Nordic Particle Accelerator School,

NPAS-2015,

August 17-23 2015

Course Description

Monday 17

C1 – Introduction to Synchrotron Light Sources – Pedro Fernandes Tavares, pedro.fernandes_tavares@maxlab.lu.se

The electromagnetic radiation produced by accelerated charged particle beams, known as synchrotron light, is a key tool in the characterization of a wide range of matter at the molecular and atomic level. Worldwide about 70 facilities have been built over the past 40 years to produce synchrotron radiation and deliver it to experiments across a wide range of sciences such as physics, chemistry, medicine/biology, and engineering.

After briefly introducing the application of synchrotron radiation for the study of materials, interfaces, and surfaces, the lecture will give an overview how highly intense synchrotron radiation is generated by beams of charged particles in high-energy accelerators. In order to set the stage for the rest of the school, the physics of the radiation emission process and the dynamics of the charged particle beams will be briefly introduced as well as the types of accelerators that serve as the most intense radiation sources. Several such accelerators are available on site and will serve as examples.

C2 and C3 - Accelerator Physics Introduction - Francesca Curbis, francesca.curbis@maxlab.lu.se

This course will describe 1) Basic relations (units, kinetic energy, 4-momentum, relativistic); 2) Lorentz force & Maxwell's equations; 3) types of accelerators and electron guns; 4) Oscillating EM fields in linacs; 5) Circular accelerators; 6) Synchrotrons and phase stability; 7) Magnets (dipoles, quadrupoles, sextupoles) and 8) focusing properties [NO equation of motion, NO dynamics].

C4 - Introduction to Spallation Source – Mats Lindroos, mats.lindroos@esss.se

The European Spallation Source is a Partnership of 17 European Nations committed to the goal of collectively building and operating the world's most powerful long-pulse source of neutrons with a peak brightness of at least 30 times greater than any of today's similar facilities. Thus, the ESS will provide the much-desired transformative capabilities for interdisciplinary research in the physical and life sciences. The ESS accelerator high level requirements are to provide a 2.86 ms long proton pulse at 2 GeV at repetition rate of 14 Hz. This represents 5 MW of average beam power with a 4% duty cycle on target.

This lecture will introduce the principle of spallation using proton acceleration and based on simple examples. The accelerator components and functions will be described to support the following school lectures on the topic of accelerator technology.

T1 – Exercices, Acc. Physics
T2 – Exercices, Acc. Physics
T3 – Visit old Max-lab

Tuesday 18

C1 and C4 – Accelerator Physics, Optics and Tools – Sverker Werin
sverker.werin@maxlab.lu.se
This course will describe general electro-magnetic fields and matrices, phase space, beam transport as basis for accelerator science. It will introduce the function and use of dipole and quadruple magnets Magnets (D, Q) and Radio-frequency cavities.
This course will describe particle motion in magnetic fields, single particle, betatron motion, dispersion, beams, TWISS, Liouville, resonances. Tools to study those parameters will be introduced.

T1 and T2 – Computer simulations
This tutorial will introduce the use of Winagile on your own PCs.

T3 – Cont, or Instruction for project and examination

Wednesday 19

C1 and C2 – Beam Diagnostics for particle accelerators – Maja Olvegård,
maja.olvegard@physics.uu.se
Beam diagnostic instruments are the eyes of the accelerator, the best - or even the only - tools that we have to monitor and control the beam. This lectures will give the basics of "what, where and how" of beam diagnostics.
Different types of accelerators calls for different diagnostic methods. We will discuss the most important beam parameters that generally are monitored, a few common detector types, and how to analyze and meet the needs of each and every accelerator.
Types of parameter: position, intensity, transverse and longitudinal profile, energy.
important concepts: resolution and accuracy, invasive or non-invasive, single-shot or multi-shot, common techniques: Faraday cup, pick-up, scintillation and OTR screens, wire scanner, SEM-grid, laser-based instruments.

C3 – Accelerator Components and Technologies – Christine Darve,
Christine.darve@esss.se
This course will describe the different components and technologies used to operate particle accelerators, from the Radio-Frequency Quadrupole, Drift Tube Linac and supraconducting cavities. We will use the example of the ESS proton accelerator and the LHC machine to support the description of accelerator environment and interfaces (e.g. RF systems, cryogenics, vacuum, water, radiation environment).
An overview of the life-cycle of accelerator components will illustrate the integration of key-components, from their fabrication, testing, installation to their operation in the tunnel. On this basis, we will also talk on the instrumentation, which are needed to condition, monitor and control the signals to operate safety an accelerator.

C4 – RF sources - Carlos Martins, Carlos.Martins@esss.se
The RF sources are power systems that convert electrical power from a standard electrical power grid into RF microwave power, at the desired frequency and amplitude, in order to excite the RF cavities, which in turn will generate the electrical fields that will accelerate the particle beam.
The related power chain consists of different components which are very specific and unique at a worldwide scale: the high voltage modulators (power supplies) convert AC low/medium voltage electrical power into high voltage power compatible with RF amplifiers; RF amplifier tubes (klystrons, tetrodes, IOT’s, etc.) convert electrical

power into RF microwave power; RF distribution networks (waveguides, circulators, couplers, etc.) transmits the RF power from amplifiers to the final load (RF cavities).
In addition to the power chain described above, a sophisticated control system (LLRF) is required in order to assure that the RF power is generated, transmitted and delivered to the loads according to the requirements derived from the accelerator application like duty cycle (Pulsed or Continuous Wave), precision, stability, etc.

T1, T2 and T3 - Visit MaxIV and ESS

Thursday 20

C1 and C2 – Magnet Technology - Franz Bødker, DANFYSIK, frbr@danfysik.dk
This course will describe the magnets needed in a particle accelerator. We will start out by looking into the basic functions of a classic electromagnet with magnetic flux generated by a current and guided by a magnetic iron frame. Then we will go into details with the basic functions of the bending dipole such as the required field strength and field quality. This will lead to a description on how the iron pole is shaped in order to obtain the desired magnetic performance. Quadrupole magnets and higher order correction multipoles will also be discussed. Magnet properties like hysteresis, eddy currents and iron saturations will be mentioned in order to understand some of the non-linear complexities of electromagnets.
On this basis we will talk about the more complicated accelerator magnets such as fast ramped and pulsed magnets like kicker and bumper magnets. High field superconducting magnets and permanent magnet driven green alternatives will also be considered. The tools used for magnetic design and testing of accelerator magnets will be mentioned. Examples will be given on different types of accelerator magnets that have been produced at Danfysik such as the compact MAX-Lab magnets with up to 13 different magnets in one shared iron yoke. The basic function of insertion devices used at free electron laser and synchrotron light facilities and for the generation of intense synchrotron light is illustrated by the multipole wiggler and undulators as compared to radiation from bending magnets. The basic function of high field wiggler is compared to high brilliance undulators and the general features of these devices will be described. Example will be shown of insertion devices like permanent wigglers, in-vacuum cryogenic undulators and the superconducting alternatives.

C3 and C4 – Accelerator technologies: vacuum - Pauli Heikkinen,
pauli.heikkinen@jyu.fi
This course will describe: 1) Vacuum**:** Introduction to basic concepts and units; vacuum regions; residual gas: Maxwell - Boltzmann distribution for energy for residual gas (velocity distribution, average collision distance, molecular layer formation); 2) Basics of vacuum equipment (Pumping speed, conductance, hardware); 3) High voltage use (DC, AC): Forces due to electric and magnetic field (Electric rigidity); HV devices (conditioning, sparking, hardware).

T1 – Exercise, Beam diagnostic
T2 and T3 – Exercises: Magnets and RF technologies; accelerator technologies
Code FEM; magnet design

Friday 21

C1 and C2 – Production of Synchrotron Radiation, Sverker Werin
sverker.werin@maxlab.lu.se
This course will describe Radiation, electromagnetic fields, relativity, bending magnet radiation, undulators, wigglers, coherence, bandwidth, diffraction, pulse lengths

C3 – Medical applications of electron accelerators – Lars Præstegaard, Aarhus University Hospital, larsprae@rm.dk
This course will describe 1) Short introduction to the basic theory of waveguides, cavities, and linear accelerators; 2) Rationale for radiation therapy (what is cancer, radiation damage, fractionation, therapeutic window); 3) Electron linacs for radiotherapy (beam optics, how to change the energy, and treatment head design).

C4 - Medical application of proton accelerators - Lars Præstegaard, Aarhus University Hospital, larsprae@rm.dk
This seminar will present the following topics:
- Basic theory of the proton cyclotrons (and recap. of proton synchrotrons)
- Medical applications of isotope production
- Rationale for hadron therapy (Bragg peak, dose distribution, skin dose, biological effectiveness).
- Treatment delivery of hadron therapy (gantries, passive scattering, pencil beam scanning, lateral dose penumbra, uncertainties in hadron therapy).

T1 – Applications to particle physics and nuclear physics - Erik Adli
Erik.adli@cern.ch
The study the fundamental particles and the forces of nature is the reason particle accelerators were invented about hundred years ago. This field has driven the development of accelerator technology up to today. I will discuss the requirements that particle physics and nuclear physics impose on particle accelerator design, and I will review some of the major discoveries achieved by particle accelerator experiments

T2 – Pushing the frontiers - Erik Adli, Erik.adli@cern.ch
The users communities continuously ask for improved accelerator parameters; higher beam energy, better beam brilliance and higher beam power. Clever accelerator physicists have throughout history invented new theory and better technology in order to overcome limitations in particle accelerator performance. In this tutorial we together go through a few of the main limitations of current accelerator technology and we discuss ideas and research aimed to overcome these limitations.