos Museum Athens, Greece

Optrion s.a Liège, Belgium

Qimonda Dresden GmbH & Co. OHG Dresden

Polytec GmbH Waldbronn

Robert BOSCH GmbH Gerlingen, Schwieberdingen

Sirona Dental Systems GmbH Bensheim

Tate London, England

Zygo Corporation Middlefield, USA

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 option "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 lectures:

- **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)

  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 moire-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 lectures

- optical phenomena in nature and everyday life (Dr. T. Haist)
- opto-electronical image-sensor and digital photography (Dr. K. Lenhardt)
- coherence and polarisation in optics / optics of thin films, surfaces and crystals (Dr. K. Leonhardt)
- optical lithography / measuring techniques for micro-structures (Dr. M. Totzeck)
- design and calculation of optical systems (Dr. H. Zügge / Dr. Ch. Menke)
- optoelectronic devices and fibre sensors (Dr. R. Groves)

Additional studies

- project work and theses within our field of research
- practical course "optics-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 measurements 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
- deflectometry

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Active Optical Systems

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
- adaptive optics
- active wavefront sensors
- dynamic holography
- components, algorithms, and strategies

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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.

ITO has developed a modularised program package called MicroSim for:
- the rigorous computing of the light-object interaction using RCWA
- the visualisation of the near and farfield in 2D and 3D
- the simulation of the microscopic imaging process

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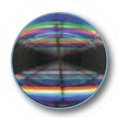

Interferometry and Diffractive Optics

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
- interferometry
- fabrication of diffractive optics
- dynamic wavefront coding

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Coherent Measurement Techniques

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

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