सुविधा विकास, प्रचालन एवं अनुरक्षण

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भापअ केंद्र-टीआईएफआर पेलेट्रॉन त्वरक

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भापअ केंद्र-टीआईएफआर पेलेट्रॉन लीनॉक (एलआईएनएसी) सुविधा की त्वरण नली

सारांश

भापअ केंद्र-टीआईएफआर पेलेट्रॉन लीनॉक (एलआईएनएसी) सुविधा देश के त्वरक-आधारित अनुसंधान कार्य हेतु नाभिकीय भौतिकी, परमाणु एवं संघनित पदार्थ भौतिकी तथा बहु-विषयक क्षेत्रों के लिए एक कार्यस्थल (गतिशक्ति/प्रगतिकारक) रही है। त्वरक आधारित मूलभूत एवं अनुप्रयुक्त अनुसंधान समुदाय की बढ़ती अपेक्षाओं को पूरा करते हुए, इसने भविष्य में देश के हरित-क्षेत्र त्वरक हेतु विकास कार्यक्रमों को भी सुविधाजनक बनाया है। यह आलेख, भारी द्रव्यमान के उच्च ऊर्जा कणपुंजों के साथ त्वरक के लिए भविष्य के विकास कार्यक्रमों के साथ-साथ देश में त्वरक-आधारित गतिविधियों के ऐतिहासिक परिप्रेक्ष्य को संक्षेप में प्रस्तुत करता है।

Facility Development, Operation & Up-keep

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BARC-TIFR Pelletron Accelerator

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Accelerating tube of Pelletron.

ABSTRACT

The BARC-TIFR Pelletron LINAC facility has been a workhorse for accelerator-based research in the country in the domains of nuclear physics, atomic and condensed matter physics and multidisciplinary areas. While catering to the expanding horizons of the accelerator based basic and applied research community, it has also facilitated developmental programmes for futuristic green-field accelerator in the country. This article would briefly present a historical perspective of accelerator-based activities in the country along with the future developmental programmes for accelerator with higher energy beams of heavier masses.

KEYWORDS: *Pelletron, LINAC, Heavy-ion, Radiation applications*

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Introduction

The Pelletron accelerator has been operational on a round the clock basis since 1988, serving diverse users from within and outside DAE. The Pelletron accelerator has been consistently working with very high efficiency, delivering a wide variety of ion beams ranging from proton to Iodine. A number of developmental activities have been carried out in-house to improve the performance of the accelerator. While a majority of the researchers at this facility are scientists from BARC and TIFR, the experimental community includes researchers and students from VECC, SINP and universities within India and abroad. About 150 Ph.D. theses and about 750 publications in international refereed journals have resulted from the research activities at the PLF. These include a large number of publications in high impact international scientific journals.

The accelerator has been a workhorse for accelerator-based research in the country in the domains of nuclear physics, atomic and condensed matter physics and multidisciplinary areas. This article briefly presents a historical perspective of accelerator-based activities in the country. The accelerator developmental and associated activities which have increased the scope of accelerator utilization shall be described later. The accelerator continues to serve the diverse physics communities in fundamental and applied research. The accelerator while catering to the expanding horizons of the accelerator based basic and applied research community has also facilitated developmental programmes for futuristic green-field accelerator in the country. This article would also present the future developmental programmes for accelerator with higher energy beams of heavier masses.

Historical Perspective

The accelerator development in the Department of Atomic Energy set out in the fifties. One MeV Cockroft–Walton accelerator was commissioned at Tata Institute of Fundamental Research (TIFR), Mumbai in 1953. In early sixties a 5.5 MV Van de Graaff accelerator manufactured by High Voltage Engineering Corporation (HVEC), was installed at the Bhabha Atomic Research Centre (BARC), Mumbai that provided much-needed boost to accelerator-based research in the country. In the late seventies, the only accelerator facility in medium energy range available in the country was indigenously developed Variable Energy Cyclotron at Kolkata. In order to meet the diverse requirements of nuclear physics community, a Medium Energy Heavy Ion Accelerator (MEHIA) project was conceived to accelerate ions right from proton to highest possible mass at intermediate energies. In 1982, the project MEHIA started, where a 14 UD Pelletron Accelerator was purchased from M/s NEC, USA and installed at Tata Institute of Fundamental Research campus, Mumbai. This accelerator was commissioned on 30th December 1988 [1] and since then it has been serving as a major facility for heavy ion accelerator based research in India.

Developmental Activities & associated applications at BARC-TIFR Pelletron Accelerator over last 35 years

Since its inception, the accelerator has been continuously working with progressively increased efficiency. The accelerator upgradation was done by implementing following features; the original NEC accelerator has voltage grading based on corona needles that were replaced by resistances, a new terminal potential stabilizer was installed, two turbomolecular pumps were introduced in the terminal to improve performance of gas stripper, development of negative ion beams for a wide range of species [2].

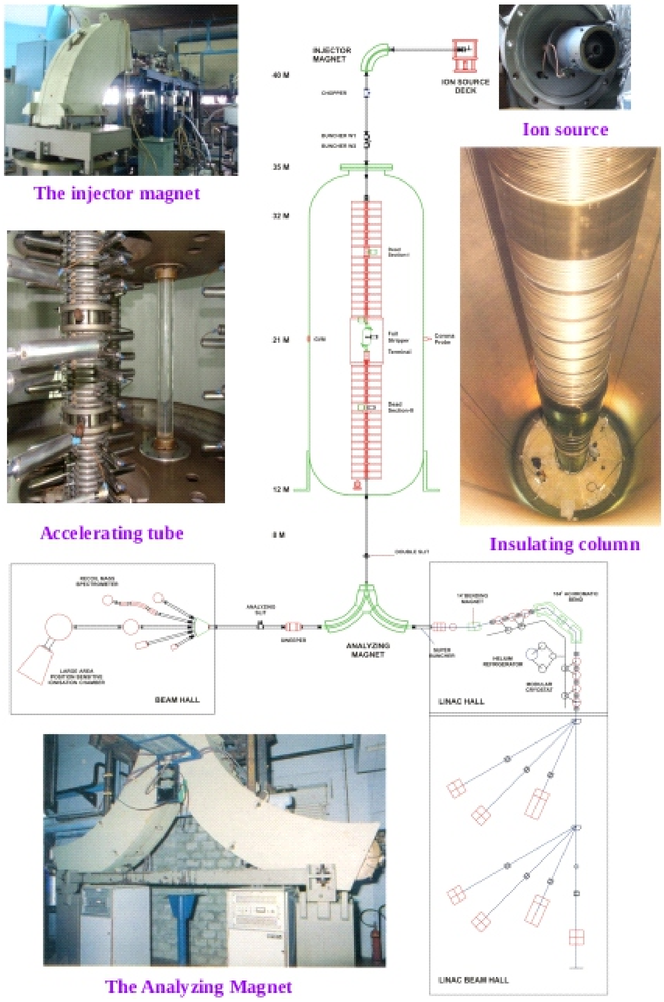

Fig.1: Schematic layout of the BARC-TIFR Pelletron LINAC facility.

At BARC-TIFR Pelletron Linac Facility (PLF), various application-oriented programmes such as radioisotopes production, radiation damage studies (space bound devices, yield improvement in wheat and rice seeds), secondary neutron production for cross-section measurements, radiation dosimetry studies, ion irradiation in semiconductor crystals for photoconductive Tera Hz emitters, Accelerator Mass Spectrometry, and production of track-etch membranes, are also pursued. Experimental facilities are attached to dedicated beamlines installed in the Cascade beam hall for Pelletron energies and two new LINAC beam halls I and II for both Pelletron and LINAC boosted energies.

The accelerator based developmental activities and the application-oriented programs have resulted in enhanced uptime and utilization of the accelerator.

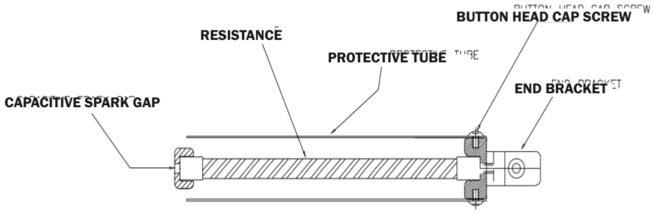

Fig.2: Details of resistance mount assembly.

Resistor Grading

An important consideration in high voltage design of an electrostatic accelerator is the potential grading system used to divide the terminal potential equitably (or as required) across the column or tube electrode gaps. Development of very high values ceramic metal resistor technology has been found to be most suitable for use in high voltage grading chains. Corona needles in high-energy column were replaced by these resistances. A resistance chain consisting of 2 GΩ per gap in the column and 1 GΩ per gap in the accelerating tube (1 GΩ resistors; 1008 in columns and 924 in accelerating tubes) was installed. As a result a voltage stability of 0.01% has been achieved and the operation of accelerator has become very stable even at lower terminal voltages, and it is now possible to deliver beam even at as low voltage as 4 MV.

Accelerator Based Spectrometry

Due to the enhanced stability and high voltage control achieved with the resistor grading system, Accelerator Mass Spectrometry based experiments with ^{36}Cl based measurements could be performed, successfully. As the interfering isobar in the ^{36}Cl detection is ^{36}S, a segmented gas detector was developed in-house to circumvent the rather intense isobaric interference. The ratio obtained for standard sample is in agreement with the value specified by the Prime Lab within a statistical error of 12%. Such a good agreement obtained for direct measurement of ratio indicates that transmission for Cl isotopes through the accelerator is well optimized. Estimated detection limit is ~ 7 x 10^{-14} [3]. These experiments were subsequently extended to ^{129}I.

Recirculating Terminal Gas-Stripper

Gas pressure has a major role in getting intense and highly stripped ions, but at the same time bad vacuum conditions in accelerator tube causes loss of beam transmission due to charge exchange and scattering. The gas stripper system was originally installed with Titanium Sublimation pumps in high voltage terminal section. These pumps require periodic replacement of cartridges and pumping speed of these pumps used to come down with time. A new recirculation gas stripper system has been installed, consisting of two Turbo Pumps in place of sublimation pumps. The gas stripper system is utilized during accelerating beryllium beam through Pelletron [4] and also while accelerating beams through Linac. The installation of turbo pump in the accelerator tank is based on an existing stripper housing (see Fig.3).

Linux based Control System

The Pelletron accelerator parameters are controlled and monitored through a Linux based software and associated graphical User Interface (GUI). The operator interacts through the GUI to control and monitor the accelerator. The GUI incorporates features like software assignable meters and slider controls. This has obviated the need for shaft encoders and assignable meters that were in use for the past twenty years. The control system software consisting of client-server architecture utilizing ethernet connectivity is relatively more reliable and user friendly compared to the old system that was DOS based and was in use for twenty years.

Pelletron control system hardware

The Pelletron control system hardware is CAMAC based. The CAMAC interface modules are more than twenty years old. To ensure continuity of the CAMAC platform, general purpose FPGA based CAMAC modules like DAC [5], ADC and digital input/output modules have been designed and developed at the Pelletron accelerator (see Fig.4). All the modules have been tested. Of these, a 16 channel, 12 bit CAMAC ADC module has been installed and is currently in continuous use.

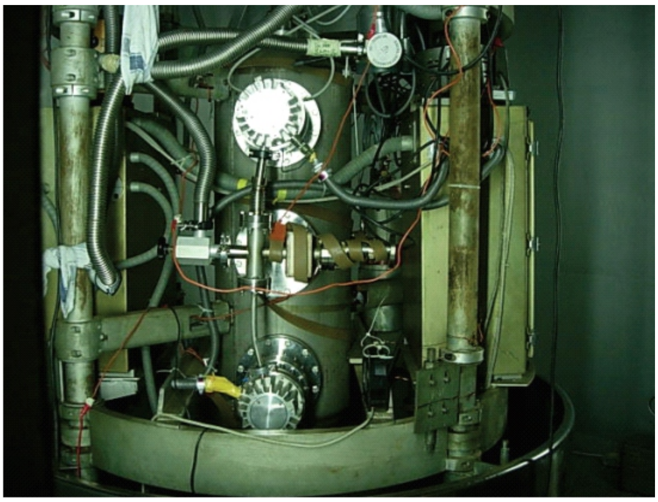

Fig.3: Terminal Gas Stripper System.

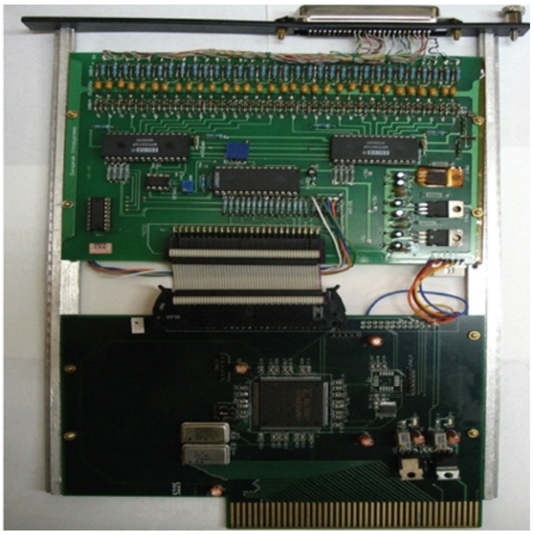

Fig.4: FPGA based CAMAC ADC module.

Ion Source and Beam Development

To produce a wide range of negative ions, sources such as SNICS (Source of Negative Ions by Cesium Sputtering) and Alphatross are commonly used in tandem accelerator facilities. An ion source test bench was set up to meet the increasing demand of intensity and quality of beams at Pelletron Accelerator Facility. The sputter characteristics of the cathodes are optimized using the 'cooking systematics' generated in the ion source laboratory. Different types of composite-sputter cathodes, gas feed-sputter cathodes and disc covered-gas feed-sputter cathodes have been developed and tested at our test bench, with particular emphasis given to the elements of user's interest [6,7]. Composite-sputter cathodes development has led to a significant reduction in the down time of the accelerator by eliminating the beam changeover delays and enhanced ion source lifetime. Gas feed-sputter cathodes provide molecular negative ions of low electron affinity elements. Disc covered-gas feed-sputter cathodes are developed to generate negative ions of the rare earth elements without impairing the ionization efficiency of ionizer. Over the years, various versions of high intensity negative ion sources based on cesium sputtering i. e. SNICS, Gas feed-SNICS, MC-SNICS (Multi Cathode Source of Negative Ions by Cesium Sputtering) have been developed, in house [8, 9]. Recently, ^{9}Be beam has been accelerated through Pelletron Accelerator Facility, successfully. Given to the toxicity of beryllium, a dedicated ion source was used and stringent safety requirements were followed as recommended by the BARC Safety Committee (BSC), BARC, at different levels of production, acceleration, and utilization [10].

Track Etch Membrane Set Up

Microporous membranes with well-defined and uniform pore size and pore density, uniform thickness, high tensile strength and inertness to toxic environments are in good demand for growing number of scientific and technological applications. Heavy ion accelerators provide greater flexibility to produce Track Etch Membrane (TEM) of a wide range as they can provide various heavy ions of different atomic number (Z), kinetic energy (E) and particle flux. Pore densities of the order of 106 to 108 pores/cm^2 and pore size of the order of 0.2 to 1.0 micron are required for many applications. A magnet was used to scan the heavy ions from the accelerator in horizontal direction and the polymer film was moved in vertical direction using a roller mechanism. The scanner magnet gives a peak magnetic field of 1.35 Kgauss [11]. To get larger deflection higher charge states of the desired ions are produced using post stripper. The deflection, at the exit of the scanner is few centimeters, which is then widened using a horn chamber of one metre length. At the end of the scanner deflection up to 25 cm is achieved. The film is wound on a perspex shaft of 19 mm diameter and is continuously unwound on to another roller that is driven by a D.C. motor from outside the chamber.

Coupling is done using a vacuum rotary feedthrough. The linear speed of the film is kept at 60 cm/min. The beam is defocused in vertical direction to get almost uniform particle distribution. These membranes are being used by Radiation Medicine Centre, Mumbai to immobilize antibodies against specific analyte and are also used for purification of gases, in separating various Actinides and metals.

Fig.5: Proton Beam Irradiation Setup.

High Current Irradiation Set Up

Drift space above analyzing magnet has been modified to accommodate a Proton Beam Irradiation Setup at 6 meter level at this facility (see Fig.5). This setup is capable of delivering proton beam in the energy range of 2 MeV to 26 MeV and current in µA range. The shielding at this level is such that radiation is within permissible limit when proton beam with high energy and high current is accelerated. In order to study radiation effects on metals at a higher temperature a hot target assembly is developed which can go up to 500^{0} C. Radionuclides such as ^{52}Mn, ^{67}Ga, ^{96}Tc, and ^{236}Pu have been produced for radiopharmaceutical applications.

Radiation Biology Set Up

A thin window (20µm) of Titanium is placed at 30^{0} N beam line to bring out ion beam in air. Various users have used this facility. A large area proton beam of size 25 mm to 40 mm diameter in air was made available to Indian Space Research Organization for testing their on-line electronic devices.

Future Programmes

The experimental nuclear physics (NP) research has progressed rapidly with the advancement in accelerator technology. Currently, in India, Pelletron-LINAC accelerator facilities at Mumbai and Delhi and the cyclotron accelerators at Kolkata are driving the NP research. Most of the interesting NP results have come from experiments performed at and around a beam energy region called Coulomb energy where the projectile has just enough energy to overcome the mutual electrostatic repulsion between projectile and target which varies roughly as a product of projectile and target atomic number. There is a need to have higher energy beams of heavier masses with higher beam current compared to the current accelerators in India, which can bring in not only higher nuclear temperature but also higher angular momentum thus expanding the horizons of NP research in the country.

To cater to the demands of the NP community, a versatile ECR (Electron Cyclotron Resonance) Ion Source (IS) based heavy ion accelerator facility capable of accelerating wider species of beams at higher beam currents to energies beyond the capability of BARC-TIFR Pelletron-LINAC Facility, is planned as a greenfield facility at BARC-Vizag accelerator complex. This accelerator facility consisting of an ECR-IS, a room temperature radiofrequency quadrupole (RT-RFQ) and low & high beta superconducting radio frequency (SRF) niobium cavities would be developed to produce, accelerate and transport the highly charged high current stable ion beams to experimental facilities in beam halls for experimental studies.

Acknowledgement

The authors thank their colleagues of Pelletron Accelerator Facility for their contribution. We are also thankful to all past members of the division for their constant support and encouragement.

References

[1] S. S. Kapoor, V.A. Hattangari and M.S. Bhatia,Indian J. Pure and App.Phys. 27 (1989) 623.

[2] A. K. Gupta, P. V. Bhagwat and R. K. Choudhury, Proceedings of Heavy Ion Accelerator Technology (HIAT09), June 08-12, 2009, Venice (Italy)

[3] P. Surendran, A. Shrivastava, A. K. Gupta, R. M. Kale, J. P. Nair, M. Hemalatha, K. Mahata, M. L. Yadav, H. Sparrow, R. G. Thomas, P. V. Bhagwat, S. Kailas, Nucl. Inst. & Meth. Phys. Res. B 267 (2009) 1171.

[4] S. C. Sharma, N.G. Ninawe, M.L. Yadav, M. Ekambaram, Ramjilal, U.V. Matkar, Q. N. Ansari, R. L. Lokare, Ramlal, A. K. Gupta, R. G. Pillay and P. V. Bhagwat, Indian Particle Accelerator conference (Inpac-2009), Feb. 10-13, 2009, RRCAT, Indore.

[5] S. G. Kulkarni, J. A. Gore, A. K. Gupta, P. V. Bhagwat,R. K. Choudhury, Indian Particle Accelerator conference (Inpac-2009), Feb. 10-13, 2009, RRCAT, Indore, India.

[6] A. K. Gupta, N. Mehrotra, R. M. Kale, D. Alamelu, and S. K. Aggarwal, DAE Symposium on Nuclear Physics, Dec. 2003.

[7] A. K. Gupta, N. Mehrotra, R. M. Kale, D. Alamelu, and S. K. Aggarwal , DAE-BRNS 50th Symposium on Nuclear Physics, BARC, Mumbai, Dec. 12-16 (2005).

[8] A. K. Gupta, P. Ayyub, European Physical Journal D 17 (2001) 221.

[9] S. C. Sharma, R. M. Kale and A. K. Gupta, DAE symposium on Nuclear Physics, Dec. 21-25, (1998).

[10] A. K. Gupta, R. M. Kale, N. Mehrotra, P. N. Bhat, S. Soundararajan, A. Shanbag, D. D. Thorat, P. V. Bhagwat, R. K. Choudhury, Indian Particle Accelerator conference (Inpac-2009), Feb. 10-13, 2009, RRCAT, Indore, India.

[11] J. P. Nair et al. J Radioanal Nucl Chem (2014) 302:947–950.