1. ACCELERATOR

1.1 15 UD PELLETRON ACCELERATOR

G Raturi, J Singh, Pranav Singh, S Kumar, S Mohan, N S Panwar, M P Singh, R Kumar, J Prasad, V P Patel, R P Sharma, Deeksha Khandelwal, G Umapathy, Rajveer, P Baghel, K Devarani, M 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 1st April 2021 to 31st March 2022. Around 595 shifts of beamtime were delivered to 55 users from 30 different Universities/Colleges/Institutes. LINAC campaign was held during the months of November-December 2021 during which around 152 shifts of beamtime were delivered to the users. Pulsing system was ON during 348 shifts of beamtime including all the shifts of LINAC runs. Maximum terminal potential at which the beams were delivered was 13.74 MV. In the lower potential side the beam was delivered to the user at 6.33 MV, but for testing purpose, Pelletron group operated accelerator at 4.0 MV to test beam transmission, charge state distribution and available energies for ^{7}Li beam. Maximum terminal potential attained during conditioning (without beam) was around 14.8 MV. We could achieve higher potential and deliver beam with higher energies as we had changed three damaged column support post during prior maintenance which reduced the electrical shorting in the accelerator. Figure 1 shows the voltage distribution graph of Terminal Potential used for beam runs for the mentioned period.

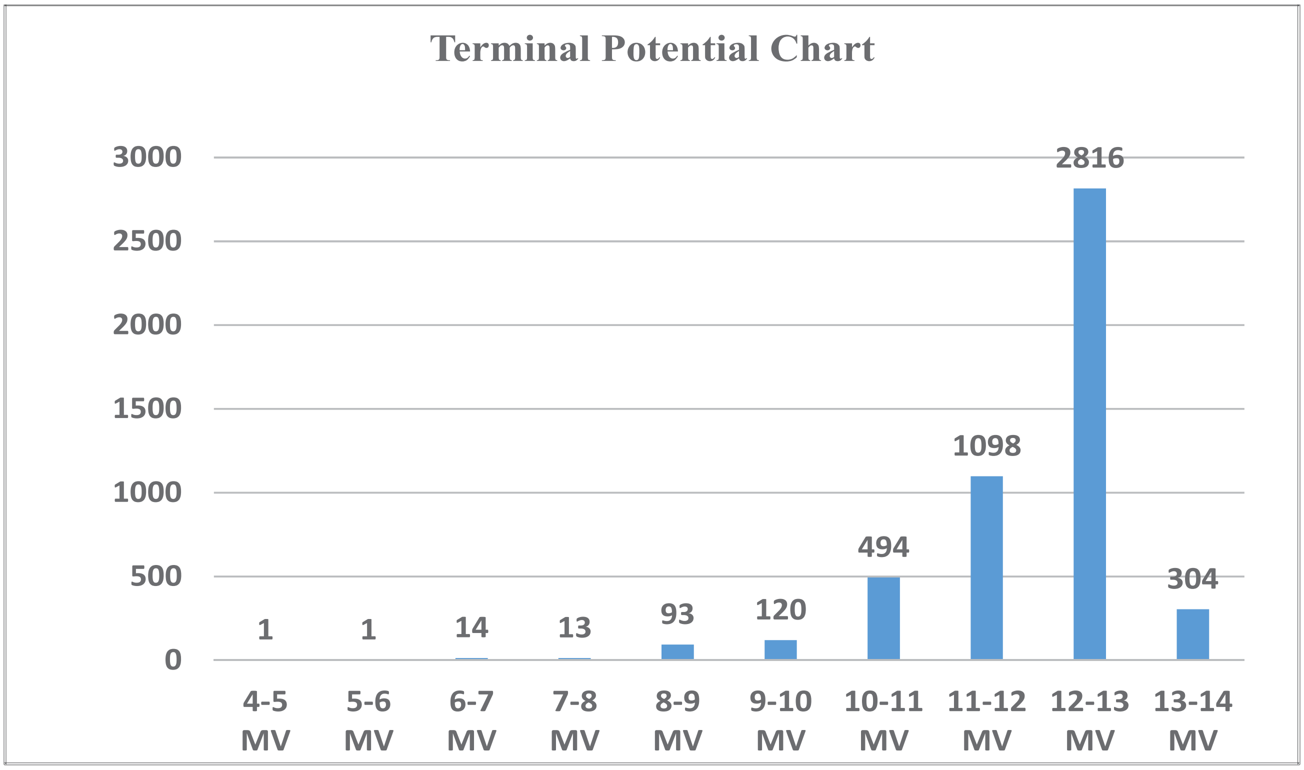

Figure 1: Voltage distribution graph in Hours

^{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 April 2021 to March 2022 is mentioned below.

Total No. of Chain Hours	=	7368 Hours
Total Beam utilization	=	4961 Hours
Breakdown during operation	=	658 Hours
Accelerator Conditioning	=	1374 Hours

Around 77% of beamtime was utilized by the users of nuclear physics facilities. As the LINAC was in continuous operation for two months, most of the nuclear physics beamtime were in beam hall II facilities (HYRA/INGA and NAND). 22 users from 11 Universities took their beamtime utilizing various nuclear physics facilities. 28 Materials science users from 20 different Universities / Colleges / Institutes utilized their beamtime in Mat. Sc. I, Mat. Sc. II and GPSC I beamline facilities. Similarly different users utilized facilities of Radiation Biology and Atomic Physics. Around 200 hours of beamtime was utilized by Pelletron, LINAC and Pulsing group for testing of beam feasibility and stability of the facilities prior to LINAC runs. After a long gap, Proton beam line facility was commissioned back and the facility was tested with proton beam. 50 nA, 25 MeV proton beam was accelerated and tuned in the Proton beamline facility. Beam was scanned to test the installed scanner in the beamline. Figure 2a shows the distribution of beamtime with respect to different experimental fields and Figure 2b depicts the beamline wise distribution of the beamtime.

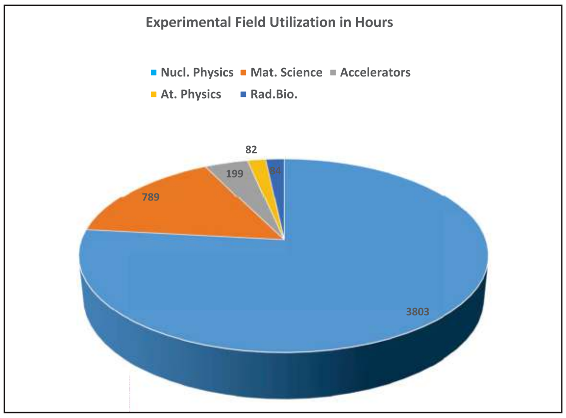

Figure 2a: Experimental field wise breakup of delivered beamtime.

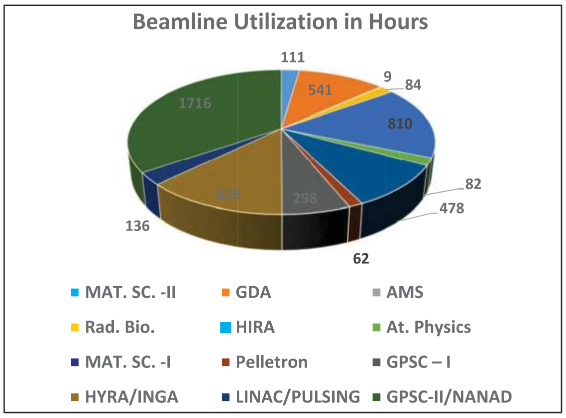

Figure 2b: Beamline utilization in hours.

There was a minor breakdown in the Pelletron accelerator system during the first week of September 2021. A rubber coupler of rotating shaft between unit number 23 – 24 was damaged and due to which the shaft stopped operating from unit 23 to lower terminal shell. It was repaired quickly and beam was delivered to the users. After continuous operation of the Pelletron accelerator for a year, the facility was opened for servicing in the month of March 2022.

1.1.2 Maintenance

In the academic year there was a short breakdown maintenance in September 2021. Later the accelerator tank was opened in the month of March 2022 for scheduled maintenance after continuous operation of one year. Both the maintenances are described in the following sections.

1.1.3 Breakdown Maintenance (September 2021)

During the operation it was observed that the systems installed in Dead Section-II and some electronics in the terminal area were not working. Also the terminal potential was not going up above 6.0 MV. The tank was opened and it was observed that the rotating shaft II in high energy section was not rotating above junction of unit number 23-24 (Fig 3). Dead Section-II falls in the area where the shaft was not moving therefore the instruments inside it (foil stripper assembly and ion pump) were not operating. The gas stripper inside terminal also gets power from the generator operated by rotating shaft II, therefore it was also not functioning. The dust in the high energy section generated due to the broken rubber coupler (Fig 4) was preventing the terminal potential to increase above 6.0 MV. Besides this there was no other issue inside the Pelletron accelerator tank. The damaged rubber coupler was replaced and the dust generated was cleaned thoroughly. Tank was closed after insulation testing of the electrical gaps in the accelerator. No other section of accelerator was opened for maintenance.

Figure 3: Damaged rubber coupler of Unit 23 - 24.

Figure 4: Dust inside accelerator due to damaged rubber coupler.

Due to lot of sticky dust inside the accelerator (Fig 5), it took longer time to attain high potential of 13.0 MV during conditioning. All the dust were burnt out by forced conditioning and within a week we could achieve 13.8 MV potential. Beam was delivered to the user soon after.

Figure 5: Sticky dust in the gaps.

1.1.4 Scheduled Maintenance (March 2022)

The Pelletron Accelerator was in regular operation since March 2021 and it was still in good condition. We were achieving around 13.8 MV potential during conditioning and delivering stable beam in the potential range 12.5-13.0 MV. But we had utilized all the foil strippers due to which we were unable to provide beam with higher energies. Also all moving systems inside the Pelletron accelerator tank needs thorough inspection. Therefore it was decided to go for a scheduled maintenance of the accelerator. The main works lined up during the ongoing maintenance are:

- Loading of foil strippers in the terminal and dead section II
- Charging system check-up
- Maintenance of rotating shafts
- Inspection of electrically weak sections of the accelerator and replacement of Column Support Posts, if required
- Inspection of all motors and generators inside the accelerator
- Maintenance of ion pumps and electronics installed inside the tank
- Safety inspection inside accelerator tank
- Beamline component maintenance (mostly vacuum pumps and controllers)
- Maintenance of other subsystems by concerned groups (Magnet group, Vacuum group, AC system, Water system etc.)

Although most of the listed maintenance works have been completed, but some maintenance part is continuing at the time of writing this report.

1.1.5 Ion Source activities

The 40 cathode MC SNICS source was operational throughout the year. There was one major breakdown of the source in the month of April 2021. The Einzel lens (Fig. 6) in the source was not holding operating voltage and was shorting after few hours of operation. The source was repaired and made operational within a week. Cathodes were loaded in the source 7 times during last year to deliver beams as per the schedule. No scheduled maintenance of the source was carried out. Only occasional cleaning was performed during cathode loadings.

1.1.5.1 Einzel Lens maintenance (April 2021)

During one of the nuclear physics experiments, when the source was operated at extreme condition to produce high current, it was noticed that the power supply of the Einzel lens was loading. Within a few hours of operation, the voltage level of the lens dropped to very low value. Resistance of the gaps of the Einzel lens was measured. It was noticed that the resistance had dropped down to low value.

The ionizer body (Fig. 7) and Einzel lens were removed from the source. The Einzel lens was dipped in alcohol for 24 hours. It was cleaned and heated using hot air gun. The gap resistance improved and the lens was installed back. The Ionizer source body was disassembled and all its part were cleaned thoroughly. There was a lot of Caesium deposition because of which there were minor fires while cleaning it. Special care was taken to handle the ionizer (Fig. 8) as it is very fragile and we have limited number of them in stock.

The source was aligned, reassembled and installed back. Evacuation process was performed and we could achieve the required vacuum within a day. The source was operated and now the Einzel lens was holding the required voltage. Very soon the beam was delivered to the user.

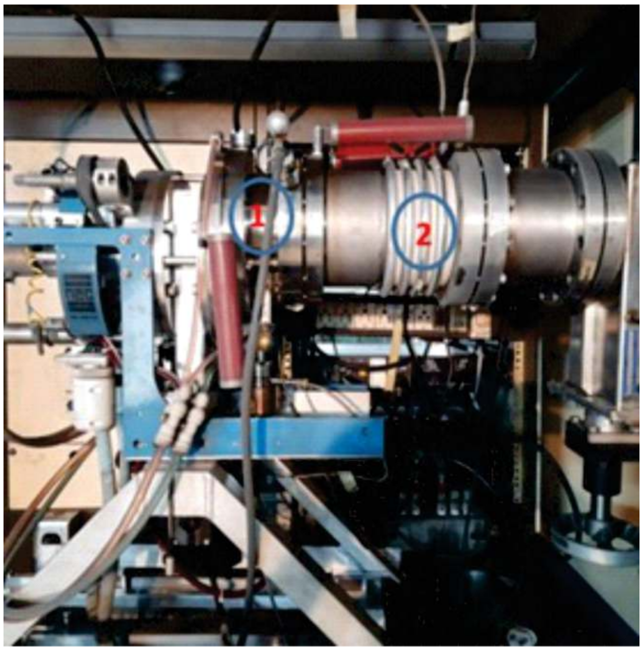

Figure 6: MCSINCS Ion source 1.) Ionizer body 2.) Einzel lens

Figure 7: Ionizer source body removed from the source.

Figure 8: Ionizer assembly of MC-SNICS.

1.2 SUPERCONDUCTING LINEAR ACCELERATOR (SC LINAC)

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

1.2.1 Operation of the superconducting linac

This year, the scheduled operation [1] of the Superconducting Linear Accelerator (Linac) was planned from April 2021 onwards. During January-February '21, the Linac was readied for this purpose. Cooldown of the Linac started in mid-March and during the preparatory period in March-April, offline conditioning of the resonators and measurements were performed. All the resonators could be phase locked at an average gradient of 3.15 MV/m. However, due to the spurt in the Covid-19 cases across the country during the second wave of the pandemic, the Linac run had to be aborted in the last week of April. Figure 1 shows the average phase locking field obtained in the three Linac cryomodules.

The Linac was subsequently re-started in mid-September 2021 and operated for around three months (~140 shifts) till 31st December 2021. Due to cryogenics related issues, the first accelerating module could not be made superconducting and beam was accelerated only through the second and the third modules. After a month-long offline conditioning and measurements on the resonators, three different beam species, namely ^{19}F, ^{28}Si and ^{32}S were accelerated through the linac and delivered for scheduled user experiments. The maximum energy gain from the two operational linac modules was 6.1 MeV/charge state. A total of six experiments for student PhD work were successfully completed with the linac beams. Figure 2 below shows the energy gain from the linac for the three accelerated beam species. The experimental location and the duration of the six experiments conducted using the linac beams are shown in table 1.

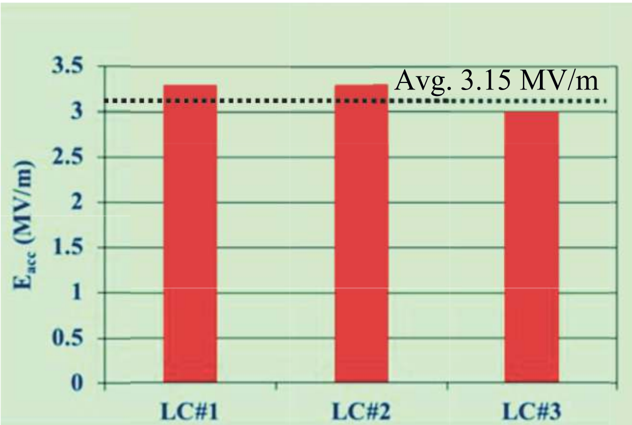

Figure 1: Average gradient in the three Linac modules during the aborted run in March-April 2021.

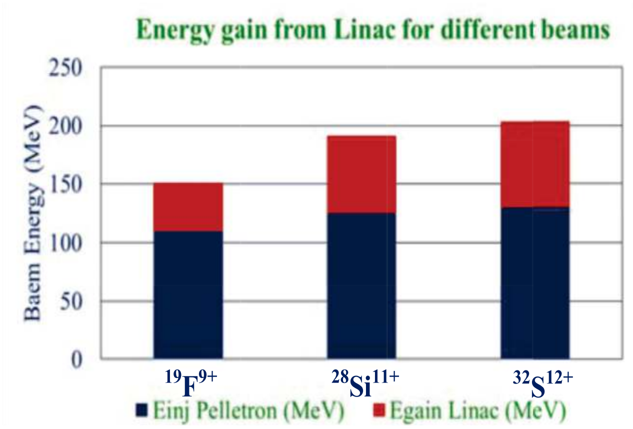

Figure 2: Injection energy from Pelletron and max energy gain from Linac for the three beam species.

Beam species	Max. Energy delivered to User [MeV]	Experimental Area	Schedule
$^{19}F^{9+}$	150	NAND	05 / 11 / 21 - 16 / 11 / 21
$^{28}Si^{11+}$	155	INGA	21 / 11 / 21 - 24 / 11 / 21
$^{28}Si^{11+}$	191.6	NAND	25 / 11 / 21 - 06 / 12 / 21
$^{32}S^{12+}$	200	HYRA	08 / 12 / 21 - 15 / 12 / 21
$^{32}S^{12+}$	203.6	NAND	16 / 12 / 21 - 23 / 12 / 21
$^{28}Si^{11+}$	192.5	NAND	24 / 12 / 21 - 31 / 12 / 21

Table 1: Location and duration of the six experiments conducted with the Linac beams.

1.2.2 Superconducting Resonator Fabrication (SRF)

Six spare QWRs and fourteen spare niobium tuner bellows are being fabricated to provide the necessary cushion in the long term operation of the linac. These resonators will also provide opportunities to perform studies aimed at improving the accelerating gradients in low frequency TEM class niobium cavities which in turn would be helpful in increasing the energy gain from the linac. Seven drift tube assemblies have been made ready in this year after electron beam welding (EBW) of the upper caps, end caps and beam tube with the drift tube cylinders. Of these, six will be used in the spare resonators and one will be a spare for future repairs as and when required. The drift tube assemblies were thereafter sent to the vendor's workshop for edge machining and fitting with the loading arms. Two loading arms and drift tube pairs were subsequently electron beam welded to complete the central conductor assemblies. Figure 3a shows the setup for tack welding of the loading arm to the drift tube while the same for full welding is shown in figure 3b.

Figure 3a: Tack weld of loading arm to drift tube.

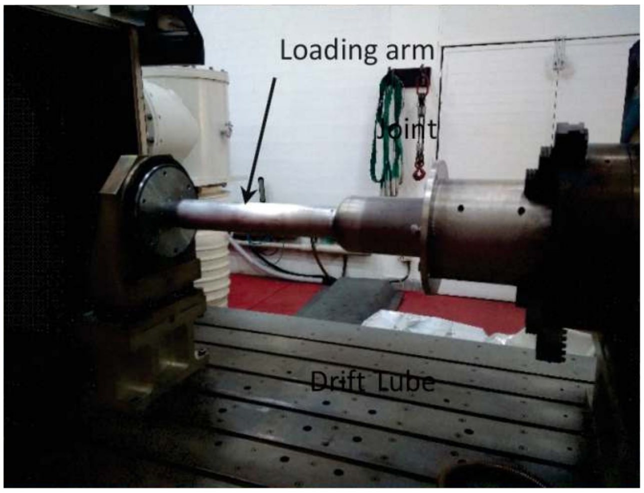

Figure 3b: Full welding of the two components to complete the central conductor assembly.

1.2.3 Automation of Q curve measurements for superconducting resonators

A scheme for the automation of the Q curve measurements of superconducting resonators is being developed and tested. In this, automatic decay time measurements (for field level calibrations) are performed after digitizing the pickup signal from the cavity using a NI PXI digitizer module. The input power and pickup signals are acquired through the RF millivolt meters operated in remote control mode through the PC. The interfacing between the computer and the RF instruments is provided using the Lab VIEW code. The automation scheme will be useful in that it will not only reduce the time and human effort required in performing the Q measurements for all the 24 resonators in linac but also reduce the person dependent error in them.

References:

[1] Operational Status of the Superconducting Linac at IUAC, A. Rai et al, accepted for publication in the Proceedings of Indian Particle Accelerator Conference (InPAC) 2022 (virtual conference), Variable Energy Cyclotron Centre, Kolkata, March 22-25, 2022.

1.3 PARAS: 1.7 MV (5SDH-2) Pelletron Accelerator based Ion Beam Analysis Facility

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

1.3.1 Operation

The 1.7 MV Tandem accelerator for Rutherford Back scattering Spectrometry (RBS), RBS-Channeling, Resonance-RBS, and Elastic Recoil Detection Analysis (ERDA) measurements for hydrogen, is in continuous operation. In the year 2021-22 total 816 measurements of 49 users from 22 Universities, colleges and institutes were performed. The facility was operational throughout the year. The Operation during this period was smooth and stable. The operational summary of the 1.7 MV (5SDH-2) Pelletron Accelerator for Ion Beam Analysis activities is consolidated in Table 1.

Table 1: The Operation details of Terminal Voltage, Charge state, Energy for different measurement technique using He beam

Terminal Potential (MV)	Charge State	Energy (MEV)	Measurement	Application
0.86- 0.987	+1	1.8-2	RBS and Channeling	Thin films, Nuclear targets Single crystals, Epitaxial layer
1.07-1.25	+2	3.045-3.09	O resonance RBS	Near and depth probe for O
1.198	+2	3.61	N resonance RBS	Near and depth probe for N

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, 2021 and the second was in the month of November 2021. In March, it was observed that source was generating low current. Clearing Rubidium chocking at aperture didn't improve the current. The source was opened, charge exchange cell was cleaned and reassembled with new beam exit bore and insulator canal. After the maintenance the ion source was found to be stable and was in regular operation till September 2021.

Once again, current production from the ion source deteriorated during operating in the month of October. 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 properly and two ampules (5gm each) of fresh Rb loaded. The stable He^- beam extraction was possible with few a hours of source conditioning.

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

The Accelerator operation was smooth during this period. The terminal voltage remained stable around 1.0 million volts (MV). In the month of April 2021, SF_6 was found to be at around 15 psi, and was refilled to 35 psi. At this pressure the terminal could hold 1.2 MV.

The RC43 interface software for End-station and computer developed a snag. It was rectified by assigning new serial port addresses to various sections of end-station, viz. sample manipulator and charge collector.

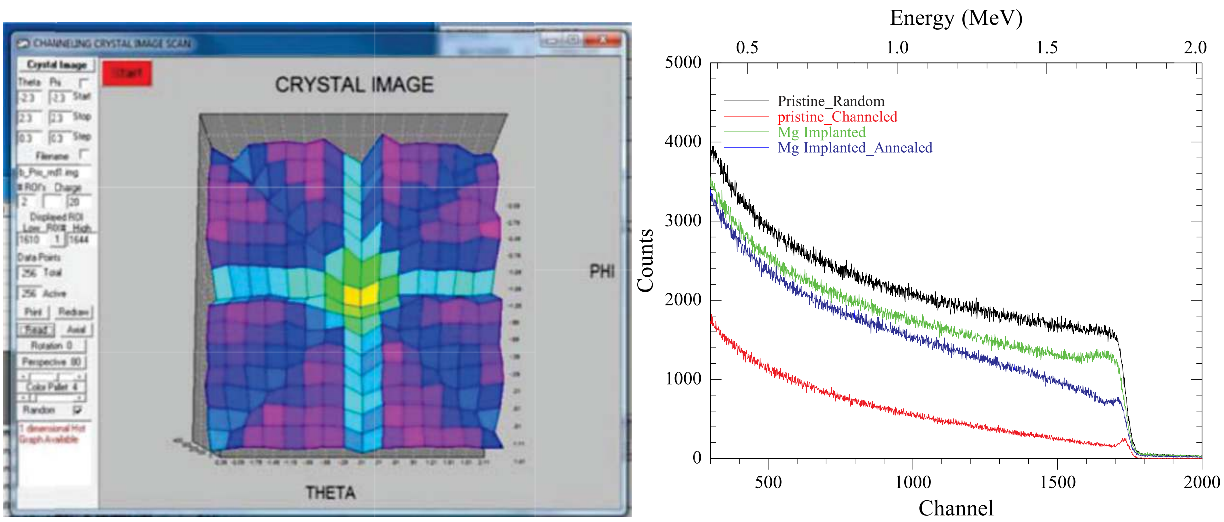

Figure: (1A) & (1B) RBS random and channeling spectra of InSb single crystal with 100 keV Mg implanted annealed (RTA) at 900^{0}C.

1.4 AMS AND GEOCHRONOLOGY FACILITIES

1.4.1 Accelerator Mass Spectrometry

Deeksha Khandelwal, Leema Saikia, Pavitra V. Kumar, Anit Dawar, Meenakshi, Gaurav Raturi, N S Panwar, Pranav Singh, Rajveer Sharma, Pankaj Kumar, S. Ojha, S. Gargari and S. Chopra

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. Due to Covid-19 pandemic, for half of the year we prepared the samples sent by the users and performed the measurement. Later on, when the Covid situation improved, the users were invited to perform the analysis by themselves.

1.4.1.1. Graphitization Laboratory: Graphitization laboratory is equipped with three Automated Graphitization Equipment (AGE) which are coupled with three elemental analysers 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 2021-March 2022, 1062 samples have been pre-treated and graphitized by 56 users from different universities and institutes for their research work. Beside the routine maintenances of refilling the different tubes in the graphitization equipment, ball valve of one of the elemental analyser (EA) of one of the AGE system was also cleaned.

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

In the measurement of cosmogenic radionuclides (CRN's) using AMS, chemical pre-treatment is a very important part. For this, a clean AMS chemistry lab (Figure.1) has 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, 320 samples (^{10}Be-190 and ^{26}Al-130 samples) belonging to 10 users from 8 institutes were processed for AMS measurements. Along with the samples, 18 process blanks and 17 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.

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 1136 samples of ^{14}C and ^{10}Be have been measured this year. 51 users from different institutes have utilized this facility for their research work.

1.4.1.3.2 Installation of drop in Silicon Surface Barrier Detector (SSBD) in XCAMS

XCAMS is equipped with gas ionization detector for the measurement of ^{14}C, ^{10}Be and ^{26}Al. However, we have large number of ^{14}C AMS users in comparison to ^{10}Be and ^{26}Al. Therefore, operation time for ^{14}C AMS is larger than the other two isotopes. To make the XCAMS system more user friendly for ^{14}C AMS, a drop in SSBD has been installed. Secondary standard samples have been measured to test this detector and results were in the range of their nominal values. We are conducting more test runs to study the results in detail before starting to use it routinely.

1.4.1.3.3 Maintenance activities of XCAMS

Following maintenance activities were carried out in this facility.

i. 40 MC SNICS was opened for maintenances in June, November and February. Cathode voltage was changing by itself while changing the immersion voltage. Source was cleaned, re-assembled and brought back to operation

ii. 134 MC SNICS was also opened for maintenance in February. Cathode voltage was changing by itself while changing the immersion voltage. Source was cleaned, re-assembled and brought back to operation

1.4.2 National Geochronology Facility

Deeksha Khandelwal, Leema Saikia, Anit Dawar, Meenakshi, Prem Chand Kisku, Atul Kumar Singh, Umapathy G R, 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)

Installation and commissioning of 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 completed this year. Figure 2 shows the High Resolution Secondary Ion Mass Spectrometer facility at IUAC. 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. It has a Normal Incidence electron Gun (NIG) for compensating the accumulation of positive charges on the sample. Samples can be outgassed before analysis in the storage chamber having capacity of storing six samples under vacuum of the order of 10^{-8} mbar. For sputtering, vacuum at the sample surface is very important and its analysis chamber has vacuum of the order of 10^{-10} mbar. Samples from the storage chamber can be loaded in the analysis chamber with just one click of the software. It has one Electro Static Analyzer (ESA) which does energy filtering followed by one magnet which does the mass separation. It has monocollection and multicollection detection system for sequential and simultaneous isotope ratio measurements, respectively. A microchannel plate and CCD camera make it to work as an ion microscope. It covers a broad mass range of elemental and isotopic species, from low mass (H) to high mass (U and above) maintaining high transmission even at high mass resolution. Stable isotope measurements, zircon geochronology and trace element analysis, small particle analysis (nuclear and environmental studies), planetary research, deep earth process and hard rock studies are some of its applications.

The primary beam was tested in terms of its intensity, density, stability and minimum achievable size. Cs and oxygen beam intensities were found to be > 0.8 µA and 1.5 µA, respectively. The densities were >50 mA/cm^2 and 150 mA/cm^2 for cesium and oxygen beam respectively. Long- and short-term stability of the beam (I/I) was found to be < 2 % over 14 hrs for oxygen source and <0.7 over 20 min for oxygen source. For determination of the minimum beam diameter, the Si/Ta grid was used. This grid has some special patterns, which can be used to get Scanning Ion Image (SII). From the scanning ion image, using the software 'spotshape' the size of the primary beam can be determined. The Cs primary beam was tuned and the SII of pattern shown in figure 3 was obtained. Max area 160 µm^2, Contrast aperture 400 µm and Field aperture 7000 µm were used in secondary column. It can be noted from the figure that the primary beam diameter (84% - 16%) is found to be 0.49 µm in X and 0.49 µm in Y. This shows that beam shape is circular. The minimum possible primary beam diameter was ~1 µm for the oxygen beam. For routine zircon analysis, we used 5-6 nA O_2^- beam in Kohler illumination mode having beam diameter ~ 10 µm.

Figure 2: High Resolution Secondary Ion Mass Spectrometer (HR-SIMS) at IUAC.