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Scientific Course SC2

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Abstract

Through the Doc-TIC PhD Programme a number of course modules in areas related to photonics (active and passive devices), quantum mechanics, solid-state physics and integrated photonics are given to the ESRs. In this Scientific-based course (SC3) the process of fabrication and measurement has been covered.

Keywords: Photonics, Physics, Solid-state physics, Robotics, Training, Automation

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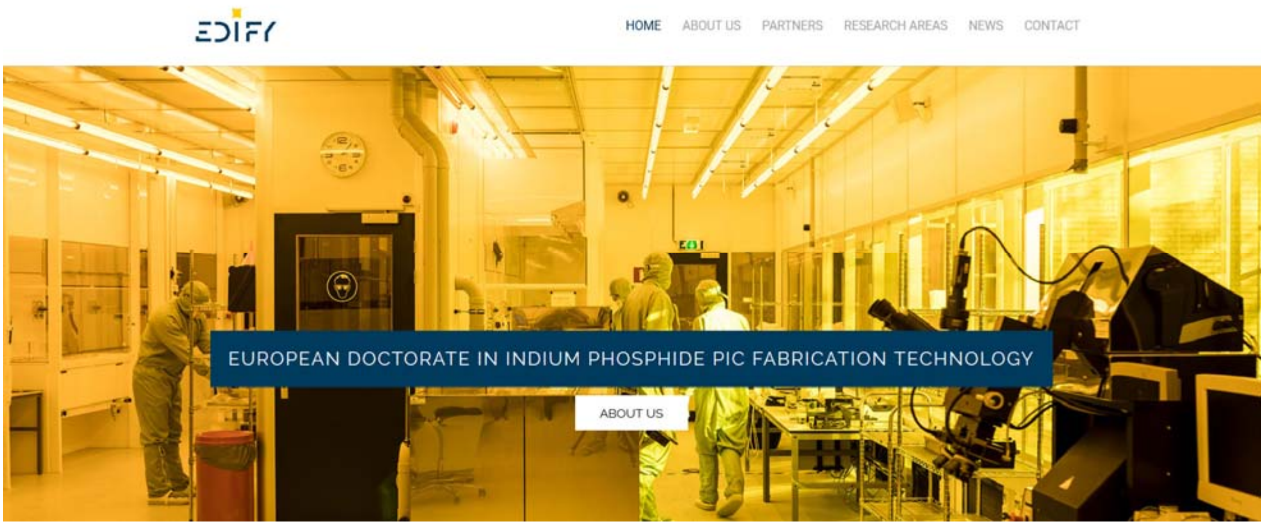
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1. INTRODUCTION

The aim of this report is to provide a brief overview of the first **Scientific Course 3** organized in the framework of the project EDIFY. The challenge for the EDIFY Training Network is to develop new fundamental skills on simulation, design, measurement automation, fabrication and validation, and organization in an integrated photonics foundry. The trainings are intended to develop a new generation of researchers that lead technology advances in material and semiconductor properties aimed for low loss waveguides to develop more efficient passive devices as well as aluminium containing quantum wells for active devices like semiconductor optical amplifiers, saturable absorbers modulators and lasers. To achieve this, EDIFY training strategy aims to combine scientific advanced training (Scientific Courses 1-5), technical hands-on courses (TC1-3), Winter School and regular EID meetings and networking events. Furthermore, all ESRs will be equipped with a range of transferable skills, as defined in the proposal.

The four ESRs **have been enrolled (07/10/2019) in the PhD program from the UVigo (Doc-TIC)**. Doc-TIC is the PhD Program promoted by the School of Telecommunications Engineering and atlanTTic. Its mission is to train the best professionals and researchers to generate quality research with international impact and to provide the industry with professionals with advanced knowledge to improve its competitiveness at global level. Doc-TIC involves the merging and expansion of the previous PhD Programmes in Signal Theory and Communications (TSC) and Telematics Engineering, both with Mention of Excellence awarded by the Spanish Ministry of Education. Each ESR will be required to accumulate at least 30 ECTS (European Credit Transfer and Accumulation System) credits, among the pool of scientific- and transferable skills-based courses at UVigo and TUe **to obtain their PhD title**.

Through the Doc-TIC PhD Programme, **this scientific-based course (SC3) offered to each ESR, will allow them to obtain five ECTS** (30 lecturing hours and 20 hours of homework).

1.1 SCIENTIFIC COURSE 3

In the following Table we describe the fundamentals of this scientific-based course and corresponding skills acquired by the ESRs.

Title	*Photonic integration: technology and characterization (SC3)*	Month: 30	Duration: 1 Month
Lead	TUe		
Contents: In the technology part the following subjects are covered: Crystal properties of semiconductors, Substrate manufacturing, Vacuum technology, Epitaxy, Lithography, wet and dry etching, Plasma deposition, Metallization. The characterization part will explain how the basic parameters of a realized device can be determined. For electrical properties diode characteristics, contact and sheet resistances based on IV measurements will be explained, including the interpretation of the results. Optical characterization focusses on waveguide propagation loss (Fabry-Perot measurement), electrooptic phase shifting (interferometric measurement), gain measurement (Thomson method), laser emission (LI curves and spectral analysis), and photodetection (responsivity and dynamics). Also here proper interpretation of the results is included.			
Skills for ESRs: To understand the process steps needed for fabrication of devices and photonic integrated circuits. To learn which process steps and technologies are needed to fabricate a device or photonic integrated circuit. To understand how devices and photonic integrated circuits are measured and tested including electrical and optical characterization.			

1.2 SYLLABUS

The outline of this course is described below. SC3 has been held from Mon 08/04 till Wed 07/05 between 10:00 - 13:00. This course has been taught in a virtual mode by Dr. Francisco Soares, former Senior Scientist in HHI Fraunhofer.

Topics covered in the course were: crystal properties of semiconductors, substrate manufacturing, vacuum technology, epitaxy, lithography, wet and dry etching, plasma deposition, metallization.

Scientific Course SC3: Photonic Integration: Technology and characterization (Dr. Francisco Soares)

Basics of this course: To understand the process steps needed for fabrication of devices and photonic integrated circuits. To learn which process steps and technologies are needed to fabricate a device or photonic integrated circuit. To understand how devices and photonic integrated circuits are measured and tested including electrical and optical characterization.

Syllabus

1. Technologies, materials and properties.
2. Foundry platforms and fabrication technologies: Group IV and III-V.
3. Applications depending on the technologies.
4. Introduction to characterization: the characterization part explains how the basic parameters of a realized device can be determined.
5. Electrical properties: diode characteristics, contact and sheet resistances based on IV measurements have been explained, including the interpretation of the results.

6. Optical characterization:
    a. Waveguide propagation loss (Fabry-Perot measurement).
    b. Electrooptic phase shifting (interferometric measurement).
    c. Gain measurement (Thomson method).
    d. Laser emission (LI curves and spectral analysis) .
    e. Photodetection (responsivity and dynamics). Proper interpretation of the results is included.

Dr. Francisco Soares has more than 20 years experience in the design, fabrication, and characterization of photonic integrated circuits (PICs). His main expertise is in PICs based on Indium-Phosphide technology, but he is also experienced in several other technologies as well, such as silica waveguide technology, Silicon-On-Insulator technology, and the polymer technology. He has worked in four different cleanrooms (in Europe and the US) developing fabrication processes for realizing PICs. He was one of the first researchers to implement the generic foundry model in the InP technology for realizing highly-integrated PICs containing DFB lasers, optical amplifiers, high-speed Mach-Zehnder modulators, high-bandwidth photodetectors, and all kinds of passive devices. He has supervised one PhD Student, and around five MSc Students. He has authored and co-authored more than 50 publications, and co-authored one chapter in a book.

1.3 SKILLS, OUTCOMES AND METHODOLOGY

With these contents, the students have acquired a set of **competences**:

- Ability to project, calculate and design products, processes and facilities in photonics areas.
- Capacity for mathematical modeling, calculation and simulation in engineering companies, particularly in research, development and innovation tasks in areas related to photonics and associated multidisciplinary fields.
- Ability to apply acquired knowledge and to solve problems in new or unfamiliar environments within broader and multidiscipline contexts, being able to integrate knowledge.
- Ability to apply advanced knowledge of photonics, optoelectronics and high-frequency electronics.

As well as proposed **learning outcomes**:

1. Functional knowledge of the essential photonic devices for optical communications: LEDs and lasers, photodetectors, optical modulators, couplers, circulators, AWG, fibre amplifiers, semiconductor optical amplifiers, optical filters, single-mode fibres, multi-mode fibres and multicore fibres.
2. Knowledge of the noise models used to characterise the optical transmitter subsystems, optical amplifiers and receivers, and capacity to calculate its impact in terms of the signal to noise ratio and error probability.

3. Knowledge of the physical concepts underlying semiconductor physics, band gaps, electrical and optical properties and their application to physical devices.
4. Understanding and mastering of the basic concepts on the general laws of Mechanics and Thermodynamics; Ability to use the basic instrumentation to measure physical quantities.

The **methodology** applied was based in:
Lectures: The professor introduces the main contents of each chapter to the students. These lectures did not cover all the contents of each subject. For that reason, the students had to review the supplementary notes provided in class. It is also expected that the students reviewed the concepts introduced in the classroom and expand on their contents using the guide of each chapter, together with the recommended bibliography, as a reference.
Laboratory: The lectures included some exercises in the lab involving different optical devices and optical communication systems.
Case studies: It consisted on activities that complement the master sessions and allow a better understanding of the theoretical concepts.