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Scientific Courses SC1 a and b

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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 modern physics concepts and photonics.

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

Change Record

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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 Courses (1a and 1b)** 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 group of Scientific-based courses (SC1) offered to each ESR, will allow them to obtain ten ECTS** (60 lecturing hours and 40 hours of homework).

1.1 SCIENTIFIC COURSES 1a AND 1b

In the following Table we describe the fundamentals of these first scientific-based training group of courses and corresponding skills to be acquired by the ESRs.

ESR1 and 4	**Title**	***Photonics, quantum mechanics, solid-state physics (SC1a)***	**Month: 8**	**Duration: 1 Month**
Lead		UVigo		
Contents: This group of courses covers the latest research of optical communications and optical devices, semiconductors and quantum mechanics. Concepts on physical foundations of the optical transmission systems and optical information processes, in particular, those that deviate most from the classical technics such as the optical generation and photonic detection; Basic theory of optical devices and optical subsystems like, for example, LEDs and lasers, photodetectors, modulators, fibre amplifiers and optical filters.				
Skills for ESR1: To understand the origin and reasons for the use of optical transmission systems. To be able to specify the type of optical fibres and other necessary opto-electronical components that are needed for a certain optical link. Also, to understand their physical and technological limitations; To understand the physical concepts underlying semiconductor physics, band gaps, electrical and optical properties and their application to physical devices like optical Lasers and LEDs; To apply deep concepts related to quantum mechanics to interfaces with semiconductor materials.				
ESR2 and 3	**Title**	***Classical and Modern Physics (SC1b)***	**Month: 8**	**Duration:1 Month**
Lead		UVigo		
Contents: Fundamental concepts from classical and modern physics form the basis for the design and behaviour of materials and devices as well as provide an understanding of natural phenomena. This course will provide a basis for the specialization courses that deal with physical processes in devices such as telecom systems, electric motors, power plants, lasers, electronics or detectors and sensing systems. Basic concepts in mechanics, thermodynamics, special relativity, quantum mechanics and atomic and solid state structure are introduced.				
Skills for ESR2 and 3: Resolve problems applying the laws of Ampère, Gauss and Faraday and the Maxwell Equations; Calculate the main parameters of the electromagnetic waves: frequency, wavelength, propagation constant, polarization, Poynting vector, phase constant, attenuation constant; Analyze the propagation of waves in media with and without losses; 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.				

Although these courses were divided and tailored for each ESRs needs (ESR1 and 4 to SC1a; and ESR2 and 3 to SC1b), mainly due to their different background and skills, after the recruitment process it was clear that they could attend all the courses. Moreover, they wanted to attend these courses not only for refreshment purposes but to interact with other teammates and for group working.

1.2 SYLLABUS

The outline of these courses is described below.

Photonics, quantum mechanics, solid-state physics (SC1a) Prof. Francisco Javier Fraile-Pelaez

1. Basic Concepts of Photonics and Optical Communications
2. Electromagnetic Formalism of the Propagation and Amplification of Light
3. Laser Oscillation
4. Basic Nonlinear Optics
5. Direct and Coherent Optical Detection. Noise
6. Fundamentals of Quantum Mechanics
7. Fundamentals of Semiconductor Physics
8. Semiconductor Optical Sources and Amplifiers

Classical and Modern Physics (SC1b) Prof. Angel Paredes Galan

1. Introduction: from electromagnetism to optics
2. Laser physics
    Laser oscillation: basic concepts.
    Interaction of radiation with matter and line broadening.
    Passive optical resonators.
    Pumping.
    Rate equations.
    Pulsed lasers.
    Types of lasers.
3. Nonlinear optics
    The nonlinear wave equation.
    Frequency mixing.
    The Kerr effect and nonlinear effects on beam propagation. Numerical simulation.
4. Quantum optics
    Photon statistics.
    Coherent states and squeezed light.

Cold atoms.

Quantum information processing.

APPENDIX: Extra topics

Relativistic / ultrafast optics

Optical tweezers

Optical clocks

Topological photonics

Prof. Francisco Javier Fraile Pelaez has more than 25 years of experience in research areas like optoelectronic devices, optical communications, nonlinear optics and quantum optics. He has supervised more than 10 PhD. students and 3 postdocs. He is national evaluator from the Spanish Ministry of Education and ANEP auditor. He has more than 50 articles and has written two internationally recognized books on optical communications.

Prof. Angel Paredes Galán is Ph. D. in Particle Physics from the University of Santiago de Compostela in 2004. Postdoctoral stays at École Polytechnique (France) - as a Marie Curie fellow -, University of Utrecht (the Netherlands) and University of Barcelona (Spain). His current research interests lie at the intersection of particle physics, many body quantum physics and laser-driven optical technologies.

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 SC1a and b can be found below. With this schedule the students fulfilled the ten ECTS intended for these scientific courses 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							