Chapter 1

ACCELERATORS

1.1 15UD Pelletron accelerator

Gaurav Raturi, Jaswant Singh, Pranav Singh, Suraj Kumar, Mohan Nishal, N. S. Panwar, M. P. Singh, Rakesh Kumar, Jagdish Prasad, Vijay P. Patel, Rajpal Sharma, Deeksha Khandelwal, G. R. Umapathy, Rajveer Sharma, Pankaj Kumar, Ksh. Devarani Devi, Mukesh Sota, Ambuj Mishra, Abhilash S. R., A. Kothari, P. Barua, Chandrapal, D. Kabiraj, S. Ojha, S. Gargari and S. Chopra

1.1.1 Operational summary

The 15 UD Pelletron accelerator was in regular operation during May 2023 to March 2024. The accelerator underwent maintenance twice. 546 shifts of beam time were delivered to 46 users from 32 different universities / colleges / institutes. The maximum terminal potential at which the beams were delivered was 13.39 MV and the maximum terminal potential attained during conditioning (without beam) was around 14.2 MV. Fig. 1.1 shows the distribution of the terminal potential used for beam runs for the mentioned period.

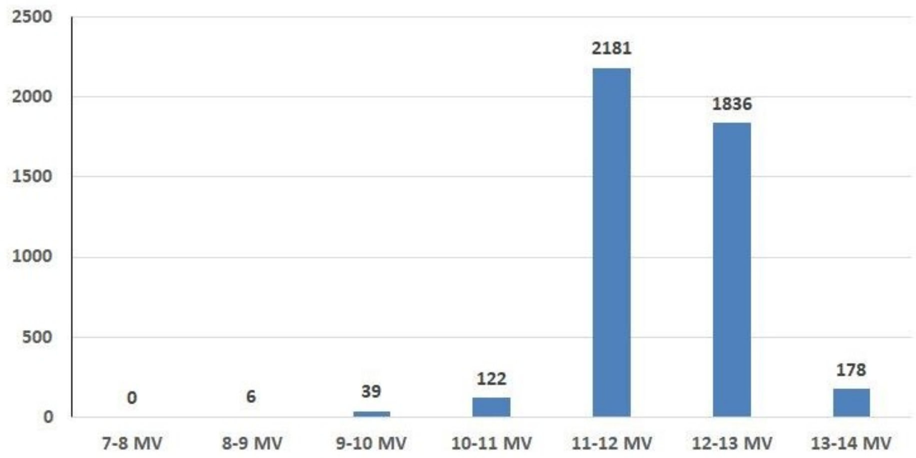

Figure 1.1: Voltage distribution graph in hours.

^{7}Li, ^{11}B, ^{12}C, ^{14}N, ^{16}O, ^{19}F, ^{28}Si, ^{30}Si, ^{31}P, ^{32}S, ^{48}Ti, ^{56}Fe, ^{58}Ni, ^{63}Cu, ^{107}Ag, ^{127}I and ^{197}Au beams were delivered to the users for their experiments. The operational summary of the accelerator from May 2023 to March 2024 is mentioned below:

- Total chain hours: 67,902 hours
- Total beam utilization: 4,365 hours
- Breakdown during operation: 336 hours
- Accelerator conditioning: 1,827 hours

Out of 4365 operational hours, 3041 hours were utilized by the users of nuclear physics facilities, 756 hours were utilized by users of materials science and the rest were utilized by users of radiation biology and accelerator groups. Fig. 1.2 shows the distribution of beam time with respect to different experimental fields. For various nuclear physics experiments ^{12}C, ^{16}O, ^{19}F, ^{28}Si, ^{30}Si, ^{31}P, ^{32}S and ^{48}Ti beams were pulsed for different time periods ranging from 250 ns to 4 μs and provided to the users for their experiment.

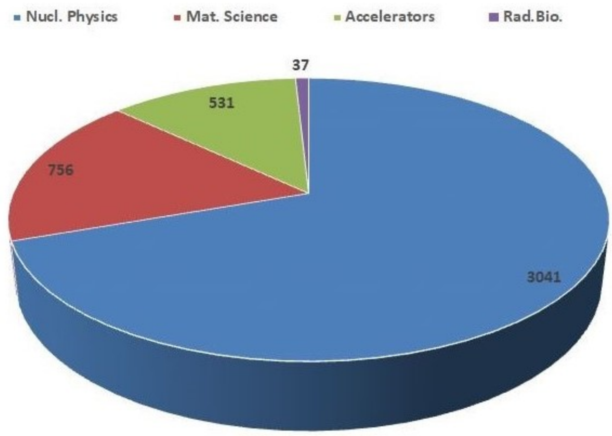

Figure 1.2: Experimental field-wise breakup of delivered beam time.

The linac campaign to cater users of high energy nuclear physics community started during the month of November 2023 and continued till March 2024. More than 300 shifts of beam time was delivered during this period. Pulsed beams of ^{12}C, ^{16}O, ^{28}Si, ^{30}Si, ^{31}P, ^{32}S and ^{48}Ti were delivered by the Pelletron accelerator and further accelerated by the superconducting linear accelerator.

There were some minor problems from the Pelletron side during the linac campaign. Initially a few problems were encountered in the ion source. The current was low during experiments in which ^{48}Ti beam was required. The source was operated at extreme conditions due to which the maintenance of the source had to be done a few times. The ion pump inside the accelerator showed very high pressure due to which we had to change the plan slightly and deliver the beams using the foil stripper instead of gas stripper. Also, a couple of units inside the Pelletron accelerator had to be shorted due to which the beam energy from the Pelletron accelerator was reduced. This was compensated by the linac.

1.1.2 Maintenance

The Pelletron accelerator was opened for maintenance in the month of March 2023 and maintenance continued till the end of April 2023. Routine maintenances were carried out to ensure smooth operation of the accelerator. In view of the upcoming linac run, the accelerator was once again opened during September-October 2023. Besides routine maintenance, the problem with the movement of the foil stripper assembly was looked into and resolved.

1.1.3 Ion source activities and maintenance

The 40 cathode MC SNICS source was operational throughout the year. Cathode loading was performed 7 times in the academic year to provide various beams to the users. There were many pulsing runs (approx. 427 shifts) due to which the source had to be operated at extreme conditions resulting in a series of breakdowns. Source maintenance was carried out 6 times in this academic year. Fresh caesium was loaded during November 2023, just before the start of the linac campaign. The Ionizer (Filament) of the source broke down, which had to be replaced in March 2024. During other maintenances, source cleaning and replacement of immersion lens were performed.

1.2 Linac and SRF

A. Rai, A. Pandey, R. N. Dutt, D. S. Mathuria, G. K. Chaudhari, P. Patra, J. Karmakar, B. Karmakar, S. S. K. Sonti, K. K. Mistri and P. N. Prakash

1.2.1 Operation

The operation of the superconducting linac (SC-Linac) began in the last week of September 2023 with the cool down of all the five cryomodules (Superbuncher, three accelerating modules and Rebuncher) to 4.2 K. The cooldown was followed by the usual offline conditioning and RF measurements. All the resonators were conditioned through the low-level multipacting barrier followed by high power pulse conditioning and Q-curve measurements. Helium processing [1] was also performed on a few eligible resonators in the 2nd and 3rd accelerating modules. The resonators were thereafter phase locked at the operational field levels after optimization of their coupling coefficients. The stability of the phase locks was observed for a period of more than a week and was accompanied with minor adjustments in the operational gradients and coupling coefficients. Fig. 1.3 shows the operational gradients achieved in the three accelerating modules. The offline preparations took ~ 3 weeks and the SC-linac was ready for beam acceleration by mid-October 2023. However, due to an unscheduled Pelletron tank opening to repair the dead-section foil stripper, the beam acceleration was delayed by about a month. A water leak in the cooling line of one of the RF power amplifiers in the linac control room further delayed the beam acceleration by about a week and it began only in the last week of November 2023. Beam delivery for scheduled experiments in HYRA / INGA and NAND beam lines has been continuing ever since and 13 experiments have been conducted with ~ 285 shifts of beam time delivered till March 31, 2024. The 14th experiment with ^{12}C beam is presently underway and will end on 2nd April 2024 marking the end of the present linac campaign. The maximum energy gain from the linac was 11.4 MeV/q for a ^{48}Ti 14^{+} beam of 145 MeV energy from the Pelletron accelerator.

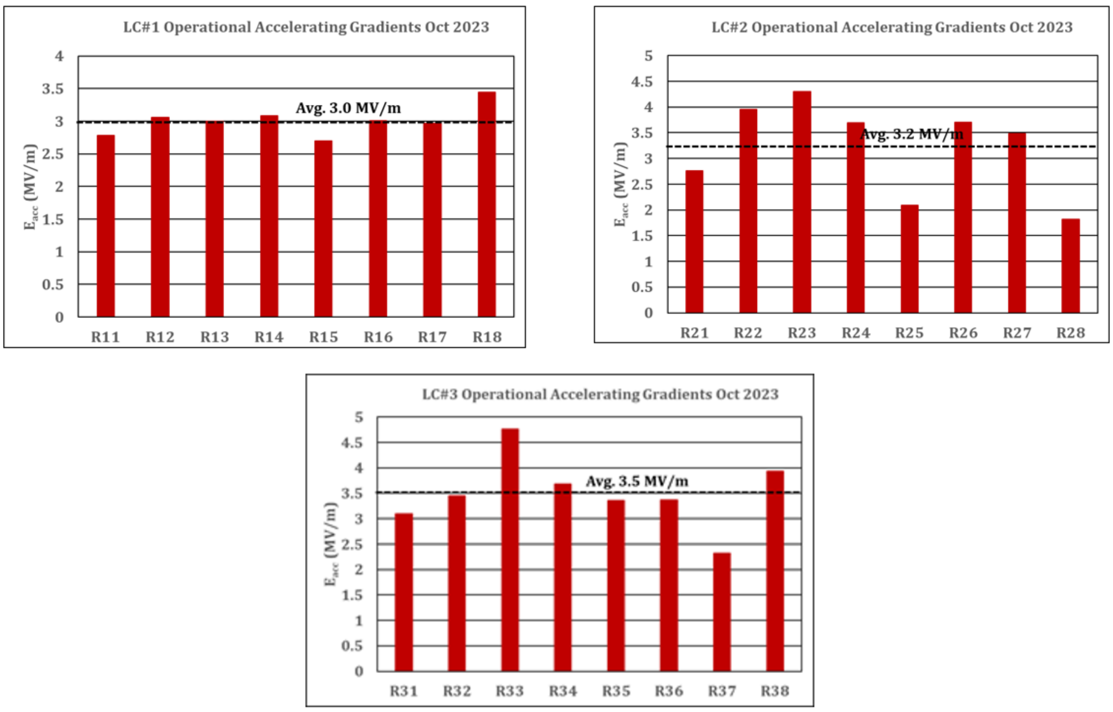

Figure 1.3: Operational gradients in the three accelerating modules.

The beams accelerated through the SC-linac along with the injection energy from the Pelletron, maximum available beam energy from the linac, maximum energy used in each experiment, the experimental area and the duration of the experiment are listed in Table 1.1.

Table 1.1: Details of the beams accelerated through the SC-linac for user experiments.

Sl. no.	Beam specis	Energy from Pelletron	Max. energy available	Max. energy used in expt.	Beamline	Duration
1	^{48}Ti (14^+)	145 MeV	305 MeV	285 MeV	NAND	Nov. 26 - Dec. 05 ($\sim$ 31 shifts)
2	^{48}Ti (14^+)	145 MeV	305 MeV	214 MeV	HYRA	Dec. 09 - Dec. 15 Dec. 20 - Jan. 01 ($\sim$ 50 shifts)
3	^{48}Ti (14^+)	145 MeV	305 MeV	263 MeV	HYRA	Jan. 01 - Jan. 11 ($\sim$ 24 shifts)
4	^{30}Si (9^+)	125 MeV*	218 MeV	187 MeV	HYRA	Jan. 14 - Jan. 18 ($\sim$ 13 shifts)
		115 MeV*	209 MeV	156 MeV	HYRA	Jan. 20 - Jan. 23 ($\sim$ 9 shifts)
5	^{30}Si (9^+)	115 MeV	209 MeV	208 MeV	NAND	Jan. 24 - Jan. 31 ($\sim$ 21 shifts)
6	^{30}Si (9^+)	115 MeV	209 MeV	200 MeV	HYRA	Feb. 01 - Feb. 04 ($\sim$ 11 shifts)
7	^{32}S (9^+)	115 MeV	209 MeV	164 MeV	HYRA	Feb. 09 - Feb. 13 ($\sim$ 12 shifts)
8	^{28}Si (9^+)	115 MeV	209 MeV	209 MeV	HYRA	Feb. 14 - Feb. 19 ($\sim$ 16 shifts)
9	^{28}Si (9^+)	115 MeV	209 MeV	180 MeV	NAND	Feb. 19 - Feb. 26 ($\sim$ 23 shifts)
10	^{28}Si (9^+)	115 MeV	209 MeV	190 MeV	INGA	Feb. 26 - Mar. 01 ($\sim$ 12 shifts)**
11	^{28}Si (9^+)	115 MeV	209 MeV	155 MeV	INGA	Mar. 03 - Mar. 07 ($\sim$ 15 shifts)
12	^{31}P (9^+)	115 MeV	209 MeV	184 MeV	NAND	Mar. 08 Mar. 12 - Mar. 16 ($\sim$ 13 shifts)
13	^{16}O (6^+)	80 MeV	139 MeV	133 MeV	NAND	Mar. 17 - Mar. 22 ($\sim$ 22 shifts)
14	^{12}C (6^+)	80 MeV	133 MeV	125 MeV	NAND	Mar. 27 - Apr. 01 ($\sim$ 15 shifts)

* Beam injection energy was reduced in between the experiment due to shorting of two units in the Pelletron. The SC-linac was subsequently re-tuned for the reduced beam energy.

** Experiment was called off by the user.

1.2.2 Linac operation with the high current injector

In a milestone development, a ^{20}Ne, 7^+ beam $\left(\frac{A}{q} = 2.86\right)$ of 36 MeV energy from the High Current Injector (HCI) was injected into the SC-linac for post acceleration. The best time width achieved from the super-buncher at the linac entrance was 820 ps. The beam could be accelerated through the first 12 Resonators of the linac, *i.e.*, up to R24 (the fourth resonator in the second accelerating module). An energy gain of 41 MeV was obtained, increasing the beam energy to 77 MeV. The energy spectrum started displaying multiple peaks from R18 (the last resonator in the first module) onwards and the actual acceleration peak disappeared in the background beyond R24. It was therefore no longer possible to measure the energy gain beyond R24. A large time width ($\sim$ 800 ps), coupled with a large energy spread in the beam injected into the linac, was thought to be the reason for the observed phenomenon. Nevertheless, this was an important step forward towards the coupling of HCI with the SC-linac.

1.2.3 Superconducting resonator fabrication

1.2.3.1 Fabrication of spare QWRs and slow tuners for SC-linac

Significant progress has been made towards the completion of 6 spare Quarter Wave Resonators (QWRs) and 14 slow tuners for the SC-linac. The remaining 3 out of the 6 bare niobium cavities were bulk electropolished and subsequently heat treated at 850 °C. The open-end transition flanges were electron beam (EB) welded to all the 6 cavities after trimming them to their proper length. The stainless steel (SS) outer jackets for these resonators were also machined to proper length. These have to be now slit and installed on the 6 cavities followed by the EB welding of beam port and coupling port transition flanges and full TIG welding of the SS jacket. Fabrication of 13 out of the total 14 slow tuner bellows was also completed.

1.2.3.2 Fabrication of 5-Cell 650 MHz $\beta = 0.61$ niobium cavities

The Variable Energy Cyclotron Centre (VECC) has to develop two 5-Cell 650 MHz, $\beta = 0.61$ niobium elliptical cavities [2] for the Fermilab under the IIFC collaboration (Indian Institutions and Fermilab Collaboration). IUAC is extending its technical expertise and SRF infrastructure. All the EBW related work for the project is being carried out at IUAC. A team from VECC has been regularly visiting IUAC to carry out the work. They have visited four times in the last academic year and the following progress has been made:

(A) Eight niobium half cells were e-beam welded at the iris to complete four dumb bells. With this, all the 8 dumb bells required for completing the two cavities, are ready.

(B) Weld parameter development of the stiffener ring to the half cells was completed successfully and qualified after visual inspection and radiography tests to determine the depth of penetration. More than fifteen trial welds were carried out on Nb samples and dummy half cells for this development.

(C) Four sets of stiffener rings have been successfully attached thereafter to 4 dumb bells. EBW of the remaining four sets is pending and will be carried out during the next visit of the VECC team. In a bid to develop the e-beam welding parameter for the critical equator joint, the first trial was taken on a set of niobium half cells. The result was quite good with a visible under bead, although it was not uniform and therefore required slight tweaking of the parameter. A second trial is planned in the next visit of the VECC team.

(D) For attaching the Nb-Ti Spool to the End Groups, at the ends of the cavity, two trials of a ring on the beam tube were taken. The piece will be cut to determine the depth of penetration to ascertain if any further trial is required.

References:

1. Helium Processing of Niobium Quarter Wave Resonators, A. Rai *et. al.*, Proceedings of 8th DAE-BRNS Indian Particle Accelerator Conference (InPAC-2018), January 9-12, 2018, RRCAT, Indore, ID-15.
2. Design of 650 MHz, $\beta = 0.61$, 5-cell dressed SRF cavity as per functional requirement specification under IIFC collaboration, Sudeshna Seth *et al.*, Proceedings of 8th DAE-BRNS Indian Particle Accelerator Conference (InPAC-2018), January 9-12, 2018, RRCAT, Indore, ID-45.

1.3 1.7 MV tandem accelerator-based ion beam analysis facility

G. R. Umapathy, Jaswant Singh, Pranav Singh, Suraj Kumar, Mohan Nishal, N. S. Panwar, Jagdish Prasad, Vijay P. Patel, Mukesh Sota, Sunil Ojha, S. Gargari and S. Chopra

1.3.1 Operation

The 1.7 MV Tandem accelerator for ion beam analysis techniques which performs Rutherford Backscattering Spectrometry (RBS), RBS-Channelling, Resonance-RBS and Elastic Recoil Detection Analysis (ERDA) measurements for hydrogen, is in continuous operation. In the year 2023-24, a total of 300 measurements of 26 users from 19 universities, colleges and institutes were performed. The facility was operational throughout the year (Fig. 1.4 show two typical RBS spectra).

1.3.2 Maintenance

1.3.2.1 Ion source maintenance

The RF charge exchange ion source maintenance was performed twice during this period, the first one during April - May 2023 and the second one during December 2023 - January 2024. On both the occasions, one ampule (5 gm) of rubidium was loaded. During the 1st cycle of operation, it was found that the optimum temperature to produce maximum current from the source was 170 °C. The source was again opened for maintenance in the month of December 2023. In the current operation cycle, the source was operated at optimized temperature and showed stable and uninterrupted operation. The procedure for the quartz tube cleaning was optimized and on successful removal of the inner deposited layer (etching via 45% HF), the same has been used after the ion source maintenance in January 2024 and the source has been working fine since then.

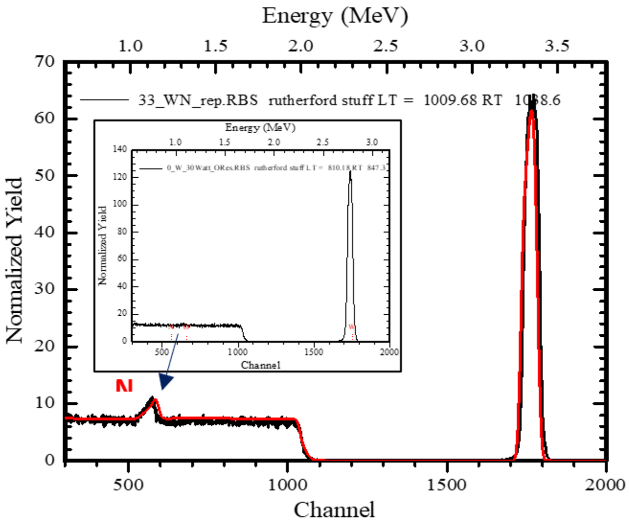

Figure 1.4: RBS spectra for N detection at nitrogen resonance energy of 3.67 MeV and for the same sample repeated at oxygen resonance energy of 3.045 MeV.

1.3.2.2 The 5SDH-2 Pelletron accelerator and end-station maintenance

During operation, the terminal potential of the accelerator dropped to 0.80 MV. It was observed that the terminal remained stable around 0.8 MV and could be raised with a higher capacity Charging Power Supply (CPS). Higher charge loss was observed when the potential was increased to 1 MV for regular operation. The charge loss was around 50% with 35 psi SF_6 gas in the accelerator tank. The SF_6 was refilled to 60 psi for the next cycle of operation, and the dew point was measured to be -26 °C. In the recent operation, no charge loss was observed.

1.4 Low energy ion beam facility

Pravin Kumar and A. Tripathi

1.4.1 Operation

The Low Energy Ion Beam Facility (LEIBF) [1] based on a 10 GHz, NANOGAN type of electron cyclotron resonance ion source (based on fully permanent design) has been in regular operation since 2000 with the objective of realizing fundamental and novel applications in the fields of atomic and molecular physics and materials science. For this purpose, the LEIBF had a design in which the ion source and its peripheral electronic and electrical equipment are installed on a high voltage (maximum 400 kV) platform along with vacuum pumps. The power is supplied through a 25 kW isolation transformer. In the ion source, a plasma is confined using suitable magnetic fields, and ions are extracted by applying appropriate electric fields to form a beam using electromagnetic lenses. The energy and momentum of the ions are analysed by a dipole magnet and it is transported to the desired beam line for research experiments. There are three beam lines at 75°, 90° and 105° for research experiments in atomic and molecular physics and materials science. Fig. 1.5 shows the layout of the LEIBF. During April 2023 to March 2024, there was a long breakdown maintenance and 87 shifts of beam time was used for research and testing.

1.4.2 Maintenance

For proper and smooth operation of the LEIBF, it is essential that its various components (electronic amplifier, power supply, dipole magnet, vacuum pump, electromagnetic lens, remote control of accelerator from computer etc.) keep functioning properly. Hence, repairs / maintenance (preventive and predictive) of these components / units were carried out from time to time by various support laboratories such as the

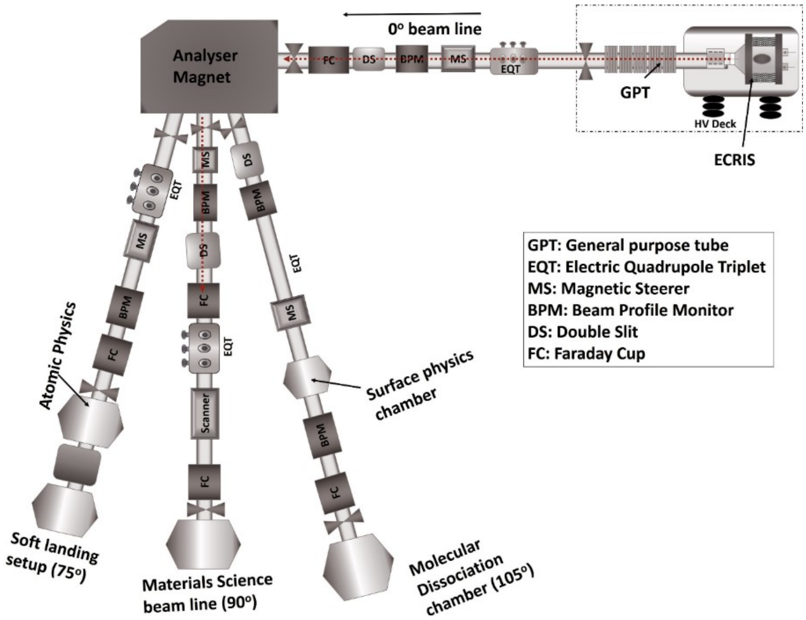

Figure 1.5: Layout of the LEIBF.

Ion Source Group (ISG), Vacuum Systems and Diagnostics (VSD) group, Remote Control (REC) and Beam Transport System (BTS) group.

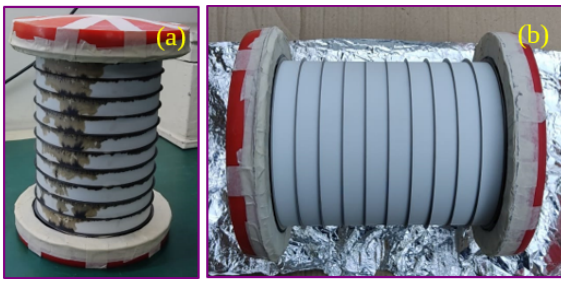

Figure 1.6: A GP tube (a) before and (b) after cleaning.

During the last year, there was a breakdown of 400 kV power supply and the same was systematically investigated by a team comprising members from various support groups. A committee was formed to decide on the essential maintenance work to be undertaken. After detailed discussions, it was decided to take up a thorough cleaning of the ion source and GP tubes as the same was not taken up for many years.

ECR source cleaning: The ECR source was cleaned and serviced with help from Mr. Kedar Mal and Dr. G. O. Rodrigues. The source was reassembled and tested and is operational now.

GP tube cleaning: After detailed discussions, elaborate GP tube cleaning was planned and undertaken with help / guidance of Mr. Mukesh Kumar, Mr. R. K. Gurjar, Mr. Ashok Kothari, Mr. Kedar Mal, Mr. Sunil Ojha, Mr. Satinath Gargari, Mr. Abhishek Rai, Dr. C. P. Safvan and Dr. G. O, Rodrigues. A thorough cleaning was undertaken using water jet cleaning, sandblasting and cleaning in alcohol. The tubes were subsequently baked in oven and leak-tested. The whole assembly was re-assembled, leak tested and has been functioning normally since then. A typical GP tube before and after the cleaning is shown in Fig. 1.6.

The various steps are summarized in Fig. 1.7 which led to a substantial improvement in the performance of GP tubes. The typical values for the first GP tube are summarized in Fig. 1.8. The other details are included in Sec. 3.1.11.

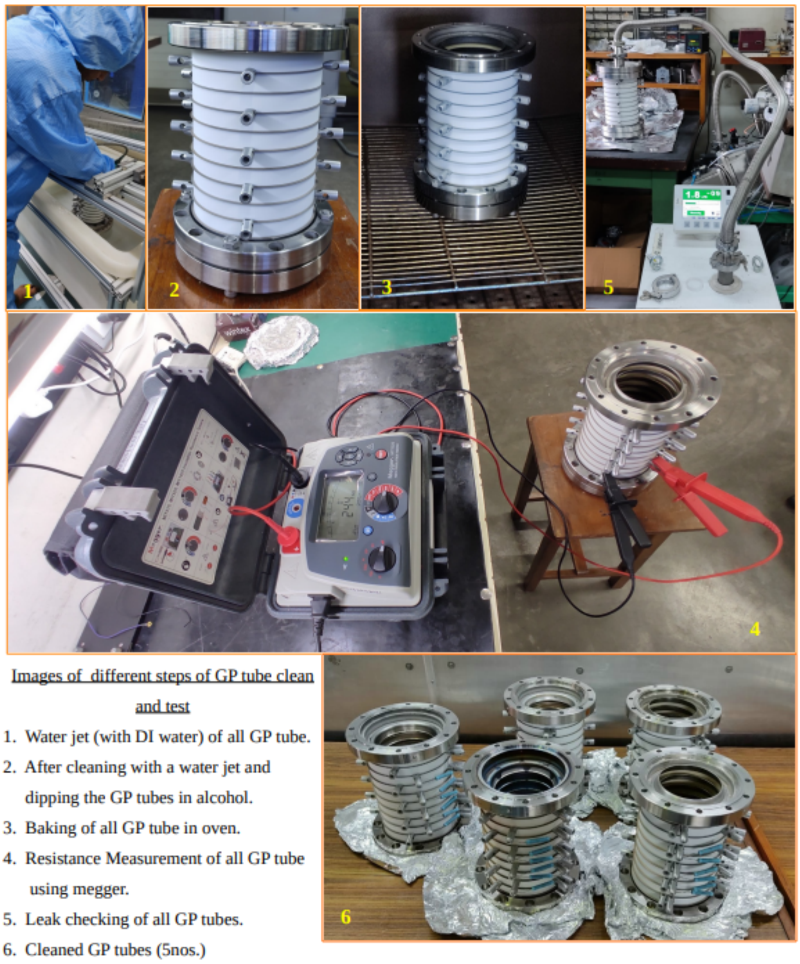

Figure 1.7: Steps followed for cleaning the GP tubes.

GP Tube serial no.	Column/ section of GP Tube	Resistance measurement at different voltages					
		Before Cleaning			After sandblast, water jet cleaning and baking		
		1kV	2.5kV	5kV	1kV	2.5kV	5kV
1st G P Tube	1	139.7 MΩ	2.96 MΩ	2.17 MΩ	56.00GΩ	92.90GΩ	129.60GΩ
	2	139.6 MΩ	8.56 MΩ	8.64 MΩ	71.30GΩ	123.00GΩ	182.10GΩ
	3	264 MΩ	9.39 MΩ	6.90 MΩ	74.90GΩ	122.40GΩ	179.10GΩ
	4	343 MΩ	9.88 MΩ	6.94 MΩ	81.70GΩ	117.00GΩ	172.80GΩ
	5	251 MΩ	8.92 MΩ	5.81 MΩ	81.60GΩ	116.50GΩ	161.00GΩ
	6	257 MΩ	6.81 MΩ	5.56 MΩ	73.90GΩ	111.60GΩ	158.60GΩ
	7	159 MΩ	6.93 MΩ	6.56 MΩ	73.80GΩ	106.50GΩ	145.40GΩ
	8	223 MΩ	5.62 MΩ	5.06 MΩ	70.90GΩ	103.50GΩ	135.50GΩ
	9	139.9 MΩ	8.02 MΩ	8.52 MΩ	67.40GΩ	82.00GΩ	96.70GΩ
	10	150.9 MΩ	11.28 MΩ	11.64 MΩ	70.00GΩ	86.60GΩ	110.70GΩ
	Total (1-10)	363 MΩ	105.1 MΩ	98.7 MΩ	68.10GΩ	98.10GΩ	144.90GΩ

Figure 1.8: Parameters of the first GP tube.

1.4.3 Research work

While the LEIBF can be used for a wide range of research in different fields, a few of the research work carried out are summarized below. Gas mixing in electron cyclotron resonance plasma and the consequent isotope anomaly effects [2,3] have been obscure from the beginning, with no model fully explaining the experiments conducted for them. In Xenon plasma, it was observed for the first time that if the amount of the heavier isotope exceeds that of the lighter isotope, the anomaly effect does not disappear but remains present as a mirror image on the negative axis [4].

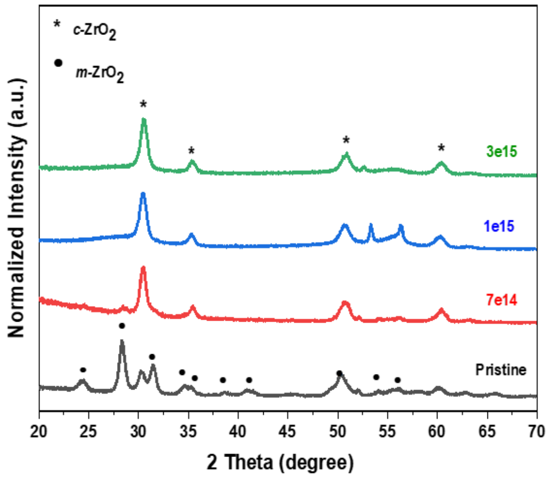

Figure 1.9: X-ray diffraction spectra of zirconia after bombarding it with Kr ions at 1.4 MeV energy for different durations.

Zirconia (ZrO_2) is found as a monoclinic crystal at normal temperature and pressure, while it is tetragonal between 1170 °C and 2370 °C and cubic above 2370 °C. Since zirconia is widely used in cubic form in technology development, the stability of its cubic phase is an important area of research which is usually achieved by adding ytterbium oxide (Y_2O_3) or calcium to zirconia. Bombarding zirconia with krypton ions at 1.4 MeV energy has resulted in the direct conversion of monoclinic phase to cubic phase and its stability (see Fig. 1.9; recording of X-ray diffraction spectrum confirms cubic crystal).

Hafnium dioxide (HfO_2) or hafnia has also been shown to form mixed or pure phases by bombarding them with ions of different energies, as shown in Fig. 1.10.

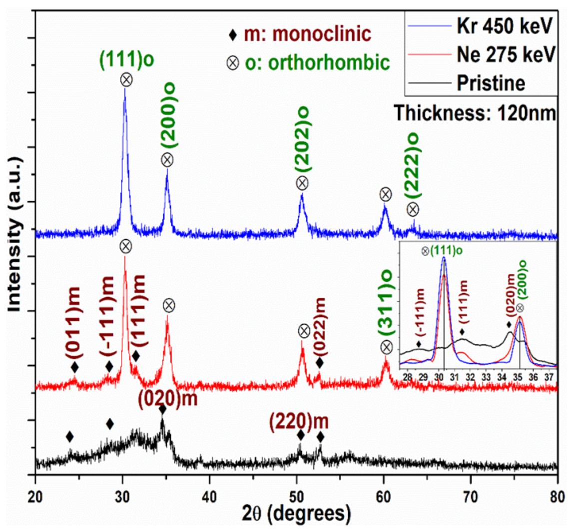

Figure 1.10: X-ray diffraction spectrum of hafnia with and without bombardment by different ion beams (different energies and masses). The fluence was 1.5×10^{16} /cm^2.

The above three research works were submitted with detailed description for Ph.D. degree in this academic year, out of which one research work has been approved for the degree and the other two research works are under review. The research activities associated with atomic and molecular physics are covered in Chap. 5.

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1.5 AMS and geochronology facilities

1.5.1 Accelerator mass spectrometry

Deeksha Khandelwal, Leema Saikia, Pavitra V. Kumar, Anit Dawar, Surabhi Tiwari, Mahadev, Abhishek Kumar, Prem Kumar, Gaurav Raturi, Jaswant Singh, N. S. Panwar, Pranav Singh, Mohan Nishal, Jagdish Prashad, Rakesh Kumar, Vijay P. Patel, Mukesh Sota, Prem Verma, Rajveer Sharma, Madhav Krishna Murari, Pankaj Kumar, S. Ojha, S. Gargari, S. Chopra and A. C. Pandey

An Accelerator Mass Spectrometry (AMS) facility for the measurement of ^{14}C, ^{10}Be and ^{26}Al, based on a 500 kV Pelletron accelerator is in operation since March 2015. Carbon sample processing and graphitization are performed in a graphitization laboratory while ^{10}Be and ^{26}Al samples are processed in a clean chemistry laboratory.

1.5.1.1 Graphitization laboratory

The graphitization laboratory is routinely utilized for the sample pre-treatment and graphitization of charcoal, wood, macrofossils, plant remains, sediment, paper, bones, textile and carbonate samples (shells, foraminifera). It is equipped with three Automated Graphitization Equipment (AGE) which are coupled with three Elemental Analysers (EA) for the graphitization of organic samples and one Carbonate Handling System (CHS) for the graphitization of carbonate samples. During April 2023 - March 2024, 1062 samples have been pre-treated and graphitized by 52 users from different universities and institutes for their research work. One of the AGE system is under maintenance because its reactors are not heating.

1.5.1.2 Clean chemistry lab for ^{10}Be and ^{26}Al sample preparation

Sample preparation is a very important part in the measurement of cosmogenic radionuclides (CRNs) using AMS. In particular, for ^{10}Be and ^{26}Al, chemical pre-treatment is a long process and needs specifically designed work area. For this, a clean AMS chemistry laboratory has been developed at IUAC which is being used for pre-concentration of Be and Al. This includes initial physical processing, mineral separation and extraction of Be and Al from bulk sample.

During the last academic year, 196 samples (^{10}Be / ^{26}Al) belonging to 11 users from 10 institutes were processed for AMS measurements. Along with the samples, 25 process blanks and 18 standard samples were prepared. Quality checks were also carried out to test the validity of sample processing protocol and to identify the background contamination sources, if any, present in lab. To keep the background contamination at the minimal level, cleaning and maintenance of lab is done at regular intervals. This year, the HEPA (High Efficiency Particulate Absorbing) filters of fume hoods and AHU were changed. After the required maintenance, the background contamination levels of clean lab were checked and minimized.

1.5.1.3 XCAMS facility

AMS measurements: The compact ^{14}C Accelerator Mass Spectrometer eXtended for ^{10}Be and ^{26}Al (XCAMS) is routinely utilized for the measurement of ^{14}C, ^{10}Be and ^{26}Al. A total of 811 samples have been measured in the period from April 01, 2023 to March 31, 2024. 61 users from different institutes have utilized this facility for their research work. Fifteen research paper have been published in peer-reviewed journals using the data produced by the AMS facility of IUAC.

During the last academic year, maintenance activities related to MC-SNICS ion source, magnet power supply, GVM, gap lens etc. were carried out.

1.5.2 National geochronology facility

Deeksha Khandelwal, Leema Saikia, Pavitra V. Kumar, Anit Dawar, Surabhi Tiwari, Abhishek Kumar, Prem Kumar, Mahadev, Rajveer Sharma, Madhav Krishna Murari, Pankaj Kumar, S. Ojha, S. Gargari, S. Chopra and A. C. Pandey

1.5.2.1 High Resolution Secondary Ion Mass Spectrometer

Large forward geometry High Resolution Secondary Ion Mass Spectrometer (HR-SIMS) (model: CAMECA IMS 1300-HR3) has been operational at IUAC since December 2021. HR-SIMS facility has been routinely utilized for the U-Pb and oxygen isotope studies in zircon, depth profiling studies in multi-layered materials and study of Al-Mg isotope systematics in Ca–Al-rich inclusion (CAIs) in meteorites. A total of 1687 measurements in samples from 11 users from 6 universities and institutes have been completed during this year.

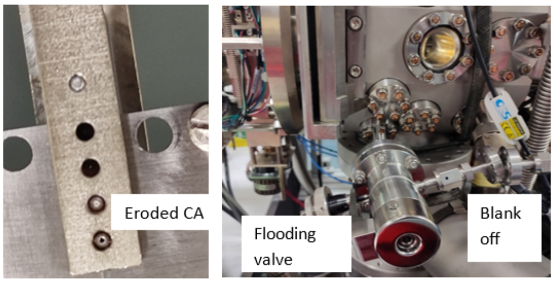

Figure 1.11: Eroded contrast apertures (left) and oxygen flooding valve and blank-off (right).

Maintenance activities related to the entrance slits and contrast apertures (left panel of Fig. 1.11), PBMF apertures, z-axis movement of the analysis chamber, oxygen flooding valve (right panel of Fig. 1.11) and RF coil power failure in oxygen ion source were carried out this year.

1.5.2.2 Femto second laser ablation high resolution inductively coupled plasma spectrometry

Laser Ablation High Resolution Inductively Coupled Plasma Mass Spectrometer (LA-HR-ICPMS) is a pivotal analytical tool in geochronological studies, particularly in U-Pb isotopic analysis of zircon grains and REE analysis. LA-HR-ICPMS was installed in IUAC in 2018 and is being used since then for various research problems. During 2023-2024, the type of samples analysed using this instrument include zircon grains fixed on epoxy mounts, nuclear targets and powdered materials. About 2832 spots / samples of 6 users from 5 universities / institutes were analysed. Utilizing U-Pb geochronology techniques facilitated by the LA-HR-ICPMS, researchers aimed to unravel the intricate processes underlying the formation of tourmaline and to determine the age range of detrital formations. These endeavours underscore the significance of advanced analytical methods in enhancing our understanding of geological phenomena and earth history.

The LA-HR-ICPMS encountered significant maintenance challenges during the last academic year. The system experienced a major breakdown related to the absence of counts and plasma ignition. Rigorous troubleshooting efforts ensued, including thorough cleaning of the chiller filters, inspection of all connections and multiple attempts to restart the system. Subsequently, critical components such as the power supply module were replaced and repairs were carried out on the chiller fans. These measures were crucial in restoring functionality to the LA-HR-ICPMS, ensuring its continued operation for the analysis of diverse samples.

1.5.2.3 Quadrupole - inductively coupled plasma spectrometry

ICP-MS technique offers very efficient and convenient method for elemental characterization of samples analysis at ppb to ppt level. Quadrupole ICPMS (Q-ICPMS) is such an instrument which utilizes a quadrupole as mass analyser. This instrument can be used for a wide range of applications like chemical identification of geological, environmental, biological samples; quality analysis of ground water; toxic metal contamination in soil and water, etc. ICP-MS technique can measure metal concentrations as low as 0.1 ppb. At IUAC, Q-ICPMS system equipped with auto-sampler was installed in 2018 and is being used regularly since then. In the last year this facility was used for analysis of about 2134 samples by 35 users from different institutions. Type of samples studied included bulk sediment, clay samples, dust particles suspended in air, plant samples, fish samples, etc. In addition, the facility was also used for precise estimation of ^{9}Be and ^{27}Al in quartzite samples as partial requirement for AMS measurements for surface exposure studies.

1.5.2.4 Field emission–scanning electron microscope

Field Emission–Scanning Electron Microscope (FE-SEM) is a widely used technique to examine the topography at micron, sub-micron and nano-scale level. FE-SEM along with Coater (gold and carbon; JEOL make, Model No. JSM-7610F) is installed at IUAC as shown in Fig. 1.12.

FE-SEM enables examination of a very broad range of sample types. Rocks, nuclear targets, materials science and atmospheric samples are studied using FE-SEM. Zircon grains for the characterization of growth zoning are studied using Cathodoluminescence (CL) detector. During 2023-2024, more than 30 users from 16 universities / institutes from all over India with 254 samples have utilized the facility.

Surface morphology of the following types of samples has been imaged using FE-SEM:

Figure 1.12: FE-SEM with coating unit installed at IUAC.

(A) *Geological samples:* Fluvial samples of Cauvery river basin and Thamirabarani river basin, Foraminifera images from north-east India etc.
(B) *Cathodoluminescence (CL):* Zircon grains from Arunachal Pradesh, Quartz (Johaz Rajasthan), Detrital Zircons from Manipur, granite rock of Ladakh, felsic minerals in Granitoid from Bundelkhand and Lalitpur district, materials science samples such as nickel oxide thin films over glass substrate, synthesis of ZnO, hBN pristine and exfoliated, high energy irradiation CeO_2.
(C) *Nuclear targets:* $^{120,124}Sn$.
(D) *Cross-sectional samples:* Cross sectional SEM images of Pervoskite substrate, Si / SiO_2 heterojunction between sulphide and Pervoskite, Y-doped HfO_2 on platinized Si substrate.
(E) *Atmospheric sciences:* Surface morphology of Particulate Matter (PM10) on quartz paper.

Maintenance activities related to TMP, interlock, water sensor strip and baking (Fig. 1.13) and alignment of FE-SEM to resolve the issue of sputter ion pump were taken up during the last year.

Figure 1.13: Baking of the column.

1.5.2.5 Wavelength dispersive X-ray fluorescence spectrometer

X-ray fluorescence (XRF) spectrometer was installed at IUAC in 2018 and is routinely used by different users across the country. XRF study helps to find the different geological processes by knowing the quantity of elements or oxides found in a geological sample 13 sediment standards including JMS-1, PACS-3, JSO-1, MESS-4, JSD-3, GXR-2, GXR-6, JLK-1, NCSDC73307, HISS-1, SDC-1, JSD-1, JSD-2 have been used to prepare the calibration for sediment samples.

From April 2023 to March 2024, 238 unknown (sediment) samples of 4 users from 1 university and 2 institutes along with 92 standard samples, considered as unknown, were measured using the XRF spectrometer. Maintenance activities related to X-ray tube were carried out to ensure smooth operation of the XRF system.

1.5.2.6 X-Ray diffractometer

An X-ray Diffractometer (XRD) was installed at IUAC in 2017 and is being routinely used by different users across the country. Characterization of different types of samples from geological, archaeological, materials science, nuclear targets is done using the p-XRD method. This method helps to find out the different crystal parameters or phases in a sample. In earth science, this study helps in better understanding of paleoclimatic reconstruction, soil forming processes, weathering profile etc. of a specific region. Similarly in materials science or nuclear science it helps to know the properties of matter.

From April 2023 to March 2024, 479 samples of 21 users from 8 different universities and 5 institutes were measured using XRD.

1.6 Low energy negative ion implanter facility

Ksh. Devarani Devi, G. R. Umapathy, S. Ojha, Rajveer Sharma, Gaurav Raturi, Jaswant Singh, Pranav Singh, Suraj Kumar, Mohan Nishal, N. S. Panwar, M. P. Singh, Rakesh Kumar, Jagdish Prasad, Chandrapal, A. Kothari, P. Barua, Deepak Kumar Munda, Kundan Singh, Vijay P. Patel, Mukesh Sota, R. K. Gurjar, Mukesh Kumar, S. Gargari and S. Chopra

1.6.1 Operation

The operational status and ion beam delivery of the implanter facility had been excellent during the academic year 2023-2024. A variety of ion species were produced in the energy range 30 - 200 keV and utilized for ion implantation and irradiation experiments. Users from different colleges, universities and institutes availed the beam time. The operational statistics of the facility were as under:

- Number of users: 17
- Number of samples implanted: 585
- Ion beams delivered: ^{7}Li, ^{11}B, ^{31}P, ^{48}Ti, ^{58}Ni, ^{59}Co, ^{63}Cu, ^{107}Ag and ^{197}Au
- Energy range: 30 - 200 KeV
- Ion fluence range: 1×10^{10} - 5×10^{17} ions/cm^2

1.6.2 Maintenance

The implanter accelerator had a smooth run. The Ion source also performed well. However, a few minor breakdowns occurred in the ion source, beam line components, vacuum system and the target ladder assembly, which were resolved. The Cockcroft Walton voltage multiplier, ion source, general purpose accelerating tubes, high voltage room and high voltage decks were cleaned at regular intervals to avoid any discharge paths formed due to dust. Following are the detaills of the maintenance activities:

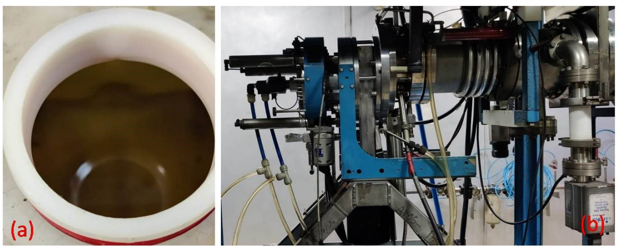

Figure 1.14: (a) the damaged coolant (LOBS) inside the reservoir and (b) the ion source with coolant lines.

Ion source: The cathode electrode experienced fluctuations in voltage and current. It happens mostly due to the discharge paths caused by cesium contaminated surfaces when the ion source runs for long duration. Often, it demanded removal of the cesium contaminated surfaces. The cathode wheel and its shroud were cleaned thoroughly in every cathode loading, and thereafter the ion source was baked and conditioned. It was observed that the insulating properties of the coolant (Fig. 1.14 (a)) were degraded and it formed a conducting path to both the cathode as well as the high voltage deck. The problem was fixed by replacing the contaminated coolant with fresh coolant.

Beam line components: There were a few instances of malfunctioning of the Faraday Cup controllers, which were resolved.

Vacuum system: The pneumatic valve of the turbo pump, namely TP-0-11, in the ion source, was intermittently closing and opening. The problem was traced to the faulty turbo pump controller, which was fixed. Another gate valve (Fig. 1.15(a)) which separated the turbo pump from the target chamber stopped functioning. The problem was fixed by repairing the faulty solenoid.

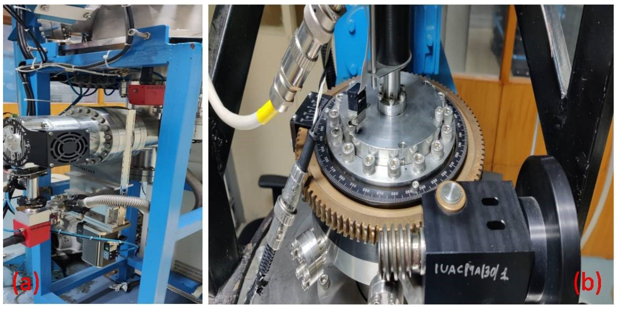

Figure 1.15: (a) the gate valve that separates the turbo pump from the experimental chamber and (b) the rotator of the target ladder.

Target station: The target ladder can be rotated manually using the rotator with a handle (Fig. 1.15(b)). However, the rotator was hard to move and slipped occasionally while moving. The edges of the rotator also got cut. The positioning of the rotator handle was adjusted and fixed in such a way that the rotator moved accurately and easily.

Radiation safety: The display for "BEAM ON" and "ACCESS ALLOWED" stopped functioning, which was resolved.

Target station: The video to digital converter used for signal processing of the video images of 'beam on target' stopped functioning. The problem was resolved after changing to a new unit.

1.6.3 Development activities

Development of new beams: Recent research in materials science involving ion implantation and irradiation in low energies demanded a variety of ion beams with high intensities. Therefore, there were attempts to develop new ion beams as well as to improve ion intensities of various ion species. Improvement in beam current (600 nA) was achieved for boron beam. However, other beams did not show much improvement in their intensities.

1.7 Tabletop accelerators

Raj Kumar and C. P. Safvan

IUAC had designed, developed and installed 30 kV and 60 kV tabletop accelerators in-house. Both of them were used during the last academic year. There was no breakdown during the year. Regular maintenance, mainly on ion source, was carried out. Table 1.2 summarizes the usage of the accelerators during the last year.

Table 1.2: Operational summary of the tabletop accelerators.

	60 kV accelerator	**30 kV accelerator**
No. of runs	2	8
No. of samples implanted	30	75
Beams provided	H_2^+, He^+, He^{2+}	N^+, Ar^+
Energy range	20 - 90 keV	10 - 27 keV