



## अन्तर-विश्वविद्यालय त्वरक केन्द्र Inter-University Accelerator Centre

(विश्वविद्यालय अनुदान आयोग का स्वायत्त अंतराविश्वविद्यालय केन्द्र)  
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### Implementation of Piezoelectric Actuator Based Phase Lock System in LINAC for Delivering Heavy Ion Beams



*Fig. 1. LINAC cryostat with piezoelectric tuners.*

The phase locking of the superconducting Quarter Wave Resonators (QWRs) used in heavy ion accelerator of IUAC consists of electronic and mechanical control operated in fast and slow time scale respectively. The slow control of the frequency is done by mechanical tuner by using pure helium gas to flex the Niobium tuner bellows. In order to improve the dynamics of existing control in slow time scale, an alternate scheme using piezoelectric actuator based tuner has been developed and tested with superconducting QWRs at 4.2 K. After several successful tests, this control scheme has been implemented on the superconducting resonators installed in linac cryostat and ion beams have been successfully accelerated and delivered for scheduled experiments. The electronics modules for the piezoelectric actuator have been developed in house. The feedback loop of the piezoelectric control includes an integral control along with a Positive Position Feedback (PPF) based control loop. This feedback

loop works with the existing I-Q based dynamic phase control. This control scheme is found suitable to arrest the slow drifts in the resonator frequency in a much faster time scale in comparison to the existing gas based system and thus reduces the RF power to phase lock the cavities. So, extra RF power is now available to increase the accelerating field of the resonators. In addition, this scheme substantially damps the microphonic vibrations picked up from the ambience of the resonator, thus improving the phase stability of the resonator.

### Cryogenics and Applied Superconductivity Laboratory



*Fig. 2. Superconducting quadrupole magnet.*

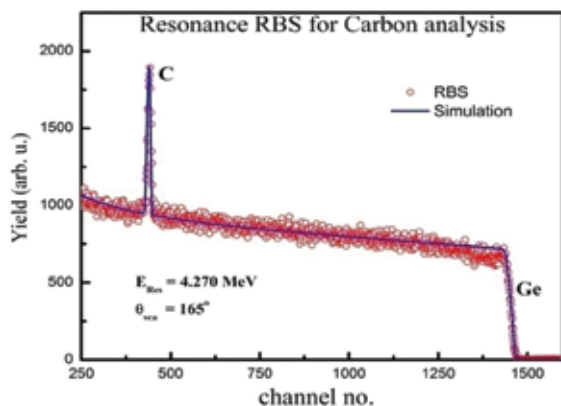
A superconducting quadrupole doublet magnet with cold super-ferric iron cover for HYbrid Recoil mass Analyzer (HYRA) has been commissioned recently. The total cold mass of the magnet at 4.2 K is 2000 kg which is mainly contributed by iron yoke and pole. A total of 8

coils, each of approximately 2000 turns of niobium titanium conductor, have been developed. The cryostat has been designed on similar concept of MRI magnet with a two stage cryocooler and two pairs of HTS current leads. The second stage of the cryocooler is fitted with a condenser which is used to re-liquefy evaporated helium and the first stage provides cooling necessary to maintain intermediate shield temperature to 50-60 K. The complex structure of cryostat and magnet has been developed with local support from Indian Industry.

After successful cool-down of the cryostat, quadrupole magnets have been charged up to 70 A current to generate a pole tip field of 2 T with a field gradient of 15 T/m. The magnet has been operating in the cold condition for last 2 months with its helium level maintained between 80-85%. The development of this ever-cooled superconducting magnet has been a first of its kind in the country.

### PARAS Laboratory Report

Rutherford Backscattering Spectrometry (RBS) facility has been operational and utilized by users for analysis of the samples. Around 1500 measurements have been performed from 16 different institutes, universities and colleges. RBS end station consists of a 4 axis goniometer on which 10 – 15 samples, depending on sample size, can be mounted at one time for analysis. There is increase in demand for analysis of single crystal samples via channeling technique



**Fig. 3. Carbon analysis using resonance RBS, the  $^{12}\text{C}(\alpha,\alpha)^{12}\text{C}$  reaction with the resonant energy 4.27 MeV was chosen to measure the carbon concentration. The backscattered alpha particles were detected by a surface barrier silicon detector with scattering angle of  $165^{\circ}$  from the incident beam direction. The RRBS spectrum is simulated using SIMNRA software.**

Amorphization of single crystal and ion beam induced recrystallization of amorphised layers have been analyzed by pursuing channeling measurements. Channeling method

has also been utilized for determining the quality of epitaxial layers.

Normally Rutherford backscattering spectrometry (RBS) is used for ion beam analysis (IBA), which is a popular, fast, non-destructive technique. However RBS with  $^4\text{He}^+$  ion beam, in many cases, is ineffective for light element (like C, N, O, ...) analysis due to overlapping signals and small scattering cross section. But nuclear reaction analysis (NRA) and resonant Rutherford backscattering spectrometry (RRBS) have been widely used for analysis of light elements in solids. These two ion-beam methods complement more traditional analysis by RBS. There are several resonant elastic reactions available with narrow resonance width and enhanced cross sections.  $^{16}\text{O}(\alpha,\alpha)^{16}\text{O}$  at 3.04 MeV,  $^{14}\text{N}(\alpha,\alpha)^{14}\text{N}$  at 3.69 MeV and  $^{12}\text{C}(\alpha,\alpha)^{12}\text{C}$  at 4.27 MeV are regularly performed for measuring oxygen, nitrogen and carbon in high mass substrates.

Newer version of data analysis software for acquiring and analysis of RBS data has been installed for possible augmentation of the facility. The facility did not have electron suppressor due to which we could not accurately measure charge deposited on samples. An electron suppressor has been designed, installed, tested and is being routinely used.

### Repair of Clover detectors and training of personnels

Servicing of Clover detectors by the engineers from Canberra, France has been done at the new clean-room annealing set-up at IUAC. Four of the Clover detectors have been repaired. One of the highlights of this exercise has been the training of technical personnels of IUAC and other collaborating institutes.



**Fig. 4. An engineer from Canberra demonstrating to IUAC and other personnel during the repair of Clover detectors.**

## Test of Recoil Distance Device (Plunger) in GDA beam line

The old GDA plunger device which is used to measure lifetime of nuclear states in sub-nanosecond range has been repaired. Plunger has been put to test with three un-suppressed Clover detectors, two Compton suppressed HPGe and 14 BGO multiplicity filter detectors in the GDA beam line. The  $^{12}\text{C}$  beam of 67 MeV from the Pelletron on a thin  $^{94}\text{Zr}$  target, has been used to populate states in  $^{102}\text{Pd}$  nucleus. Students from Delhi and Viswabharti universities have been actively involved in this test.



Fig. 5 (a) Plunger inside GDA set-up.



Fig. 5 (b) Inside view of GDA with Plunger.

## IUAC's 50 kV Tabletop Ion Accelerator

To inculcate the interest of young students towards physical sciences in education and research, IUAC takes the pleasure in announcing the in-house development of a 50 kV ion accelerator for physics students and faculty at the university/college level. UG and PG students will get hands-on exposure on

- Ion source
- Bending magnets
- Analysed - ion beams- molecular beams and neutral beams at different energies
- Vacuum systems

- Beam transport
- Energy selection
- Beam Scanner
- Building an Accelerator etc.

The faculty and students can do the following experiments using alpha, proton and molecular hydrogen beams up to 50 kV without any radiation hazard within their university/college.

- Positive ion implantation
- Ion induced fluorescence studies
- Particle detector experiments
- Scattering experiments
- Production of neutral atomic species in beam form etc.



Fig. 6. 50 kV Tabletop Accelerator.

### Machine Highlights

Design : Simple and rugged design. Can be assembled on site for learning.

Utility : Need only 1 kVA, 240 V electric power.

Space : Need only 3 X 3 m<sup>2</sup> space

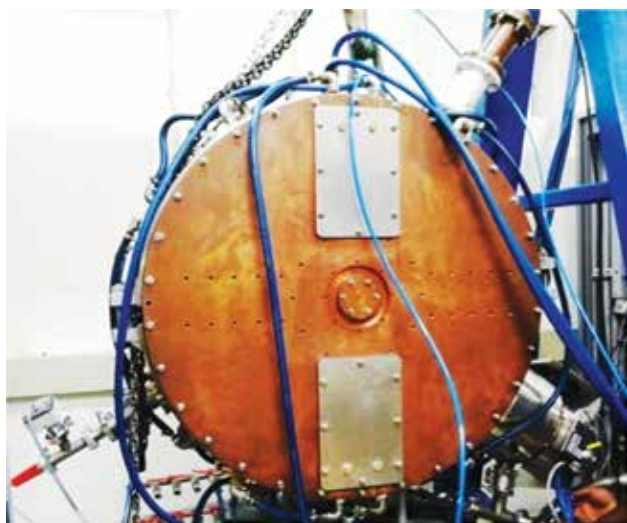
Physical Size : 1.6m X 1.4m X 1.5m (W X H X D)

| Beam energy range and beam current |                    |             |                           |
|------------------------------------|--------------------|-------------|---------------------------|
| Beam                               | Energy Range (keV) | Field (G)   | Current ( $\mu\text{A}$ ) |
| H <sup>+</sup>                     | 23.43 – 46.87      | 891 - 1230  | 4.45                      |
| H <sub>2</sub> <sup>+</sup>        | 14 – 46.87         | 1007 - 1758 | 52                        |
| He <sup>+</sup>                    | 14 - 33.75         | 1398 - 2110 | 43.5                      |
| He <sup>2+</sup>                   | 37.5 - 91.86       | 1130 - 1748 | 0.16                      |

IUAC can provide technical support, design & drawings to interested University/Institutions for setting up such accelerators. Those interested are welcome to contact: safvan@iuac.res.in, kumar@iuac.res.in

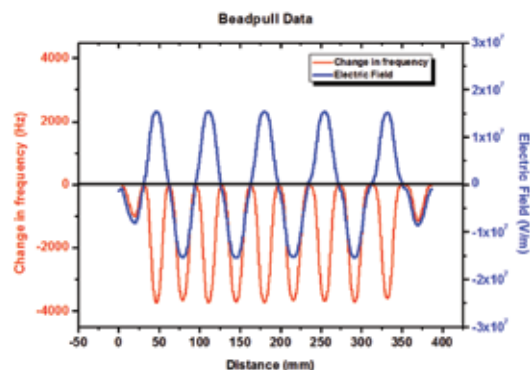
## Drift Tube Linac

The High Current Injector (HCI) would be an alternate source of ion beams to the existing superconducting LINAC modules in addition to the already functional Pelletron accelerator. HCI is being developed to inject highly charged ions into the superconducting linear accelerator at Inter University Accelerator Centre (IUAC). The HCI would use a Radio Frequency Quadrupole (RFQ), Drift Tube Linac (DTL) and low beta superconducting cavities to accelerate heavy ions from the high temperature superconducting electron cyclotron resonance ion source (HTS-ECRIS called PKDELIS) to the existing superconducting linear accelerator.



*Fig. 7. High Power Test Setup.*

The Drift Tube Linac (DTL) has been designed to accelerate the heavy ion beams having  $A/q \leq 6$  from 180 keV/u to 1.8 MeV/u. It would consist of six independent inter digital (IH) type DTLs which would be independently phased from separate RF amplifiers. IH type DTL resonators are the preferred due to their high shunt impedance values. The resonant frequency of each DTL is 97 MHz. The design, fabrication and RF power test of the first DTL has been completed successfully. The resonator has been successfully tested up to 6 kW RF input power for more than 100 hours. The first resonator was designed to give a quality factor of 11500 and consume 5kW of RF power to provide an effective accelerating voltage of 1 MV. The measured Q is around 10500 and the resonator has been powered up to 6 kW. The temperature of the tank body has been kept under 40°C, during the powering. The cavity is undergoing further tests to verify and validate the various design and RF parameters.



*Fig. 8. Bead Pull Data for DTL Resonator # 1.*

## Materials Science Activities

In a joint research work between IUAC Delhi and NIMS Tsukuba, it is shown that a nanocomposite thin film consisting of ZnO nanoparticles in silica matrix under the swift heavy ion irradiation results in reduction of ZnO nanoparticles to Zn and elongation of these metal nanoparticles in direction of ion beam [H. Amekura et al., Appl. Phys. Lett. 103(2013)203206].

The dependence of the sputtering yield from metal-dielectric nanocomposites on the size of the nanoparticles is studied and the effect of the size of the nanoparticles on the sputtering yield is explained quantitatively in framework of ultra fast thermo-elastic model, in terms of transient stress and strain induced by thermal effects [Fouran Singh et al JI. Of Appl. Phys. D 46(2013) 325305].

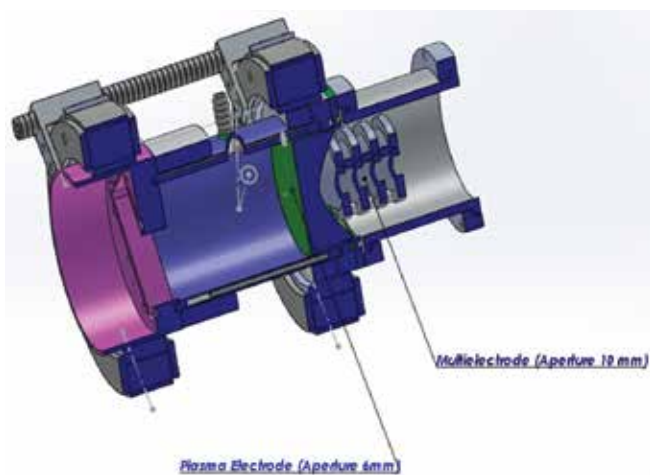
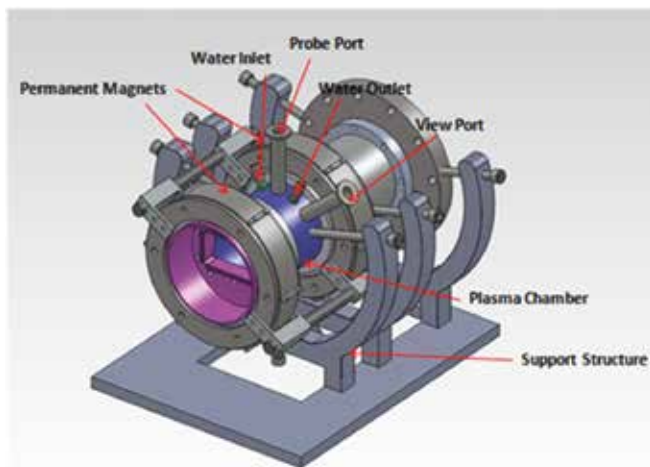
The vertically protruding nanostructures of PbTe are synthesized by ion beam mixing of Te/PbO layers under 100 MeV Ag ion irradiation. Such nanostructures of PbTe are of interest from thermoelectric properties point of view [Srashti Gupta et al, Appl. Surface Science 265(2013)124].

It is shown that surface plasmon resonance in noble metal fullerene nanocomposite thin film can be tuned by swift heavy ion irradiation [R. Singhal et al., J. Nanoparticle Resesearch 15(2013)1641].

## Development of a new, compact 2.45 GHz microwave ion source and associated experimental facility

Based on the performance of the older version of a 2.45 GHz microwave ion source, a relatively new and improved version of a 2.45 GHz ,compact microwave ion source was designed and developed with a water cooled plasma chamber and is shown in figure 9. It has been designed for providing intense beams of singly charged ions for materials science related experiments, keeping in mind the main objective

of reducing the total ion implantation time required for the experiment when compared to using multiply charged ions. The plasma chamber of the ion source, due to its complexity, has been fabricated using the so-called ‘Laser Cuiasing’ technique where fine metallic powder is locally fused by a laser, and the component is built up layer by layer ( $\sim 20$  to  $60 \mu\text{m}$ ) by lowering the bottom of the installation space, applying more powder and fusing it again. It has a double walled, stainless steel plasma chamber design having an inner diameter of 90 mm and length of 101 mm. The cooling water can flow all over the chamber through equally spaced ribs in between the walls and also cold and hot water are separated by a closed rib. The dimensions of the resonant cavity have been chosen to excite the TE<sub>111</sub> dominant mode at 2.45 GHz. The actual length of the plasma chamber has been kept 135 mm in order to accommodate the magnet structure. Additional ports have been provided on the chamber wall for Langmuir probe plasma diagnostics. The microwave injection line has been designed to couple microwave power from a 1.2 kW magnetron into the plasma chamber using a four-step ridged waveguide.



**Fig. 9.** (above) View of the indigenous, compact 2.45 GHz microwave ion source and (below) cross-sectional view of the ion source and beam extraction system.

The newly designed ion source is expected to further enhance the performance with respect to the older version of the ion source. With the new ion source, alternate plasma heating mechanisms (for example, electrostatic wave heating) and RF coupling to plasma at these low frequencies can be studied in more detail. Understanding plasma physics processes during breakdown and decay is of special significance to particle accelerator science, nuclear fusion reactors and plasma processing industry. Langmuir probe measurements can possibly show increased ion saturated currents where the Bernstein waves are generated or absorbed. The ion source can be further operated a very low voltages ( $\sim 500 \text{ V}$ ) to form nano-structures.



**Fig. 10.** View of the older version of the microwave ion source installed in the low energy facility.

## The IUAC High Performance Computing Facility

The Centre's high performance computing facility, funds for which were sanctioned by the Department of Science and Technology in 2008, was inaugurated in April, 2010. The facility provides supercomputing access to university users across the country, and also provides a boost to the ion-solid, nuclear physics and atomic physics simulation programs at IUAC. The facility is targeted at computational chemists, physicists and biologists in the university system, working in the areas of materials science, atomic and molecular physics and chemistry, radiation biology and nuclear physics.

The facility, currently one of the largest in the country, consists of three systems: a 200-node, 3200 core, 61 teraflop MPI cluster; a 96-node, 768 core, 9 teraflop cluster; and a 80-core shared memory Sun Enterprise server with 256 GB of RAM. Together, the facility is configured to take on a variety of scientific HPC applications, with different requirements of CPU and memory access. A feature of the facility is the data centre housing the distributed computing cluster. With a capacity of 600 servers and associated networking equipment in a space of 50 m<sup>2</sup>, this is one of the densest computing facilities. The cold water based in-rack cooling infrastructure in the data centre was the first such in the country when it was installed, and is capable of cooling 20 kW per rack, at power efficiency about 30% better than standard data centre precision air conditioning.

The facility is currently used by 90 research groups from 55 institutions in the country. The usage of the cluster computing infrastructure is also among the highest, with an average of 25 jobs running, 35 in queue, and 95% core utilization at any time. The user base is diverse, including groups from colleges in Tonk, Baraut and Chhota Udepur, universities in Srinagar, Thanjavur, Varanasi, Bhavnagar and Kolkata, and institutions like NPL, NCL, CECRI, and the IITs. The research domains are as diverse. Research work published include results from the exploration of the fragmentation of water molecules by ion impact, electronic and magnetic properties of Heusler alloys, unzipping of DNA under a periodic drive, and identification of candidate compounds which act against multi-drug resistant tuberculosis.

## Workshops / Schools / Acquaintance Programs (April – October, 2013)

**One Day Acquaintance Program at Guru Ghasidas Vishwavidyalaya (A Central University), Bilaspur:** To make the users aware about the facilities and to avail

the facilities available at IUAC, Department of Pure and Applied Physics, Guru Ghasidas Vishwavidyalaya, Bilaspur organized “One Day Acquaintance Programme of Inter University Accelerator Centre (IUAC), New Delhi” on July 19, 2013. The objective of the programme was to spread awareness to the researchers of this region with the facilities available at IUAC and the procedure for availing these facilities. The programme was attended by all the officers, professors, and research scholars of the university along with delegates who came from central region of the country. A total of 115 delegates from various institutions/ universities/ colleges participated in the programme.



*Dignitaries on dias during the inauguration of the two acquaintance programmes.*



**Acquaintance program at CCSU Meerut, UP :** One day acquaintance program (Sept. 20, 2013) on the utilization of IUAC ion beam facilities was held at Ch. Charan Singh University (CCSU), Meerut, UP. In association with Prof Rakesh Kumar, Head of Physics Department, CCSU and Dr. Beer Pal Singh, faculty member; Dr. Pravin Kumar co-ordinated the program. The program started with the inaugural speech by Dr. D Kanjilal, Director IUAC and chief guest of the event. About 150 participants from nearby universities and colleges attended the event. The attendance

certificate was issued to all participants in the end of the program.

An **International Conference** on 'Nanostructuring by ion beams' was organized at Gold Palace, Jaipur was jointly organized by Rajasthan university, Jaipur, MNIT, Jaipur and IUAC Delhi from 23<sup>rd</sup> to 25<sup>th</sup> October. There were one hundred and thirty four registered participants including nine foreign invited speakers/participants from Germany, Spain, Russia and Japan. There was a school on 'Ion beams in materials science' prior to the conference. There were sixteen invited talks, sixteen oral presentations and sixty nine posters. Prof. Y.K. Vijay, Rajasthan University and Dr. D.K. Avasthi, IUAC Delhi were chairman and co-chairman respectively. The convener and secretary for the event were Dr. A. Tripathi, IUAC and Dr. Kamendra Awasthi, MNIT Jaipur.

### **Conference on Particle Accelerators: Technology and Applications in Science (CPATAS)**

Inter-University Accelerator Centre organized a conference during April 4-5, 2013 on the particle accelerator technology and their use in basic and applied sciences. This conference was organized in close proximity to the 65th birthday of Dr. Amit Roy in honour of his life time contributions in this important field of development and research.



Dr. Amit Roy was felicitated by Dr. P.Singh, President, Indian Society for Particle Accelerator (ISPA), along with the Executive Committee Members Dr. D. Kanjilal and Dr. S. Chopra.

The topics related to energetic ion beams covered were:

- Accelerator Science and Technology
- Radioactive Ion Beams
- Applied Superconductivity and Cryogenics for Modern Accelerator
- Nuclear Structure and Reaction Dynamics
- Materials Science
- Atomic/Molecular Physics
- Radiation Biology
- Accelerator Mass Spectrometry

The conference was convened by Dr. D. Kanjilal, the present Director of IUAC and it was attended by about 250 physicists and engineers in the field of accelerators and applied areas from India and abroad. The participation of the conference was by invitation only and there were a total of 16 invited presentations from eminent personalities in these fields. The conference was concluded by a long reminiscence by the colleagues of Dr. Amit Roy, followed by a hearty and emotional speech by Dr. Roy himself.

Dr. D. Kanjilal took over charge on 24<sup>th</sup> July, 2013, from Dr. Amit Roy.

## **AMS Facility**

A new <sup>14</sup>C AMS facility, supported by the Ministry of Earth Sciences, is being set up at IUAC and will be operational in 2014. The proposed facility will have 500kV ion accelerator with two MC-SNICS ion sources. A sample preparation laboratory is also being set up to prepare <sup>14</sup>C samples with automated graphitization system. The proposed accelerator system can perform <sup>10</sup>Be and <sup>26</sup>Al measurements also with better precision than using existing <sup>15</sup>UD Pelletron accelerator. This new facility will provide <sup>14</sup>C, <sup>10</sup>Be and <sup>26</sup>Al AMS measurements to perform research in earth sciences as well as in other frontier areas of science such as climate change, biomedicine and forensic sciences, archeology and human heritage studies.

## **Forthcoming events**



- ❖ **The VI International Conference FUSION14 will be hosted by IUAC during February 24 - 28, 2014. All correspondence regarding the conference may be sent to: [fusion14@iuac.res.in](mailto:fusion14@iuac.res.in).**
- ❖ **International school on 'Ion Beam in Materials': October 2014**
- ❖ **International conference on 'Swift Heavy Ions in Materials Engineering and Characterization, SHIMEC' October 2014**

## Status of 15 UD Pelletron (1<sup>st</sup> April 2013 to 30<sup>st</sup> September 2013)

Operational performance of Pelletron was quite satisfactory from 1<sup>st</sup> April 2013 to 30<sup>th</sup> September 2013 with two unscheduled tank opening maintenance of Pelletron accelerator, in the month of April 2013 and July 2013.

The first unscheduled opening in April was due to instability in charging current. This was solved by an adjustment of pick-off wheel position. The second unscheduled opening occurred in July 2013, due to non-functioning of in-tank ion pumps. After opening tank, it was observed that the problem of ion pumps was due to damage of rubber coupler connecting rotating shaft RS-1 to alternator. This maintenance was during 17-22 July, 2013.

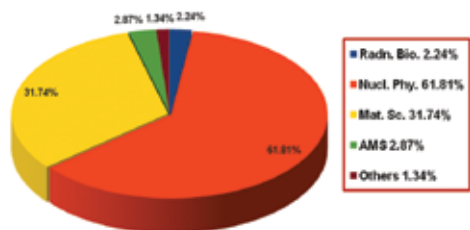
Maximum terminal voltage achieved during high voltage conditioning was 13.1 MV. 128 MeV of <sup>32</sup>S beam were delivered to user at the maximum terminal potential of 12.79 MV and 20 MeV of <sup>7</sup>Li beam was delivered to user at the minimum terminal potential of 4.98 MV.

Out of total beam time of 2176 hours, 626 hours of beam time was used for pulsed beam runs using multi harmonic buncher (MHB) along with low energy chopper and traveling wave deflector. <sup>11</sup>B, <sup>16</sup>O, <sup>19</sup>F, <sup>30</sup>Si and <sup>32</sup>S beams were bunched and delivered to users for different experiments. All the pulsed beam runs were quite stable.

### Statistical Summary

|                                |   |           |
|--------------------------------|---|-----------|
| Total Chain Hours              | = | 3669 Hrs. |
| Beam utilization time          | = | 2176 Hrs. |
| Beam change time               | = | 7 Hrs.    |
| Machine Breakdown time         | = | 273 Hrs.  |
| Machine scheduled maintenance  | = | 599 Hrs.  |
| Accelerator conditioning       | = | 260 Hrs.  |
| Beam tuning time               | = | 94 Hrs.   |
| Experimental setup time        | = | 18 Hrs.   |
| Machine setup and testing time | = | 52 Hrs.   |

**Fieldwise Breakup of Utilized Beam Time  
(April 2013 to September 2013)**



## User List: April to October, 2013

| S. No. | University / Institute / College     | Shifts utilized |
|--------|--------------------------------------|-----------------|
| 1.     | Allahabad University                 | 3               |
| 2.     | Aligarh Muslim University            | 16              |
| 3.     | BARC, Mumbai                         | 4               |
| 4.     | Bareilly College                     | 6               |
| 5.     | Calcutta University, Kolkata         | 1               |
| 6.     | Delhi University                     | 13              |
| 7.     | GGSIPIU, Delhi                       | 4               |
| 8.     | Guru Nanak Dev University, Amritsar  | 4               |
| 9.     | Gujarat University                   | 3               |
| 10.    | HNBG University, Garhwal             | 6               |
| 11.    | Hyderabad University                 | 3               |
| 12.    | IIT, Delhi                           | 6               |
| 13.    | Indian School of Mines, Dhanbad      | 2               |
| 14.    | IPR, Gandhi Nagar                    | 4               |
| 15.    | ISRO, Bangalore                      | 3               |
| 16.    | IUAC (Facility test and experiments) | 52              |
| 17.    | IUAC (Research Scholars/Associates)  | 30              |
| 18.    | Jaipur University                    | 3               |
| 19.    | Kalyani University                   | 3               |
| 20.    | Mumbai University                    | 5               |
| 21.    | Pondicherry University               | 5               |
| 22.    | Punjab University                    | 41              |
| 23.    | SINP, Kolkata                        | 13              |
| 24.    | SMST, Varanasi                       | 3               |
| 25.    | TIFR, Mumbai                         | 19              |
| 26.    | Utkal University, Bhubaneswar        | 5               |
| 27.    | VECC, Kolkata                        | 16              |

The uptime of machine for this period was 92.56% with 59.31% of beam utilization.

**Userwise Breakup of Utilized Beam Time  
(April 2013 to September 2013)**

