# Photon and Neutron Production for Science
# MAXC11 = EXTF90

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## Contents



## 1 Course description of the course Photon and Neutron Production for Science (MAXC11= EXTF90)

The course Photon and Neutron Production for Science, MAXC11, is given to international undergraduate students in physics during the third or fourth year of their education and the course can be included in a Bachelor or Masters degree.

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In the course the students will learn about different types of accelerators for the production of photons and neutrons for research.

The students will learn about methods of producing photons with highly relativistic electron beams in combination with special magnets called undulators and the method of producing neutrons by letting a relativistic proton beam hit a target.

The students will also learn about the experimental stations, the experimental methods, and the different kinds of research that can be carried out with neutrons and photons

### 1.1 Course responsible

Francesca Curbis is responsible for the course.

### 1.2 Intended Learning Outcomes

On completion of the course students shall possess basic knowledge of:

- How photons and neutrons are produced for scientific use.
- Linear accelerators and synchrotron accelerators for the acceleration of electrons and protons.
- Beamlines for photons, including sub-systems like for example the monochromator, optical system and detectors.
- Neutron guides and the target stations of accelerator based neutron sources including the different sub-systems like for example the detectors.
- Conventional light sources and reactor based neutron sources.
- Current research methods, with their applications in natural sciences, medicine and technology, based on synchrotron radiation and neutrons

After completion of the course, participants should be able to:

- Describe and explain the working principles of a linear accelerator and a synchrotron accelerator to a non-expert audience.
- Describe how photons and neutrons are produced with accelerators and further led to the experiments to a non-expert audience.
- Describe other photon and neutron sources and related (nuclear) reactions to a non-expert audience.
- Discuss the use of photons and neutrons within research, medicine and industry through examples.

### 1.3 Teaching and Learning Activities

The teaching and learning activities are composed of:

- **Lectures**: 12x(2x45min) = 18 hours.

  The lectures will cover the contents of the course, which is how photons and neutrons for scientific use are produced with accelerators and used in science.

- **Exercises**: 6x (2x45min) = 12 hours.

  The exercises will cover basic relations for accelerators, photon optics, target stations, and neutron guides. The students will solve problems under peer tutoring from a lecturer.

  The set of exercise problems are intended to illustrate the fundamental working principles of the different parts of the photon or neutron source systems, e.g. the accelerator, the target, the neutron guide, the detectors, the undulators, or the optical system of a photon beamline.

  The exercise question will be given to the students in advance and during the scheduled exercise hours the teacher is going through the solutions explaining the relations used.

  A few additional simulation or exercise problems (without solutions) are given to the students for doing hand-in solutions that are part of the assessment/examination.

- **Demonstrations and study visits**: 2x3 hours = 6 hours.

  The study visits will show the existing accelerators at MAX-lab and also an existing photon research beam line at MAX-lab.

- **Presentations by students**: 2x(2x45min) = 4 hours.

  Towards the end of the course the students should present an application of production photons or neutrons for science. The students will do this in an oral presentation 10-15 minutes for the other students. The students will also write an approximately 1000 words long hand-in report about the topic of the presentation.

  The topic of the presentation will be selected by the student in agreement with the course responsible teacher at the beginning of the course. The topic of the presentation might be a description of an accelerator based neutron or photon research facility, a specific experimental station, a specific experimental method, a specific accelerator, a specific target station, or some other sub-system used for the photon and neutron production for science. Also ethical aspects of the construction and operation of facilities for the photon and neutron production for science may be considered as topics of the presentation.

### 1.4 Assignments

The students should hand in solutions to 4 selected exercise duties during the course. The solutions can, if needed, be amended by the student after correction of the teacher in order to obtain a correct solution.

The students should give a 10-15 min long oral presentation of a research facility, instrument, or experiment using photons or neutrons. The topic of the presentation should be decided by the student in agreement with the course responsible teacher. An approximately 1000 words long hand-in report is written about the topic of the presentation.

Guidelines for writing a report:

- The report should have a title.
- The report should have an author.
- The report should have a date.
- The author of the report should write the text of the report.
- The report should be written in English.
- The report should be divided into sections with names such as, for example, "Introduction", "Historical background", "Summary" or "References".
- All figures and tables in the report should have captions explaining the contents of the figure or table.
- There should be references from the text to the figures and tables, like for example "The layout of the SPring8 accelerator system is shown in Figure 2" or "The measured photon flux for different running modes of the LCLS are given in Table 4".
- If a figure or table is copied from another document, e.g. a website or an article, a reference to the source document should be given in the caption.
- If text is copied from another document it should be marked with citation marks and a reference to the source should be given.
- The references should be listed in the end of the report in a section called "References" and not in the form of footnotes on different pages.
- More information about academic writing and citation and referencing techniques can be found on the Lund University web page with the html-address: http://www.lub.lu.se/en/student/academic-conduct/academic-writing.html.

The students should do the home exam that is running over 1 week. The home exam will have 5 questions, each worth 3 points, giving a total maximum score of 15 points. A score of 9 points or better are required to pass the exam The questions consists of 3-4 questions similar to the exercise questions and 1-2 questions about fundamental relations without a numerical answer. The solutions handed in by the students will discussed during a meeting with the course responsible teacher before the score of the written home exam is finalized.

The students should participate at the study visits.

The students are advised to follow the lectures and exercises during the course but presence is however not a criteria for the examination/assessment.

## 1.5 Examination/Assessment

The examination/assessment of the course is:

- Passed hand-in simulation and exercise problems
- Passed written examination
- An oral 10-15 min long student presentation
- Passed report about the topic of the presentation

The final grade for the course is determined by the aggregated results of the different parts of the examination.

The students are graded for the course according to the following levels: Passed with distinction (VG), Passed (G), and Failed.

## 1.6 Credits

The university credits of the course is 7.5 points.

## 1.7 Course material

The teachers of the course will distribute lecture notes and additional information during the course. There is no need for the participants in the course to buy specific books in order to follow the course. However, the following sub-sections described suitable reference literature for further studies.

### 1.7.1 Overview information about accelerators

The United States Department of Energy has produced a report covering the use of accelerators in medicine, industry and research [1]. Pages 77-80 in [1] covers the use of accelerators for photon and neutron production.

The widespread commercial use of accelerators has recently been described in an article in Physics Today [2]

### 1.7.2 Electron (lepton) accelerators and photon production

The lectures about basic relations, electron accelerators, and synchrotron radiation are based on the book ”Accelerator Technique” by Sverker Werin [3]. The chapters 1, 2, 4, 5, 6 (excluding edge focusing), 7, 8, 11, and 12 are incuded in the course material. The parts about electron sources in chapter 7 of [3] is replaced by a comprehensive overview article about electron sources in Physics Today [4].

The proceedings of the CERN Accelerator Schhool in Brunnen 2003 [5] is a comprehensive book covering the theoretical and practical aspects of synchrotron radiation and free electron lasers.

### 1.7.3 Photon beam lines and experimental methods

A good understanding of photon science and related instrumentations can be found in a recent book by Philip Willmott, “An Introduction to Synchrotron Radiation, Techniques and Applications” [6]. The book is available as an e-book at the Lund University Library and the lecture about Scientific Applications with Photons is heavily relying on that. The same reference can be also used for parts related to beamlines and instrumentation therein.

### 1.7.4 Proton (hadron) accelerators and neutron production

To be completed

A thorough description of linear accelerators for protons can be found in [7].

### 1.7.5 Neutron guides and experimental methods

To be completed

## References


[1] Walter Henning and Charles Shank. http://www.acceleratorsamerica.org/report/, 2010.

[2] Robert W. Hamm and Marianne E. Hamm. The beam business: Accelerators in industry. Physics Today, 64(6):4651, 2011.

[3] Accelerator Technique, 2.5th edition, Sverker Werin, Max-lab, 2006.

[4] Carlos Hernandez-Garcia, Marcy L. Stutzman, and Patrick G. OShea. Electron sources for accelerators. Physics today., 61(2):4449, 2008.

[5] Editor: D. Brandt. Cern accelerator school - synchrotron radiation and free electron lasers. CERN Accelerator School Proceedings CAS-2005-012, November 2005.

[6] P. Willmott. An Introduction to Synchrotron Radiation, Techniques and Applications. John Wiley and Sons, Ltd, United Kingdom, 2011.

[7] Thomas Wangler. RF Linear Accelerators. WILEY-VCH Verlag Gmbh & Co. KGaA, 2008.

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