Master's thesis proposed for academic year 2009-10

at Institut d'Optique Graduate School – Paris

Biomedical optical imaging
Arnaud DUBOIS (arnaud.dubois@institutoptique.fr)

Development and application of original biomedical optical imaging technologies based on:
- Optical Coherence Tomography (OCT),
- Multi-photon fluorescence microscopy,
- Second harmonic generation microscopy,
- Stimulated emission depletion (STED) microscopy.

New lasers
Patrick GEORGES (patrick.georges@institutoptique.fr)

- High power laser based on new diode-pumped crystal fiber doped with ytterbium ions, a way to overcome the thermal limitations in bulk crystals and the nonlinear limitations of classical fiber lasers.

- High power diode-pumped femtosecond oscillator based on new Ytterbium doped CALGO crystal in a thin disk configuration, the solution to produce high power and very short pulses.

- Amplification of ultrashort pulses in large mode area ytterbium doped fiber, active control of the phase, amplitude and spectrum of the pulses in order to reach the limits and replace the Titanium based femtosecond sources.

- Development of UV diode pumped solid state laser based on new Neodyme transitions and non linear conversion with borates crystals, a solution for a solid state laser to replace the excimer laser at 193 nm.

- Towards high power single-frequency emission of optically pumped vertical external cavity semiconductor lasers for spectroscopy applications.

Metamaterials with NEGATIVE refractive indices at optical frequencies
Philippe LALANNE (philippe.lalanne@institutoptique.fr)
Christophe SAUVAN (christophe.sauvan@institutoptique.fr)

The work includes both theoretical, numerical and experimental contributions, in collaboration with the "Laboratoire des Nanostructures" for the fabrication and the characterisation of the metamaterials.

Optical antennas for efficient photovoltaic cells
Jean-Jacques GREFFET (jean-jacques.greffet@institutoptique.fr), Marine LAROCHE (marine.laroche@institutoptique.fr)

The aim of the project is to design nanostructures which will optimize the absorption of the incoming light by the photovoltaic cell. This work is made in collaboration with IRDEP (Institut de Recherche et Développement de l'Energie Photovoltaique, EDF-CNRS) and LPN (Laboratoire Photonique et Nanostructures).

Thermal radiation at the nanoscale
Jean-Jacques GREFFET (jean-jacques.greffet@institutoptique.fr), Marine LAROCHE (marine.laroche@institutoptique.fr)

At the nanoscale, the exchange of energy by radiation is no longer given by the well-known Stefan's law (proportional to σT^4). When two materials are located at few nanometers from each other, photon tunneling can occur and the power exchanged is enhanced by several orders of magnitude. This is becoming a key issue in the nano-electromechanical systems whose performances are limited by their thermal management. This project is made in collaboration with the CEA-LETI.

Optically bistable compounds: physics and applications to optical signal processing
Carole ARNAUD (carole.arnaud@institutoptique.fr)

Innovative holographic data storage architectures
Gilles PAULIAT (gilles.pauliat@institutoptique.fr)

New laser sources for biological applications based on liquid filled photonic crystal fibres
Sylvie LEBRUN (sylvie.lebrun@institutoptique.fr)

Stimulated Raman scattering in the evanescent field of a microfibre
Sylvie LEBRUN (sylvie.lebrun@institutoptique.fr)

Wavelength conversion in photonic crystals for quantum information processing
Philippe DELAYE (philippe.delaye@institutoptique.fr)

Non linear micro-cavities for optical information processing
Nicolas DUBREUIL (nicolas.dubreuil@institutoptique.fr)

Production and detection of correlated atoms
Christopher WESTBROOK (christopher.westbrook@institutoptique.fr)

Quantum non destructive measurement of BEC coupled in an optical resonator
Philippe BOUYER (philippe.bouyer@institutoptique.fr)

Master thesis at Institut d'Optique Graduate School – Paris

Ultracold atomic gases in optical disorder: a theoretical study
Laurent SANCHEZ-PALENCIA (lsp@institutoptique.fr)

Detection and Manipulation of single biomolecules for the study of protein traduction dynamics
Karen PERRONET (karen.perronet@institutoptique.fr) and Nathalie WESTBROOK (nathalie.westbrook@institutoptique.fr)

Development and application of optical single-molecule methods to study biomolecular motors such as ribosome
- fluorescence microscopy including Förster Resonance Energy Transfer
- optical tweezers and accurate measurement of exerted forces
- microfluidics

work in close collaboration with biologist teams and use of biochemical techniques

---

Optics in XUV
Franck DELMOTTE (franck.delmotte@institutoptique.fr)

- Optics for attosecond pulses
- Nanometric thin films and multilayers for extrem UV optics

Potential topics of OpSciTech master thesis work (2009/2010)
at Warsaw University of Technology

Title of work: *The development of a method to detect changes in the 3D shape of ground level.*

Supervisor: dr Robert Sitnik

Content of work:

1. Literature studies: Overview of related and existing technology.
2. Preparation of suitable testing scenes and subsequent collection of data.
3. Proposal of the concept or solution.
4. Implementation of the concept in Windows platform with C++.
5. Testing, Validation and optimization of the solution.

Required skills: Knowledge of image processing, C++ programming

Title of work: Interferometric methods for microlens investigations
Supervisor: dr Michal Jozwik

Content of work:

1. Literature studies including theoretical aspects of optical elements in microscale (with focus on microlenses) and optical inspection methodes.
2. Development of virtual interferometric setup for reference data creation.
3. Experimental verification of simulated data with interferometric system dedicated for microlens investigation.
4. Description of works.

Required skills:
Software development with Matlab or LabView
Ability of experimental work with optical laboratory systems

Title of work: **Micro object vibration measurements using advanced interferometric techniques**
Supervisor**: dr Adam Styk**

Content of work:

1. Literature studies concerning different methods applied to micro-objects vibration measurement;
6. Comparison of two selected measurement methods – time averaging interferometry with heterodyning and classical time averaging interferometry with advanced Bessel fringes evaluation;
7. Numerical simulations showing the influence of selected measurement errors on the accuracy of amplitude calculations for both methods;
8. Experimental work for numerical studies verification;
9. Conclusions

Required skills:
- Matlab programming abilities; laboratory work dexterity, interferometric measurement method as well as fringe pattern analysis knowledge;

Potential topics of OpSciTech master thesis work (2009/2010)
at Warsaw University of Technology

Title of work: **Design of cavity waveguide grating microinterferometer with automatic fringe pattern analysis**

Supervisor: **prof. Leszek Salbut**

Content of work:

1. Survey of literature referred to grating interferometry (GI) and configurations of grating interferometers.
2. Theoretical analysis and numerical modelling of cavity waveguide GI head.
3. Development of the method for implementation of automatic fringe pattern analysis based on temporal phase shifting technique.
4. Experimental modelling of the interferometer with implemented FringeApplication software for interferogram analysis.
5. Design of the grating microinterferometer working with a standard optical microscope:
   - selection of the source, detector, actuators and other commercial elements,
   - design of the optical system (GI head and illuminating optics),
   - design of the mechanical parts and phase shifting module,
   - development of the mounting and adjusting procedures.
6. Development of the user manual.

Title of work: **Optical diffraction tomography for internal structure investigation in tapered fiber optics**

Supervisor: **Prof. M. Kujawinska**

Content of work:

1. Literature search with the focus on the optical diffraction tomography methods to enhance signal-to-noise ratio and spatial resolution in projections (interferometric and digital holography)
2. Development of two modified experimental systems providing projections and capturing of initial projections of tapered fiber
3. Critical analysis of data obtained in both systems and proposal of experimental-numerical enhancements
4. Simulation of tomographic process (filtered backprojection) with the model and experimental projection data
5. Determination of the projection and tomographic reconstruction errors and the ways of their elimination
6. Performing a series of measurements of tapered optical fibers by means of the selected tomography method (based on interferometry or digital holography)

Required skills: programming in MatLab and experimental skills

Laboratory intership at Institute of Physics, Military Academy, Warsaw

Title of work: ***Analysis of systematic errors in multiwavelength interferometric system for cerified measurements of long (1m) gauge blocks***

Supervisor: **Prof. Leszek Salbut**

Required skills: programming in MatLab and experimental skills

Student internship in Polish Bureau of Standards, Warsaw

Title of work: **Development of hybrid termographic/digital image correlation method of monitoring big civil engineering structures**

Potential topics of OpSciTech master thesis work (2009/2010) at Warsaw University of Technology

Supervisor: Prof. Malgorzata Kujawinska
Required skills: programming in MatLab and experimental skills Student internship in infrared detector company Vigo Inc., Warsaw

Master projects at the Optics research Group of TU Delft

Optics Research Group

+31 (0)15 2781444
http://www.tudelft.nl

Interesting topics for 2010/2011 are:

1) Highly Accurate Distance Measurements in Space using a Frequency Comb Laser; *supervision: prof.dr. H.P. Urbach, email, **h.p.urbach@tudelft.nl** and Prof.dr. E. Gill, Chair Space Systems Engineering (SSE), email, **e.k.a.gill@tudelft.nl***
2) Manipulating light-metal interactions at the nanoscale for solar applications; s*upervision: prof.dr. H.P. Urbach, email, **h.p.urbach@tudelft.nl***
3) Detection of bio-markers using cavity ring down spectroscopy using a fiber base femtosecond comb; *supervision, Dr. N. Bhattacharya, email, **n.bhattacharya@tudelft.nl***
4) Inspection of defect on aeronautic composites using terahertz (far-infrared) radiation; *supervision, Dr. A.J.L. Adam, email **a.j.l.adam@tudelft.nl** and Prof.dr. P.C.M. Planken, email, **p.c.m.planken@tudelft.nl***
5) Multiplexing in optical recording *Supervision: Dr. S. F. Pereira, email, **s.f.pereira@tudelft.nl***
6) New scanning microscope using cavities: *Supervision: Dr. S. F. Pereira, email: **s.f.pereira@tudelft.nl***
7) Nulling interferometry using three beams: *Supervision: Dr. S. F. Pereira, email, **s.f.pereira@tudelft.nl***
8) Highly focussed light beams: *Supervision: Dr. S. F. Pereira, email, s.f. pereira@tudelft.nl*
9) Networks of local minima and saddle points in optical system optimization: *Supervision: Dr. F. Bociort, email, **f.bociort@tudelft.nl***
10) THz bio photonics: Ultra fast dynamics of molecules. *Supervision: Prof.dr. P.C.M. Planken, email: **p.c.m.planken@tudelft.nl***
11) THz bio photonics: THz time-domain spectroscopy of organic crystal. *Supervision: Prof.dr. P.C.M. Planken, email: **p.c.m.planken@tudelft.nl***
12) Diffractive Optics for flat panel displays; *supervision: prof.dr. H.P. Urbach, email, **h.p.urbach@tudelft.nl** and Philips NV, Eindhoven.*
13) *Diffractive lenses for 3D TV; supervision: prof.dr. H.P. Urbach, email, **h.p.urbach@tudelft.nl** and Philips NV, Eindhoven.*

General Information:

For more information about the topics please contact one of the above supervisors, or maybe you want to do another project, please contact: Prof.dr. H.P. Urbach, email, ***h.p.urbach@tudelft.nl***.

Master projects at the Institute of Applied Optics of FSU Jena

Prof. Dr. Richard Kowarschik

Implementation and experimental evaluation of a fringe projection system

Dipl.-Phys. Marcus Große (sucram.essorg@googlemail.com)

There exist several structured light methods to encode the objects surface so that geometric information can be retrieved from images of the object. At the Institute of Applied Optics (IAO) we are using statistical patterns at the moment. In order to compare our results to that of the standard technique, we want to realize a fringe projection setup.

Precise work to be done:

- Implementation (using C++) of a 4-step phase shifting using gray-code or statistical patterns for phase unwrapping.
- Evaluation of stripe projection and projection of statistical patterns by experimental means, e.g. measurement of normal-bodies.
- Simulation of stripe projection setup and statistical pattern setup to evaluate the theoretical limits and differences of both techniques.

All tasks require good programming knowledge in C or C++!

Implementation and experimental evaluation of sub-pixel algorithms

Dipl.-Phys. Marcus Große (sucram.essorg@googlemail.com)

There exist several structured light methods to encode the objects surface so that geometric information can be retrieved from images of the object. At the Institute of Applied Optics (IAO) we are using statistical patterns at the moment. In order to realize the best measurement accuracy, we must be able to find corresponding features in stereo images with sub-pixel accuracy.

Precise work to be done:

- Overview of the available literature to answer questions like: which sub-pixel algorithms exist? What accuracy is possible? What is the fastest way to find a sub-pixel match?
- Implementation (using C++) of one or more sub-pixel-algorithm and an evaluation of the results compared to current used sub-pixel algorithm on experimental and simulated data.

All tasks require good programming knowledge in C or C++!

Photoinduced holographic structures in photopolymers based on plexiglass

Dr. Vladislav Matusevich (vladislav.matusevich@uni-jena.de)

Photopolymer materials based on PMMA with Phenanthrenquinone are investigated. The PMMA is modified by changing of the polymer matrix in order to reach better thermal stability of holographic gratings written in the photopolymer. A new modification of the photopolymer was recently developed. Its optical (photorefractive) and thermal properties have to be measured and analyzed. Recently the photoinduced (1+1)D-self-trapping of a laser beam was observed in the photopolymer based on PMMA. Theoretical and experimental investigations of this effect are planed. Also experiments for the generation of (1+2)D-self-trapping are in preparation.

Institute of Photonic Technology, Jena

Prof. Dr. Hartmut Bartelt (hartmut.bartelt@ipht-jena.de)

Selected topics on characterisation and analysis of fibers and fiber components

Characterisation and analysis of special fibers and fiber components, including microstructured fibers, Photonic Crystal Fibres, nanofibers and nanotapers, photosensitivity of fibers, active laser fibers.

Selected topics in application of fibers

Subjects of applications of fibers, including fiber Bragg gratings as sensors, nanoprobes based on fiber nanotapers, fibers for light sources and fiber lasers.

Investigation of loss mechanisms in UV-induced phase gratings in optical fibers

Subject of this thesis would be the investigation of effects in photosensitive fibers, which are used to record fiber Bragg gratings in the core of an optical fiber. The gratings are recorded as phase gratings by illumination with UV light. Loss effects may influence the efficiency of such gratings in applications such as multiplexed fiber sensors.

Institute of Applied Physics (IAP)

Prof. Dr. Andreas Tünnermann

IAP Fiber & Waveguide Lasers

Dr. Jens Limpert

Spectral phase measurement of ultra-short pulses by using an extended spectral interferometry technique

To characterize ultra-short pulses spectral amplitude and phase measurements are necessary. With a standard optical spectrometer only spectral amplitudes can be investigated. Spectral phases can be measured, for example, by using the frequency resolved optical gating technique (FROG) or spectral interferometry (SI).

The main topic of this master thesis is to simulate, design and build up a special phase measurement device called SEA-TADPOLE (spatially encoded arrangement for temporal analysis by dispersing a pair of light e-fields) which is based on spectral interferometry. Normally, a reference pulse and an unknown pulse with a variable time delay interfere in a spectrometer, producing an interference pattern. This pattern, which is dependent on the time delay, is used to obtain the phase difference between the reference and the unknown pulse. The SEA-TADPOLE device doesn’t need a time delay because it creates the interference spatially. Spectral phases can be resolved directly from a two dimensional interference pattern by a simple fast Fourier transformation (FFT). After building the phase measurement device, it will be applied to a high energy fiber-based CPA system to characterize and study ultra-short pulses amplified by this system.

IAP Nanooptics Group

Prof. Dr. Thomas Pertsch (Thomas.pertsch@uni-jena.de)

Plasmon based nanostructured Metamaterials

Metamaterials are artificial compound effective media possessing extraordinary optical properties. Experimental measurements of optical properties of metamaterials are an inherent part of a design process. Spectral characterization of the samples forms the basis of the experimental characterization procedure. Comparison between the measured spectra of a sample with theoretically calculations gives important information about the quality of a sample and characteristic features. Thus, performing spectral measurements of high quality is a central subject of our work. Some specific features of the samples like high absorption makes the measurement process challenging. These difficulties are mostly overcome in our modern spectrometers which offer additional functionalities as, for example, diffusion measurements.

In the project, the student will learn the theoretical background of plasmon based nanostructured metamaterials. The main part of the work will be dedicated to spectroscopic measurements using standard tools. In addition additional techniques can be developed, such as zero degree reflection measurement.

Dual-probe scanning near-field optic microscope

The topic is centered on scanning near-field optical microscopy (SNOM). The SNOM is at the forefront of science and technology already 20 years because it combines the potentials of scanning probe technology with the power of optical microscopy. SNOM is an imaging technique used to obtain resolution beyond the Abbé diffraction limit. SNOM possesses the excellent spectroscopic and temporal selectivity of classical optical microscopy with a lateral resolution reaching well into the sub-100 nm regime.

The operational principle behind near-field optical imaging involves illuminating a specimen through a sub-wavelength sized aperture, formed at the end of metal-coated etched fiber, whilst keeping the specimen within the near-field of the source. An image is built up by raster-scanning the aperture across the sample and recording the optical response of the specimen through a conventional far-field microscope objective.

Since SNOM outperforms the spatial resolution of far-field optical microscopes by at least one order of magnitude, it is a very useful technique for studying individual nanostructures and crystal defects, single molecules etc.

Implementing interferometric-heterodyne detection (HD) technique in the SNOM allows measuring phase and amplitude of the optical near field with nanometric resolution. Further development of this technique led to time-resolved HD-SNOM which has been used to visualize and track the propagation of femtosecond laser pulse inside a photonic structure. From the time-dependent and phase-sensitive measurements, both the group velocity and the phase velocity are unambiguously and simultaneously determined. It is expected that this technique will find applications in the investigation of the local dynamics of integrated optical circuits, photonic crystals, regular arrays of nanostructures etc.

The goal of this master thesis will be the development of a Heterodyne Detection Double-Probe Scanning Near-Field Optic Microscope for studying local excitation propagation.

Amplitude and phase measurements in a photonic crystal waveguide by using heterodyne scanning near-field optical microscope

Scanning near-field optical microscopy (SNOM) is an advanced form of microscopy which overcomes the Abbé diffraction limit and produces images with a resolution reaching well into the sub-100 nm regime. SNOM is based upon the detection of non-propagating evanescent waves in the near-field region. The near-field region is defined as the region away from the sample that is less than the wavelength of the incident light. In SNOM this distance is typically on the order of a nanometer. In order to achieve an optical resolution better than the diffraction limit, a probe has to be brought within the near-field region. The probe can detect in the near-field directly, by means of a sub-wavelength size aperture.

The most widespread technique for regulating the tip-sample distance is shear-force feedback method based on a quartz crystal tuning fork which allows keeping the distance below 10nm.

Implementing interferometric-heterodyne detection (HD) technique in the SNOM allows measuring phase and amplitude of the optical near field with nanometric resolution. The concept of heterodyne interferometry is to introduce a small frequency shift between two interfering beams. As a result of this shift, the interference of the two beams produces an intensity modulation at the beat frequency, which is then detected.

In the HD-SNOM the laser beam is split in a part that is coupled into the waveguide and subsequently detected with the SNOM and a part that forms a reference branch. The two signals are brought together in a coupler in which the fixed phase of the reference branch is compared with the phase of the optical field in the waveguide. Combination of these two signals yields the interference signal. Heterodyne interferometric detection is achieved by acousto-optic modulation of the light in the reference branch. The resulting signal, measured with a lock-in amplifier, contains the phase information and is proportional to the field amplitudes of both the local waveguide field and reference signal. The relative phase distribution within the waveguide is measured by scanning the probe over the waveguide surface.

High-Q optical microresonators

The topic is centered on monolithic optical microcavities. With a nearly atomic-scale surface finish, surface-tension induced microcavities are superior to all other dielectric microresonant structures when comparing their giant photon lifetime or equivalently ultra-high Q factor. These devices have opened a myriad of lab-on-chip applications ranging from Laser Physics, Quantum Optics, Nonlinear Optics to Biochemical Sensing. For instance toroid microcavities have been the enabling setting for observation of strong coupling of a single atom and a microresonator, as well as the demonstration of chip-based parametric oscillators or radiation pressure induced phenomena.

Wafer-based processing of resonators can achieve unprecedented process parallelism and control. However, such resonators-on-a-chip suffer from Q factors that are many orders of magnitude lower than for single microspheres.

The goal of the activities will be the producing, characterization, and demonstration of microresonators-on-a-chip with ultra-high Q factors, as well as applications of the high-Q microresonators. This result will open the door to creating highly integrated nonlinear devices, as e.g. Raman lasers, Erbium microlasers, as well as optical parametric oscillators.

Discrete-optics beam combiner for astrointerferometers

Dr. Stefano Minardi (stefano.minardi@uni-jena.de)

Recently, optical interferometry has become one of the most powerful methods available to astronomers to unveil the secrets of the Universe. Modern astro-interferometers are already getting images of young star’s environments with unprecedented resolution, therefore providing precious data for the understanding of stellar evolution, planet formation and, eventually, life in the Universe. This progress is mainly due to the application of photonics to astronomical instrumentation. Future astro-interferometers will be able to connect telescopes trough fiber links. Passive photonic circuits will soon be used to perform multiple beam combinations at large interferometric facilities. The main drawback of integrated optics components is the realization cost which too high to justify the improved performance respect to bulk optics combiners.

In this context, we propose to explore the possibility to perform beam combination by means of an array of coupled waveguides. By exciting three different waveguides with three light beams, a complex pattern of light will be observed at the end of the waveguide array. It is possible to demonstrate that the intensity pattern is uniquely determined by the phase and amplitudes of the three input beams.

Precise work to be done:

- Find optimal conditions (input excitation pattern and sample length) for best performance of the discrete-optics phase meter using numerical techniques.
- Build a setup that can prove the numerical results.

IAP Optical Modeling and Design Group

Prof. Frank Wyrowski

Development of diffusers for lighting and display

Lighting and display technology is of enormous importance in our life and gain huge technical and economic momentum. The availability of LEDs has drastically influenced this development. In addition to conventional optical systems, diffusers are of special concern for future trends in lighting and display. In the master thesis you contribute to new types of diffusers. Your work comprises theoretical, simulation, and experimental activities.

Design of computer-generated holograms for 3D security applications

Everybody knows the application of holograms and other optical concepts for documents like credit card or passport in order to impede counterfeiting. The optical security business needs always new ideas to make the job of falsifiers as difficult as possible. Computer-generated holograms (CGH) of 3D signals are such an interesting chance in which security companies are interested in. Moreover it is just beautiful for any optician, to generate a three-dimensional light distribution which has been originated at a PC. In the master thesis you deal with and contribute to state-of-the-art techniques to design and model CGHs of 3D signals. Your work comprises theoretical, simulation, and experimental activities.

Simulation of ultra short pulse propagation through optical systems

Physicists distinguish between stationary and non-stationary sources. Most light you see in nature and also in a lab is originated by stationary sources. Typical optical modeling techniques deal with such kind of radiation. In ultra-short optics non-stationary sources are investigated and utilized in an ever increasing number of R&D and industrial applications. Hence, simulation of the propagation of pulses through optical systems is extremely important but also not well established. In the master thesis you contribute to state-of-the-art techniques to linear simulations in ultra-short optics. Your work comprises theoretical, simulation, and experimental activities.

Modeling of optical characteristics of laser resonators

The quality of laser beams drastically depends on all physical effects which take place in the laser resonator. Thus, the simulation of the laser output beam is of central concern for the laser manufactures and their consumers in industry and R&D. The simulation of laser resonators includes in particular the optical cavity, all passive and active components in the resonator and the physics inside the active medium. The laser can be stable or instable. Polarizing and diffractive components can be included. In short, the simulation of laser resonators offers numerous interesting topics for your master thesis, which are of concern in the laser industry worldwide. Your work comprises theoretical and simulation work. Dependent on the topic experimental work is included too.

Light propagation through anisotropic media and interfaces between them

Polarization effects are of increasing importance in optical modeling. LCD screens use for example polarization effects to deliver great picture quality. Besides the representation of the state of polarization of light in simulations the inclusion of anisotropic media in modeling gains momentum. Of particular interest is the propagation through birefringent media, which typical appears for crystals but also for artificial media in nanooptics. In the master thesis you investigate physical and geometric optics methods to model light propagation through birefringent media and interfaces between them. Your work comprises theoretical, simulation and experimental activities.

Fraunhofer Institute for Applied Optics and Precision Engineering, Jena

Prof. Dr. Andreas Tünnermann (andreas.tuennermann@iof.fraunhofer.de)

Optical concepts for miniaturized surface sensors by relying on bi-directional microdisplays

Bi-directional micro displays constitute a new class of optical active elements, which is able to provide for the first time a structured light source (OLEDs) and a receiver elements (CMOS) integrated into a single optical chip. Based on these elements new concepts for ultra-compact surface sensors can be developed. In the context of the proposed work the fundamental optical concepts covering such elements shall be developed and the device performance shall be evaluated. This work shall be complemented by first experiments.

3D structure recognition using optical systems

To define the structural resolution of scanning procedures used to probe the texture of a surface is so far a not solved problem. For this purpose new methodological and algorithmic investigations needs to be done but also the development of suitable test objects must be accomplished. Therefore suitable test bodies (edges, pyramid-shaped bodies, wedge-shaped bodies, multi-wavelength structures) need to be examined regarding their suitability for the determination of the pattern definition theoretically and experimentally. A comparison to tactile systems is to be made.

Algorithms and methods for the THz-Tomography

Terahertz radiation (THz, also far IR) can penetrate many materials, which are optically impenetrable in the UV-NIR range. In the context of this work, new mathematical and methodical approaches to compute tomographical pictures from a sequence of amplitude and spectrally coded THz pictures shall be examined. This leads in result to a new kind of tomography with the possibility to determine the spatial distribution of spectral information.

Self-calibrating deflectometry for quantifying reflecting surfaces

Current strip projection procedures are limited to the measurement of the 3D-surfaces of objects with strongly scattering surfaces. By means of the deflectometry, a special strip projection procedure, also the measurement of reflecting surfaces becomes possible. In the context of this work, the principle of self calibration, well-known from classic strip projection procedures, shall be applied to a system based on deflectometry. The ideas shall be implemented into a devoted experiment. First test measurements to examine optical surfaces (e.g. passenger car lights) are planned.

Institute of Condensed Matter Theory and Optics

Prof. Dr. Falk Lederer

Optical properties of metamaterials

Dr. Carsten Rockstuhl (carsten.rockstuhl@uni-jena.de)

At the heart of a master thesis about metamaterials could be an analytical investigation about possible paths to introduce effective material parameters for such nanostructured media, an analytical and/or numerical analysis of the impact of a gain medium incorporated into the metamaterial, rather numerically oriented studies on the design and the resulting properties of metamaterials or the investigation of possible application of metamaterials. Most of these subjects can be done in close collaboration with experimental physicists.

Optics in multiple-quantum well structures

Dr. Carsten Rockstuhl (carsten.rockstuhl@uni-jena.de)

A slab of doped multi-quantum-well (MQW) materials has a Drude-like dipersion relation, which is, intrinsic to the structure, strongly anisotropic. It resembles therefore an artificial anisotropic metal. The advantage if MQWs as compared to metals is the strong reduction of losses. It is the aim of this thesis to investigate theoretically and numerically the optical properties of plasmonic elements and metamaterials that can be fabricated using MQWs.

Ultra-fast light propagation in nonlinear media including plasmonic elements

Dr. Carsten Rockstuhl (carsten.rockstuhl@uni-jena.de)

Numerical techniques shall be used to simulate the light propagation through nanostructured media comprising materials with a strong nonlinear response. It should be furthermore investigated how the incorporation of metallic nanostructures that sustain plasmonic resonances allow to enhance the conversion efficiency of the nonlinear processes. The work should be complemented with development of analytical, though simplifying, models that permit to understand the occurring effects on a phenomenological level.

Photon management in solar-cells

Dr. Carsten Rockstuhl (carsten.rockstuhl@uni-jena.de)

As photon management one understands all efforts to maximize the in-coupling of photons into the light absorbing layers of solar cells. Presently, the investigations focus on plasmonic elements, photonic crystals, diffracting grating, appropriate multilayer structures, or combination of such elements. Most of the analysis thus far is done for single layer solar cells. The diploma thesis shall investigate the incorporation of such elements into multilayer solar cells.

Properties of SNOM tips

Dr. Carsten Rockstuhl (carsten.rockstuhl@uni-jena.de)

A scanning near-field optical microscope (SNOM) is an instrument that comprises a tip which is scanned above a surface. Various geometries for SNOMs exist, though the basic idea is that the tip provides either a strongly localized light source in the vicinity of the surface or it measures the strength of the light in spatially highly localized domains. The aim of a SNOM is to obtain information about the optical near-fields with unprecedented resolution. A problem is that in the analysis of the images the interaction of the tip with the sample and its transfer function is usually neglected. It is the aim of this work to investigate both aspects in detail.

Light propagation in 3 dimensional random photonic materials

Dr. Carsten Rockstuhl (carsten.rockstuhl@uni-jena.de)

In a possible master thesis the peculiarities of light propagation through a media composed of randomly placed scattering entities shall be investigated. Depending on the index contrast and the size of the scatterers, various analytical and numerical techniques can be used for the analysis of such situations. Emphasis shall be put on the identification of possible regimes for a weak and strong localization of light in such structure.

Institute of Physical Chemistry

Prof. Dr. Jürgen Popp (juergen.popp@ipht-jena.de)

Working at the detection limit: Optimizing the conditions for SERS experiments

Just recently it was shown that heme and heme degradation products cause unexpected reactions in cells and living organisms. The exact mechanisms are still unclear. One reason for that are the very low concentrations (in the nanomolar range) at which free heme and its complex, partly unstable degradation products occur in living cells. These concentrations are beyond the detection limit of many standard analytical methods.

Optical methods are ideal for the non-destructive detection of heme in biological samples. However, in order to trace the low physiological concentrations the application of enhancing effects is necessary. Surface enhanced Raman spectroscopy (SERS) makes use of the local field enhancement in the close vicinity of rough metal surfaces upon excitation of the metal surface plasmons. Enhancement factors up to 1014 have been reported and therefore, the detection of nanomolar heme concentrations should be feasible.

Within this lab class different metal colloids should be tested for their SERS enhancement and the resulting detection limit should be determined using different laser excitation wavelengths. Furthermore, the SERS spectra of different degradation products and mixtures of suchlike should be studied.

Other questions to be answered are: Is it possible to selectively detect heme in the presence of different cellular components, such as amino acids, nucleic acids, proteins, etc. What effects have various concentration ratios? Is it possible to insert the SERS active colloids into living cells and how can the resulting in-vivo-SERS spectra be interpreted?

Surface enhanced Raman spectroscopy (SERS): Probing of SERS-active substrates and their application towards (bio)analytical devices

The requirements of an ideal analytical tool are both a high specificity and a high sensitivity. With Raman spectroscopy highly specific investigations using for instance the specific spectroscopic fingerprints is feasible. However, the limit-of-detection of conventional Raman is rather low. However, Raman modes can be efficiently enhanced by metallic nanostructures, resulting in the so called surface enhanced Raman spectroscopy (SERS). Enhancement factors up to 14 orders of magnitude are reported in the literature.

Within this lab class, different kinds of SERS-active substrates are introduced, for instance enzymatically produced silver nanoparticles and regular patterned gold nanostructures. The lab course starts with the production and characterization of the SERS substrates following by the application towards (bio)analytical devices.

Institute of Organic Chemistry and Macromolecular Chemistry

Prof. Dr. U. S. Schubert

Chemical nanolithography for optically active nanostructures

Dr. Stephanie Höppener (stephanie.hoeppener@uni-jena.de)

The aim of the project is to create metallic nanostructures for optical applications, e.g., split-ring resonators. In the framework of this project, skills in basic chemical lab work, self-assembly and structuring techniques will be obtained. Major investigation and structuring tool is the Scanning Force Microscope, which allows both the fabrication and the analysis of the nanostructures. Thereby, the tip of the microscope is used as an electrical connection to the surface, which can locally change the surface properties by oxidation.

This electrochemical structuring technique is performed on self-assembled monolayers, which are locally activated. These activated areas can serve as a platform for the deposition of metals. The design of such structures is very flexible and will be adjusted to theoretical investigations.

The project is interdisciplinary (involving chemical and physical aspects) and provides insight into different research areas. The project is designed to be transferred into a full master project after completion of the “Research labwork” phase. During the initial period, the candidates will obtain all necessary knowledge and skills to transfer the approach to the next level of fabricating tailor-made photonic nanomaterials.

Institute of Optics and Quantum Electronics

Prof. Dr. G. G. Paulus (gerhard.paulus@uni-jena.de)

Strong-field ionization with intense few-cycle laser pulses

Carrier-envelope phase stabilization of few-cycle lasers

Spatio-temporal evolution of optical filaments with and without phase singularities

Charged particle acceleration at relativistic laser intensities

An attosecond streak camera for the temporal characterization of relativistic high harmonics

Generation of intense extreme ultraviolet radiation by colliding a laser-accelerated dense electron pulse with terawatt optical pulses

Possible Project areas in Optics for Second Year Erasmus Mundus students at Imperial College London

Introduction

As part of your general considerations, projects will be available in areas where projects have previously been offered as part of our Masters level teaching. This means that previous project titles are a useful indication of topics in which projects are likely to be available. The following is a list of past projects offered by MSc students studying Optics. The 2008-09 and 2009-10 Erasmus Mundus projects are in red.

Adaptive Optics and Interferometry:

Development of a background polarimetric imaging technique;
Design and Construction of a low light wavefront sensor
Programmable holographic references for wavefront interferometry
Adaptive Optics using cost function minimisation
Measuring group display dispersion with a white light interferometer
Quadature Interferometer in Fibre for use in MAGPIE.

Imaging, Biomedical Imaging and Imaging Through Turbulence:

Three dimensional super-resolution imaging by localization microscopy;
Measuring the dynamic topography of the tear film
OPT-FLIM: Optical Projection Tomography with Fluorescence Lifetime Imaging
Modeling light propagation in biological tissues by Monte Carlo method
Mid-IR biological imaging
Optimising photodetection for microfluidic chemiluminescence
High Performance Short Pass Filters for Chemical and Biological Analysis
Extracting 3-D images from endoscopic images
Hyperspectral FLIM of biological tissue
LED microstrip arrays for FLIM;
Development and analysis of a novel optically sectioning microscope;

Optical Displays:

Real-time projection using computer generated holograms
Optical testing of Large Optical Displays
3D Displays with vertical parallax
Contact printed polymer thin film transistors for liquid crystal displays

Optical Analysis and Sensors:

Characterisation of gas jet targets for laser Wakefield accelerators
Surface roughness measurement through speckle analysis
Testing of aspheric surfaces of variable profiles
Setup of a stimulated emission depletion (STED) microscope
Comparing the performance of wide-field optically-sectioning microscopes
Characterisation of wavefront errors for segmented mirrors
Measurement of complex pupil function of high NA lenses
Integrated optical chemical sensors;
Optimising photodetection for microfluidic chemiluminescence; High Performance Short Pass Filters for Chemical and Biological Analysis.

Laser Development:

Self-organising laser networks
High finesse optical fibre resonators
Mode-Locking of high power bounce geometry lasers
Passive Q-switched eye safe laser

Nonlinear modelocking of high power DPSS lasers
Carbon Nanotube mode-locked lasers;
Strongly coupled lasers.

Ultrafast Laser Development:

OPAC: Optical Parametric Correlator
Pico-Second OPCPA Front-end For Vulcan
Novel Optical Phase Shaper for High Power Femtosecond Pulses
Processes of transformation of femtosecond pulses
Development of an infra-red ultra-short pulse OPG
Computer simulation of ultrafast pulse propagation
Polarisation Gating for Attosecond Pulse Generation
Building and modeling an alternate gradient guide
Generation of high-power few-optical-cycle laser pulses for driving attosecond pulse production from solid targets: theory and experiment
Shaping of sub ps pulses with an LCD array;
Validation of XPWG filters for ultrashort pulses.

Quantum Optics:

Quantum Cryptography

Optical Design:

Design of lens systems for mobile phones;
Historical review of Binoculars;
Optical design of a stereo viewing device
Design of an Optical Pen
Thermally compensated plastic lenses
Adaptive forward lighting system

Optical Trapping and Cold Matter:

Casimir-Polder forces on moving atoms – friction forces;
Design and implementation of a 3D vision and manipulation for an optical tweezers system;
Optical fibres for single atom traps
Holographic optical trapping

Optoelectronics and Telecommunications:

Development and characterisation of a micro-photoluminescence system;
Electromagnetic simulation of optical nano-antennae;
Self-assembled quantum dot lasers;
Propagation in Optical Fibres;
Double Grating Fabrication by Using Soft Lithography;
Fabrication of photonic crystal lens structures using holographic lithography
Measuring the Performance of Triple-Junction Solar Cells
Optically Pumped ZnO Nanowire Lasers
INAs/GaAs quantum dot bilayer laser optical emission
Silicon Germanium Distributed Feedback Reflector: Modeling and Experimental Investigation
Waveguiding in aluminium using surface plasmon polaritons
FTTH free space optical communications
Characterisation of multimode optical fibres
Photoluminescence spectroscopy of quantum dots in charge tuneable structures
Emitter structure and current collection in concentrator solar cells

Polymer Light Sources:

Light Efficiency Enhancement for Polymer LEDs
Organic thin film phototransistors
Hybrid Organic/Inorganic Quantum Dot Photosensitive Devices
Electroabsorption Spectroscopy of organic Light Emitting Diodes
Organic solar cells on flexible substrates
Coherent Control of the Nitrogen-Vacancy Centre Spin Qubit with Detuned Optical Pulses.
Characterisation of liquid crystal devices using a polarimetric measurement system;
Investigation of Molecular Semiconductor Based Photodiode Arrays Fabricated Via Spray Coating.

Research group links:

Details of the Optics Research in the Department may be found at:
http://www3.imperial.ac.uk/pls/portallive/docs/1/55893696.PDF
(Department's annual report)
http://www.imperial.ac.uk/research/photonics/research/topics/index.htm
http://www.imperial.ac.uk/research/qols/research_areas/index.htm
http://www3.imperial.ac.uk/experimentalsolidstate/researchactivities
Projects in these areas can be arranged.