1. ACCELERATOR

1.1 15 UD PELLETRON ACCELERATOR

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1.1.1 Operational Summery

The 15 UD Pelletron accelerator was in regular operation during May 2022 to March 2023. The accelerator was under maintenance during the month of April 2022. A total of 548 shifts of beamtime were delivered to 68 users from 46 different Universities/Colleges/Institutes. Maximum terminal potential at which the beams were delivered was 13.52 MV and maximum terminal potential attained during conditioning (without beam) was around 14.2 MV. Figure 1 shows the voltage distribution graph of Terminal Potential used for Beam runs for the mentioned period.

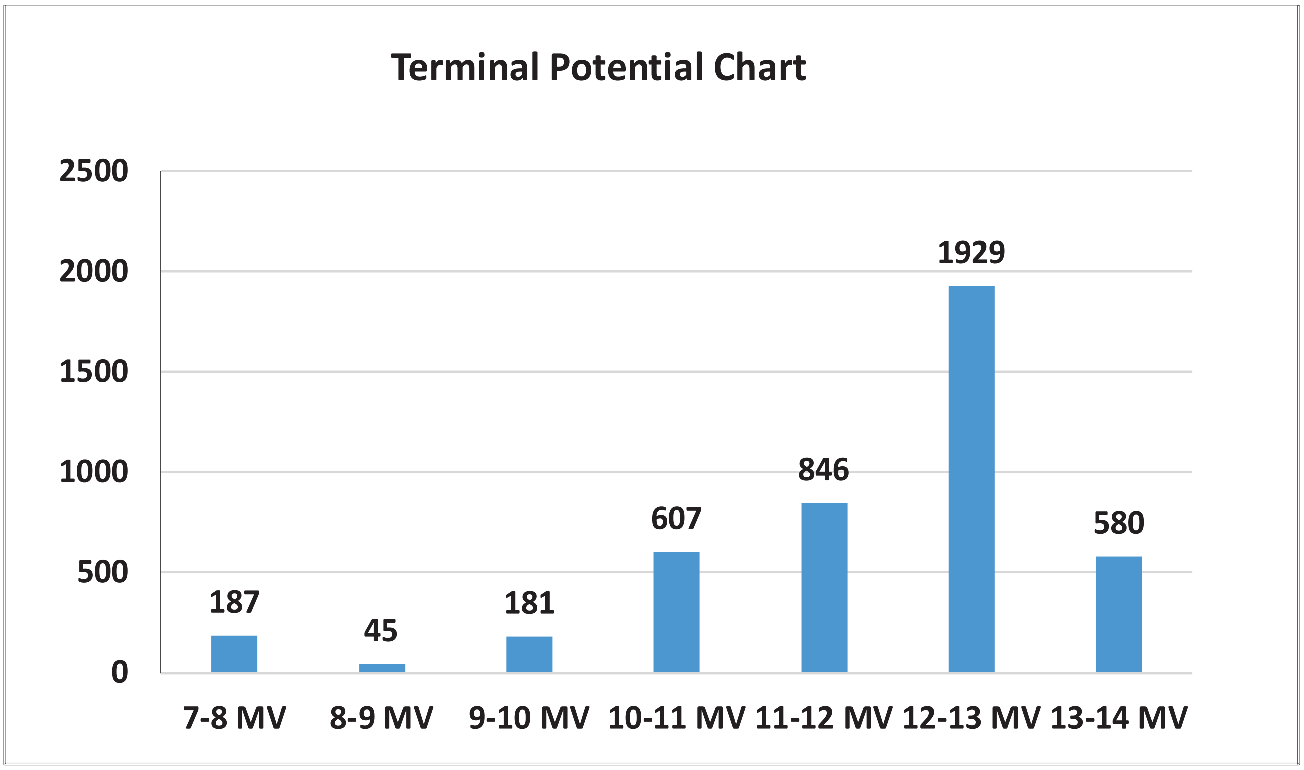

Figure 1: Voltage distribution graph in Hours.

^{1}H, ^{7}Li, ^{10}B, ^{11}B, ^{12}C, ^{14}N, ^{16}O, ^{19}F, ^{28}Si, ^{30}Si, ^{32}S, ^{35}Cl, ^{48}Ti, ^{58}Ni, ^{107}Ag, ^{197}Au beams were delivered to the users for their experiments. The operational summary of the accelerator from May 2022 to March 2023 is shown below.

Total Chain Hours	=	6882 Hours
Total Beam utilization	=	4380 Hours
Breakdown during operation	=	246 Hours
Accelerator Conditioning	=	2282 Hours

Out of 4380 operational hours, 2900 hours were utilized by the users of nuclear physics facilities, 1200 hours were utilized by users of materials science, rest were utilized by users from the fields of atomic physics, radiation biology and accelerator groups. Figure 2 shows the distribution of beamtime with respect to different experimental fields. For various nuclear physics experiments, ^{7}Li, ^{11}B, ^{14}N, ^{16}O, ^{19}F, ^{28}Si, ^{30}Si and ^{32}S beams were pulsed for different time periods ranging from 250 ns to 4 µs and provided to the users for their experiment.

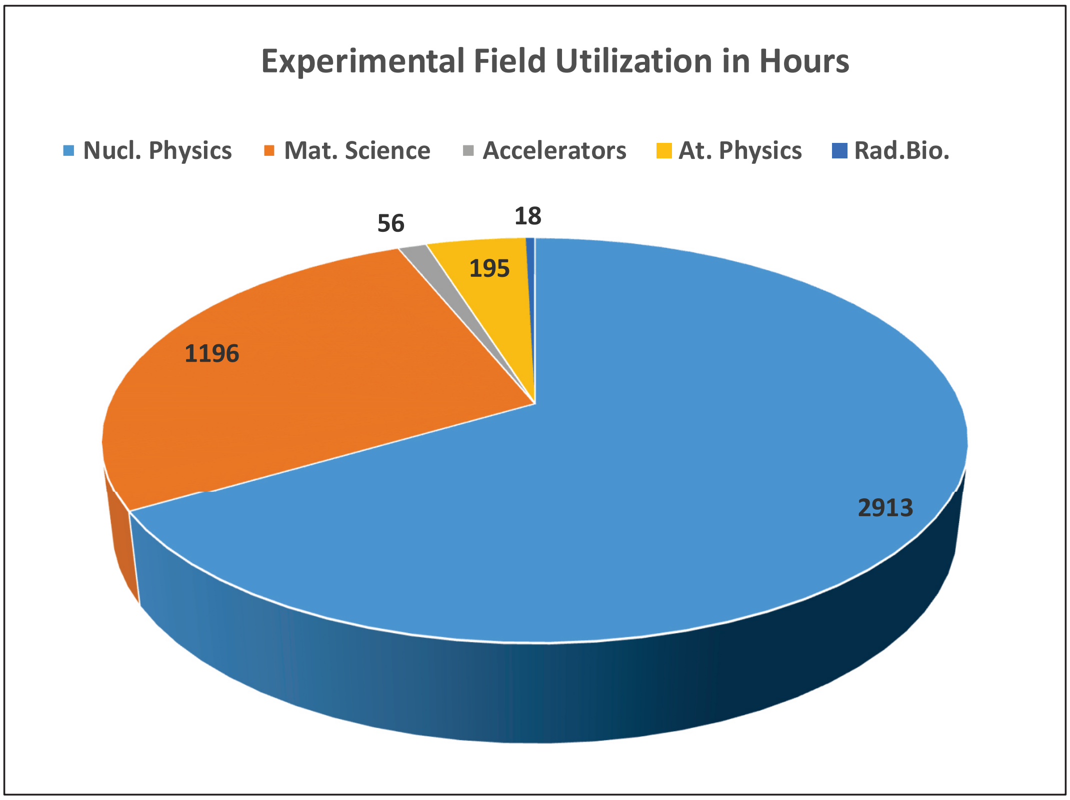

Figure 2: Experimental field wise breakup of delivered beamtime.

For accelerating proton beam, the existing facility had limitation of beam current. AERB had permitted to accelerate only 50 nA current through the Pelletron accelerator. It was noticed that for other elements also, the permission was granted for very less beam currents. An application was submitted to AERB seeking permission to enhance the beam currents of not only proton beam, but also other elements ranging from lithium to gold. The beam tests of the requested elements were performed and the radiation levels were monitored at different locations in the accelerator and beamlines. The test reports were submitted to AERB which in turn provided us the necessary permission to operate the Pelletron facility with high beam current ratings.

There were no breakdowns in the Pelletron accelerator facility. Intermittently the beam times were stopped for various other reasons like HCI related work, pulsing system check-up, AC plant upgradation works etc. In all, a total of 6 weeks of beamtime was affected due to all these works. Around the middle of the academic year, it was noticed that one of the foil stripper assemblies inside the accelerator tank stopped functioning but that didn't affect the routine operation of the accelerator.

1.1.2 Maintenance

The academic year started with the maintenance which lasted up to end of April 2022. The accelerator was opened after one year of successful operation. Routine maintenance, like loading of foil strippers, charging system maintenance and inspection and repairing of accelerating tubes & column support posts, rotating shaft maintenance were carried out.

Safety advisory Council comprising of academic and technical staff from BARC and IUAC visited the accelerator facility during the maintenance and pointed out their observations for safe and secure maintenance and operation procedure. Most of the recommendations have been implemented.

The Pelletron accelerator was once again opened for maintenance in the month of March 2023 after routine operation of 10 months. The maintenance has been taken up pre-maturely to accommodate HCI installation work and other important projects of the institution. The maintenance is underway till the writing of this report.

1.1.3 Ion Source activities

The 40 cathode MC SNICS source was operational throughout the year. Cathode loading was performed 6 times in the academic year to provide various beams to the users. There were many pulsing runs with repetition rates of pulsed beam ranging from 250 ns to 4 μs for which source had to be operated at extreme conditions. High voltage conditioning of the source deck was performed and it has been observed that the -320 kV is easily achieved. Source maintenance was carried out in the month of May 2022 after which source operated very smoothly and there were no breakdowns.

1.1.3.1 Ion Source Maintenance (May 2022)

Routine source maintenance was not carried out for a long time. Cesium was last loaded in the source in 2019. Therefore it was decided to go for maintenance of the 40 cathode MC SNICS. The whole ion source was disassembled. The source body, ionizer, immersion lens and Einzel lens looked very dirty. Gaps in the Einzel lens were showing very low resistance. It was cleaned by dipping in alcohol for 24 hours, dried and baked with an air gun. The gap resistance improved after the cleaning. The lens was aligned and replaced back.

While cleaning the source body, the ionizer broke down. It had lasted for 16 months. Continuous operation at extreme conditions due to various pulsing beam runs can be one of the probable reasons. A new ionizer was installed, the source was aligned and installed back and fresh cesium was loaded. The source has been operating smoothly post the maintenance.

1.2 LINAC AND SRF ACTIVITIES

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1.2.1 Superconducting Linac

In the previous Linac operation that concluded in December '2021, it was observed that the average accelerating gradient achieved by the resonators in the 3rd Linac Cryomodule (LC-3) was below par. It was therefore decided to take down the underperforming cavities from the cryomodule after the operation got over, and give them appropriate surface treatment to improve their performance. Following this decision, LC-3 was opened in March '2022 and the three under-performing cavities, namely R32 (QWR # I-05), R35 (prototype QWR ANL) and R36 (QWR # I-09) were uninstalled from the cryostat. Based on the detailed study that we had conducted a few years ago, appropriate processing recipe for an individual cavity according to its performance history was applied. This is described in the following sub-sections.

R36 (QWR # I-09): The resonator and its accessories were given high pressure rinse (HPR) using high purity deionized water. After drying and dressing it in a class-100 clean room, the cavity was loaded in the test cryostat. In the performance test at 4K, it showed a dramatic improvement in the achievable accelerating gradient (figure 1) reaching 4.4 MV/m @ 4W RF input power and 5.1 MV/m @ 6W input power. This was in stark comparison to 1.3 MV/m @ 4W RF input power and 1.7 MV/m @ 6W input power that the cavity had achieved in the December '2021 Linac run.

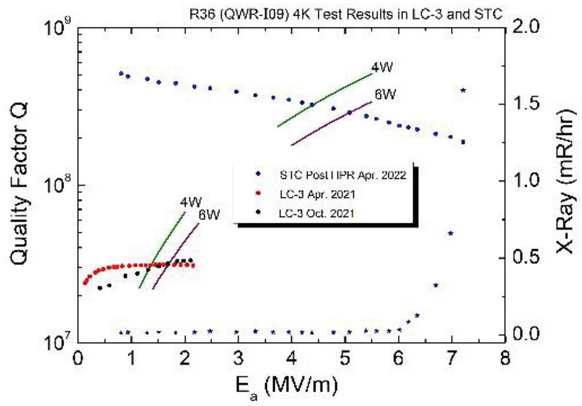

Figure 1: Quality factor Q as a function of accelerating gradient E_a at 4.2K for R36 (QWR # I-09).

R35 (prototype QWR from ANL): Figure 2 shows the performance history of this QWR in the offline tests conducted in 2015; magenta dots - immediately after cooldown, green dots - after deliberately warming up the cavity to 100K and holding it there for 12 hours before cooling it back to 4K for the Q measurements, which clearly showed that the cavity suffered from Q-disease. The performance of this cavity in the Linac run (orange dots) indicated that the cooldown rate in the cryomodule is not fast enough to avoid the Q-disease completely. So, it was decided to give the cavity a 550 °C heat treatment for 12 hours in the high vacuum furnace, followed by HPR. In the offline performance test at 4K (red dots), the cavity achieved the accelerating gradient of 3.53 MV/m @ 4W RF input power and 3.99 MV/m @ 6W input power. In order to test whether the cavity was cured of the Q-disease, it was warmed up to 120K and held there for 12 hours before cooling it back down to 4K for the Q-measurements (black dots). This time the cavity achieved the accelerating gradient of 3.72 MV/m @ 4W RF input power and 4.14 MV/m @ 6W input power, clearly indicating that it is now free from Q-disease.

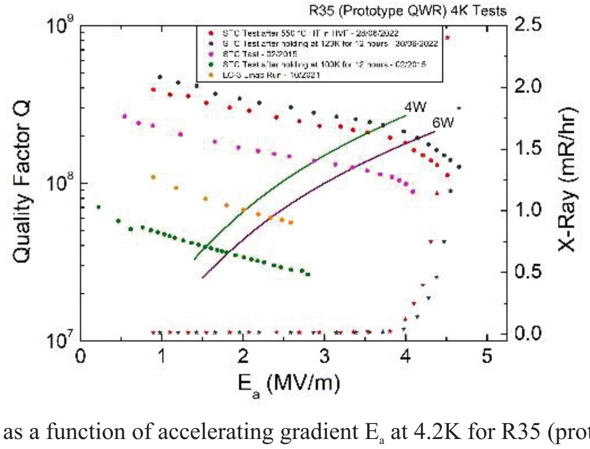

Figure 2: Quality factor Q as a function of accelerating gradient E_a at 4.2K for R35 (prototype QWR from ANL).

R32 (QWR # I-05): There was an indication of Q-disease in this cavity also, as observed during the last Linac run. Therefore it was also given a 550 °C heat treatment for 12 hours in the high vacuum furnace, followed by HPR. In the offline performance test at 4K, the cavity showed a significant improvement by reaching the accelerating gradient of 3.38 MV/m @ 4W RF input power and 3.93 MV/m @ 6W power, whereas in the Linac run in '2021, it could achieve only 2.3 MV/m @ 4W RF input power and 2.7 MV/m @ 6W power (figure 3).

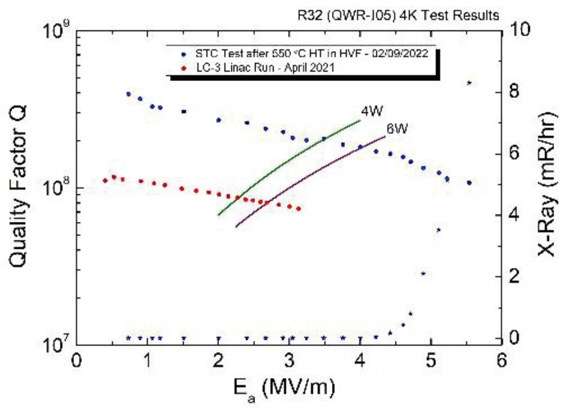

Figure 3: Quality factor Q as a function of accelerating gradient E_a at 4.2K for R32 (QWR # I-05).

With the improvement in the field gradients in the three QWRs, it is expected that the average accelerating gradient in LC-3 will increase by more than 25%. This implies that the energy gain from the third cryomodule will also increase by a similar amount. The three cavities were reinstalled and aligned in Linac Cryomodule-3. Since we want to use the solenoid magnet in this cryomodule for transverse focusing of the beam in the next linac run, it was also aligned with the beam axis with a greater accuracy. The cryostat was closed, evacuated and the cavities were baked at 70 °C for a week in preparation of the forthcoming Linac operation.

1.2.2 Linac Operation

The Linac operation was scheduled to begin from the last week of January '2023, for which extensive preparations were carried out. These include servicing of all the RF power amplifiers and piezo controllers, power line calibrations for all the cavities, installation of gold foils in the diagnostic box, installation of a single slit before the switching magnet, remote testing of the target ladder movement, RF coupler movement and RF test of all the cavities, testing of the gas-based slow tuners in cryomodule #1, etc. After the cryomodules were cooled-down, multipacting conditioning of the resonators was started. However, due to the failure of the UPS that fed electrical power to the liquid helium refrigerator, the linac run had to be abruptly stopped. It has since been postponed to July in order to accommodate the testing of the superconducting magnet for the IMRI project.

1.2.3 SRF Activities

1.2.3.1 Fabrication of Spare QWRs for Linac

Significant progress has been made in this project in the last academic year (figure 4). The present status of the project is as follows.

- All the six bare niobium QWRs have been successfully completed. Three of them have been Electropolished and heat treated.
- Electropolishing and Heat Treatment of the fourth cavity is under process.
- Machining and Electron Beam Welding of the Open End Flanges for the three heat treated bare niobium resonators is underway in parallel, and two flanges have been welded to their corresponding resonators. They are now ready for the final SS jacketing.
- Fabrication and EBW of 13 Niobium Slow Tuner bellows has been completed. The Slow Tuner flanges (Nb-Cu) are ready for welding to the bellows for completing the assemblies.

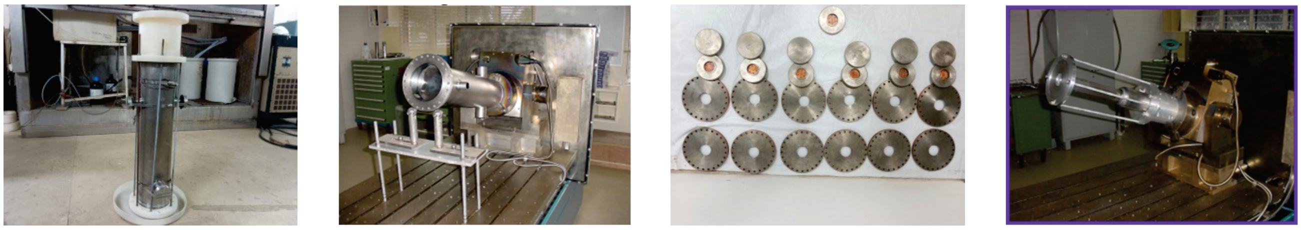

Figure 4: (L to R) a QWR setup for electropolishing, setup showing the EBW of open end flange to niobium outer housing, slow tuner bellows along with their Nb-Cu flanges ready for the final assembly, setup showing the EBW of a niobium central conductor to top flange.

1.2.3.2 Five-Cell 650 MHz Low Beta Cavity (=0.6)

This is a collaborative project between IUAC and VECC, Kolkata for the development of two 5-Cell 650 MHz niobium low beta cavity (LBC) under the Indian Institutions and Fermilab Collaboration (IIFC). IUAC is sharing its infrastructure, especially its electron beam welding facility, and SRF expertise in the work. EBW of the cavity components and its sub-assemblies is going-on in IUAC. Presently, eight Niobium half cells have been EB wended at the iris to make four dumbbells. Two dummy dumbbells have also been EB welded for the weld parameter development of the stiffener ring. In addition, five Niobium Beam Pipes and three Niobium Branch Pipes, have been EB welded (figure 5).

Figure 5: EBW setups showing (L to R): welding of a beam pipe, inside welding of the iris joint, stiffener ring attached to a dumbbell and outside welding of the iris joint.

1.3 5 SDH-2 (1.7 MV) TANDEM ACCELERATOR BASED ION BEAM ANALYSIS FACILITY

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1.3.1 Operation

The 1.7 MV Tandem accelerator for Ion Beam Analysis Techniques: Rutherford Backscattering Spectrometry (RBS), RBS-Channeling, Resonance-RBS, and Elastic Recoil Detection Analysis (ERDA) measurements for hydrogen, is in continuous operation. In this academic year 1540 measurements of 67 users from 37 Universities, colleges and institutes were performed. The facility was operational throughout the year. The Operation during this period was smooth and stable.

1.3.2 Maintenance

1.3.2.1 Ion Source Maintenance

The RF charge exchange ion source maintenance was performed twice during this period, first in the month of April-May, 2022 and then in the month of August-September 2022. In mid-March 2022, it was observed that the coolant level was gradually going down. The LOBS (Low Odor Base Solution) cooling is an essential part of the charge exchange cell to keep Rubidium (Rb) within the chamber and drain to the reservoir in contact with the chamber wall. Seepage in the coolant flow pump was observed. The pump is special seal-less centrifugal magnetic drive pump ideal for chemical recirculation. It was replaced by the MC-SNICS coolant unit. The plasma formation issue was observed in the 1st week of April and ion source was opened for maintenance.

The source and the facility started functioning back after successful Rb loading. The charge exchange cell was cleaned and reassembled with new beam exit bore and insulator canal. Smooth operation was noticed till August. Once again, current production from the ion source was noticed. This time there was no chocking, but the operation stopped due to probe current saturation. The source was opened for maintenance, residual Rubidium was disposed-off properly and two ampules (5gm each) of fresh Rb was loaded. The stable He-beam extraction was possible with a few hours of source conditioning.

1.3.2.2 5SDH-2 Pelletron Accelerator and End-station Maintenance

The SF6 leak detection was performed and a leak was identified at column current feedthrough. The Pelletron accelerator tank was refilled to 72 psi with storage of 20 psi. At this pressure, the terminal could hold 1.47 MV.

The Rotary pumps in the high energy section and at experimental end station were serviced with the help of vacuum lab personnel but vacuum system of end station kept on tripping at low vacuum (~10^{-2} Torr). In February 2023 the experiments were called off as vacuum system did not start. The turbo controller TCP 380 was found to be faulty and it was replaced. The interlock signal from the control system to the TCP 380 controller was not recognized as it was through an external attachment. The rotary and turbo were performing fine in the 'bypass' mode operation. At present the vacuum pumping is in bypass mode and is not controlled through control software RC43.

1.4 AMS AND GEOCHRONOLOGY FACILITIES

1.4.1 Accelerator Mass Spectrometry

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

1.4.1.1. Graphitization Laboratory

Graphitization laboratory is equipped with three Automated Graphitization Equipment (AGE) which are coupled with three elemental analyzers for the graphitization of organic samples and one carbonate handling system (CHS) for the graphitization of carbonate samples. The graphitization laboratory is routinely utilized for the sample pre-treatment and graphitization of charcoal, wood, macrofossils, plant remains, sediment, bones, textile and carbonate samples (shells, foraminifera). During April 2022-March 2023, 1348 samples have been pre-treated and graphitized by 74 users from different universities and institutes for their research work.

1.4.1.2 Clean Chemistry lab for ^{10}Be and ^{26}Al Sample Preparation

Sample preparation is a very important part in the measurement of cosmogenic radionuclides (CRN's) 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 lab had been developed in IUAC and being used for pre-concentration of Be and Al. This includes extraction of Be/Al from geological samples and their conversion to oxide form to be measured using AMS.

In last one year (2022-2023), 255 samples (^{10}Be-150 and ^{26}Al-105 samples) belonging to 11 users from 7 institutes were processed for AMS measurements. Along with the samples, 20 process blanks and 12 standard samples were prepared. Along with regular samples, 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/repaired. Also, the maintenance of fume hoods and wooden furniture was carried out. After the required maintenance the background contamination levels of clean lab were found lower.

Figure 1: Chemistry lab for Be and Al pre-concentration.

1.4.1.3 XCAMS facility

1.4.1.3.1 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. Total 1684 samples of ^{14}C, ^{10}Be and ^{26}Al have been measured this academic year. 77 users from different institutes have utilized this facility for their research work. We have measured ^{26}Al at 380kV terminal potential this year at this system in place of earlier used 500kV terminal potential. All the secondary standard and background sample ratios were close to their nominal values and background sample ratio was also in the acceptable range at this potential. Total 16 research paper / book chapters are published using AMS facility of IUAC.

1.4.1.3.2 Maintenance activities of XCAMS

Following maintenance activities were carried out in this facility.

i. Both the ion sources (40 and 134 cathode MC SNICS) were opened for maintenances in June and August 2022. The sources were cleaned, re-assembled and brought back to operation. Fresh Cs was also loaded in the source S1 (40 Cathode) in June 2022.

ii. Cooling water headers (supply and drain) in XCAMS were choked. They were replaced with new headers by water system group. Water system group provided a 48 cm long header with six ports. It was cut in two pieces of length 24 cm and three ports and installed in the XCAMS.

iii. Analyser magnet (BM 03) power supply of XCAMS was fluctuating randomly. Due to these fluctuations, performing measurements was becoming difficult. Beam transport system (BTS) group installed a 200 A magnet power supply in place of it to keep XCAMS operational.

1.4.2 National Geochronology facility

Deeksha Khandelwal, Leema Saikia, Anit Dawar, Pavitra V. Kumar, Mahadev, Prem Chand Kisku, Atul Kumar Singh, Umapathy G, Rajveer Sharma, Madhav K. Murari, Pankaj Kumar, S. Ojha, S. Gargari, and S. Chopra

1.4.2.1 High Resolution Secondary Ion Mass Spectrometer (HR-SIMS)

Large forward geometry High Resolution Secondary Ion Mass Spectrometer (HR-SIMS) (model: CAMECA IMS 1300-HR^3 (high Reproducibility, high spatial Resolution, high mass resolution) has been operational at IUAC since its installation and commissioning in December 2021. This mass spectrometer is equipped with two ion sources: Cs microbeam source and Hyperion RF source for the analysis of negative and positive secondary ions, respectively. HR-SIMS facility has been routinely utilized for the U-Pb and oxygen isotope studies in zircon, depth profiling studies in semiconductor materials and study of Al-Mg isotope systematics in Ca-Al-rich inclusion (CAIs) in meteorites. A total of 1866 measurements in samples from 6 users from 2 universities and 3 institutes have been completed during this year.

Maintenance activities

- **Problem with z-movement of the analysis chamber:** It was seen that the Z-axis movement of the sample stage stopped. It happened twice during the reporting year. One of the ICs in the Z-axis motor power board was burnt. Both times, the board was replaced with newer one and the problem was solved.
- **Problem of leakage in the oxygen flooding valve:** Sensitivity of ^{206}Pb is increased for U-Pb isotopic measurements when analysis chamber is flooded with oxygen gas at pressure ~1 E-6 mbar. Flooding is achieved with the help of oxygen flooding valve. This flooding valve started leaking and even after fully closing the valve, the pressure of the analysis chamber was maintained at ~1 E-5 mbar. The valve was blanked off with the help of vacuum group and the machine could be used with oxygen source (figure 2). The valve will be replaced with a new one in the future. Currently the machine is being used for secondary negative configuration.
- **Replacement of Electron multiplier (EM):** Electron multiplier of mono-collection detection configuration (ETP make) came to its end of life. It was replaced with a new one and necessary changes in the software were done.

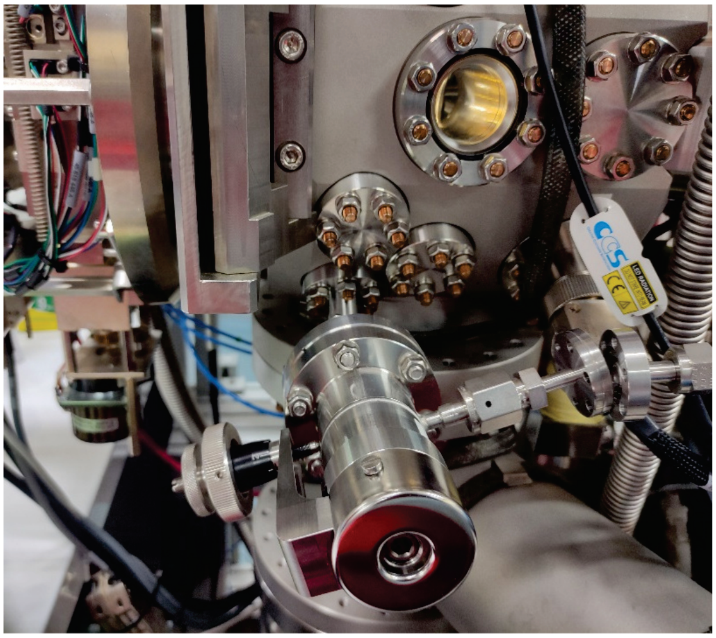


Figure 2: Oxygen Flooding valve and installed blankoff

- **Replacement of Entrance slits and contrast apertures (CA):** It was seen that the edges of the entrance slit got eroded due to impact of the secondary beam and it was difficult to get a good flat top peak. Entrance slits and CAs were replaced with new ones.
- **Replacement of Primary Beam Mass Filter Aperture (PBMF-A):** Due to the use of the primary beam in Kohler illumination mode, PBMF-As 100 m were replaced with new ones.

Figure 3: Eroded contrast apertures (CAs)

1.4.2.2 Femto second Laser Ablated High Resolution Inductively Coupled Plasma Spectrometry (LA-HR-ICP-MS)

HR-ICP-MS (model: Thermo Scientific, Element XR) coupled with femto second Laser Ablation (model: Teledyne) is now an extensively used instrument for U-Pb dating and REE measurements in different minerals. In laser mode, the sample is exposed to laser which ablates it and converts it into aerosol. The sample is then fed to a plasma using helium as a carrier gas. The advantage of HR-ICPMS over conventional ICP-MS is that it uses magnetic sector Single-Collector (SC) Mass Spectrometer (MS) to measure isotopic ratios of elements. The primary application of HR-ICPMS is to measure the isotopic ratios of elements used in geochronologic radiogenic isotopic studies. The LA-HR-ICP-MS has significantly contributed to understand the crustal evolution of the Indian Craton and the different stages of Himalayan orogeny.

In solution mode ~100 samples (unknown + standards) were measured. Samples were provided by BARC and $^{176}Lu/^{175}Lu$ were measured. In laser mode, ~6000 grains were ablated for U-Pb dating of Zircons and REE analysis in different minerals. Different projects from 12 users were undertaken during this year. These projects cover different geological terrains from Ladakh in the North to Tamil Nadu in the South and Manipur in the East to Rajasthan in the West.

1.4.2.3 Quadrupole- Inductively Coupled Plasma Spectrometry (Q-ICPMS)

ICP-MS technique offers very efficient and convenient method for elemental characterization of the analysis of samples at ppb to ppt level. Quadrupole ICPMS (Q-ICPMS) is such an instrument which utilizes a quadrupole as a mass analyzer. 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. During April 2022 – March 2023, this facility was used for the analysis of about 1660 samples by 21 users from different institutions. In addition, the facility was also used for precise estimation of Be and Al in quartzite samples as partial requirement for AMS measurements for surface exposure studies. The major thrust areas of research include:

- Environmental studies- Soil and water pollution.
- Heavy metal contamination in soil, water and plants
- Earth Sciences-Soil profiling
- Water quality assessment and human health risk association
- Micronutrients in Human health.

1.4.2.4 Field Emission–Scanning Electron Microscope (FE-SEM)

The JEOL Field Emission–Scanning Electron Microscope (FE-SEM, JSM-7610F) installed in our laboratory at IUAC is a sophisticated high resolution scanning electron microscope equipped with Energy dispersive X-ray spectrometer (EDS) for elemental composition, Electron backscattered diffraction (EBSD) for crystallographic information and *Cathodoluminescence* (CL) for optical analysis of the samples as shown in figure 4. For coating of non-conductive samples, we have facilities of two compact and automatic rotary pumped coaters as shown in figure 5 below. The FE-SEM with CL facility competently performed all-round the year except EDS and EBSD. 47 users from 25 Universities/Institutes all over India have utilized the facility.

Following type of samples were performed from different fields for surface topography

- **Geological Samples**: CL of Zircon grains from Saigaon (Chandrapur), Nagpur (Maharshtra), Gangotri Bhagirathi valley, Bhaironghati, Manipur, Arunachal, Meghalaya, Dhauliganga Valley, Dabari Conglomerate (Rajasthan), Himachal Pradesh, Madurai (Tamil Nadu), Deobhog (Chattisgarh), Lohit and Dibang Valley of Arunachal Pradesh, etc.. , CL imaging of Tourmaline and Quartz, Sediments samples from Malari Joshimath, Clay separated from bulk sediments,
- **Materials Science Samples**: WSe_2, $MoSe_2$ pristine and with surfactant, SiC+Egg Shell reinforcement, CuO thin films pristine and with Ni implantation, Carbon derived from Bio-waste, Cl and I crystals, Cu over Si Substrate, PbSe over Si Substrate, Fe nanopowder heated and graphitized, etc...
- **Nuclear Targets Samples**: ^{93}Nb
- **Biological Samples**: Gall Bladder Stones, Fungal Non-Contagious
- **Textile**: Control cotton with Castic soda treatment, Control wool with dyed samples

Maintenance

- “Water Circulation” error came while operation and was resolved by JEOL by resetting the Turbo Pump.

Figure 4: FE-SEM (JEOL-JSM-7610F)

Figure 5: Carbon and Platinum Coater

1.4.2.5 Wavelength dispersive X-rays fluorescence spectrometer (WD- XRF)

Wavelength dispersive X-rays fluorescence spectrometer has been installed and operational since 2018. A fuse bead machine, pellet press and vibratory cup mill are also being utilized for the sample preparation.

Calibration is done for major oxides and trace elements of mafic samples.

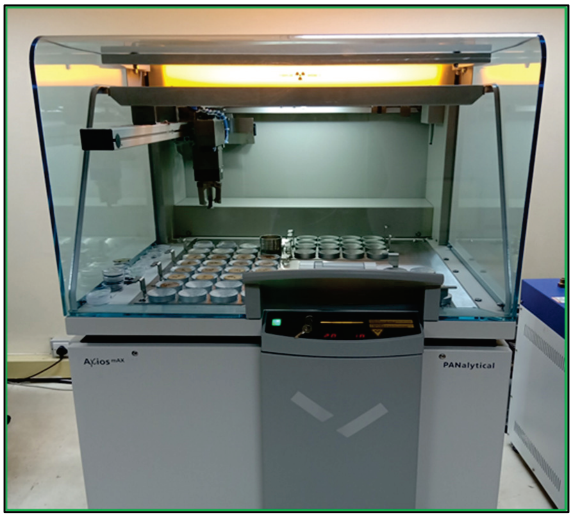
Standards used for this calibration are JB-1B, JB-2a, JB-3, W-2a, CGL014, BIR-1a, BHVO-2, NCSDC73303, MBH, JA-2, GUWBM.

From April 2022 to March 2023, XRF measurements of 32 samples from 2 user from 1 university and 1 institute have been done.

Maintenances related to XRF during the year (2022-2023) are listed below:

- Leakage in chiller of XRF. Repaired and working fine.
- Pre filter of XRF chiller was changed with a new one as there was an error showing 'heat exchange flow is too low'.

Following photographs show equipment related to XRF system:



WD-XRF Spectrometer

Pellet press

Vibratory cup mill

Fusion machine

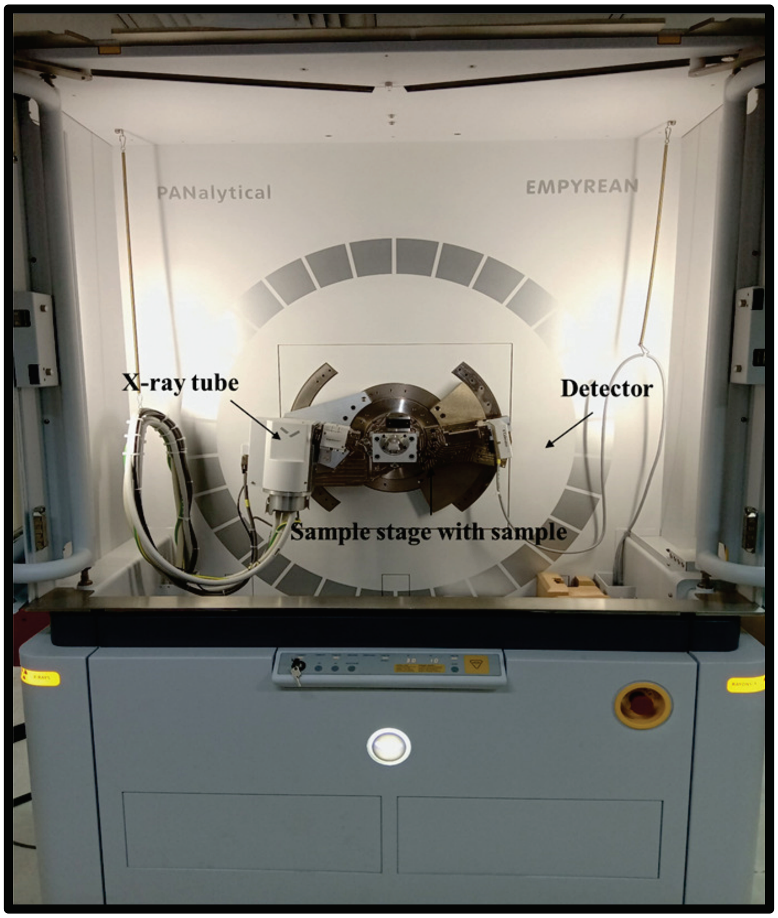
1.4.2.6 X-Ray Diffractometer (XRD)

X-ray diffractometer has been operational since 2017 and being utilized routinely by users for characterization of their samples. These samples include different types of geological, archaeological, environmental, nuclear targets, processed material etc. In earth science samples, the presence of minerals helps to find out the paleoclimatic condition of a particular location. In materials and nuclear target, the study is mainly focused on studying the different crystallographic parameters.

From April 2022 to March 2023, 674 samples of 35 users from 14 different universities and 6 institutes, were measured using XRD.

Maintenances related to XRD during the year (2022-2023) is listed below:

- XRD chiller was found with the error message as compressor trip and AFT fault. Chiller was repaired and working fine after that.
- The X-ray tube of the system found turned off many times. When checked it was found that the pre filter of the chiller was choked. Hence it was replaced with a new one.
- There was a shift in the peaks of the diffractogram of standard Si sample. The zero-error shift was corrected manually and after that the XRD system started working fine.



X-ray Diffractometer

1.5 LOW ENERGY ION BEAM FACILITY (LEIBF)

Pravin Kumar & Ambuj Tripathi

1.5.1 Operation

All-permanent-magnet 10 GHz Electron Cyclotron Resonance Ion Source (ECRIS) based Low Energy Ion Beam Facility (LEIBF) [1-3] is functional since 2001 with the aim to provide all possible support for user experiments in materials science, atomic and molecular physics. The upgraded LEIBF consists of three different beam lines (at 75°, 90° and 105°) in the beam hall as shown in figure 1. The research proposals approved by the accelerator user committee (AUC) under BTR-5 category and scheduled by BTSG (beam time scheduling group) are being entertained at LEIBF to promote transparency and equal opportunity to all users/scholars across the country. Further, the guidelines of atomic energy regulatory board (AERB) are being followed up strictly while operating this low energy accelerator facility for regular experiments. Furthermore, the responsibilities as illustrated in the organization structure are being shared among the available human resources (permanent and contractual). During the period April 2022 to March 2023, the beam time of 125 shifts (19 user experiments) had been utilized.

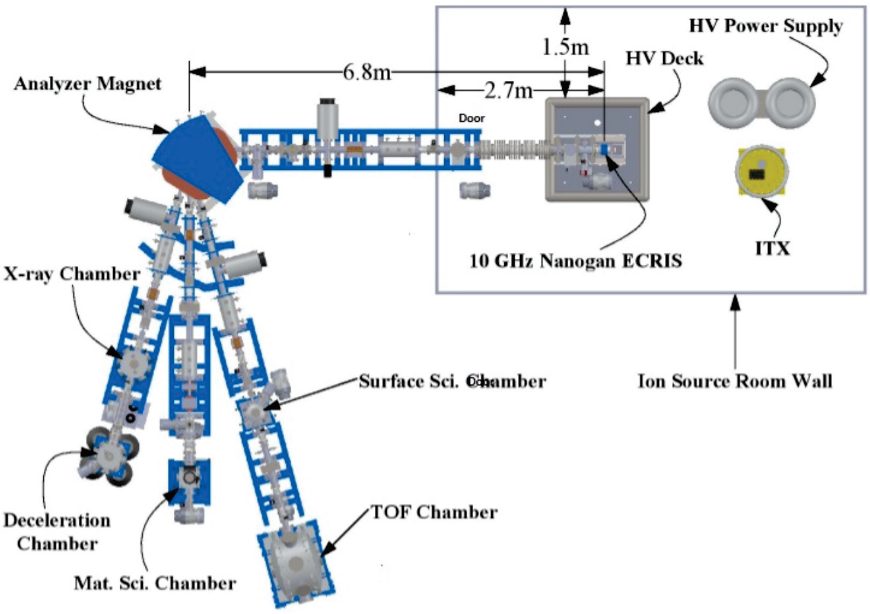


Figure 1: Schematic of LEIBF. All abbreviations have their usual meanings.

Some of the novel experiments done with LEIBF are listed below;

- Surface nano patterning by the ion beams
- Ion beam mixing
- Ion beam induced re-crystallization
- Synthesis of embedded metal nano-particles
- PIXE
- Ion beam induced fragmentation of molecules and dissociation dynamics

1.5.2 Maintenance

The maintenance of LEIBF is being taken care by the support labs viz. vacuum system, beam transport group, ion source lab, remote control group etc. The routine problems such as faulty read back of control signals, leaks in beam lines and experimental chambers, malfunctioning of interlocks, latching of IN/OUT status of Faraday cups, shutting down of dehumidifier, improper cooling of dipole have occurred and resolved in time. In the beginning of 2023, we faced major problem with 400 kV power supply, which is used to polarize the high voltage platform. Initially, the power supply was unable to polarize the platform beyond 200 kV and finally, it did not yield any output. The problem is still being examined by the ion source group, which is responsible for the up-keep of high voltage power supplies in LEIBF.

1.5.3 Development activities

- A new setup for the formation of neutral beam in the energy range of 50 - 350 keV has been employed in 105^0 beam line of LEIBF (figure 2).

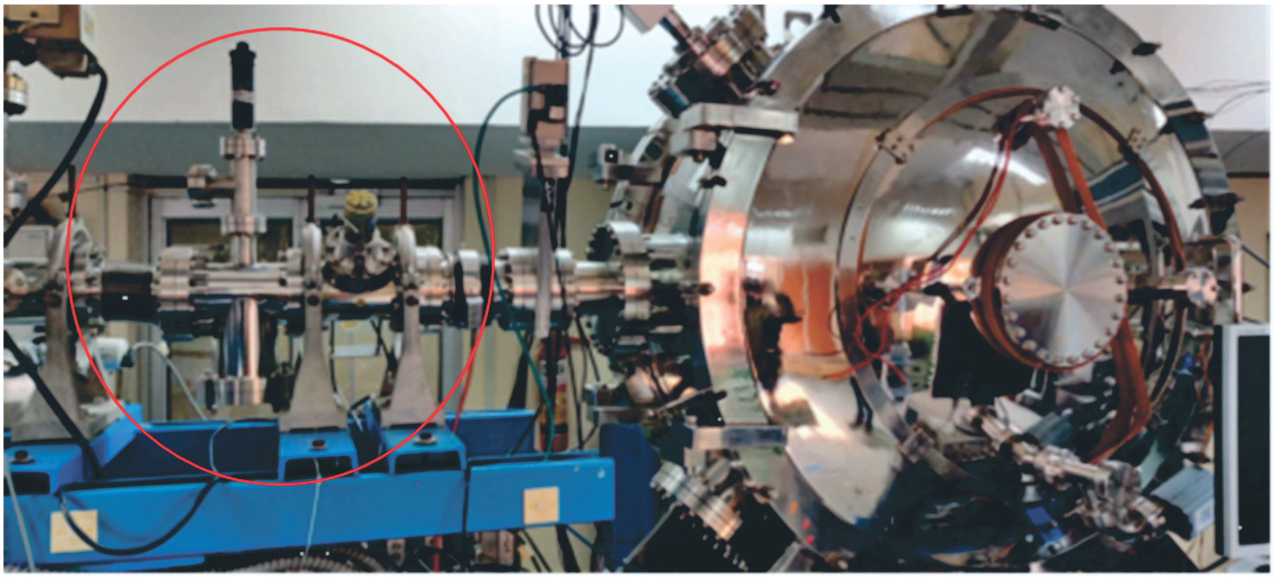


Figure 2: The neutral beam formation chamber installed in 105^0 beam line.

The chamber, consisting of a carbon foil (20 nm thickness) for the neutral beam formation, was successfully installed, aligned precisely with other components and tested for vacuum ($\sim 2.0 \times 10^{-7}$ Torr).

- To look for the feasibility of novel experiments, the facility test for the fragmentation and dissociation dynamics of Butadiene gas with $^{129}Xe^{3+}$ ion beam was successfully done in May 2022.
- A post collision energy analyzer was installed in 75° line of LEIBF (in December 2022) to measure the energy of the decelerated ions (figure 3).

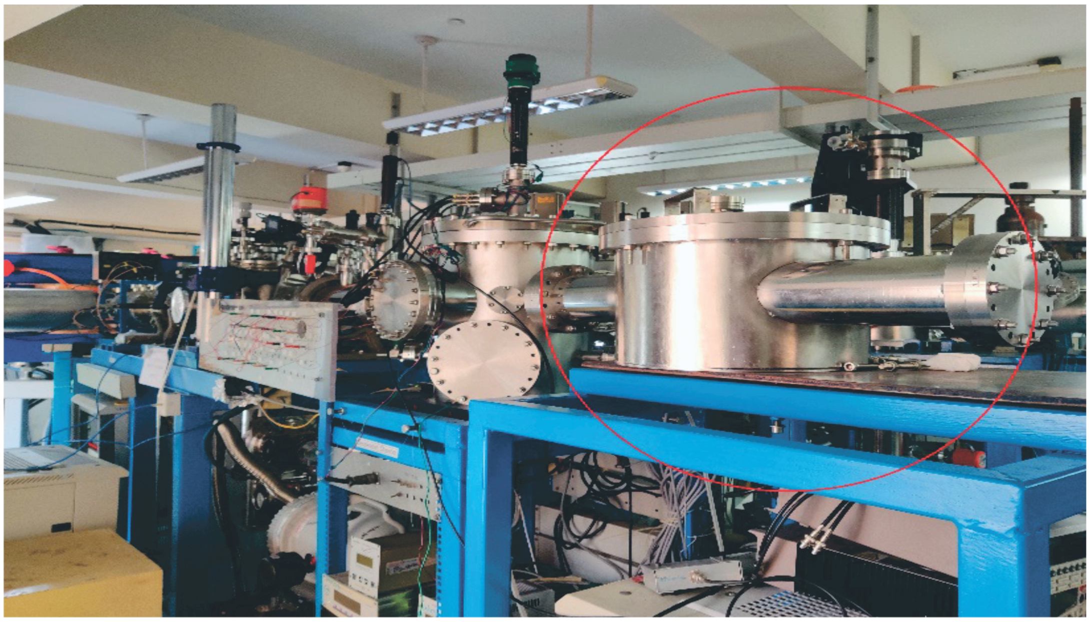


Figure 3: The post collision energy analyzer installed in 75^0 beam line.

References:

[1] Kumar P, Rodrigues G, Kanjilal D, Roy A, Singh B P and Kumar R 2006 *Nucl. Instrum. Methods* B 246 440

[2] Kumar P, Rodrigues G, Lakshmy P S, Kanjilal D, Singh B P and Kumar R 2006 *Nucl. Instrum. Methods Phys. Res.* B 252 354

[3] G Rodrigues, Kedar Mal, Narender Kumar, R Baskaran, P S Lakshmy, Y Mathur, P Kumar, D Kanjilal, and A Roy, *Rev. Sci. Instrum*. 85, 02A944 (2014)

1.6 LOW ENERGY NEGATIVE ION IMPLANTER FACILITY

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1.6.1 Operation

The Low Energy Negative Ion Implanter Facility was operational round the year. About 20 users from different colleges, universities and institutes availed the beam time.

Total no. of users: 20

Total number of samples implanted: 777

Ion beams delivered: ^{7}Li, ^{16}O,^{27}Al,^{28}Si,^{48}Ti, ^{54}Al$_2$, ^{56}Fe, ^{58}Ni, ^{59}Co,^{63}Cu,^{74}Ge, ^{107}Ag, ^{130}Te and^{197}Au

Energy range: 30 to 200 KeV

Ion fluence range: $4x10^{11}$ to $3x10^{16}$ions/cm^2

1.6.2 Maintenance

The implanter accelerator had a smooth run delivering a verity of ion beams of energies ranging from 30 to 200KeV.The ion source also performed well since its maintenance in January 2022. However, few minor breakdowns occurred in ion source, beam line components, vacuum system, target ladder assembly and control system, which were resolved. In regular intervals, Cockcroft Walton voltage multiplier, ion source ,high voltage room, high voltage decks and beam line were cleaned. The following maintenances of the devices listed below were performed.

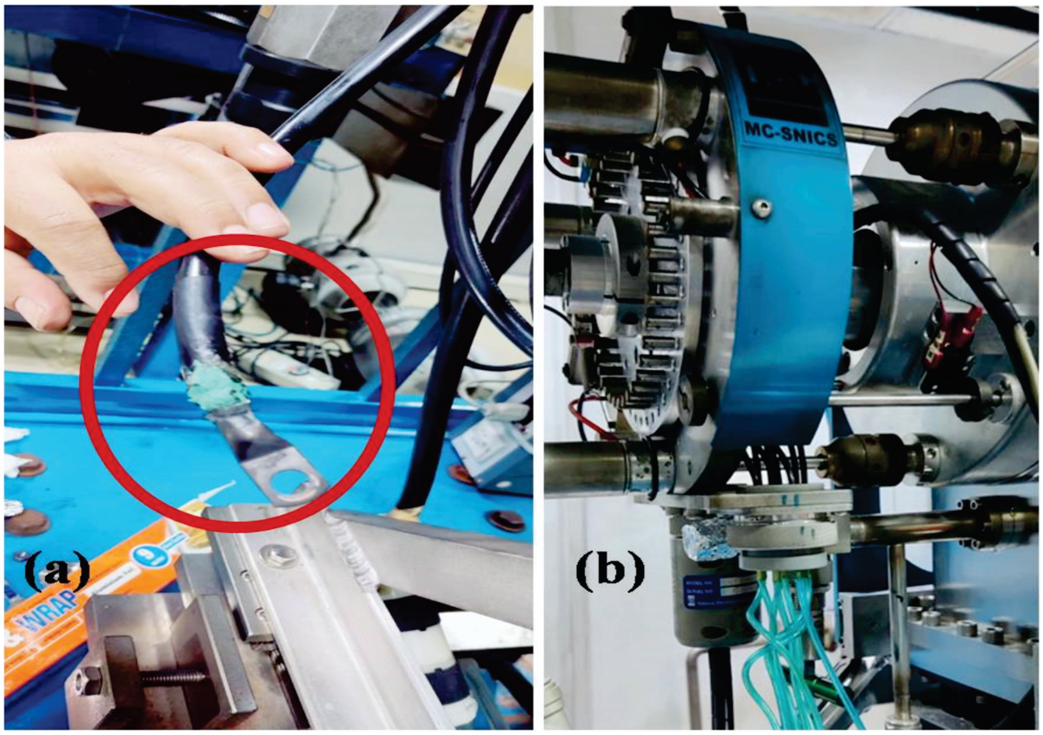

Figure1. (a) Filament power supply cable with corroded end and (b) Repaired compress airline pipes.

Ion source: The filament power supply cable got corroded at the ion source end, as shown in figure 1(a). It was due to high relative humidity of the ion source room which mostly stayed around/or above 52%. The corroded part was cleaned thoroughly with alcohol and, then a new lug was affixed to it by crimping and soldering. Insulation sleeves were put on the cleaned part of the cable for insulation as well as protection from oxidation. In another occasion, the compress air lines (2 numbers), figure 1(b),used for the cathode wheel movements got damaged (broken).The damaged pipes were traced and removed from both the ion source end and indexer controller end. New pipes were laid out and fixed. The cathode wheel movement was tested. The piston direction was corrected by adjusting the support cylinder to have a smooth and accurate positioning of the cathode.

Beam line components: The electrostatic quadrupole triplets, located in front of the target chamber, EQT-021 could not focus the beam at the target wafer since its +Y pole electrode could not hold high voltages. The EQT-021 and its adjoining area were vented. The high voltage feed through of +Y pole, the pole, its mount and nearby areas were thoroughly cleaned. The feed through was tested for its voltage holding capability by applying voltages in ramp mode with a megger to a maximum voltage of 10KV.Additionally, the problem was also due to the high voltage cable(+Y pole) puncture at voltage level beyond 500V. The cable was repaired and fixed with newly fabricated Teflon insulator mount. During this maintenance, the MKS vacuum gauge controller attached to the EQT-021 port went bad. The faulty gauge controller was replaced with the one removed from the ion source. The Faraday Cup head stud of FC-021 was found broken, as shown in figure 2(b). After repairing, its movement and positioning were tested and corrected by iteratively performing opening and closing. There were few instances of malfunctioning Faraday Cup controllers, which were resolved.

Target Station: The target ladder got bent after a fall during sample loading. The ladder assembly was dismantled by detaching its copper cuboids and Teflon adapter. The bent linear motion feed through (LMFT) was checked for its smooth movement and any vacuum leak. The bend was carefully corrected and straightened in the IUAC workshop. All the components, i.e. LMFT, copper cuboids and Teflon adapters were thoroughly cleaned and then assembled and aligned. Before and after its installation on the chamber, the ladder assembly was tested for its movement and vacuum leak tightness. Finally, the alignment was tested which showed normal functioning.

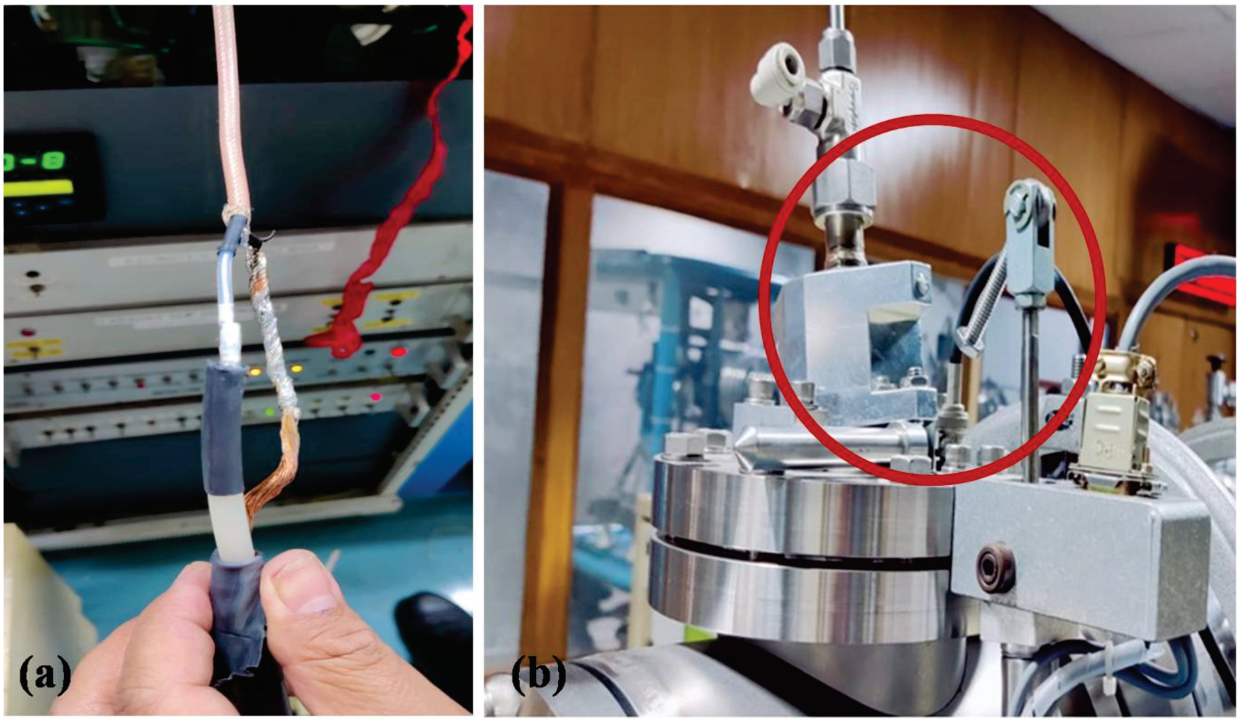

Figure 2: (a) High voltage cable of +Y pole of EQT-021 (puncture) (b) Broken head stud of FC-021.

1.6.3 Development Activities

Development of New Beams: Implantation experiments demand varieties of ion beams with high intensities. Therefore, routine attempts were made to develop new ion beams as well as to improve ion intensities of various ion species. In this academic year, the cathodes of Iodine, Tin, Bismuth, Tellurium and Titanium were prepared as per the available literature. Bismuth current abruptly rose to few hundred nanoamperes and died down to 18nA within 30 minutes. Iodine cathode could give intense ion beams (few microamperes). Tin and Tellurium cathodes showed marked improvement with 125 nA and 700nA. However, Ti beam showed disappointing results with the maximum beam current limited to 120 nA.

Target station: A light manipulator which could provide variable light intensities to the target wafer was fabricated and incorporated.

Radiation Safety: A display for "BEAM ON" and "ACCESS ALLOWED" was fabricated and installed at the entry door of the negative ion implanter facility.

1.7 TABLETOP ACCELERATORS

Raj Kumar, C. P. Safvan

IUAC has designed, developed & installed 30 kV & 60 kV Tabletop Accelerators in-house. Both of them have been in regular use during last year. There has been no breakdown during the year. Regular maintenance, mainly on ion source, has been carried out.

The following table indicates the usage of the accelerators during the last academic year.

	60 kV Tabletop Accelerator	30 kV Tabletop Accelerator
No. of runs	6	10
No. of samples implanted	78	140
Beams provided	H^+, He^+	N^+, Ar^+, O^+
Energy range	20 to 30 keV	10 to 25 keV