Course guide
230697 - OFLAB - Fibre Optic Telecommunications Laboratory

Last modified: 11/04/2025

Unit in charge: Barcelona School of Telecommunications Engineering
Teaching unit: 739 - TSC - Department of Signal Theory and Communications.

Degree: MASTER'S DEGREE IN TELECOMMUNICATIONS ENGINEERING (Syllabus 2013). (Optional subject).
MASTER'S DEGREE IN ADVANCED TELECOMMUNICATION TECHNOLOGIES (Syllabus 2019). (Optional subject).

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

LECTURER

Coordinating lecturer: JOAN MANUEL GENE BERNAUS

Others:

PRIOR SKILLS

Basic knowledge on:
- Digital communications and
- Fiber-optics.

If you don't have it, we will provide it for you.

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CE1. Ability to apply information theory methods, adaptive modulation and channel coding, as well as advanced techniques of digital signal processing to communication and audiovisual systems.
CE13. Ability to apply advanced knowledge in photonics, optoelectronics and high-frequency electronic
CE3. Ability to implement wired/wireless systems, in both fix and mobile communication environments.

Transversal:
CT3. 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.

TEACHING METHODOLOGY

Laboratory practical sessions

LEARNING OBJECTIVES OF THE SUBJECT

The aim of this course is to train the students in using advanced equipment to measure, characterize and/or evaluate sophisticated fiber-optic devices and systems. Also, to use specialized software to model, manage, and design both the data and the control planes of optical networks.

Learning results:
1.-Ability to operate, characterize and design optical fibers, optical transmitters, optical receivers, optical amplifiers, optical filters and multiplexers/demultiplexers.
2.-Ability to implement and evaluate the quality of a fiber-optic digital transmission system.
3.- Ability to operate advanced lab equipment such as optical spectrum analyzers, high-speed oscilloscopes, bit error ratio testers, etc.
4.- Ability to use fiber-optic-specific software to simulate and/or design both devices and systems.
5.- Ability to operate a fiber-optical control plane.
6.- Ability to use machine learning (ML) and artificial intelligence (AI) in optical networks.
7.- Ability to design an optical quantum key distribution (QKD) system.

STUDY LOAD

Type	Hours	Percentage
Hours small group	39,0	31.20
Self study	86,0	68.80

Total learning time: 125 h

CONTENTS

Introduction

Description:
Introduction to the Fiber-optics Lab:
1.-Description of the practices to be performed
2.-Explanation of the hardware equipment to be used
- Optical spectrum analyzers (OSA)
- High-speed (4-6 GHz) oscilloscopes
- Bit error rate testers
3.-Introduction to the software tools to be used
- Virtual photonics incorporated (VPI)
- Matlab
- Python

Full-or-part-time: 5h
Laboratory classes: 3h
Self study : 2h

Practice 1: Optical Amplifiers

Description:
Optical amplifiers are one key element in fiber-optic communications. They allow transparent optical amplification. Without optic amplifiers the transoceanic communications would not be possible. The invention of such a device will most likely be awarded by the Novel Prize in the following years following the invention of the laser (1958) and the optical fiber (2009). In this practice you will learn how to characterize an optical amplifier. You will also design one such device.

Characterization of:
1.-A semiconductor optical amplifier (SOA) (hardware).
2.-An erbium-doped fiber amplifier (EDFA) (hardware).

Design of:
1.-An EDFA (hardware or software).
2.-Raman amplifier (software).

Specific objectives:
Characterization and design of optical amplifiers.

Full-or-part-time: 20h
Laboratory classes: 6h
Self study : 14h

Practice 2: Optical Modulators

Description:
Optical modulators allow mapping the information from an electrical signal (modulation signal) onto an optical signal (carrier). The Mach-Zehnder modulator (MZM) is the most used technology. The use of 2 MZMs permit implementing an optical in-phase/quadrature (IQ) modulator which is required to modulate both the real and imaginary parts of the optical carrier. In this practice you will learn how to operate and characterize a MZM. You will also design an integrated MZM and/or an optical IQ modulator.

Characterization of:
1.-A Mach-Zehnder optical modulator (hardware).

Design of:
1.-A Mach-Zehnder modulator using photonic integrated circuits (hardware and/or software).
2.-An optical IQ modulator (software).

Specific objectives:
Operation, characterization, and design of optical modulators.

Full-or-part-time: 20h
Laboratory classes: 6h
Self study : 14h

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Practice 3: Optical Transmission System

Description:
Fiber-optics is the only known technology that allows ultra-high-speed and ultra-long-haul communications. This is why it has become the technology of use in transport networks. Without fiber-optics, internet and mobile networks wouldn't be possible. In this practice you will learn how to operate, characterize, and design and end-to-end optical communications system.

Characterization of:
1.-An optical transmitter (hardware and software).
2.-An optical receiver (hardware and software).

Design of:
1.-A 1-10 Gb/s intensity-modulation with direct detection (IMDD) 50 km system (hardware).
2.-A 100-1000 Gb/s quadrature amplitude modulation (QAM) with coherent detection 10,000 km system (software).

Specific objectives:
Implementation and characterization of a high-capacity fiber-optical transmission system.

Full-or-part-time: 20h
Laboratory classes: 6h
Self study : 14h

Practice 4: Optical Control Plane

Description:
The control plane is a fundamental layer in optical networks. The particularities of the optical layer such as its optical components (lasers, modulators, amplifiers, photodetectors, filters, etc.) and the optical channel (chromatic dispersion, polarization mode dispersion, fiber nonlinearities, etc.) need to be addressed in the control plane. In this practice you will learn how to provide connectivity to an optical network using state-of-the-art technologies and protocols.

Operation of:
1.-Control plane-based approach of connectivity provisioning (hardware and/or software).

Evaluation of:
1.-Connectivity provisioning according to different requirements (latency, QoS, etc) (hardware and/or software).

Specific objectives:
Operation and evaluation of a control-plane for optical networks.

Full-or-part-time: 20h
Laboratory classes: 6h
Self study : 14h

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Practice 5: Artificial Intelligence (AI)

Description:
Machine learning (ML) and artificial intelligence (AI) are two disruptive technologies affecting also the optical communications systems. Such new tools can be used in almost every aspect, from the design of optical components to the management of optical networks. In this practice you will learn about two particular applications, one for the physical layer (data-plane) and another one for the management layer (control plane).

Applications:
1.-ML and AI in the data-plane (software).
2.-ML and AI in the control-plane (software).

Specific objectives:
Applications of machine learning (ML) and artificial intelligence (AI) in optical networks.

Full-or-part-time: 20h
Laboratory classes: 6h
Self study : 14h

Practice 6: Quantum Key Distribution (QKD)

Description:
Quantum mechanics provides us with a complete new (and weird) set of tools to be applied in optical communications. The most promising application is QKD which claims to guarantee unbreakable security (we will see if that is true). In this practice you will implement an optical QKD system. First a discrete-variable QKD and then a more advanced continuous-variable QKD.

Design of:
1.-A discrete-variable QKD system (software)
2.-A continuous-variable QKD system (software)

Specific objectives:
Implementation of an optical quantum key distribution (QKD) system.

Full-or-part-time: 20h
Laboratory classes: 6h
Self study : 14h

GRADING SYSTEM

Lab reports: 100%

BIBLIOGRAPHY

Basic:
- Govind P. Agrawal. Fiber-optic communication systems [on line]. 4th ed. Wiley, 2010Available on: http://onlinelibrary.wiley.com/book/10.1002/9780470918524.
- Rongqing Hui and Maurice O'Sullivan. Fiber optic measurement techniques. 2nd ed. Academic Press, 2022. ISBN https://doi.org/10.1016/C2020-0-02762-3.

Complementary:
- Govind P. Agrawal. Lightwave Technology: Components and Devices. Wiley-Interscience, 2004. ISBN 0471215732.
- Le Nguyen Binh. Optical fiber communication systems with MATLAB and Simulink models [on line]. 2nd ed. Taylor & Francis Group, 2015Available on: https://ebookcentral-proquest-com.recursos.biblioteca.upc.edu/lib/upcatalunya-ebooks/detail.action?pq-origsite=primo&docID=1680665.

- Emmanuel Desurvire. Erbium-doped fiber amplifiers: principles and applications. Willey & Soncs, 1994. ISBN 0471589772.
- Rajiv Ramaswami, Kumar N. Sivarajan and Galen H. Sasaki. Optical networks: a practical perspective [on line]. 3rd ed. Elsevier, 2010Available on: https://www.sciencedirect.com/science/book/9780123740922.
- Calvin C. K. Chan. Optical performance monitoring : advanced techniques for next-generation photonic networks. 1st ed. Academic Press, 2010. ISBN 9780123749505.
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- Lau, A.P.T.; Khan, F.N. (eds). Machine learning for future fiber-optic communication systems [on line]. London, England: Academic Press, 2022 [Consultation: 25/10/2024]. Available on: https://www-sciencedirect-com.recursos.biblioteca.upc.edu/book/9780323852272/machine-learning-for-future-fiber-optic-communication-systems. ISBN 9780323852272.
- Cariolaro, Gianfranco. Quantum communications [on line]. Cham: Springer, 2015 [Consultation: 16/10/2024]. Available on: https://link-springer-com.recursos.biblioteca.upc.edu/book/10.1007/978-3-319-15600-2. ISBN 9783319156002.