PHY542: Fundamentals of Accelerator Physics and Technology with Simulations and Measurements Lab

Syllabus

Course Overview

The course is intended for graduate students who want to gain knowledge about contemporary particle accelerators and their applications. During the semester, students will learn the basics on accelerator physics principles and accelerator operation as well have the unique opportunity to gain "hands-on" experience on an operational accelerator. Students will also learn advanced computational techniques in order to model and analyze their experiments.

Course Procedure:

A total of 7 experiments will be conducted focusing in three different research areas: Beam control and focusing, beam diagnostic techniques, and electromagnetic phenomena on particle beams. The students will have hands-on experience on an operational accelerator and will be responsible for setting up the equipment, obtaining their own measurements, and analyzing the data. For same experiments students will be asked to model the experiments and compare results with measurements.

Three lectures will be given – one for each group of experiments. During the lecture the students will learn the basics on beam diagnostic and imaging methods, beam manipulation techniques as well as the basic theory on electromagnetic phenomena on particle beans. A fourth lecture will be devoted on advanced computation techniques for analyzing results in accelerator physics. The primary simulation codes for this class will be ASTRA and ELEGANT while some experience with MATLAB, or Mathematica will be useful.

During the semester, students will prepare two reports (each at different group areas). The content should include: 1) A background section which describes the experiment and explain the objectives, 2) A summary of measurements taken in the lab, 3) detailed data analysis and discussion, and 4) conclusion remarks.

In addition, at the end of semester each student will be asked to prepare a presentation covering an experiment from a different group of experiments from any of the reports

Grading:

- 20% active participation in the lab
- 60% lab report
- 20% presentation

Textbook

There will be no required textbook but the instructors will handle notes to the students that are relevant to the experiment as well as maintain a webpage were all the required material (and lectures) will be posted. Some recommended textbooks are:

1) The Theory and Design of Charged Particle Beams" by Martin Reiser, published by Wiley (1994)
2) "Fundamentals of Beam Physics" by James Rosenzweig, published by Oxford 2003
3) "Classical Electrodynamics", third edition, by J.D. Jackson, published by Wiley (1999). Chapters 11 and 12 are of particular relevance to this course.
4) Accelerator Physics, by S. Y. Lee
5) Data Reduction and Error Analysis for the Physical Sciences, P.R.Bevington & D.K. Robinson (2nd or 3rd ed., McGraw-Hill Inc., 1992, 2002)

List of experiments:

Group A: Beam control and focusing

A1: Measurement of quantum efficiency

During this lab activity the students will learn to setup and operate a photocathode gun, measure electron beam charge, measure the photocathode yield –e.g. quantum efficiency (QE), and study its dependence with the laser parameters.

A2: Magnetic measurement:

During this activity the students will measure the magnetic profile of a quadrupole lens by using a strained wire. Then, they will model a particle beam passing through a quadrupole that uses the focusing field measured in the experiment. The impact of magnet misalignments or positioning errors on beam dynamics will be numerically analyzed. .

Group B: Beam diagnostic techniques

B1: Emittance measurement with a quad scan

The students will vary the magnet focusing strength (measured in A2), record beam images for each setting on a fluorescent screen and measure rms beam size. Then, by fitting the data to a polynomial fit, they will measure the beam emittance (by using the theory taught in class). The students will also compare the measurements with predictions from numerical calculations.

B2: Emittance measurement with a screen method

The students will steer the beam through four profile monitors and record images. Then they will analyze the images and obtain the beam size on each screen. Using theory (taught in class) they will obtain the beam emittance using statistical analysis.

B3: Phase-space mapping

During this exercise the students will measure the beam profile for different magnet settings. Then using tomographic principles (taught in class) will obtain the 2-D beam phase-space by using the measured 1-D profiles. From the phase-space and by doing appropriate statistical analysis they will extract important beam parameters such as the beam size and divergence.

Group C: Electromagnetic effects on particle beams

C1: Coherent synchrotron radiation

Coherent synchrotron radiation (CSR) effect is responsible for energy spread increase and emittance degradation for short electron bunches in systems included bending magnets. Students will conduct a set of energy profile measurements using beam profile monitor installed at location with large dispersion. As a results of measurements students will be able to reconstructs CSR effect dependency on bunch length, charge per bunch and peak current. These measurements could be supported by numerical simulation using accelerator design codes (e.g. *ELEGANT*).

C2: Generation of bunched beams

In this clas s students will learn mask technique developed at ATF: the idea, purpose and procedure. Mask transmission contrast measurements will be proposed for practice. During measurements students will vary beatatron beam size by control quadrupoles triplet strength located upstream of beamline dogleg section. Series of saved BPM images have to be analyzed, dependence of mask transmission contrast from beam can be derived. Data supposed to be filtered and averaged, error from charge fluctuations can be estimated.