Course guide
2301115 - 3DLICO - 3D Light Control for Biological Applications

Last modified: 24/03/2026

Unit in charge: Barcelona School of Telecommunications Engineering
Teaching unit: 748 - FIS - Department of Physics.

Degree: MASTER'S DEGREE IN PHOTONICS (Syllabus 2013). (Optional subject).
ERASMUS MUNDUS MASTER'S DEGREE IN PHOTONICS (Syllabus 2024). (Optional subject).

Academic year: 2026 **ECTS Credits:** 3.0 **Languages:** English

LECTURER

Coordinating lecturer: MARTÍ DUOCASTELLA SOLÀ

Others: Primer quadrimestre:
MARTÍ DUOCASTELLA SOLÀ - 10

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CE3. Know the fundamentals of laser physics, the types of lasers and their main applications.
CE4. Demonstrate knowledge of the fundamentals of image formation, propagation of light through different media and Fourier Optics.
CE6. Have carried out a set of advanced laboratory works, similar to that of future experimental research work.
CE9. Ability to synthesize and present photonics research results according to the procedures and conventions of scientific presentations in English.

Generical:
CG1. Ability to project, design and implement products, processes, services and facilities in some areas of photonics, such as photonic engineering, nanophotonics, quantum optics, telecommunications and biophotonics.
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.
CG4. Ability to understand the generalist and multidisciplinary nature of photonics, seeing its application, for example, to medicine, biology, energy, communications or industry

Transversal:
CT1. ENTREPRENEURSHIP AND INNOVATION. Knowing and understanding the mechanisms on which scientific research is based, as well as the mechanisms and instruments for transferring results between the different socioeconomic agents involved in R&D&I processes.
CT3. TEAMWORK. Be able to work as a member of an interdisciplinary team, either as another member, or performing management tasks in order to contribute to developing projects with pragmatism and a sense of responsibility, assuming commitments taking into account the available resources.
CT4. SOLVENT USE OF INFORMATION RESOURCES. Manage the acquisition, structuring, analysis and visualization of data and information in the field of the specialty and critically assess the results of this management.
CT5. ENGLISH. Accredit an adequate level of this language, both orally and in writing, in line with the needs that the graduates will have.

Basic:
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
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.
CB8. Students should be able to integrate knowledge and face the complexity of formulating judgments based on information that, being incomplete or limited, includes reflections on the social and ethical responsibilities linked to the application of their knowledge and judgment.
CB10. Students should possess the learning skills that allow them to continue studying in a way that will be largely self-directed or autonomous.

TEACHING METHODOLOGY

Lectures
Hands-on training session on light control
Description:
- A practical session showing an encoded optical microscope and a varifocal lens will be held, with an estimated duration of 2 hours.
- Seminars based on the contents of the course may be included in the subject, depending on availability of relevant speakers.
Full-or-part-time: 2h

LEARNING OBJECTIVES OF THE SUBJECT

The ability to rapidly deliver light at targeted positions within a sample is the primary enabler of a number of biological applications ranging from imaging to laser surgery. However, optical diffraction and the non-homogeneities of biological tissue make it a challenging task. This can be further aggravated when the sample is moving or evolving, as in most in vivo systems. In this course, we will survey efforts to address these issues and achieve rapid three-dimensional control of light inside biological samples at cellular resolution. We will first describe the traditional and state-of-the-art methods, including optomechanical systems, varifocal lenses and beam shaping strategies. We will then provide examples of applications where they have been successfully used, both for imaging as well as non-imaging scenarios, such as optogenetics, deep light imaging and ultrafast microscopy.

STUDY LOAD

Type	Hours	Percentage
Hours large group	24,0	32.00
Self study	51,0	68.00

Total learning time: 75 h

CONTENTS

1. Methods for light-control in biological applications

Description:
Description:
1.1. The need for controlling light inside biological samples
1.2. Mechanical translation (piezoelectric, galvo mirror, resonant mirror)
1.3. Varifocal lenses
1.4. Remote focusing
1.5. Temporal focusing
1.6. Beam shaping (extended depth of field, non-conventional beam shapes)
1.7. Light modulation (phase and amplitude)
1.8. Computational methods
Full-or-part-time: 10h
Theory classes: 10h

Full-or-part-time: 10h
Theory classes: 10h

2. Applications in bioimaging

Description:
Description:
2.1. Endoscopy
2.2. Wavefront shaping
2.3. Photoacoustic microscopy
2.4. Encoded optical microscopy
Full-or-part-time: 8h
Theory classes: 8h

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

3. Non-imaging scenarios

Description:
Description:
3.1. Optogenetics
3.2. Laser surgery
3.3. Photodynamic therapies
Full-or-part-time: 6h
Theory classes: 6h

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

GRADING SYSTEM

- Written exam (30%)
- Oral presentation on a topic selected from a list provided by the professor (40%)
- Homework assignments, active attendance to classes, seminars and visit (30%)

BIBLIOGRAPHY

Basic:
- Kubby, J.; Gigan, S.; Cui, M. Wavefront shaping for biomedical imaging [on line]. Cambridge: Cambridge University Press, 2019 [Consultation: 21/07/2023]. Available on: https://www-cambridge-org.recursos.biblioteca.upc.edu/core/books/wavefront-shaping-for-biomedical-imaging/9354E60823ABC0FE0AE8E7FC65A9331B. ISBN 9781316403938.
- Pawley, J.B. Handbook of biological confocal microscopy. 3rd. ed. New York: Springer, 2006. ISBN 9781489977168.
- Chunlei Guo, Subhash Chandra Singh. Handbook of Laser Technology and Applications : Laser Applications: Medical, Metrology and Communication. (Volume Four). 2nd ed. Boca Raton (FL), United States of America: CRC Press, 2024. ISBN 780367655631.