2010-2011: OPSCITECH COURSE MODULES at TU DELFT

Code	Name	ECTS	*Only for 1st year*
G-phys list	**= General optical physics courses**		
AP3061 G	Advanced Wave Propagation	6	*Compulsory*
AP3071 G	Advanced Electrodynamics	6	*Compulsory*
G-math list	**= General mathematics courses**		*Choose at least 6 ECTS credits*
WI4014TU	Numerical Analysis	6	
WI4143TN	Complex Analysis	6	
WI3150TU	Partial Differential Equations I	3	
WI4150TU	Partial Differential Equations II	3	
S-list	**= Societal/Non-technical courses**		
WM0320TU	Ethics for Engineering	3	*Compulsory*[1]
	English (level depending on intake test)	3	*Compulsory*[2]
D-list	**= Courses at the Department of IST**		*Choose at least 12 ECTS credits*
AP3111 D	Quantum Electronics and Quantum Optics	6	
AP3121 D	Imaging Systems	6	
AP3131 D	Advanced Signal Analysis and Processing	6	
AP3231TU D	Medical Imaging	6	
R-list	**= Research course modules**		*Choose at least 12 ECTS credits*[3]
AP3401	Introduction to charged particle optics	6	
AP3381	Theoretical optics	6	
AP3391	Geometrical optics	6	
AP3601	Optical Fabrication Technology	6	
ET4283	Advanced Digital Image Processing	6	
WB2433	Humanoid Robots	3	
IN4085	Pattern recognition	6	
AP3361	Medical Physics & Radiation Technology: Imaging	6	
Project	**= Research project**		
AP3941	In the 1st year: Internship	12	*Compulsory*
AP3901	In the 2nd year: Master thesis	48	*Compulsory*

1. The course Ethics for Engineering is offered twice a year, in the first and third period.
2. If your English is exceptionally good, you can also take courses for another language, such as Dutch, German or French. This should be approved by the Delft OpSciTech scientific supervisor. For more information on S-list modules please consult the website of the faculty Technology, Policy and Management www.tbm.tudelft.nl.
3. Should be approved by the internship supervisor or the scientific supervisor.

Look for possible changes on the online study guide of TU Delft: **http://studyguide.tudelft.nl**. OpSciTech can be found under: Year: 2010/2011, Organization: Technische Natuurwetenschappen, Education: Master Applied Physics, Track Optics in Science and Technology. This site also contains a detailed description of each course that can help you in your choices.

2010-2011: *OPSCITECH COURSES at FSU JENA*

COURSE SCHEDULE (overview):

please consult http://www.asp.uni-jena.de/Master+Course/Course+Schedule.html

DETAILED module catalogue:

please consult ***http://www.physik.uni-jena.de/ordnungen/mc-master-photonics_2009_WS_2009_10_09.pdf***

2010-2011: *OPSCITECH COURSES at IMPERIAL COLLEGE London*

YEAR 2

YEAR 2 / 1st term

	Course	ECTS
12 ECTS	Lasers	6
	Imaging	6
	Optical Communications Physics	6
	Optical Measurement and Devices	6
	Laboratory work	4
	Business / Entrepreneurship	2
	Project (background research)	6
	Total	24

YEAR 2 / 2nd & 3rd terms

9 ECTS	Laser Technology	3
	Laser Optics	3
	Nonlinear Optics	3
	Biomedical Optics	3
	Fibre Technology	3
	Photonic Structures	3
	Optical Displays	3
	Quantum Physics and Chemistry of Cold Matter	3
	Experimental Realizations of Controlled Quantum Dynamics	3
	Optoelectronic Components and Devices	3
	Optical design	6
	Optical Design Laboratory	6
	Self Study Project	27
	Total	36

Imperial College London

Course: Imaging

Lecturer: Dr. Peter Török

Aims
This course provides an introduction to geometrical and wave optics and their application to imaging systems.

Syllabus

- Fermat's Principle, Snell's law.
- Gaussian (paraxial) optics, stops and pupils, ray tracing, principal and marginal rays.
- Transverse ray and wavefront aberrations, the aberration polynomial, primary aberrations, Seidel aberrations, Zernike polynomials.
- Chromatic aberration. Finite (exact) ray tracing.
- Complex amplitude.
- Physical theory of diffraction: Huygens-Fresnel approach; Kirchhoff diffraction integral.
- Application to imaging systems. Point spread functions, Airy pattern. Point spread function with defocus and aberrations. Strehl tolerances for aberrations.
- Fourier Transform treatment of the imagery of incoherently illuminated extended objects; line, edge and periodic objects.
- Coherent and incoherent imaging.
- Optical transfer function; effects of aberrations.

Imperial College London

Course: Lasers

Lecturer: Prof. Geoff New

Aims

This course provides an introduction to lasers and laser physics covering the basic physics underlying the principles of laser operation. The closely related field of nonlinear optics is reviewed at the end of the course.

Syllabus

- Laser basics: stimulated emission and population inversion, laser materials and pumping schemes, laser beam characteristics.
- Basic radiation theory: the Planck radiation law, Einstein A and B coefficients, transition cross section.
- Laser action: laser rate equations, 3- and 4- level schemes, laser threshold condition, steady state laser power.
- Linewidth characteristics: homogenous and inhomogenous broadening, cavity resonances, spectral and spatial hole burning.
- Typical lasers and laser classes: HeNe, Ar, ion, ruby, neodymium, Ti:S and other solid state materials, excimer lasers, CO2 lasers, dye lasers, semiconductor lasers.
- Laser cavities: paraxial wave propagation, Gaussian beams, stable and unstable resonators.
- Laser pulses: Q-switching and mode-locking. Nonlinear optics: brief review.

Imperial College London

Course: Optical Communications Physics

Lecturer: Dr. M. A. A. Neil

Aims

This course enables the student to understand the nature of information and how it is communicated. Optical communications is at the heart of modern day high bandwidth data transfer and this course outlines the principles and optical fibre technology that underpins this photonics industry.

Syllabus

- Quantifying information; Shannon's formula for channel capacity; digital encoding of analogue signals; sampling theorem; Nyquist rate, quantization; multilevel signalling.
- Information theory; redundancy; data compression; error detection and correction; System limitations: bandwidth, attenuation, noise, dispersion.
- Comparison of transmission media: free-space, twisted pair and coaxial cable, optical fibre. Baseband and modulated carrier transmission; communication networks (LAN, MAN, WAN); multiplexing (TDM, WDM, SDM); packet- and circuit-switched networks; network protocols.
- Fourier series; Fourier transforms; convolution theorem; noise; bandwidth filtering; modulated transmission; demodulation and signal recovery.
- Optical fibres: step index, graded-index, multimode and single-mode; acceptance angle; basic mode theory; attenuation and dispersion.
- Optical telecoms.

Imperial College London

Course: Optical Measurement and Devices

Lecturer: Dr. Kenny Weir and Dr. Carl Paterson

Aims

Optical measurement techniques are important to manufacturers and users of optical equipment and in a wide range of applications. This foundation course will include the following underlying generic optical concepts: polarisation of light; interferometers; testing of optical components; and optical thin films.

Syllabus

- Light as a wave; definition of the polarisation state of light; polarisation calculus; devices for the manipulation of polarisation; measurement of polarisation; ellipsometry.
- Principles of interferometry; division of wavefront and division of amplitude; multiple beam interferometers; laser interferometers; practical interferometers. Interferometric and non-interferometric techniques for testing the quality of optical surfaces, optical components and image forming systems; optical techniques for making other types of measurement.
- Optical properties of thin films; design of thin film antireflection coatings, mirrors, beam splitters and polarisers; narrow band optical interference filters; practical techniques for the manufacture of thin film devices.

Imperial College London

Course: Laboratory

Lecturer: Dr. Mark Neil and lecturers, post-graduate and PhD students as demonstrators and markers.

Aim
The aim of the laboratory work is to provide students with an introduction and experience of important optical phenomenon, techniques and instrumentation and to develop their practical skills.

Syllabus

Element 1
Compulsory Experiments: Telescope star test.Interpretation of interferograms, Spectrographic investigation of filters, FECO multiple beam fringes, Characteristics of semiconductor light sources, Laser speckle, Fibre optics, Astigmatism and field curvature, Near and far field diffraction, Phase sensitive detection, Polarisation, Illumination of a microscope, What is holography? Modelling a network.

Element 2
Select five from: Twyman Green Interferometer, Moller Wedel Interferometer, Star Test, Laser Modes, Holography, Optical Fibre Communications, Erbium Doped Fibre Amplifier, Knife Edge Test, Modelling of Optical Fibre Networks, Fourier Optics, Spectral Characteristics of sources.

Element 3
Students choose one of the following experiments: CD autofocus system transducer.Optical bar code scanner, Object sorting by colour and size, Length measurement with direction (Optical Ruler), Surface profiling system, A non contact optical fibre displacement sensor, Measuring the properties of thin films, Measuring the refractive index of liquids, Laser Anemometry.

Imperial College London

Course: Entrepreneurship/Business Skills

Lecturer: Academic Staff at Imperial College and external consultants (where appropriate).

Aims
To develop the personal and business skills necessary for the students to have a challenging and productive career when they leave university.

Syllabus
Imperial College offers postgraduate students a wide variety of courses covering the skills involved in generic areas of research learning, communication and management (personal and professional career development). Some of the courses offered are listed below:

- Information Retrieval Lecture,
- Personal Organisation & Effectiveness Workshop,
- Professional Issues in Science: Research Ethics Workshop,
- Research Skills Development Course.
- Technical Writing Lecture Series.
- Efficient Reading.
- Motivation.
- Myers Briggs.
- Negotiation Skills.
- Networking.
- Presenting with Passion.
- Problem Solving & Ideas Generation.
- Project Management.
- Statistics.
- Stress Management: Postgraduate Study and Beyond.
- Working for the PhD.

The Tanaka Business School offers several courses and programmes to the postgraduates of the College, including the Entrepreneurial Challenge, which the students will undertake as part of their studies.

Imperial College London

Course: Project

Lecturer: Dr. Kenny Weir, plus the academic members of staff.

Aims

The project allows the students to apply the academic and practical skills they have developed to a substantial, real-world problem and to gain experience of how to solve technical and professional problems and to gain and practice the skills necessary for a successful career.

Syllabus

The projects are of six months duration and are hosted by a research group or an industrial/research organisation and contribute to the continuing work of the organisation.

Imperial College London

Advanced Option Course: Laser Technology

Lecturer: Prof. Michael Damzen

Aims

This course introduces the student to the practical aspects of the laser market, including modern laser systems, techniques, technological issues, and applications that are relevant to the industrial, commercial, military and scientific market sectors.

Syllabus

- Semiconductor diode lasers: heterojunction structures, single-mode, broad-stripe, high power arrays, VCSELs, distributed Bragg reflectors, external grating-tuned cavities.
- Diode-pumped solid-state lasers, microchip lasers, tunable solid-state media, ultrafast lasers. Fibre amplifiers, cladding-pumped fibres, fibre lasers.

High power industrial lasers.

Imperial College London

Advanced Option Course: Laser Optics

Lecturer: Dr. M. Tarbutt

Aims

The way laser beams propagate is based on Maxwell's equations however, the particular solutions found that are relevant to the case of many common lasers, have a number of interesting and unique properties. This course provides an in-depth treatment of the mathematical tools required for an understanding of the peculiar kinds of light beams produced by lasers. A firm understanding of this subject is of paramount importance in the design of optical systems that employ laser beams.

Syllabus

- Ray transfer matrices, laser cavities, stable and unstable resonators, modes (longitudinal and transverse), mode frequencies.
- Gaussian beams: waist size, radius of curvature, Rayliegh distance, the Guoy phase.
- Gaussian beam propagation: the ABCD law for Gaussian beams, complex radius of curvature, beam transformation through optical components and systems, focusing and imaging.
- Higher order modes, beam quality, spatial filtering, beam expanders.
- Laguerre Gaussian beams, Bessel beams.

Applications (optical tweezers, optical spanners).

Imperial College London

Advanced Option Course: Nonlinear Optics

Lecturer: Dr. John Tisch

Aim
This course will provide the basic insights needed to understand how intense laser light could be used to modify the polarisation of atomic mater and through this modify the pump light, for example, generating new frequencies. The course will allow the student to assess the scope and applicability of nonlinear optics.

Syllabus

- Review of nonlinear optical processes; second-, third- and higher order processes; perturbation theory and nonlinear coefficients.
- Crystal optics and the Pockels effect.
- Frequency mixing processes and coupled wave equations.
- Birefringent phase matching, quasi-phase matching and periodically-poled media; optical parametric generation; four wave mixing and optical phase conjugation.
- Raman processes.
- Nonlinear fibre optics, pulse compression and optical solitions.

Imperial College London

Advanced Option Course: Biomedical Optics

Lecturer: Dr. Chris Dunsby

Aims

To introduce students to the state-of-the-art of biomedical applications of optical imaging techniques

Syllabus

- Introduction to biomedicine and imaging.
- Optical properties of biological tissue: macroscopic to microscopic.
- Imaging through biological tissue: an overview.
- Diffuse Optical Tomography: imaging through thick tissues.
- Introduction to microscopy: wide-field and confocal. Imaging in the eye.
- Advanced microscopy techniques: nonlinear and multi-photon microscopy; OCT; structured illumination and super-resolution; Fluorescence imaging
- Endoscopic imaging and near field microscopy.
- Optical therapies: surgery via photocoagulation, disruption, ablation; PDT.

Imperial College London

Advanced Option Course: Fibre Technology

Lecturer: Dr. S. Popov

Aim
This course provides an introduction to optical radiation confined within guided wave dielectric structures. The course intends to explicate the features of guided wave optics and their contrast to bulk optics.

Syllabus
- Guided waves in slab waveguides.
- step-index and graded index fibres.
- ray and propagation models, single-mode and multimode fibres.

attenuation and dispersion, fibre devices.

Imperial College London

Advanced Option Course: Photonic Structures

Lecturer: Dr. Martin McCall, Dr. Paul Stavrinou

Aims

To show how 1-D and 2-D periodic dielectric structures that comprise sub-wavelength features can be used to confine, manipulate and re-direct light for various applications in modern photonics.

Syllabus

• **1-D structures:**

- Concept and origin of a photonic bandgap using symmetry arguments on a 1-D 'unit cell'.
- Quantitative description of 1-D structures via coupled mode theory. Derivation of Bragg wavelength and bandwidth.
- Defects in 1-D structures. Use in VCSEL's and quarter wavelength shifted DFB structures.

• **2-D structures:**

- Introduction and interpretation of photonic band structure diagrams (Bloch modes) Types of lattice structure (square, triangular…). Propagation in the plane, propagation out of the plane (scattering - losses etc).
- Calculations in frequency and time domain. Comparison of computational methods (FEM, FDTD, RCWA, PW).
- Applications and key practical issues (fabrication, PBG guides): super prisms, compact waveguiding, emissive structures.
- Passive - guiding, routing etc.. - Active, especially emitters - density of modes to control emissive properties generally applicable to (1,2 and 3D).

• **Emerging topics based on sub-wavelength diffractive structures**

Holey fibre (SM operation), Liquid crystals and chiral structures, Meta-materials (sub-sub-wavelength patterns, designer EM materials).

Imperial College London

Advanced Option Course: Optical Displays

Lecturer: Dr. T. Anthopoulos

Aims

Display devices are ubiquitous components of most of the machines that we use in our everyday life and they are on their way to becoming the most important element for information presentation. Knowledge of the general characteristics of the technologies in commercial use and those being developed, together with the role of human factors in determining performance of the systems.

Syllabus

- Introduction to Display Characteristics (Brightness, Colour hue and saturation, Contrast, Viewing angle, Efficiency, Response time, Memory, Resolution, Durability).
- Display Devices: Emissive (Cathode ray tube, Vacuum fluorescent, Plasma, Thin film electroluminescence, Field emission, Organic LED, Inorganic LED, Fluorescent liquid crystal) and Non-emissive (Liquid crystal, Micromirror, Electrochromic, Electrophoretic).
- Other Display Issues: Driving Schemes (Active matrix, Passive matrix), Flexible Substrates, Display optics.

Advanced Option Course: Quantum Physics and Chemistry of Cold Matter:

Lecturer: Dr. Ben Sauer and Dr. Mike Tarbutt

Syllabus

In this lecture course the students will learn the physics of cold atoms, ions and molecules. The course will cover both the theory and the modern experimental techniques of the field. The course will begin with lectures on atomic physics and atom-photon interactions, and will then cover a set of advanced topics including laser cooling, magnetic and optical trapping of atoms, formation and manipulation of quantum degenerate gases, ion trapping, cold molecules and collision physics at low temperatures.

Imperial College London

Advanced Option Course: Experimental Realizations of Controlled Quantum Dynamics:

Lecturer: Dr. Danny Segal

Syllabus

Building on the introduction in earlier courses, a thorough discussion of a variety of physical implementation for CQD will be taught, including matter based systems such as trapped atoms and ions, superconducting devices, quantum dots and photonic systems such as optical cavities, polarization and photon number degree of freedom of travelling light. Matter-light interfaces and their realizations will be discussed and strategies for combating noise will be discussed.

Imperial College London

Advanced Option Course: Optoelectronic Components and Devices

Lecturer: Dr. N. Ekins-Dawkes

Aims

Semiconductor optoelectronic devices are key components in all types of optical systems. Students should have a basic understanding of the principles of operation of these devices.

Syllabus

- Semiconductor materials, hetero-structures and quantum structures (2 lectures).
- Absorption, gain, density of states (1 lecture).
- Principles of amplification and lasing (including small signal dynamics) (3 lectures).
- Practical laser structures including DFB, DBR in-plane, and VCSELs (1 lecture).
- Quantum confined Stark effect and modulators (2 lectures).

p-i-n and APD detectors (1 lecture).

Imperial College London

Advanced Option Course: Optical Design

Lecturer: Prof. Robin Smith

Aim

This course provides an introduction to optical lens design. Following on from basic geometrical optics, study of the aberrations of optical systems leads to an understanding of why particular optical systems such as telescope, microscope, eyepiece and camera lenses take the form they do and how aberrations are controlled.

Syllabus

- Finite ray tracing. Paraxial ray tracing, principal and marginal rays. Transverse ray and wavefront aberrations, the aberration polynomial, primary aberrations.
- Seidel formulae for primary aberrations, variation of aberrations with stop position. Chromatic aberrations. Conditions for zero Seidel aberration contributions from a surface.
- Petzval field curvature and thin lens treatment of field curvature. Thin lens treatment of correction of longitudinal and transverse chromatic aberrations, secondary spectrum. Astigmatism of a thin lens. Distortion. Spherical aberration and coma for a thin lens at the stop in terms of the lens power and conjugate and shape parameters. Stop shift effects.
- Design of corrected doublets, limitations of doublets, aberration correction using separated doublets, correction of astigmatism.
- Microscope objectives, eyepieces, camera lenses. IR lenses. The use of aspheric surface in refractive, reflective and catadioptric imaging systems. Optical systems of special interest: the Schmidt camera and simple zoom lenses.

Imperial College London

Advanced Option Course: Optical Design Laboratory

Lecturer: Prof. Robin Smith, Mr. Eddie Judd

Aims

The student will learn how to design a wide range of optical systems, such as singlets, doublets, eyepieces and magnifiers catadioptric systems, telephoto and inverse telephone lenses, triplets and Tessars, double gauss lenses and infrared optics. The emphasis is on practical, tolerant and economic design.

Syllabus

- Thin lens layout of optical systems.
- Design of particular lens systems such as singlets, doublets, eyepieces and magnifiers catadioptric systems, telephoto and inverse telephone lenses, triplets and Tessars, double gauss lenses and infrared optics.

Imperial College London

Course: Self-study project

Lecturer: Dr. Kenny Weir, plus the academic members of staff.

Aims

The aim of this course is a carry out a research review to provide students with the opportunity of independent study relating to business or technical aspects of optical technology, preparatory to the six month project, under the guidance of a supervisor. No practical work is undertaken.

2010-2011: *OPSCITECH COURSES at Institut d'Optique Graduate School/ Université Paris-Sud 11*

	YEAR 2 / 1st semester	**ECTS**	**Professor(s) in charge**
4 courses	*Quantum Optics*	3	C. Westbrook
	Technology of Lasers	3	P. Georges
	Nanophotonics	3	H. Benisty
	Statistical Optics	3	P. Chavel
	Guided and coupled waves	3	JM. Jonathan
4 courses	*Advanced nonlinear Optics*	3	N. Dubreuil
	Near-field microscopy	3	R. Carminati
	Electrooptics, optoelectronics, Optical Communications	3	JP. Huignard
	Biophotonics	3	A. Dubois
	Signal and image processing	3	F. Goudail
	Semiconductors for nonlinear optical functions	3	A. Levenson
	New trends in Optics (conferences and visits)	0	
	Optics Labworks	3	L. Jacubowiez
	Intellectual Property	3	P. Brochard
	French	0	A. Manco
	Total	30	

YEAR 2 / 2nd semester		
French	3	A. Manco
Innovation in Science and Engineering	3	T. Esselman
New trends in Optics (conferences and visits)	0	
Master's Thesis	24	F. Delmotte
Total	30	

Course: Statistical Optics

Instructor: Dr. Pierre CHAVEL and Nathalie WESTBROOK

Aims

Statistics are essential in optics, mainly because the electromagnetic field of light undergoes random fluctuations in time or in space that in most cases cannot be monitored individually, but only in statistical terms. The random character of light results from two basic phenomena: coherence and scattering.

This results from the fact that, except in lasers where stimulated emission is the basic phenomenon, individual light emitters, typically atoms, are not synchronised. The correlation between light waves is described by "coherence", a concept that directly impacts the visibility of interference effects.

Another everyday life phenomenon is the interaction of light with a large number of obstacles that are not ordered at the scale of the optical wavelength: the result is scattering, which in the presence of laser illumination manifests itself as speckle.

This course will treat both coherence and scattering, assuming that the student is familiar with elementary statistics and has had an introduction to coherence. A review of Fourier optics, summarizing a practical introduction at diffraction and the filtering relationship that exists between an object and an image, will be offered as an introduction to the concepts of interest.

Exercise classes will be offered on all subjects covered by this course.

Syllabus

1. - Review of Fourier optics :
    a. Linear filtering
    b. Spatial frequency filtering in both the coherent and the incoherent limits.
2. Review of random variables and random processes (in coordination with the Signal and Image Processing course)
3. Temporal coherence
4. Spatial coherence and localisation of interference fringes
5. Speckle
    a. An introduction on a simple case
    b. Fourier speckle: shape and size of the scattered light distribution and of the speckle grains
    c. Speckle from atmospheric turbulence
    d. Speckle in images

Course: Intellectual property

Instructors: Person in charge (lecture): P. Vigand (Cabinet Hirsch)
Other teachers (for practicals): G. Desrousseaux, L. Deppeley, M. Kheirallah (Cabinet Hirsch), P.Brochard (Varioptic)

Aims

To give future engineers and researchers basic notions on the protection of innovations by means of patents and to increase awareness of the more subtle points in patent analysis (validity, counterfeit). Teaching is carried out through a lecture course rich in examples from jurisprudence, and two practical sessions to study applications.

Syllabus

The course gives the legal definition of a patent and its place in a company's overall strategy. It explains the various procedures that are involved in obtaining a patent, the costs incurred, and describes counterfeit law suits and counterfeit charges. In the practicals, future engineers are made aware of internet research concerning patents and the legal study of a patent, both from a point of view of its validity and counterfeit.

Contents

1) What is a patent?
2) How can a patent be a commercial lever?
3) Patentability and patent procedure (procedure in view of a national, European or international patent
4) Costs
5) Counterfeit charges
6) What is/ should be protected and why ? First practical "patent information"
7) Using a computer, research concerning a patent via the data bases available on Internet (espacenet and USPTO)
8) Careful reading of a patent, and study of its legal scope. Second practical "paper patent"
9) Analysis of a patent's validity in view of previous state-of-the-art (novelty, inventiveness).
10) Analysis of a manufactured product's potential counterfeit features.

Course: Optics labworks

Coordinator: Dr. Lionel JACUBOWIEZ

Aims

Students have to make 6 labworks. The duration of each labwork is $4^{1/2}$ hours.
The labworks are organized at the Laser Center of the University Paris-Jussieu and at Institut d'Optique Graduate School.

Syllabus

At the Laser Center of the University Paris-Jussieu (instructor: Aline Brunet-Bruneau):
- Helium-neon Laser (laser emission, longitudinal and transverse modes, Gaussian beams)
- Light emitters and detectors in optoelectronics (Laser diodes, light emitting diodes, photodiodes, CCD)
- Frequency-doubled diode-pumped Nd:YAG Laser

At Institut d'Optique Graduate School (instructors: Lionel Jacubowiez et Guillaume Dupuis):
- Electrooptic modulator
- Ellipsometry
- Speckle

Course: Laser technology & applications

Instructors: Dr. Patrick GEORGES

Aims

The aim of this course is to present state of the art oscillators and laser amplifiers, in the CW and pulsed regime, from the infra-red to the ultraviolet, through innovative technologies recently applied.

Syllabus

Solid state lasers technologies

1. Overview of lasers and of the laser market.
2. Flash pumped solid state lasers. Wave front correction by optical phase conjugation, tunable lasers.
3. Power laser diodes : single emitter laser diode, laser diode arrays, brilliance improvement.
4. Diode pumped solid state lasers. The advantages of diode pumping. Properties of laser crystals. Longitudinal and transverse pumping. Optically pumped semi-conductor laser.
5. Frequency conversion using non linear effects. Properties of non linear crystals. Optical Parametric oscillators. Quasi phase matching materials.
6. Ultra short pulse lasers. Mode locking techniques. Titanium doped sapphire femtosecond lasers. Chirped amplification. Presentation of commercial femtosecond laser systems at low or high repetition rates. Tunability through the optical parametric effect. New laser diode pumped femtosecond lasers.
7. Application of ultra short pulse lasers. Non linear time-resolved spectroscopy. Two photon absorption fluorescence microscopy. Athermal micro machining.

Optical fiber amplifiers

1. The physics of erbium doped fibre amplifiers. Light matter interaction. Optical and geometrical optimization of the amplifying fibre. Noise factor and signal to noise ratio. Intrinsic power performances.
2. Technology of erbium doped fibre amplifiers. Technologies of the pump sources. Relevant passive components. Multi stage amplifiers. Double band amplifiers. Cladding pumped amplifiers. Amplifiers for submarine applications.
3. Raman amplification and new amplification bands. Principles of Raman amplification. Spectral and energetic characteristics. Noise performances, associated technologies. 11. New amplification windows . Raman amplification, Rare earth solutions (Thulium…), relevant pumping sources (Fiber lasers..)
4. Conferences by industry specialists

Course: Language course (French as a foreign language)

Instructor: Annick MANCO

Aims

On the Palaiseau Campus, it will be possible to offer an opportunity for foreigners to follow one or two semesters of French. Different levels can be chosen from. The courses will take place at the Ecole Polytechnique nearby, but not necessarily. In any case access will be easy and coordination with the school ensured. Two hours a week are provided, unless special arrangements are requested.

Course: Nanophotonics

Instructor: Pr. Henry BENISTY

Aims

To set the gap with scales laws in the case of optical nanostructures (photonic crystals, microcavities...) but also in the case of electronic nanostructures for optics (quantum boxes).

Syllabus

The course starts with diffractive optics, which is the bridge between continuous and discontinuous. Crystal photonics systems in fibres or optical waveguides illustrate the non trivial originalities of intermediate regime. Then, electronic quantum boxes show the wide-range of new systems for optics. Conferences support specialized aspects (biology etc..). The course is evaluated by a bibliographic study that leads to a presentation.

Diffractive Optics
- Subwavelength regime: mean effects (Clausius Mossotti, Maxwell-Garnett), birefringence, theorical approaches
- limits towards diffraction threshold
- applications complexe structures : binary blased gratings, lenses photoniques bandgap materials, photonic cristals, microcavities
- unidimensional case (Bragg mirror), implementation with guided optics,
- 2D and 3D bandgaps / gap, extreme dispersions
- Defects and microcavities
- 2D Cristals within waveguides

Photonic crystals fibres
- current limitations of optical fibres
- skew rays in a 2D structure
- various limitations: "ever-single-mode" fibre; "high -Delta fibre", "air-guide fibre" Wells and electronic quantum boxes for optics
- Physics of electrons in semiconductorrs : bands, Fermi levels, DOS
- Role of electronic dimensionnality
- Crossed interaction of electronic and optical dimensionnalities: quantum well in a laser diode
- Self-organized quantum boxes, epitaxial implementation (InAs/GaAs), colloidal implementation, etc., use in optoelectronics, biology, material science

Lectures
- use of quantum boxes based nanomaterials
- nanoelectronics (nanotubes, one-electron junctions,...)
- nanophysics & biologie or nanostructures and environment

Course: Quantum optics

Instructor: Dr. Christopher WESTBROOK

Aims

The aim of the course is to learn more about using density matrix for the description of the optical susceptibility, and what "photon" means.
This course will give insight into the description of the interaction of light with a quantum system (atom, quantum well…). In a first part, we will deal with light as a classical wave. In a second part, light will also be treated as a quantum object.

Syllabus

I. Reminder: simple models for atom-radiation interaction
- a. Lorentz atom (electron with elastic force)
- b. Einstein coefficients (population equations)

II. Electronic transitions in atoms
- a. Electrical dipole approximation
- b. Application to Hydrogen and quantum well

III. Two-states atom:
- a. Rabi oscillations
- b. Density matrix
- c. Examples: continuous or pulsed spectroscopy

IV. Case of relaxation, Bloch equations
- a. Effect of losses, linear susceptibility
- b. Other sources of relaxation
- c. Link with the Lorentz and Einstein models

V. Applications
- a. Two-states atom nonlinear susceptibility
- b. Polarisation effects: Faraday effect

VI. Quantification of light field
- a. Reminder: quantum harmonic oscillator
- b. Quantum interpretation of stimulated and spontaneous processes
- c. Calculus of the spontaneous emission rate
- d. Pairs of photons by mean of parametric

VII. Mechanical effects of light
- a. Radiatives forces
- b. Examples: magneto-optique trap, optical tweezer ...

Course: Signal and Image processing

Instructor: Pr. François GOUDAIL

Aims

Digital processing of signal and images is essential in many applications of optics. Optical communications, remote sensing, industrial control often require performing such tasks as signal detection, parameter estimation, target identification. As another example, nowadays, the design of the optics of an imaging system is performed together with the development of signal processing algorithms aimed at exploiting the data. Basic knowledge of signal processing is thus very useful to develop and to estimate the performance of optical systems.

This course is an introduction to signal and image processing for optics scientists. Half of it consists of « interactive » lectures where basic principles are explained and illustrated with exercises. The second half consists of laboratories where students will develop and test signal and image processing algorithms using Matlab.

Syllabus

1. Random variables and functions
   - Random variables used in physics
   - Central limit theorem
   - Random functions : stationarity, ergodicity, filtering

2. Estimation theory:
   - Biais and variance of an estimator
   - Maximum likelihood, nuisance parameters
   - Cramer-Rao lower bound.
   - ➔ Application distance and position estimation (radar, lidar, …).

3. Detection theory :
   - Optimal detection
   - Neyman-Pearson theory : likelihood ratio
   - Nuisance parameters : generalized likelihood ratio
   - ➔ Application radar et communication signals.
   - ➔ Application to edge detection in images

Course: Guided and coupled waves

Instructor: Prof. Jean-Michel JONATHAN

Aims: The course provides the physical bases for some major components of optical communications, such as optical waveguides and fibers, passive or active components. The first section describes (mostly in the weak guidance approximation) the optical modes propagating in guiding optical structures and provides notions such as modal dispersion and losses, central to telecommunications. The second section details the tools for using the electro-optic and acousto-optic effects in their applications for the modulation and the coupling of free space as well as guided optical modes.

Syllabus

Guided optical waves

1- The optical modes in planar waveguides. The 1D dielectric (step index and quadratic index) waveguide and its TE and TM modes. Ray optics and electromagnetic description: guiding condition, cut-off frequency, dispersion, confinement, effective refractive index.

2- Optical fibres in the weak guidance approximation. Electromagnetic filed in step index cylindrical optical fibre. Weak guidance and scalar propagation equation of the LP modes. Gaussian approximation of the LP01 mode and its application in engineering. Introduction to dispersion management, polarization in optical fibres, micro structured optical fibres.

3- Introduction to optical fibres technology. Materials and their losses, fibres fabrication, connections, controls and characterization.

The linear coupling of optical waves

1- The linear and quadratic electro-optic effects. Its application to the modulation of the polarization of polarization, phase or amplitude of a guided or free space optical mode.

2- The acousto-optic effect and its application to the generation of dynamic refractive index gratings.

3- The coupled wave theory and its application to the coupling of plane waves through thick gratings. The Bragg condition in isotropic and anisotropic media. Applications of the acousto-optic effect to the deflection and modulation of optical waves, spectrum analyzer, voltage controlled interference filter.

4- The coupling between guided modes. Coupling the modes of two close optical waveguides: application to the 3dB optical coupler, wavelength multiplexer, interferometer and electro-optical switch. Coupling two modes of an optical waveguide: co-directional and contra-directional coupling, input and output couplers, Bragg filters in optical fibres.

Text books

- Optical waves in crystals. Propagation and control of laser radiation. / YARIV (Amnon) ; YEH (Pochi). , 2003. - XI - p589

- Introduction to Fiber optics / THYAGARAJAN (K.) ; GHATAK (Ajoy K.). , 1998. - XVI - p565

Course: Biophotonics

Instructor: Pr. Arnaud DUBOIS

Aims

To give insights, through scientific lectures, into modern research trends in biophotonics.

Syllabus

- Optical properties of biological media
- Imaging through biological tissue: an overview
- Diffuse Optical Tomography: imaging through thick tissues
- Introduction to conventional microscopy
- Confocal and fluorescence microscopy
- Advanced microscopy techniques: nonlinear and multi-photon microscopy, OCT, structured illumination and super-resolution
- Optical tweezers, single molecule manipulation
- Therapeutic applications of lasers and photodiagnostic

Course: Advanced non-linear Optics

Instructor: Dr. Nicolas DUBREUIL

Aims

Since laser was invented, a new dimension was opened in optics, ushering in the non linear world with already numerous applications to light sources and optical processing of information. This course will introduce the students to this domain and enable them to fully master its innovative aspects. It describes the physics of the non linear interaction between light and matter from a perturbation approach and shows its consequences on the propagation of optical waves. Its describes in detail the second and third order non linear effects rich in applications.

Syllabus

1. Introduction to nonlinear optics

2. Non linear propagation of optical waves

Atomistic bases of Maxwell theory. Linear susceptibility, linear propagation. Non linear response and non linear susceptibility. Non linear propagation equations.

3. Second order non linear effects

The Manley-Rowe relations. Second harmonic generation. Frequency mixing,
Parametric amplification and oscillation.

4. The microscopic theory of susceptibility.

Local field and polarizability. Dynamics of a system of particles in an electromagnetic field. Description of a system of particles by the density matrix. Simplified calculation of polarizabilities. The 1st order polarizability. 3^{rd} order resonant phenomena. The polarizability mechanism. Calculus of electronic polarizabilities. Influence of the local field. Non linear materials

5. Third order non linear effects

Introduction. Four wave mixing and phase conjugation. The dynamic Kerr effect (optical bistability, self focusing, self phase modulation and soliton propagation. Spontaneous and stimulated diffusions (Raman, Brillouin, Rayleigh and Rayleigh wing). Two photon absorption.

Reference

Non linear optics, R.W. Boyd, "Nonlinear Optics" (2nd Edition), 2003.

Course: Near-field optical microscopy

Instructors: Pr. Remi CARMINATI

Aims

- To illustrate near field optical spectroscopy: principles, issues, current performances.
- To open up to other near field microscopy techniques (atomic force, tunnelling effect).
- To give an understanding of difficulties linked to experiment and modelization in this domain.

Syllabus

Optical near field brings together the techniques that allow for optical measurements at the nanometric scale (surface imaging, single molecules, etc.). The course presents these techniques, with emphasis on both the practical implementation and the theoretical modelization. It gives the state of the art and impact of optics in the context of nanotechnologies.

Optical and electronic microscopy techniques

• Electrons and Photons
• Transverse and axial resolutions
• Data acquisition: scanning and multiple detectors
• Description of some systems and performances

Classical optical microscopy: domain of application, physical and technological limitations.

• Current Spectral ranges (UV, VIS, IR) and their domain of application
• Signals and noises
• Polarisation, interferometry and surface investigation

Concepts of optical near field I: angular spectrum

• Plane waves decomposition, propagatives waves and evanescent waves
• Spatial frequencies, uncertainty relation
• Propagation, spatial filtering and diffraction
• Near field: definition and length scales

Concepts of optical near field II: radiating field

• Reminder: near field and far field dipolar radiation
• Near field: electrostatic limit
• Anisotropy of dipolar radiation: polarisation effects
• Radiating field (or scattered) by any object considered as an ensemble of dipoles
• Link between radiation of point sources and angular spectrum

Introduction to atomic force microscopy (AFM)

• The instrument: principle of operation.
• Forces at work: nature and magnitude orders
• Applications: from topography to physical measurements

Different approaches in optical near field microscopy (SNOM)

• Optical tunneling effect
• Metallic fibres as nanosources or nanodetectors.
• Probes without aperture

Introduction to modelisation near field optics

• Imaging : general approach
• Modelisation from reciprocity theorem (from a simple example)
• Examples: spectral response and polarisation response.
• Issues and current limitations

Course: Electro- and Opto- electronics

Instructor: Dr. Jean-Pierre HUIGNARD and Dr. Daniel DOLFI

Aims

This course explains electrooptical phenomena in various materials and presents technical applications, especially in the domain of telecommunications.

Syllabus

Electrooptics phenomena and applications
Induced birefringence in crystals and ceramics
Operation in free space and guided modes
Light modulators for optical telecommunications

Optical and electrooptical properties of liquid crystals
Liquid crystal phases
Optical properties
Technology of liquid crystal cells
Applications
Comparisons with other technologies

Applications of wave mixing in photorefractive materials
Volumic holography
Application of wave mixing to image amplification, and wave conjugaison
Applications to signal processing, laser beam control, and thermal effect compensation

Course: Semiconductor for nonlinear optical function

Instructors: Dr. Ariel LEVENSON and Dr. Robert KUSELEWICZ

Aims

The aim of the course is to become aware of the potentialities for the photonics of semiconductor that ally strong non-linear coefficients and capacity for integration and submicronic structuration.

Syllabus

This course describes the 2nd and 3d order non-linear optical properties of semiconductor materials. It derives the new concepts for photonics and also presents the main current and emerging devices for the optical processing of information.

I Introduction; interest of non-linear optics in semiconductors
II Reminder about semiconducteurs; electronic and optical properties of semiconductors
III Optical nonlinearities (ONL) in semiconductors
- III.1 Introduction: intrinsic non-linearities vs. dynamic nonlinearities.
- III.2 Intrinsic 2nd and 3d order nonlinearities
- III.3 Non-linéarités governed by the dynamic of excited states: spatio-temporal effects in ONL systems.

IV Some semiconductor ONL devices
- IV.1 Vertical access systems Amplifiers, gates, memories, all-optical regenerators
- IV.2 Guided-optics based devices
- IV.3 Future of semi-conductor devices and research Second-harmonic generation, quasi-phase matching, non-linear photonic crystals, spatial solitons and optical logic.

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2010-2011 OPSCITECH COURSES at Warsaw University of Technology (WUT)

II year, semester 1

		ECTS	lecture	Lab/ proj.	
1.	Optical methods of measurements and control	5	30	20	prof. M. Kujawińska prof. L. Salbut
2.	Photonics devices and systems	5	30	15	dr inż. T. Kozacki dr inż. M. Jozwik
3.	Opto-numerical 2D/3D/4D measurements methods	4	30	10	dr inż. R. Sitnik prof. M. Kujawinska
5.	Advanced wave propagation (with project)	4	15	15	dr inż. T. Kozacki
6	Computer vision and angumented reality	4	15	15	Dr inż Sitnik
6.	Technical elective: Biophotonics Image processing and recognition (with project) Optics of liquid crystals (elective) Choice of Project at Mechatronics, Physics or EiTI Faculties WUT	 4 4 4 6	 24 30 30	 6	 prof. K. Patorski dr.R. Sitnik Prof. T. Wolinski *(Faculty of Physics)*
7.	Polish language	2	-	30	
	Min ECTS	30			

II year, semester 2

		ECTS	lecture	lab./ proj	
1.	6-months internship in research laboratory (diploma work)	27			
2.	Diploma seminar	3		30	prof. inż. M. Kujawińska
	Min ECTS	30			

Course: Optical methods of measurements and control

Instructors: Prof. M. Kujawinska, Prof. L. Sałbut

Aims

The course introduces optical methods of measurements and control and their applications in science and industry.

Syllabus

1. **Introduction.** Introducing and characterization of point-wise and full-field optical methods based on coherent and incoherent illumination. Information coding and decoding techniques.
2. **Laser interferometry for length measurements.** One, two and multiple wavelength interference. Linear displacements and length of gauge blocks measurements.
3. **Surface characterization**. Micro-shape and roughness measurements. Microinterferometry and profilometry. Scatterometry. Polarized light techniques
4. **Shape measurements.** Passive and active triangulation techniques. Moiré and fringe projection techniques. Optical and digital holography. Quasi-monochromatic and multi-wavelength interferometry. White light and low coherence interferometry.
5. **Vibration measurements.** Laser vibrometry. Time average and stroboscopic techniques. Pulse interferometry.
7. **Optical methods in experimental mechanics and material engineering.** Geometric moiré and moiré interferometry, holographic interferometry, electronic speckle pattern interferometry (ESPI and ESPSI), photoelasticity, image correlation methods and thermography. Laser and video extensometry. Non-destructive techniques.
8. **Optical elements testing.** Classification of techniques based on geometric and wave optics. Basic configurations of measurement instruments and systems. Exemplary methods and instrumentation for refractive index, flatness and sphericity of optical elements measurements. Methods for optical transfer function measurements.
9. **Laser spectrometry.** Emission, absorption, fluorescent Fourier transform and other spectrometers and theirs applications.

Course: Photonics devices and systems

Instructor: Dr T. Kozacki, Dr A. Styk, Dr M. Józwik

Aims

The course gives theoretical and practical engineering information on photonics components and systems. Student will also gain the knowledge about present applications and state of art of several photonics devices.

Syllabus

1. **Introduction.** Systematics and main definitions of photonics devices and systems (PDS). PDS in the present techniques: applications to medical, telecommunication and information processing fields. Architecture of basic PDS.
2. **Photonic materials.** Semiconductor, ferroelectric and organic materials. Optical and mechanical properties and applications.
3. **Optoelectronic devices.** Working principles (photon – electron and hole interaction). Semiconductor light sources (LED, lasers) and detectors (PIN Photodiodes, Avalanche Photodiodes, detector matrices).
4. **MEMS/MOEMS technology.** Silicon and glass micromachining. Fusion of optics, electronics and mechanics in MEMS technology. Microlenses and arrays of microlenses. Fabrication process examples.
5. **MEMS/MOEMS applications.** Classification of MEMS/MOEMS devices. Sensors and actuators. Review of applications and microsystem market.
6. **PDS applied to optical data processing and optical storages.** Optical analog systems: spectrum analyzers and acusto-optic correlators; image processors. Optical digital systems: switches, gates, photonic connections, scanners. Optical computer and its architecture. Optical systems for data storage, optical systems for data writing and decoding.
7. **Photonics devices in telecommunication.** Architecture of optical network. Broadband internet. Hardware. Solutions based on optical fiber technology, integrated optics and MEMS/MOEMS.
8. **Diffractive elements (DOE).** Diffractive vs. Refractive optical element, Phase profile, Efficiency of step profile diffractive element, Diffractive Lenses, Diffractive Lens Design issues, Diffractive gratings, holographic DOE, methods of numerical analysis of DOE, Effective Media theory, Application of DOE.
9. **Waveguides.** Waveguide structures, modes of optical waveguide, single mode waveguide, slab analysis method of waveguide structures.
10. **Photonics crystals.** Fourier optics of Periodic media, photonic crystal properties, dispersion relation of photonic crystal structure, defects in photonic crystal, photonic crystal fibers (PCF), PCF vs. classical optical fibers, dispersion relation of PCF.

Course: Opto-numerical 2D/3D/4D measurement methods

Instructor: Prof. M. Kujawinska, Dr R. Sitnik

Aims

The course introduces full field, opto-numerical methods applied for measurements, control and monitoring in science, industry, medicine and multimedia.

Syllabus

1. **Introduction.** Definition an d classification of full-field optical methods. Coding of 2D, 3D and 4D information. Functional structures of measurement systems and their connection with CAD/CAM/CAE, computer graphics and animation software.
2. **Image processing and recognition.** Intensity based methods. Automatic fringe pattern analysis methods. Wavelet methods. Feature vector.
3. **Active and adaptive interferometry.**
4. **Hybrid methods in experimental mechanics and material engineering** (based on grating interferometry and ESPI techniques).
5. **Measurement and processing path for 3D/4D data processing** (shape, movement and morphing of 3D objects).
6. **Machine vision systems for industry and robotics.**
7. **Digital holography and digital holographic interferometry.** Numerical and optoelectronics solutions.
8. **Opto-numerical and computer tomography.** Systems and algorithms for medical and engineering applications.
9. **Thermovision systems.** Analysis of thermograms. Civil and military applications.
10. **Coding and biometrics recognition systems.**

Course: Advanced wave propagation methods

Instructor: Dr. T. Kozacki

Aims

The curse presents numerical methods of wave propagation. Following wave propagation methods with focus on implementation are discussed: Finite-difference time domain method (FDTD), beam-propagation method (BPM), wave propagation method (WPM), free space propagation method.

Syllabus

1. **Optical field free space propagation algorithms.** Fresnel diffraction. Angular spectrum of plane waves.
2. **Digital representation of free space propagation algorithms.** Sampling problems. Aliasing errors.
3. **Numerical solution of scalar Helmholtz differential equation.** BPM method.
4. **Implementation of basic algorithm.** Fourier transform method. Finite Difference method. Boundary conditions. Matrix equation solver. Alternate Direct Implicit Scheme.
5. **Advanced BPM. Wide angle scheme.** Vectorial scheme. Time domain scheme.
6. **Wave propagation method.** Implementation.
7. **Numerical solution of Maxwell equation.** FDTD method.
8. **FDTD using Yee Algorithm.** Numerical dispersion and stability. Incident wave source. Perfectly matched layer absorbing boundary conditions (PML).
9. **Numerical solution of Maxwell using Pseudospectral time domain method (PSTD).** Numerical dispersion and stability. Incident wave source. PML.

Course: Computer Vision and Augmented Reality

Instructor: Dr R. Sitnik

Aims

The course introduces techniques for 3D/4D scene/objects identification on the base of Computer Vision data processing with strong connection to Virtual and Augmented Reality applications. 3D (shape of objects surface: clouds of points) and 4D (dynamic shape of object surface: clouds of points, "motion capture" data) data processing paths are described. Common Computer Vision techniques and algorithms used for real time visualization/processing in VR/AR applications are introduced. Several selected VR/AR engines will be presented and discussed.

Syllabus

1. **Introduction.** Short description of Virtual and Augmented Reality systems architecture: input devices, output devices, feedback devices, 3D engines. Basic 3D/4D recognition techniques: photogrammetry, laser triangulation, structured light, time of light.
2. **Input devices processing.** Detailed description of processing (real time and off-line) in optical input devices (photogrammetry, laser triangulation, structured light, time of light) with distinction from medical, computer graphics and industrial applications.
3. **Output devices processing.** Detailed description of optical output processing (real time and off-line) for different devices: 3D screens (with different polarization solutions), feedback systems, HMD and Cube systems.
4. **VR/AR systems survey.** Survey through most representative VR/AR systems. Survey through applications of VR/AR with strong emphasize on Computer Vision role.

Course: Biophotonics

Instructor: Prof. K. Patorski

Aims

The courses introduces applications of laser techniques in medical diagnosis and therapy. Fundamentals of laser generation are treated in short together with laser classification for medical purposes. After introducing various effects of laser radiation interaction with biotissue, a comprehensive review of modern imaging diagnostic and therapy systems is given together with clinical examples.

Syllabus

1. **Lasers in medicine.** Historical overview. Optical spectrum. Most important parameters characterizing optical radiation. Fundamentals of laser operation. Basic classification of lasers for medical applications. Preliminary examples.
2. **Laser light interaction with biotissues.**
3. **Laser light dosing.**
4. **Selected applications of laser therapy.** Low light level therapy (LLLT) - biostimulation. Energetic laser applications, including photodynamic therapy (PDT), gastroenterology, blood vessel recanalization, ophthalmology, coronary arterial diseases – angioplasty and mioplasty.
5. **Novel imaging modalities in biomedicine.** Light propagation in highly turbid media. Photon sorting techniques. Exemplary modalities: LTPS, Kerr cell method, optical coherence tomography (principles, implementation, application in weakly and highly dispersing media), thermo(opto)acoustics (principles, implementation, applications including oncology).
6. **Work safety with lasers**

Course: Image processing and recognition

Instructor: Dr R. Sitnik

Aims

The course introduces fundamentals of digital image processing (DIP). It starts from common detectors characterization (eye, CCD, CMOS) together with different color spaces definitions. Geometrical, arithmetical, morphological and filtering operations in image space are explained. DFT, FFT, Hough and Wavelet transforms are introduced. Basic recognition techniques are presented. Coding and compression methods for images and image sequences are described.

Syllabus

1. Introduction. Definitions. Digital versus analog representation. Sampling and quantization. Eye versus matrix detector (CCD/CMOS). Electromagnetic spectrum. Color spaces.
2. Image space operations. Geometrical operations. Image correction. Camera calibration. Arithmetical operations. LUT. Histogram. Multi image operations. Binarization. Filtering operations (convolution, statistical, etc.).
3. Image transforms. Fourier transform (DFT, FFT). Wavelet transform. Hough transform. Image space filtering versus transform based filtering.
4. Coding and compression. Image and image sequences coding. Coding and compression versus eye properties. Loss and lossless compression. Basic algorithms. Standards.
5. Morphological operations and Segmentation. Morphological operations (opening, closing, skeleton operators). Segmentation.
6. Recognition. Basing recognition techniques. Features based on geometry, topology, texture. Examples.