US Particle Accelerator School and UCLA

Course Descriptions

PHYSICS X269A Introduction to Accelerator Physics
3 Semester Hours
Wu-Tsung Weng and Sateesh Mane - Brookhaven National Laboratory

This course will review physics principles governing the design and performance analysis of particle accelerators. Using existing accelerators as examples, the interplay among design goals, component performance, and operational experience will be emphasized. Subjects to be covered include principles of particle beam focusing and transport, the design of magnetic systems, design of machine lattice, multipole imperfections and nonlinear dynamics, acceleration and rf systems, rf beam control, space charge and coherent instabilities, synchrotron radiation, linear accelerators, colliding beams, and the method of achieving high energy by chains of accelerators. Prerequisites: elements of classical mechanics and electromagnetism.

WEEK ONE

PHYSICS X269B Magnetic Measurements
1-1/2 Semester Hours
Arnaud Devred and Robert I. Schermer, SSC Laboratory

Mathematical representations of magnetic field. Review of magnetic designs and field quality requirements. Review of magnetic measurement equipment: 1) systems based on field measurements (e.g., NMR and Hall probe arrays...), 2) systems based on magnetic flux measurements (e.g., various designs of search coils, stretched wires...), and 3) exotic techniques (e.g., optical based systems, colloidal solutions...). Detailed description of rotating coil systems for particle accelerator magnets: mechanical design, electronic readout, signal processing, calibration, accuracy and precision. Origins of field errors in superconducting particle accelerator magnets: geometric errors, effects of persistent magnetization currents, effects of iron saturation, and effects of eddy currents. Statistical factors for magnet qualification and production process controls.

PHYSICS X269C Experimental Techniques for Electron Accelerators
1-1/2 Semester Hours
John T. Seeman, SLAC and Ian Hsu, National Tsing Hua University

The course material covers experimental and analytical techniques to study observed beam dynamics in linear and circular high energy electron accelerators. A brief general overview of beam properties in accelerators is given first, followed by many detailed examples. Beam position measurements are described emphasizing their use in trajectory correction, tune measurements, lattice and component error determination, and observation of beam dynamics. Beam size measurements are reviewed including profile monitors using synchrotron radiation, fluorescent screens, and wire scanners. Several examples are given using size measurements to study the phase space density of beams under a variety of conditions including simple lattice transport, space charge, filamentation, transverse wakefields, and higher order optics. New ideas for future techniques are included throughout the course.

PHYSICS X269D Electron Sources
1/1-2 Semester Hours
James Rosenzweig and Spencer Hartman, UCLA

This course will introduce the physics principles underlying the design and operation of a large class of modern electron sources, where the electron emission is induced by the photoelectric effect. The aim is to give the student a basic practical knowledge of how to design, construct and optimize these sources for a variety of applications, including production of low emittance, high brightness (for FEL and linear collider applications), high peak current (for wakefield acceleration), and polarized electron beams (for high energy physics). A wide range of topics are discussed in this context: laser-solid interaction, photoemission, longitudinal and transverse beam dynamics in ultra-high field structures, rf structure design, picosecond lasers, control of emittance growth due to space charge and applied fields, and electron beam diagnostics. Lectures will provide the theoretical basis for the sources, and a computer laboratory section will introduce the student to codes for the design of electrostatic gun structures, and for modelling the self-consistent beam dynamics in these sources. Laboratory demonstrations of rf photocathode source operation will be shown at the UCLA Particle Beam Physics Laboratory.

PHYSICS X269E Intense Particle Beam Accelerators
1-1/2 Semester Hours
Pace VanDevender, Sandia National Laboratories

This course will introduce the physics and technology of Intense Particle Beam Accelerators -- those in which the collective fields of the particle beam dominate the beam dynamics and determine the accelerator architecture. These accelerators generate beam currents of 10^4 to 10^7 amperes at beam energies of 10^5 to 10^7 electron volts. The following topics will be covered in lectures and problems: the design of the pulsed power systems, the vacuum insulator design, self-magnetically insulated power transport, electron and ion diodes, plasma accelerators, and applications for national defense, commercially valuable technologies, and fusion energy.

PHYSICS X269F Design of High Energy Accelerators
1-1/2 Semester Hours
Donald A. Edwards, DESY and Michael J. Syphers, SSC Laboratory

Issues in the design of modern high energy accelerator facilities. Flow from end-use specifications such as luminosity, cost, user requirements down toward systems parameters. Constraints imposed by accelerator physics, technology, and funding sources. Trade-offs involved in overall facility design will be described. Primary emphasis will be placed on beam optics, emittance, and intensity considerations, as the next level under the end-use specifications. Examples will be selected from existing facilities and present designs for synchrotron colliders, synchrotron radiation sources, and linear colliders. Prerequisite: A course, or equivalent, in basic accelerator physics.

WEEK TWO

PHYSICS X269G Radio Frequency Systems
1-1/2 Semester Hours
Stefan Simrock and Lia Merminga, CEBAF

The course begins with an overview of various types of RF systems: electron vs. proton vs. heavy ion; circular vs. linear; pulsed vs. cw; superconducting vs. normal; standing vs. travelling wave. An engineering and theoretical description of the main components used in all RF systems (cavity, power transmission system, high power amplifier, low-level control, phase shifter, attenuator) follows. Given overall accelerator specifications (including power requirements, accelerating gradient requirements and phase stability) and using equivalent circuits, these components will then be used to design and analyze an actual RF system. Feedback will be added to improve system performance and control. The principles of feedback (transfer function, frequency response, open and closed loops, stability criteria, gain and frequency response optimization) will be discussed in detail. Examples of existing systems (CEBAF, CERN, SLAC, etc) will be given. The course will conclude with an application for the active damping of longitudinal and transverse instabilities. Prerequisites: Some knowledge of the principles of beam acceleration, resonators, waveguides, transmission lines, etc.

PHYSICS X269H Accelerator Control: The Senses, Brain & Nervous System of an Accelerator
1-1/2 Semester Hours
Thomas Himel, SLAC

A proper control system is essential to a modern accelerator. Proper design of a tunable, reliable, accelerator requires knowledge of the fundamentals of control systems. In the area of sensors and actuators, we will cover BPMs, wire scanners, vacuum gauges, temperature sensors, power supplies, rf phase timing, etc. It is always preferable to control parameters (e.g. magnet currents), but it is sometimes not practical to do this accurately enough. Enter the method of feedback. Topics included are loops, their complexity and optimization, deamplification and amplification, the disturbance spectrum, time and spatial filtering, sensor resolution, optimum control, and the interaction of multiple feedback loops. Control system architectures are analyzed and compared. Subjects considered are standards, integrated systems, costs, the importance of flexibility, the ease of adding new devices, realtime distributed databases, speed and response time, and the importance of realtime information. The course will conclude with some high level applications (control room design, models, correlation plots, and history buffers) and some real world problems encountered in designing, commissioning and operating a tunable accelerator.

PHYSICS X269I Radiation from Relativistic Electron Beams
1-1/2 Semester Hours
Claudio Pellegrini, UCLA

The course will start with a general discussion of the generation of electromagnetic radiation from relativistic electron beams moving in a magnetic field, followed by a description of the physics and technology of Free Electron Lasers (FELs). In particular, we will study the high gain regime of FELs; electron beam requirements for short wavelength FELs; high brightness electron beam sources; the acceleration of electron beams in an RF linac including beam compression and preservation of beam brightness; and undulator magnets including field tolerances and beam propagation. After reviewing the present state of the art in FEL development, we will consider in more detail the issues limiting the shortest wavelength at which FELs operate, and the possibility of building an X-ray FEL in the near future. Prerequisites: Elements of electromagnetism and classical and quantum mechanics.

PHYSICS X269J Pulsed Beams
1-1/2 Semester Hours
Craig L. Olson, Sandia National Laboratories

The physics of the generation, transport and focusing of intense charged particle beams is discussed. 1) A brief summary of pulsed power accelerators is given, explaining how intense beams are generated. Fundamental beam characteristics are described, including space charge and magnetic limiting currents, beam particle trajectories (force neutral condition, betatron oscillations, envelope equations), and beam quality concepts (emittance, microdivergence, brightness, Liouville's theorem). 2) The transport and focusing of intense relativistic electron beams is examined, including the low pressure collective ion acceleration regime, the ion focus regime, the 1 Torr regime (including cone focusing and plasma heating), and the high pressure regime. 3) The transport and focusing of intense ion beams is examined, including charge-neutralized propagation (co-moving electrons and related schemes), ballistic propagation in gas or plasma, preformed channel propagation, wire-guided transport, and self-pinched propagation. In all cases, emphasis is on understanding gas breakdown, and the equilibrium and stability properties of the beam.

PHYSICS X269K Nonlinear Accelerator Physics
1-1/2 Semester Hours
Alexander W. Chao and Yiton Yan, SSC Laboratory

A review of linear optics is given. Various concepts and methods are introduced including non-symplecticity and symplectification techniques. "Conventional" nonlinear dynamics is studied with the smooth approximation and canonical perturbation theory. Examples are the beam-beam problem and the sextupole problem. Modern methods, including Lie and differential algebraic techniques will be introduced. Analytic problems and computer exercises are included.