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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 (SC5), the technology, simulation concepts, systems and devices on Silicon are studied.

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

Change Record

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0.1	15-06-2021	Outline proposal	Francisco J. Diaz Otero
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1. INTRODUCTION

The aim of this report is to provide a brief overview of the first **Scientific Course 5** organized in the framework of the project EDIFY. The trainings are intended to show concepts on 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. 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 (SC5) 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	*Systems on Silicon (SC5)*	Month: 31	Duration: 1 Month
Lead	TUe		
Contents: This course presents the student with the design trajectory to implement complex Systems on a Chip. Emphasis lies on design approaches to improve the overall system performance in terms of robustness, power-delay product, and hands-on experience to design an integrated circuit using commercial EDA tools. At the end of the course, the student will understand the various trade-offs between area, time, power, cost, and design effort, and also have the basic knowledge and hands on experience to carry out both the front and back end stages needed to implement circuits on silicon.			
Skills for ESRs: To understand SoC design complexity and performance/power trade-offs as well as manufacturing costs. To learn Physical design using EDA tools, logic simulation and synthesis and to learn technology trends in nanometer technologies.			

1.2 SYLLABUS

The outline of this course is described below. SC5 has been held from Mon 21/06 till Mon 28/06 between 10:00 - 13:00 and 15:00 – 17:00. This course has been taught in a virtual mode by Dr. Francisco Soares, former Senior Scientist in HHI Fraunhofer. Due to the covid pandemia, we´ve had first to move this training to June in a virtual mode and to reschedule the training to accommodate the ESRs chronograms and working tasks in SMART-Bright Photonics.

Topics covered in the course were: waveguiding, coupling, passive devices, resonant structures, sources, heterogeneous sources, detectors and packaging.

Scientific Course SC5: Systems on Silicon (Dr. Francisco Soares)

Basics of this course: < comprehensive repository of information, starting from the theoretical fundamentals to outlining the technical and practical issues in producing optical devices in silicon. We start with a solid theoretical analysis on the properties of guided waves, optical modes and optical dispersion. Then it takes this theory and describes how to translate it into designing waveguides in silicon using a basic rib structure and the parameters required to make these waveguides single-mode. Then we went through the processing steps that are needed to produce optical waveguides and photonic devices in silicon and is exposed to some of the processing tolerances and techniques that affect optical device performance. A very thorough and detailed analysis for producing an active device is taught and we showed the various parameters that can be varied to improve device performance. Finally, there is a technical review of the silicon-based light emitters, as well as concepts on silicon packaging.

Syllabus

1. Fundamentals.
2. The basics of waveguides. Reflection coefficients. Modes. Confinement factor.
3. Silicon-on-insulator (SOI) photonics. Effective index and refractive index. Loss and coupling. Optical modulation mechanisms.
4. Concepts on fabrication. Oxidation and doping. Metallization.
5. SOI devices: phase modulators; variable attenuators. Modelling, parametric variation, switching and performance.
6. SOI devices (II): bends, Mach-Zehnder interferometer, couplers, array waveguide gratings (AWGs).
7. Light emitting devices: erbium doping, low-dimensional geometries, Raman excitation.
8. Packaging concepts.
9. Hybrid integration with InP

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**:

- To project, calculate and design products, processes and systems in silicon photonics.
- Capacity for modeling, calculation and simulation, particularly in research, development and innovation tasks in areas related to silicon photonics.
- Ability to apply this new knowledge to solve problems in new environments within broader and multidiscipline contexts, being able to integrate knowledge.
- Ability to apply advanced knowledge of silicon photonics and optoelectronics.

As well as proposed **learning outcomes**:

1. Functional knowledge of the essential photonic devices for silicon technology: lasers, photodetectors, optical modulators, couplers, AWGs, MZIs.
2. Knowledge of the models used to characterise silicon photonics subsystems and components and capacity to calculate its impact in terms of performance improvement and comparison to theoretical modeling.
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:

<u>Lectures:</u> 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.

<u>Laboratory:</u> The lectures included some exercises in a simulation environment involving different optical devices and optical communication systems.

<u>Case studies:</u> It consisted on activities that complement the master sessions and allow a better understanding of the theoretical concepts.