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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. This first of group of Scientific-based courses (SC1) offered to each ESR is already tailored to refresh previous concepts and as an introduction to the basic concepts of photonic integration; to understand the physics and behaviour of semiconductor optoelectronic devices

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

Change Record

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0.1	01-09-2018	Outline proposal	Francisco J. Diaz Otero
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EDIFY

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1. INTRODUCTION

The aim of this report is to provide a brief overview of the first **Scientific Course 2** organized in the framework of the project EDIFY. As a general introduction, 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. These are intended to develop new generation of 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 following specific training objectives (TOs) are defined to fulfill these goals:

- TO1: To enhance the attractiveness of a career in the front-line area of research in integrated photonics InP design, fabrication, characterization and modelling. To provide the opportunity for the fellows to be involved in the creation of a new line of industrial automation and organization of tasks in the InP foundry.
- TO2: To provide academic and industrial sector employers with researchers skilled in a wide range of techniques and methods, and direct experience of interaction across disciplines and sectors.
- TO3: To produce researchers with excellent transferable skills and the ability to transform abstract and challenging ideas into influential and practical outcomes.
- TO4: To create an active, long-term network of young researchers whose personal contacts, support and expertise will help Europe shape the future of research in active/passive devices and enhance/optimize the process of automated integrated photonics fabrication to enable the future of photonics industry in Europe in the next years.
- TO5: To cascade expertise and spread good practice throughout Europe by personnel exchange, and delivering European researchers able to become leaders in the fields of integrated photonics design, fabrication and characterization and industrial organization and automation in photonics industry in the near and mid-term future.

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 the UVigo offers a number of **course modules in areas related to photonics (active and passive devices), quantum mechanics, solid-state physics**, all of which are given in English. Between them, **this scientific-based course (SC2) offered to each ESR, will allow them to obtain five ECTS** (30 lecturing hours and 20 hours of homework).

1.1 SCIENTIFIC COURSES 1a AND 1b

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

Title	***Photonic Integrated Devices Design (SC2)***	**Month: 8**	**Duration: 1 Month**
Lead	UVigo		
Contents: Covered is the theory of optical waveguiding: propagation in free space, reflection and refraction, three layer waveguides. Guided optical modes and modal fields are treated. Three dimensional wave guides and curved waveguides are described. Waveguiding devices such as splitters/combiners arrayed waveguide gratings. Optoelectronic devices such as lasers (FP, DBR, DFB, VCSEL), semiconductor optical amplifiers and photodiodes will be explained. The steady state and dynamic behaviour of lasers is discussed using rate equation models.			
Skills for ESRs: To understand the basic concepts of photonic integration; to understand the physics and behaviour of semiconductor optoelectronic devices such as waveguiding devices, (de)multiplexers, diode lasers, detectors and their applications.			

1.2 SYLLABUS

The outline of this course is described below.

Photonic Integrated Devices Design (SC2) Prof. Jose Ramon Salgueiro

1.Introduction
Optics for communications. Integrated optics. Waveguides. Types of waveguides. Fabrication technologies.
2. The step-index planar waveguide
Geometrical analysis. Propagation and radiation modes. TE and TM modes. Electromagnetic analy- sis. Energy carried by the modes. Mode excitation and coupling. Experimental techniques.

3.Graded-index planar waveguides
Parabolic profile. Variational method. WKB method.
4.Channel waveguides
Introduction and examples. Modal equations. Scalar approximation. Marcatilli's method. Effective index method.
5.Modal coupling theory
Coupled modal equations. Parallel waveguides. Symmetric waveguides. Proximity couplers. Y-junctions.
6.Numerical methods
Modal analysis in the frequency domain. Beam propagation methods. Time-domain simulation methods.
7.Optical fibers
Types of fibers. Propagation modes. Step-index fibers. Weak-guiding approximation. LP modes. Dispersion phenomena in optical fibers. Attenuation in optical fibers.
8.Photonic crystals and metamaterials
Miscellaneous topics

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Capmany, J. et al., *Fundamentos de comunicaciones ópticas*, Síntesis (1998).

Saleh, B. E. A., Teich, M. C., *Fundamentals of photonics*, segunda edición, Wiley (2007).

Joannopoulos, J. D. et al., *Photonic crystals. Molding the flow of light*, 2nd ed., Princetown University Press 2008.

Prof. Jose Ramon Salgueiro, PhD in Physics from University of Santiago de Compostela (Spain) in 2001 working with the Group of Integrated Optics and Optical Fibers. After his PhD he became assistant professor at the University of Vigo in Ourense (Spain) working in nonlinaear optics with the Physical Optics Group. In 2002, he joined for two years the Nonlinear Physics Group at the The Australian National University in Canberra (Australia). Then, he had a tenure track contract of the Ramón y Cajal program in 2005 at the University of Vigo, where he is currently Professor and researchs on the fields of photonic crystals, nonlinear optics and quantum optics.

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.

1.4 AGENDA

The agenda for SC2 can be found below. With this schedule the students fulfilled the five ECTS intended for this scientific course with an intensive training scheme. There was an introductory session with ESRs and lecturers to provide a first basis to develop the learning plan, meeting in person with all the ESRs and answering doubts or questions. Finally, as a remark, not only the ESRs attended the courses. As they are part of the Doc_TIC program, two other PhD students also participated in the sessions scheduled.

Week 1	Mon jun 10	Tue jun 11	Wed jun 12	Thu jun 13	Fri jun 14	Sat jun 15	Sun jun 16
9:00							
10:00			EDIFY KICK OFF MEETING				
11:00							
12:00							
13:00							
14:00							
15:00							

Week 2	Mon jun 17	Tue jun 18	Wed jun 19	Thu jun 20	Fri jun 21	Sat jun 22	Sun jun 23
9:00							
10:00		SC1a	SC1b	SC2			
11:00							
12:00							
13:00							
14:00							

Week 3	Mon jun 24	Tue jun 25	Wed jun 26	Thu jun 27	Fri jun 28	Sat jun 29	Sun jun 30
9:00							
10:00	SC1a	SC1a		SC2	SC2		
11:00			SC1b				
12:00							
13:00							
14:00							
15:00			SC1b	SC1b			
16:00							
17:00							
18:00							
19:00							

Week 4	Mon jul 1	Tue jul 2	Wed jul 3	Thu jul 4	Fri jul 5	Sat jul 6	Sun jul 7
9:00							
10:00	SC1a	SC1a		SC2	SC2		
11:00			SC1b				
12:00							
13:00							
14:00							
15:00			SC1b	SC1b			
16:00							
17:00							
18:00							
19:00							

Week 5	Mon jul 8	Tue jul 9	Wed jul 10	Thu jul 11	Fri jul 12	Sat jul 13	Sun jul 14
9:00							
10:00	SC1a	SC1a		SC2	SC2		
11:00			SC1b				
12:00							
13:00							
14:00							
15:00			SC1b	SC1b			
16:00							
17:00							
18:00							
19:00							