Course guide
230853 - LF - Large Facilities: Synchrotron and Neutron Sources

Last modified: 14/12/2023

Unit in charge: Barcelona School of Telecommunications Engineering
Teaching unit: 748 - FIS - Department of Physics.

Degree: MASTER'S DEGREE IN ENGINEERING PHYSICS (Syllabus 2018). (Compulsory subject).
ERASMUS MUNDUS MASTER'S DEGREE IN BIO & PHARMACEUTICAL MATERIALS SCIENCE (Syllabus 2021). (Compulsory subject).

Academic year: 2023 **ECTS Credits:** 5.0 **Languages:** English

LECTURER

Coordinating lecturer: Consultar aquí / See here: https://telecos.upc.edu/ca/estudis/curs-actual/professorat-responsables-coordinadors/responsables-assignatura

Others: Consultar aquí / See here: https://telecos.upc.edu/ca/estudis/curs-actual/professorat-responsables-coordinadors/professorat-assignat-idioma

PRIOR SKILLS

- Basic general physics, specially electromagnetism, propagation of electromagnetic waves in vacuum, metals and dielectrics
- General background in instrumentation
- Solid state physics, specially crystalline structures
- Basics of probability
- Some background in special relativity could be helpful but not mandatory

REQUIREMENTS

None

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Basic:
CB6. Possess and understand knowledge that provides a basis or opportunity to be original in the development and/or application of ideas, often in a research context
CB7. Students should know how to apply the knowledge acquired and their problem-solving ability in new or little-known environments within broader (or multidisciplinary) contexts related to their area of ¿¿study.
CB10. Students should possess the learning skills that allow them to continue studying in a way that will be largely self-directed or autonomous.

TEACHING METHODOLOGY

- Master classes
- Practical and theorethical exercises using software tools
- Laboratory practice
- Project development

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LEARNING OBJECTIVES OF THE SUBJECT

- To get acquainted with the main concepts of charged particle acceleration and principles of operation of synchrotrons
- To understand the principles of generation of synchrotron radiation and neutron beams and know their main characteristics
- To know the main systems used in large facilities
- To recognize the complementarity of each technique (synchrotron and neutron scattering)
- To know the fundamentals of the main techniques in synchrotron and neutron sources
- To know the physical properties of the materials that are possible to measure in large facilities
- To know the fundamentals to analyze the data obtained in large facilities

STUDY LOAD

Type	Hours	Percentage
Hours large group	48,0	37.21
Self study	81,0	62.79

Total learning time: 129 h

CONTENTS

1. Basics of particle accelerators

Description:
In this first topic, a general introduction to particle accelerators will be given, explaining the different types, the systems used to accelerate electrons and their main parameters.

Specific objectives:
General introduction. Types of accelerators. Methods of acceleration. Liniar and circular accelerators. Magnetic systems. Main accelerator systems and RF. Beam characteristics.

Related activities:
Related exercices.

Full-or-part-time: 8h
Theory classes: 8h

2. Generation of electromagnetic radiation

Description:
The different methods of generation of electromagnetic radiation, both Bremsstrahlung and synchrotron, will be explained and the existing facilities where experiments with synchrotron radiation will be performed will be detailed. A description of the ALBA synchrotron will be given.

Specific objectives:
Bremsstrahlung. X-ray applications. Synchrotron radiation. Methods of SR generation. Insertion devices. Characteristics of SR. Beamlines and experiments. Alba SR facility.

Related activities:
Related exercices and visit to ALBA.

Full-or-part-time: 4h
Theory classes: 4h

3. Examples of large facilities: colliders, ion accelerators, synchrotron radiation and spallation sources

Description:
The operation of the large existing facilities, both particle colliders, accelerators, synchrotrons and neutron and spallation sources, will be explained and detailed.

Specific objectives:
CERN accelerator complex and LHC. Neutron sources. European Spallation Source and other examples. Spanish synchrotron radiation source ALBA. New types of electromagnetic radiation facilities.

Related activities:
Laboratory practices at ALBA: Magnetic measurements, RF measurements, Linac energy dispersion measurements

Full-or-part-time: 4h
Theory classes: 4h

4. The basics of X-ray and neutron scattering

Description:
The different mechanisms by which radiation can interact with matter will be addressed, making a classic description of the atomic structure. We will begin by explaining the interaction with an isolated electron to then generalize it to a complex system characterized by its electron density. Finally, the differences will be discussed depending on whether the interaction occurs with photons or neutrons.

Specific objectives:
The interaction of X-rays with matter. Scattering from one electron. Scaterring from a cloud of electrons. Scattering function for neutrons. Scattering function for X-rays. Absorption.

Related activities:
None.

Full-or-part-time: 2h
Theory classes: 2h

5. Beamlines

Description:
The different components of a beamline will be described in detail, taking into account everything that has been learned in the previous topic about the interaction of X-rays with matter. There will also be a description of the different existing experimental techniques with their field of application and specific examples.

Specific objectives:
Front end: Primary aperture, front end slits, low energy filters. Primary optics: x-ray mirrors, monochromators. Microfocus and nanofocus optics. Beam Intensity monitors. Detectors. Experimental techniques at beamlines.

Related activities:
Speciallized seminars by ALBA staff

Full-or-part-time: 2h
Theory classes: 2h

6. Inelastic neutron scattering

Description:
The process of inelastic neutron scattering will be explained in detail and the type of information that can be extracted will be detailed.

Specific objectives:
Coherent and incoherent scattering. Van –Hoff functions (localized, delocalized and intramolecular motions).

Related activities:
None.

Full-or-part-time: 4h
Theory classes: 4h

7. Neutron applications

Description:
The different applications that can be made with neutrons will be described in detail, including those related to scattering measurements, those related to magnetism in matter, and those related to obtaining images using neutrons.

Specific objectives:
Inelastic Neutrons Scattering Methods (Time of flight, Spin Echo, Backscattering). Magnetism using neutrons. Imaging using neutrons.

Related activities:
None.

Full-or-part-time: 2h
Theory classes: 2h

8. Diffraction at Synchrotron Sources

Description:
A description of the matter in terms of crystal lattice and how this structure can be obtained from X-ray diffraction measurements will be given. The problems of the technique and how they can be solved will be explained and finally it will be explained how to extract information from disordered materials, whether liquid or solid.

Specific objectives:
Crystals and Bragg peaks. Reciprocal lattice. Atomic planes and Bragg's Law. Influence of the basis. The phase problem. Powdered samples. Liquids and amorphous materials: radial distribution functions, structure factors.

Related activities:
- Related exercices.
- Practice of data analysis with specific software.

Full-or-part-time: 6h
Theory classes: 6h

9. Fundamentals of X-ray Absorption Fine Structure (XAFS)

Description:
The most common technique based on X-ray absorption will be explained, focusing on the description of the physical phenomenon that produces oscillations in the absorption coefficient of a material and the type of information that can be extracted from the analysis and fitting of these oscillations. Finally, it will be explained how to design a XAFS experiment, especially with regard to sample preparation.

Specific objectives:
X ray absorption and fluorescence. Simple theoretical description. Multiple Scattering. Data analysis. Experiment design. Sample preparation.

Related activities:
- Practice of data analysis with specific software.

Full-or-part-time: 4h
Theory classes: 4h

10. Hard X-Ray Synchrotron Imaging Techniques and other technics

Description:
There will be a brief description of how to obtain images of different types of samples using synchrotron radiation and a generic description of other more specialized techniques with particular reference to the type of information that can be extracted from them.

Specific objectives:
Hard X-Ray Synchrotron Imaging Techniques. Other applications: Photoemission spectroscopy , Resonant and magnetic XRD , X-ray microscopy , Infrared synchrotron radiation , Inelastic X-ray scattering.

Related activities:
None.

Full-or-part-time: 2h
Theory classes: 2h

11. Frequentist data analysis

Description:
Given the importance of carrying out a correct treatment of the experimental data obtained in large facilities, in this topic there will be a review of the statistical treatment of the data and its errors from a classical or frequentist view of statistics.

Specific objectives:
Data and errors: an statisitical view. An overview on classical fitting methods. Statistical distributions. Hypothesis testing in classical statistics.

Related activities:
None.

Full-or-part-time: 2h
Theory classes: 2h

12. Bayesian data analysis

Description:
An introduction will be made to Bayesian statistics, highlighting their usefulness in discriminating between different models compatible with the experimental data obtained.

Specific objectives:
Bayesian statistics: from numbers to Probability Distribution Functions (PDF). Bayes theorem and measurement: where are the PDFs hidden? Fitting functions using a Bayesian approach. Markov Chain Montecarlo method to obtain Posterior PDFs. Model selection in Bayesian statistics.

Related activities:
- Practice of model selection.

Full-or-part-time: 4h
Theory classes: 4h

GRADING SYSTEM

Written examns: 40%
Written assignements: 25%
Project: 15%
Laboratory practices: 20%
There are no reevaluable acts.

EXAMINATION RULES.

The written exams will be multiple choice tests or short exercises that will be carried out during teaching hours once the part of the syllabus to be assessed has been completed. For these individual tests, only a calculator can be used. The exercises, project and practices can be done both individually and in groups and will be carried out both during teaching hours and outside it.

BIBLIOGRAPHY

Basic:
- Mobilio, S.; Boscherini, F.; Meneghini, C. Synchrotron radiation: basics, methods and applications [on line]. Berlin, Heidelberg: Springer Berlin Heidelberg, 2015 [Consultation: 02/06/2020]. Available on: https://ebookcentral.proquest.com/lib/upcatalunya-ebooks/detail.action?docID=1802923. ISBN 9783642553158.
- Als-Nielsen, J.; McMorrow, D. Elements of modern X-ray physics [on line]. 2nd ed. West Sussex: John Wiley & Sons, 2011 [Consultation: 18/05/2020]. Available on: https://onlinelibrary.wiley.com/doi/book/10.1002/9781119998365. ISBN 9780470973943.
- Willmott, P.R. An introduction to synchrotron radiation: techniques and applications [on line]. 2nd ed. Hoboken, New Jersey: Wiley, 2019 [Consultation: 18/05/2020]. Available on: https://onlinelibrary.wiley.com/doi/book/10.1002/9781119280453. ISBN 9781119280392.
- Sivia, D.S. Elementary scattering theory: for X-ray and neutron users. Oxford: Oxford University Press, 2011. ISBN 9780199228683.
- Wiedemann, H. Particle accelerator physics. 4th ed. Cham: Springer, 2015. ISBN 9783319183169.

RESOURCES

Other resources:
- Course presentations (through the UPC Atenea digital campus)