

Indo-Japan Accelerator School cum
Workshop (IJAS-2020)
28th-31st January 2020

Book of Abstracts

VECC, KOLKATA

Technical Session 1: Overview of accelerators at VECC

28th January 2020, (11:30 – 13:30 Hrs)

Overview of Particle Accelerator activities at VECC

SumitSom, VECC

Accelerators for RIB programme at VECC (L1)

Arup Bandyopadhyay, VECC

Basics of Accelerator Physics

Animesh Goswami, VECC

The basic aim of building the particle accelerators is to generate streams of nuclear particles with high kinetic energy. These energetic particles are then used for basic science experiments to investigate structure of matter or commercially for material processing, food preservation etc. They are also used for cancer therapy and production of radioisotopes for medical diagnostic applications. The purpose of this talk is to introduce the students to the physics of particle beam accelerators. After a brief introduction to the principle of particle accelerator we review the dynamics of charged particles in accelerator and beam transport lattices. The basic principles of linear single particle dynamics in the transverse phase plane is discussed. The general equations of motion of a charged particle in magnetic fields are derived. Next, the linearized equations of motion in the presence of bending and focusing fields are solved. Both weak and strong focusing of relativistic particle beams, types of magnetic lenses are discussed. Linear transverse single-particle dynamics is treated both in terms of transfer matrices and betatron oscillations. Transfer matrices of the most common accelerator lattice elements are given, including a brief introduction to quadrupole doublet focusing. The concept of beam emittance, including Liouville's Theorem, is also discussed.

Technical Session 2: Advanced Electron and Radiation Sources

28th January 2020, (14:30 – 16:00 Hrs)

Advanced Electron Sources (L1)

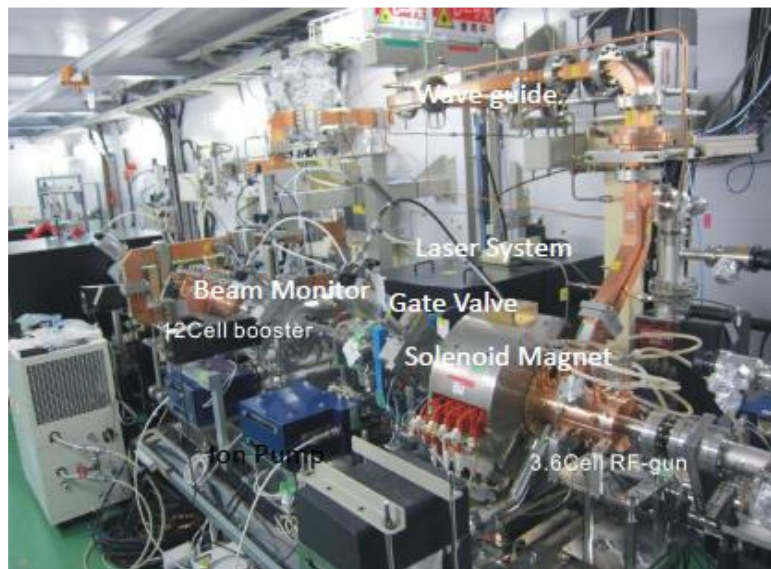
Junji Urakawa, KEK

Compact Accelerator of Advanced Facility is very useful for educating graduate students and young researchers on science and technology, especially electron Linac to learn Electromagnetics, Vacuum Technology and Mechanics. Also, since the operation of this machine

requests the skill on beam control and instrumentation, they must understand how to measure the beam parameters and control them remotely. So, they have a chance to upgrade the ability for computer programming, developing diagnostic system and promoting their research.

The electron beam is bunched to accelerate with high gradient acceleration more than 10MV/m efficiently. Compact electron source without the buncher system is a photo-cathode RF gun and we can reduce a space charge effect in order to keep a high quality beam. I will explain how to get an extremely good electron beam and several examples on real applications. Below photo shows the real example of the RF gun.

I will propose the advanced compact electron accelerator facility which has the possibility to construct at each institute. KEK constructed the Accelerator Test Facility (ATF) and the Superconducting Accelerator Facility (STF) for ILC R&D and operates them for educating and training young researchers. Also, Compact Energy Recovery Linac (cERL) and Laser Undulator Compact X-ray source (LUCX) for the application were constructed and are operated. From many experiences based on the construction and the operation in these four facilities, I would like to explain how to design and construct the advanced electron accelerator in the energy range of 3MeV to 30MeV as extremely useful facility.



Slow Positron Beams at KEK (L1)

Yoshinori Enomoto, KEK

There are two unique slow positron facilities in Tsukuba at KEK and AIST. Both facilities provide slow (eV - keV) positron beam, which is generated from 40 - 50 MeV primary electron beam, for user experiments.

In this presentation, details of beamline for primary electron and generated positron will be presented along with several applications using slow positron beam.

Technical Session 3: Electron linac and cyclotron

28th January 2020, (16:30 – 17:30 Hrs)

Electron Linac & plans for slow positron beam at VECC

S. Dechoudhury, VECC

The proposed ANURIB facility would be producing both n-rich and p-rich exotic beams. The photo-fission driver for producing n-rich exotic beams would be a 50 MeV, 2mA e-linac based on 1.3 GHz, 2K SRF technology. Installation of upto 10 MeV has been planned at present VECC campus in the first phase. Brief introduction of the e-linac for accelerating electron beam to 10 MeV which is presently undergoing installation, would be presented. One of the immediate possible utilisation of the e-linac facility would be to develop a CW variable energy positron beam based on the e-linac. This can provide access to depth dependent Doppler broadening studies. Preliminary study based on available empirical relation and simulation has been used to estimate the flux of moderated positron for a 10 MeV, 100 μ A electron beam. Design and operational experience would help us for building the full scale pulsed positron set-up with 50 MeV, 2mA e-linac proposed for ANURIB.

Basics of Cyclotrons

P.S. Chakraborty, VECC

The K130 variable energy cyclotron (also known as Room Temperature Cyclotron) has been operating round the clock and delivering light and heavy ions for producing radio-isotopes, radiation damage studies and nuclear physics experiment etc. The high charge state heavy ions are produced in an external ECR ion source which is then transported to cyclotron for further acceleration. An internal PIG ion source is used for production of light ions. This presentation is

going to describe the importance of an accelerator, forces used for charged particle acceleration, basic principle of cyclotron and its acceleration process. It will also describe the major components of K130 cyclotron.

Beyond Boundaries, Local Science to Global Science, A World Wide Web

Evening Talk: Prof. Bikash Sinha

28th January 2020, (17:30 – 18:30 Hrs)

INSA Senior Scientist

Former Homi Bhabha Professor, DAE

Former Director, VECC & SINP

Variable Energy Cyclotron Centre

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Collaboration, in a national or international scale has become the norm. The demand of Big Science, Mega Science in particular, has precipitated this scenario. From the early days of the changing scenario of unipolar science to contemporary multipolar science is traced, with special emphasis on India and Asia. The cultural and sociological impact of such a phenomenon will also be discussed.

Technical Session4: RF technology

29th January 2020, (09:30 – 11:00 Hrs)

Cavity and High power RF couplers for International Linear Collider programme (L1)

Taro Konomi, KEK

International Linear Collider (ILC) is proposed as the next energy-frontier electron-positron machine, and would be built as a global effort. The main linacs of the ILC are based on 1.3 GHz superconducting radio-frequency (SRF) accelerator technology. The ILC design assumes a field gradient of 31.5 MV/m in the SRF accelerator cavity to achieve a center-of-mass energy of 125 + 125 GeV with two 11-km long main linacs. Main linacs consists with 8000 9-cell 1.3 GHz superconducting cavities , and RF is supplied from one 10MW multibeam klystron for 39 cavities. KEK has been developed main linac technology at the Superconducting RF Test Facility (STF) and operated the first beams during February and March 2019 and demonstrated results that satisfy the specifications for ILC. I will talk about the structure of the main cavity of ILC and the result of RF & beam test in STF.

Development of Efficient and Qualified RF power systems for Accelerators

Manjiri Pande, BARC

Today particle accelerator facilities need to be very productive while simultaneously having high energy consumption. In order to reduce its total energy consumption, improvement in the energy efficiency of an accelerator is needed. Best utilization of electrical energy, design of efficient subsystems while understanding the power flow in the accelerator, recovery of spent energy or heat generated are some of the action points.

High power radio frequency (HPRF) system is one the major subsystems of an RF accelerator consuming the major power budget. So, design of high (electrical) efficiency RF power systems is a very important and critical.

For uninterrupted and reliable operation of an accelerator, all its sub systems including high power RF (HPRF) systems must perform for very long durations without trips/ faults. So HPRF needs demonstration of high technological performance with quality, safety and reliability. To accomplish this, HPRF systems should get qualified and validated for various standards.

At BARC, high power RF systems based on klystron, tetrode and LD MOSFET based solid state RF systems have been designed and developed for ion accelerator applications. RF electronics inclusive of solid state RF amplifiers have designed and developed for Pulse Positron Annihilation Lifetime Spectrometer (PALS).

This talk gives an overview of all these indigenous efforts taken.

Solid state RF amplifiers/RF Systems and Associated Technologies

Akhilesh Jain, RRCAT

Radio Frequency (RF) system is an integral part of the particle accelerator, required for energizing the elementary particles. Particle accelerators are widely used in many frontier areas of basic and applied research of physics, chemistry, and biology. Depending on the type of particle and energy of the accelerator, RF systems in the frequency range from few MHz to tens of GHz are employed. Such systems typically include pre-amplifier, low level RF signal processing sub-system, high power amplifier, bias power supply, transmission lines and RF cavity. Commonly used RF devices for developing high power amplifiers are tetrodes, klystrons, IOT and more recently are MOSFETs. RRCAT is one of the premier research institute of Department of Atomic Energy (DAE) where, Klystron, Inductive output tube and MOSFET based amplifiers are operating, in Indus-2 synchrotron radiation source. Recently, many particle accelerator laboratories like SOLEIL, LNLS, ESRF, and RRCAT have harnessed the power of the last one *viz.* MOSFET or solid-state RF technology-based, amplifiers. Its numerous advantages, and ubiquitous use of superconducting cavities in particle accelerators are the main driving forces behind its rapid research and deployment. Today, the laterally diffused metal-oxide-semiconductor (LDMOS) device technology has spectacularly improved power and efficiency performance of the such amplifier, at UHF and wireless frequencies. Apart from including RF Systems and Associated Technologies, this talk will explore brief design details, operational experience and major challenges, for these Solid-state RF amplifiers. RRCAT is one of the accelerator institutes where, solid state technologies based 240 kW Indus-2 RF system is operating in round the clock mode for more than last 7 years. Such high power was attempted

here first time in the world. This lecture will also address the innovative technology of harmonic tuned PA operating modes, radial power combiner; aperture coupled rectangular directional coupler and amplifier architecture and their application for designing such high-power state-of-the-art amplifiers.

Technical Session 5: Rare Isotope Beam Accelerator Technology

29th January 2020, (11:30 – 13:30 Hrs)

Development of RIB of Carbon-11 for Medical Applications

Ken Katagiri, NIRS

An isotope separation on-line (ISOL) system is necessary to provide C-11 ion beams for heavy-ion cancer therapy with simultaneous verification of the dose distribution using positron emission tomography. To realize the ISOL system, we have developed instruments in the ISOL system, such as a proton-irradiation target, a molecule separation system, and a singly-charged ion source, and have carried out tests to verify performances of each instrument. As a next step of the development, we have started an experiment of on-line production of singly-charged C-11 ions at the proton irradiation port of NIRS-cyclotron facility. In the presentation, we present an overview of the ISOL system and the results of the test of the on-line production system.

Accelerators for RIB programme at VECC (L2)

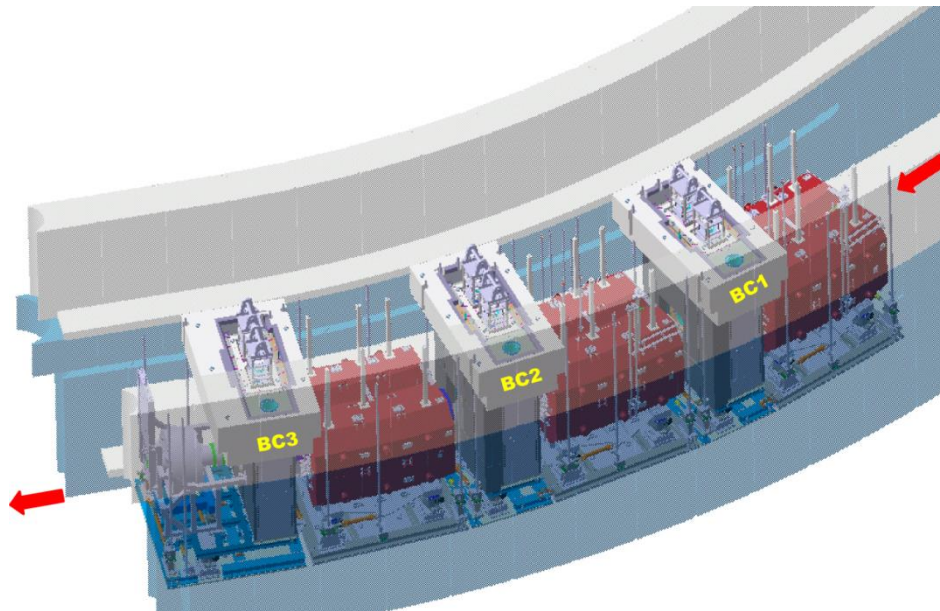
Arup Bandyopadhyay, VECC

Design of High power beam dumps for Super- FRS in FAIR project

Avik Chatterjee, CSIR-CMERI

Facility for Antiproton and Ion Research (FAIR) is an international accelerator and experiment facility of nuclear physics, under construction at GSI Helmholtzzentrum für Schwerionenforschung Darmstadt, Germany, and is set to be one of the largest accelerator research facilities for basic research in physics worldwide. India is one of founder members and the third largest shareholder in FAIR science project.

Beam Stoppers (synonymously used for Beam Dumps or Beam Catchers in this context) are primarily energy intercepting and dissipating devices, widely used for intercepting beams of various energy levels, starting from laser to very high energy accelerators beams like electron/positron beam, proton/antiproton beam, ion beam etc. Beam dumps has been designed to safely absorb and dissipate particle energy influx addressing technological challenges of distribution of huge thermal gradient compounded by thermal shockwaves and material irradiation damage. In addition to that, downstream ion-optical systems are to be protected from radiation damage.



Layout of Beam Stoppers BC1, BC2 and BC3 in the Super- FRS tunnel preceded by dipole magnets

CSIR-CMERI is involved in engineering design and analysis of each of the three beam stoppers which sits in the Super-FRS tunnel, aligning with the beamline and has the primary function of safely stopping unwanted fragments and the primary beam on requirement. Each beam catcher chamber contains two insertable shielding plugs to which a copper and a graphite beam absorbers are mounted for slow extraction and fast extraction mode of operation, respectively. A transmission drive for vertical positioning of the required absorber is used and the third beam stopper has additional provision of horizontal positioning of the absorbers for full or partial obstruction of beam. The absorbers are water cooled. The specification of a beam catcher for fast extraction is with 0.4-1.5 GeV/nucleon primary heavy ion beam, in the order $\sim 5 \times 10^{11}$ particles per spill, depositing ~ 29 kJ energy in the absorbing medium (graphite) within a pulse of 50-100 ns duration at a time interval of 1.67s.

The beam profile is a two dimensional Gaussian with varying spread according to the position along the ion-optical system, and the energy deposition is calculated by the stopping power for fast heavy ions in matter (inputs from GSI@FAIR). The localized energy deposition (Bragg peak) density in the absorber with water cooled copper heat sinks specially brazed at the top and bottom, causes the peak energy density to be as high as 300 J/g per pulse. This is expected to induce thermal shock waves in the absorbers and is one of the major challenges in design of beam catchers for this facility which has been analyzed and brought in safe operating range in the design.

Technical Session 6: Advanced Electron and Radiation Sources

29th January 2020, (14:30 – 16:00 Hrs)

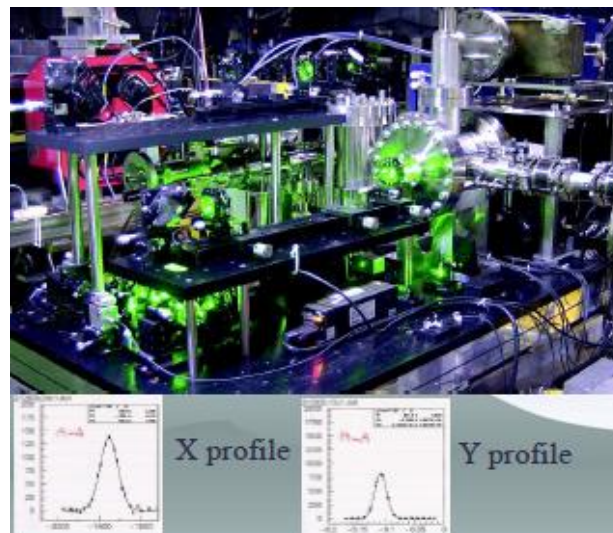
Photon generation by Laser-Compton scattering (L2)

Junji Urakawa, KEK

KEK Linear Collider Group has developed the laser wire for beam instrumentation and made Laser-Compton Scattering (LCS) experiments for polarized positron source since 1997. So we constructed the Accelerator Test Facility (ATF) and the Superconducting Accelerator Facility (STF) for ILC R&D and operates them for educating and training young researchers. Also,

Compact Energy Recovery Linac (cERL) and Laser Undulator Compact X-ray source (LUCX) for developments to X-ray application were constructed and are operated.

A short pulse and quasi-monochromatic X-ray source has been developed via LCS between a high-quality multi-bunch electron beam and a high-power laser for applications in various areas, such as the medical, biological, and scientific fields. We are developing basic technologies for the X-ray source in the range from 7keV to 150keV for biological, medical imaging and cancer therapy. Normal conducting, super conducting and energy recovery linear electron accelerator with 4-mirror optical cavity for laser pulse storage have been operated for research and development on the high brightness X-ray source at KEK. The power of electron beam should be increased by 1MW (10MeV x 100mA) and stored laser pulse power also more than 10MW (650MHz x 16mJ/pulse) because the interaction cross section of the LCS is very low. To obtain the high brightness X-ray, the size of the light source should be less than 20 μm in \square , which is made by focusing the laser pulse at the collision point in the optical cavity. To increase the luminosity on the collision between electron and laser, we make high repetition rate collision up to 650MHz and focus electron beam size at the collision point as small as possible. Below photo shows the laser wire profile monitor to measure micron beam at ATF.



KEK Electron - Positron Injector Linac(L2)

Yoshinori Enomoto, KEK

KEK electron positron injector Linac has been providing positron beam to collider ring for more than 35 years. The positron source have been upgraded several times to satisfy increasing requirement from the experiments.

In this presentation, several unique features of the Linac will be shown especially focused on the positron source.

Technical Session 7: SRF technology

30th January 2020, (09:30 – 11:00 Hrs)

SRF Niobium cavity processing, fabrication technology (L2)

Taro Konomi, KEK

Cavity performance is key to the design as the ILC main linac lengths are determined by the average field gradient in the cavities, and the required cryogenic cooling power depends on the cavity quality factor. The acceptance gradient in Technical Design Report 2013 (TDR) is 35 MV/m with quality factors of 10^{10} or higher with a yield of 90 %. This should ensure reliable operation at 31.5 MV/m during the machine running. Current R&D efforts have resulted in more than ten 9-cell cavities with. In recent years, new heat treatment methods have been developed to modify the cavity surface such as nitrogen doping and infusion, etc. We are also exploring ways to improve the cavity acceptance gradient to 40 MV/m by applying these methods. I will talk about the recent cavity processing and performance for ILC cavities.

SCRF cavity and tuner related technologies.

Vikas Jain, RRCAT

Design and development of low beta 650 MHz niobium cavity at VECC under IIFC

Sudeshna Seth, VECC

VECC has been involved in the design, analysis and development of 650 MHz, beta 0.61 (LB650), elliptical Superconducting niobium RFLinac cavity, as part of research and development activities on SRF cavities and associated technologies under Indian Institutions Fermilab Collaboration (IIFC). This low beta cavity is a part of the high current, high energy proton linear accelerators required for development of ADSS and Spallation Neutron Source by DAE and for the PIP-II Project of FERMILAB. I will discuss about the design of LB650 cavity based on optimization of different electromagnetic criteria (like peak surface magnetic field and peak surface electric field at energy gain at optimal beta, cavity quality factor, bandwidth, dynamic cryogenic load, Multipacting etc.) and operational criteria (Lorentz Force detuning, sensitivity to fluctuation of helium pressure, Cavity stiffness, tuning sensitivity etc.). Also I will discuss about the fabrication, RF measurement and testing of prototype aluminium and copper cavity and niobium cavities.

Technical Session 8: Medical Accelerators

30th January 2020, (11:30 – 13:30 Hrs)

Advanced Medical Accelerators(L1)

Ken Takayama, KEK

Advanced Medical Accelerators(L2)

Ken Takayama, KEK

ESCORT: Energy sweep extraction and necessary devices

Tanuja Dixit, SAMEER

ESCORT is energy sweep compact hadron therapy driver which is based on a fast cycling induction synchrotron. One of its main features is two extraction mechanisms- Fast 1 turn extraction of C6+ bunch with variable energy in each cycle and the other is energy sweep extraction in which C5+ ions are continuously extracted in a desired time period with expected energy variation. Energy sweep extraction is assisted with charge exchange mechanism using Carbon foil. The extracted C6+ beam spill can sweep a tumor from its front edge to the far edge at 10 Hz without causing undesired activation. Thus, quick irradiation which is much faster than the natural motion of target is possible. The talk will discuss two extraction mechanisms in detail and LISE++ simulation results for charge exchange efficiency. Necessary devices specific to the extraction mechanism will be explained in the talk.

Technical Session 9: Medical Accelerators

30th January 2020, (14:30 – 16:00 Hrs)

Linacs for Cancer Therapy and other applications at SAMEER Mumbai

Abhay Deshpande, SAMEER

At SAMEER, we have dedicated group with focus on Accelerator based Medical applications. The design team also support design, development and training of physicist, engineers and technicians for Accelerator design, fabrication and tuning. We have successfully made Standing Wave, Side Coupled Linac and are able to deliver 6 MV photons and treat patients at hospitals in India. The linac is capable of delivering stable beam with 500 RMM dose rate and desired flatness and symmetry. As next stage of development we have developed dual energy, dual mode linac. This can deliver Photons as well as Electrons. The photons can be of 6 or 15 MV energy thus helping treatment at various depths. The electron energy can vary from 6,9,12,15 and 18 MeV and can help treatment of skin cancer etc.

The accelerator operates $\pi/2$ mode at 2.998 GHz frequency. In this talk, I will elaborate the design features of bi-periodic, standing wave structures and design details of SAMEER linac. I will also discuss operational principles of gun and suitability of linac for various applications. As a next stage example I will show the design details of 30 MeV Linac which we will be using for generation of ^{99}Mo from which $^{99\text{m}}\text{Tc}$ will be eluted.

Design and development of Medical Cyclotron for radio-isotope production

M.K. Dey, VECC

Technical Session 10: Advanced Electron and Radiation Sources

30th January 2020, (16:30 – 17:00 Hrs)

Basic concept of Free Electron Laser (L1)

Subhendu Ghosh, IUAC

Free Electron Laser (FEL) is a fourth generation light source widely used in many laboratories worldwide to perform cutting edge research in Biological Science, Materials Science, Physical Sciences, Medicine, etc. Relativistic energized electrons produced in FEL accelerator are injected into Undulator having an alternative array of strong magnets. When the electrons move through the magnetic fields, they take the wiggling path and thus emit spontaneous electromagnetic radiation. The frequency of the emitted radiation will depend on the energy of the electron beams, the magnetic field and magnetic period of the undulator. The spontaneous radiation produced by the wiggling electrons will interact with the wiggling electrons moving ahead of the radiation. Due to this interaction, the velocity modulation will take place among the wiggling electrons and slowly they will be re-distributed and a microbunch structure will be formed inside a single macro-bunch of electrons. These electrons microbunches while moving through the undulator can produce very intense coherent radiation.

The basic concept of the operation of Free electron Laser with a few equations and with the help of some animations will be discussed during the presentation.

Superconductivity and Accelerators

Evening Talk: Prof.Amit Roy

30th January 2020, (17:30 – 18:30 Hrs)

Fellow, National Academy of Sciences, India

Former Raja Ramanna Fellow, DAE

Former Director, IUAC New Delhi

Technical Session 11: Advanced Particle Accelerator Technology

31st January 2020, (09:30 – 11:00 Hrs)

DLC - THz Light source at N. Delhi (L2)

Subhendu Ghosh, IUAC

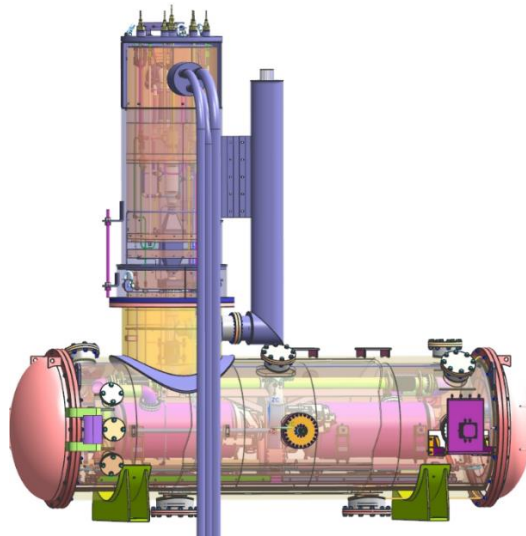
A compact, pre-bunched Free Electron Laser facility named as Delhi Light Source (DLS) is presently being commissioned at IUAC [1,2,3]. A low emittance pulsed electron beam with energy in the range of ~ 4 - 8 MeV produced by a photocathode based normal conducting RF gun operating at 2860 MHz will be injected into a compact undulator to generate intense THz radiation in the frequency range of 0.18 to 3.0 THz. Beam optics calculations were performed with GPT and GICOSY codes. Another code, developed in-house, based on Lienard-Wiechert potential formulation, is used to calculate the parameters of the THz radiation emitted from the wiggling electrons inside the undulator. The electron gun with the photocathode deposition system, the complete beam line, the undulator and the experimental stations using THz/electron beams are being accommodated inside a class 10000 clean room. The final commissioning/testing of the High power RF system to power the electron gun will be completed in Feb. 2020. The design of the laser system has been finalized and the system is in the final stage of development at KEK, Japan. The design of the photocathode deposition mechanism has been completed at IUAC and it is currently being fabricated and tested at BNL, USA. The design of the undulator has been carried out by IUAC's team using the code RADIA. An undulator with specifications closely matching to our design will be made available at IUAC within a collaboration with HZB and DESY, Germany. Design, manufacture and qualifications of all the electromagnets (quadrupoles, steering magnets and dipole magnets) for DLS have been done by BARC, Mumbai as per the required specification of DLS and soon the magnets will arrive at IUAC. Power supplies for the electromagnets are being developed at IUAC. Acceleration of electron beam and subsequent production of THz radiation are expected to be carried out by the middle of 2020.

Cryostat technology

Shailesh Gilankar, RRCAT

The term cryostat is generally used to describe any container or system housing devices or fluids and kept at very low temperatures; typically, below 120 K. One can say that the very first performing cryostat (which was silver-plated double-walled glass containers to collect the first liquefied hydrogen) was invented by Sir James Dewar in 1897 and hence cryostats containing/storing cryogenic fluids nowadays are also called as Dewar. Since then, the evolution of cryostats has been led by specific requirements for the variety of applications. Today, cryostats are used in a large range of applications spanning from industrial products to specific scientific research devices /instruments.

Here typical cryostats, for linear accelerator technology (mainly cryomodules) are discussed. This talk will cover large cryostats (cryomodules), basic functions of cryomodule, main sub-systems of cryomodules, cryogenic schemes of a cryomodule, thermal aspects, mechanical aspects and different types of cavity support systems extra will be discussed. Talk will be concluded with glimpses of recently developed HTS cryostat at RRCAT.



3-D Model of a Bi-cavity Horizontal Test Cryostat for 650 MHz SCRF cavities

Cyclotron Control System in VECC

Anindya Roy, VECC

Technical Session 12: Advanced Particle Accelerator Technology

28th January 2020, (11:30 – 13:30 Hrs)

Magnet design and development programme at BARC

Sanjay Malhotra, BARC

Magnets form a major portion of particle accelerators. Ranging from solenoids, dipoles, Quadrupoles, sextupoles and octupoles to undulators and wigglers, they implement variety of functions and have distinct design and developmental challenges. They form part of beam transfer lines, accelerators, storage rings and beam lines etc. Development cycle of magnets include electromagnetic design to meet beam optics requirements, field optimizations, magnet production, physics and engineering qualifications and beam line installation. Electromagnetic Applications and Instrumentation Division, BARC has expertise on design and development of various types of magnet technologies, viz conventional iron-dominated electromagnets, permanent magnets and superconducting magnets. Focusing lenses of Drift Tube Linac for LEHIPA; Quadrupoles, dipole correctors and bending dipole magnets for IUAC; Quadrupoles and dipole correctors for MEBT for PIP-II injector; Superconducting Solenoid magnets for SSR2 Cryomodules; and Quadrupole & Dipole correctors for high energy section of PIP-II at Fermilab are some of the magnets designed and developed at Electromagnetic Applications and Instrumentation Division, Bhabha Atomic Research Centre. Beam line magnets for XMCD and XRD studies were developed and installed in the INDUS-II beamline at RRCAT. The magnets are fabricated in Indian Industry based on an inclusive magnetic and engineering design developed at BARC. Comprehensive qualification facilities for accelerators magnets has also been developed and commissioned. These include stretch wire magnetometer, rotating coil bench, hall probe scanning system, VSM, Hysteresis loop tracers, cryostats for superconducting magnets and facilities for electrical and thermal characterization of these magnets. The talk will cover various design and development aspects of magnets.

Cryogenic plants and technology for particle accelerators

Sandip Pal, VECC

Accelerators are electromagnetic machines, which energizes charged particle beams via electric and magnetic fields for accelerating, guiding and focusing them. The larger the accelerators the higher the requirement of electromagnetic fields to reach higher beam energy, containing the dimensions of particle accelerators. Particle Accelerators such as Cyclotrons, circular accelerators, e-linac, synchrotron etc. mainly have either superconducting magnets or RF cavity. Normal-boiling helium at 4.2 K appears an adequate coolant for most magnets wound with niobium-titanium superconductor creating field <5.5 T, which has a critical temperature of about 9.5 K. As the demand increases, if one wishes to produce fields in the 8 to 10 T range with niobium-titanium, one has to operate the magnets at temperatures lower than the normal boiling point of helium, e.g. below 2.2 K in superfluid helium in order to maintain sufficient current-carrying capacity at high field. Similarly, the RF cavities are used as resonators for which one wishes to maximize the quality factor in order to reduce the power dissipation in the wall, characterized by its surface resistance. Niobium cavities are used in such cases and operates in superfluid helium.

Hence, applied superconductivity and ancillary helium cryogenics have emerged as key technologies to high-energy particle accelerators. The helium refrigerator started at refrigeration capacity of few hundred Watt in 1960 to the hundreds of kW today at CERN. At VECC, two helium liquefiers (@ 50 l/h or 215 W @ 4.5K and 85 l/h or 415 W @4.5K without LN₂ precooling) have been operating since 2001 and 2010, respectively. These liquefiers are used for maintaining 4.5K of Superconducting magnet and cryopanel of the cyclotron. A high-frequency superconducting e-linac is under development at VECC under ANURIB project. In the e-linac, electron beam from a 300 kV thermionic gun will be accelerated first to 10 MeV in an Injector Cryo-Module (ICM) housing one 1.3 GHz, 2K 9-cell cavity. The 10 MeV electron beam would be further accelerated to 50 MeV in two Accelerator Cryo-Modules (ACM) each housing two 9-cell cavities. All the cavities will be operated at temperatures lower than the normal boiling point of helium, e.g. in superfluid helium at 2K. An ICM has been delivered to VECC by TRIUMF and is made ready for testing. A new Linde make helium liquefier LR280 has been commissioned at VECC. During testing, the liquefier's performance showed capacity in refrigeration @ 4.5K, mixed and liquefaction modes with LN₂ precooling as ≥ 690 W, 205 W and 293 l/h, and 375 l/h respectively. The refrigeration and liquefaction capacity of that liquefier without LN₂ precooling are 569 W @ 4.5K and 126.5 l/h respectively. A cryogenic distribution system will be installed for connecting ICM and ACM modules. This presentation will focus the cryogenic system presently operating at VECC and its future extension.

Development of a Compact High Current Super-Conducting Linear Electron Beam Accelerator for Treating Industrial and Domestic Effluents

Manisha Meena, IITB

The total volume of water on earth is about 1400 million km³ of which only 2.5% is freshwater. The usable portion is less than 1% of all freshwater which amounts to 0.01% of all the water on earth. Today's increasing population, urbanization, and industrialization is producing a lot of waste like carcinogenic halogenated hydrocarbons, human waste, effluents from industries. A large amount of these effluents in India are discharged into rivers without or with very little processing. Moreover the usage of pesticides, fertilizers in agriculture are responsible for ground water impurities. The conventional treatments have often been found to be insufficient for purification because of carcinogenic byproducts and bacteria's mutation making it resistant to chemicals.

There is therefore an urgent need for alternative purification methods for domestic and industrial effluents which should be economically beneficial, operationally robust and compact in size and can be duplicated and placed all along the water resources like rivers. One of the ways could be irradiation of the effluent with high-energy electron beam. It has been established that this would not result in harmful byproducts and the pathogens would be rendered ineffective because of destruction of their DNA. Radiation essentially works on the principle of radiolysis of water. It results in very reactive radicals like Hydrated electrons, Hydrogen atom (H) (reducing agents) and OH. and Hydrogen peroxide (H_2O_2) as oxidizing agents. They removes organic impurities with radiation chemical reactions, colour by destruction of the double bonds, odour by opening up rings in aromatic compounds and disinfects the water by destroying the DNA of micro organisms.

We are therefore, with the help of KEK, Japan, designing a high current super-conducting linear electron beam accelerator with 40 kW beam power and 1 MeV beam energy to treat 1000 m³/day water. The estimated cost is about 68 ₹ for 1 million litre per day. This includes the depreciation of the capital equipment and the running costs. The average life of such facility is expected to be very long and recurring costs should be moderately low. We would like to establish feasibility of large scale water treatment facility in India.

END OF EVENT
