ACCELERATOR PHYSICS

MULTIFACULTY

PREREQUISITES :B.Sc in Physics or B.E, The course is a stand-alone course for application of accelerators in research in Physics, medical sciences, industrial applications and national security.

INTENDED AUDIENCE: Ph. D. Students and researchers, Hospital Doctors and Staff and Industry people and Defence personnel.

INDUSTRY SUPPORT: Several academic institutions, industries and defence departments will be interested. Many accelerators are in operation in industry for food irradiation and for medical treatment in hospitals.

COURSE OUTLINE:

Accelerators have an important role both in basic and applied research, eg., medical science, industry, national security, environmental science etc Electron accelerators are built for food irradiation etc and as Synchrotron Radiation Source for material science research. Depending on how particles are accelerated, accelerators are categorized as DC accelerators, Linear and Cyclic accelerators and Laser-Plasma Accelerators. Today, accelerators in the energy range of keV to TeV have been designed, built and used. In order to design, operate and utilise them efficiently, the physics of the accelerators should be well understood. In this course, physics of DC, Linear and Cyclic accelerators will be discussed and high energy accelerators will be briefly reviewed.

ABOUT INSTRUCTOR:

Prof. Amalendu Sharma graduated from the BARC Training School, RRCAT, Indore in 2001. He has worked on the relaxed optics for ease commissioning of 2.5 GeV Indus-2 synchrotron radiation source at RRCAT and participated in commissioning exercises of Indus-2. Dr Sharma also carried out studies on the inclusion of harmonic sextupole magnets in Indus-2 to improve the beam lifetime for low emittance, high brightness optics. He was the convenor of the team responsible to increase the beam current at in Indus-2 and shaping it in the routine stable operation mode. He also participated in the optics design of an electron beam transport line to compress the bunch length for CTF3 project at CERN under the DAE-CERN collaboration and on this work, he obtained his PhD, in 2014 by HBNI. Presently, Dr Amalendu Sharma is leading the beam dynamics activities for designing the 1 GeV Proton Accumulator Ring of Indian Facility for Spallation Research. He is also contributing to the optics design of energy filtering and beam delivery system of radiation processing facility development at RRCAT, Indore. Dr Amalendu Sharma has been teaching Accelerator Physics in BARC Training School at RRCAT, Indore for the last 14 years. He also took classes in the Orientation Course on Accelerator and Laser (OCAL) in RRCAT, in which M.Sc and B.Tech students participated. Dr Sharma also delivered lectures in the course on Accelerator Science and Technology, conducted by IUAC. New Delhi.

Prof. Rajni Pande graduated from the 45th batch of BARC Training School at RRCAT, Indore in 2002. She obtained her PhD from Homi Bhabha National Institute in 2014 in accelerator physics. She has been teaching Accelerator Physics at BARC Training School for the past 12 years. She has also taught accelerator physics at DAE Centre for Excellence in Basic Sciences, University of Mumbai. She has been working on the design and development of high intensity proton accelerators at BARC. Her current research interests are design of accelerating structures and beam dynamics in high intensity LINACS & study of non-linear effects in high intensity particle accelerators. She co-authored several papers in refereed journals.

Prof. Pitamber Singh graduated from 19th batch of BARC Training School in 1976. He was formerly the Head, Ion Accelerator Development Division, BARC. He is a nuclear physicist and made pioneering contributions in design and development of accelerators. He worked at Max Planck Institute fur Kernphysik (MPI), Heidelberg as a post-doctoral fellow during 1985-86. He has more than 400 publications including 85 papers in reputed international journals. Some of his noteworthy contributions are as follows : Dr. Singh made very important contributions to the design and development of a 2 Million Volt Tandem Accelerator and a 6 Million Volt Folded Tandem Ion Accelerator (FOTIA) at BARC For outstanding contributions to the indigenous development of accelerators, Dr Singh was conferred the DAE's Technical Excellence Award in the year 2000. Dr Singh steered a project to develop a 1 GeV, 30 mA proton accelerator for the Indian ADS program to use Thorium in the nuclear fuel cycle. He has also contributed to the India-Fermilab (USA) collaboration for development of high intensity accelerators and was a key member of the Technical Board at the Fermilab for Project-X/PIP-II and Indian Technical Coordinator for the Indian Institutes Fermilab Collaboration (IIFC). In recognition of his excellent contributions to the development of accelerators and nuclear reaction studies, Dr. Singh was awarded INS High Technology Award in 2013. He has also received several Group Achievement Awards in DAE. Dr. Singh has also made very important contribution in the field of nuclear physics. As a Senior Professor at Homi Bhabha National Institute (HBNI), Dr Singh had been actively involved in teaching and guiding PhD students.

COURSE PLAN:

Week 1: Introduction to Accelerators, Accelerator as microscope, up and down quarks, High voltage systems for accelerators -Charging and discharging of capacitors, time constant of the circuit; diode I-V characteristics, Introduction to DC accelerators-Cockcroft-Walton accelerators, capacitance, neutron generation

Week 2: Van de Graaff, Tandem, Pelletron accelerators, negative ions, electron stripping, Belt charging, induction charging, pellet chain, Generating Voltmeter, corona feedback, voltage stabilisation, beam energy calibration

Week 3: Beam focussing using electrostatic and magnetic lenses and beam optics, Einzel lens, functioning of quadrupole lenses, Beam focussing, beam dynamics, Ion Sources, Duoplasmatron, SNICS ion source, Alphatross ion source, RF accelerator, Linear accelerator, Relativistic mechanics,Lorentz force, Magnetic field, Electric field

Week 4: RF Acceleration, Isochronism, Principle of successive acceleration, phase stability, Transit time factor, Wideroe linac, Alvarez linac, Electromagnetic waves in free space, Electromagnetic waves in free space, TEM waves, Boundary conditions, standing waves, travelling waves, modes, cut off frequency, guided wavelength, waveguide, Standing waves, travelling waves, modes, cut off frequency, guided wavelength, rectangular waveguide, cylindrical waveguide, Rectangular cavity, cylindrical cavity

Week 5: Accelerating structures-Pillbox cavity and DTL, Accelerating structures- Travelling wave linacs and periodic accelerating structures, Power dissipation, superconductivity, superconducting cavity, normal conducting cavity, DC, CW, Pulsed beam, HWR, QWR, SSR, elliptical cavity

Week 6: Transverse Dynamics in Linacs, Different focusing lattices used in linacs, Hill’s equation and its solution,Twiss parameters and beam emittance, Space charge force, beam phase space, emittance, beam distribution, KV distribution, Waterbag distribution, rms emittance, envelope equation with space charge

Week 7: Longitudinal dynamics in LINACs, Synchronous phase, phase stability, separatrix, separatrix phase width, Longitudinal stability, stability criteria, separatrix, synchronous oscillation with small and large amplitudes, Radio Frequency Quadrupole, Focusing in the RFQ, Beam bunching and acceleration in the RFQ, TE210 like mode in the RFQ cavity

Week 8: Overview of the cyclic accelerators, Basic introduction to cyclotrons, Basic introduction to microtrons

Week 9: Introduction to the coordinate system useful in accelerator physics, Geometric focusing, focusing for charged particle optics, based on dipole magnet, gradient and quadrupole magnet, Solving Hills’s equation using method of matrices, transfer matrices of different elements, Analysis of optics using transfer matrices

Week 10: Obtaining Twiss parameters and invariant of motion, periodic optics and Twiss parameters, Concept of beam emittance, RMS emittance and normalized emittance, FODO optics and concept of stability, Introduction to dispersion and achromat

Week 11: Chromaticity and its formula, Correction of chromaticity by sextupole magnets, Introduction to phase stability and synchrotron oscillations in a synchrotron, Concept of booster and storage ring, Introduction to synchrotron radiation source.

Week 12: Proton synchrotron, Spallation Neutron Source, Collider, Luminosity, Wakefield, electron plasma wave, electron density perturbation, plasma oscillation, accelerating gradient