UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH

Course guide
230553 - BEAMFO - Beam Propagation and Fourier Optics

Last modified: 11/04/2025

Unit in charge: Barcelona School of Telecommunications Engineering
Teaching unit: 1022 - UAB - (ANG) pendent.

Degree: MASTER'S DEGREE IN PHOTONICS (Syllabus 2013). (Compulsory subject).
MASTER'S DEGREE IN TELECOMMUNICATIONS ENGINEERING (Syllabus 2013). (Optional subject).

Academic year: 2025 **ECTS Credits:** 5.0 **Languages:** English

LECTURER

Coordinating lecturer: JUAN CAMPOS COLOMA

Others: Primer quadrimestre:
SALVADOR BOSCH PUIG - 10
JUAN CAMPOS COLOMA - 10

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CE4. Demonstrate knowledge of the fundamentals of image formation, propagation of light through different media and Fourier Optics.

Generical:
CG2. Ability to modeling, calculate, simulate, develop and implement in research and technological centers and companies, particularly in research, development and innovation tasks in all areas related to Photonics.

Transversal:
1. EFFECTIVE USE OF INFORMATION RESOURCES: Managing the acquisition, structuring, analysis and display of data and information in the chosen area of specialisation and critically assessing the results obtained.

2. FOREIGN LANGUAGE: Achieving a level of spoken and written proficiency in a foreign language, preferably English, that meets the needs of the profession and the labour market.

4. TEAMWORK: Being able to work in an interdisciplinary team, whether as a member or as a leader, with the aim of contributing to projects pragmatically and responsibly and making commitments in view of the resources that are available.

5. ENTREPRENEURSHIP AND INNOVATION: Being aware of and understanding how companies are organised and the principles that govern their activity, and being able to understand employment regulations and the relationships between planning, industrial and commercial strategies, quality and profit.

Basic:
CB7. Students should know how to apply the knowledge acquired and their problem-solving ability in new or little-known environments within broader (or multidisciplinary) contexts related to their area of ¿¿study.
CB6. Possess and understand knowledge that provides a basis or opportunity to be original in the development and/or application of ideas, often in a research context

TEACHING METHODOLOGY

- Lectures

The students should bring their own desktop computer. Along the lectures, we will use scripts to show the explained concepts. The computer languages we will use are Python and Matlab/Octave. Octave is a free clone of Matlab. In particular, OctaveUPM also have the user interface. You can download it in https://mat.caminos.upm.es/octave/. The concepts to program in these languages will be given in the first part of the course.
The student should select 5 items of the course index shown below, and present the homework?s and exam corresponding to them. The student may attend to the other items if he/she wishes.

LEARNING OBJECTIVES OF THE SUBJECT

The subject will address the basics of geometrical optics, intermediate topics of electromagnetic optics, polarization of light and anisotropic media, the fundamentals of light beam propagation and elements of Fourier optics, including concepts of digital holography.
The aim is to develop several topics (which are key for the future subjects of the Master) that usually are not covered in previous physics or engineering courses.

STUDY LOAD

Type	Hours	Percentage
Self study	85,0	68.00
Hours large group	40,0	32.00

Total learning time: 125 h

CONTENTS

1. Python.

Description:
1.1 Python programming
1.2 Matrices. Graphics. Basic algorithms.
1.3 Introduction to Matlab/Octave

Full-or-part-time: 8h
Theory classes: 8h

2. Geometrical optics.

Description:
2.1.- Basic concepts. Ray tracing.
2.2.- Perfect and real optical systems. Aberrations. Seidel and Zernike polynomials.
2.3.- Review of image forming instruments.

Full-or-part-time: 8h
Theory classes: 8h

3.- Electromagnetic optics.

Description:
3.1.Propagation in media with complex refractive index.Inhomogeneous plane waves.Energy flux.
3.2. Fields near interfaces. Reflection and refraction.Fresnel equations.
3.3. Evanescent waves.

Full-or-part-time: 8h
Theory classes: 8h

4. Polarization of light.

Description:
4.1.TE and TM electromagnetic waves in layered structures.Thin films.
4.2. Guided waves.
4.3.- Polarization Ellipse. Jones vectors. Jones matrix. Combinations of polarizing devices.
4.4.- Stokes parameters. Mueller matrices. Poincaré sphere.

Full-or-part-time: 8h
Theory classes: 8h

5. Anisotropic media.

Description:
5.1.- Anisotropic media: Susceptibility of an anisotropic media. Wave propagation, normal modes. Index ellipsoid. Effective refraction index.
5.2.- Distortion of the index ellipsoid. Pockels effect. Liquid crystals.

Full-or-part-time: 6h
Theory classes: 6h

6.- Fourier Transform.

Description:
6.1.- Definition and FT of some functions.
6.2.- The FT as a decomposition. Wave Packets. 2D FT of images.
6.3.- Convolution and correlation between two functions.
6.4.- Linear systems. Impulse response. Transfer function.

Full-or-part-time: 6h
Theory classes: 6h

7- Beam propagation and focalization.

Description:
7.1.- Angular spectrum of plane waves.
7.2.- Field propagators.
7.3.- Gaussian beams. Description and properties. Transmission through a thin lens.
7.4.- Other beams with particular polarization (radial, azimuthal,...)
7.5.- Focusing of fields through high numerical aperture systems.

Full-or-part-time: 7h
Theory classes: 7h

8. Fourier Optics.

Description:
8.1.- Coherent optical processing. Point spread function and optical transfer function. Resolving power of optical instruments.
8.2.- Holography (basic concepts). Digital holography.

Full-or-part-time: 8h
Theory classes: 8h

GRADING SYSTEM

- Homework (35%).
- Exam (65%)

To pass the course will require a quite accessible level of knowledge but high final grades will be obtained only by demonstrating enough proficiency.

EXAMINATION RULES.

The exam will have two parts corresponding to each Professor. The material the student may have during the exams will be expalined at the begining of the course.

BIBLIOGRAPHY

Basic:
- Hetch, E. Optics. 5th ed. Pearson, 2016. ISBN 9781292096933.
- Born, M.; Wolf, E. Principles of optics: electromagnetic theory of propagation, interference and diffraction of light. 7th. Cambridge University Press, 1999. ISBN 9780521642224.
- Goodman, J. W. Introduction to Fourier optics. 3rd. Roberts and Company Publishers, 2005. ISBN 9780974707723.
- Lizuka, Keigo. Elements of photonics Volume I. Wiley-Interscience, 2002. ISBN 9780471839385.
- Saleh, B.E.A.; Teich, M.C. Fundamentals of photonics. 3rd ed. Hoboken: John Wiley & Sons, 2019. ISBN 9781119506874.
- Novotny L., Hecht B. Principles of nano-optics. Cambridge University Press, 2012. ISBN 9781107005464.
- Goldstein D. H. Polarized light. 3rd. Marcel Dekker, 2011. ISBN 9781439830406.
- Mahajan, v.n. Aberration theory made simple. SPIE, 2011. ISBN 0819488259.