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 2011 about their current 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. Ongoing activities are directed at both the profound investigation of our strategic research topics such as multi-scale sensor fusion, computational microscopy, resolution enhancement, model-based reconstruction, asphere and freeform metrology, hybrid optics, digital holography, and optical systems design, and the modernization of our infrastructure. Meanwhile the operation of our reactive ion etching facility has reached the routine level and the Helios Nanolab 600 has been proven as stable and reliable tool for different processing and inspection tasks in the nano world. Our aim to assure flexible structuring technologies with high resolution and reliability not only for a few crucial experiments but for making dedicated optical components is on a good way.

To ensure that ITO can fulfill its mission under changing boundary conditions, we have founded in 2008 the cooperative network SCoPE at the Stuttgart University. The impact of SCoPE is continuously improving and shows encouraging results in the aimed fields: research, teaching and technology transfer. One of the main objectives is the extension of the curriculum in the field of photonic technologies. With the installation of the joint master course in Photonic Engineering, this ambitious goal could be achieved in spring 2013. Scientists from 3 different faculties – physics, electrical engineering and mechanical engineering – are teaching together now the state of the art in Photonics. A continuous increase in students can be observed as a welcome trend. Furthermore, several joint research projects are on the way
and the cooperation with our industrial partners is progressing in various fields of common interest.

As a member of the Faculty of Mechanical Engineering, the Institute represents the University of Stuttgart in the field of Applied Optics in research and education. Together with our national and international partners, our research work focuses on the exploration of new optical measurement, imaging and design principles and their implementation in new components, sensors and sensor systems. One of our long-term 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 still on our agenda such as the implementation of a multi-sensor measurement systems where the systematic cooperation of different classes of sensors is controlled by a sophisticated assistance system, the implementation of our new software system ITOM that helps us to improve the software development for our setups considerably, the completion of the prototype of our new tilted wavefront interferometer with the goal of market launch in 2014, and the further improvement of our model-based strategies for the solution of different kind of identification problems in optical imaging and metrology.

Our overall research approach “Optical Metrology and Systems Design” is structured into ten main research directions:

- Active Metrology,
- Model-based Metrology,
- Remote Metrology,
- Resolution Enhanced Technologies,
- Computational Imaging,
- Sensor Fusion,
- Sensor Integration,
- Hybrid Optics,
- Simulation, and
- Optical Systems Design.

The strong interaction between these directions gives the Institute the required depth across the broad range of our activities in optics. The considerable number of research projects that are referred to in this report reflects again the success of this approach.

Besides our wide research activities, an ongoing strong commitment of ITO is directed to high-quality teaching on different levels (bachelor, master, PhD). Our consecutive bachelor-master course in medical technology – a joint and challenging project of the University of Stuttgart and the Eberhard Karls Universität Tübingen – is running very successful and enters now the master level. Since the beginning in 2010, ITO is one of the drivers of that course. In 2011 we started a new master course with the dedication “Mechanical Engineering – Micro, Precision and Optical Engineering M.Sc.” and in spring 2013 the mentioned master course “Photonic Engineering M.Sc.” has been implemented.

To cope with our ambitious and extensive approach to Applied Optics, a deep understanding of physics needs to be combined with practical engineering implementation. This is 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 are a good basis to meet these and future challenges.

Stuttgart, July 2013

Wolfgang Osten

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1 Stuttgart Research Center of Photonic Engineering, http://www.scope.uni-stuttgart.de/
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**Eugenio Garbusi** ............................................................... left on 31.08.2011
**David Hopp** ................................................................. left on 30.09.2011
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Dr. Caojin Yuan * ....................... Univ. of Science and Technology Chenggong (China) ........... 12/2009 – 06/2011
Giorgio Pariani .............................. Politecnico di Milano (Italy) .................. 10/2010 – 03/2011
Dr. Francisco Salgado-Remacha ....... Universidad Complutense de Madrid (Spain) .............. 04/2011 – 07/2011
Dr. Vani Chanival ......................... Parul Inst. of Engineering & Techn., Vadodra (India) .................. 05/2011 – 07/2011
Prof. Benfeng Bai .......................... Tsinghua University (China) ............... 02/2012 – 03/2012
Prof. Anand Krishna Asundi .......... Nanyang University (Singapur) ........... 03/2012 – 04/2012
Pavel Pavlicek .............................. Palacky University (Czech Republic) .... 05/2012 – 06/2012
Dr. Dinesh Naik * .......................... The University of Electro-Communication (UEC) (Japan) ........... since 06/2012
Prof. Anhu Li ................................. Tongji University (China) ............... 07/2012 – 01/2013
Foreign Guests visiting the Institute: 2011 – 2012

Prof. Dr. R. Leach ........................................ NPL, Teddington, UK ........................................... January 2011
Prof. J. Coupland ........................................ Loughborough Univ., UK ........................................ January 2011
Prof. Dr. Min Yuung Kim .......................... Kyungpook National University, Korea .........................February 2011
Dr. R. Völk ........................................ SUSS Microoptics, Neuchatel ........................................ March 2011
Dr. Jiri Novak .................................. Czech Technical University in Prague, Czech Republic ......................... May 2011
Prof. Dr. W. Coene .................................. ASML, Veldhoven, Netherlands .................................. May 2011
Prof. Dr. Albertazzi .................................. Univ. Florianopolis, Brazil ........................................... May 2011
Prof. Dr. M. Takeda .................................. UEC, Chofu, Japan ................................................. May 2011
Prof. Dr. B. Javidi .................................. Univ. of Connecticut, Storrs, USA ................................. May 2011
Dr. N. Reingand .................................. Patent Hatchery, Baltimore, USA .................................. May 2011
Dr. C. Gorecki .................................. Univ. Besancon, France .................................................. June 2011
Dr. Arun Anand .................................. Institute for Plasma Research, Gujarat, India .................. June 2011
Prof. Dr. C. Joenathan .................. Rose-Hulman Inst. of Technology; Terre Haute, USA .................. July 2011
Dr. D. Mansfield .................................. Taylor Hobson, Leicecster, UK ..................................... October 2011
Prof. Dr. F. Mugele .................................. Univ. Twente, NL ..................................................... November 2011
Prof. Dr. P. Bryanston-Cross .................. Univ. Warwick, UK ...................................................... November 2011
Prof. Dr. I. Moreno .................................. Univ. Alicante, Spain ................................................ December 2011
Prof. Dr. J. Campos .................................. Univ. Barcelona, Spain ............................................. December 2011
Prof. Dr. C. Joenathan .................. Rose-Hulman Inst. of Technology; Terre Haute, USA .................. October 2012
Dr. P. de Groot .................................. Zygo, Middlefield, USA ................................................ May 2012
Dr. Arie den Boef .................................. ASML Veldhoven, Netherlands .................................. June 2012
Prof. Dr. C. Joenathan .................. Rose-Hulman Inst. of Technology; Terre Haute, USA .................. October 2012
Dr. A. Bernal .................................. Rose-Hulman Inst. of Technology; Terre Haute, USA .................. October 2012

* 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 Microscopy .......................................................................................................................... Jena
Carl Zeiss AG ................................................................................................................................. Oberkochen
Carl Zeiss SMT AG .......................................................................................................................... Oberkochen
Centre Spatial de Liege .................................................................................................................. Liege, Belgium
Centre Suisse d’Electronique et de Microtechnique .............................................................. Zurich, Switzerland
DermoScan GmbH ................................................................. Munich
ESTEC .................................................................................................................. Noordwijk, Netherlands
FOS Messtechnik GmbH ........................................................................................................ Schacht-Audorf
Fraunhofer ENAS ........................................................................................................................ Chemnitz
Fraunhofer IOF ................................................................................................................................ Jena
Fraunhofer IAP .......................................................................................................................... Potsdam
Holoeye AG ................................................................................................................................. Berlin
HSG-IMAT ........................................................................................................................................ Stuttgart
ILM ............................................................................................................................................... Ulm
LaVision GmbH ......................................................................................................................... Göttingen
Mahr OKM GmbH ................................................................................................................................ Jena
Polytec GmbH ............................................................................................................................. Waldbronn
Robert Bosch GmbH .................................................................................................................. Gerlingen
Shenzhen University .................................................................................................................. China
Sick AG ................................................................................................................................. Waldkirch
Siemens AG .................................................................................................................................. München
Staatliche Akademie der Bildenden Künste Stuttgart .................................................................. Stuttgart
Statice ........................................................................................................................................ Besancon, France
Trumpf GmbH + Co. KG ........................................................................................................ Ditzingen
Tsinghua University .................................................................................................................... Peking, China
Université de Franche-Comté ................................................................................................ Besancon, France
University of Eastern Finland ................................................................................................... Joensuu, Finland
VTT Technical Research Centre of Finland ................................................................................ Espoo, Finland
Studying optics

Traditionally our curriculum is primarily directed towards the students in upper-level diplom courses of Mechanical Engineering, Cybernetic Engineering, Mechatronics, and Technology Management. Since the academic year 2011/12 this courses are offered as Master courses and an increasing number of master students is going to join our lectures.

This applies especially for the new master programme “Micro-, Precision- and Optical Engineering” which enjoys great popularity also by students from other universities even from other countries.

Since the academic year 2009/10 we also offer our optics courses within the new bachelor and master program “Medical Engineering”, and since 2012 also within the new master program “Photonic Engineering”. We also welcome students from other courses, such as “Physics” and “Electrical Engineering” and “Information Technology”.

The following list should give you an overview about the lectures given at the ITO. Be aware that not all lectures are suitable for all courses and that the lectures are held in German language.

Core subjects in Master Courses (6 ECTS - Credit Points):

- **Fundamentals of Engineering Optics**
  - Lecture: Prof. Dr. W. Osten
  - Exercise: H. Gilbergs, E. Steinbeißer

- **Optical Measurement Techniques and Procedures**
  - Lecture: Prof. Dr. W. Osten
  - Exercise: Dr. K. Körner, E. Steinbeißer

- **Optical Information Processing**
  - Lecture: Prof. Dr. W. Osten
  - Exercise: Dr. T. Haist, Dr. K. Frenner

- **Fundamentals of Optics**
  - Lecture: Prof. Dr. A. Herkommer
  - Exercise: D. Rausch

- **Optical Systems in Medical Engineering**
  - Lecture: Prof. Dr. A. Herkommer
  - Exercise: D. Rausch
Elective subjects in Master Courses (3 ECTS - Credit Points):

- **Optical Phenomena in Nature and Everyday Life**
  Lecture: Dr. T. Haist

- **Image Processing Systems for Industrial Applications**
  Lecture: Dr. T. Haist, Dr. Ch. Kohler

- **Fundamentals of Colorimetry and Digital Photography**
  Lecture: Dr. K. Lenhardt

- **Polarization Optics and Nanostructured Films**
  Lecture: Dr. K. Frenner

- **Introduction to Optical Design**
  Lecture: Dr. Ch. Menke, Prof. Dr. A. Herkommer

- **Current Topics and Devices in Biomedical Optics**
  Seminar: Prof. Dr. A. Herkommer

Additional studies:

- **project work and thesis within our fields of research**
  (you will find a list of all student project works at the end of this annual report)

- **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

Contact: ofm@ito.uni-stuttgart.de

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
- computational imaging

Contact: aos@ito.uni-stuttgart.de
**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 sub-wavelength information about the structure.

Current research areas:
- modelling and rigorous simulation
- computational electromagnetics
- 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 for aspheres and freeform surfaces that aim to 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 imaging systems, UV-measurement systems, beam shaping applications and wavefront sensing.

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

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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
- remote and virtual laboratories

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Optical Design and Simulation

Focus of the group is the classical optical design of imaging and illumination systems, as well as ray-based and wave-optical system simulations. Main research targets are the development of novel tools for simulation and optimization and the design of innovative complex optical systems for industrial or medical purposes.

Current research topics are:
- imaging design
- illumination design
- optical simulations (ray-tracing and wave-optical)
- phase space methods in optical design and simulation
- complex surfaces in optical system design
- design and simulation of hybrid optical systems

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