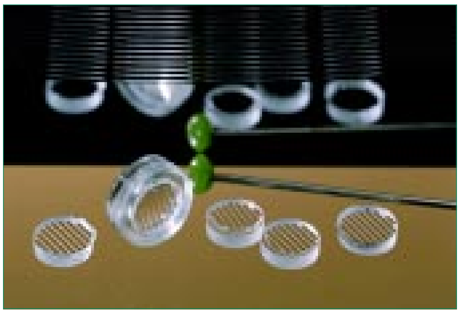
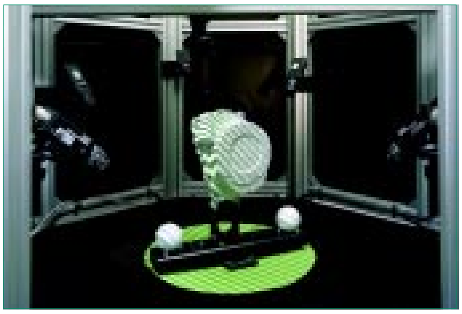
Fraunhofer

Institut
Angewandte Optik
und Feinmechanik

Annual Report 2000





Annual Report 2000
Fraunhofer-Institut für Angewandte Optik und Feinmechanik IOF

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Fraunhofer-Institut für
Angewandte Optik und
Feinmechanik IOF

Postal and Visitors' Address

Schillerstrasse 1
07745 Jena
Phone +49 (0) 3641/ 807-202
Fax +49 (0) 3641/ 807-600
Internet http://www.iof.fhg.de

Institute Director

Prof. Wolfgang Karthe
Phone +49 (0) 3641/ 807-201
e-mail karthe@iof.fhg.de

For Initital Contacts

Astrid Deppe
Phone +49 (0) 3641/ 807-203
e-mail deppe@iof.fhg.de

Preface

Dear reader,

The past year saw a stabilization of the Institute's core competences and a growth of its business lines. As in the years before, the account balance and the earnings situation were positive. A share of more than 80% of the 6.8 million Euro operating budget was covered by project earnings. 45% of this budget resulted from direct contracts with industry and commerce.

An important item in the balance of accounts is the support given to businesses hived-off from the Institute: GRINTECH started as a GmbH (private company limited by shares) marketing the know-how in ion-exchanged glass used for micro-optical components and modules, and unique m.o.d.e. was incorporated as an AG (public limited company) delivering micro-optic solutions with power laser diodes. This increased the number of hive-offs to three; they all still operate on the Institute's premises.
As a result, the Institute has become a cramped place. There is no space for growth, although growth is both necessary and possible in view of developments in our business lines. Technical conditions such as floor load capacities and the technical infrastructure are utilized to the very limits. Only with great difficulty did we manage to install some indispensable, advanced equipment for optical coating and micro-optical assembly.
It is all the more satisfactory, therefore, that a new building for the Institute is under construction on Beutenberg Campus, Jena's new science park. Progress on the site is conspicuous, and the Institute looks forward to enjoying improved conditions from mid-2002. We are much obliged to the federal and Thuringian state governments who made grants for the new building, and we thank all those participating in the construction work for their efforts.

The Fraunhofer IOF has further strengthened its position and efficiency within the scientific community. The Institute collaborated with Jena's Friedrich Schiller University in special research areas and DFG (German Research Society) projects, and conducted joint projects with the Ilmenau University of Technology and non-academic institutes. Outstanding activities were the Mikrotechnik Thüringen MTT 2000 Conference, and the Institute's active participation in drawing up the German Agenda of Optical Technologies for the 21st Century. The Fraunhofer IOF is still involved in following up the Agenda's recommendations. The Institute is one of the partners contributing to the installation of a regional optics network and to the creation of an Optical Technologies Competence Network in a contest organized by the German Federal Ministry of Education and Research.

We wish to express our sincere thanks to all our partners in industry and in our scientific partner institutes for their excellent cooperation, and to the Federal Ministry of Education and Research and the Thuringian State Ministry of Science, Research and Art for their support of the joint projects.

Last but not least, I give my heartfelt thanks to all Fraunhofer IOF staff for their highly competent work, their commitment and their willingness to face new challenges – indispensable ingredients for the Fraunhofer IOF's capability to master its future tasks.

W. Karthe

Jena, January 2001

Fraunhofer IOF Profile

Profile

The Fraunhofer-Institut für Angewandte Optik und Feinmechanik IOF is engaged in research and development in the fields of optical and mechanical processes, components, modules and systems. We develop, fabricate and characterize ultrastable metal/dielectric coatings for optical radiation (up to the extreme UV) of high energy densities, and micro-optical and integrated optical components of glass, Si and polymers, and we upgrade methods for non-contacting optical 3D form measurement and surface topography acquisition. Our competences include the designing of precision mechanical systems, precision manipulators and medical instruments, and the development of assembly processes including those for microsystems.

Fields of Work

The Fraunhofer-Institut für Angewandte Optik und Feinmechanik IOF develops and designs optical and mechanical processes, components, modules and systems. Our main fields of activity are components and subsystems for optical information, laser and illuminating technologies; optical testing and measuring methods including optical sensors; modules for precision mechanical systems; optical coatings, and optical instruments and techniques for medical diagnosis and therapy.
The projects carried out in these fields are supported by our core competences: Design and analysis of optical and optomechanical systems, micro-optical technologies and systems, optical shape and surface testing, and optical coating.
We design, for example, ultrastable multilayer dielectric/metal interference filters for the visible, ultraviolet, and soft x-ray wavelength ranges down to 1 nm and for energy densities up to 30 J/cm², and develop the processes for their manufacture.
Micro-optical and integrated optical components designed at the Fraunhofer IOF, made of plastic materials, silicon or glass, are largely used in industry. Miniaturized optomechanical systems and passive and active components developed at the Fraunhofer IOF are employed in tele- and data communication, sensor technology, and in manufacturing, medical and environmental technologies.
Optical measurement methods including non-contacting 3-D form measurement and surface defect characterization developed at the Fraunhofer IOF are used in industrial applications like Reverse Engineering, dental technique, automotive and airplane system developing, optical element construction, and quality management systems.
In collaboration with, and under contracts from, industrial corporations the institute develops and designs precision mechanical systems, e.g. for precise manipulators and top-resolution lithographic machines, and develops assembly techniques for optical and micromechanical systems.
The projects carried out at the Fraunhofer IOF include methods and equipment for the measurement and testing of the components mentioned, and the manufacture of prototypes and preproduction test series.
By engaging the Fraunhofer IOF's collaboration, industrial clients can enhance their manufacturing capabilities and create new products for the market. The institute is partly funded by state, federal and EU projects. Its permanent staff of 85 and about as many temporary staff work in laboratories and offices totalling about 3000 m² of floor space.

Profile

Le Fraunhofer-Institut für Angewandte Optik und Feinmechanik IOF est spécialisé en recherche et le développement dans les secteurs de l'optique et des procèdés mécaniques, l'élaboration de composants, de modules et de systèmes.
Nous développons, fabriquons et caractérisons des traitements métal/diélectrique d'une extrême stabilité (jusque dans l'EUV) aux hautes énergies, des composants d'optique intégrés et de micro optique sur verre, Si et polymères et nous parachevons des méthodes de mesures optiques 3D sans contact ainsi que des acquisitions de topographie de surfaces. Nos compétences incluent le design de systèmes mécaniques de précision, des manipulateurs de précision, des instruments médicaux et le développement et l'assemblage de procédés incluant ceux pour micro systèmes.

Secteurs d'activités

Fraunhofer-Institut für Angewandte Optik und Feinmechanik IOF conçoit et développe des procédés optiques et mécaniques, des composants, des modules et des systèmes. Nos principaux secteurs d'activités sont les composants et les systèmes d'information optique, les lasers et les technologies d'éclairage, les méthodes de mesures et de tests optiques incluant les détecteurs optiques, les modules pour les systèmes mécaniques de précision, les traitements optiques, et – dans une plus large mesure – les instruments et techniques optiques pour les thérapies et diagnostiques médicaux. Les projets menés à bien dans ces secteurs sont le fruit du fleuron de nos compétences: l'analyse et le design de systèmes optiques et opto mécaniques, les systèmes et technologies de la micro optique, les tests optiques de surfaces et contours ainsi que les couches minces optiques. Nous fabriquons, à titre d'exemple, des filtres interférentiels multicouches métal/diélectrique pour le visible, l'ultraviolet et les rayons X mous jusqu'à des longueurs d'onde de 1 nm et résistants à des densités d'énergie de 30 J/cm² et développons les procédés pour les fabriquer.
Les composants d'optique intégrés et de micro optique produits à Fraunhofer IOF, sur verre, silicium ou sur matériaux plastiques sont largement utilisés dans l'industrie.
Les systèmes opto mécaniques et les composants passifs ou actifs développés à Fraunhofer IOF sont employés dans la télé et data communication, les technologies des capteurs, dans l'industrie des technologies médicales et de l'environnement.
Les méthodes optiques développées à Fraunhofer IOF, telle que les mesures sans contact de forme 3D et la caractérisation des défauts de surface sont utilisées dans des applications industrielles comme le Reverse Engineering, les techniques de dentisterie, la construction aéronautique et automobile, la fabrication d'élément d'optique et les systèmes de gestion de qualité.
En collaboration ou sous contrats avec des industriels, l'institut conçoit et développe des systèmes mécaniques de précision, à savoir des manipulateurs de précision et des machines hautes résolution pour la lithographie, et développe des techniques d'assemblage pour les systèmes optiques et micro mécaniques.
Les développements de projets menés à bien au Fraunhofer IOF incluent les méthodes et équipement pour les mesures et tests des composants mentionnés, la manufacture de prototypes comme les tests de pré-production en série.
En engageant une collaboration avec Fraunhofer IOF, les clients industriels augmentent leur potentiel de fabrication en créent de nouveaux produits pour le marché.
Cet institut est en partie financé par l'état, les projets européens et régionaux. Son effectif permanent est de 80 personnes et compte autant en effectif temporaire dans ses laboratoires et bureaux qui s'étendent sur une surface de 3000 m².

Advisory Committee

The Advisory Committee supports the Fraunhofer Institute as well as the Board of Directors of the Fraunhofer-Gesellschaft and is comprised of the following members:

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Carl Zeiss Jena GmbH
(Vorsitzender)

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Universität Stuttgart,
Lehrstuhlinhaber für Technische Optik
(stellvertretender Vorsitzender)

Dr. K. Bartholmé
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Friedrich-Schiller-Universität Jena,
Physikalisch-Astronomische Fakultät

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Dr. L. Ross
JDS Uniphase Photonics
GmbH & Co. KG
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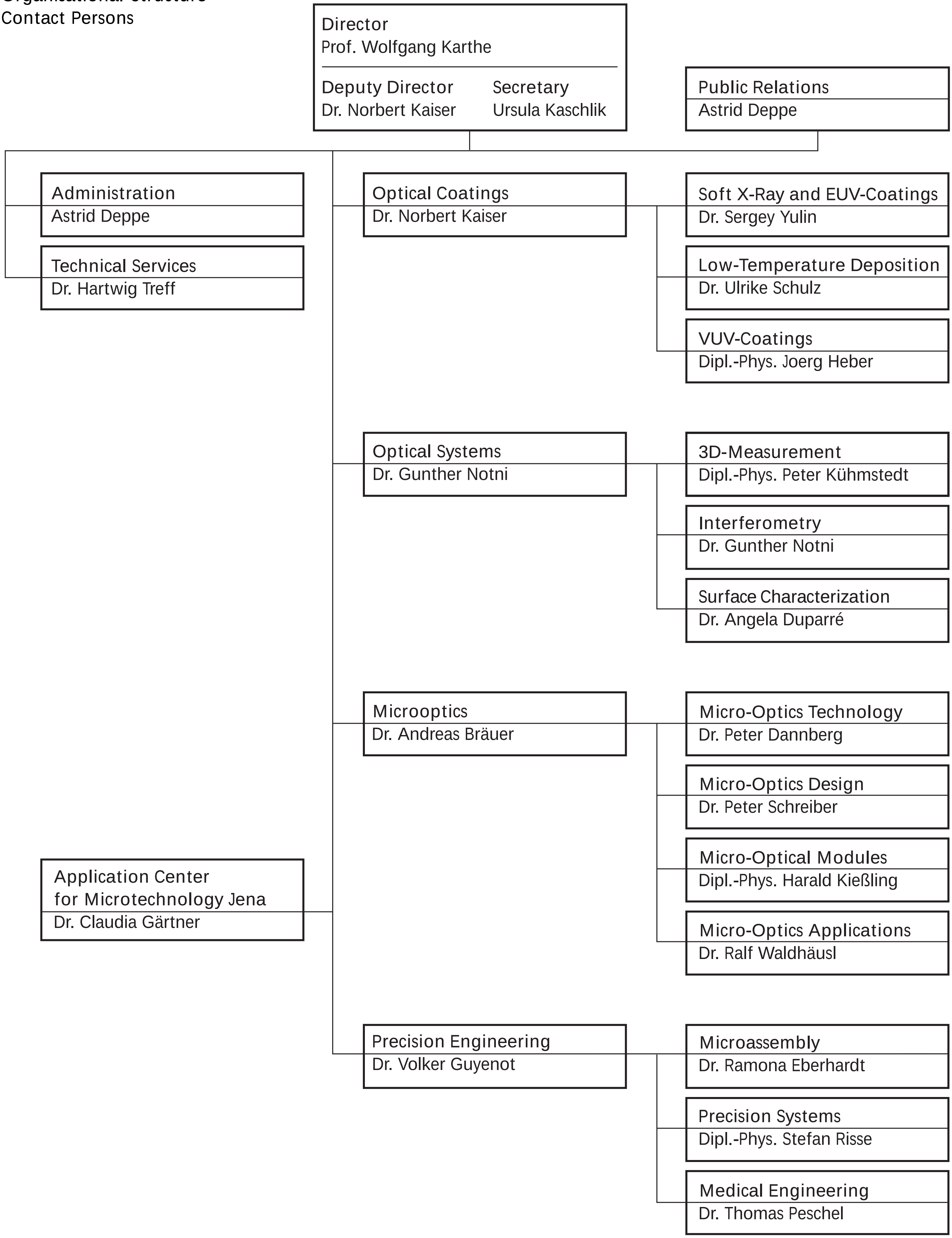
Prof. G. Scarbata
TU Ilmenau, Fakultät für Elektrotechnik und Informationstechnik,
Fachgebiet Mikroelektronische
Schaltungen und Systeme

Herr J. von Schaewen a. G.
Ministerialrat im Bundesministerium
für Bildung und Forschung, Bonn

Prof. B. Wilhelmi
Jenoptik Strategische Technologieentwicklung GmbH, Jena

Organisational Structure
Contact Persons



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    - **Microassembly** Dr. Ramona Eberhardt
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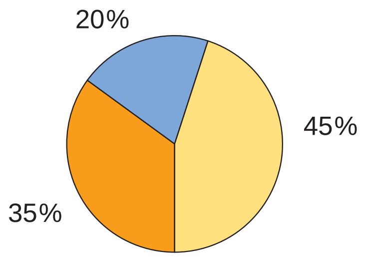
    - **Medical Engineering** Dr. Thomas Peschel

Competences of Fraunhofer IOF

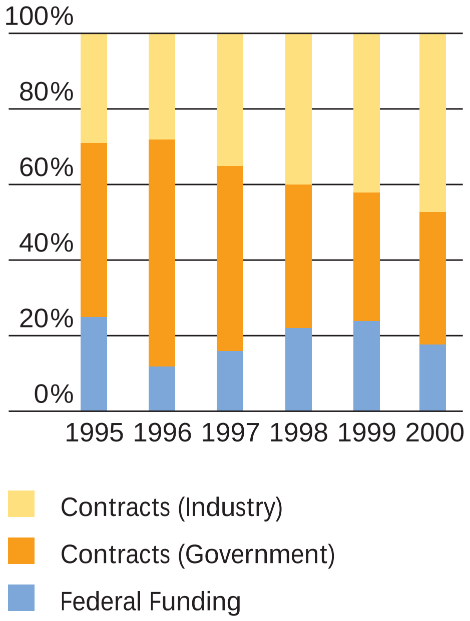
	Competences	Design and analysis of optical and optomechanical systems	Microoptics technology and systems	Optical shape and surface measurement	Optical coatings technology
Business fields					
Devices and Subsystems for optical information technology, laser technology and illumination		●	⬤	·	·
Optical test and measuring methods/optical sensing		•	●	●	
Modules for mechanical precision systems		⬤			
Optical coatings		•			⬤
Medical – optical equipment and methods		·		•	

Fraunhofer IOF Statistics

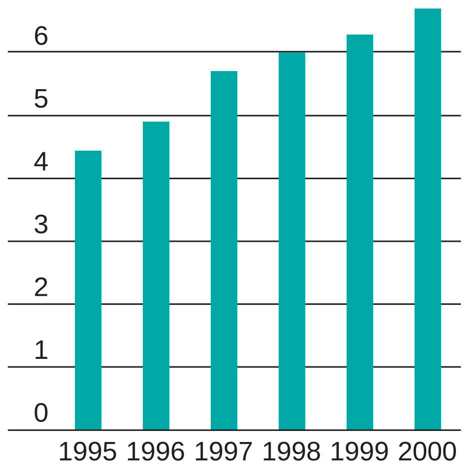
Budget year 2000



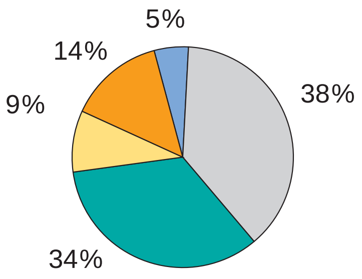
Budget



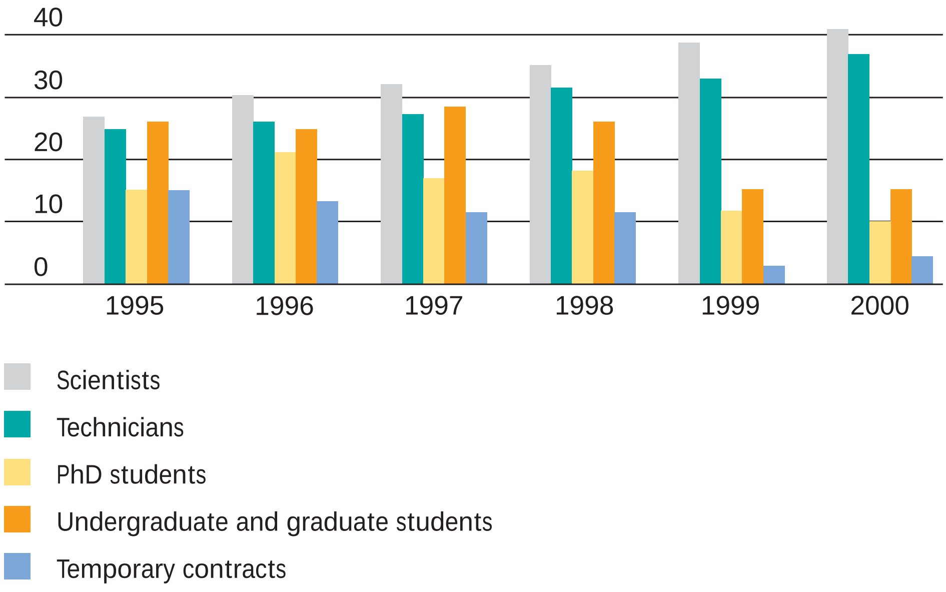
Budget (Mio Euro)



Staff year 2000



Staff (overall employment figures)



The Fraunhofer-Gesellschaft – Overview

The Fraunhofer-Gesellschaft is the leading organisation of applied research in Germany. It undertakes contract research on behalf of industry, the service sector, and government.

Customers are provided with rapid, economical and immediately applicable solutions to technical and organisational problems.

The Fraunhofer-Gesellschaft works within the framework of the European Union’s technology programmes, striving to improve the competitiveness of European industry through the enhancement of technical systems and processes. The international collaboration is also promoted through Fraunhofer branches in the USA and in Asia. The association´s headquarter is in Munich.

Commissioned and funded by the Federal and State governments, the Fraunhofer-Gesellschaft undertakes strategical research projects which contribute to the development of innovations in key technologies and spheres of major public concern, such as energy, transport and the environment.

A staff of around 9.000 are employed at 48 research establishments throughout Germany, most of them are scientists and engineers.
The operating performance of the Fraunhofer-Gesellschaft in 1999 was around 700 million Euro, of which almost 600 million Euro was accounted for by contract research.

The Fraunhofer-Gesellschaft was founded in 1949 and is a recognised public welfare institution. Among its members are well-known companies and private patrons who contribute to the promotion of its application-oriented policy.

The Fraunhofer-Gesellschaft takes its name from the Munich scholar Joseph von Fraunhofer (1787-1826), who was equally successful as a scientist, inventor and entrepreneur.

Selected Results

Fraunhofer IOF research and development activities carried out during 2000 and brought at least to a preliminary stage of completion are presented here. The work undertaken by the various departments at the institute illustrates the competence in cooperating with both private enterprises and multiinterest projects.

Our competence matrix has been adapted to the development of business fields and the concentration of our competences. The qualitative and quantitative extension of the core competence in the design of optical and optomechanical systems, its concentration on microoptics and combination with mechanical precision systems were continued.

In optical coating technology we focused on the development of high performance coatings for short wavelength. With respect to the next generations of photolithography equipment the research activities were extended in the wavelength range from 157 nm to 1 nm. In the soft x-ray range reflectivities of the coatings of more than 67 % and thermal stability up to 600 °C have been achieved. Progress in optical coatings of plastics is also presented in the report.

The projects in precision engineering show also the competence of the Fraunhofer IOF for developing semiconductor fabrication equipment. The great demands on positioning precision in next generation lithography equipment could be achieved outstandingly for special chucks and wafer stages. The know-how of the Fraunhofer IOF in microoptics is demonstrated by the papers on devices for optical communication and the examples for fiber assembling and wafer scale replication. Progress in 3-D shape measurement could be achieved by application in a few projects, the research capacity had to be increased for this field. Further development of self-calibrating technique and evaluating methods is presented. Last but not least an example of the Fraunhofer IOF cooperation with clinical research in described in the paper on cardiotherapy.

Optical coatings for soft x-ray applications

S. Yulin, T. Feigl, T. Kuhlmann, and N. Kaiser

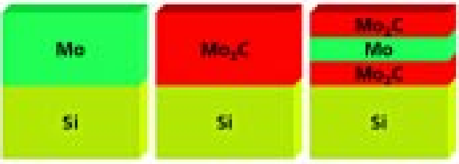


Fig. 1:
Improvement of the thermal stability of Si-based multilayers by the replacement of Mo by Mo_2C and the insertion of Mo_2C diffusion barriers.

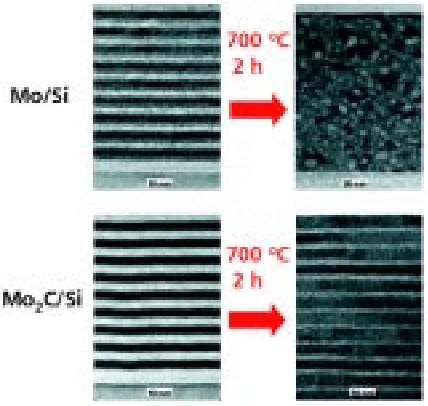


Fig. 2:
TEM images of 7 nm Mo/Si and Mo_2C/Si multilayer mirrors in as-deposited state and after annealing at 700 ˚C for 2h.

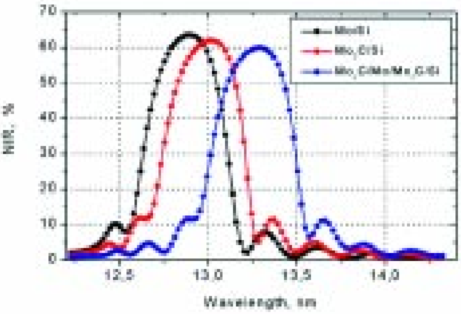


Fig. 3:
Normal incidence reflection (NIR) for different multilayer systems measured with synchrotron radiation at the PTB reflectometer at BESSY.

Introduction

A trend towards the utilization of ever shorter light wavelengths can be observed in many applications, including extreme ultraviolet (EUV) right on up into the range of soft x-rays. Photolithography is one of the most significant applications for short wavelengths in the field of optics. This results from the fact that smaller structures can be replicated on microchips with the help of shorter wavelengths. Thus the semiconductor industry has enormous interest in the continuing development of this technology. By now work is being conducted on lithography techniques for the distant future (NGL – next generation lithography): As compared with other competing technologies, EUV lithography with wavelengths of only 10 to 14 nm appears to have very good prospects. All materials are so absorptive within this spectral range that imaging with lenses is not possible. The optical system must therefore be entirely made up of mirrors. Because the reflectivity at any single interface is extremely small, adequate reflectivity can only be achieved within this spectral range through the use of so-called multilayer mirrors. These consist of many individual layers made of two different materials, each of which has a thickness of about ¼ of the wavelength. Superposition of the reflex amplitudes at all interfaces (interference) results in reflectivity for the entire system which can exceed 70%, for example with the material combination molybdenum and silicon which is commonly used in the EUV range. This presupposes the maintenance of extremely tight accuracy tolerances as regards the thickness of the individual layers, as well as minimal roughness at the interfaces. The fact that the thickness of the layers amounts to only a few atoms represents a great challenge for coating technology, as well as for layer analysis methods.

Multilayer mirrors for EUV

We focused our interest on the development of multilayer mirrors that provide not only high reflectivity, but also a good thermal stability to take into account the heating of the multilayer by EUV irradiation of a plasma source that will be used in future EUV-lithography tools. In fact, we have shown that the thermal stability of Si-based multilayer mirrors can be considerably improved in two ways: (1) The replacement of Mo by Mo_2C and (2) the insertion of thin Mo_2C layers at the silicon interfaces which act as interdiffusion barriers (Fig.1). All multilayer mirrors were prepared by dc-magnetron sputtering, designed for normal incidence at about 13 nm and compared in terms or reflective properties and heat resistance in the temperature range from 200 °C to 700 °C. X-ray scattering, transmission electron microscopy (Fig.2), atomic force microscopy and synchrotron radiation were used for the characterization of the multilayer structures. So far, we achieved a maximum NIR (normal incidence reflectivity) of 65.4 % at 12.9 nm wavelength for Mo/Si, 61.9 % at 13 nm wavelength for Mo_2C/Si and 59.9 % at 13.3 nm wavelength for Mo/Mo_2C/Si/ Mo_2C multilayers in as-deposited state (Fig. 3). The small angle X-ray reflectivity (Fig. 4) and the multilayer period of Mo/Si multilayer mirror drastically decrease after annealing to temperatures above 300 °C, whereas the corresponding changes in Mo_2C/Si and Mo/Mo_2C/Si/ Mo_2C multilayers occur after heating to temperatures above 600 °C and 500 °C, respectively. The high thermal stability and excellent reflective properties of Mo_2C/Si multilayer mirrors provide a good potential for their use as elements in EUV optics under heavy radiation load of plasma, synchrotron etc.

Multilayers mirrors for soft X-rays

The use of thin-film technologies for extremely short wavelengths is not restricted to the field of photolithography. Optics for extremely short wavelengths are also required for x-ray astronomy, for research with the help of synchrotron radiation and for the development of X-ray microscopes. For example, the wavelength range from 2.3 to 4.4 nm, the so-called water window, is of special interest in the field of X-ray microscopy. This energy range is situated between the absorption edges of oxygen and carbon, which means that water is significantly more transmissive for X-ray radiation than are organic molecules. This narrow range of wavelengths thus allows for good contrast for the examination of biological objects.

The development of multilayer mirrors for this wavelength range is even more difficult than in the EUV range because individual layers of less than 1 nm thickness must be produced, and the number of periods must be increased to approximately 300. We have chosen the material combination Cr/Sc because of its high reflective properties and the good interface stability. The multilayers deposited by magnetron sputtering show smooth interfaces in the multilayer stack even for very small period spacings, as shown in TEM-images (Fig. 5).

The reflectivity of the samples was measured at the PTB reflectometer at BESSY in Berlin using the water window wavelength l = 3.16 nm. For normal incidence the measured reflectivity is 6%. For d = 1.86 nm we obtain R = 13% and for d = 3.17 nm the measured reflectivity is R = 30% (Fig. 6).

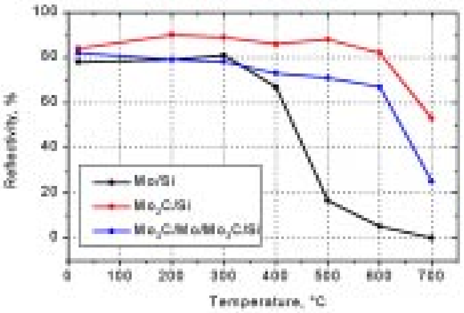


Fig. 4:
Evolution of reflectivity at l = 0.154 nm for different multilayer systems with increase of annealing temperature.

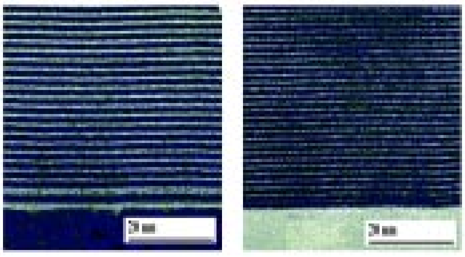


Fig. 5:
TEM images of Cr/Sc multilayers with periods 2.35 nm and 1.57 nm.

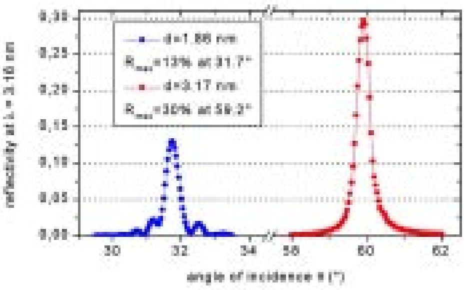


Fig. 6:
Reflectivity of Cr/Sc multilayers at the water window wavelength l = 3.16 nm.

Hard UV coatings for free electron laser

A. Gatto and N. Kaiser

Country	Storage Ring	Minimum wavelength
France	SuperACO	300 nm
Germany	DELTA	420 nm
Italy	ELETTRA	**218 nm [3]**
Japan	UVSOR	238 nm
	NIJI-IV	212 nm
USA	Duke University	194 nm

Table 1:
Table of operating Storage Ring FEL's

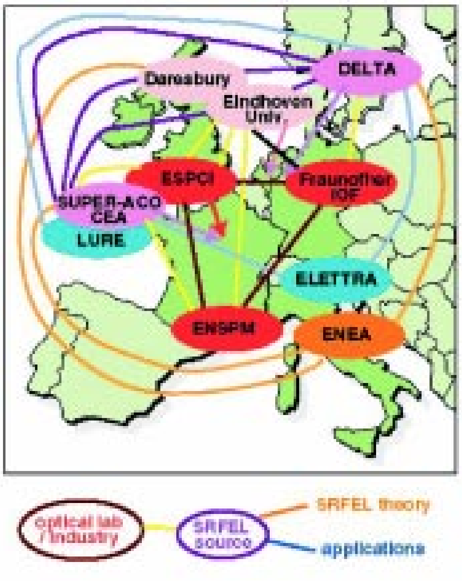


Fig. 1:
EU Network "Storage Ring Free Electron Lasers down to 200 nm" Fraunhofer IOF manages and coordinates the optical task.

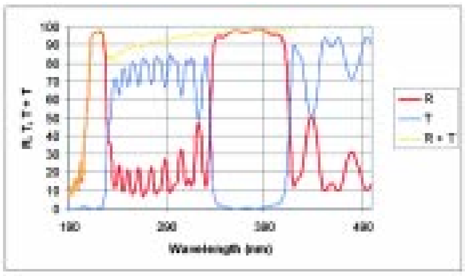


Fig. 2:
Dual Band Mirror HR @ 220 nm and 380 nm designed for the Elettra Storage Ring Free Electron Laser.

Free Electron Lasers (FELs) are tunable sources of monochromatic and coherent radiation delivering high peak and average power. FELs have the great advantage of being easily tunable in wavelength as well as being able to achieve very high average and peak powers without material breakdown. Being intense and tunable light sources in the UV/VUV range, they can fill the gaps in the wavelength regions covered by conventional lasers.

At the moment, there are only six operating storage ring FELs in the world and in all these facilities (listed in Table 1), there is a continuing effort to reduce lazing wavelength and improve the quality of the FEL as an advanced light source for scientific applications. In particular, tunable and reliable operation with high power below 200 nm is a very important target since it cannot be presently obtained with conventional lasers.

In the context of a EU network, Fraunhofer IOF is working for the three European SRFELs, leading and coordinating a large R&D program for the design of prototype FEL mirrors. Indeed, it is crucial to produce high reflectivity and robust mirrors in order to optimize the extracted power required for most of the applications.

The front mirror of the laser cavity receives not only the first harmonic where the lasers operates but all the synchrotron radiation emitted by the undulator: a wide spectrum extending towards X-rays. These short wavelengths are responsible for the mirror degradation which results from changes in the coating materials (high induced absorption, color centers, heating ...) as well as from carbon contamination.

For Fraunhofer IOF Jena, Plasma and Ion Assisted Deposition techniques had provided dense films of low absorption also in the UV region close to the electronic band gap of the oxide materials (SiO_2, Al_2O_3, HfO_2) which were employed with very good results. The degradation tests have been successfully validated at both the synchrotron facilities Super ACO (Orsay, France), Elettra (Trieste, Italy) and Delta (Dortmund, Germany). Checked tests have proven the good robustness of IOF mirrors able to maintain their reflectivity even under extreme environmental conditions /1/, /2/ such as synchrotron radiation.

More over, in May 1999, the Elettra FEL, "third-generation" synchrotron radiation facility, lazed at both 356 nm and 220 nm /3/ using IOF dual band mirror (Fig. 2).

The lowest tuning range achieved was 217.9 nm – 224.1 nm. New designs are currently in fabrication. As shows in table 1, "218 nm" is yet actually the third world record, just behind the Japanese and the American machine.

References

/1/ A. Gatto, et al.,
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Abrasion resistant antireflection coatings for plastic optics

U. Schulz, U.B. Schallenberg*, and N. Kaiser
* mso jena Mikroschichtoptik GmbH

Transparent plastics like PMMA, Polycarbonate, COC and Zeonex are widely used today for optical and optoelectronic components.
Coating of these soft components is mainly intended to improve their mechanical durability. Additionally, antireflection coating is necessary for many optical applications.
Plasma-Ion Assisted Deposition (Plasma-IAD) using plasma source APS is a well applied technique to deposit optical interference coatings without additional substrate heating. Nevertheless, temperature on a polymer substrate can reach a critical value of about 90°C and higher if thick layers have to be deposited. The increase of temperature is mainly determined by the high energy of electron beam gun during evaporation of high refractive material Ta_2O_5.
A new coating design AR_hard (Fig. 1) has been developed to produce abrasion-resistant antireflective coatings on plastics. In contrast to other antireflective coatings, high refractive index layers are almost evenly distributed over the stack. The total thickness of coatings of this design type can be adjusted from about 800 nm to over 2200 nm.
The temperature on plastic substrates during the PVD process has been reduced compared to common coating stacks by using thinner layers with high refractive index (Fig 2).

The coating has been deposited on PMMA, PC, Zeonex and COC.
The average reflectance of plastic surfaces was reduced from about 4–5% to values lower than 0.5% in the visible spectral range. The abrasion resistance of the coatings deposited on plastics corresponds to that of a single SiO_2 layer of the same thickness (Fig. 3).

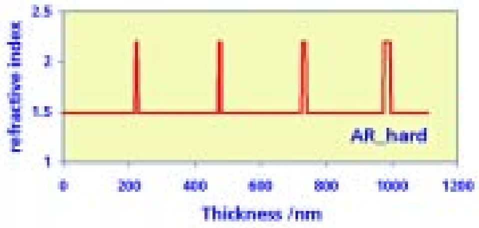

Fig. 1:
Coating design AR_hard – schematic presentation of the alternating high index (n = 2.0) and low index (n = 1.46) layers in dependence on geometrical thickness of coating.

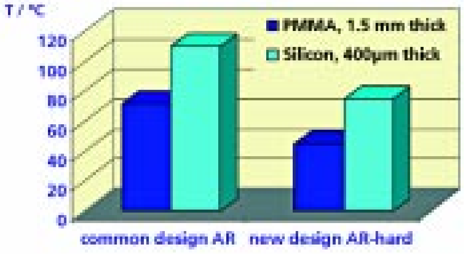

Fig. 2:
Maximum temperature on backside of PMMA and silicon-substrates during coating with common antireflective system and using the novel design AR_hard.

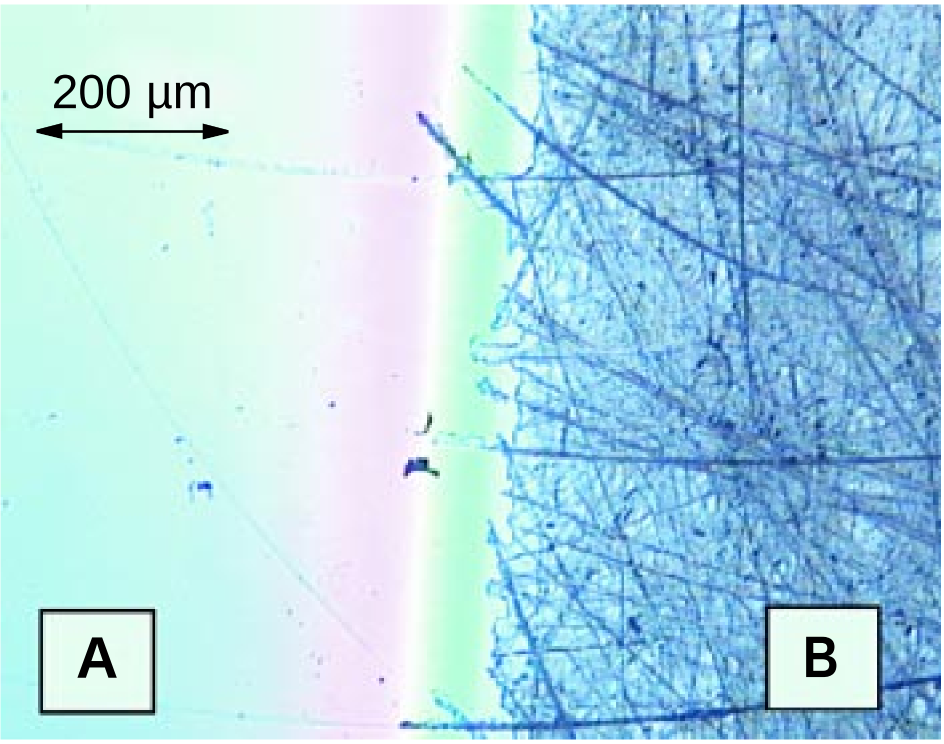

Fig. 3:
Light Microscope image of PMMA-samples after rubbing with Steel Wool (F » 0.1 N)
A – coating AR_hard, B – no coating

Coating of new polymers for optical applications

P. Munzert, U. Schulz, and N. Kaiser

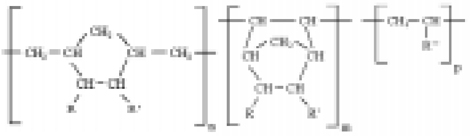

Fig. 1:
Molecular structure of the new polymers
left: Cycloolefin-Polymer (COP) ZEONEX®
right: Cycloolefin-Copolymer (COC) TOPAS®

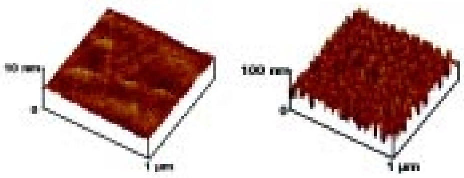

Fig. 2:
AFM images of a Zeonex substrate
(left: untreated, right: after Ar-plasma treatment 1800s, 80V BIAS)

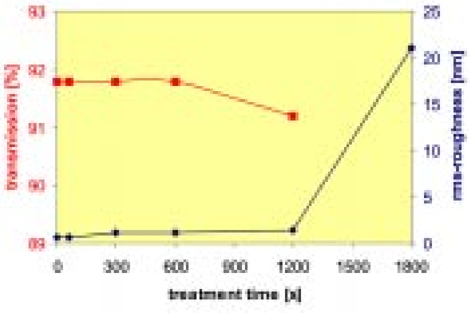

Fig. 3:
Rms-roughness and transmission (at 400nm) of a Zeonex substrate (1mm thick) depending on Ar-plasma treatment time with 80V BIAS

New polymers will play a major role as materials for optics and optoelectronics in the next decades. A new class of amorphous thermoplastics, the cycloolefinic polymers (known as ZEONEX® and TOPAS®), was introduced to the world market about five years ago /1/. These materials promise considerable advantages concerning optical properties, heat distortion temperature and water uptake compared to PMMA and PC, which are still common materials for optical applications until today.
Surface functionalisation by thin film coatings is one of the main requirements for plastic optical parts. High scratch resistance, anti-reflection properties, electrical conductivity or wettability of polymer surfaces can be obtained by coating with inorganic layer systems.
For PVD (physical vapor deposition) -coating problems, like adhesion of the inorganic layer on the organic substrate, a solution must be found for every single polymer. Broad basic coating knowledge exists only for PMMA and PC as a result of many years of research.
Our investigations are part of the project "Polymere 2000", which is financed by the Arbeitsgemeinschaft industrieller Forschungsvereinigungen (AiF) under AiF-FV-Nr.12180BR. More than 10 different companies from the optics and coating industry take part in the project committee.

Aim of this project is to investigate the coatability of cyclopolyolefin substrates and their behavior under evaporating and pretreatment conditions, to create a basic knowledge base for the development of industrial coating procedures.
The behavior of ZEONEX® and TOPAS® sample surfaces under pretreatment and coating conditions, simulated by Ar ion bombardment and UV radiation from a plasma, has been investigated. It was possible to increase the samples free surface energy with Ar-plasma pretreatment, even with short treatment times (< 5s). A high surface energy value is a condition for good coating adhesion. For extremly long plasma treatment times a strong increase of surface roughness as well as a decrease of transmission in the visible wavelength range were determined.

The results indicate that normal coating conditions with pretreatment times < 300s and moderate BIAS-voltage will not influence a polycycloolefin surface in a negative way. Above that, very short plasma pretreatment is sufficient to increase free surface energy values, so the "possible parameter window" of PVD-coating processes should be much wider for the polycycloolefins than for PMMA or PC.

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Substrates and optical coatings for 157 nm applications

J. Heber and N. Kaiser

157 nm radiation of F_2-excimer laser is considered to be one of the promising exposure tools for the 70 nm node in further integrated circuit production. /1/, /2/ Similar to the general concept at 248 nm and 193nm, a 157 nm lithographic tool will probably consist of the following components:
157 nm lithography laser, beam delivery system, beam forming unit and projection optics, which all together form a closed, purged beam-line.

Due to material properties and expected higher optical losses, the projection optics will probably be a catadioptric one /3/, although all reflective designs have also be proposed for projection purposes /4/. Generally, different types of high effective optical coatings are required for 157 nm applications: high reflectors (HR) and antireflection coatings (AR) for different angles of incidence.

Fluoride single layers and multi-layer optical coatings for use in the vacuum ultra-violet spectral region, especially at 157 nm have been deposited by a conventional vacuum processes. The optical properties have been studied to evaluated limiting factors on their performance. Additional to coatings, surface and bulk properties of CaF_2 substrates have been investigated and first results on the influence of roughness and surface contamination on the transmittance are presented.
For dielectric mirrors, reflectance values of 95%–96% at near normal incidence have been measured at 157nm for conventional deposited QWOT-mirror coatings. For both side AR-coated CaF_2, a residual reflectance well below 1% and a high transmittance have been obtained. The optical performance of these multi-layer coatings is limited by absorption (intrinsic, impurities) and by scattering losses due to the morphological and crystalline structure of the fluoride films. Further investigations and optimisation of technology are necessary to improve the optical performance of the layer systems.

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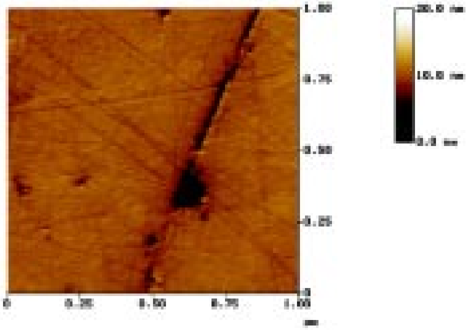

Fig. 1:
Normal polished CaF_2 substrate

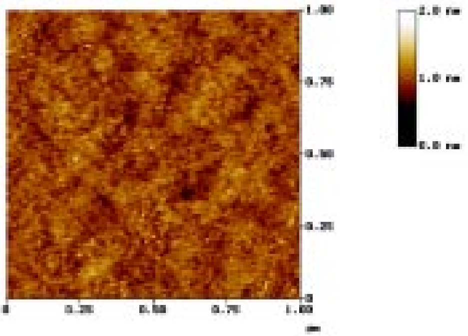

Fig. 2:
Super-polished CaF_2 substrate

AFM scans of a normal polished and a super-polished CaF_2 surface. Note the different height scale. Super-polished samples show a better smoothness and a very low defect density.

Light scattering measurement with 157 nm techniques

A. Duparré, M. Flemming, S. Gliech, Ch. Petit, and J. Steinert

As a result of lithography systems moving to ever shorter wavelengths, industry and research are facing drastically increasing requirements for low-scatter optics in the DUV/VUV spectral region. Hence, appropriate methods for scattering measurements at the wavelengths 193 nm and 157 nm are necessary, which meet the industrial needs.

In earlier reports, we reported on total scattering (TS) measurements of optical coatings and substrates in the visible, IR and UV extending to 193 nm with a set-up operating in air /1,2/. In this report, a new scattering instrumentation for use at 157 nm (as well as 193 nm) is presented.

The design and construction of the equipment for measurements at 157 nm was driven by the following demands:

- Measurements must be performed either in vacuum or dry nitrogen to avoid absorption of VUV light by ambient oxygen and water vapor.
- Both operation in vacuum and nitrogen shall be possible, as comparison of results obtained under different conditions is desirable.
- Vacuum better than 1 x 10^{-4} mbar as well as high purity nitrogen are required.
- Time for sample change in the measurement chamber shall not exceed several minutes.
- Easy 2D mapping of sample surfaces.
- Easy change from backward to forward scattering modus in the chamber.

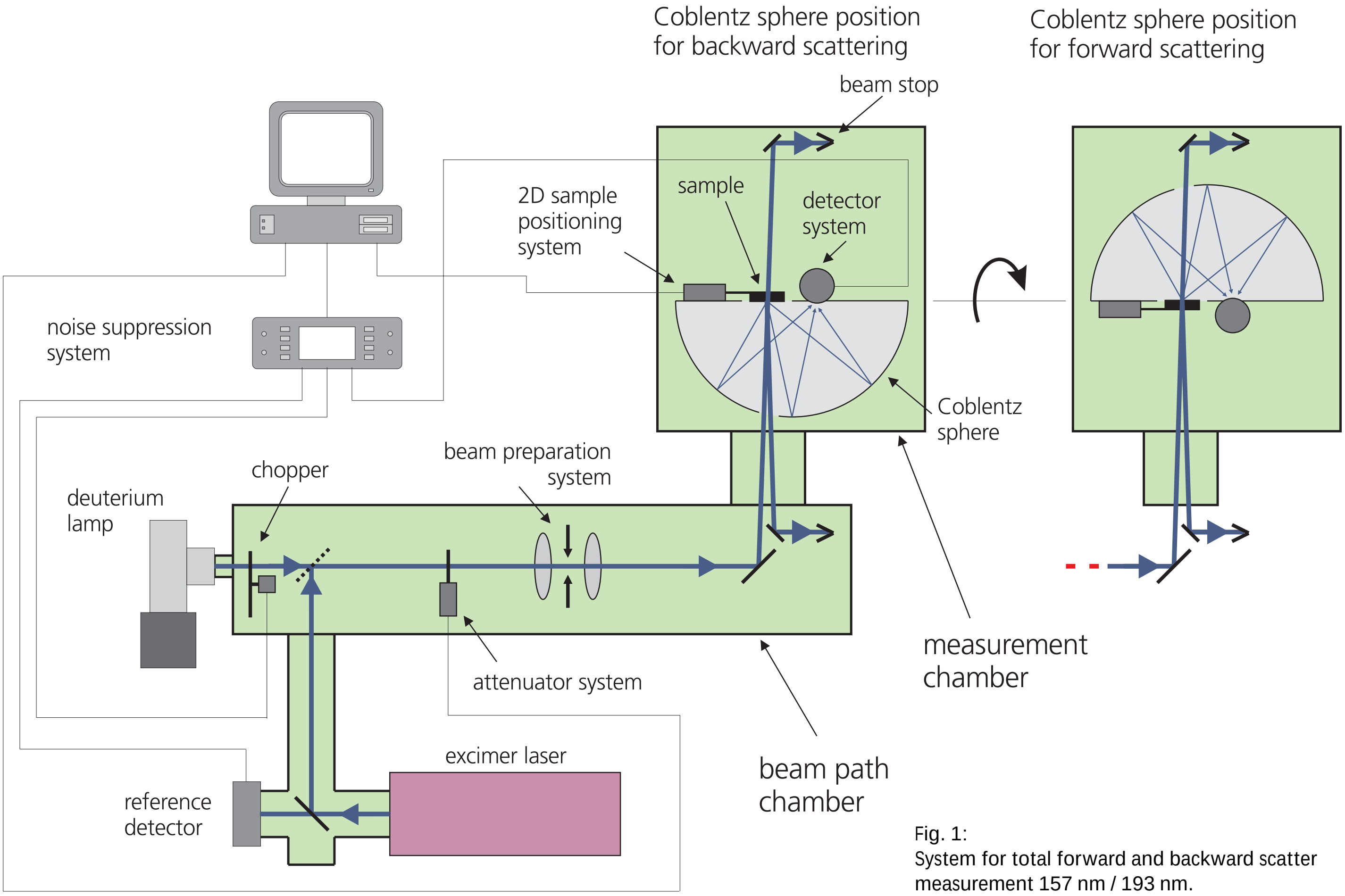

Fig. 1:
System for total forward and backward scatter measurement 157 nm / 193 nm.

- Both excimer laser and deuterium lamp as alternative radiation sources.
- High sensitivity.
- Measurement procedure shall follow the instructions of ISO/DIS 13696 as far as possible.

Furthermore,

- VUV-set-up shall be suitable for 193 nm measurements as well.
- The equipment (beam path, detection system etc.) shall also enable transmission, reflectance and lifetime experiments.

According to these requirements, we built the instrumentation schematically shown in Fig. 1. The well proven principles of the arrangement described in /1/ were kept similar wherever this was possible. Main components of the new set-up are:

- Coblentz sphere designed for scattering angular range from 2° to 85° in the backward and forward directions.
- Two vacuum chambers (steel with special surface treatment, see picture of Fig. 2): measurement chamber containing the Coblentz sphere with backward/forward positioning system, sample positioning unit, detector unit; beam preparation chamber containing optics and beam attenuator.
- Detector: photomultiplier (R1220, Hamamatsu).
- Two light sources: 30 W deuterium lamp (L7293, Hamamatsu), excimer laser (LPF 220i, Lambda Physik) with pulse energies > 25 mJ at 157 nm and > 275 mJ at 193 nm.
- Two different systems of noise suppression: lock-in-amplifier when using deuterium lamp, pulse integrating system for excimer laser operation.

Figs. 2 and 3 display pictures of the entire set-up and the Coblentz sphere in forward scatter position, respectively.

The system was successfully tested and first measurements were carried out. Even though optimization of the set-up has just started, high sensitivity has been accomplished: scatter levels as low as 1 ppm and < 10 ppm in the forward and backward directions, respectively. Change from forward to backward modus takes only 10 s. Sample change is accomplished within 6 minutes time.

Up to now, there is no established calibration procedure nor standard available for 157 nm. Our future studies will address this problem and search for new solutions. As a preliminary attempt to "calibrate" the measured data, we used as a 100% signal the incident beam directed into the Coblentz sphere, which is then reflected on the detector.

In the following, first results of measurements are presented. Both the D_2 lamp and the excimer laser were used as radiation sources. Figs. 4 and 5 refer to experiments with the D_2 lamp, the other measurements were performed with the excimer laser.

Fig. 4 shows 1D scans of back-scattered light from multilayer fluoride mirrors. One mirror was measured after deposition, the other one after aging effects had caused degradation. In Fig. 5, the results of backward and forward scatter measurements on ground CaF_2 are given. These samples are used as diffuser discs in front of the detector in the 157 nm arrangements. Fig. 6 compares backscatter measurements on HR fluoride mirrors from different suppliers. Fig. 7 provides the TS curves of differently polished CaF_2 substrates together with

Fig. 2:
157 nm / 193 nm TS set-up.

Fig. 3:
Coblentz sphere, position for total forward scatter measurement.

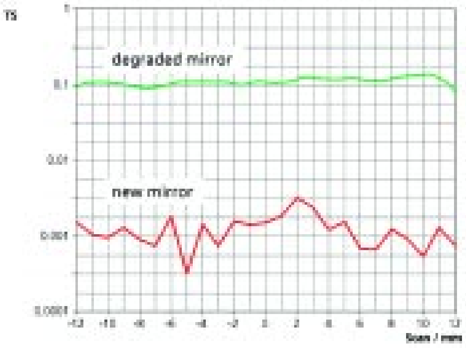

Fig. 4:
Backscatter measurements from HR multilayer (fluoride) mirrors on CaF_2 substrates, radiation source: D_2-lamp.

a two dimensional mapping for one sample. The forward and backward scatter of a 157 nm AR coating on CaF_2 with a corresponding two dimensional mapping is given in Fig. 8.

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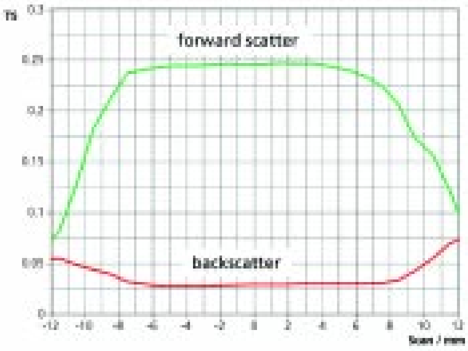


Fig. 5:
CaF_2 diffuser, total scatter measurements, radiation source: D_2-lamp.

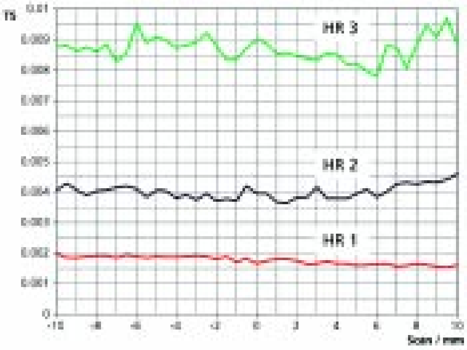


Fig. 6:
Backscatter measurements from HR multilayer (fluoride) mirrors on CaF_2 substrates, radiation source: excimer laser.

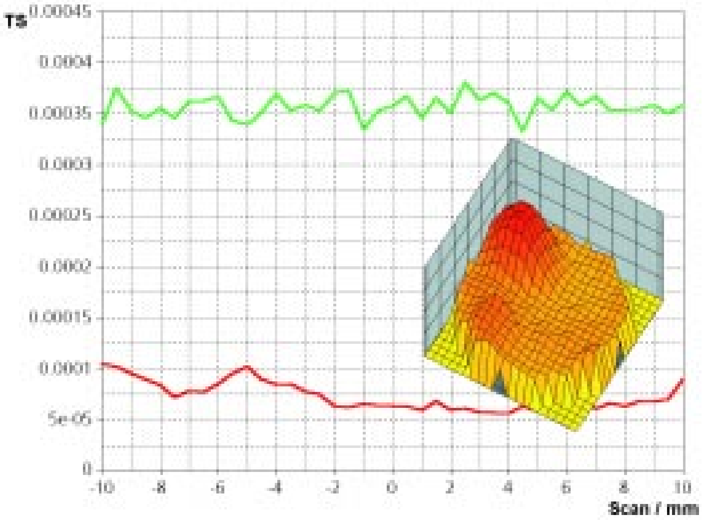


Fig. 7:
Forward scattering measurements on CaF_2 substrates with different polishing qualities, radiation source: excimer laser. Rms roughnesses of these samples calculated from measurements with mechanical profiler: low scatter sample: » 0.3 nm, high scatter sample: » 0.8 nm.

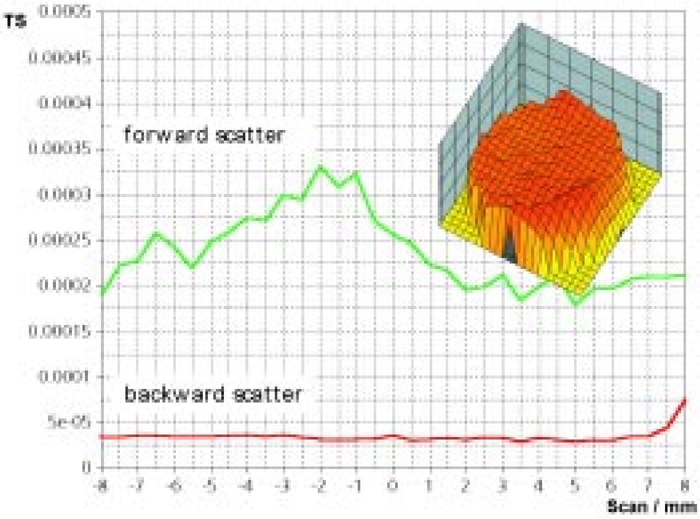


Fig. 8:
Forward and backward scattering measurements of AR coating on CaF_2, radiation source: excimer laser

Electrostatic chucks for vacuum lithography

G. Kalkowski, S. Risse, G. Harnisch, and V. Guyenot

Motivation

At ambient conditions, picking and placing of silicon wafers or fixture during lithographic exposure is done with vacuum chucks. This ensures flat adherence and avoids scratches and other damage as is common when using mechanical clamps. Inside vacuum, this principle doesn't work and mechanical clamps are still used widely. As a consequence, wear and generation of particles, uncontrolled wafer bending and poor thermal contact of the wafer to the support are encountered.
For advanced lithography applications this is not acceptable and electrostatic chucking has emerged as a means to avoid such problems. Through the generation of an electric field between wafer and supporting chuck, an attractive force is exerted on the wafer. The force is distributed homogenously over the surface, can be switched on/off and adjusted electrically. It ensures flat wafer adherence to the support as well as good thermal contact. Handling behaves in many respects similar to vacuum gripping, while the principle works inside and outside vacuum.

Chucking principle

The basic design of an electrostatic chuck is illustrated in Fig. 1. It closely resembles that of a parallel plate capacitor, with the wafer being used as one of the plates. The second is a metal electrode incorporated into an insulating substrate that supports the wafer from below.

By applying a voltage U between the two plates, the wafer is attracted to the chuck. The thickness d of the dielectric film between the wafer and chuck electrode and the relative dielectric constant e of the film material contribute to the force. From theoretical considerations the electrostatic force F per area A has been estimated to

$$F/A = \frac{1}{2}\, e\, e_0\, (U/d)^2$$

with an ideally insulating dielectric /1/.

Here e_0 denotes the electric permittivity of free space. For dielectrics with a finite conductivity, much higher forces due to so-called Johnsen-Rahbek behavior are known /2/. There are different electrical design possibilities. In the basic design a single chuck electrode is used and direct electrical contact of the voltage source to the wafer is required. Implementing a bipolar or multipolar electrode configuration circumvents the need for contacting the wafer directly and may be appropriate when wafer charging by impinging electrons or ions is not a problem.

Materials investigations

Optimizing the chuck for a specific application includes a careful materials selection. Alumina (clean and doped) and SiO_2 are well-established dielectrics, while other materials are less common, albeit of great potential for vacuum lithography and

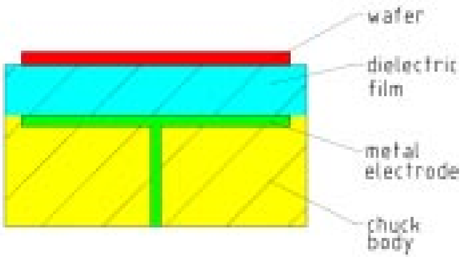
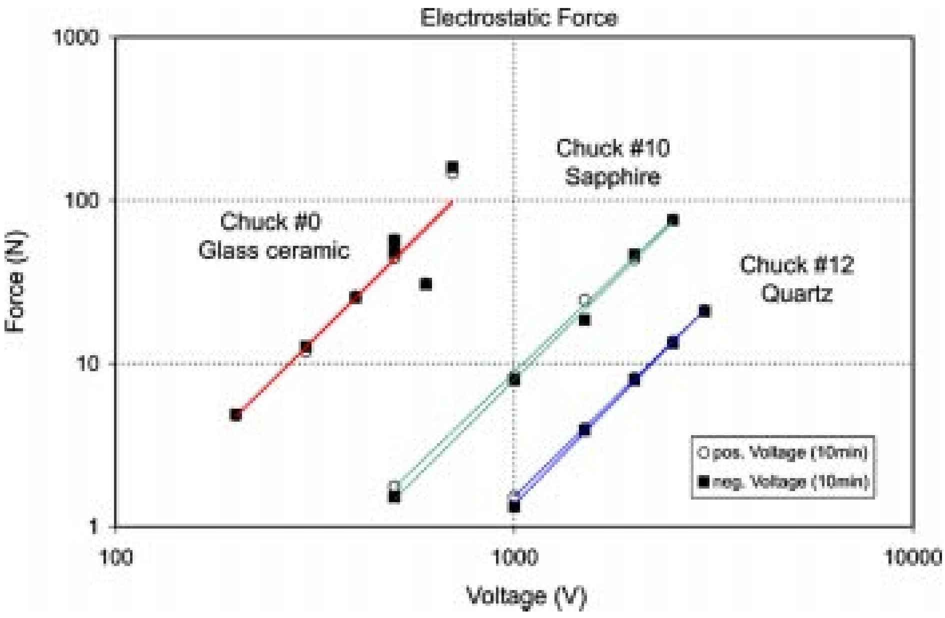


Fig. 1:
Electrostatic chuck

Fig. 2:
Electrostatic forces versus voltage for various chuck materials



measurement applications. We have investigated a series of materials, including glass and glass-ceramics with respect to its use as a dielectric in electrostatic chucks /3/.
Electrostatic forces were measured in a vacuum equal or better 10^{-4} mbar using unipolar test chucks of about 70-80 mm diameter and a dielectric film thickness around 250 µm. The results are displayed graphically in Fig. 2. Note the logarithmic scales. Large differences in electrostatic force for quite similar geometry are apparent.
In particular, the glass-ceramic dielectric is identified as a Johnsen-Rahbek system, providing forces about two orders of magnitude larger than with quartz.
By using this material as chuck dielectric, a highly attractive force on the wafer at moderate voltage can be obtained.

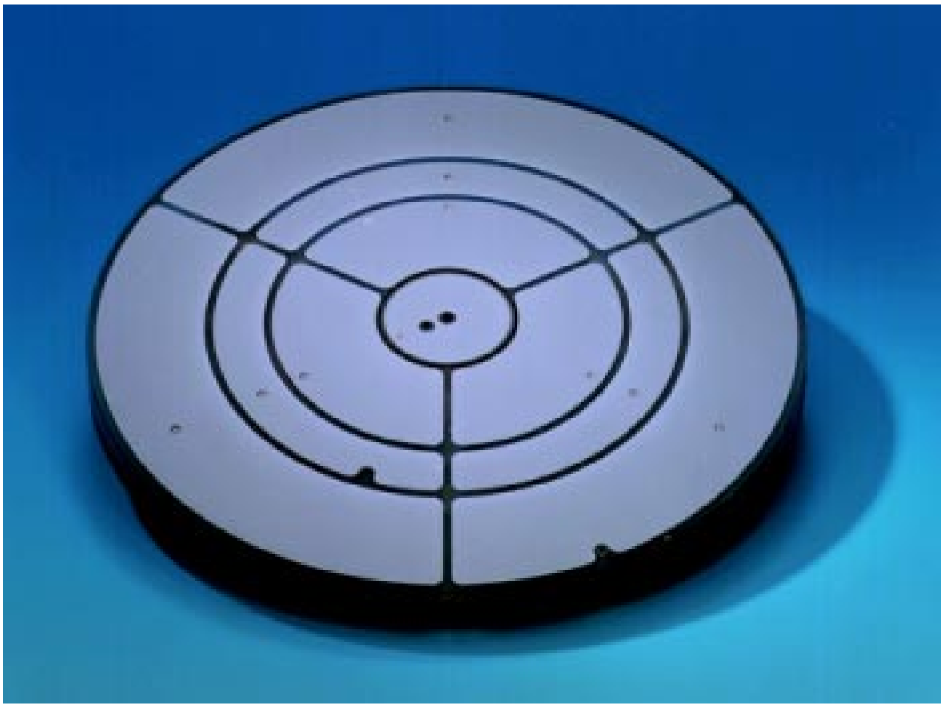


Fig. 3:
12-inch electrostatic chuck for Ion Projection Lithography

Lithography chuck

Chuck designs of different size and material for a diversity of lithographic applications have been realized in our institute. As an example, Fig. 3 shows a 12-inch chuck made out of glass-ceramics for use in Ion Projection Lithography /4/. Planarity and absolute height dimensions of the chuck are controlled to µm precision. This ensures a well-defined plane of focus for the lithography process and a clear geometrical relationship to the underlying metrology stage. Electrical design is somewhat more complex than described above due to a multi-polar electrode configuration, which allows for flexible electrical adoption to different process requirements. In fact, part of the chuck is even movable and can be extended or retracted with high precision to ease wafer transfer off and onto the chuck.

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/4/ in cooperation with Leica Microsystems Lithography GmbH (patent pending)

Wafer stage assembly for Ion Projection Lithography

C. Damm, T. Peschel, S. Risse, and U. C. Kirschstein*
* Leica Microsystems Lithography GmbH

In the framework of the Ion Projection Lithography (IPL) project a resolution and position repeatability of written patterns better than 36 nm (stitching error) is required. This resolution exceeds that of the best present optical lithography systems approximately by a factor of six. Though the exact position of the written pattern is controlled electronically during exposure via a pattern lock system a submicrometer stability of the wafer position is required.

Furthermore the horizontal orientation of the ion-optical axis implies a vertical orientation of the wafer stage, which results in additional challenges to the mechanical design. Because of the high dynamics of the stepping motion a resonance frequency in excess of 200 Hz is required for the wafer stage assembly.

In the framework of the IPL project, the IOF, as a subcontractor of Leica Microsystems Lithography GmbH Jena, is responsible for the development of a wafer stage assembly which has to comply with the above-mentioned stability requirements.

All major components of the wafer stage assembly are made from glass ceramics. The advantages of the chosen material are

- mirrors for interferometric position control may be incorporated directly into the stage body
- high specific stiffness and low specific weight allow for high dynamics and low power consumption of the drives
- high stability, no creep
- non-magnetic.

The wafer stage assembly consists of a lightweight glass ceramic metrology unit, which carries the interferometer mirrors and an exchangeable electrostatic chuck. A small, pneumatically activated chuck for wafer handling is integrated into the center of the main chuck.

The interferometer mirrors are orthogonal to each other with a precision of 2 seconds of arc while the pyramidal error is below 15 seconds of arc. The remaining deformation of the metrology unit under gravity load amounts to 40 nm which is close to the theoretical limit of 30 nm which is set by the material properties when an ideal mount is assumed.

The whole assembly of metrology unit and chuck is mounted cinematically to a moveable frame via 6 solid-state hinges, which bind each degree of freedom separately. This way strains in the mounting frame are completely decoupled from the wafer stage assembly.

The frame is clamped via piezo actuators to an vertically oriented 800 mm long, hollow, Si/SiC ceramics beam with a bending stiffness of 115 N/µm which is moved in the horizontal direction for stepping from one exposure area to the next one. For vertical motion the clamping is released and the wafer stage is lifted along the beam to the next exposure area.

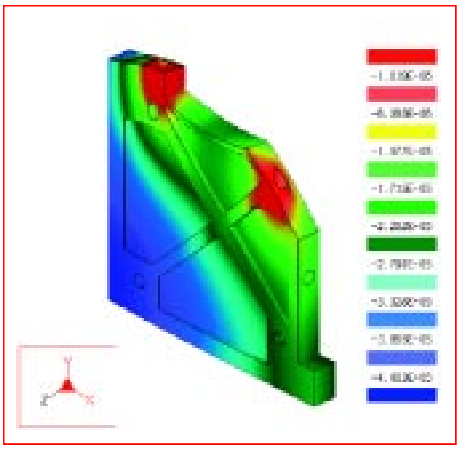

Fig. 1:
Finite element investigation of the deformations of the metrology unit

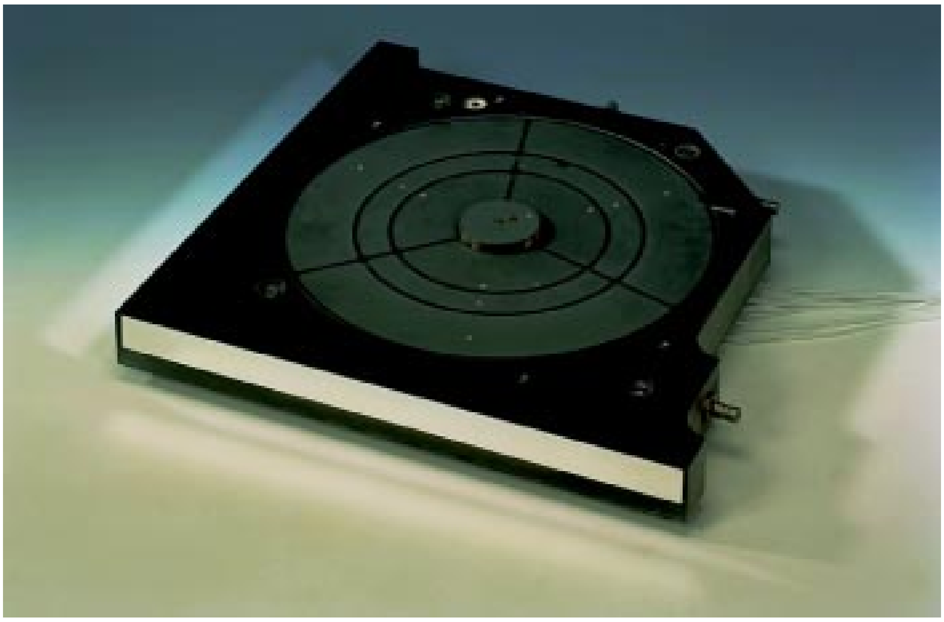

Fig. 2:
Assembled wafer-metrology unit with handling chuck activated

Fig. 3:
Mount frame for the metrology unit attached to the ceramics beam.
The whole wafer stage assembly is integrated into the IPL machine. In its working position the ceramics beam is connected with two linear magnetic drives which move the whole wafer stage assembly during stepping.

Acknowledgement

The IPL project is labeled by MEDEA and is supported by the German Ministry of Education and Research BMBF under grant number 01 M 2983C.

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Miniaturized bulk-optical Mach-Zehnder filter for optical code division multiplexing

P. Schreiber, B. Höfer, and G. Borchhardt

Introduction

With the increase in voice and data communications over the recent years, the need for bandwidth is growing with an exponential rate. Multiplexing techniques for multiple use of existing fiber transmission lines are the preferred way to satisfy this need. Optical code division multiplexing (CDM) has been demonstrated to be an interesting transmission technique for access and metro networks, where reduction of implementation and maintenance cost is a vital issue /1/.
In the framework of the german KomNet field trial a CDM system applying periodic spectral encoding of directly driven LEDs operating at 155.52Mbit/s per channel was demonstrated /2/. For encoding fiber Mach-Zehnder filters with free spectral ranges of FSR = 10-20GHz working in the wavelength region of 1550±35 nm were used. The optical decoding filters at the receivers are miniaturized bulk-optical Mach-Zehnder interferometers (MZI) with their FSR matched to the respective encoding filter FSR at the transmitter. The development and manufacturing of these MZI decoding filters will be described in this paper.

Optics design

From the system specifications, the required parameter of the MZI are derived: The FSR of the MZI must match the transmitter FSR to better than 10^{-5} which is guaranteed by adjusting the optical path difference by a piezo actuator. The minimum required contrast of the interferometer is 20dB even for random polarization of the incoming light. The basic design of the MZI is sketched in Fig. 1.
Design calculations with ray tracing (ZEMAX) and the free space wave propagation software package GLAD (Fig. 2) showed, that the most critical parameter of the optical elements are polarization dependent phase retardations of the beam splitters and the piezo-actuated reflecting prism. Thermal behavior and adjustment tolerances turned out to be less critical because active FSR fine-tuning is provided during operation.

Components

Standard reflecting prisms operating with total internal reflection (TIR) cause large phase retardances between the p- and s-components of the incoming light. To suppress depolarization during reflection on the legs of the prism, a special coating of this element is necessary to replace TIR. The coating designed and fabricated by the company mso jena guaranteed a reflection of more than 99% at a retardance of the reflected beam below 1° over the whole wavelength range (Fig. 3).
All other optical components are selected commercially available miniature non-polarizing beam splitters, aspheres and right angle prisms. Because manufacturers do not specify the retardance of the non-polarizing beam splitters extensive measurements of polarization behavior of these elements were carried out. The utilized beam splitters showed orientation dependent retardation and a beam splitting ratio requiring proper orientation and combination of elements for each module to satisfy the design constraints. The customized piezo-drive including tilt adjustment screws for the first beam splitter and the reflecting prism was supplied by the company piezosystem jena.

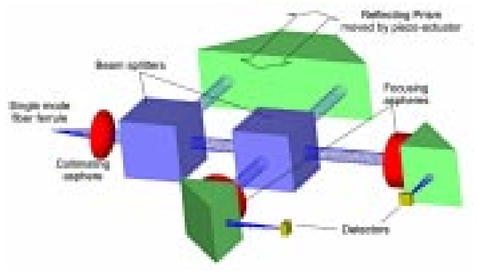

Fig. 1:
Schematic design of the Mach-Zehnder interferometer

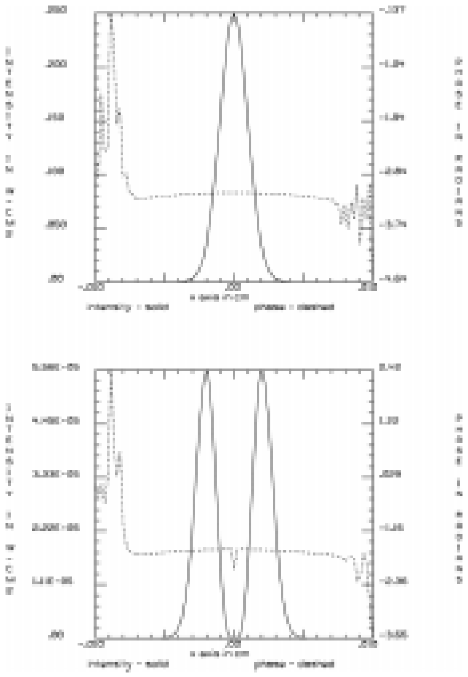

Fig. 2:
Point spread function for constructive and destructive interference, respectively, calculated with GLAD

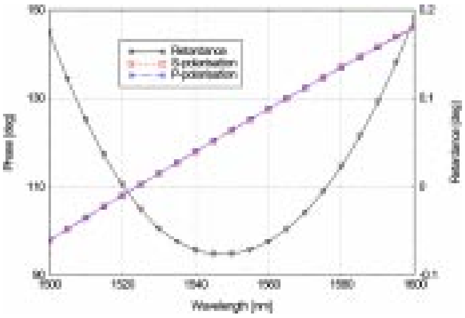

Fig. 3:
Phase behavior of the non-polarizing reflection coating

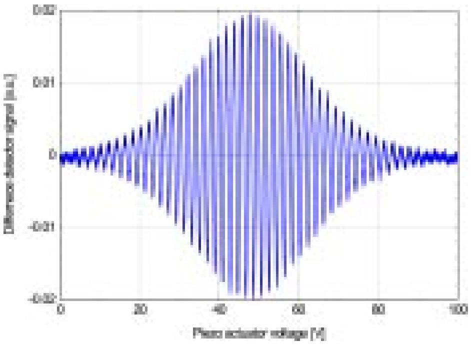

Fig. 5:
Typical transmission curve of the interferometer in dependence from piezo actuator voltage

Assembly

The proper distance of the reflecting prism to achieve the required FSR and the pointing and parallelism of the interfering beams are the most critical parameters to be maintained during assembly. Both are disturbed mainly by wedge errors of the beam splitters. The beam splitters and the reflection prism are positioned onto the housing of the piezo-drive by means of precision alignment elements equipped with a vacuum gripper.
To assess the state of adjustment, each filter was assembled with either a fiber-coupled DFB laser diode or the signal from the transmitter LED with the matched filter applied. After the optimum position was found, the elements were attached onto the piezo housing with UV-curing glue.
To optimize differential detector operation of the two photodiodes an adjustable knife edge obscuration is applied to equalize the electrical output of both diodes.

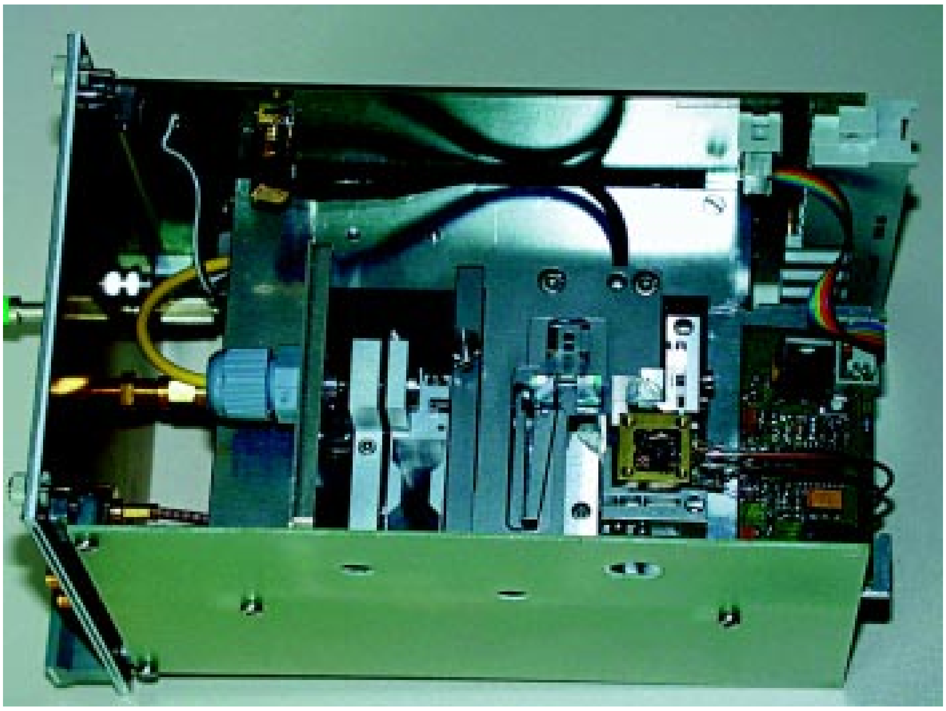

Fig. 4:
Mach-Zehnder filter (cover removed) integrated into receiver module

Results

For the specified FSR range of 10-20GHz a total of 10 matched filters (Fig. 4) with frequency spacing of about 1 Ghz were manufactured with typical responses as sketched in Fig 5. The prototypes showed sufficient mechanical and thermal stability. In agreement with the design calculations and the characterization of the utilized elements, the contrast of the interferometers and the dependence of the filter response curves from the state of polarization are well within the specification.

Acknowledgement

This work was funded under contract 01 BP 813/1 by the German Ministry of Education, Science, Research and Technology. We like to thank Dr. Pfeiffer from Alcatel SEL AG, Dr. Goering and Mr. Martin from company piezosystem jena and Mr. Schallenberg from company mso jena for support and fruitful discussions during the project.

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Novel multilayer waveguide technology for optical fan-out structures

U. Streppel, P. Dannberg, C. Waechter, A. Oelschlaeger and A. Braeuer

The increase of packaging densities as well as the ongoing integration of microoptic and electronic components leads to the opening of the third dimension for integrated optic devices, see e.g. /1/ and references therein. The rapid progress in this area drives the development of new materials and technologies. Those have to meet the requirements of the applications with regard to the fabrication tolerances but also to the opportunities for cost-effective mass-production /2,3/.

Within the framework of the project "DONDODEM" (Development of new dielectric and optical materials and process-technologies for low cost electrical and/or optical packaging and testing of pre-competitive demonstrators), sponsored by the Brite Euram contract, the IOF developed a novel three-dimensional optical multilayer fan-out structure.

It was the first time in the focused field of application that such a highly integrated device was conceived and realized. The scale of this work included all steps from design up to carrying out a suitable manufaction technology.

The aim of the fan-out structure is to bring together signals coming from different sources so that they can be detected at the output with one sensor. Essential for the design is to achieve equal path lengths for all waveguides which leads to the layout, composed of four uncoupled layers of waveguides. All of them are shown in Fig. 1.

The incoming signals will be fed into the device by standard fiber 1 x 8 arrays butt-coupled to the input facet. BPM and FEM calculations predict a total loss of 1.6 dB @ l = 1.3 mm for a 5 mm x 5 mm quadratic waveguide cross-section and a device length of 41 mm. Pitch, layer distance and cross-sections have to be designed in such a way that the fields at the output do not overlap.

Experimental investigations show that the inorganic-organic ORMOCERä copolymers, developed by the Fraunhofer Institute of Silicate Research, Würzburg, offer the potential for a multilayer technology. Especially properties like temperature stability of up to 250°C, low absorption in the telecommunication wavelengths regions and the possibility to structure the material by common photopatterning processes qualify polymers of the ORMOCERä family for the manufacturing of highly integrated waveguide devices.

The stacking process for realizing the different layers of the fan-out structure follows a successive scheme of spinning, photopatterning and heating steps. A key point for the device operation is an excellent waveguide homogeneity regarding the index distribution and the cross-sections. To this end, several processing steps had to be optimized:

- The structures are sensitive to exposure parameters like exposure gap and time. The actual height of the stack has to be carefully considered.
- Back reflection of light from the substrate during exposure has to be avoided. Otherwise scattering effects will occur and lead to waveguide broadening. The real exposure conditions would change from core layer to core layer in dependence on the changing structure in deeper layers.
- Layers manufactured so far had to be passivated prior to the preparation of the following layer. If material diffuses into deeper regions, index gradients will appear, losses and cross-talk will increase.

The final technology scheme which meets the requirements mentioned above is shown in Fig. 3.

Before the preparation of ORMOCERä layers an UV-absorbing undercladding

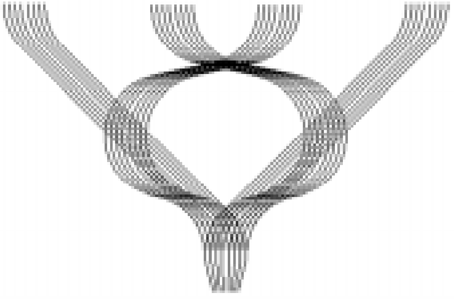

Fig. 1:
Design of fan-out structure, four stacked layers of single mode waveguides

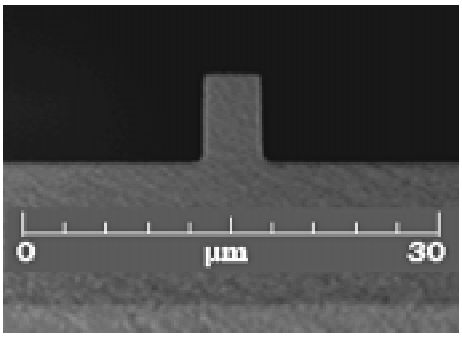

Fig. 2:
Waveguide after exposure and dissolving the unexposed material

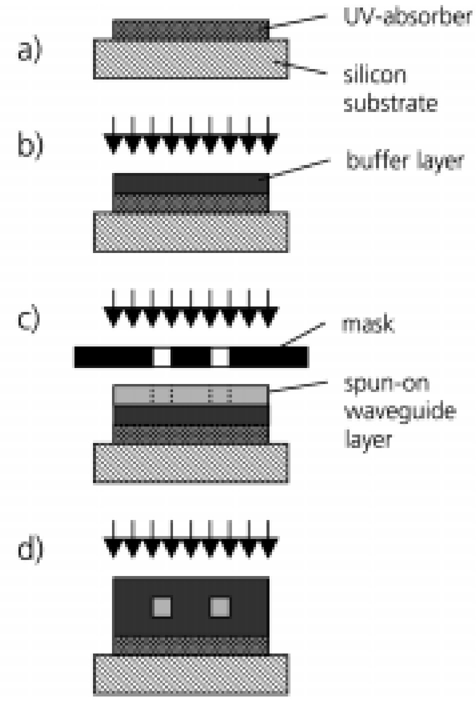

Fig. 3:
Technology scheme for the stacking process

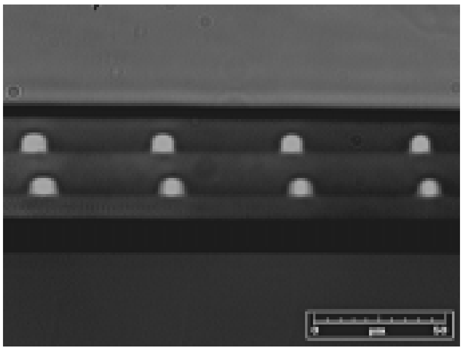

Fig. 4:
Stack of single mode waveguides according to the technology scheme of Fig. 3

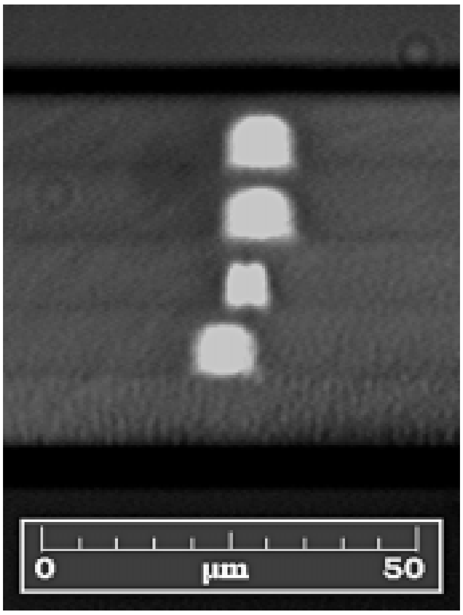

Fig. 5:
Stack of 4 waveguides

is manufactured (a). This measure leads to precise waveguide cross-sections (Fig. 2) and a homogeneous index distribution in the stack without any gradients in the cladding layers (Fig. 4).

The further technological steps (compare Fig. 3b-d) are:

- Spinning and curing of cladding material (b)
- Spinning of waveguide layer (core material), photo-structuring in a mask aligner by a proximity exposure (c) and washing out the unexposed uncured polymer
- Spinning of cladding layer and flood exposure (d)
- Continuation at step (b) after activation of the last surface by an oxygen plasma treatment and repetition until four layers (compare Fig. 5) are prepared

In conclusion, the developed new stacking technology enables for the fabrication of vertically stacked integrated optics devices with high precision. The demonstrated fan-out structure represents passive circuits without any evanescent coupling of waveguides, neither horizontally nor vertically. Decreasing of the height of the cladding layers and of the waveguide spacings leads to coupling via the evanescent fields in both transversal directions. Consequentially, this is the formation of an array of directional couplers. The fact that the described fabrication process is also applicable to these structures /2/ proves its potential for future vertically integrated optoelectronic applications.

The authors wish to thank M. Popall, Fraunhofer Institute of Silicate Research, Würzburg (Germany), for supplying them with the ORMOCER material.

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Integration of microoptics on wafers with vertical emitting lasers

G. Mann, P. Dannberg, W. Buß and M. Popall*
* Fraunhofer Institut Silikattechnik Würzburg ISC

Arrays of vertical cavity surface emitting lasers (VCSELs) are available as light source for various optical systems such as optical networks, parallel optical interconnects at onboard- and on-chip level (see Fig. 1), high speed printing, display systems and more.

VCSELs are predestinate for use in arrays because of their vertical emission with low divergence and low threshold current /1/.

UV moulding enables for the generation of micro-optic elements on top of a wafer equipped with VCSELs by a wafer scale process. The process requires only one single alignment and replication step /2/.

Subject of the investigations are design, generation and characterization of microoptical elements directly on top of VCSELs on a wafer scale (see Fig.2).

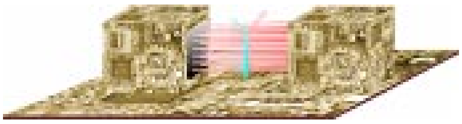

Fig. 1:
Application of 2D VCSEL arrays in an parallel optical interconnect at on-board-level

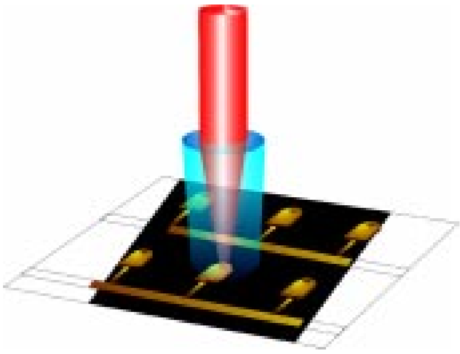

Fig. 2:
Beam shaping by microoptic elements (blue) on top of VCSELs (gold) on a wafer scale

The design calculations aim for lowest beam divergence of the VCSEL beam in order to avoid crosstalk between neighboring channels. Another goal is to reduce wavefront deviations, which hedge refocusing. The collimation characteristics is determined by the present VCSEL pitch (250 µm) and the laser N.A. (0.1 ... 0.2 according to the drive current). It turns out that an optimum distance between lens and VCSEL is like 350 µm (Fig. 3), the corresponding curvature radius is 150 µm. This leads to a 55% illumination of the lens aperture which theoretically means diffraction limitation and full beam power transmission. The beam propagation void of crosstalk is limited to 2,5 mm.The generation of the structure requires selection of a suitable polymer material and an appropriate uv-moulding process.

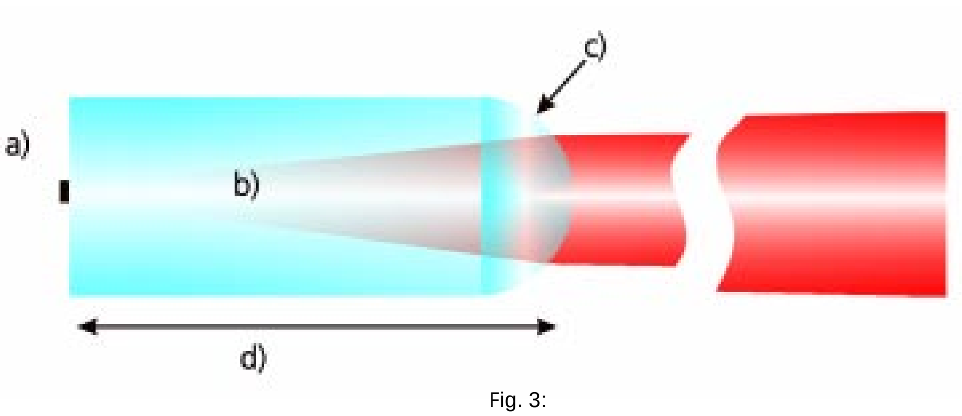

Fig. 3:
The optical system consists of the VCSEL emitter face a) and the polymer lens b), which is characterized by its length c) and its curvature radius d).

Thermal and mechanical stability, and optical characteristics like transparency and stability of the refractive index are deciding factors for choosing a polymer which embodies the microoptical structure.

A cooperative project with the ISC Würzburg /3/ discloses that ormocersä (organic-inorganic copolymers) in combination with photoinitiators are material class convenient concerning processing, stability and optical demands.

The lifetime of the polymer structure may decrease by duty in direct contact to the VCSEL emitter face. Absorption of light leads to yellowing and degradation which impairs the optical performance /4/. In order to test the longtime stability time acceleration is implemented by using much higher beam power density than at the VCSELs emitter face. Furthermore, the VCSELs wavelength of 873 nm is displaced by 488 nm, which increases the absorption.

Depending on the polymer composition the measured lifetimes spread from seconds to hours, as Fig. 4 shows. Estimation commits a resulting lifetime of 9 years for the favorite material combination, available for temperature and humidity in a laboratory's environment.

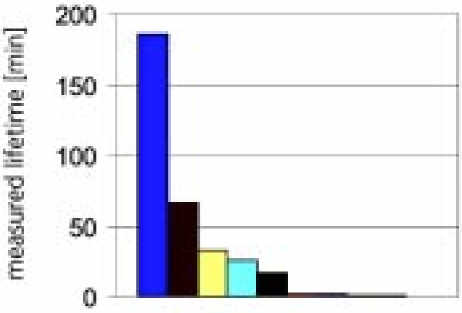

Fig. 4:
The lifetime of different polymers depends on their composition, notable variations occur

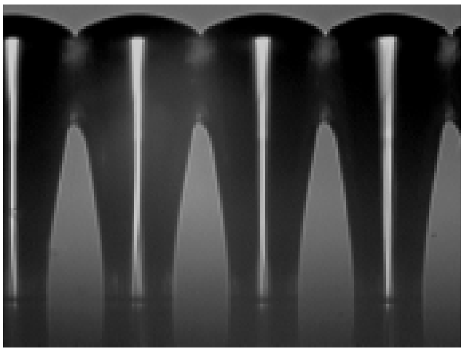

Fig. 5:
Photopolymerisation process is controlled by a exposure regime which generates clear, mechanical stabile structures

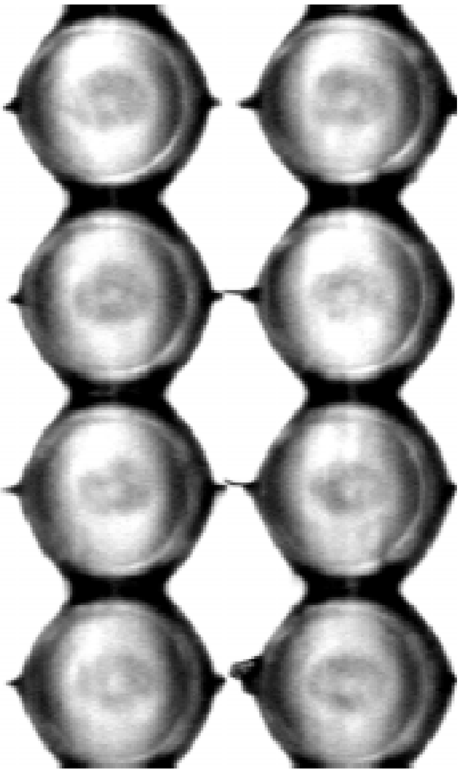

Fig. 6:
Generation of isolated structures in arrays is the most complicated application for selective photopolymerisation

The generation of the microoptical structure is realized by photopolymerisation through a mask in combination with uv-moulding using a replication tool [2]. Optimizing the process achieves accurate surface replication, optical transparency and selective patterning. Selective processing allows to develop isolated structures, which are separated by free space e.g. for electrical bonding. By applying an exposure regime filamentary inhomogenities of the refractive index are suppressed, the generated structures in one- and two-dimensional arrays are shown in Fig. 5 and Fig. 6. The replication is reproducible with a lens curvature radius deviation of 2…5 µm.

The emission of a VCSEL array integrated with microoptical structures showed no intensity changes after the replication process and following 1700 hours operation. The optical performance of the system displays that proper alignment between mask and substrate is feasible. Fig. 7 shows the test setup. The residual beam spread is < 1°, which enables for transmission without crosstalk over 2,5 mm.

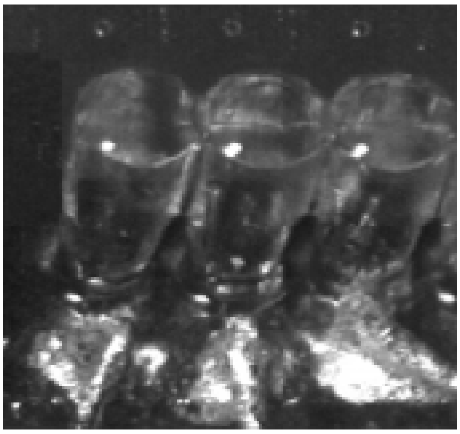

Fig. 7:
Test setup for 1D-array VCSELs with polymer lenses, the lasers are bonded to a board

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Selfcalibrating 360-deg shape-measurement systems

G.Notni, M.Heinze, G.H.Notni and P. Kuehmstedt

Introduction – problem description

It is quite difficult when using normally fringe projection, triangulation or light sectioning 3-D-measurement techniques to obtain a full-body view, i.e. to measure 360-deg around. For this, the sensor or the object have to be moved into multiple, overlapping measuring positions so as to view the entire surface. The resulting point clouds taken from the different views then have to be merged into a common coordinate system to obtain the final complete 3-D view by time consuming matching procedures or the viewing positions have to be known a-priori with a high accuracy.

Our solution – measurement principle

At the IOF a concept of selfcalibrating 3-D-measurement using structured-light illumination with a digital-light projection unit (DMD) has been developed overcoming these problems /1, 2/. On the basis of this concept measurement set-ups have been developed, which have the ability to obtain a full-body view within a selfcalibrating measurement procedure, whereas the necessary merging of the single views takes place fully automatically and is done without any marker on the object surface, objects features, other merging procedure or high accurate object/sensor handling system.
To get an automatically, selfcalibrating full-body the following measurement condition has to fulfil. Two or more cameras have to image the object from the desired different views. Neighbouring cameras should have overlapping area of their viewing fields, see Fig. 1. During the measurement procedure it have to ensured that these neighbouring cameras measure phase values for ³ 2 projector positions, whereas from each projector position two sets of fringe systems rotated by 90° have to project. These phase values in the overlapping areas can be used like the markers in photogrammetry to calculate the orientation of the projectors to each other by using a bundle adjustment calculation. This can be done step by step around the complete object. As a result one get different single 3-D views within one world coordinate system. It should be pointed that because all of the calculations are performed within one world-coordinate system, no further fitting/merging of the single views have to be performed to get a whole-body view. Because of that an error between the overlapping views (patches) cannot occur i.e. a homogeneous all-over-all accuracy is achieved.

On the basis of this strategy different mobile and stationary arrangements have been proposed.

A) Mobile camera – projector network

The simplest arrangement consists of one mobile projection unit and two mobile cameras, as shown in Fig. 2 and Fig.3. Both of the cameras capture the image simultaneously having a small overlapping area, while projecting the two sets of fringes from at least two different positions. Then one of the cameras can change in its position to get an other view of the object. The projection of the fringes is now repeated from other positions. Subsequent the other camera can change its position and a further set of fringes have to project. These procedure can be repeated as much as necessary to get the whole body measurement, i.e. one can “go” step by step completely around the object. The calculation of all of the necessary orientation parameters and 3-D coordinates then takes place

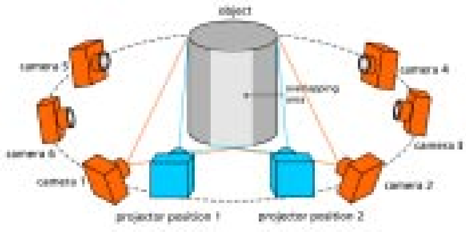

Fig. 1:
Basic camera – fringe projector arrangement for whole body measurement.

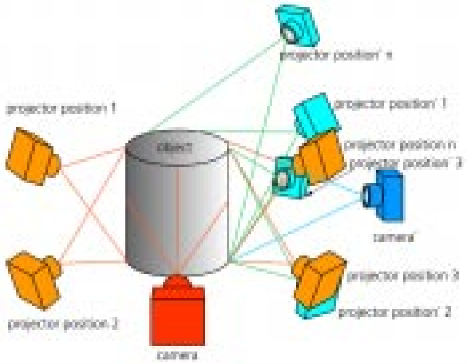

Fig. 2:
Mobile selfcalibrating camera – fringe projector network for whole body measurement.

Fig. 3:
Mobile camera-fringe projector network while measuring the owl above the entrance of the Fraunhofer IOF.

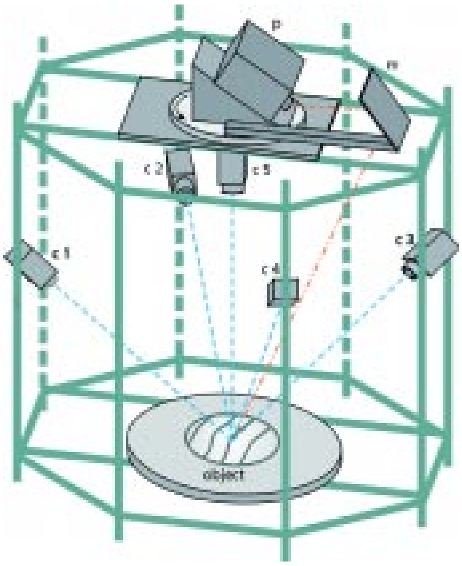

Fig. 4:
Schematic representation of a self-calibrating measurement system – kolibri.

Fig. 5:
View within the measurement system kolibri.

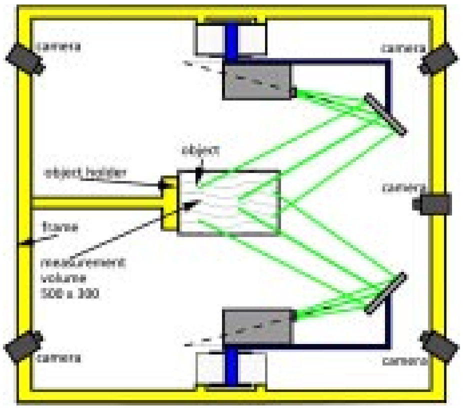

Fig. 6:
Schematic representation of a self-calibrating measurement system – kolibri-duo.

within one calculation after the consumption of the measurement values. It should be pointed out that no information of the position of the projector(s) as well as of the cameras during the whole measurement is necessary.

B) Stationary measurement system – kolibri™

A possible stationary self-calibrating measurement set-up for whole body measurement – named "kolibri"™ – according to the above concept is shown in Fig. 4 and 5 /3, 4/. Here the object under measure is put on a holder which is mounted on a frame. At this frame the cameras (c1–c5, for example) are mounted so that the position of the cameras with respect to the object are fixed during the whole measurement procedure.
To get the necessary different projection directions for the self-calibration (i.e. at least two) the projector P, illuminating the object via the mirror m, is rotated with respect to the fixed object and cameras.

The procedure of data consumption is the following one. At each rotation (projection) position the mentioned two grating sequences rotated by 90° are projected onto the object.
All cameras capture these fringe pictures simultaneously. On the basis of these fringe pictures at least 4 phase values for each pixel of the camera can be calculated. Using these phase values, the 3-D-coordinates as well as all of the orientation parameters are calculated.
As described before each camera measures its own single view (patch), whereby the different patches automatically fit together to the full-body view because they are measured in the same world-coordinate system.

The following features of the measurement system have been realized:

- measurement field:
  Æ 100–600 mm
- maximum number of simultaneous measured patches (cameras): 12
- maximum number of measurement points: 3 Mio.
- maximum number of measurement points per patch:
  250 000 (512 x 512 pixel)
- measurement accuracy:
  1/20 000 of the illuminated field
  < 20 µm standard deviation
- measurement time
  (with 12 cameras): 30 s–5 min

The only restriction of the measurement set-up kolibri is that it is not easily possible to measure an object from the top and from beneath within one measurement procedure, because only one projection unit can be used illuminating the object within one half sphere.

C) Stationary measurement system – kolibri-duo™

To solve the mentioned problem it is straightforward to illuminate and observe the object at the same time from the top and beneath. The schematic arrangement of such a measurement setup is shown in Fig. 6 – named kolibri-duo.

Measurement examples showing the power of this system-concepts are shown in Fig. 7, 8 and 9.

Conclusions

The developed system-concept(s) ensure a high number of object points, quick data acquisition, and a simultaneous determination of coordinates and system parameters (self calibration), making the system completely insensitive to environmental changes. Furthermore, there is no necessity of any marker on the object surface and a subsequent matching of the single views is not required to obtain a full-body measurement. These all giving the possibility to use the systems directly in a production line.

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Fig. 7:
The owl above the entrance of the IOF (STL-data set).

Fig. 8:
Seat measured with kolibri (STL-data set).

Fig. 9:
Point-cloud of an automotive part measured with kolibri.

Correction of 3-D coordinates using consistence check

P. Kuehmstedt, M. Heinze, J. Gerber, and G. Notni

Fig. 2c:
brake drum: photo of the object

Motivation – problem description

Optical 3-D measurement methods often lack on the fact that some faulty measurement points within the 3-D points cloud appear, so called "scattered points", which can strongly influence the quality of the 3-D data. Normally available 3-D-shape measurement systems then use filtering or complex mask operations to reduce these faulty points.
The problem is, that by these methods neighbourhood relations between the different measurement points are used yielding to an averaging and at the end a "bending" of the data points.
We have developed a new method using only information's on a single point and not on their surroundings for a detection and automatic masking of these faulty points which utilised a consistence check method.

Method of solution

The basis of this method is that the 3-D coordinates in the developed 3-D-measurement systems /1, 2, 3/ are calculated from an overestimated equation system, i.e. that more than 3 phase values can be used to calculate the 3-D coordinates of a single measurement point. The developed check consists on the following procedure: At the first the 3-D coordinates are calculated using all phase values. The next step is a backward calculation of so-called theoretical phases based on these coordinates. The difference of the measured phase values and these theoretical phases giving a phase error for each measurement. Then the complete set of all phase errors is normalized. In the consistence test phase values whose normalized phase error is over a given limit are cancelled, i.e. they do not fit this consistence check and are not considered in further calculations. This procedure is repeated iteratively until the single-phase errors are in a given limit.
So faulty measurement points are removed, especially values near the surface of the measured object which are not detected by usual filters.

Result

In the example we are showing on two different objects the effect of these algorithm. In both cases the checked point clouds contain a reduced number of inconsistent points and can be analysed more easily.
Looking at the parameters of the consistence check, the minimum number of valid phase measurements is 3 in theory, but in practice, a suitable number of this parameter is 4 to 5 phase-values.
The normalized relative phase error should by between 2.5 up to 4 in maximum.
With the method "Consistence Check of 3-D coordinates" one reduces the total number of measured points by about 10 to 20%. In addition, the program offers the possibility to calculate quality parameters (accuracy as a scalar value for one point) for each data point and its coordinate components (x, y, z) separately (accuracy of the 3 coordinates).

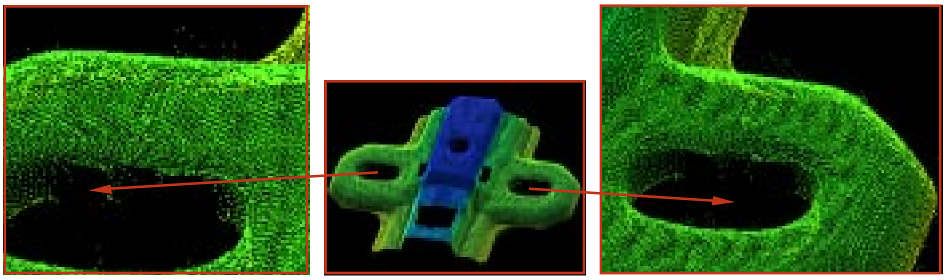

Fig. 1a:
metal fitting: without consistence check – faulty data points

Geometry parameters like angles and distances of objects can be estimated automatically on the resulting point cloud.

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/2/ Kowarschik R., Kuehmstedt P., Gerber J., Schreiber W., Notni G.
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Optical Engineering 39 (2000)
p. 150-158

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Selfcalibrating 360-deg shape-measurement systems within this Annual Report

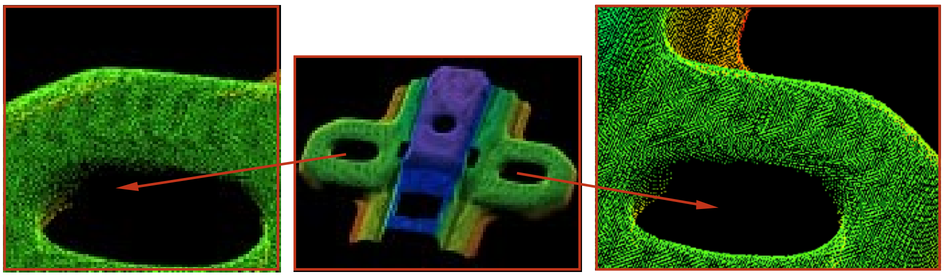

Fig. 1b:
metal fitting: with consistence check – reduced point cloud, no faulty data points

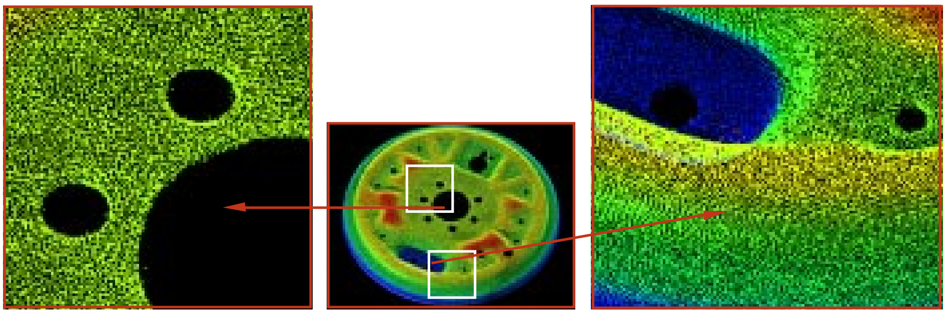

Fig. 2a:
brake drum: without consistence check – faulty data points

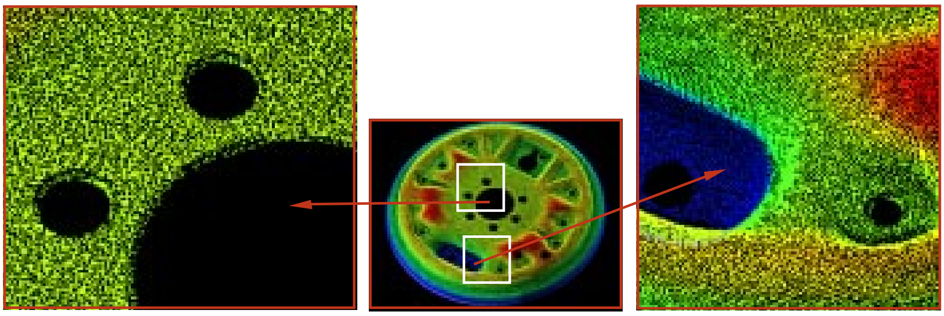

Fig. 2b:
brake drum: with consistence check – reduced point cloud, no faulty data points;
463442 à 408639 points equal 12% reduction

Percutaneous transvascular aortic valve replacement with a self-expanding stent-valve device

M. Ferrari*, I. Tenner*, H.R. Figulla*, C. Damm, and T. Peschel
*Clinic of Internal Medicine, Friedrich-Schiller-University Jena, Germany

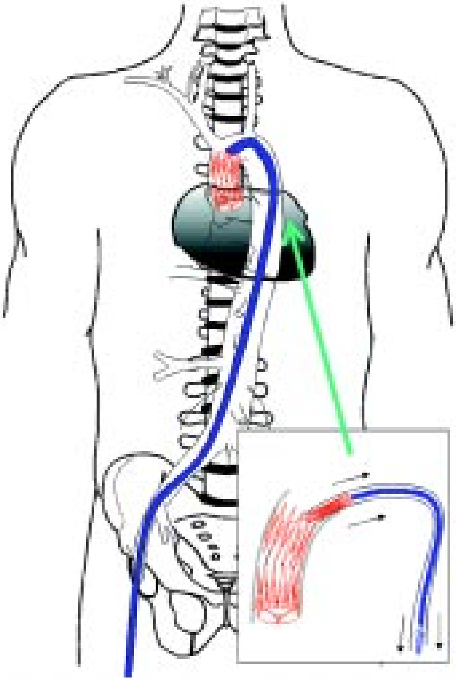

Fig. 1:
Impantation of the stent-valve device

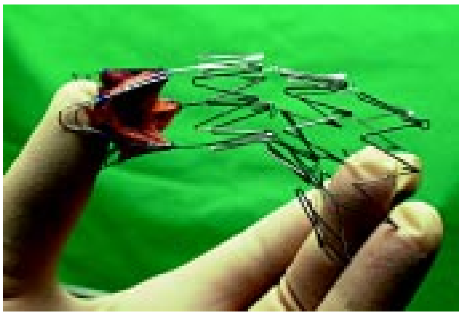

Fig. 2:
Prototype of the stent-valve device

Besides surgical replacement for treatment of aortic valve stenosis or insufficiency sufficient alternatives still lack. Due to high risks of open heart operation especially in elderly and multi-morbid patients a minimal invasive therapeutically approach would be favorable.

A possible solution of these problems can be seen in a transvascular implantation of a so-called bio-valve which is made of porcine heart valve by chemical fixation. This bio-valve is attached to the distal end of a Nitinol-stent. The stent valve device can be implanted with a catheter by folding it to a diameter of 6 mm. The self-expanding stent deflates the bio-valve in an orthotopic position in the left outlet tract pushing the old valve into the aortic vessel wall.

A newly designed self-expanding Nitinol- stent was designed as the result of a cooperation of Friedrich-Schiller-University and Fraunhofer Institute in Jena. The Nitinol- stent was designed to stabilize the bio-valve after deflation in a physiological manner. Its construction was optimized for high flexibility as well as stiffness to provide a optimum placement in the outlet tract of the beating heart.

For correct placement of the commissures the coronary ostials should be marked by guiding catheters. Fluoroscopy and transesophageal echo are useful for optimal implantation of the valve-stent device.

We tested the self-expanding stent valve device in an artificial circulation model achieving the following results:

- no dislocation occurred up to pressure load of > 200 mmHg
- maximum transvavular pressure gradient was < 22 mmHg under flow rate of 5 l/min
- leakage flow was < 500 ml/min under pulsatile pressure load of 120/80 mmHg
- diameter of the folded device below 6.5 mm

Due to these promising results in vitro we intend to perform animal experiments with the self-expanding stent valve device.

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/3/ H.R. Figulla, N. Eitge, M. Ferrari, „Konstruktion und in vitro Testung einer perkutan implantierbaren Aortenklappe“, Z Kardiol 85 (Suppl 2, 1996): 161

International Guests

Dr. Toshikuni Kaino,
Tohoku University, Sendai, Japan

Dr. Naomichi Okamoto,
Shizuoka University, Shizuoka, Japan

Dr. Nobutaka Tanigaki,
NIMCR (Nat. Inst. of Materials and Chemical Research), Ibaraki, Japan

Dr. Tetsuyuki Kurata,
Mitsubishi Electric Corporation, Hyogo, Japan

Masatoshi Toda,
Mitsubishi Rayon Co., LTD, Tokio, Japan

Dr. Nobuo Miyadera,
Hitachi Chemical Co., LTD, Ibaraki, Japan

Dr. Lyong Sun Pu,
Fuji Xerox Co., LTD, Kanagawa, Japan

Junji Yokoi,
Japan Chemical Innovation Institute, Tokio, Japan

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Oxford Institute for Laser Science, Oxford, UK

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MA(Cantab)MIChemE Ceng MBA, Telford, UK

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Clarendon Laboratory, Oxford, UK

Antony Hurden,
Scientific Generics Limited, Cambridge, UK

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Pilkington Optronics, Wales, UK

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DERA, Malvern

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Principle Scientific Investigator, Toronto, Canada

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Vic DiCiccio,
Vice-President Research, Ontario Centre of Excellence CITO, Canada

Richard Normandin,
Director General IIT, National Research Council NRC, Institute for Microstructural Systems IMS, Ottawa

John Deacon,
Senior Mission Representative Photonics, Industry Canada, Ottawa

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Program Manager, Science and Technology Program of the Canadian Embassy in Germany, Berlin

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Takeshi Okamoto,
Matsushita Electric Works, Ltd., Shizuoka, Japan

Toshitake Kitagawa,
Toshiba Corporation, Yokohama, Japan

Mark Worthington,
Vice President, Optical Disc Research & Development, Burstein Technologies, Inc., Irvine, CA, USA

Raj R. Barathur,
Ph. D., Executive Vice President, Technology Integration, Burstein Technologies, Inc., Irvine, CA, USA

David O’Bryan,
Ph. D., Executive Vice President, Burstein Technologies, Inc., Irvine, CA, USA

Jorma Virtanen,
Ph.D., Vice President & Director, Chief Scientist, Burstein Technologies, USA

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Inha University, Korea,
Dept. of Physics

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Lebedev Physical Institute, Moscov,
Russia

Pascal Marlier,
BIPE, France

Robert Breault,
ProIncorporation, Optics Cluster
Arizona, USA

Prof. R. Bruch,
University of Nevade, Reno, USA

Prof. C. E. Webb,
Oxford Institute

Dr. Alexandre Gatto,
ENSPM, LOSCM, Institut Fresnel,
Marseille, France

Dr. Sergey Yulin,
Kharkov State Polytechnic University,
Kharkov, Ukraine

Mag. Georg Strauss,
University Innsbruck, Innsbruck,
Austria

Prof. Johann Pulker,
University Innsbruck, Innsbruck,
Austria

Tan Fong Hock,
Singapore Productivity and Standards
Board, Singapur, Singapur

Dang Xuan Cu,
NACENTECH, Hanoi, Vietnam

Dr. Pham Hong Tuan,
NACENTECH, Hanoi, Vietnam

Corentin Bresson,
University Paris VI, France

Bernhard Schaffer,
University Graz, Graz, Austria

Dr. Keith Bates,
MIT Lincoln Lab, Lexington, USA

Dr. J.M. Bennett
Naval Air Warfare Center,
China Lake, CA, USA

Dr. J. Ferré
University Barcelona, Spain

Dr. Ch. Petit
University Paris VI, France

Co-operation with Institutes and Companies in other Countries

Austria:
University Graz, Prof. Leising

Ireland:
Trinity College Dublin, Prof. W. Blau

France:
CNC Cachan, Prof. Zyss

France:
CEA Saclay, Prof. Nunzi

Italy:
University “La Sapienze“,
Dr. Michelotti

USA:
CREOL Orlando, Prof. Stegeman

Sweden:
ACREO Norköping, Prof. Robertson

Japan:
Tohoku University, Prof. T. Kaino

Russia:
Lebedev Institute Moscov,
Prof. A.V. Vinogradov

Memberships

A. Bräuer
- Conference Program Committee “Linear Optical Properties of Waveguides”, SPIE USA
- Conference Program Committee “Micromachining technology for Micro-optics”, SPIE USA
- Member of the AMA advisery board for “Optical Sensing”
- Referee for journal “Applied Optics”

A. Duparré:
- Topical Editor ”Applied Optics”, Optical Thin Films
- Assessor Board Member of the Australian Research Council
- Chair International Conference ”Optical Metrology Roadmap for the Semiconductor, Optical, and Data Storage Industries”, SPIE Symposium 2000, San Diego, USA
- Chair International Conference ”Optical Metrology Roadmap for the Semiconductor, Optical, and Data Storage Industries”, SPIE Symposium 2001, San Diego, USA
- Program Committee Member International Conference ”Optical and Infrared Thin Films”, SPIE Symposium 2000, San Diego, USA
- DIN-Normenausschuss NAFuO, AA O18 AK2, “Optische Komponenten und Werkstoffe”
- ISO-Committee Member ISO/TC 172/SC 9/WG 6

R. Eberhardt:
- DIN-Normenausschuss NAFuO, AA F3, “Fertigungsmittel für Mikrosysteme”

C. Gärtner:
- Member of the „Cooperation Network from Jena“
- Member of the “OptoNet e.V.”

V. Guyenot:
- Member of the Board of the Scientific-Technical Advisory Committee of the Fraunhofer-Society (Hauptkommission des Wissenschaftlich-Technischen Rats der Fraunhofer-Gesellschaft)
- Member of the Board of the Scientific Club ”Ophthalmo-Innovation of Thuringia” (OpthalmoInno Thüringen e.V.)

N. Kaiser:
- Member of Advisory Board “Laser and Optoelectronics”
- Member of the International Program Committee “International Symposium on Laser Induced Damage in Optical Materials”, Boulder, USA
- Chairman FDS Technical Committee „Thin films for optics and optoelectronics“
- Member of Technical Program Committee “8th Topical Meeting on Optical Interference Coatings”, Banff, Alberta, Canada

W. Karthe:
- Speaker of the Fraunhofer Alliance Surface Technology and Photonics
- Scientific Advisory Board of Jenoptik AG – Member
- Scientific Advisory Board of the Institute Microelectronical and Mechatronical Systems – Member
- Board of Curators of the Technical College Jena – Member
- Board of Curators of the Hermsdorf-Institute Technical Ceramics – Member
- Advisory Board of the VDI-Competence Field of Optics Technologies – Member
- Scientific Board of AMA – Member
- Experts Group German Agenda Optical Technologies for the 21st Century – Member
- Board Member Journal Microsystem Technology
- Program Committee Member Opto 2000 Congress
- Program Committee Member Micro.tec 2000 Congress
- Program Committee Member Workshop Mikrooptik 2000
- Program Committee Member Annual Conference 2000 of the German Society for Applied Optics (DGaO)
- Program Committee Chair Microtechnology Thuringia MTT 2000 Conference
- Jury Member for Innovation Award Thuringia
- Study group Integrated Optics – Member
- Study group Microsystem Technology at VDI TZ IT Teltow
- Special Committee Microoptics of GMM-Society
- Referee for Journal “Applied Physics“
- Referee for AiF-Society
- Referee for Thuringian Foundation for Technology and Innovation Promotion (STIFT)
- Board Member of Microtechnology Thuringia Association (MTT e.V.)
- Board Member of OptoNet Association (OptoNet e.V.)

P. Kühmstedt:
- Association of the German Precision Mechanics and Optical Industries (F+O Association), trade association imaging&photo technology

G. Notni:
- AMA association
- Editorial Board “Zeitschrift für Angewandte Gewässerökologie“
- VDI/VDE-GMA board 3.32. “Optical 3D-measurement“
- Association of the German Precision Mechanics and Optical Industries (F+O Association), trade association medical technology

T. Possner:
- DIN-Normenausschuss NAFuO, AA O21, “Integrierte Optik”
- ISO standardization committee TC 172/SC 9 WG 7 (microlens arrays)

- Program Committee MOC/GRIN
- Member of the European Optical Society (EOS)

U. Schulz:
- DIN-Normenausschuss NAFuO, AA O2 AK3, “Umweltprüfungen für optische Geräte”

R. Waldhäusl:
- Referee for journal “Applied Optics” and “Optical Engineering”
- Bio Regio
- Working group for chemical and biological micro technique

Ch. Wächter:
Program Committee
“Integrated Optics Devices IV”,
SPIE- The International Society
for Optical Engineering

Special Events

Winter school optical thin films, 02.- 03. March 2000 in Tabarz

Workshop of the DGM committee “Optical Thin Films“
of the DGM and the FDS committee
“Coatings for Optics and Optoelectronics”, 30 May 2000
in Freiburg im Br.

Science Fair Participation

L.O.B. 2000
08.03. – 09.03., Berlin
- Selfcalibrating optical 3-D-measurement system „Kolibri“
- Optical 3-D-Digitizer
- Beam transformation systems for high power laser diode bars and stacks
- Polymeric microoptical components

Hannover Messe 2000
20.03. – 25.03., Hannover
FhG – Fraunhofer Vision
- Selfcalibrating optical 3-D-measurement system “Kolibri”

FhG – Surface Technology
- Coatings on polymers, interference filters, laser mirrors, Fresnel lenses

Kompetenzzentrum-Zentrum
CC UPOB e.V.
- Reproduction of natural optical nanostructures with interference coatings

Research Location Thuringia
- Polymeric microoptical and microfluidic components

OPTO/MTT 2000
09.05. – 11.05., Erfurt
- Hybrid assembly of micro systems
- Metrology system for Ion Projection Lithography
- Quality assesment using light scattering techniques
- Micro-optical elements
- Beam transformation systems for high power laser diode bars and stacks
- Polymeric micro-optical and microfluidic components

Control 2000
16.05. - 20.05., Sinsheim
FhG - Fraunhofer Vision
- Selfcalibrating optical 3-D-measurement system „Kolibri“
- Quality assesment using light scattering techniques

ACHEMA 2000
22.05. – 27.05., Frankfurt/ Main
- Bio-sensors
- Polymeric microoptical and microfluidic components

OPTATEC 2000
27.06. – 30.06., Frankfurt/Main
- Assembly of micooptical systems
- Metrology system for Ion Projection Lithography
- Quality assesment using light scattering techniques
- Microoptical elements and systems
- Beam transformation systems for high power laser diode bars and stacks
- Polymeric microoptical components

Micro and Nano-Engineering
19.09. – 21.09., Jena
- Precision systems for astronomy, lithography and precision mechanics
- Design and integration of microassembly processes for industrial applications
- Design and rapid prototyping of microoptical elements and systems

Canadian International Dental Congress/Fair
22.09. – 23.09., Toronto
- ”Hint-El’s DentaCad System”

Conference and Exhibition on Micro & Nanoscale Technologies for the Biosciences
28.11. – 30.11., Montreux
- Microfluidic components

Euromold 2000
29.11. – 02.12., Frankfurt/ Main
FhG - Rapid Prototyping
- Selfcalibrating optical 3-D-measurement system “Kolibri”

Patents

Patent Awards

19852149
Meßanordnung zur simultanen, berührungsfreien Bestimmung der Koordinaten von Meßpunkten, der Orientierungsparameter des Sensors und von Korrekturparametern für die Meßwerte
Dr. G. Notni, Dr. W. Schreiber

19812981.5-09
Vorrichtung zur Ausführung linearer Bewegungen
B. Höfer, P. Pertsch

US 6055056
3D-Meßanordnung zur Ganzkörpererfassung und Einmessen einer entsprechenden Meßanordnung
P. Kühmstedt, Dr. G. Notni,
Dr. W. Schreiber

19604255 C2
Vorrichtung zur optischen Erfassung beschleunigungs- und/oder neigungsbedingter Bewegungen eines Körpers in einem Medium
H. Kießling, Dr. M. Palme,
(R. Baur, B. Link, H. Schiffl,
K.-D. Wierzioch: TEMIC)

DE 44 04 608 C2
Vorrichtung für Eingriffe in eine röhrenförmige Körperhöhle
G. Harnisch

6,151,168
Optische Anordnung zur Symmetrierung der Strahlung von Laserdioden
Dr. P. Schreiber, (Dr. Poßner: GRINTEC GmbH), (Dr. Göring: piezosystem jena GmbH)

Patents Pending

00/36412
Anordnung zur Strahlumlenkung in Wellenleitergeometrien
Dr. Ch. Wächter,
(Prof. Lederer; U. Peschel:
Friedrich-Schiller-Universität Jena)

00/36273
Vorrichtung zum Dispensieren und Auslesen doppelseitiger Arrays im CD-Format
Prof. W. Karthe, Dr. R. Waldhäusl,
Dr. A. Bräuer,
(Dr. R. Kindervater: GeneDisc AG)

00/36232
Abriebfeste Antireflexbeschichtung für Kunststoffe
Dr. U. Schulz, Dr. N. Kaiser,
(U. Schallenberg: mso)

00/36205
Hochauflösendes ein- und zweidimensionales berührungsloses Wegmesssystem
Dr. P. Schreiber, Dr. U. Zeitner,
Dr. A. Bräuer, Dr. P. Dannberg,
(Dr. Stegmüller, H. Brunner: OSRAM)

00/36204
Substrat mit gering lichtstreuender Oberfläche
Dr. A. Duparré, Dr. G. Notni

00/36202
Modenselektierende Phasenstrukturen für Halbleiterlaser
Dr. U. Zeitner,
(Dr. R. Güther: FBH Berlin)

00/36167
Verfahren und Vorrichtung zur berührungslosen Messung von räumlichen Koordinaten mit variabler Kamera und Projektoranordnung
Dr. G. Notni, M. Heinze

00/36086
Abrissvorrichtung
zur Haftfestigkeitsprüfung
Dr. U. Schulz, G. Harnisch, U. Schmidt

00/36069
Sensorelement zur optischen
Detektion von chemischen
oder biochemischen Analyten
N. Danz, Dr. R. Waldhäusl

00/36050
Methode zur Eliminierung
bzw. Reduzierung des Einflusses
von Strukturen auf Oberflächen
oder Schichten auf das Transmissions- bzw. Reflexionsverhalten
von Objekten
Dr. A. Duparré, St. Gliech, J. Steinert,
Dr. G. Notni

00/36049
Sputtern von Schichtsystemen
mit schichtdickenabhängiger
Substrat-BIAS-Spannung
T. Feigl, Dr. S. Yulin, W. Stöckl,
Dr. N. Kaiser

00/36040
Thermisch stabile Mo_2C/Si-Schichtsysteme für den
EUV-Spektralbereich
Dr. S. Yulin, T. Feigl, Dr. N. Kaiser

00/36039
Thermisch stabiles Schichtsystem
zur Reflexion von Strahlung
im extremen ultravioletten
Spektralbereich (EUV)
Dr. S. Yulin, T. Feigl, Dr. N. Kaiser

00/36038
Thermisch stabiles Schichtsystem
zur Reflexion von Strahlung im
extremen ultravioletten
Spektralbereich (EUV)
Dr. S. Yulin, T. Feigl, Dr. N. Kaiser

00/36036
Verfahren zur Ausrichtung
eines optischen Elementes
in Bezug zur Rotationsachse
einer Welle
Dr. G. Kalkowski, St. Risse,
G. Harnisch, A. Gebhardt

00/36034
Vorrichtung zur Befestigung und
Verankerung von Herzklappenprothesen
C. Weber, Dr. Th. Peschel, Ch. Damm,
(Prof. H.-R. Figulla, Dr. M. Ferrari:
Friedrich-Schiller-Universität Jena)

00/36007
Verfahren zur gleichzeitigen
Erfassung von 3D-Form und Farbe
von Objekten bei Beobachtung
mit monochromen Kameras
Dr. G. Notni

00/36337
Modularer mikrooptischer
Raumlichtschalter
Dr. A. Bräuer, W. Buß, Prof. W. Karthe,
Dr. P. Schreiber, Dr. Ch. Wächter

Educational Activities

Diploma Theses

Helbig, Lars
“Aufbau und Charakterisierung eines Messplatzes zur evaneszenten Feldanregung fluoreszenter Moleküle”,
Fachhochschule Leipzig, 07/00

Haase, René
”Aufbau und Charakterisierung eines Detektorsystems für die Fluoreszenzmessung mit einem Photomultiplier auf der Basis der evaneszenten Feldanregung”,
Fachhochschule Leipzig, 07/00

Rau, Sven-Tino
“Untersuchung eines durchstimmbaren frequenzverdoppelten, diodengepumpten Mikrokristall-Laser für den Einsatz in der optischen Formvermessung mittels Speckleinterferometrie“,
Fachhochschule Jena, 02/00

Munzert, Peter
“Entwicklung eines Mikrowellen-Niederdruckplasmaprozesses zur Oberflächenaktivierung von PMMA“,
Fachhochschule Jena, 02/00

Fischer, Rainer
“Untersuchungen zu Farbwiedergabeeigenschaften, Montage- und Fügeprozessen sowie der Prüfung von Mehrfach-CCD-Farbköpfen”,
Fachhochschule Jena, 12/00

Müller, Sandra
“Experimentelle Untersuchungen zur Charakterisierung von aerodynamischen doppelsphärischen Lagern”,
Fachhochschule Jena, 11/00

Steinkopf, Ralf
“Entwicklung und Test einer Handhabungseinrichtung zur Inspektion von Mikrobauteilen”,
Fachhochschule Schmalkalden, 11/2000

Thaut, Michael
“Untersuchungen zur automatisierten Justage mittels Impulsantrieben für die Feinwerk- und Mikrotechnik”,
Fachhochschule Jena, 12/00

Dissertations

Recknagel, Rolf-Jürgen, Dr. rer. nat.
“Defekterkennung an Oberflächen mittels Waveletmethoden“,
Friedrich-Schiller-Universität Jena, 12/00

Uhlendorf, Christina, Dr. rer. nat.
“Konfokale Mikroskopie mit phasenkonjugierendem Spiegel”,
Friedrich-Schiller-Universität Jena, 06/00

Feigl, Torsten, Dr. rer. nat.
“Struktur und Eigenschaften von Schichtsystemen für den EUV-Spektralbereich“,
Friedrich-Schiller-Universität Jena, 10/00

Siebenhaar, Christian, Dr. rer. nat.
“Präzisionsjustage durch Einleitung von mechanischen Impulsen”,
Technische Universität Ilmenau, 11/00

Scientific Publications

Publications

Apel, O.; Mann, K.; Heber, J.; Thielsch, R.:
Nonlinear absorption phenomena in oxide coatings for 193 nm
In: Gregory J. Exarhos; Arthur H. Guenther; Mark R. Kozlowski; Keith L. Lewis; M. J. Soileau (eds.): Laser-Induced Damage in Optical Materials, Proc. SPIE vol. 3902, p. 235-241; Bellingham: SPIE, 2000; ISBN 0-8194-3508-2

Becker, H.; Gärtner, C.:
Polymer microfabrication methods for microfluidic analytical applications
In: Electrophoresis 21 (2000), p. 12-26; ISSN 0173-0835

Becker, H.; Gärtner, C.:
Mikrotechnik – Ein ganzer Kosmos
In: CADWORLD 5 (2000), p. 72-73; Vaterstetten: IWT-Verlag, ISSN 1435-9766

Bosch, S.; Leinfeller, N.; Quesnel, E.; Duparré, A.; Ferré-Borrull, J.; Günster, S.; Ristau, D.:
A new procedure for the optical characterization of high quality thin films
In: Al-Jumaily, G.A.; Duparré; A.; Singh, Bhanwar: Optical Metrology Roadmap for the Semiconductor, Optical, and Data Storage Industries. SPIE Proc. vol. 4099, p. 124-130; Bellingham, Wash.: SPIE, 2000; ISBN 0-8194-3744-1

Buß, W.; Mohaupt, M.; Woldt, G.:
Wafer level integration of micro-optic elements and photodiodes by assembly and structuring of a glass-silicon wafer stack
In: Reichl, H. (Eds.): FhG-IZM: "System Integration in Micro Electronics", p. 311-318; Berlin: VDE-Verlag, 2000; ISBN 3-8007-2548-7

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Integration of optical interconnects and optoelectronic elements on wafer-scale
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Dannberg, P.; Erdmann, L.;. Bierbaum, R.; Krehl, A.; Bräuer, A. Kley, E.B.:
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In: Microsystem Technologies 6 (2000) 2, p. 41-47; ISSN: 0946-7076

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Polymer UV-molding for micro-optical systems and opto-electronic-integration
In: Sing H. Lee, Eric G. Johnson: Micromachining Technology for Micro-Optics; Proceedings SPIE vol. 4179, p. 137-145; Bellingham, Wash.: SPIE, 2000; ISBN 0-8194-3835-9

Danz, N.; Waldhäusl, R.; Bräuer, A.:
Novel Bio-Chips using integrated optical waveguides for fluorescence excitation
In: Proceedings OPTO 2000. Optical Sensors & Measuring Techniques; p.187-192; Wunstorf: AMA Service GmbH

Eberhardt, R.; Mohaupt, M.; Scheller, T.:
Hybrid assembly of microoptical systems
In: Proceedings vol.1 MICRO.tec 2000: Applications, trends, visions; p.459-464; Berlin: VDE-Verlag, 2000; ISBN 3-8007-2579-7

Feigl, T.; Yulin, S.; Kaiser, N.; Thielsch, R.:
Magnetron sputtered EUV mirrors with high thermal stability
In: Elizabeth A. Dobisz (ed.): Emerging Lithographic Technologies IV. SPIE Proc. vol. 3997, p. 420-430; Bellingham: SPIE, 2000; ISBN 0-8194-3615-1

Ferré-Borrull, J.; Duparré, A.; Quesnel, E.:
Roughness and light scattering of ion-beam-sputtered fluoride coatings for 193 nm
In: Applied Optics vol. 39 (2000) no. 31, p. 5854-5864; ISSN 0003-6935

Ferré-Borrull, J.; Duparré, A; Steinert, J.; Ristau, D.; Quesnel, E:
Microroughness analysis of thin film components for VUV applications
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Rauheits- und Streulichtuntersuchungen an Oberflächen und Schichten für den VUV-, EUV- und X-ray-Bereich
Lecture: 101. Jahrestagung der DGaO, 13-17 June 2000, Jena, Germany

Uhlendorf, K.; Notni, G. Kowarschik, R.:
Auflösungserhöhung durch die Ausnutzung von Interferenzeffekten in konfokalen Mikroskopen mit phasenkonjugierendem Spiegel
Lecture: 101. Jahrestagung der DGaO, 13-17 June 2000, Jena, Germany

Waldhäusl, R.; Danz, N.; Schmidt, K.; Vetter, D.:
Planarer Bio-Chip auf der Basis integriert-optischer Wellenleiter
Lecture: 10. Heiligenstädter Kolloquium, Technische Systeme für Biotechnologie und Umwelt, October 2000, Heiligenstadt, Germany

Wippermann, F.; Göring, R.; Kubitz, K.; Dannberg, P.; Leibeling, G.; Bräuer, A.:
Fiber optic switches using transmittive micro optical components
Lecture: MICROtec 2000, 25-27 September 2000, Hanover, Germany

Yulin, S.; Feigl, T.; Kaiser, N.:
Si-based multilayers with high thermal stability
Lecture: X. International Conference Nonresonant Laser-Matter interaction – NLMI-10, 21-23 August 2000, St. Petersburg, Russia

Zeitner, U.; Wyrowski, F.:
Nutzung von Designfreiheiten bei der resonatorinternen Laserstrahlformung
Lecture: 101. Jahrestagung der DGaO, 13-17 June 2000, Jena, Germany

Zeitner, U.D.:
Anwendungsbeispiele diffraktiver Optik
Lecture: Institutsseminar des Heinrich-Hertz-Instituts, July 2000, Berlin, Germany

Directions to Fraunhofer IOF

The Fraunhofer IOF is located in the former Carl Zeiss building called ”Die Eule” (“The Owl”) on the corner of Teichgraben and Leutragraben-Schillerstrasse, directly across from the Goethe Galerie shopping mall.

By Train

To avoid confusion, realize that Jena has four railway stations or “Bahnhof”: Westbahnhof, Saalbahnhof, Paradiesbahnhof and Bahnhof Göschwitz.

If you take the Frankfurt/Main - Dresden Intercity (IC) route, change trains in Weimar and leave the train at Jena-Westbahnhof.

If you take the Berlin-München (Munich) Intercity (IC) route, leave the train at Jena-Paradiesbahnhof.

From both railway stations you will reach the Fraunhofer IOF after a short downtown walk of approximately five minutes.

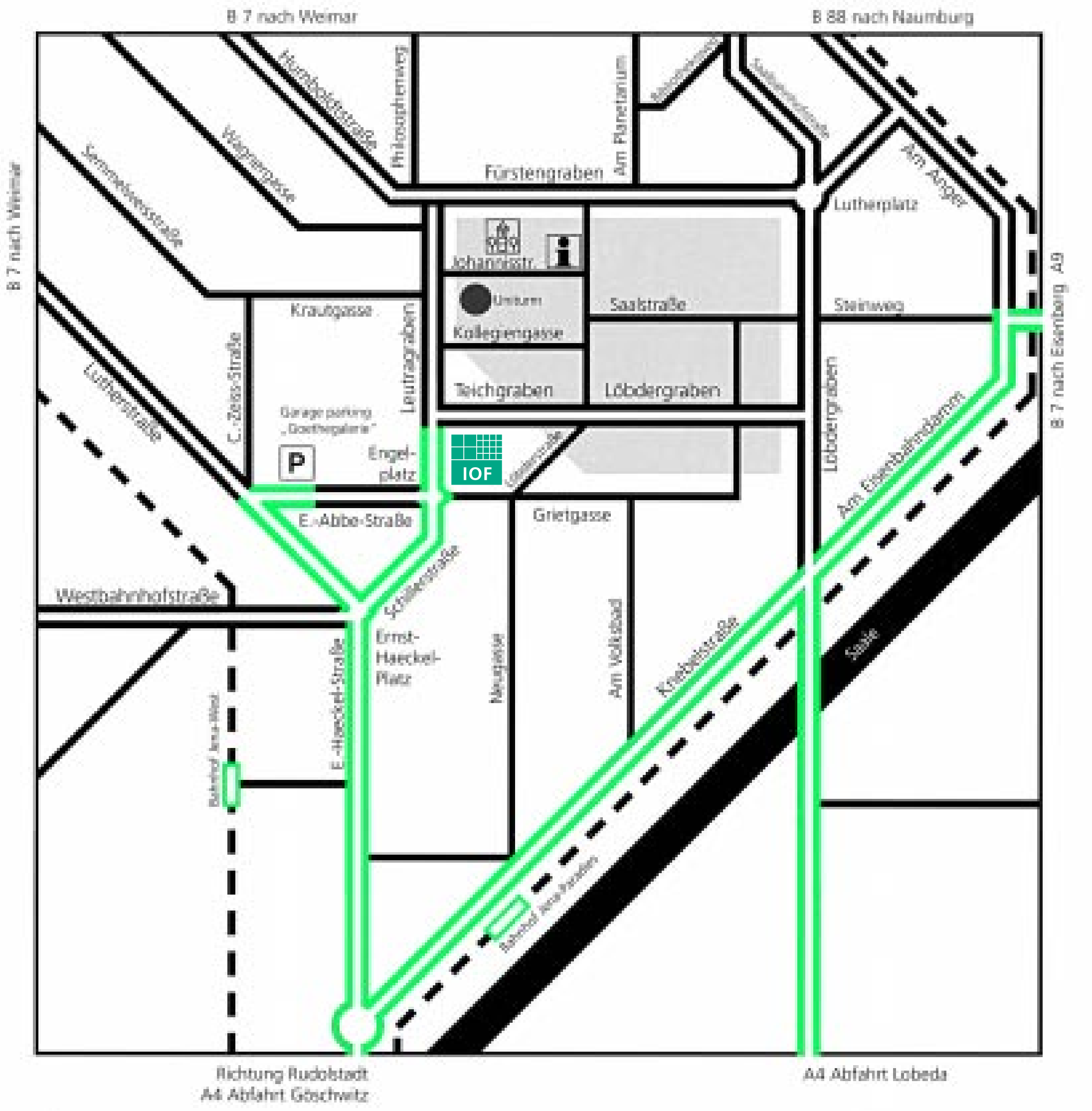
By Car

Leave the A4 motorway (Autobahn) at the Jena-Göschwitz exit, and drive to the city on the B 88 road. Just before Paradies Bahnhof, a small railway station on the right, you get to a small roundabout, where you take a slight left turn on to Haeckelstrasse. Proceed to the first traffic light and turn right on to Schillerstrasse. On Schillerstrasse you pass the main post office on the left, and after one more block you will find the Fraunhofer IOF on the right hand side on the corner of Teichgraben, directly across from the Goethe Galerie shopping mall. Garage parking is available under the Goethe Galerie.

By Airplane

From the Erfurt airport, follow the signs directing you to the A4 motorway (Autobahn), exit Erfurt-Ost. On the A4 drive eastward (direction Dresden). Leave the A4 at the Jena-Göschwitz exit. Then follow the directions given above under “By Car”.

From the Halle/Leipzig airport, follow the signs directing you to the A9 motorway (Autobahn). On the A9 drive south (direction Munich) until you reach the Hermsdorfer Kreuz intersection, then turn right and follow the A4 motorway westward (direction Erfurt). Leave the A4 at the Jena-Göschwitz exit. Then follow the directions given above under “By Car”.



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Fraunhofer-Institut
für Angewandte Optik und
Feinmechanik IOF
Diplom Kauffrau Astrid Deppe
Schillerstrasse 1
07745 Jena
Phone +49 (0) 3641/ 807-203
Fax +49 (0) 3641/ 807-610
e-mail info@iof.fhg.de
Internet http://www.iof.fhg.de

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system “Kolibri“ with case

Plastics for optical
applications